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Analysis of Deflagration Isolation in Wood Pellet Production for Safer Operation

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EXECUTIVE SUMMARY

This report describes the work completed under the project titled “Analysis of Deflagration Isolation in Wood Pellet Production for Safer Operation” funded by Dalhousie University and completed in collaboration with Wood Pellet Association of Canada (WPAC) and BC Forest Safety Council (BCFSC).

There have been incidents involving the propagation of combustible wood dust deflagrations in wood pellet plants. Due to these similar incidents, WorkSafeBC has identified enhancing the understanding of deflagration isolation as an area for improvement. Deflagration isolation, as described by NFPA 69 (2019), prevents the propagation of flame and deflagration pressure to interconnected equipment.

The objective of this report is to serve as an easily digestible resource and reference for wood pellet producers that:

- Provides information on the different types of deflagration isolation systems that are available,
- Provides information on the installation, operation, and maintenance of these systems to improve understanding,
- Summarizes failure modes and degradation factors associated with these systems,
- Provides considerations for how these failure modes and degradation factors can be managed to make systems more reliable and effective.

This project involved extensive input from subject matter experts involved in the wood pellet industry, including wood pellet operations, process safety consulting, research and development, risk management and explosion protection equipment suppliers. Relevant information was collected from NFPA (National Fire Protection Association) standards. NFPA 69 is referenced in this report, as this standard encompasses the design, installation, maintenance and testing of systems for the prevention of explosions. Additional research was completed using archival literature, as well as bow tie analyses conducted as part of the WorkSafeBC Innovation at Work project (*Inherently Safer Bow Ties for Dust Hazard Analysis*).

This report describes the most common deflagration isolation techniques for wood pellet plants, which are chemical isolation, passive flap valves, fast-acting mechanical valves, and rotary valves. Inherently safer design (ISD) considerations for deflagration isolation are also discussed, including unit segregation for the avoidance of domino effects (moderation) and material chokes (moderation).

The different locations in a wood pellet plant that commonly require deflagration isolation are also discussed with respect to why isolation is needed and what isolation technique is most applicable. The equipment discussed are hammer mills, dust collectors, bucket elevators, drag chain conveyors and cyclones, which commonly need isolation due to the propensity of ignition sources and levels of suspended dust.

The different ways the deflagration isolation techniques can be degraded, or fail, are also identified. These failure modes and degradation factors associated with different deflagration isolation techniques include devices not actuating due to being locked out for maintenance, challenges associated with mechanical expansion and contraction, and process material adhering to device components. The approaches for managing these challenges (degradation factor controls) are also identified, which include important points such as inspections as per NFPA 69 (2019) and preventative maintenance as per manufacturer specifications.

A four-step guide for implementing deflagration isolation in a facility is described, which consists of the following:

1. Conduct a DHA (Dust Hazard Analysis)
2. Work with Equipment Suppliers on Recommended Deflagration Isolation Points
3. Install Deflagration Isolation Equipment
4. Maintain Deflagration Isolation Equipment

This report provides an extensive overview of dust hazard analysis (DHA), as performing a DHA is a critical step in managing combustible dust hazards. A DHA ensures that a facility's hazards associated with combustible dust can be properly identified and managed. In Canada, an Authority Having Jurisdiction (AHJ) can request a DHA to be conducted.

Lastly, several challenges in the area of combustible dust hazards are discussed with recommendations on moving forward:

- Emphasizing the importance of a dust mitigation program,
- Enhancing combustible dust hazard awareness,

- Addressing issues and opportunities around explosion isolation - other recommended activities for facilities to consider, and
- Enhancing process safety management (PSM) and element of process safety culture.

It is recommended that pellet plant operations use this report to support activities around deflagration isolation, including enhancing training and awareness, as well as addressing any areas for improvement in programs and practices.

LIST OF ABBREVIATIONS USED

BCFSC	British Columbia Forest Safety Council
CCPS	Center for Chemical Process Safety
DHA	Dust Hazard Analysis
EIV	Explosion Isolation Valve
FAQ	Frequently Asked Question
HAZOP	Hazard and Operability Study
HRD	High Rate Discharge
ISD	Inherently Safer Design
LOTO	Lockout and Tagout
MOC	Management of Change
NFC	National Fire Code of Canada 2015
NFPA	National Fire Protection Association
OEM	Original Equipment Manufacturer
P&IDs	Piping and Instrumentation Diagrams
PFD	Process Flow Diagrams
PHA	Process Hazard Analysis
PSM	Process Safety Management
SDS	Safety Data Sheets
SME	Subject Matter Expert
SOP	Standard Operating Procedure
WorkSafeBC	Workers' Compensation Board of British Columbia
WPAC	Wood Pellet Association of Canada

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Obex Risk Ltd. acknowledges project funding provided by Dalhousie University and arranged by Dr. Paul Amyotte (Professor, Chemical Engineering, Department of Process Engineering and Applied Science).

Obex Risk Ltd. wishes to sincerely thank all the subject matter experts for providing input and expertise to the project, including all those from wood pellet operations, process safety and combustible dust hazard consulting, research and development, risk management, and explosion protection equipment suppliers. These include (in alphabetical order by first name) Jay Juvenal (CV Technology), Jeff Mycroft (Fike), Jeramy Slaunwhite (Rembe), Luc Cormier (Jensen Hughes), Dr. Paul Amyotte (Dalhousie University), Tim Heneks (Dustcon Solutions Inc.), as well as all others who wished to provide input without attribution.

Obex Risk Ltd. also acknowledges the WPAC Safety Committee, BC Forest Safety Council and Dr. Chris Cloney (DustEx Research Ltd.) for providing guidance on project scope and definition. Special thanks to Bill Laturnus (BC Forest Safety Council) for extensive project support, including project scoping, research methodology development, stakeholder outreach, and report review. Thank you, as well, to Dr. Paul Amyotte, for extensive project support and report review.

Lastly, Obex Risk Ltd. extends thanks to WPAC and Dalhousie University for commissioning Obex Risk Ltd. to conduct this work.

CHAPTER 1
REPORT INTRODUCTION AND OVERVIEW

This report describes the work completed under the project titled "Analysis of Deflagration Isolation in Wood Pellet Production for Safer Operation" funded by Dalhousie University and completed in collaboration with Wood Pellet Association of Canada (WPAC) and BC Forest Safety Council (BCFSC).

The introductory chapter of this report provides an overview of the project as well as the motivation, scope of work and objectives of the report. The organization of this report document is also outlined.

1.1 Wood Pellet Plants and Combustible Wood Dust Hazards

Combustible wood dust is generated in wood pellet plants, which presents the risks of dust deflagration, dust explosion and flash fire. A deflagration is defined as "propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium" (NFPA 652, 2019). During a deflagration, a substance burns, and releases heat and hot gases, and sparks spread the fire (CCOHS, 2021). A dust deflagration presents the risk of propagating flame and deflagration pressure to interconnected equipment. NFPA 69 (2019) defines deflagration isolation as the technique for the "interruption or mitigation of flame, deflagration pressures, pressure piling and flame-jet ignition between enclosures that are interconnected by pipes or ducts."

There have been incidents in wood pellet plants involving wood dust deflagrations and fires that have escalated by means of flame propagation in interconnected equipment. An example of such an incident began with a primary deflagration in a hammermill, after which a flame front propagated upstream to an interconnected belt dryer, which resulted in a secondary fire. While there was an isolation device (an active chemical isolation system) installed between this interconnected equipment, an interlock in this isolation system failed, which allowed the flame to propagate between the equipment.

Due to other events like this, WorkSafeBC has identified the need to improve the understanding of deflagration isolation systems, how they can degrade or be less effective, and how these failure modes can be managed to make systems more reliable and effective.

1.2 Report Motivation

The motivation for this report and its purpose is to provide a resource to wood pellet producers to help improve the understanding of deflagration isolation systems and their modes of failure to increase the success of these systems and prevent flame propagation from causing secondary fire, deflagration, and explosion incidents.

1.3 Report Objectives

The objective of this work is to provide an easily digestible resource and reference for wood pellet producers that:

- Provides information on the different types of deflagration isolation systems that are available,
- Provides information on the installation, operation, and maintenance of these systems to improve understanding,
- Summarizes failure modes and degradation factors associated with these systems, and
- Provides considerations for how these failure modes and degradation factors can be managed to make systems more reliable and effective.

1.4 Report Scope

This report is a resource to serve the wood pellet producers and Wood Pellet Association of Canada (WPAC) member companies across Canada. The scope of this report is deflagration isolation methods used within wood pellet production applications, aligned with system types described in NFPA 69 (2019) Standard on Explosion Prevention Systems. Priority is given to the passive and active systems outlined in Chapters 11 and 12 of NFPA 69 (2019); namely flame front diverters, passive float valves, passive flap valves, material chokes (rotary valves), flame arresters, hydraulic and liquid product arresters, chemical barriers, fast-acting mechanical valves, externally actuated float valves and actuated pinch valves. Additionally, isolation measures in the form of inherently safer design (ISD) are identified and recommended for consideration.

NFPA 69 is referenced throughout this report, as this standard encompasses the design, installation, maintenance and testing of systems for the prevention of explosions. NFPA 69 is a reference standard in the National Fire Code, and it is referenced for explosion protection of vessels.

Explosion prevention and other explosion protection measures were out of scope for this report; explosion isolation was the core focus of the work, although some there are some mentions of explosion prevention and protection.

1.5 Research Methodology

A series of interviews were completed with subject matter experts (SMEs) from wood pellet operations, process safety consulting, research and development, risk management and explosion protection equipment suppliers. These interviews were 1-2 hours long, with questions provided to the different stakeholders beforehand. Additional questions arose throughout the course of the conversations and interviews. These questions are found in Appendix A.

There are extensive contributions made by subject matter experts (SMEs) in this report. The SMEs who have granted permission to be identified by name and company are listed here. References and attributions to them will be made throughout the report. The contact information for the SMEs is included in Appendix B. The SMEs are listed (by first name alphabetically) in Table 1-1.

Table 1-1. Subject matter experts (SMEs) who had input and contributed to this report and granted permission to be identified.

Name and Title	Company	Expertise
Jay Juvenal, Sales Engineer	CV Technology	Explosion Protection Equipment Supply
Jeff Mycroft, B.Sc., Sales Manager	Fike Canada, Inc.	Explosion Protection Equipment Supply
Jeramy Slaunwhite, P.Eng., Explosion Safety Consultant	Rembe Inc.	Explosion Protection Equipment Supply
Luc Cormier, M.Eng., P.Eng., Market Lead – West Canada	Jensen Hughes	Process Safety and Combustible Dust Consulting
Dr. Paul Amyotte, P.Eng., Professor (Chemical Engineering)	Dalhousie University	Process Safety and Combustible Dust Research and Development
Timothy Heneks, P.E., Director of Engineering Services	Dustcon Solutions Inc.	Process Safety and Combustible Dust Consulting

A review of NFPA 69 (2019) was completed to identify key information for this report, including defining the project scope, as well as key points about maintenance, installation, and inspection of deflagration isolation equipment. Other standards, including NFPA 652 (2019) and NFPA 664 (2020), were also reviewed for additional information.

A review of CCPS (2005) was completed to collect information about the isolation systems, operating mechanisms, as well as identify failure modes and challenges associated with these systems.

A review of the bow tie analyses that were completed as part of the WorkSafeBC Innovation at Work project (Inherently Safer Bow Ties for Dust Hazard Analysis) (undertaken by Dalhousie University, WPAC, BCFSC, DustEx Research Ltd.) was also performed to identify degradation factors and controls (challenges associated with isolation systems).

1.6 Organization of Report

The report structure is as follows:

Chapter 1 presents an introduction to the project, along with the background information for the motivation, scope of work and objectives.

Chapter 2 introduces deflagration isolation, including what it is and why it is needed.

Chapter 3 describes the different deflagration isolation systems commonly used in wood pellet plants.

Chapter 4 describes the different locations in a wood pellet plant that commonly need deflagration isolation.

Chapter 5 discusses different failure modes and degradation factors for deflagration isolation systems, as well as how they can be managed (degradation factor controls).

Chapter 6 provides a guide for incorporating deflagration isolation systems into a facility.

Chapter 7 discusses challenges associated with deflagration isolation and addressing combustible hazards.

Chapter 8 provides the summary, recommendations, and conclusions of this report.

CHAPTER 2 INTRODUCTION TO DEFLAGRATION ISOLATION

This chapter provides background information on deflagration isolation, including what it is and why it is needed.

2.1 What is isolation?

The definition of "isolation" provided in NFPA 69 (2019) Standard on Explosion Prevention Systems is "a means of preventing certain stream properties from being conveyed past a predefined point."

2.1.1 Difference between deflagration isolation, protection, and prevention

Deflagration isolation is different than the terms *deflagration prevention* and *deflagration protection* (which are out of scope of this report but need to be distinguished from isolation). As stated in Section 1.1, the objective of *deflagration isolation* is to prevent the propagation of flame and deflagration pressure to interconnected equipment. Isolation is a component of *deflagration protection*, which encompasses other protection measures, including venting, suppression, pressure containment, systems for spark detection and extinguishing, and prevention of secondary explosions. Deflagration venting is widely used in industry. NFPA 68 (2018) Standard on Explosion Protection by Deflagration Venting focusses on devices and systems that vent the combustion gases and pressures resulting from the deflagration within an enclosure so that structural and mechanical damage is minimized. Deflagration venting is used to protect process equipment, ducting and buildings by providing overpressure relief, allowing combustion products to escape from the enclosure prior to reaching a greater rise in pressure than it can tolerate. However, vent sizing (as calculated by NFPA 68) is only applicable to the primary, individual vessel and not the interconnected equipment. Deflagration isolation should be used in conjunction with deflagration venting to prevent propagation of the flame in the primary equipment to upstream and downstream connected equipment (CCPS, 2005).

Lastly, in contrast, the focus of *deflagration prevention* is reducing the likelihood of a deflagration. It includes prevention or mitigation of dust cloud formation, oxidant reduction (inerting) and combustible concentration reduction (air dilution) (CCPS, 2005). Figure 2-1 uses a layers of protection concept with timeline to demonstrate the difference between explosion prevention and explosion protection (CV Technology, 2021).

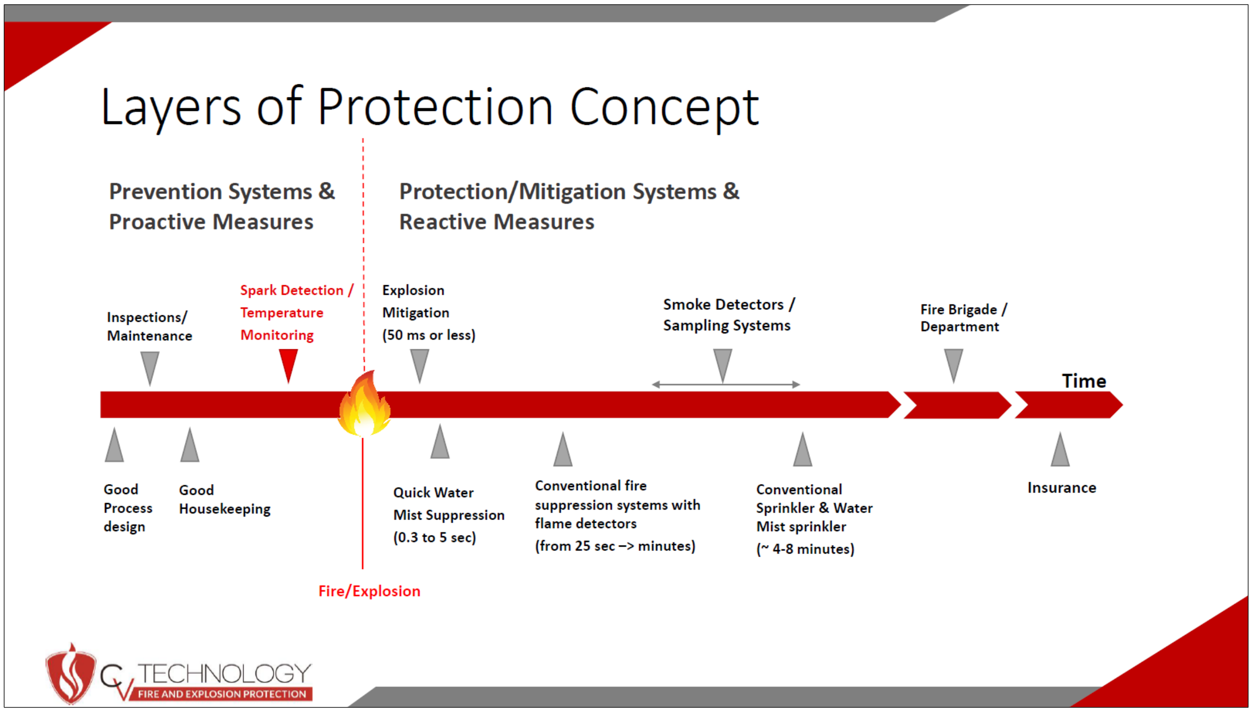

Figure 2-1. Layers of protection concept with timeline to demonstrate difference between explosion prevention and explosion protection (CV Technology, 2021) (used with permission)

2.1.2 Why isolation?

Different units in plants handling combustible dust are interconnected by ducts, equipment, chutes, and conveyors. As highlighted in the introduction in Section 1.1, a deflagration that initiates in one unit can propagate through the connecting equipment and cause a secondary fire or deflagration in units upstream or downstream (CCPS, 2005). The use of a deflagration isolation system prevents this propagation and reduces the risk for subsequent fires and explosions.

The document "Dust Explosion Propagation: Myths and Realities" (Fike, 2013) with excerpts from Amyotte (2013) is a valuable resource that further illustrates the importance of deflagration isolation. Important myths about explosion propagation and brief explanations are as follows (readers are encouraged to refer to Amyotte (2013) and Fike (2013) for further detail and explanation):

- Myth #1: a large amount of dust is needed for an explosion to propagate
    - Dust explosions do not need large amounts of fuel to propagate; a dust layer as little as 1/100 inch (0.0254 mm) thick can fully propagate an explosion.
- Myth #2: a dust explosion starting in a vented vessel cannot propagate through connected pipes
    - Experiments and past combustible dust incidents have demonstrated that a dust explosion that initiates in vented equipment can propagate through the interconnected process plant over long distances.
- Myth #3: a dust explosion cannot propagate against process flow
    - Experiments and propagation tests have demonstrated that it is possible for an explosion to travel with and against process flow.
- Myth #4: a dust explosion weakens as it propagates
    - Dust explosions worsen during propagation due to flame acceleration[1], flame jet ignition[2] and pressure piling[3].
- Myth #5: small diameter pipes do not support dust explosion propagation

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[1] Increased flame speeds and pressure created by gas flow of primary explosion
[2] Ignition of material in secondary enclosure by large flame from primary enclosure moving quickly
[3] Increased pressure in pipes and secondary enclosure from primary explosion gas expansion

- While it has been argued that propagation in small pipes is difficult because of heat loss to the pipe walls, several researchers have conducted a range of experiments using different conditions and variables (e.g., pipe diameter, pipe length, dusts of different reactivities, enclosure size, enclosure venting) and have observed that propagation is possible in pipes as small as 4 inches (10 cm) in diameter.

2.2 Deflagration isolation success story

Deflagration isolation is a tool available for effectively reducing the spread of wood dust explosions throughout a wood pellet plant, which has extensive benefits for protecting people, property, business, and the environment. Below is an excerpt of an anecdote provided by a subject matter expert from a wood pellet plant. This excerpt describes first-hand experience observing the difference between a deflagration that occurred at a pellet plant prior to installation of a deflagration isolation system (an active chemical isolation system) and after the system was installed.

"There was no flame, there were no sparks, there was nothing basically the second time, and they were back up and running within a day – they had to replace the bottles. The first time, it burst all the panels, up through the conveyor going back to the dryer. It burnt up the belt and the dryer, and it [the plant] was [down] a week or two."

“A small issue somewhere becomes a big issue because it makes it through the whole process.”

This anecdote highlights the value that deflagration isolation brings to each facet of the operation:

- reduced risk of the devastating effects of a dust explosion harming personnel,
- protection of critical process equipment from damage due to pressure and heat,
- protection of potential impacts to the environment by way of air or water contamination due to a fire or suppression efforts, and
- a dramatic reduction in production downtime, as well as reduction in other potential business impacts of an incident (e.g., reputation).

2.3 NFPA 69 overview

The scope of NFPA 69 (2019) Standard on Explosion Prevention Systems is the design, installation, maintenance and testing of systems for the prevention of explosions using the following methods:

1. Control of oxidant concentration
2. Control of combustible material concentration
3. Predeflagration detection and control of ignition sources
4. Explosion suppression
5. Active isolation

6. Passive isolation
7. Deflagration pressure containment
8. Passive explosion suppression

The purpose of the standard is to “cover the minimum requirements for installing systems for the prevention of explosions in enclosures that contain flammable concentrations of flammable gases, vapours, mists, dusts or hybrid mixtures.” NFPA 69 (2019) 7.1.6.1 states “where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.”

Deflagration isolation is discussed in Chapters 11 and 12 of NFPA 69 (2019). Chapter 11 covers active isolation and Chapter 12 covers passive isolation. Active techniques use detection and control (detection and actuation) to perform as the isolation barrier. Passive isolation techniques perform independently of energized detection and control equipment (do not require detection and actuation).

Active isolation techniques include the following:

1. Chemical barrier
2. Fast-acting mechanical valve
3. Externally actuated float valve
4. Actuated pinch valve

Passive isolation techniques include the following:

1. Flame front diverters
2. Passive float valves

3. Passive flap valves
4. Material chokes (rotary valves)
5. Static dry flame arresters
6. Hydraulic (liquid-seal)-type flame arresters
7. Liquid product flame arresters

The types of isolation devices that are most commonly used in wood pellet plant applications are:

- Chemical isolation (active),
- Fast-acting mechanical valves (active) and,
- Flap valves (passive).

Inherently safer design (ISD) also provides considerations for deflagration isolation. Rotary valves are another piece of isolation equipment commonly used, but have challenges associated with them in wood processing applications. These techniques will be discussed in further detail in Chapter 3.

2.4 NFPA 652 and inherently safer design (ISD)

NFPA 652 (2019) Standard on the Fundamentals of Combustible Dust provides the basic principles and requirements for identifying and managing the fire and explosion hazards of combustible dusts and particulate solids. NFPA 652 (2019) includes chapters on dust hazard analysis (DHA) (which is further discussed in Section 6.1 of this report), as well as hazard management with respect to prevention and mitigation of dust fires and explosions. The isolation equipment outlined in Section 2.3 is critical for preventing deflagration propagation between interconnected equipment. The active and passive deflagration isolation devices listed in Section 2.3 fall within the hierarchy of controls, which is shown in Figure 2-2, along with inherently safer design (ISD) and administrative controls. The hierarchy of controls is the preferred order of risk reduction measures. In order of preferred consideration, these are as follows: inherently safer design (ISD), passive engineered, active engineered and administrative. ISD focusses on the elimination of hazards and treatment of hazards at the source, rather than relying on only add-on equipment and procedures (Kletz and Amyotte, 2010).

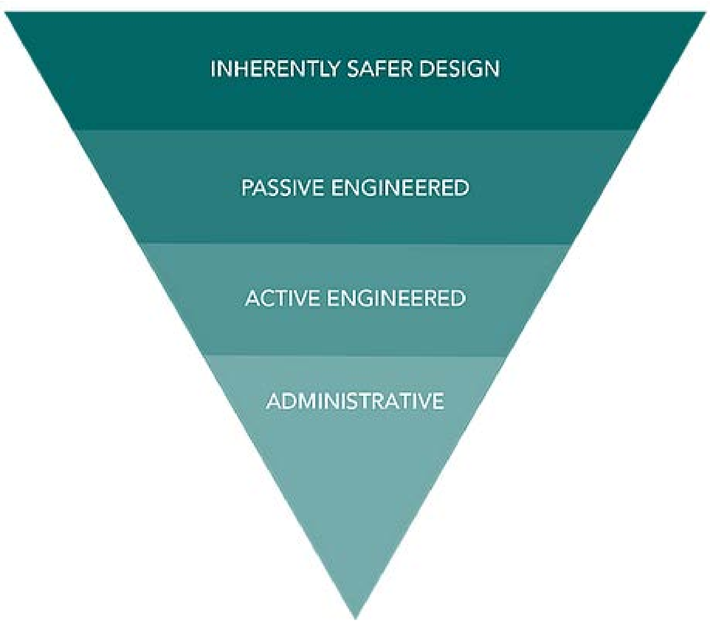

Figure 2-2. Hierarchy of controls

ISD is based on four principles – minimization, substitution, moderation, simplification. NFPA 652 (2019) outlines several ISD considerations for managing combustible dust hazards. Examples of ISD from NFPA 652 (2019) are highlighted in Table 2-1.

Table 2-1. Examples of ISD to manage combustible dust hazards from NFPA 652 (2019)

ISD Principle	Example
Minimization	Design facilities to minimize horizontal surfaces where dust can accumulate
Substitution	Replace bucket elevator with dense phase conveying system
Moderation	Use processing methods that minimize fine dust generation
Simplification	Locate dust collectors outdoors in unoccupied areas, where explosion vents can be used instead of more complex protection systems

ISD should be considered by facilities when designing or modifying processes through the management of change (MOC) program, during process hazard analysis (PHA), and incident investigations. ISD considerations for deflagration isolation include:

- unit segregation and avoidance of domino (knock-on) effects (moderation in the form of limitation of effects), and
- material chokes.

ISD considerations for deflagration isolation are discussed in further detail in Chapter 3.

CHAPTER 3 TYPES OF DEFLAGRATION ISOLATION METHODS FOR WOOD PELLET FACILITIES AND HOW THEY WORK

This chapter describes the different types of deflagration isolation devices commonly used in wood pellet facilities and how they work. The isolation devices and techniques that are explained in this chapter are:

- Chemical isolation,
- Flap valves,
- Fast-acting mechanical valves,
- Rotary valves, and
- Inherently safer design (ISD).

Other isolation methods, including pinch valves and float/poppet valves, are less common in wood pellet plants and are not discussed in this chapter.

3.1 Chemical isolation

NFPA 69 (2019) defines chemical isolation as “a means of preventing flame front and ignition from being conveyed past a predetermined point by injection of a chemical suppressant.”

Chemical isolation is a type of active isolation. Active devices consist of detection and actuation. NFPA 69 (2019) states the function of a chemical isolation system is to inject a barrier of extinguishing agent into the interconnection prior to the arrival of the flame front. The chemical isolation system is comprised of one or more detectors, a control panel and agent injection equipment. Actuation is based on the detection of pressure or radiant energy with a control panel, which provides the initiating signal to the agent containers (NFPA 69, 2019).

An optical sensor can be used to detect an oncoming deflagration flame and emit a signal to a control unit. The optical sensor is installed in the conduit or duct between equipment. After detecting the flame front, the signal triggers the extinguishing agent to be injected into the pipeline from an HRD (high-rate discharge) suppressant bottle, which extinguishes the flame (CCPS, 2005). Typical suppressant agents include sodium bicarbonate and monoammonium phosphate (Fike, 2021a).

Examples of chemical isolation systems are shown in Figure 3-1 and Figure 3-2.

Figure 3-1. Example of chemical isolation system (Interceptor®-HRD Isolation by CV Technology) (CV Technology, 2021a) (used with permission)

Figure 3-2. Example of chemical isolation system (Fike, 2021a) (used with permission)

3.2 Passive flap valves

When a deflagration begins to propagate down a duct or pipeline, a passive flap valve closes due to the pressure of the deflagration. The flap valve remains shut to prevent additional propagation of flame (NFPA 69, 2019). The different valve positions when the process is not running, when the process is running normally and when there is a deflagration are demonstrated in Figure 3-3, 3-4 and 3-5, respectively.

Figure 3-3. Basic position of flap valve - when the process is not running, the valve blade rests in an inclined position (Rembe, 2021a) (used with permission)

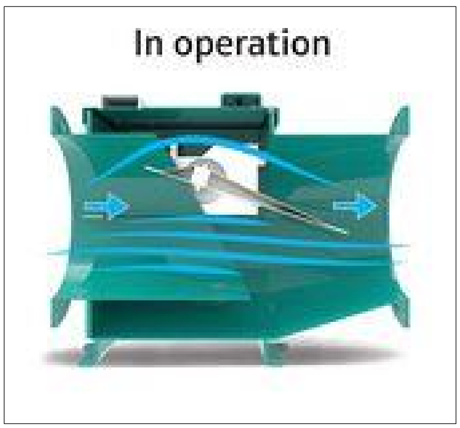

Figure 3-4. Operating position of flap valve - when the process is running and is operating normally, the flap valve is kept open by system air flow (Rembe, 2021a) (used with permission)

Figure 3-5. During deflagration, valve blade is closed due to pressure wave (Rembe, 2021a) (used with permission)

3.3 Fast-acting mechanical valves

A fast-acting mechanical valve (explosion isolation valve) prevents the propagation of flame and combustion-generated pressure beyond the valve by providing a positive mechanical seal (NFPA 69, 2019).

The isolation valve, a slide gate valve, is open during normal operation, and when a pressure sensor detects an input, a signal is relayed by a control system to compressed air, which rapidly discharges and closes the valve (CCPS, 2005). This mechanism is demonstrated in Figure 3-6.

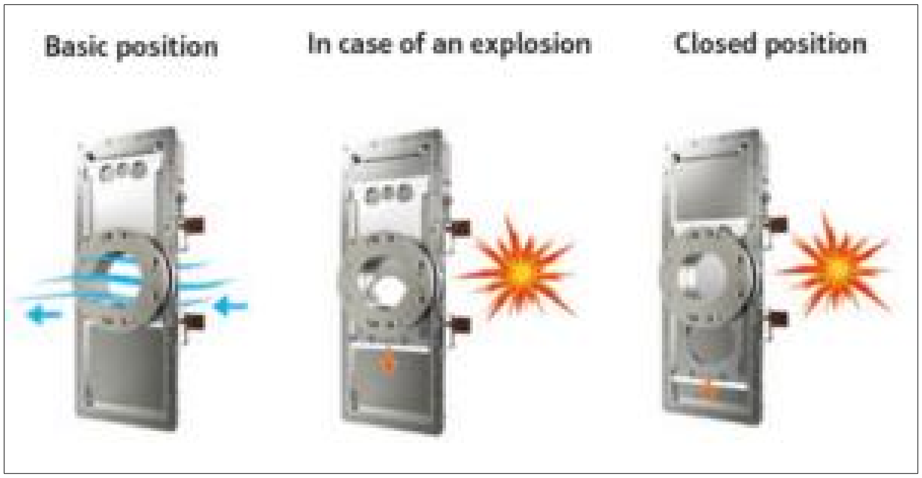

Figure 3-6. Mechanism for deflagration isolation with slide valve (Rembe, 2021b) (used with permission)

Other examples of active explosion isolation valves are shown in Figure 3-7 and 3-8.

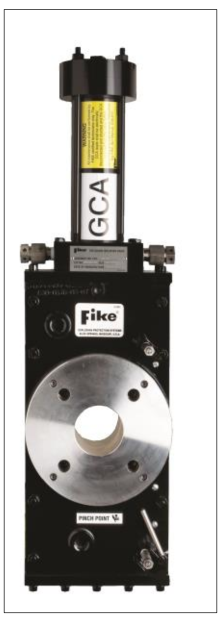

Figure 3-7. Example of explosion isolation slide gate valve (EIV – Fike) (Fike, 2021b) (used with permission)

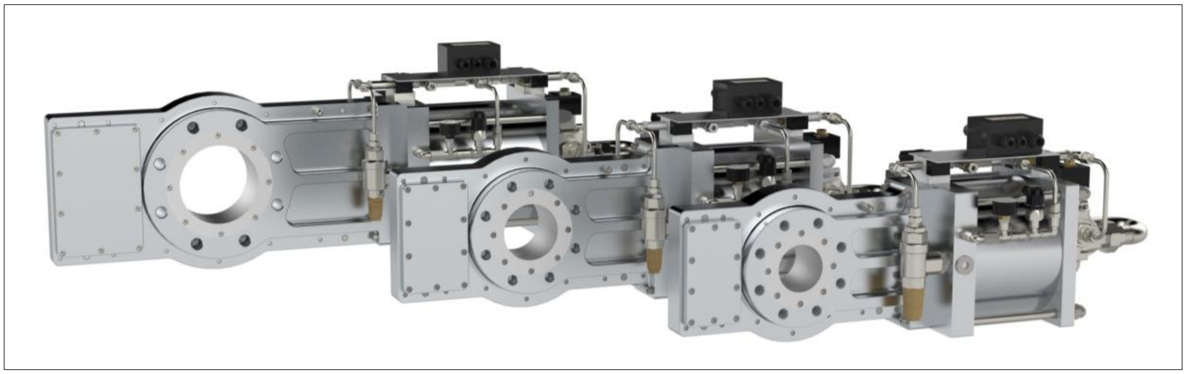

Figure 3-8. Example of explosion isolation slide gate valve (Interceptor®-SG® - CV Technology) (CV Technology, 2021b) (used with permission)

3.4 Rotary valves

Flame propagation can be stopped between process equipment by bulk solids/powders conveying equipment, including rotary valves (rotary airlocks) and screw conveyors (CCPS, 2005). The material creates a material choke, which is an obstructive path for the gas and flame. Material chokes are discussed further in the following section on inherently safer design (ISD).

3.5 Inherently safer design (ISD)

Two primary considerations for the application of ISD for deflagration isolation are discussed in this section – moderation (limitation of effects) and material chokes.

3.5.1 Moderation (limitation of effects)

The principle of moderation, in the form of limitation of effects, can be applied to equipment isolation. If the plant is being redesigned or rebuilt, the avoidance of domino (knock-on) effects should be considered. Domino (knock-on) effects are described in Amyotte (2013), with reference to Cozzani et al. (2006). The three features of incidents with domino effects are as follows:

1. A primary condition begins (initiates) the chain of events in the domino series,
2. The primary event creates an escalation vector, which propagates this event and leads to further damage elsewhere; these escalation vectors can include heat radiation, fire impingement, fragments, and overpressure. Lastly,
3. Subsequent events (e.g., fires, explosions) occur in the damaged equipment impacted by the escalation vectors.

Escalation vectors initiate at one location and cause another incident elsewhere in the process. The avoidance of domino effects is the essence of isolation; preventing the initial, primary explosion from creating escalation vectors, like heat flux, pressure wave, and missiles that initiate at one location and subsequently cause another secondary incident.

Segregation and the separation of processes play a role in avoiding domino (knock-on) effects. Examples of moderation in the form of limitation of effects include:

- Locate hazardous equipment, like dust collectors, away from other equipment or outdoors, and
- Segregate, separate or detach areas where a dust deflagration hazard exists in a building or building compartment (excluding hazard within equipment) from other occupancies to minimize damage from a fire or explosion (NFPA 652, 2019).

An example of the application of the ISD principle of simplification is making process equipment robust enough to withstand process upsets and other undesired events (e.g., use process equipment designed to contain the maximum foreseeable process pressures) (Amyotte et al., 2009). This contributes to minimizing domino effects such as projectile damage or secondary dust explosions.

3.5.2 Material choke

Material chokes (plug of bulk solids) can provide isolation by means of the ISD principle of moderation. In a screw conveyor, a flight turn can be removed, which will leave a plug of bulk solids to act as a material choke that can provide isolation and can help prevent downstream damage (Amyotte et al., 2009; CCPS, 2005). Challenges can be involved with the use of material chokes, which are discussed further in Chapter 5; NFPA 69 (2019) A.12.2.4 describes that in previous editions of NFPA 69, screw conveyors had been included as material chokes, but indicates that industry experience has demonstrated that they are not reliable as isolation methods.

3.6 Advantages and disadvantages of different deflagration isolation techniques

There are several advantages and disadvantages associated with different deflagration isolation equipment. ISD considerations for isolation are the most preferred with respect to the hierarchy of hazard controls because this leads to more effective management of hazard at the source. ISD is most beneficial when considered at the design stage, but it can still be incorporated in operational plants during process hazard analysis, management of change, and incident investigation (Amyotte et al., 2007; Goraya et al., 2004; Rayner Brown et al., 2020). With respect to chemical isolation, some advantages include that it is economical and easy to clean up if it activates. A disadvantage is that the suppressant introduces foreign material, which may mean that some process material may need to be discarded if it becomes contaminated. Fast acting valves are expensive with respect to capital, though they are very rugged and robust and provide effective containment. Flap valves may need to be replaced if they become bent during operation, but the maintenance is simpler and is less demanding than an active valve. Active systems require detailed training to perform maintenance, as well as electronic skills and knowledge. Rotary valves can experience issues with maintaining close tolerances due to wear caused by abrasive material, so the close tolerance is not maintained between the vanes and valve body and the minimum gap necessary is not present.

Advantages and disadvantages associated with different deflagration isolation techniques are found in Table 3-1. Information on active and passive deflagration isolation equipment was contributed by Jeff Mycroft, Fike Canada Inc. Information on inherently safer design (ISD) as been added by the author (K. Rayner Brown). Additional details around challenges associated with different isolation techniques, including failure modes and degradation factors, and the measures that must be taken to ensure they are effective, are discussed in more detail in Chapter 5.

Table 3-1. Advantages and disadvantages associated with different types of deflagration isolation equipment (contributed by Jeff Mycroft, Fike Canada Inc.). Additional information on inherently safer design (ISD) added by author (K. Rayner Brown) and denoted by *.

Technology	Advantages	Disadvantages	Considerations
*Inherently safer design**			
	• Most preferred with respect to the hierarchy of hazard controls because it leads to more effective management of hazard at the source • Very effective when considered at the design life cycle stage	• Most beneficial when considered at the design life cycle stage • ISD barriers can still be degraded if not properly documented and managed • ISD is hazard specific - tools like checklist questions and brainstorming with subject matter experts can be used to identify opportunities for specific applications	• ISD can also be considered during operation through risk assessments (PHAs), management of change (MOC) and incident investigation/root cause analysis
Passive			
Flap Valve	• Simple to install • Simple to maintain/service • Does not require a control system or detectors to operate	• Requires regular maintenance • Will not close and isolate properly if not kept clean	• Must have dust accumulation sensor • Must be interlocked with the process so when flap valve closes, the process shuts down

Table 3-1 Advantages and disadvantages associated with different types of deflagration isolation equipment continued

Technology	Advantages	Disadvantages	Considerations
Flap Valve	• Will close without external input in the event of an explosion	• Dust load sensor alarms can go off frequently if dust is accumulating in the process line and valve • Cannot be used on dense phase or heavy flow lines • Some certified valves on market may not work as advertised if not tested properly	
Rotary Valve	• Simple to install • Can be used to isolate two connected enclosures • Can meter product • Will work even when stopped/not moving	• Requires regular maintenance • Gaps and wear must be monitored to ensure it is still compliant with NFPA 69 • Cannot be used for high flow lines • Can bind, jam, plug and cannot be used with certain material • Flow restrictions/speed of discharge limitations	• Must be interlocked with the system so when there is an explosion, the rotary valve stops • Usually only on discharge lines from vessels

.Table 3-1 Advantages and disadvantages associated with different types of deflagration isolation equipment continued

Technology	Advantages	Disadvantages	Considerations
Active			
Chemical Isolation	• Economical on larger lines or if purchased with active suppression system • Very effective • No moving parts • Can be used in sanitary applications • Uses sodium bicarbonate (baking soda) as a safe extinguishing agent	• Requires regular maintenance • Some manufacturers require the bottles to be shipped offsite to be recharged/reloaded, or additional spare bottles purchased • Requires some cleanup may be depending on the process • After activation, isolation system needs to be reloaded/recharged	Must be interlocked with the process so when an explosion occurs and the isolation device activates, the process shuts down
Explosion Isolation Gate Valve	• Very effective • Can be used with all forms of explosion protection • Can withstand up to 12 bar of pressure	• Requires regular maintenance • Can be expensive • After activation, isolation system needs to be serviced by trained personnel	Must be interlocked with the process so when an explosion occurs and the isolation device activates, the process shuts down

.Table 3-1 Advantages and disadvantages associated with different types of deflagration isolation equipment continued

Technology	Advantages	Disadvantages	Considerations
Explosion Isolation Gate Valve	• Provides solid physical barrier between the vessel and connecting equipment • Stops pressure, heat and product • Can be used in sanitary applications		

CHAPTER 4 COMMON LOCATIONS FOR ISOLATION DEVICES IN WOOD PELLET PRODUCTION

This chapter describes common locations in wood pellet production to use isolation techniques. The following chapter is based on a literature review of CCPS (2005) and material described in presentation slides provided by Jay Juvenal (Sales Engineer) with CV Technology. This complete reference (CV Technology, 2021) is found in Appendix C.

4.1 Hammer Mills

Why is isolation needed?

- Hammer mills are generally the most dangerous piece of equipment throughout a wood pellet plant due to their propensity for generating ignition sources within a dusty environment.
- Hammer mills are almost always connected to other pieces of equipment and thus isolation is imperative.

How can isolation be used?

- Because hammer mills come in many different makes and models, there is no “one-size fits all” explosion isolation solution.
- The most common protection strategy for hammer mills in wood pellet plants is to utilize chemical suppression for isolation due to the versatility that solution provides.

Figure 4-1 shows the installation of chemical isolation on a hammer mill.

Figure 4-1. Chemical isolation deployed on hammer mill dust aspiration lines (CV Technology, 2021) (used with permission)

4.2 Dust Collectors

Why is isolation needed?

- Due to the inherent operation of dust collectors, a high level of suspended fine dust is always present. Thus, they pose a significant risk.
- Because dust collectors are always interconnected to plant operations, isolation is imperative to prevent explosion spread into the production plant.

How can isolation be used?

- Depending on the application, mechanical isolation and chemical Isolation are both viable options.
- Inherently safer design (ISD) can be considered by relocating the dust collector outdoors and away from personnel and buildings. This is the principle of moderation through avoidance of domino (knock-on) effects.

Figure 4-3 and 4-4 show installation of chemical and mechanical isolation on dust collectors, respectively.

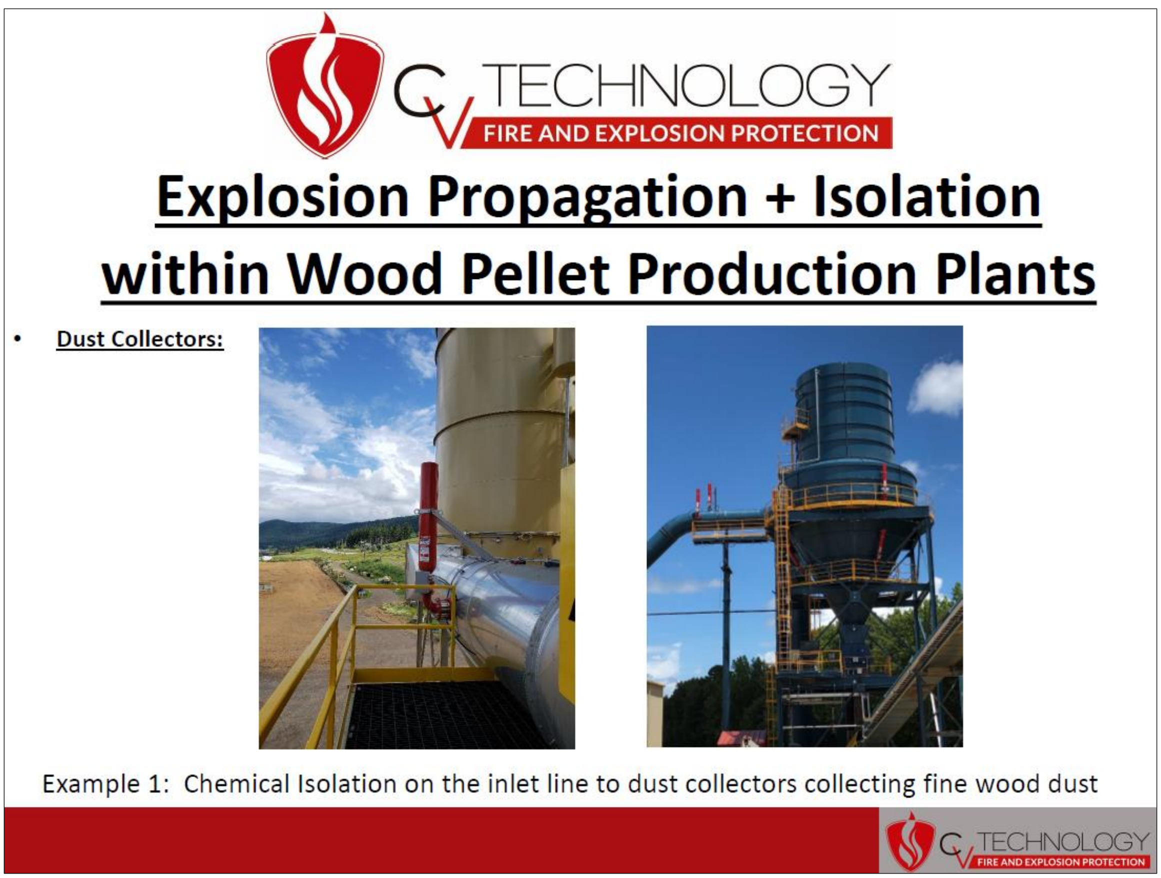

Figure 4-2. Chemical isolation on wood dust collector inlet line (CV Technology, 2021) (used with permission)

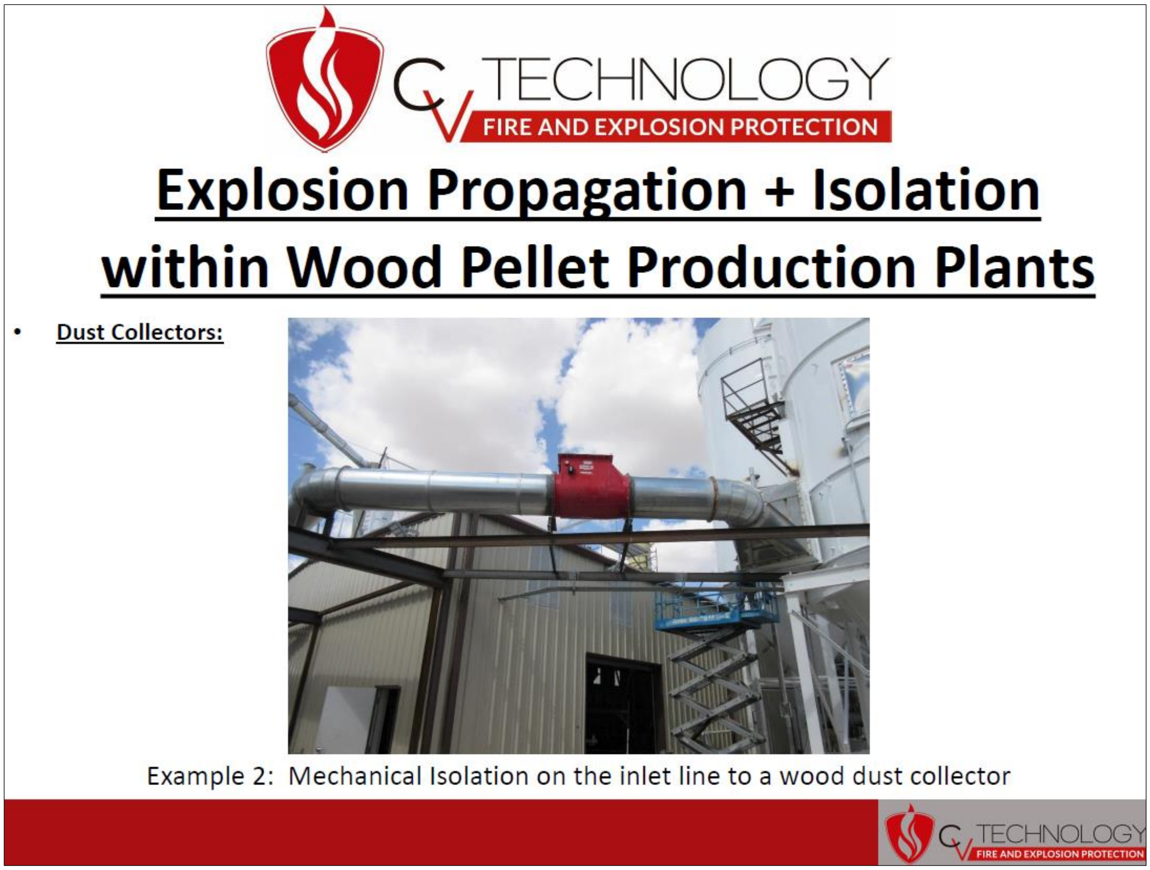

Figure 4-3. Mechanical isolation on wood dust collector inlet line (CV Technology, 2021) (used with permission)

4.3 Bucket Elevators

Why is isolation needed?

- Bucket elevators have a high propensity for fires and explosions due to their design and operation generating dust clouds continuously, as well as numerous moving parts that can have mechanical failure and generate ignition sources (CCPS, 2005).
- Similar to dust collectors, bucket elevators inherently operate with suspended dust clouds within their internal volume. Additionally, they can

also have high kinetic energy producing mechanisms integral to their operation that can act as ignition sources.

- Buckets can act as turbulence generators that increase the rate of flame propagation, thereby causing more severe explosion consequences.
- They are always connected to other pieces of equipment thus making explosion isolation vital to their safety.

How can isolation be used?

- Due to the complexity of the interconnected ducts to and from a bucket elevator in a wood pellet plant, chemical isolation is often the only option available. Rotary airlocks on the infeed/outfeed are also suitable alternatives where they can be applied. However, wood dust is often problematic for these due to its fibrous characteristic.
- From an ISD perspective, (CCPS, 2005), the bucket elevators should be designed to minimize potential ignition sources. Examples include strong anchoring of buckets to belt and strong bearings for all shafts, locating the main drive to elevator externally, and not locating bearings within the casing (as stated by NFPA 654 (2020)[4]).

Figure 4-5 and 4-6 show the installation of chemical isolation on bucket elevators.

[4] NFPA 654 (2020) Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids

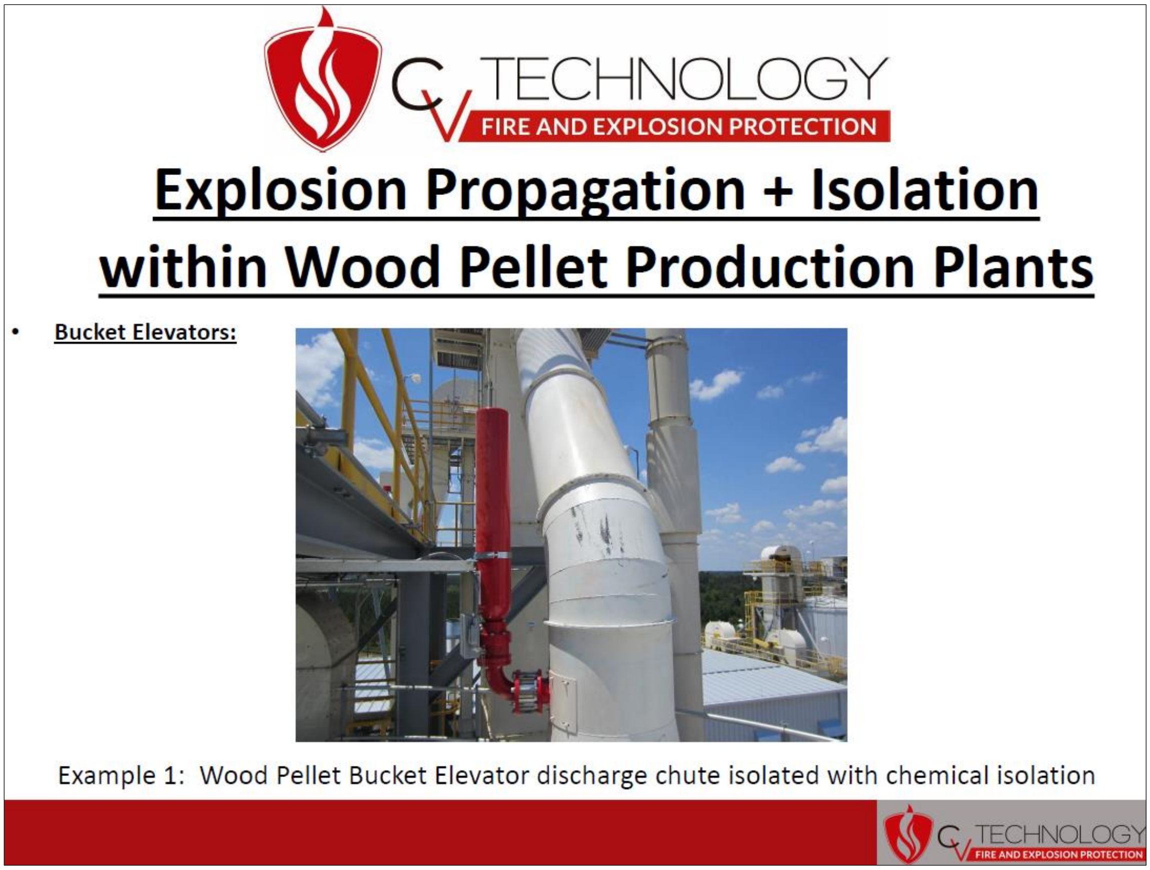

Figure 4-4. Chemical isolation on wood pellet bucket elevator discharge chute (CV Technology, 2021) (used with permission)

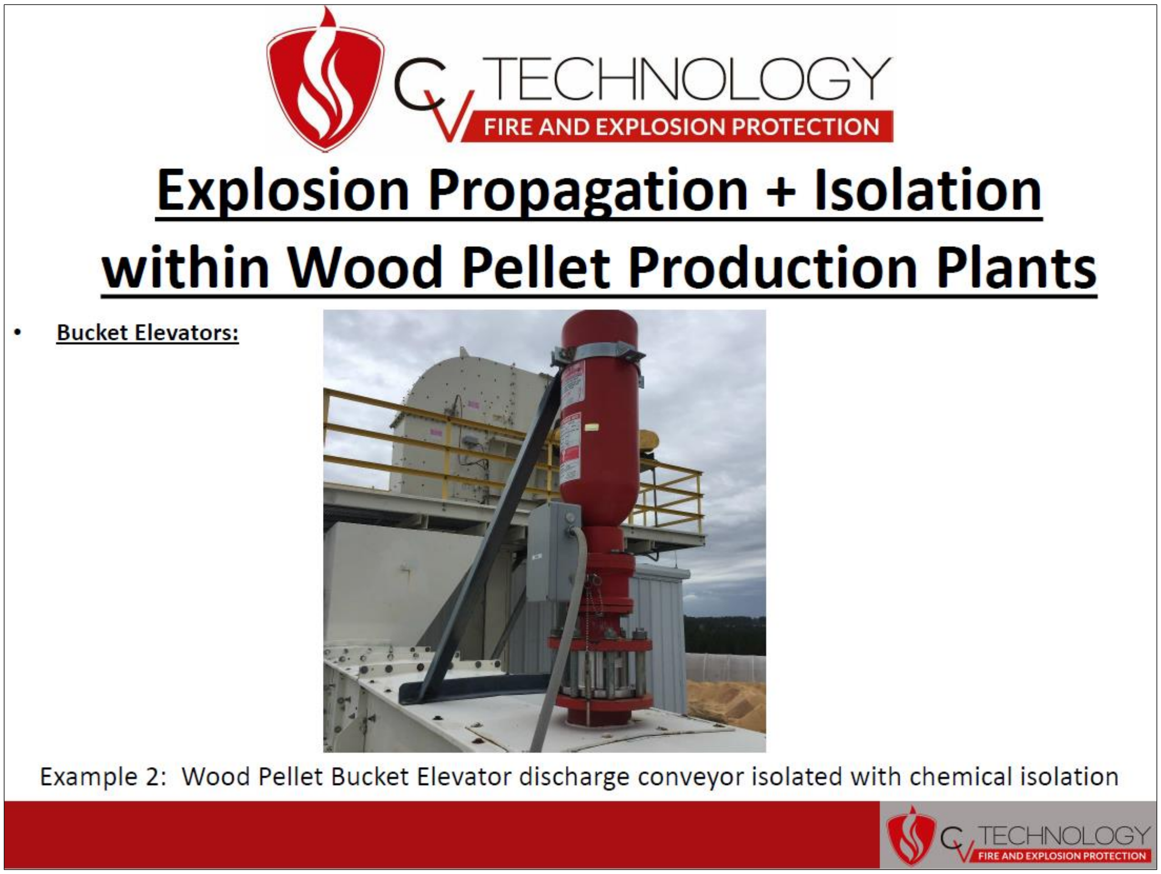

Figure 4-5 Chemical isolation on wood pellet bucket elevator discharge conveyor (CV Technology, 2021) (used with permission)

4.4 Drag Chain Conveyors

Why is isolation needed?

- Drag chain conveyors can develop electrostatic charges on solids while they are moved along the trough surface (CCPS, 2005).
- Drag chain conveyors can act as the source of the deflagration or as the conduit through which a deflagration propagates. In either scenario, explosion isolation is imperative to ensure deflagrations are isolated to their source and do not propagate elsewhere in the plant.

- Conveyors are essentially interconnections between equipment and thus isolation should always be considered.

How can isolation be used?

- Due to the size and shape of drag chain conveyors, chemical isolation is typically the only viable option.

Figure 4-6 shows the installation of chemical isolation on drag chain conveyors.

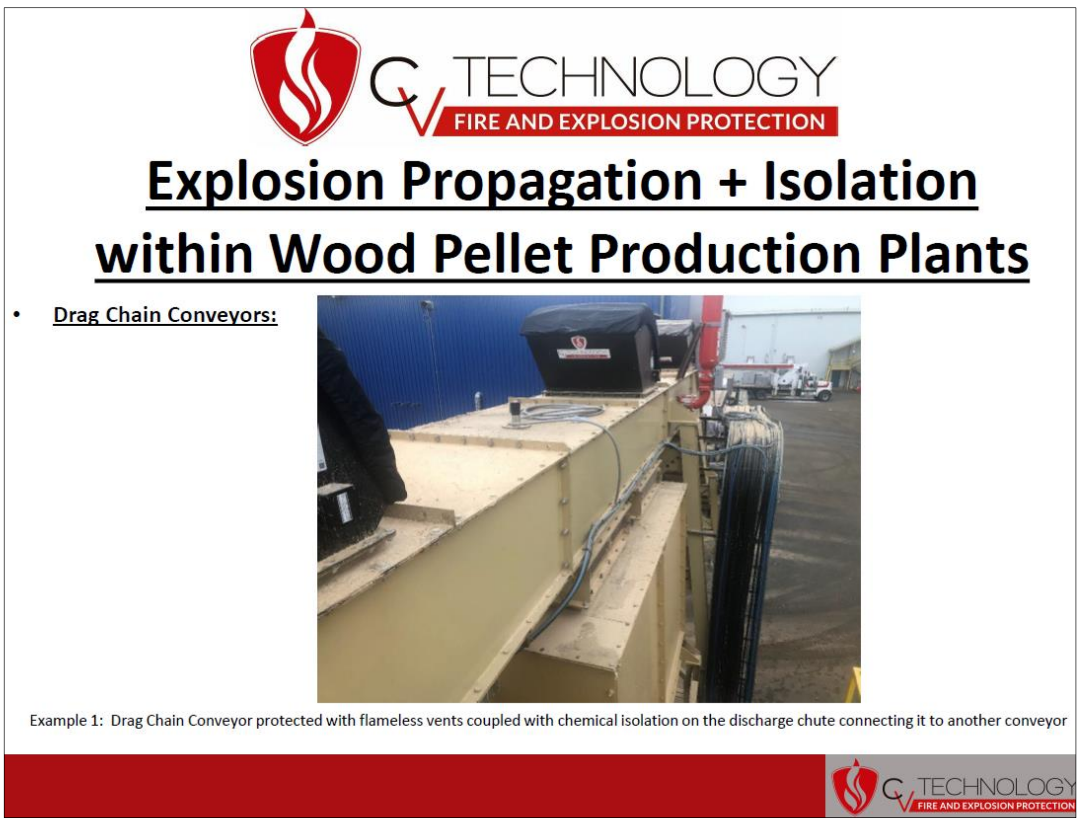

Figure 4-6. Chemical isolation (coupled with flameless vents) on drag chain conveyor discharge chute (CV Technology, 2021) (used with permission)

4.5 Cyclones

Why is isolation needed?

- Although viewed as a lower risk than dust collectors, cyclones serve the same function and thus pose a significant threat. Their operation and the material characteristics of the handled wood should be evaluated for the explosion risk.
- Cyclones are always aspirating some sort of process equipment and are often also connected to RTO's[5]; thus isolation can prove critical.

How can isolation be used?

- Mechanical and chemical isolation are both options.

Figure 4-7 shows a schematic for the installation of chemical isolation on a cyclone.

[5] Regenerative thermal oxidizer

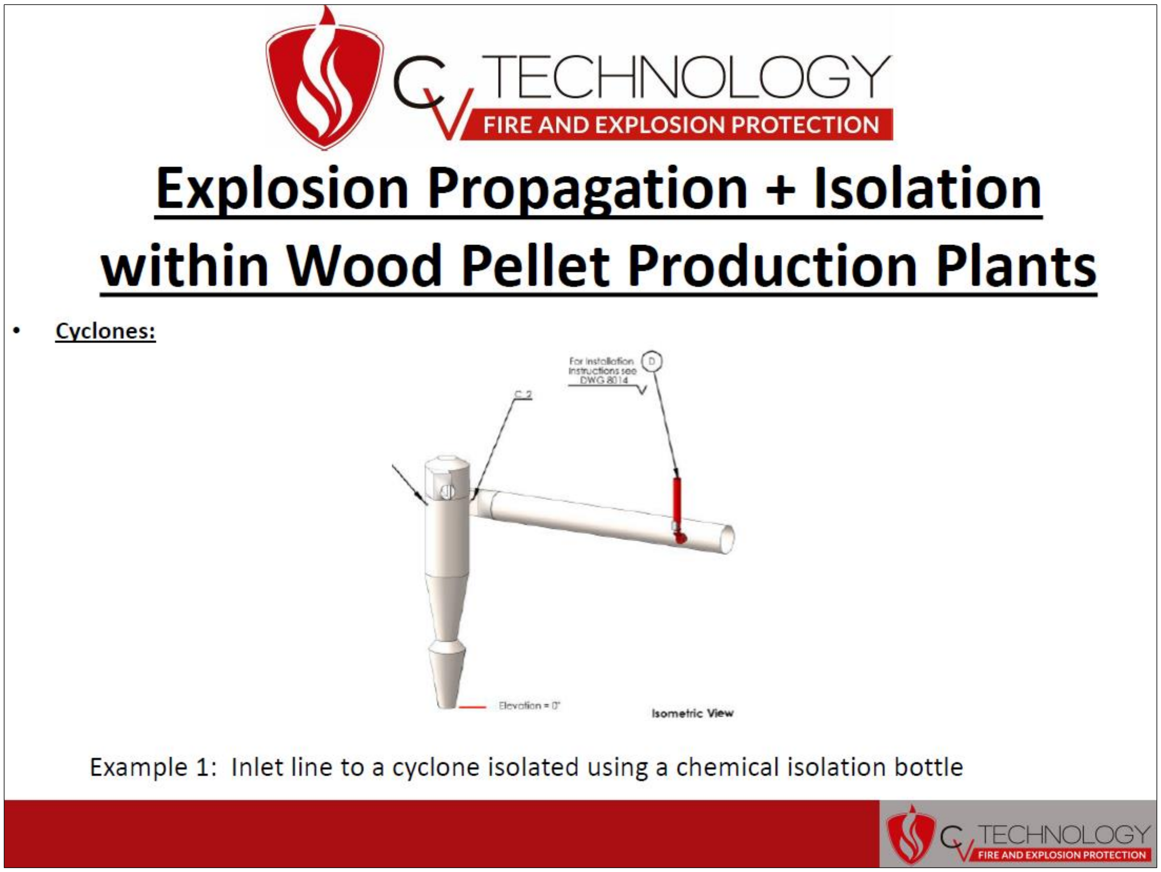

Figure 4-7. Schematic of chemical isolation on cyclone inlet line (CV Technology, 2021) (used with permission)

CHAPTER 5 MANAGEMENT OF THE FAILURE MODES AND DEGRADATION FACTORS OF ISOLATION TECHNIQUES

This chapter provides an overview of the different challenges and issues that can arise with deflagration isolation equipment as well as how to address them to ensure that the systems will perform as intended when needed. The terminology of *degradation factors* and *degradation factor controls* will be used in this section, which comes from bow tie analysis, a process hazard analysis (PHA) methodology. In bow tie analysis, degradation factors refer to weaknesses associated with barriers, and degradation factor controls identify how these can be addressed and managed. Definitions of degradation factors and degradation controls are given in Table 5-1 (CCPS/EI, 2018).

Table 5-1. Definitions of degradation factor and degradation factor control

Degradation Factor	**Degradation Factor Control**
Condition or error that defeats or degrades the effectiveness of a barrier and compromises its function Issue (e.g., environmental factors, human factors, loss of critical systems)	Physical or non-physical control (measure) that prevents a degradation factor from compromising a barrier How an issue is managed (e.g., inspections, preventative maintenance)

5.1 Chemical isolation

Degradation factors and controls associated with chemical isolation that have been identified through literature review (including CCPS, 2005), as well as discussions with SMEs, are described in Table 5-2.

Table 5-2. Degradation factors and controls associated with chemical isolation systems

Degradation Factor	Degradation Factor Control
System may not fire/activate (e.g., if the system gets locked out and not put back into operation, material could cake around detectors)	System provides indication if there is an issue using a low-pressure switch on bottles Complete inspections (check bottle pressures, test all detectors); follow frequency as per OEM[6] and NFPA, ensure only trained personnel can perform this inspection Complete spring and fall inspections to prevent overpressure and underpressure of bottles Ensure material not caking in devices (complete maintenance inspections) Complete regular training of new operators with supplier and maintain rained personnel in plant; ensure only trained personnel are allowed to perform work on system
System could be physically/electrically disabled; could forget to re-enable after down-day, inspection, or welding	Follow Electrical Safe Work Procedure; if work is going to be performed, ensure documentation is followed Ensure only trained personnel are performing this task; this should be incorporated as part of their training Ensure that workorder has directions within it to be aware of sensor; if sensor taken out of commission, directions must indicate to re-arm when work is complete

[6] Original equipment manufacturer

Table 5-2 Degradation factors and controls associated with chemical isolation systems continued

Degradation Factor	Degradation Factor Control
Abnormal conditions and issues could inhibit system performance (e.g., wire getting pulled off, low pressure, or lose power to system)	System has constant monitoring of integral components and will enter trouble mode if issue arises, which leads to shuts down. Trouble mode will indicate the type of issue and then facility can perform investigation. System has visible and audible indications and interlock System has battery backup that will run for 24 hours
Pressure detector damaged or goes outside of calibration	System will detect it is out of specification range and will enter trouble mode, then facility can perform investigation
Charge in battery goes below specified level	System will enter soft trouble mode, which indicates the need to recharge or replace battery
Optical detector not placed in correct location with respect to the extinguishing barrier HRD, and extinguishing agent may not act on the flame	Use engineering design specifications to determine correct sensor location; consider all necessary parameters for detection selection (including temperature, pressure, and vibration)
Pressure of deflagration may not be enough to activate system	System can also use optical sensors for detection

Table 5-2 Degradation factors and controls associated with chemical isolation systems continued

Degradation Factor	Degradation Factor Control
Amount of extinguishing agent may be incorrect for the specific application; it depends on the nature of the combustible dust, the diameter of the pipeline, flame velocity and maximum reduced explosion overpressure in the vessel	Use engineering design specifications to determine required amount of extinguishing agent
Spurious activation (false trips); system activates when it is not supposed to/activates in absence of deflagration	System uses algorithms to detect specific rate of rise (very sensitive of appropriate timing) Use of two sensors on vessel that have voting arrangement (both have to activate)
Water damage causing electrical shorting	Take appropriate measures in facility to protect against water damage.
Servicing problems (testing, bypassing maintenance, bringing system back on-line)	Train staff and work with equipment suppliers to ensure system can be operated effectively; ensure supplier-user relations are strong Ensure in-house personnel receive training from equipment supplier for service equipment; necessary to receive specialized training to perform maintenance (e.g., monthly sensor checks)

Table 5-2 Degradation factors and controls associated with chemical isolation systems continued

Degradation Factor	Degradation Factor Control
Suppression systems can produce pressures that could exceed the design strength of some low-strength equipment (i.e., baghouses)	Consider design limitations during suppression systems design
Sensors not positioned correctly and lead to premature activation	Use engineering design specifications to determine correct sensor location; consider all necessary parameters for detection selection (including temperature, pressure, and vibration)
Optical sensor could be affected by light leaks in duct work or by human error if personnel opens up equipment (e.g., conveyor) and sets system off	Follow operating procedures, including Standard Operating Procedures (SOPs) for Lockout and Tagout (LOTO) Post signage in the areas the sensors are located Ensure workorder contains directions to be aware of sensor
Pneumatic system upset condition (e.g., artificial pressure spike could be caused by dust collector or fan)	Follow operating procedures

Table 5-2 Degradation factors and controls associated with chemical isolation systems continued

Degradation Factor	Degradation Factor Control
Mechanical expansion and contraction can present reliability issue – extreme cold can adversely affect suppression bottles. Leaks could occur at -40°C at elastomer-metal interfaces; if nitrogen leaks out, propellant lost.	System provides indication if there is an issue using a low-pressure switch on bottles Perform spring and fall inspections, or more frequently as needed, to prevent over pressure and under pressure of bottles. Ensure personnel performing inspections are trained. System fault will indicate if the pressure is below minimum required pressure; replace bottles or contact manufacturer. Train staff and work with equipment suppliers to ensure system can be operated effectively; ensure supplier-user relations are strong.

5.2 Flap valves

The degradation factors and controls for flap valves are described in Table 5-3.

Table 5-3. Degradation factors and controls associated with flap valves

Degradation Factor	**Degradation Factor Control**
Material can build up (could be sticky or wet)	Clean appropriately (determine frequency based on operation and characteristics); perform necessary cleaning and maintenance System has sensor that will indicate material build up
Performance of valve can be affected by pressure pulse or oscillations	Source equipment from reputable suppliers that can provide valve test data
Incorrect installation	Follow supplier manuals for installation and contact suppliers if unsure. Ensure contractors have knowledge and skills to correctly install equipment.
Older model valve does not indicate status of valve (open or closed/locked)	Consider replacing with new valve model (on newer models, system has indicator that shows if flap valve is open or closed/locked)
Significant pressure drop across valve, which can cause negative impacts on fan and blower and lead to buildup of material due to insufficient velocity and flow	Use engineering specifications and calculations to consider the pressure drop; consult equipment suppliers and ask for certification (including the particular size for the application)

Table 5-3 Degradation factors and controls associated with flap valves continued

Degradation Factor	Degradation Factor Control
Incorrect installation (e.g., minimum/maximum distances not observed, elbows in ductwork not considered, installed backwards)	Consult equipment suppliers and follow installation directions and recommendations

5.3 Fast-acting mechanical valves

The degradation factors and controls for fast-acting mechanical valves are described in Table 5-4.

Table 5-4. Degradation factors and controls associated with fast-acting mechanical valves

Degradation Factor	Degradation Factor Control
Spurious activation (false trips); system activates when it is not supposed to/activates in absence of deflagration	System has buffer range around activation pressure System has dual detection (system uses minimum of two separate pressure detectors and both must detect pressure change) System has pressure and noise filtering to provide stability Consider use of flex hoses to reduce effects of vibration

Table 5-4 Degradation factors and controls associated with fast-acting mechanical valves continued

Degradation Factor	Degradation Factor Control
Spurious activation (false trips); system activates when it is not supposed to/activates in absence of deflagration	System maintains history of warnings with respect to time Ensure operators are trained on system operation and response
Valve performance could be affected by dust settling or accumulation	System installed in pipe area open and can be built without pockets and dead corners
Valve could spring back open after closure	System has special dampers that absorb significant forces from valve closure and prevent slide from springing back open
Valve performance affected by incorrect distance between protected equipment and fast-acting valve	Equipment suppliers use engineering design specifications and perform complex calculation to determine correct distance. Equipment suppliers consider numerous factors that affect minimum distance (e.g., dust characteristics, closing time of valve, flame velocity).

5.4 Rotary valves

Rotary valves (airlocks) can perform as a mechanical isolation barrier if (CCPS, 2005; NFPA 69 (2019)):

1. Two vanes per side are near the housing walls (are engaged),
2. The gap between the rotor and the housing is ≤0.2 mm, and
3. The vanes (tips) are metal.

However, there are numerous challenges associated with the use of rotary valves in wood pellet production, which impact these criteria from being met. These are described in Table 5-5.

Table 5-5. Degradation factors and controls associated with rotary valves

Degradation Factor	Degradation Factor Control
Valve body does not have sufficient strength to withstand the explosion pressure developed	Ensure calculations are used to determine necessary strength and specify when procuring valve

Table 5-5 Degradation factors and controls associated with rotary valves continued

Degradation Factor	Degradation Factor Control
Close tolerance is not maintained between the vanes and valve body (wear can increase the tolerances so that the minimum gap necessary is no longer present)	Perform proper maintenance to ensure that normal wear and tear do not impede the ability of the valve to prevent propagation. Ensure an effective testing and inspection program is established Consider the use of chemical isolation as an add-on isolation measure to reduce reliance on rotary valve as isolation measure Consider the use of valves that have rotor blades constructed of specialized abrasion-resistant metal that may contributed to minimizing wear
Friction in bearings can generate sufficient heat to cause smolders and hot spots. If rotary valve continues running during upset conditions and rotary valve not shut down immediately, smoldering solids can be transported downstream.	Consider installation of temperature sensor in valve body and bearings Interlock valve motor to shut down if smoldering occurs Ensure programming is in place to stop the rotary valve (otherwise valve will keep moving and will not isolate) Complete preventative maintenance and inspections, including examining clearances and adjusting belt and chain drives

Table 5-5 Degradation factors and controls associated with rotary valves continued

Degradation Factor	Degradation Factor Control
Rotary valve impacted by ambient temperature; tolerance issues can arise from seasonal and operational effects. High temperatures cause equipment to expand, causing the close tolerance between the vanes and valve body to be lost. Cold temperatures cause equipment to contract and vanes to jam.	Consider the use of chemical isolation as an add-on isolation measure to reduce reliance on close-tolerance rotary valve as isolation measure

5.5 Inherently safer design

Inherently safer design considerations also have challenges associated with them, which are described in Table 5-6.

Table 5-6. Degradation factors and controls associated with ISD considerations for isolation

Degradation Factor	Degradation Factor Control
Segregation difficult to perform because facility already built	Consider during capital projects, management of change (MOC), risk assessments and incident investigations, to ensure any opportunities are leveraged
Material choke issue, bridging (which creates a blockage), can arise and impact ability to maintain plug of solids above valve inlet and create material choke	Ensure equipment (hopper, bin, silo) is designed to best suit the characteristics of the bulk material being handled. Avoid hammering on sides bins, as this can damage equipment and generate dust clouds.
Abnormal, environmental or process conditions (emptying and filling, material characteristics) causes the choke to be lost. Could lead to performance deterioration (i.e., plugging, freezing)	Defined process for shutdown and startup to ensure the material choke is present and effective

Table 5-6 Degradation factors and controls associated with chemical isolation systems continued

Degradation Factor	Degradation Factor Control
Material choke may not be effective or appropriate (e.g., during start-up/shutdown, there is potential for the material choke to not be in place)	Complete proper application and management to ensure adequate level of choke is present Perform proper qualification and risk management Use chemical isolation as add-on isolation measure (when NFPA rated close-tolerance rotary valve not feasible)

CHAPTER 6

GUIDELINES FOR INCORPORATING DEFLAGRATION ISOLATION TECHNIQUES

This chapter describes how to navigate the journey of incorporating deflagration isolation in a facility. It is comprised of a four-step roadmap shown in Figure 6-1.

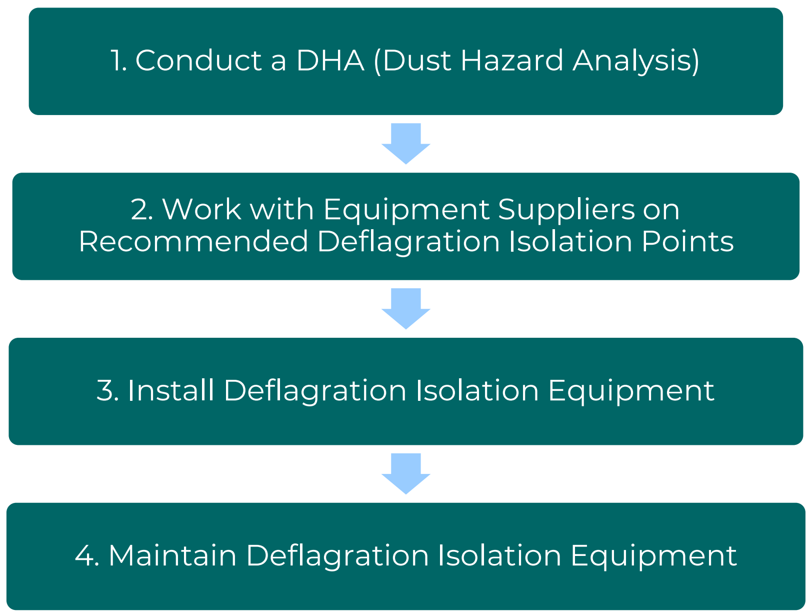

Figure 6-1. Four-step roadmap for incorporating deflagration isolation into a facility

Each of the steps in Figure 6-1 is discussed in this chapter.

6.1 Conduct a DHA (Dust Hazard Analysis)

The first step to incorporating deflagration isolation techniques is completing a dust hazard analysis (DHA) for a given facility. This DHA is the springboard for deflagration isolation methods. In Canada, an Authority Having Jurisdiction (AHJ) may require a DHA to be completed. Although the National Fire Code (NFC) in Canada does not reference a DHA or NFPA 652, a DHA is a critical step in managing combustible dust hazards. Performing a DHA ensures that a facility's hazards associated with combustible dust can be properly identified and managed. The following Frequently Asked Questions (FAQs) about DHAs describe why a DHA is a good place to start and an important first step. The answers have been contributed by Timothy Heneks, P.E. at Dustcon Solutions Inc.

What is a DHA?

A Dust Hazard Analysis (DHA) is a systematic approach to identifying and analyzing the fire and explosion hazards posed by combustible dust within a facility. The Dust Hazard Analysis is more detailed than a typical walkthrough assessment performed by equipment vendors or insurance companies; it is less detailed and encompasses a narrower scope than a process hazard analysis (PHA) as a DHA focusses only on combustible dust related fire and explosion hazards.

Why do I need it?

A Dust Hazard Analysis is needed to comply with the requirements of NFPA 652 and industry-specific Standards such as NFPA 61, 664, 484, and 654. In Canada, an Authority Having Jurisdiction (AHJ) may reference NFPA 652 and require a facility to complete a DHA. The NFPA requirements may be enforced through Occupational Health and Safety requirements or by adoption by insurance companies. The DHA requirement applies to new processes/facilities and applies retroactively for existing processes/facilities that handle, generate or store combustible particulate solids. Beyond compliance, a DHA is needed to adequately understand and prevent the consequences related to combustible dust, which may include employee injury/fatality, asset damage, and business continuity interruption.

What will it do for me? What can I use it for?

An effective DHA will identify specific areas and equipment within your facility in which fire and explosion hazards exist, identify the safeguards currently in place to prevent or mitigate the hazard, and specify additional safeguards needed to ensure proper compliance and safety. The DHA should include a basis of safety for each safeguard which can be used as documentation to ensure that future changes to the process do not negatively impact combustible dust safety. The recommendations made by the DHA to close gaps may serve as a roadmap for future improvements to equipment and management systems. In many cases, recommendations may be prioritized and ranked based on relative risk and required resources to complete the recommended actions.

What does it not give me? What is out of scope?

A Dust Hazard Analysis will not necessarily include other services such as a comprehensive Hazardous Area Classification ("Electrical Classification"), detailed

Fire/Explosion Protection Design, or Development of Management Systems. Additionally, certain hazards may fall outside the scope of a Dust Hazard Analysis. For example, a DHA does not cover inhalation hazards associated with dust in air or the determination of PPE such as half-face versus full-face respirators. Additionally, hazards posed by materials which are not particulate solids may not be evaluated as part of a DHA such as fire, flash fire, and explosion hazards from flammable liquids, gases, and vapors. Unless these gases/vapors interact with combustible dust to form hybrid mixtures, they would likely be outside the scope of a Dust Hazard Analysis.

How long does it take?

A DHA may take anywhere from a couple of weeks to several months to complete depending on the scope and complexity of the process/facility. Some simple systems may be evaluated in a couple of hours worth of time onsite and an initial draft may be available within a week or two. Other complex facilities with many different process areas and equipment types could take up to a week of onsite walk-through and it could be several months before a comprehensive report is ready.

Who can perform a DHA?

A DHA should be an effort that is undertaken by a multidisciplinary team of engineers, safety processionals, operations management, and maintenance staff along with a process safety expert, often a third- party consultant, qualified to lead the DHA. NFPA 652 states that a DHA shall be led by a qualified person and defines this as someone with “possession of a recognized degree, certificate, professional standing or skill” and has the “knowledge, training, and experience”. This definition[7] is borrowed from another unrelated NFPA Standard and does not necessarily provide clarity to facility managers looking to understand who they should assign the task of leading the DHA. A good way to determine if someone is qualified to lead a DHA is to understand if they have a firm knowledge of the related NFPA Standards (and other international or third- party standards such as ATEX[8] or FM[9]), expertise in combustible dust related hazards and safeguards, have led DHAs in the past (or participated in a prominent way), and possess experience related to the process or industry segment. When determining qualifications, it can be helpful to ask for a resume/CV[10], a sample DHA report from work previously completed, and a list of references (preferably in a similar industry sector) to contact and ask about their performance.

Is a DHA the same thing as a HAZOP?

A DHA is not the same as a HAZOP. A Hazard and Operability Study, or HAZOP, is one of multiple common methods for evaluating potential hazards within a process or facility. Others may include What-If, FMEA[11], Fault Tree Analysis, and

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[7] *Definition from NFPA 652 (2019):* ***3.3.39 Qualified Person.*** *A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems related to the subject matter, the work, or the project.*

[8] ATEX is the name commonly given to the two European Directives for controlling explosive atmospheres, ATEX 137 and ATEX 95 (HSE, 2021).

[9] FM Approvals provides product testing and standards (FM Approvals, 2021).

[10] *curriculum vitae*

[11] failure modes and effects analysis

LOPA[12]. When completing a DHA, especially DHAs using a risk-based approach, HAZOP or other hazard analysis method may be used as the structure for identifying and analyzing hazards for complex systems.

When should I get a DHA?

NFPA 652 requires a Dust Hazard Analysis (DHA) for all new and existing processes/facilities that handle combustible dust. Additionally, a DHA should be reviewed and updated at least every five years. If major changes are made to a facility or process, as part of a facility's management of change (MOC) process, it is also a best practice to complete a DHA at that time.

How do I best prepare for my the DHA? What support or resources should I have?

One should gather documentation about the process and materials including: list of materials/ingredients/products, Safety Data Sheets (SDSs), explosibility results, (materials for which there is no explosibility data should be characterized through sampling and lab testing), process flow diagrams (PFDs), piping and instrumentation diagrams (P&IDs), facility layout drawings, equipment drawings, details on explosion/fire protection systems, near miss/incident history, and management systems and programs for combustible dust safety.

[12] layer of protection analysis

6.2 Work with Equipment Suppliers on Recommended Deflagration Isolation Points

The next step is to contact equipment suppliers to source deflagration isolation equipment. There are several factors to consider when assessing equipment suppliers; this section describes some key traits to consider in equipment suppliers and what to look for.

Engineering

Ensure the correct personnel are examining the purchase, selection, and installation. It is important that proper engineering is completed by reputable and trusted suppliers and the equipment supplier provides system certification information.

Training

Supplier selection may be influenced by the available training and resources that are offered by the company. It is important that suppliers offer specialized training for servicing and maintaining the equipment. Ensure operations personnel receive this training; this is an important part of establishing a program for incorporating and implementing the isolation equipment into the facility.

Equipment Features

It can be difficult to select suppliers given the different isolation equipment options on the market. Engage in discussions with prospective suppliers and assess the advantages of the isolation products and services (e.g., automation, sensors, ongoing maintenance/service offered, support available if there are issues, and best value). It is important to compare different suppliers as advances and innovations are constantly being made.

6.3 Install Deflagration Isolation Equipment

Completing correct installation of the isolation equipment is another critical step. When the facility is selecting a contractor to complete the equipment installation, it is important to ensure the contractor is well-suited to perform the installation. The facility will be provided a comprehensive engineering package by the equipment manufacturer to be used for installation and commissioning. The engineering package is intended to be used by installers to ensure the system is installed properly. The engineering package includes application drawings of the isolation equipment installation, consisting of a custom three-dimensional (3D) model of the facility's process equipment (e.g., dust collector, conveyor, bucket elevator, hammer mill, cyclone) with the isolation equipment added to the model, along with dimensions. The equipment manufacturer will also provide wiring schematics that describe the proper electrical installation. Installation and Operation (I&O) manuals for the isolation equipment also include training material for facility personnel.

Facilities and installers can also contact the equipment suppliers if anything is unclear with respect to installation. NFPA (2019) Chapter 15 (Installation, Inspection, and Maintenance of Explosion Prevention Systems) provides information on the installation, inspection and maintenance procedures required for proper function and operation of explosion prevention and control systems. NFPA 69 15.6 describes numerous steps for system acceptance that must be completed prior to use, including visual and physical inspections of the system components, functional testing, and system calibrations. It is important to perform inspections after installation to identify any issues. Ease of access to isolation devices is critical to allow for inspection and maintenance. Inspections should also be completed after any process or equipment change as part of MOC. Facilities should refer to NFPA (2019) Chapter 15 for further detail on measures to take to ensure the deflagration isolation equipment is properly installed.

6.4 Maintain Deflagration Isolation Equipment

It is imperative that maintenance and inspections are performed according to NFPA 69 (2019) and OEM specifications and recommendations. Numerous degradation factor controls listed in Chapter 5 in this report are related to maintenance and inspections, which emphasizes the importance of proper maintenance. NFPA 69 (2019) Chapter 15 provides guidance for maintenance of the deflagration isolation equipment, including performing maintenance according to manufacturers' requirements if there was a scenario that could degrade the protection system. Additionally, NFPA 69 (2019) specifies that system components to which process material adheres shall be regularly cleaned.

CHAPTER 7 OVERCOMING CHALLENGES

Throughout the course of completing research and interviews for this report, numerous challenges in the field of deflagration isolation were identified by the subject matter experts. This chapter highlights those challenges, as well as possible solutions that were identified.

7.1 Emphasizing the importance of a dust mitigation program

Dust mitigation programs play a critical role in reducing risk. Dust leaks must be fixed to limit dust from escaping or current equipment should be replaced with dust tight equipment. Dust deposits must be regularly cleaned to ensure they are not thicker than 1/32 inch (0.8 mm) (or approximately the thickness of a paperclip) (NFPA 654, 2020). Dust mitigation programs are important because if there is a deflagration, the pressure wave can cause the dust deposits to be suspended and lead to a secondary deflagration. Secondary explosions can occur when a dust layer or cloud is ignited by the flamefront from a primary explosion in process equipment, which creates a domino effect and a series of increasingly catastrophic explosions (Amyotte, 2013).

Maintaining good hazard abatement and housekeeping procedures to remove fugitive dust accumulations is critical. Current cleaning procedures should be reviewed, and facilities should consider if they need to be updated and revised to ensure dust does not reach hazardous accumulations.

7.2 Enhancing combustible dust hazard awareness

This research also identified there is a need for improved combustible dust awareness and understanding, which is consistent with recent literature (Cloney and Snoeys, 2019; Kay and Mazur, 2020). There are a range of resources available to facilities handling combustible dust to enhance understanding, including seminars, presentations, as well as contacting subject matter experts and consultants in combustible dust hazards (including those listed as WPAC member companies). Readers are encouraged to study and explore the following valuable resources:

- BC Forest Safety Council Combustible Dust Resources (BC Forest Safety Council, 2021),
- DustSafetyScience.com, a combustible dust hazard awareness online platform (DustEx Research Ltd., 2021),
- Manufacturing Safety Alliance of BC Combustible Dust Awareness eLearning course (Manufacturing Safety Alliance of BC, 2021),
- Technical Safety BC Combustible Dust Education & Awareness Resources (Technical Safety BC, 2021),
- Three-part NFPA 652 Combustible Dust Online Training Series (NFPA, 2021),
- United States Chemical Safety Board (US CSB) combustible dust resources and videos (CSB, 2021),

- Wood Pellet Association of Canada (WPAC) Safety Resource Compendium (Wood Pellet Association of Canada, 2021), and
- WorkSafeBC Combustible Dust Resource Toolbox (WorkSafeBC, 2021).

7.3 Addressing issues around explosion isolation - other recommended activities for facilities to consider

As highlighted in Section 6.1, one of the most important steps to addressing issues around explosion isolation and identifying opportunities for areas of improvement is conducting a DHA in your facility. A DHA improves the awareness of the types of hazards that are present and identifies key steps for addressing the issues. As mentioned in Section 6.1, an important consideration for DHAs is management of change (MOC); after implementing a change or considering a change, the facility should follow up with the DHA provider, as this could change the DHA recommendations (i.e., hazard reduction/control). Changes such as ducts, velocities, equipment and material, can influence the process and the extent of this impact needs to be considered and determined.

A difficulty that was discussed extensively during the research was the challenges associated with the use of rotary valves for wood pellet plant application. It is recommended that additional deflagration isolation techniques be considered for these areas, and that end-users work closely with equipment manufacturers and suppliers to identify equipment most suitable for their specific application.

It is also recommended that facilities develop training programs for explosion safety systems awareness (including isolation systems, along with explosion prevention and explosion protection). This training program would include:

- location of systems,
- nature of systems,
- operation of systems,
- purpose of systems,
- activation zones of systems, and
- effects of system activation.

Additionally, this training should highlight the importance of the system and proper maintenance (e.g., lockout tagout procedures, importance of not bypassing systems due to the process being impeded). This training should help prevent differences between recommended best-practices for installing and maintaining isolation equipment and what is actually implemented. Personnel that should receive the training include those involved with the design and implementation of explosion isolation, as well as personnel involved with maintenance and operations. Annual refresher training as part of combustible dust training would be beneficial. Prior to incorporating and implementing explosion safety systems, facility stakeholder engagement is needed. Throughout the process of incorporating deflagration isolation equipment, communication between all stakeholders (management, supervisors, operators, maintenance technicians, electricians, health and safety specialists, engineers, equipment suppliers) is essential to ensuring system effectiveness. Effective stakeholder engagement will lead to individuals understanding their roles in ensuring the isolation equipment operates properly.

7.4 Enhancing process safety management (PSM) and element of process safety culture

Throughout the course of the research, it was observed there is an identified need for enhancing the adoption of process safety management (PSM), including the element of process safety culture. During an interview completed for this work with a subject matter expert (SME) from a pellet plant, the individual reported there was less tolerance for risk after incorporating the explosion isolation equipment (e.g., facility will not run process without all isolation systems commissioned and operating). This reduced tolerance was attributed to the knowledge and experience obtained with past events (i.e., the severity of events, and potential consequences and outcomes). This is aligned with collective mindfulness, which is one of the key concepts described by Hopkins (2005). Collective mindfulness includes a preoccupation with failure and sensitivity to operations, which align with avoiding complacency and maintaining a sense of vulnerability. This involves being cognizant that just because a significant loss-producing incident has not happened before does not mean one could not happen.

Process safety culture is one of the focusses of an upcoming project funded by the WorkSafeBC Innovation at Work research grant program. This work is being conducted through a collaboration of Dalhousie University, Wood Pellet

Association of Canada (WPAC), BC Forest Safety Council (BCFSC) and DustEx Research Ltd.. The objective of this project is the explicit and effective integration of process safety management (PSM) concepts into wood pellet facilities. The approach for the project is as follows:

(i) understanding of the current level of adoption of PSM elements and concepts in the participating wood pellet plants, thereby identifying possible gaps,

(ii) development of a plan for increasing the level of adoption and closing of gaps over time, recognizing that the most appropriate design solution may not be a one-size-fits-all model, and

(iii) creation of tools (system elements, measurement indicators, and safety culture benchmarks) to help industry integrate PSM into their operations moving forward.

CHAPTER 8 CONCLUSION AND RECOMMENDATIONS

This report described the importance of incorporating effective deflagration isolation into wood pellet facilities to help manage the risk of propagation of combustible wood dust deflagration. The different equipment in a wood pellet plant that commonly require deflagration isolation include hammer mills, dust collectors, bucket elevators, drag chain conveyors and cyclones. The different types of deflagration isolation techniques frequently used in wood pellet plants include chemical isolation, passive flap valves, fast-acting mechanical valves, and rotary valves. Inherently safer design (ISD) considerations for deflagration isolation were also discussed, including segregation for the avoidance of domino effects (moderation) and material chokes (moderation). ISD measures are the most preferred risk reduction control, as ISD addresses the hazard at the source. ISD should be considered during facility design, risk assessments (process hazard analysis), management of change (MOC), and incident investigation.

This report emphasizes that conducting a dust hazard analysis (DHA) is an important first step for implementing deflagration isolation. A DHA will identify specific areas and equipment within a facility where fire and explosion hazards exist, identify the safeguards currently in place to prevent or mitigate the hazard, and specify additional safeguards needed to reduce risk.

Important considerations to ensure that deflagration isolation systems will perform as intended when needed were also extensively discussed. The importance of working closely with reputable equipment suppliers, as well as performing inspections and preventative maintenance, was emphasized.

Lastly, the report highlighted other findings that were identified as challenges in the area of combustible dust hazards and recommendations for moving forward, which include:

- Emphasizing the importance of a dust mitigation program,
- Enhancing combustible dust hazard awareness,
- Addressing issues around explosion isolation - other recommended activities for facilities to consider, and
- Enhancing process safety management (PSM) and element of process safety culture.

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APPENDIX A STAKEHOLDER INTERVIEW QUESTIONS

Stakeholder Questions – Equipment Suppliers and Consultants

- Can you provide a summary of basic information on the operational mechanisms, installation, and maintenance of deflagration isolation systems?
- What are the known modes of failure of deflagration isolation systems?
    - What situations, conditions or scenarios cause the isolation system to be less effective or reliable? (e.g., environmental factors, human factors, loss of critical systems)
    - What challenges do you have with the design and installation of these systems?
    - What measures do you recommend for addressing this and to increase the success of the systems?
- What observed differences do you see in your recommended best-practices and the feedback you receive from producers about challenges with their installed systems?
    - Do you receive much feedback from producers?
    - Would you like more feedback from producers?
    - How would you like to receive feedback? (i.e., does feedback in the form of a video or technical data help?)
- What would you say are the biggest challenges for addressing issues around explosion isolation?
- What are other activities that you would recommend the facilities do to help address issues and opportunities around explosion isolation?
- What do you think are the biggest areas for improvement in this space? Where should facilities prioritize their efforts?
- What would be the roadmap for implementing isolation equipment in an operating facility?

Stakeholder Questions – Wood Pellet Producers

- Do you have any questions about the different types of deflagration isolation systems that are available?
    - Would a summary of the various types of deflagration isolation methods as well as the advantages and disadvantages of each be valuable?
    - Is there an identified need in your facility for deflagration isolation systems training and education, focusing on the installation, operational mechanisms, and maintenance of these systems?
- What challenges do you have with deflagration isolation systems currently installed at your operation?
    - What situations, conditions or scenarios cause your isolation system to be less effective or reliable? (e.g., environmental factors, human factors, loss of critical systems)
    - What challenges do you have with operation and maintenance of these systems?
    - How do you address and manage these challenges? (e.g., inspections, preventative maintenance)

APPENDIX B SUBJECT MATTER EXPERTS INTERVIEWED

Table B-1 List of equipment suppliers, consultants, and subject matter experts interviewed (provided permission to be acknowledged and identified by name and company, listed alphabetically)

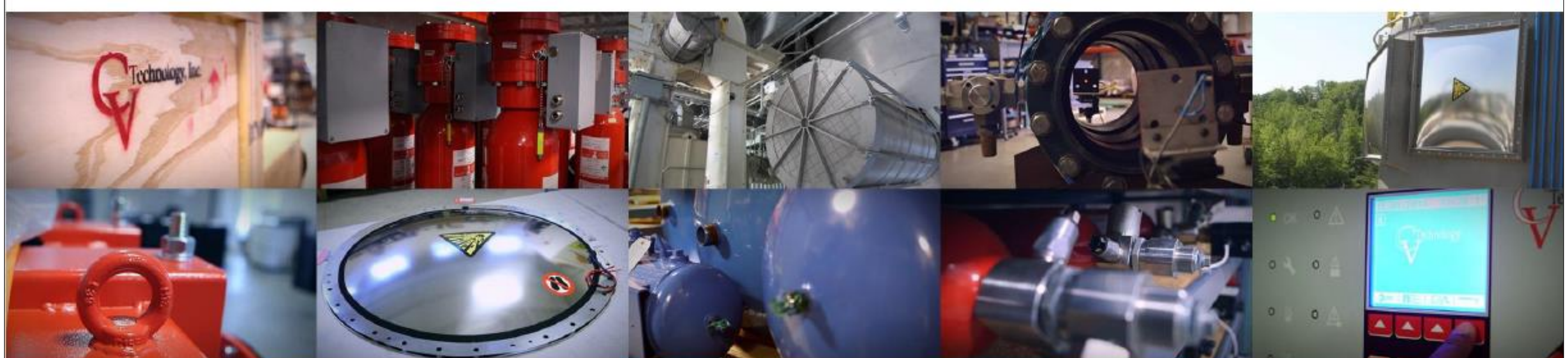
CV Technology	Equipment Supplier	Jay Juvenal Sales Engineer	Address: 15852 Mercantile Court - Jupiter, FL 33478 Main: (561) 694-9588 | Direct: (561) 318-4058 | Mobile: (352) 222-2227 Email: jjuvenal@cvtechnology.com Website: www.cvtechnology.com
Dalhousie University	Process Safety and Combustible Dust Research and Development	Dr. Paul Amyotte, P.Eng. Professor of Chemical Engineering	Address: 5273 DaCosta Row, PO Box 15000, Halifax, Nova Scotia, Canada, B3H 4R2 Email: Paul.Amyotte@dal.ca Website: https://www.dal.ca/faculty/engineering/peas/faculty-staff/our-faculty/paul-amyotte.html
Dustcon Solutions Inc.	Consultant	Timothy Heneks, P.E. Director of Engineering Services	Address: P.O. Box 33207 – West Palm Beach, FL 33420 Main: (561) 626-5556 | Mobile: (561) 789-6411 Email: theneks@dustconsolutions.com Website: www.dustconsolutions.com

Fike Canada, Inc.	Equipment Supplier	Jeff Mycroft, B.Sc. Sales Manager	Address: 4400 Mainway, Burlington, Ontario, L7L 5Y5, Canada Office: 800-363-8116 ext.226 | Cell: 905-467-2984 Email: jeff.mycroft@fike.com Website: www.fike.com
Jensen Hughes	Consultant	Luc Cormier, M.Eng., P.Eng. Market Lead – West Canada	Address: 1195 West Broadway, Suite 228, Vancouver, BC V6H 3X5 Office: +1 604-260-4545 Cell: +1 604-818-7840 Email: lcormier@jensenhughes.com Website: www.jensenhughes.com
Rembe Inc.	Equipment Supplier	Jeramy Slaunwhite, P.Eng. Explosion Safety Consultant	Halifax, NS. Canada Cell: 902.220.6396 Email: js@rembe.us North American HQ & Warehouse: 9567 Yarborough Road Fort Mill, SC 29707 Office: 704.716.7022 Fax: 704.716.7025 Website: https://www.rembe.us/

CV TECHNOLOGY
FIRE AND EXPLOSION PROTECTION

WPAC
Combustible Dust Protection: Explosion Isolation

Jay Juvenal



CV TECHNOLOGY
FIRE AND EXPLOSION PROTECTION

Objectives

- Quick Introduction to CV Technology
- Review of what Explosion Propagation is and why Explosion Isolation is required
- Review of the regulatory requirements for Explosion Isolation
- Review of where explosion isolation hazards are the greatest throughout a Wood Pellet Plant
- Explanation of available solutions + examples

CV TECHNOLOGY
FIRE AND EXPLOSION PROTECTION

Introduction

- Been in business since 1994
- Based in Jupiter, FL
- Privately, employee owned
- Manufacturer of a full line of combustible dust protection equipment at our HQ in Jupiter
- Two members that sit on the applicable NFPA committees
- Have sales representation coverage all over North America, South America and Europe
- Fully functioning service department that serves all of North America, South America and Europe
- Vertically integrated: Sales, production and service all provided directly by CV Technology

Dust Explosion Terminology

Explosion Propagation + Isolation

- Explosion Isolation is the prevention of an explosion from propagating to other locations from the site of where it initiated
- As Figure 1 shows, an explosion originating within a dust collector can propagate from the source of the explosion via the interconnected pipes and ducts from the collector.
- Propagation can have several effects:
  - Pressure release
  - Flame front exposure
  - Pressure piling
  - Secondary explosion

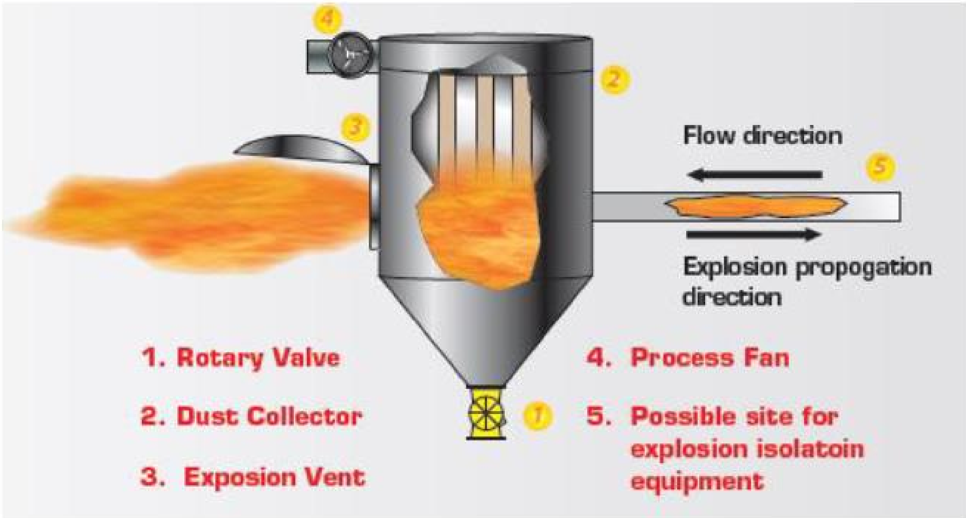


Figure 1: Explosion Propagation Example

CV TECHNOLOGY FIRE AND EXPLOSION PROTECTION

Dust Explosion Terminology

Explosion Propagation + Isolation

- Therefore, in order to prevent explosion propagation from occurring, explosion isolation equipment is required to block this transmission before it gets to unmanageable levels.
- The following slides indicate how NFPA outlines the requirements to prevent this from occurring.

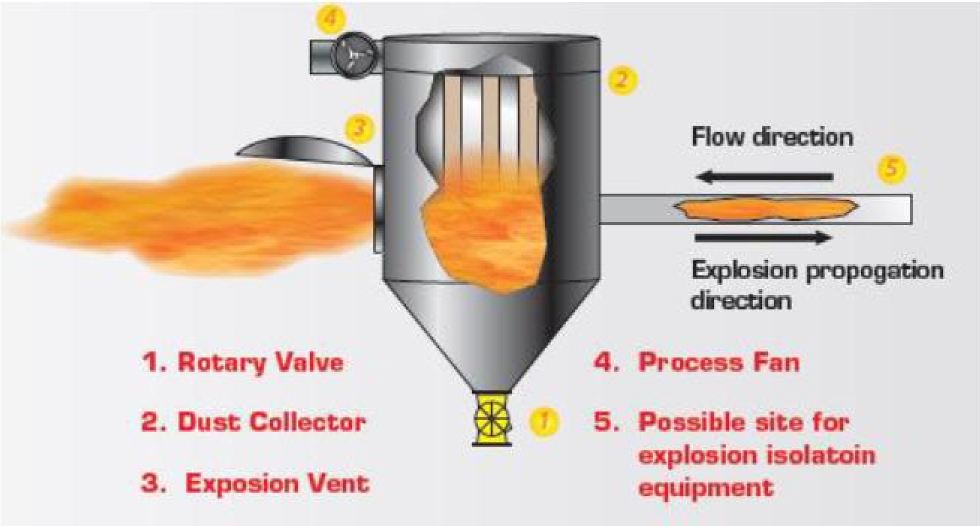


Figure 1: Explosion Propagation Example

NFPA Regulations

7.1.6* Isolation of Equipment.

7.1.6.1 Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

What does NFPA 69 say?

NFPA Regulations

NFPA 69 Standard on Explosion Prevention Systems, 2014 Edition

11.2* Isolation Techniques. Isolation methods shall be permitted to be used to interrupt or mitigate flame propagation, deflagration pressure, pressure piling, and flame-jet ignition between items of equipment. Active isolation systems shall be permitted to be based on various techniques that include, but are not limited to, the use of the following components:

(1) Chemical barrier
(2) Fast-acting mechanical valve
(3) Externally actuated float valve
(4) Actuated pinch valve

CV TECHNOLOGY FIRE AND EXPLOSION PROTECTION

EXAMPLE: Explosion Propagation

Video 1: Example of what explosion propagation looks like. The initial explosion instantaneously propagates to the connected equipment via the connecting pipe.

CV TECHNOLOGY FIRE AND EXPLOSION PROTECTION

Explosion Propagation + Isolation within Wood Pellet Production Plants

- Wood Pellet Production Plants are inherently a very hazardous operation from a combustible dust standpoint. The final product is a fuel and thus the process of making a fuel is one that must involve many levels of safety and precautions.

- When evaluating where the greatest risk for explosion propagation are within a Wood Pellet Plant, we utilize the following standard risk matrix outlined in Figure 2.

- The impact of a deflagration throughout an entire wood pellet plant, typically, is going to be severe. Because it is the same throughout the process, we generally look at the likelihood of an event as the determining criteria.

Likelihood ↑ / Impact →	Negligible	Minor	Moderate	Significant	Severe
Very Likely	Low Med	Medium	Med Hi	High	High
Likely	Low	Low Med	Medium	Med Hi	High
Possible	Low	Low Med	Medium	Med Hi	Med Hi
Unlikely	Low	Low Med	Low Med	Medium	Med Hi
Very Unlikely	Low	Low	Low Med	Medium	Medium

Figure 2: Risk Matrix

Explosion Propagation + Isolation within Wood Pellet Production Plants

- The following equipment generally has the highest likelihood of generating a dust deflagration and thus requiring **explosion isolation**:
  - 1.) Hammer Mills
  - 2.) Dust Collectors
  - 3.) Bucket Elevators
  - 4.) Drag Chain Conveyors
  - 5.) Cyclones

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Hammer Mills:**
  - Mills are generally the most dangerous piece of equipment throughout a wood pellet plant due to their propensity for generating ignition sources within a dusty environment
  - They are almost always connected to other pieces of equipment and thus isolation is imperative
  - Because mills come in many different makes and models, there is no “one-size fits all” explosion isolation solution
  - The most common protection strategy is to utilize Chemical Suppression for isolation due to the versatility that solution provides.

Explosion Propagation + Isolation within Wood Pellet Production Plants

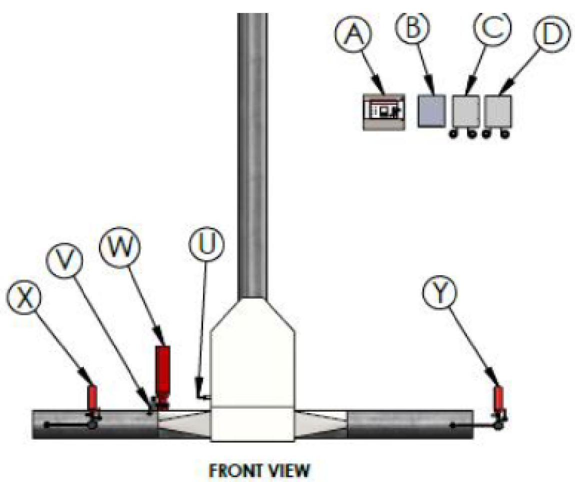
- **Hammer Mills:**

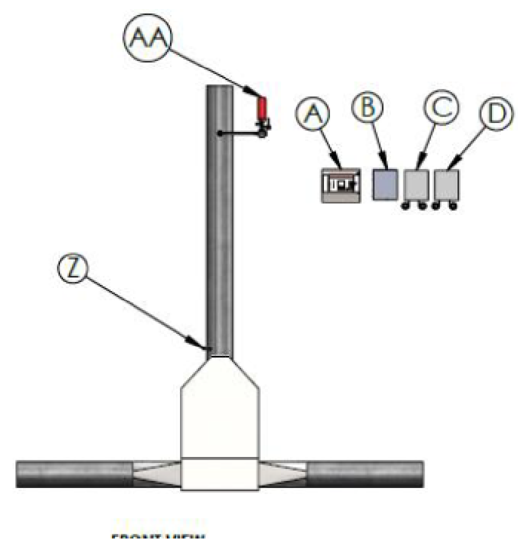
Example 1: Wood Pellet Hammer Mills plenums isolated utilizing chemical isolation on the dust aspiration lines.

CV TECHNOLOGY
FIRE AND EXPLOSION PROTECTION

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Hammer Mills:**





Example 2: Wood Pellet Hammer Mills plenums isolated utilizing chemical isolation on the air intake, material intake and mill discharge

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Dust Collectors:**
  - Due to the inherent operation of dust collectors, a high level of suspended fine dust is always present. Thus, they pose a significant risk.
  - Because dust collectors are always interconnected to plant operations, isolation is imperative to prevent explosion spread into the production plant.
  - Depending on the application, mechanical isolation or Chemical Isolation are both viable options.

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Dust Collectors:**

Example 1: Chemical Isolation on the inlet line to dust collectors collecting fine wood dust

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Dust Collectors:**

Example 2: Mechanical Isolation on the inlet line to a wood dust collector

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Bucket Elevators:**
  - Similar to dust collectors, bucket elevators inherently operate with suspended dust clouds within their internal volume. Additionally, they can also have high kinetic energy producing mechanisms integral to their operation that can act as ignition sources.
  - They are always connected to other pieces of equipment thus making explosion isolation vital to their safety
  - Due to the complexity of the interconnected ducts to and from a bucket elevator in a wood pellet plant, chemical isolation is often the only option available. Rotary airlocks on the infeed/outfeed are also suitable alternatives where they can be applied, however, wood dust is often problematic for these.

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Bucket Elevators:**

Example 1: Wood Pellet Bucket Elevator discharge chute isolated with chemical isolation

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Bucket Elevators:**

Example 2: Wood Pellet Bucket Elevator discharge conveyor isolated with chemical isolation

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Drag Chain Conveyors:**
  - Drag Chain conveyors can act as the source of the deflagration or they can just be the conduit through which a deflagration propagates through. In either scenario, explosion isolation is imperative to ensure deflagrations are isolated to their source and don't propagate elsewhere in the plant.
  - They are themselves nothing but interconnections between equipment and thus isolation should always be considered
  - Due to the size and shape and drag chain conveyors, typically chemical isolation is the only viable option

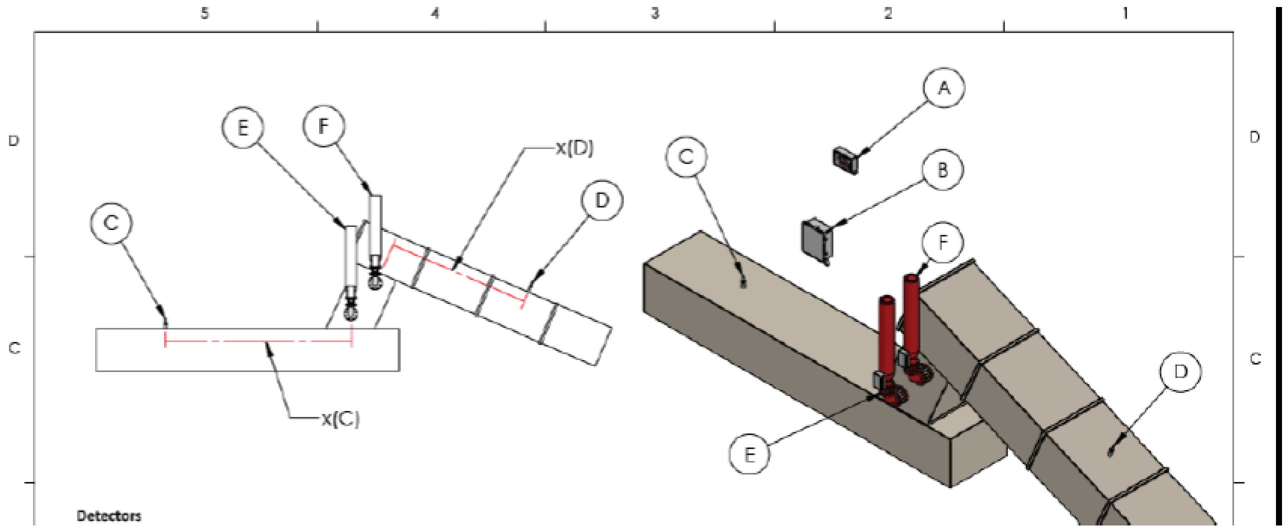
Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Drag Chain Conveyors:**

Example 1: Drag Chain Conveyor protected with flameless vents coupled with chemical isolation on the discharge chute connecting it to another conveyor

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Drag Chain Conveyors:**



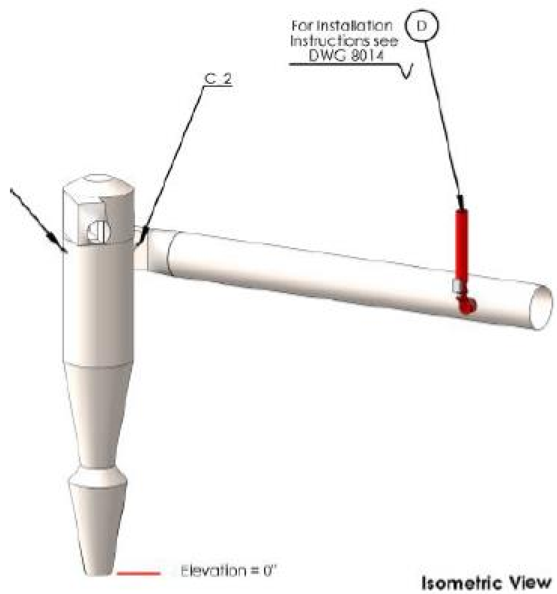
Example 2: The chute connecting (2) drag chain conveyors is equipped with chemical isolation to prevent explosion propagation in either direction

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Cyclones:**
  - Although viewed as a lower risk than dust collectors, cyclones operate in the same function and still pose a significant threat. Their operation and the material characteristics of the handled wood should be evaluated for the explosion risk.
  - They are always aspirating some sort of process equipment and are often also connected to RTO's and thus isolation can prove critical
  - Mechanical and chemical isolation are both options.

Explosion Propagation + Isolation within Wood Pellet Production Plants

- **Cyclones:**



Example 1: Inlet line to a cyclone isolated using a chemical isolation bottle

Thank you!

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