Report

BC FOREST SAFETY COUNCIL – BOW-TIE ANALYSIS OF COMBUSTBLE WOOD DUST IN VENTILATION SYSTEMS

Summary Report

Report – Rev. 0

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Acronyms & Abbreviations

BCFSC	BC Forest Safety Council
DHA	Dust Hazard Analysis
ISD	Inherently Safer Design
MOC	Management of Change
PSM	Process Safety Management
NFPA	National Fire Protection Association

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Executive Summary

This report summarizes the outcomes of a bow-tie analysis of combustible wood dust in ventilation systems in sawmills. The goal of this workshop was to assess the scenarios that can lead to ignition of wood dust, controls for risk reduction, and explore potential ways to improve safety measures.

The bow-tie analysis was developed in a workshop comprised of 25 personnel from wood products manufacturing, primarily sawmills, in June 2024 in Prince George. The information provided by the workshop participants formed the basis of the analysis. The preventative barriers for threats that can lead to ignition of combustible dust, such as mechanical failure, equipment friction, tramp metal, and mobile equipment, were evaluated. Mitigation barriers for consequences including fire or deflagration in dust collectors, silos, other ducts, machine centers and dust pick up points, were also assessed. Explosion protection on enclosures, equipment inlets and outlets, play a significant role in limiting propagation through ventilation between vessels; this safeguard, along with spark detection and deluge and preventative maintenance programs are among those controls that have been identified as critical controls.

Numerous opportunities for improvement were identified relating to:

- Preventative maintenance,
- Housekeeping,
- Predictive monitoring systems,
- Incident investigation and root cause analysis,
- Additional engineering controls,
- Strengthening administrative controls,
- Management of change, and
- Alternative design options (inherently safer design).

Operations are encouraged to consider the hierarchy of controls when implementing safety measures; inherently safer design options (ISD) that eliminate hazards, such as alternative types of equipment or removal of process equipment no longer in-service or needed, are most-effective and most preferred. This report provides resources and tools, such as factsheets, articles, and websites (e.g., Center for Chemical Process Safety) for companies to use to help address these opportunities for improvement.

Many of workshop findings are related to companies' safety management systems. It is recommended that readers complete self-assessments to evaluate their organization's safety management system and help formulate corrective action plans. This report includes self-assessments recently developed for process safety management (PSM) for the wood products manufacturing industry on the elements of management of change, process risk assessment and risk reduction, incident investigation, key performance indicators, senior leadership and safety culture.

A brief introduction to identifying critical controls and critical control management was provided in this workshop; this will be the topic of dedicated in-person workshops taking place on October 8th and 10th, 2024. This report highlights this BCFSC initiative and others that are planned for the remainder of Q4 and 2025.

Acknowledgements

Thank you to each of the bow-tie workshop participants and representatives from the Manufacturing Advisory Group (MAG) companies and the wood pellet industry, for their active participation in the workshop and contribution to the analysis. Thank you, Bill Laturnus of the British Columbia Forest Safety Council (BCFSC), for arranging the project, coordinating the onsite logistics of the bow-tie workshop in Prince George, and providing workshop assistance. Thank you as well to Ms. Tammy Carruthers and Mr. Rob Moonen for their support of the workshop. Funding from BCFSC to conduct this work is gratefully acknowledged.

1.0 Introduction

This report summarizes a bow-tie analysis that was conducted to evaluate the hazard of combustible wood dust in ventilation systems in wood products manufacturing, namely sawmills and wood pellet plants. This bow-tie analysis was conducted with BC Forest Safety Council (BCFSC) and representatives from wood products manufacturing companies, including the Manufacturing Advisory Group (MAG) companies. This section describes the scope, motivation, and objectives of the work.

1.1 SCOPE OF WORK

The scope of the bow-tie workshop was evaluating the ignition of combustible wood dust in the ventilation systems of wood products manufacturing (primarily focused on sawmills). The ventilation system collectively refers to collection points, ducting, baghouses, cyclones, fans and blowers for the wood processing and handling equipment, including planers, saws, side heads, mobile equipment, and bins/silos. Both normal and upset conditions were considered. For the purposes of the evaluation, it was assumed that all dust is deflagrable. 3.3.32.1 NFPA 664[1] defines deflagrable wood dust as "wood particulate that will propagate a deflagration flame front, when suspended in air, or the process-specific oxidizing medium, in sufficient concentration, thus presenting a deflagration hazard."

The scope of work also included the identification of critical controls as well as opportunities for improvement to assist with prioritization and formulation of actions.

1.2 MOTIVATION

Wood products manufacturing facilities, including sawmills and wood pellet plants, are known to generate and handle combustible wood dust. An area of concern with respect to fires and deflagrations is a given facility's ventilation system, which inherently involves the suspension of dust in air within enclosures to transport the material from one process vessel to another. Deflagrations can occur and propagate through processes by means of ventilation systems if ignition sources are not controlled and if equipment does not have effective explosion protection.

A bow-tie analysis allows for the systematic evaluation of how ignition of combustible dust can occur and the current safety measures, which help strengthen the risk management approach.

1.3 OBJECTIVES

The objectives of the work were to develop a bow-tie analysis to enhance the understanding of how deflagrations involving ventilation systems can arise, facilitate peer-to-peer learning in a workshop format, and identify additional safety measures that should be implemented to close gaps in protection schemes through corrective action planning to reduce combustible dust risk.

1.4 COMPLETED TASKS

The project objectives were met by completing the following tasks:

+ Preparation and delivery of full-day bow-tie analysis workshop,
+ Bow-tie quality review and finalization,
+ Qualitative evaluation of bow-tie analysis for trends, recommendations, and resource collection, and
+ Delivery of report and preparation for online webinar.

[1] NFPA 664 (2020) *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

2.0 Bow-Tie Analysis Overview and Workshop Summary

This section briefly introduces the bow-tie analysis tool and summarizes the format and focusses of the bow-tie workshop that was conducted in June 2024, namely critical controls and opportunities for improvement.

2.1 INTRODUCTION TO BOW-TIE ANALYSIS

Bow-tie analysis (also known as a bow-tie diagram) is a process hazard analysis (PHA) tool. Bow-tie analysis demonstrates and communicates how different scenarios and conditions can lead to the loss of control of a hazard and lead to consequences. Figure 1 is a generic bow-tie analysis to illustrate the structure. The elements of a bow-tie analysis, as shown in Figure 1, are as follows: hazard, top event, threat, prevention barrier, consequence, mitigation barrier, degradation factor and degradation control.

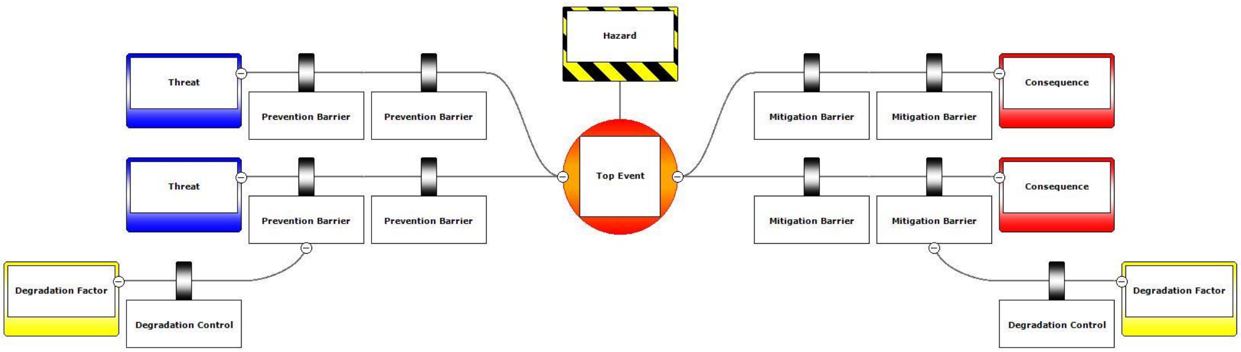


Figure 1. Generic bow-tie analysis

Definitions of the bow-tie analysis elements are outlined in Table 1.

Table 1. Bow-tie analysis element definitions (CCPS/EI, 2018).

Element	Definition
Hazard	An operation, activity, or material with the potential to cause harm to people, property, the environment, or business; a source of harm
Top Event	Within the bow tie diagram, a central event between a threat and a consequence corresponding to the loss of containment or loss of control of the hazard
Threats	A possible initiating event that can result in a loss of control or containment of a hazard (the top event)
Consequences	The undesirable result of loss of containment or control (top event); usually measured are health and safety effects, environmental impacts, loss of property and business interruption
Barriers	A control measure that on its own can prevent a threat developing into a top event (prevention barrier) or can mitigate the consequence of a top event after it has occurred (mitigation barrier). A barrier must be effective, independent and auditable.

Degradation Factors	A situation, condition, defect, or error that compromises the function of a main pathway barrier by defeating it or degrading its effectiveness.
Degradation Controls	Measures that help prevent the degradation factor from impairing the barrier. They lie on the pathway connecting the degradation threat to the main pathway barrier.

2.2 CRITICAL CONTROLS

This workshop included a discussion and identification of critical controls. CCPS/EI (2018) states that a control may be classified as "critical" if:

+ The control is in place for a threat that has a high probability of leading to the top event,
+ The control is in place for a consequence that is very severe or high risk,
+ The pathway has very few controls,
+ The control is on multiple pathways/appears numerous times, and therefore has aggregate importance,
+ The other controls on the pathway have common failure modes,
+ The control has been identified in published industry practice as a safety critical system, and
+ Expert judgement.

Examples of critical controls identified in work previously conducted by BCFSC have included spark detection and deluge systems and explosion protection equipment. Administrative controls, such as preventative maintenance (PM) programs, can also be designated as critical controls, although require different assurance approaches than typical hardware (or engineering) controls relating more to management systems and human and organizational factors (CCPS/EI, 2018).

It is recommended that critical controls identification be completed on a facility-specific basis that uses the onsite knowledge with respect to control reliability, existing control schemes, and current prioritization of operations and maintenance resources, and incident (including near-miss) experience.

2.3 OPPORTUNITIES FOR IMPROVEMENT AND THE HIERARCHY OF CONTROLS

Opportunities for improvement were explored during the workshop to identify gaps in protection schemes or areas that require further research and an action plan. Examples include alternate designs, the addition of safety equipment, and improvements that should be made to documentation. When evaluating opportunities for improvement, the hierarchy of controls (the preferred order of risk reduction measures) (Figure 2) was considered. Inherently safer design (ISD) options (e.g., alternative equipment or designs) were assessed first, followed by potential add-on passive-engineered and active-engineered equipment (e.g., explosion protection) needs, and lastly procedures (e.g., maintenance and operational plans).

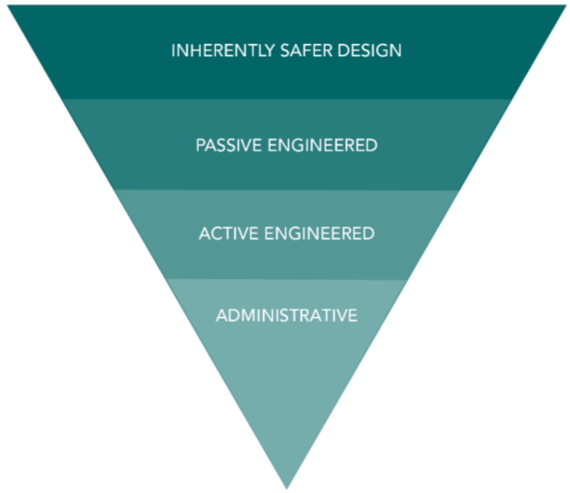


Figure 2. Hierarchy of controls

More information about ISD is provided in Rayner Brown et al. (2022), and the factsheet in Appendix A.

2.4 BOW-TIE ANALYSIS WORKSHOP STRUCTURE

The ventilation bow-tie analysis was completed during a full-day, in-person workshop in June 2024 in Prince George, BC. It involved a group of 25 subject matter experts, including health and safety resources, supervisors, and managers. The workshop was led by K. Rayner Brown (at the time Obex Risk Ltd., now Jensen Hughes), who was facilitator and scribe. Workshop assistance was provided by B. Laturnus (BCFSC Senior Safety Advisor, Manufacturing).

3.0 Bow-Tie Analysis Results and Summary

This section summarizes the outcomes of the bow-tie analysis, including threats, barriers, critical controls and degradation factors.

3.1 THREATS, PREVENTATIVE BARRIERS, AND CRITICAL CONTROLS

The threats are summarized with respect to routine/normal operating conditions, non-routine, and emergency conditions in Table 2; threats are most prevalent during routine and emergency/upset conditions.

Table 2. Summary of threats with respect to operating condition (routine, non-routine, and emergency/upset condition).

Operating Condition	Threat
Routine	Ignition source from tramp metal (e.g., nails in wood, nuts and bolts entering process)
	Ignition sources from wood processing equipment (including saws, side heads)
	Dust accumulations in pipe/duct dead legs, bins or other areas/rooms, changes to pickup points
	Ignition source from planer jointing
	Ignition source from material smoldering on hot surfaces
	Ignition source from adjacent process (e.g., energy systems produces ash and propagates into ventilation system)
	Static electricity
	Ignition of accumulated material in ventilation systems not intended for transferring wood dust, but inherently intake wood dust (e.g., ventilation for weld fumes)
	Ignition source from makeup air and heat exchangers propagates into process ventilation
	Ignition source from personnel smoking
	Electrical failure or arcing (e.g., motor failure, ground fault)
	Sanders: ignition source from friction

Table 2 continued. Summary of threats with respect to operating condition (routine, non-routine, and emergency/upset condition).

Operating Condition	Threat
Non-Routine	Ignition source from hot work
	Use of burned wood - change of species and fibre mix that presents numerous new risks
Emergency/Upset Condition	Ignition source from mechanical failure (e.g., overheated bearing, improperly installed bearing, air lock friction, shock loading, fan failure)
	Ignition source from friction fire on planer, saws, and other wood processing equipment; could be due to running beyond capacity
	Ignition of hydraulic fluid due to line failure, or due to accumulation of fluid from leak
	Ignition source propagation to chip/surge bin (i.e., hot work, mechanical failure, fire in cyclone or bins, auger or belt has debris built up).
	Ignition source from burning material from abort gate during upset conditions (e.g., at adjacent site/process - sawmill with respect to pellet plant)
	Ignition source from fire on mobile equipment or sparks from bucket
	Ignition source from fugitive embers in adjacent areas (e.g., forest fire, fire at adjacent facilities, ember on conveyor or process equipment)

Cut-out diagrams showing threats and preventative barriers are provided in Figure 3 to Figure 5. During the workshop, critical controls were identified; of the preventative barriers, those deemed critical are summarized in Table 3. CCPS/EI (2018) states that critical controls should be evaluated for their degradation factors and controls; this is described in Section 3.3. The opportunities for improvement are discussed in Section 4.

Table 3. Preventative barriers identified as critical controls.

Critical Control
Routine lubrication. Auto-lubrications or manual
Preventative Maintenance (PM) strategy/plan/program
Equipment set-up (i.e., planer, saws, other wood processing equipment)
Thermal monitoring (with interlock to auto shutdown) of equipment (i.e., planer, saws, other wood processing equipment)
Bonding and grounding

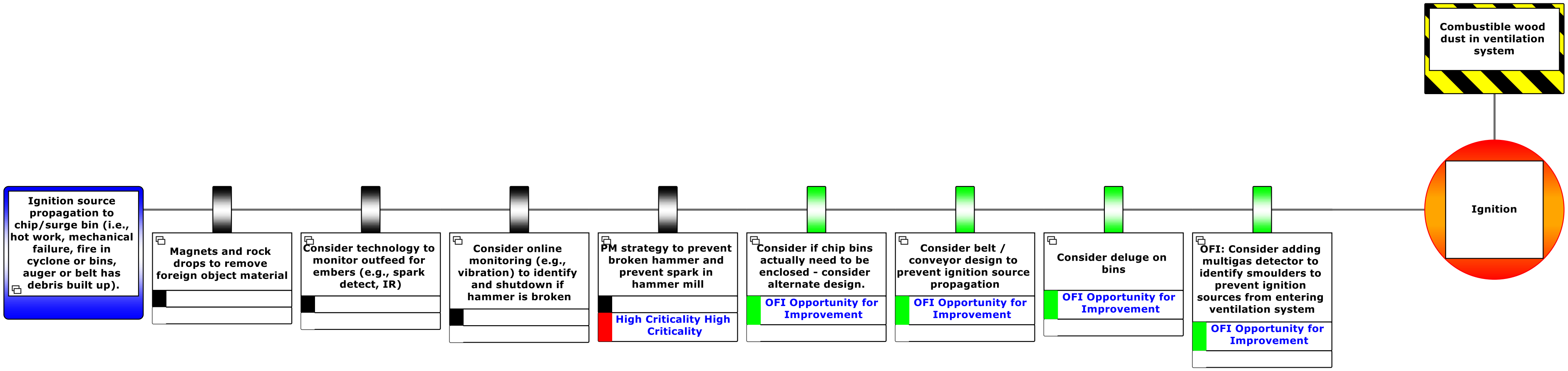


Figure 3. Preventative barriers for threat "Ignition source propagation to chip/surge bin (i.e., hot work, mechanical failure, fire in cyclone or bins, auger or belt has debris built up)."

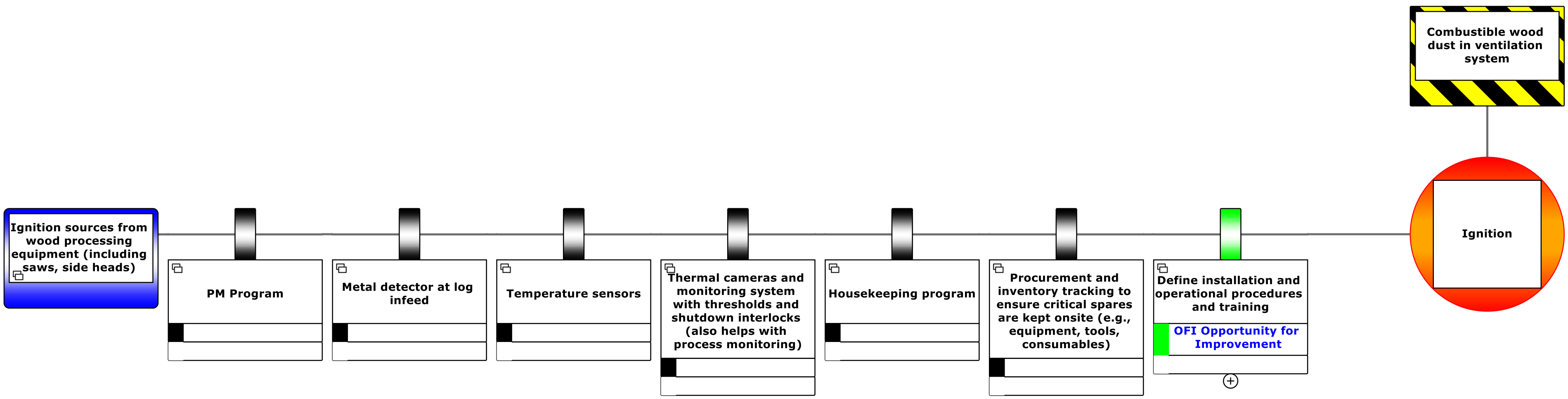


Figure 4. Preventative barriers for threat "Ignition sources from wood processing equipment (including saws, side heads)."

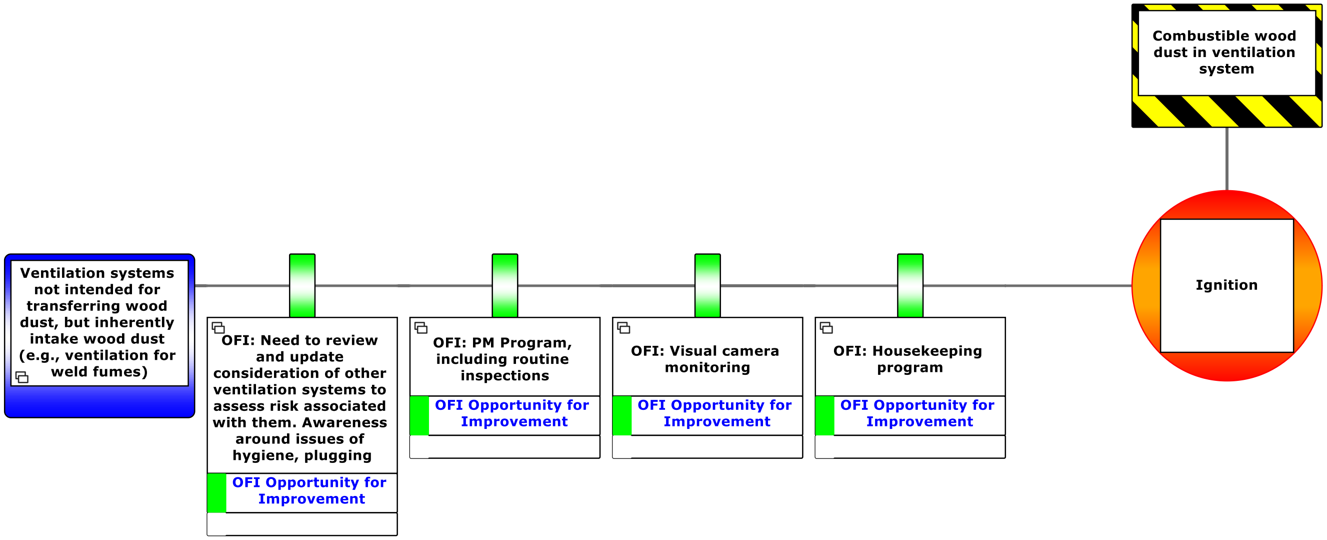


Figure 5. Preventative barriers for threat "[Ignition of material in] Ventilation systems not intended for transferring wood dust, but inherently intake wood dust (e.g., ventilation for weld fumes)."

3.2 CONSEQUENCES, MITIGATIVE BARRIERS, AND CRITICAL CONTROLS

The consequences are summarized in Table 4 with respect to categories of people (health and safety effects), environmental impacts, loss of property and business interruption.

Table 4. Categorization of consequences of ignition of combustible wood dust in ventilation system.

Consequence	Category
Harm (injury, death) to personnel (i.e., due to fire or explosion	People
Fire or deflagration in cyclone, baghouse, silo, conduit, machine centres with pick up points due to propagation of ignition	Property
Secondary explosion in confined area / room due to accumulations on floor or high horizontal surfaces	Property
Environmental damage (smoke, water runoff, release of harmful materials)	Environment
Regulatory and legal issues (may include any liabilities if cause external fire)	Business
Reputational damage	Business
Impacts to personnel (mental health, economic)	People
Business interruption due to loss production, loss of inventory and other assets (e.g., mobile equipment, kilns)	Business

A selection of cut-out diagrams showing mitigative barriers and consequences are provided in Figure 6 and Figure 7.

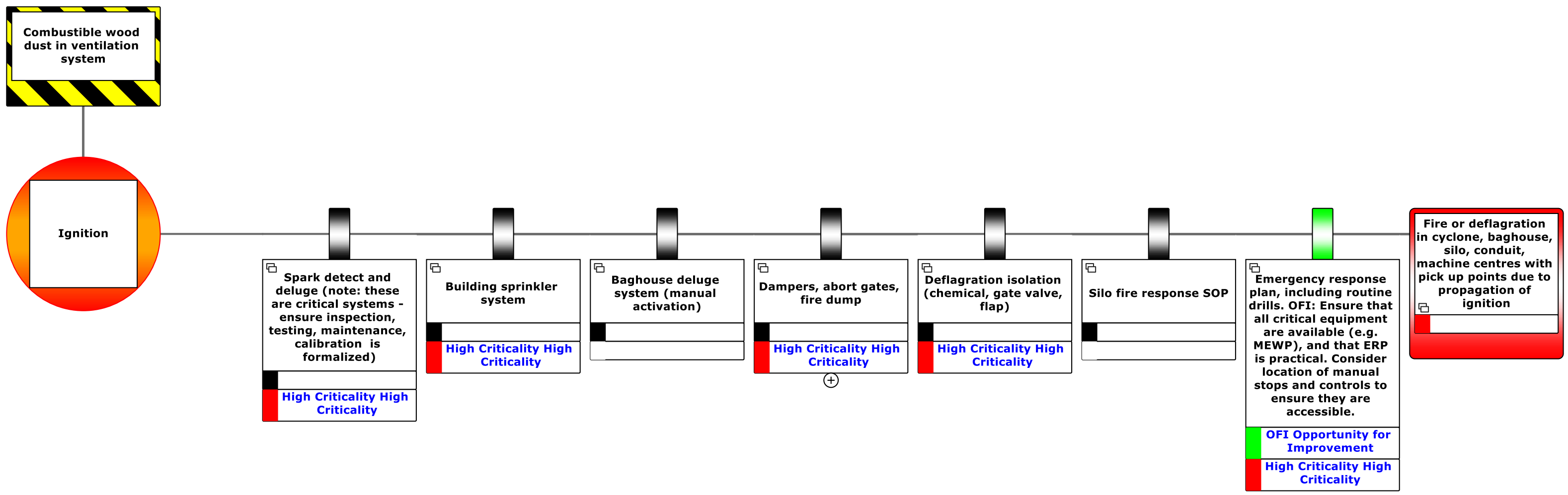


Figure 6. Mitigative barriers for consequence "Fire or deflagration in cyclone, baghouse, silo, conduit, machine centres with pick up points due to propagation of ignition."

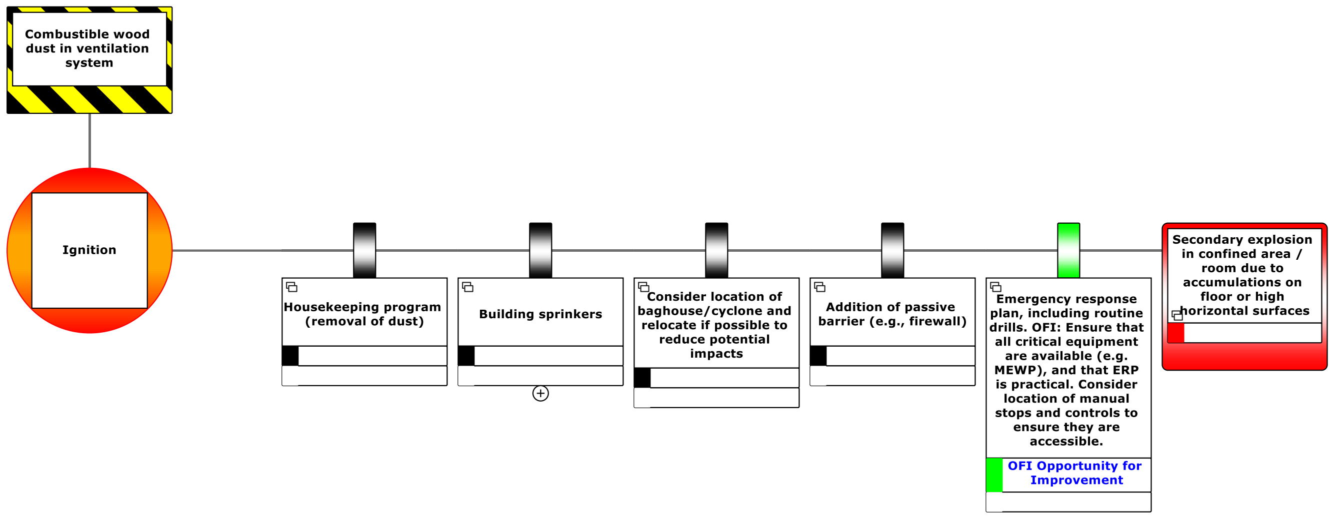


Figure 7. Mitigative barriers for consequence "Secondary explosion in confined area / room due to accumulations on floor or high horizontal surfaces."

During the workshop, a selection of critical controls was made; of the mitigative barriers, those deemed critical are summarized in Table 5.

Table 5. Mitigative barriers identified as critical controls.

Critical Control
Spark detect and deluge
Building sprinkler system
Dampers, abort gates, fire dump
Deflagration isolation (chemical, gate valve, flap)
Emergency response plan, including routine drills.

3.3 CRITICAL CONTROLS, DEGRADATION FACTORS AND CONTROLS

The scope of this workshop was not largely focused on evaluating degradation factors and controls, as there is some data available from previous work in the area that can be referred to. It is recommended that companies identify their facility-specific critical controls and evaluate their degradation factors and controls as part of future work. Table 6 provides the degradation factors and controls for selected critical controls; data has been populated from the workshop and previously completed bow-ties in sawmills, wood pellet plants, and panel board manufacturing.

Table 6. Critical controls with identified degradation factors and controls.

Critical Control	Degradation Factor	Degradation Factor Control
Routine lubrication. Auto-lubrications or manual	Poor management of change - different kind of lubrication used (either purchased or used from elsewhere onsite)	Policy: only one kind of lubrication used onsite Defined procurement standards Education and training to prevent personnel from using incorrect lubrication and try to prevent complacency.

Table 6 continued. Critical controls with identified degradation factors and controls.

Critical Control	Degradation Factor	Degradation Factor Control
Preventative Maintenance (PM) program	Preventative maintenance not effectively prioritized, including considerations of available personnel, scheduling, job scope, backlog. Over-greasing or under-greasing of bearings (if completed manually by maintenance). Unauthorized modifications to safety equipment during maintenance.	Formally define PM program in computerized maintenance management system (CMMS). Shutdown planning. Documentation of manufacturer recommendations/specifications. Automatic greasers. Bearings maintained in critical stock to ensure timely and correct replacement. Training and supervision. Investigation and review of near-miss.
Equipment set-up (i.e., planer, saws, other wood processing equipment)	Out of date documentation (e.g., machine manuals, calibration, SOPs). Personnel not adequately trained. Failure of MOC process to address temporary changes/deviations.	Formalized MOC program following best-practices. Defined procedure and parameters for starting/resetting processes.
Thermal monitoring (with interlock to auto shutdown) of equipment (i.e., planer, saws, other wood processing equipment)	Sensor could fail. Set-point or program changed.	Spare sensors kept onsite. Management of change program.
Bonding and grounding	Straps could fail or break.	Routine inspections.

Table 6 continued. Critical controls with identified degradation factors and controls.

Critical Control	Degradation Factor	Degradation Factor Control
Spark detect and deluge	Detector could fail or sensor could be faulty. Detector disabled during cleaning and not re-enabled. Detector (sensor) could become dirty. Valves could fail (leak or do not open). Nozzles could become plugged. Leaks in water line. Some water lines located outdoors (could freeze or become damaged).	Supervisory circuit/HMI indicates if there is an issue. Failsafe. Check sheet to verify if something is disabled. Operator training. Zone indicates if detector is out of order/disabled Upgraded HMI with improved interface to determine equipment status. System monitors, clean and self-check. Purge air on nozzle heads to keep them clean. Annual OEM inspection. Screens/filters to remove particulate, which are annually inspected. Flow switch before valve. Heat tape and insulation placed on lines.
Building sprinklers	System malfunctions	Valve station checks. Fault indicated on panel to notify if there is a problem with the system. Annual inspections by certified vendor. Monthly pull station checks. Weekly, monthly, quarterly and annual inspections as defined in risk control manual (e.g., flow testing by certified personnel, line flushing, corrosion checks).

Table 6 continued. Critical controls with identified degradation factors and controls.

Critical Control	Degradation Factor	Degradation Factor Control
Dampers, abort gates, fire dump	Mechanical failure Electrical failure Manually disabled; override switch tampered with Incorrect setting set by operator (operator error) Pressure differential failure	Inspection. Replacement in kind with spare parts as needed. HMI notification. Notify electrical and maintenance staff. Training and experience, progressive discipline and supervision. Coaching, Training, Supervision
Deflagration isolation/ suppression (chemical, gate valve, flap)	Pressure of deflagration may not be enough to activate system. Maintenance not performed or delayed. System may not fire/activate. System could be physically/electrically disabled (e.g., could forget to re-enable after down-day or inspection or welding).	Optical sensors used on system as well. Shutdown planning. PM/work order system. Inspections. Low pressure switch on chemical isolation bottles to indicate issue. Training. Electrical Safe Work Procedure. Indication on HMI if system is disabled. Interlock. Multi-point lock-out.

Table 6 continued. Critical controls with identified degradation factors and controls.

Critical Control	Degradation Factor	Degradation Factor Control
Emergency Response Plan (ERP)	Evacuation Plan not followed. Lack of exposure and experience, which may lead to people not following ERP. First aid kit or personnel not available.	Annual review of ERP. Drills completed annually. Training. Maps and signage and routes for muster points. Training on radio use and pre-shift radio checks. Multiple first-aid kits available and inventory is routinely checked. Regular training and certification of personnel tracked through online system.

While the hierarchy of controls should be applied and administrative controls should not be heavily relied upon, in some instances, administrative controls may be all that is practically feasible or currently in-place, and they may play a significant role in risk reduction. As seen in Table 6, administrative safeguards such as the ERP and PM program may be deemed critical controls. The degradation factor controls for these administrative safeguards primarily relate to management system elements such as training and competency, supervision, and inspections, as mentioned in Section 2.2. As such, further work in the area of the application of critical tasks, human and organizational factors and management systems for administrative critical controls is recommended.

4.0 Opportunities for Improvement and Recommendations

This section summarizes gaps that were identified, as well as suggested resources and recommended activities.

4.1 SUMMARY OF OPPORTUNITIES FOR IMPROVEMENT

The opportunities for improvement that were identified are provided in Table 7. To associate them with a management system element to support action planning, they have been organized with respect to process safety management elements, based on the 2nd Edition of CSA Z767 (2024).

Risk management framework is one of the most frequently categorized elements, as it broadly applies to those opportunities for improvement tied to proposed new safeguards to prevent or mitigate hazardous scenarios, which was a main objective of the workshop. Additionally, process safety information and documentation as well as integrity management are commonly recurring elements.

Conduct of operations and operational discipline is concept that has recently been introduced to this sector, an example of which is the research described by Rayner Brown et al. (2024); this element has the potential to enhance the reliability of critical controls through the broad perspectives of human and organizational performance, as well as aspects of leadership accountability, and hence is recommended for an area of future work.

Table 7. Opportunities for improvement of barriers associated with ignition of wood dust in ventilation system categorized with respect to management system element.

Opportunity for improvement [threat or degradation factor]	Management system element
Ongoing training and commissioning from OEM. [Personnel not familiar with equipment or standards]	Training and competency
Management of change process. [Equipment is made inhouse or it is legacy equipment, so it does not have engineering drawings and background information]	Management of change
Priority list of hazards and critical controls and actions to take in order to use time efficiently. [Ignition source from mechanical failure]	Risk management framework Process safety information and documentation
Consider any necessary interlocks that could not be bypassed in order to run or restart process. [Ignition source from mechanical failure]	Integrity management
Improve operating procedures and root cause analysis for issues and equipment shutdown (e.g., jam detection, electrical control monitoring). Establish defined process if specific event happens and trigger the defined response to ensure risk has not be introduced. [Ignition source from mechanical failure]	Investigation Process safety information and documentation
Improve preventative maintenance (PM) program to ensure all tasks are formalized, standardized, and defined in program. [Ignition source from mechanical failure]	Integrity management Process safety information and documentation
Review PM plan and identify (with respect to specific machine centres) the critical PM processes/requirements. [Ignition source from mechanical failure]	Integrity management
Examine current sensor systems (e.g., optical) that need to be reconsidered for alternate sensor systems (e.g., thermal) that are more appropriate for given applications (e.g., hot bearing). Consider multiple detection points and redundant sensors, including highest risk areas. [Ignition source from mechanical failure]	Risk management framework

Table 7. Opportunities for improvement of barriers associated with ignition of wood dust in ventilation system categorized with respect to management system element.

Opportunity for improvement [threat or degradation factor]	**Management system element**
Define installation and operational procedures and training. [Ignition source from mechanical failure]	Training and competency Process safety information and documentation
Safety culture training and education. [Personnel do not complete installation correctly because complacency, real or perceived production pressures]	Process safety culture Accountability Conduct of operations and operational discipline[2]
Procurement standards and procedures. [Ignition source from mechanical failure]	Project review and design procedures
Online predictive monitoring and trending program (temperature, vibration). [Ignition source from mechanical failure]	Integrity management
Consider/review of the use of non-ferrous tools/materials onsite (these are not able to be removed by magnets). [Ignition source from tramp metal]	Risk management framework
Consider diverting to hog system after significant maintenance, weekend or shutdown to clean out conveyance and prevent metal from entering process. [Ignition source from tramp metal]	Process safety information and documentation Risk management framework
Consider the addition of drop out traps. [Ignition source from tramp metal]	Risk management framework
Consider improvements to root cause analysis of line failures (e.g., attached to equipment not calibrated) [Ignition of hydraulic fluid due to line failure, or due to accumulation of fluid from leak]	Investigation
Consider if chip bins actually need to be enclosed - consider alternate design. [Ignition source propagation to chip/surge bin]	Risk management framework

[2] Conduct of operations and operational discipline is an element of process safety management (CSA Z767). It has been defined as "the execution of operational and management tasks, in a deliberate and structured manner, that attempts to institutionalize the pursuit of excellence in the performance of every task and minimize variations in performance." It ensures that operational and management tasks are completed consistently to achieve the defined process safety goals.

Table 7. Opportunities for improvement of barriers associated with ignition of wood dust in ventilation system categorized with respect to management system element.

Opportunity for improvement [threat or degradation factor]	Management system element
Consider belt / conveyor design to prevent ignition source propagation. [Ignition source propagation to chip/surge bin]	Risk management framework
Consider deluge on bins. [Ignition source propagation to chip/surge bin]	Risk management framework
Consider adding multi-gas detector to identify smolders to prevent ignition sources from entering ventilation system. [Ignition source propagation to chip/surge bin]	Risk management framework
Define installation, operational procedures and training. [Ignition sources from wood processing equipment (including saws, side heads)]	Process safety information and documentation
Define and formalize routine duct cleaning including gates. [Dust accumulations in pipe/duct dead legs, bins or other areas/rooms, changes to pickup points]	Process safety information and documentation
Need to define response/action if velocity is out of specification. [Dust accumulations in pipe/duct dead legs, bins or other areas/rooms, changes to pickup points]	Process safety information and documentation
Consider addition of misting system. [Ignition source from burning material during upset conditions (e.g., abort gate, adjacent area/plant)]	Risk management framework
Consider addition of interlocks in case of upset condition in nearby/adjacent process/equipment. [Ignition source from burning material during upset conditions (e.g., abort gate, adjacent area/plant)]	Risk management framework
Consider better location of ash bunker - relocate away from intakes. [Ignition source from adjacent process (e.g., energy systems produces ash and propagates into ventilation system)]	Risk management framework
Consider use of wet ash system instead of dry ash. [Ignition source from adjacent process (e.g., energy systems produces ash and propagates into ventilation system)]	Risk management framework
Review new WorkSafeBC proposed regulations that reference AMCA 99-2016 (spark resistant construction). Review hose types for specific applications. [Static electricity]	Regulations, codes, and standards

Table 7. Opportunities for improvement of barriers associated with ignition of wood dust in ventilation system categorized with respect to management system element.

Opportunity for improvement [threat or degradation factor]	Management system element
Review and update consideration of other ventilation systems to assess risk associated with them. Enhance awareness around issues of hygiene, plugging. [Ventilation systems not intended for transferring wood dust, but inherently intake wood dust (e.g., ventilation for weld fumes)]	Risk management framework
PM Program, including routine inspections. [Ventilation systems not intended for transferring wood dust, but inherently intake wood dust (e.g., ventilation for weld fumes)]	Process safety information and documentation Integrity management
Visual camera monitoring. [Ventilation systems not intended for transferring wood dust, but inherently intake wood dust (e.g., ventilation for weld fumes)]	Risk management framework
Housekeeping program. [Ventilation systems not intended for transferring wood dust, but inherently intake wood dust (e.g., ventilation for weld fumes)]	Risk management framework
Consider alternate heating systems that could limit propagation or intake of embers. [Ignition source from makeup air and heat exchangers propagates into process ventilation]	Risk management framework
FLIR camera (should be interlocked to shutdown process) with clearly understandable and set trigger/alarm thresholds. [Ignition source from friction on sanders]	Risk management framework
Management of change process to fully assess risk. [Use of burned wood - change of species and fibre mix that presents numerous new risks]	Management of change
Inherently safer design - relocation of hazardous equipment from inside to outside. [Harm (injury, death) to personnel (i.e., due to fire or explosion]	Risk management framework
Ensure that all critical ERP equipment is available (e.g. MEWP), and that ERP is practical. Consider location of manual stops and controls to ensure they are accessible. [Fire or deflagration in cyclone, baghouse, silo, conduit, machine centres with pick up points due to propagation of ignition]	Emergency management

4.2 SUGGESTED RESOURCES AND ACTIVITIES

To help support the development of action plans to incorporate the identified opportunities for improvement, resources and highlights are provided in Table 8. It is recommended that a new combustible wood dust self-assessment tool be created that is aligned with the proposed WorkSafeBC combustible dust regulations to help operations identify gaps. To support operations with the upcoming regulatory changes, two in-person workshops will be hosted by BCFSC (Oct. 8 and 10, 2024) in Prince George and Vernon providing training and information on combustible dust and critical controls. Additionally, dust hazard analyses provide systematic assessments of combustible dust hazards with recommendations in accordance with NFPA standards; an example of dust hazards analysis is provided in Annex B of NFPA 652 (2019).

Table 8. Resources to address opportunities for improvement.

Topic	Resource(s) and/or Suggested Activities
Processing of burned wood	Management of change program Combustible dust testing BCFSC (2024). Manufacturing Fire Burnt Wood Fibre
Proposed WorkSafeBC combustible dust regulations	Dust Safety Science (2024). An Interpretation of the Proposed Changes in British Columbia Combustible Dust Regulations. BCFSC/WPAC (2014). Combustible Wood Dust Audit

Table 8. Resources to address opportunities for improvement.

Topic	Resource(s) and/or Suggested Activities
Identifying and addressing safety management system gaps	Self-assessment worksheets described by Rayner Brown et al. (2024): Appendix B: Self-Assessment Worksheet – Accountability Appendix C: Self-Assessment Worksheet – Process Safety Culture Appendix D: Self-Assessment Worksheet – Process Risk Assessment and Risk Reduction Appendix E: Self-Assessment Worksheet – Investigation Appendix G: Self-Assessment Worksheet – Key Performance Indicators Rayner Brown et al. (2024): Resources collected with respect to safety management system elements. In-Person Combustible Dust and Critical Control Workshops (Oct. 8 and 10 2024)
NFPA Standards, including NFPA 652 (2019), NFPA 664 (2020).	All NFPA standards can be accessed online for free with an account set-up at NFPA (2024).
Dust hazard analysis	NFPA 652 (2019), Annex B: Dust Hazards Analysis Example.
Inherently safer design	Appendix A factsheet.
Process safety management frameworks	NFPA 652 (2019). Ch. 8 Management Systems NFPA 664 (2020). Ch. 8 Management Systems CSA (2024). Z767 Process Safety Management standard, 2nd Edition

Table 8. Resources to address opportunities for improvement.

Topic	Resource(s) and/or Suggested Activities
Online condition monitoring	Consider spectrum analysis. Resource: SKF USA Inc. (2022). Spectrum Analysis – The key features of analyzing spectra. Provides an overview of condition monitoring analysis methods to detect and analyze machine component failures for machinery maintenance workers.
Conduct of operations and operational discipline	Self-assessment worksheet (expected in 2025) Center for Chemical Process Safety (2024). Introduction to Conduct of Operations

5.0 Closing Remarks

In closing, a bow-tie analysis of combustible wood dust in ventilation systems was conducted that assessed how ignition could arise and how risk reduction approaches could be improved. Numerous opportunities for improvement were identified relating to each type of safety measure within the hierarchy of controls. A continued focus on management systems will help to address gaps; self-assessments have been provided to help operations explicitly assess their safety management system with respect to management of change, process risk assessment and risk reduction, incident investigation, key performance indicators, senior leadership and safety culture. Additional self-assessment worksheets will be developed in 2025 on elements including training and competency, integrity management, and human factors, and the others described in the CSA Z767 (2024). *Process safety management* standard.

Additional efforts related to enhancing the implementation of critical controls for combustible dust hazards are also an ongoing effort in 2024-2025, as proposed regulations in BC are expected to come into force. BCFSC is providing in-person workshops on October 8th and10th, 2024; members of the Manufacturing Advisory Group (MAG) and those in wood products manufacturing are encouraged to participate.

6.0 References

[1] NFPA 664, "Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities," 2020.

[2] CCPS/EI, "Bowties in Risk Management," 2018.

[3] Rayner Brown, K., Whelan, C., Murray, G., Laturnus, B., Yazdanpanah, F., Cloney, C., Amyotte, P.R. (2022). Application of process hazard analysis and inherently safer design in wood pellet production. ACS Omega. 7 (51), 47720-47733.

[4] NFPA 652, "Standard on Fundamentals of Combustible Dusts," 2019.

[5] CSA, "Z767 Process Safety Management standard, 2nd Edition," 2024.

[6] Rayner Brown, K., Murray, G., Laturnus, B., Yazdanpanah, F., Cloney, C., Amyotte, P.R., "Integrating process safety management into Canadian wood pellet facilities that generate combustible wood dust," 2024. (Manuscript In-Press).

[7] BCFSC, "Manufacturing Fire Burnt Wood Fibre," Last accessed August 9 2024 from https://www.bcforestsafe.org/wp-content/uploads/2024/06/20240625_Fire-Burnt-Wood-Safety-Council_Onepage.pdf

[8] Dust Safety Science, "An Interpretation of the Proposed Changes in British Columbia Combustible Dust Regulations," Last accessed August 9 2024 from https://www.loom.com/share/092d6dc42f2445069a753ef07303c48b?sid=8a3c9e69-2881-4741-9a2f-cd68769423ec

[9] BCFSC/WPAC, "Combustible Wood Dust Audit," Last accessed August 9 2024 from https://www.bcforestsafe.org/safe-companies-cor/audits/base-basic-audit-safety-evaluation-audit/

[10] NFPA, "List of codes and standards," Last accessed August 9 2024 from https://www.nfpa.org/

[11] SKF USA Inc, "Spectrum Analysis – The key features of analyzing spectra," Last accessed August 9 2024 from https://cdn.skfmediahub.skf.com/api/public/0901d1968024acef/pdf_preview_medium/0901d1968024acef_pdf_preview_medium.pdf

[12] Center for Chemical Process Safety (CCPS), "Introduction to Conduct of Operations," Last accessed August 9 2024 from https://www.aiche.org/ccps/introduction-conduct-operations

Appendices

The report includes the following Appendices:

- **Appendix A: Inherently Safer Design Factsheet**
- **Appendix B: Self-Assessment Worksheet – Accountability**
- **Appendix C: Self-Assessment Worksheet – Process Safety Culture**
- **Appendix D: Self-Assessment Worksheet – Process Risk Assessment and Risk Reduction**
- **Appendix E: Self-Assessment Worksheet – Investigation**
- **Appendix F: Self-Assessment Worksheet – Management of Change**
- **Appendix G: Self-Assessment Worksheet – Key Performance Indicators**

Appendix A. Inherently Safer Design Factsheet

September 2023 (R1)

BC Forest Safety
Safety is good business

OBEXRISK

INTRODUCTION TO
INHERENTLY SAFER DESIGN

INHERENTLY SAFER DESIGN (ISD) AND HIERARCHY OF CONTROLS

ISD reduces hazards through the system or process design, rather than relying solely on add-on measures. ISD is the most effective and preferred in the hierarchy of controls.

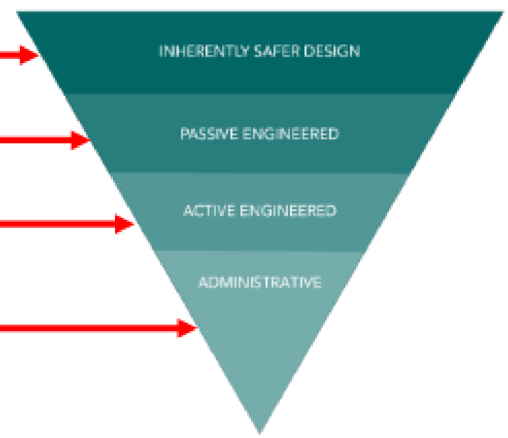
EXAMPLE OF HIERARCHY OF CONTROLS FOR COMBUSTIBLE DUST:

ISD (Minimization): Use of sloped surfaces to reduce combustible dust accumulation.

Passive Engineered: Installation of flap valve

Active Engineered: Installation of chemical isolation

Administrative: Housekeeping program

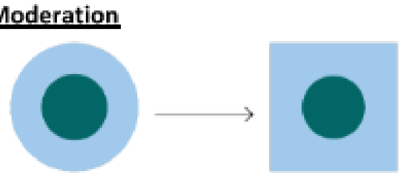


The ISD principles are minimization, substitution, moderation, and simplification.

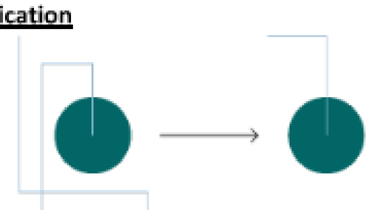
Minimization

Substitution

Moderation



Simplification



September 2023 (R1)

SAMPLE OF ISD EXAMPLES

ISD Principle	Description
Minimization	Redesign processes, equipment or areas and worksites to minimize or eliminate the hazard
Substitution	Use alternate process methods or equipment that eliminates or minimizes the hazard
Moderation	Relocate hazardous activities involving away from personnel to reduce likelihood or severity of consequences
Simplification	Redesign processes and equipment to make it difficult or impossible to produce a hazardous scenario due to operating or maintenance error

SAMPLE OF ISD CHECKLIST QUESTIONS FOR COMBUSTIBLE DUST

Guideword	Checklist Question
Minimize	Can spaces that are inaccessible to housekeeping be sealed to prevent dust accumulation? Can dead spaces at the end of lines where fine dust can accumulate be eliminated? Is equipment that is no longer needed removed?
Substitute	Can alternate less hazardous materials, processes or equipment be substituted for use? Can alternate materials of construction, processes, or equipment be used that are less likely to generate ignition sources?
Moderate	Can potential hazards be reduced by less severe operating conditions or equipment? Are all hazardous materials, processes and equipment stored or installed as far away as possible to eliminate disruption to people, property, production, and environment in the event of an incident?
Simplify	Have human factors been considered in the design of the human-machine interface (HMI)? Can equipment or tasks be designed such that it is difficult or impossible to create a potential hazardous situation due to an operating or maintenance error?

Ask yourself: Have I considered ISD during management of change (MOC), incident investigation, inspections, or risk assessments? Have I explored ISD options through an ISD workshop?

Appendix B. Self-Assessment Worksheet: Accountability

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN ELEMENT: ACCOUNTABILITY

April 2024

Accountability focusses on senior management accountability for the PSM system goals, considering process safety risks throughout the facility lifecycle.

Accountability Self-Assessment & Action Plan

When completing the Self-Assessment & Action Plan below:

- If you identify a gap in any of the questions, develop an action plan.
- When choosing due dates for the action plans, consider the following to determine priority:
  - The anticipated effort required to close the gap and make improvements,
  - The benefits expected from taking action and implementing change, and
  - The urgency (e.g., perceived risk) of the improvements needing to be made.

Key Resources

- PSM Implementation: How to Use the Self-Assessment Worksheets
- Process Safety Management on pellet.org
- CSA Z767 *Process safety management* standard

Materials are being updated all the time - come back to pellet.org often.

Visit Accountability on pellet.org for:

- Self-Assessment & Action Plan Worksheets
- Improvement Tools & Resources
- Process Safety Leadership Principles and Intervention Tool

Suggested Activities

- Establish a formal corporate process safety policy. Create a statement that outlines your organization's process safety philosophy.
- Develop a process for senior management to get feedback from all employees about the process safety policy during implementation; solicit feedback and discuss the policy during plant visits or safety/fire prevention meetings.
- Provide process safety training and instruction to workers. Develop training programs and materials.
- Commit sufficient resources to enable the continuous improvement of process safety.

Suggested Deliverables

WOOD PELLET BC Forest Safety DALHOUSIE UNIVERSITY DUST SAFETY SCIENCE OBEXRISK

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: ACCOUNTABILITY

April 2024

- Statements of the commitment to PSM in facility policies and procedures.
- Training for managers, coordinators, and supervisors in process safety culture leadership.
- Addition of PSM to recurring meetings and communications.
- Development of process safety goals with accountability.

1. Has your company established (formalized and documented) goals and objectives related to process safety at your facility? ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
2. Check all statements that apply: Senior management does the following: ☐Establishes performance requirements by setting process safety goals and objectives and makes resources available to reach these goals. ☐Sets process safety goals that encompass a range of risks (e.g., personnel, public, environment). ☐Directs decision-makers related to design to consider inherently safer design. ☐Ensures compliance with safe operating conditions through use of proper conduct of operations (Conduct of operations is defined as carrying out tasks in a methodical way to achieve excellence in operations). ☐Directs the completion of risk assessments to address mechanical equipment integrity and process integrity. ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: ACCOUNTABILITY
April 2024

3. Is an approval process established for matters relating to maintenance and production? ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
4. Does the approval process consider risks relating to the process? ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

Review of Action Plan for Accountability

Complete the following table after corrective actions have been implemented.

Improvement actions taken
How did you ensure the controls were implemented in a timely fashion? How did you prioritize your actions?
How will you ensure the implemented controls will continue to be effective over time?
How are workers involved in developing and implementing controls?

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: ACCOUNTABILITY

April 2024

How do you know that workplace decisions related to safety are effective and sustainable?
How do you measure change to establish a new performance expectation?
When changes are made, how are interrelated procedures, programs, and policies updated effectively?
Is a strategy for continuous improvement in place? How does this process work?
If you have multiple locations, are lessons learned and continuous improvements shared with other locations? How does this process work?
Is the safety management system self-sufficient, or does it rely on specific individuals to make it function? How do you ensure the system remains self-sufficient?
Overall effectiveness of improvement actions

References

- Rayner Brown, K., Murray, G., Laturnus, B., Yazdanpanah, F., Cloney, C., Amyotte, P.R. (2024). Integrating Process Safety Management into Canadian Wood Pellet Facilities that Generate Combustible Wood Dust. (Manuscript in Progress)
- WorkSafeBC. (2022). *Managing Risks in Manufacturing Workplaces: How to Use the Self-Evaluation Tool.* Last accessed April 2024.
- WorkSafeBC. (2023). *Enhancing Health & Safety Culture & Performance: Self-Evaluation Tool for Managing Risks in Manufacturing Workplaces*. Last accessed April 2024.

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Appendix C. Self-Assessment Worksheet: Process Safety Culture

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE

April 2024

Process safety culture is the collective mindset of the organization with respect to safety and risk, including attitudes and behaviours.

Process Safety Culture
Self-Assessment & Action Plan

When completing the Self-Assessment & Action Plan below:

- If you identify a gap in any of the questions, develop an action plan.
- When choosing due dates for the action plans, consider the following to determine priority:
  - The anticipated effort required to close the gap and make improvements,
  - The benefits expected from taking action and implementing change, and
  - The urgency (e.g., perceived risk) of the improvements needing to be made.

Visit Process Safety Culture on pellet.org for:

- Self-Assessment & Action Plan Worksheets
- Example Safety Culture Policy Statement
- Example of Safety Culture Survey
- Links to Webinars and Toolkits

Key Resources

- PSM Implementation: How to Use the Self-Assessment Worksheets
- Process Safety Management on pellet.org
- CSA Z767 *Process safety management* standard

Materials are being updated all the time - come back to pellet.org often.

Suggested Activities

- Create incentives and recognition for workers who provide exceptional contributions to the pursuit of process safety.
- Secure management committment to process safety, including financial commitments, as well as reviewing current policies and procedures.
- Acknowledge the critical function of frontline workers in identifying hazards. Promote the role of personal responsibility for safety.
- Engage all personnel across organization levels to facilitate cooperation and commitment to enhancing safety.
- Ensure consistency on safety through formalized policies and procedures, as well as cultivation of actions and beliefs.
- Implement initiatives to combat complacency.
- Ensure continuous improvement by regularly reviewing and refining safeguards.

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE

April 2024

Suggested Deliverables

- Documented process safety culture policy
- Safety culture survey
- Formal process for workers and supervisors to discuss and address process safety concerns.

1. Is process safety leadership and competency a core value of all management? ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Somewhat ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
2. Is there a visible and active commitment to process safety from all levels of management? ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Somewhat ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
3. As it relates to process safety culture, check all statements that apply: ☐Company policy states that process safety is a representation of successful operations. ☐ Management regularly reviews key performance indicators (KPIs) to support the process safety management system ☐ Management ensures that corrective actions from risk assessments, incident investigations, and audits are addressed. ☐Not applicable.	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE

April 2024

Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
4. Is there an understanding of the consequences that could arise from a process safety incident (e.g., loss of control) and the impact it may have on personnel, property and the environment? ☐Yes ☐No ☐Somewhat ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
5. Do personnel (including operators, maintenance technicians, electricians, and instrumentation specialists) follow conduct of operation requirements? *Conduct of operations is defined as carrying out tasks in a methodical way to achieve excellence in operations.* ☐Yes ☐No ☐Somewhat ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
6. Do personnel (including operators, maintenance technicians, electricians, and instrumentation specialists) contact their supervisors if they have a concern about any gaps, issues, or incidents with the process safety system? Check all that apply. ☐ Failures in maintenance ☐ Failure of work permits ☐ Bypasses of any safety systems (e.g., spark detectors)	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE
April 2024

☐ Operating the process beyond safe operating limits
☐ Not applicable

Action owner	Due date (yyyy-mm-dd):

Plans and actions needed to address gap or improve existing approach

7. **Do personnel (including operators, maintenance technicians, electricians and instrumentation specialists) have the responsibility and authority to stop unsafe work or operations?**

☐Yes ☐No ☐Somewhat ☐Unsure

Action owner	Due date (yyyy-mm-dd):

Plans and actions needed to address gap or improve existing approach

8. **Is there open and effective communication regarding process safety?**

☐Yes ☐No ☐Somewhat ☐Unsure

Action owner	Due date (yyyy-mm-dd):

Plans and actions needed to address gap or improve existing approach

9. **Do personnel (including operators, maintenance technicians, electricians, and instrumentation specialists) contact their supervisors if they have a concern about any gaps, issues, or incidents with the process safety system? Check all that apply.**

☐ Process safety goals
☐ Process safety issues and concerns
☐ Process safety incidents
☐ Process safety near misses

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE
April 2024

☐ Process safety performance
☐ Not applicable

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

10. Does management respond in a timely way to the following (check all that apply)?

☐ Process safety issues and concerns
☐ Process safety incidents
☐ Process safety near misses

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

11. Are process safety issues and concerns communicated with operational personnel (operators, maintenance technicians, electricians, and instrumentation specialists) in a timely way?

☐Yes ☐No ☐Somewhat ☐Unsure

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

12. Are relevant process safety-related issues and incidents at other organizations or facilities communicated with relevant stakeholders (e.g., operators, supervisors) in a timely way?

☐Yes ☐No ☐Somewhat ☐Unsure

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE
April 2024

13. How strongly is the following statement communicated and demonstrated throughout the organization: "Management and workers both hold responsibility for the role they play in preventing a process safety incident." ☐Strongly ☐Somewhat ☐A little	
Action owner	Due date (yyyy-mm-dd):
Plans and actions needed to address gap or improve existing approach	
14. Is there a system and process in place for senior management to engage with and consult personnel and workers on the implementation of the management system? ☐Yes (formalized) ☐Yes (informal) ☐No ☐Unsure	
Action owner	Due date (yyyy-mm-dd):
Plans and actions needed to address gap or improve existing approach	
15. Does management maintain a sense of vulnerability that a process safety incident (loss of control) can occur? ☐Yes ☐No ☐Somewhat ☐Unsure	
Action owner	Due date (yyyy-mm-dd):
Plans and actions needed to address gap or improve existing approach	
16. Do workers maintain a sense of vulnerability that a process safety incident (loss of control) can occur? ☐Yes ☐No ☐Somewhat ☐Unsure	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE

April 2024

Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
17. Does the organization have initiatives to prevent/avoid complacency? Check all that apply: ☐ Regular safety meetings and briefings ☐ Refresher training ☐ Development, sharing, or review of safety bulletins, factsheets, or newsletters ☐ Sharing and discussion of process safety incidents and near misses ☐ Other (specify):	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

Review of Action Plan for Process Safety Culture

Complete the following table after corrective actions have been implemented.

Improvement actions taken
How did you ensure the controls were implemented in a timely fashion? How did you prioritize your actions?
How will you ensure the implemented controls will continue to be effective over time?
How are workers involved in developing and implementing controls?

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS SAFETY CULTURE

April 2024

How do you know that workplace decisions related to safety are effective and sustainable?
How do you measure change to establish a new performance expectation?
When changes are made, how are interrelated procedures, programs, and policies updated effectively?
Is a strategy for continuous improvement in place? How does this process work?
If you have multiple locations, are lessons learned and continuous improvements shared with other locations? How does this process work?
Is the safety management system self-sufficient, or does it rely on specific individuals to make it function? How do you ensure the system remains self-sufficient?
Overall effectiveness of improvement actions

References

- Rayner Brown, K., Murray, G., Laturnus, B., Yazdanpanah, F., Cloney, C., Amyotte, P.R. (2024). Integrating Process Safety Management into Canadian Wood Pellet Facilities that Generate Combustible Wood Dust. (Manuscript in Progress)
- WorkSafeBC. (2022). *Managing Risks in Manufacturing Workplaces: How to Use the Self-Evaluation Tool.* Last accessed April 2024.
- WorkSafeBC. (2023). *Enhancing Health & Safety Culture & Performance: Self-Evaluation Tool for Managing Risks in Manufacturing Workplaces*. Last accessed April 2024.

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Appendix D. Self-Assessment Worksheet: Process Risk Assessment and Risk Reduction

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION

April 2024

Process risk assessment and risk reduction involves the identification and analysis of process-related hazards, documentation of hazard analyses, and implementation of risk reduction measures.

A risk assessment is a series of steps to identify hazards, determine the level of harm they can cause, determine control measures to eliminate or reduce the risk and record the findings. Risk reduction focuses on mitigating potential losses by reducing the likelihood and severity of a possible loss or injury due to a hazard.

Process Risk Assessment and Risk Reduction Self-Assessment & Action Plan

When completing the Self-Assessment & Action Plan below:

- If you identify a gap in any of the questions, develop an action plan.
- When choosing due dates for the action plans, consider the following to determine priority:
  - The anticipated effort required to close the gap and make improvements,
  - The benefits expected from taking action and implementing change, and
  - The urgency (e.g., perceived risk) of the improvements needing to be made.

Visit Process Risk Assessment and Risk Reduction on pellet.org for:

- Self-Assessment & Action Plan Worksheets
- Example Risk Management Standard
- Example Risk Register and Action Plan Worksheet

Key Resources

- PSM Implementation: How to Use the Self-Assessment Worksheets
- Process Safety Management on pellet.org
- CSA Z767 *Process safety management* standard

Materials are being updated all the time - come back to pellet.org often.

Suggested Activities

- Define responsibility and the process for safety approval of new projects and changes.
- Assess abnormal operation, emergency settings and protection requirements during process hazard evaluations.
- Implement safeguards aligned with good engineering practice (e.g., spark detection and deluge systems, explosion protection)

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION
April 2024

Suggested Deliverables

- Documented hazard identification and risk analyses.
- Documentation and clear communication of hazards, safeguards and risks to affected personnel.
- Documented and effective emergency response plan, along with trained emergency response team and fit-for-duty emergency equipment.

1. Has a Process Hazard Analysis (PHA) or Dust Hazard Analysis (DHA) been completed at your facility? *A PHA is a systematic method for identifying and assessing hazards associate with operations to facilitate the control and management of them. A DHA is a hazard analysis focussed on combustible dust.* ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
2. How are hazards identified and documented? Check all that apply: ☐The scenario pathway from the initiating event to consequences is described, as well as event relationships/connections (links, interdependence). ☐The incidents that have occurred at the facility previously and pertinent incidents that have occurred at other facilities. ☐Any hazards that be new to the facility that may have arose due to changes. ☐ Existing barriers and controls that decrease the probability and/or severity of consequences of hazardous scenarios. ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION
April 2024

3. **Does the PHA or DHA include an estimation of risk (as a function of consequence and likelihood) for the identified hazard scenarios?**

☐ Yes ☐No ☐Unsure

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

4. **Has a consequence analysis been completed that involves the identification, analysis and documentation of consequences for hazardous scenarios?**

☐ Yes ☐No ☐Unsure

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

5. **Which of the following does the consequence analysis consider (check all that apply):**

☐Effects on people
☐Effects on the environment
☐Effects on business operations
☐Effects on property
☐Any interaction of materials released in a given loss of containment situation
☐Potential knock-on effects
☐Not applicable

Action owner	**Due date (yyyy-mm-dd):**

WOOD PELLET BC Forest Safety DALHOUSIE UNIVERSITY DUST SAFETY SCIENCE OBEXRISK

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION
April 2024

Plans and actions needed to address gap or improve existing approach	
6. Has a likelihood analysis been completed? ☐ Yes ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
7. Which of the following does the likelihood analysis include (check all that apply): ☐Events within the facility/operations ☐Events outside of the facility/operations ☐Human error ☐Equipment failure ☐Process control failure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
8. Which of the following are practiced with respect to risk management? Check all that apply. ☐Risks that were deemed intolerable have been reduced to broadly tolerable or conditionally tolerable range. ☐Risks that are deemed tolerable are managed. ☐Measures implemented for risks in the conditionally tolerable or ALARP (as low as reasonably practicable) range are assessed and documented.	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION
April 2024

☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
9. Has an implementation plan been put in place for implementing control measures related to the risk assessment, PHA or DHA? ☐ Yes (formalized process) ☐ Yes (informal process) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
10. Is there a plan for implementing risk reduction measures/controls that includes prioritizing controls and creating a schedule? ☐ Yes (formalized process) ☐ Yes (informal process) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
11. Is there a formal process (e.g., corrective action plans) to track the implementation of risk reduction measures/controls to completion? ☐ Yes (formalized process) ☐ Yes (informal process) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION
April 2024

12. Indicate if the following items are completed during the implementation and completion of risk reduction measures/controls (check all that apply): ☐Confirming that changes involving equipment, procedures, or organization have been adequately executed. ☐Determining that the risk reduction measures have successfully reduced risk to the target level. ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
13. Is the hierarchy of controls and inherently safer design (ISD)considered when identifying and selecting control measures from the risk assessment, PHA or DHA? *The hierarchy of controls is the preferred order of consideration of risk reduction measures. The hierarchy of controls is inherently safer design (ISD), passive engineered, active engineered, and administrative (procedural). Inherently safer design (ISD) treats hazards at the source through the fundamental design rather than add-on equipment or procedures. ISD is based on the principles of minimization, substitution, moderation, and simplification.* ☐ Yes (formalized process) ☐ Yes (informal process) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
14. Are risk assessments revalidated (re-examined) after changes to any of the following? Check all that apply: ☐Facility ☐Operation/Process ☐Operating environment ☐After 5 years regardless of any changes	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION

April 2024

☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

Review of Action Plan for Process Risk Assessment and Risk Reduction

Complete the following table after corrective actions have been implemented.

Improvement actions taken
How did you ensure the controls were implemented in a timely fashion? How did you prioritize your actions?
How will you ensure the implemented controls will continue to be effective over time?
How are workers involved in developing and implementing controls?
How do you know that workplace decisions related to safety are effective and sustainable?
How do you measure change to establish a new performance expectation?
When changes are made, how are interrelated procedures, programs, and policies updated effectively?
Is a strategy for continuous improvement in place? How does this process work?
If you have multiple locations, are lessons learned and continuous improvements shared with other locations? How does this process work?

WOOD PELLET BC Forest Safety DALHOUSIE UNIVERSITY DUST SAFETY SCIENCE OBEXRISK

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: PROCESS RISK ASSESSMENT AND RISK REDUCTION

April 2024

Is the safety management system self-sufficient, or does it rely on specific individuals to make it function? How do you ensure the system remains self-sufficient?
Overall effectiveness of improvement actions

References

- Rayner Brown, K., Murray, G., Laturnus, B., Yazdanpanah, F., Cloney, C., Amyotte, P.R. (2024). Integrating Process Safety Management into Canadian Wood Pellet Facilities that Generate Combustible Wood Dust. (Manuscript in Progress)
- WorkSafeBC. (2022). *Managing Risks in Manufacturing Workplaces: How to Use the Self-Evaluation Tool.* Last accessed April 2024.
- WorkSafeBC. (2023). *Enhancing Health & Safety Culture & Performance: Self-Evaluation Tool for Managing Risks in Manufacturing Workplaces*. Last accessed April 2024.

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Appendix E. Self-Assessment Worksheet: Investigation

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: INVESTIGATION

April 2024

Investigation is the program established to identify, report, investigate, and record process safety incidents. Process safety incidents include near misses as well as significant events. This includes a system to identify, report, investigate and record all incidents including near misses and abnormal events.

Investigation
Self-Assessment & Action Plan

When completing the Self-Assessment & Action Plan below:

- If you identify a gap in any of the questions, develop an action plan.
- When choosing due dates for the action plans, consider the following to determine priority:
  - The anticipated effort required to close the gap and make improvements,
  - The benefits expected from taking action and implementing change, and
  - The urgency (e.g., perceived risk) of the improvements needing to be made.

Visit Investigation on pellet.org for:

- Self-Assessment & Action Plan Worksheets
- Example of Process Safety Incident Reporting and Investigation Procedure
- Example of Process Safety Incident Report Form

Key Resources

- PSM Implementation: How to Use the Self-Assessment Worksheets
- Process Safety Management on pellet.org
- CSA Z767 *Process safety management* standard

Materials are being updated all the time - come back to pellet.org often.

Suggested Activities

- Establish what constitute as a reportable incident and define reporting criteria including incident classification.
- Set-up an incident review committee or team that involves senior leadership to ensure incidents are effectively acted on.
- Implement incident investigation guidelines.
- Create a program to track incident reports and action plans to completion.
- Provide resources and guidance for incident investigation team members.

Suggested Deliverables

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: INVESTIGATION

April 2024

- Documented incident investigation management system, including near misses.
- Documented process for identifying root causes and developing recommendations for preventing recurrence.
- Collection of data for analyzing trends and causes
- Established process for learning from incident investigations.

1. Do you have a system to identify, report, investigate and record all incidents including near misses and abnormal events? ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
2. Which of the following components does the incident investigation system have? Check all that apply. ☐Procedures for conducting an investigation ☐Process to designate a competent individual to lead investigation ☐Process to engage personnel knowledgeable in process where incident occurred, and where possible, personnel involved in incident or health and safety representative ☐Process to establish scope of investigation proportionate with significance of incident ☐Capacity to identify outside subject matter expertise to be included in investigation ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: INVESTIGATION
April 2024

3. Which of the following is included in incident investigation reports? Check all that apply. ☐Incident date ☐Incident description ☐Detailed description of equipment failures and/or human errors ☐Contributing factors of the incident ☐Incident analysis method and/or identification of root causes ☐Recommendations to prevent the incident from happening again ☐Not applicable.	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
4. Is there a process to follow-up on and implement recommendations made in incident investigation reports? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
5. Are corrective action plans (including timelines) developed to implement recommendations from incident investigation reports? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: INVESTIGATION

April 2024

Plans and actions needed to address gap or improve existing approach	
6. Are corrective actions based on recommendations from incident investigation reports monitored for implementation? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
7. Are key findings of incident investigations communicated and shared with other facilities in the organization? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
8. Are key findings of incident investigations communicated and shared more broadly (i.e., other facilities in the same industry) where lessons learned could be applied? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: INVESTIGATION
April 2024

9. Are incident investigation reports analyzed to identify consistent recurring or systemic causes? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
10. Are incident investigation reports used to enhance process safety knowledge? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
11. Is the hierarchy of controls (inherently safer design, passive engineering, active engineering and procedures) considered during investigation? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Sometimes ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: INVESTIGATION

April 2024

Review of Action Plan for Investigation

Complete the following table after corrective actions have been implemented.

Improvement actions taken
How did you ensure the controls were implemented in a timely fashion? How did you prioritize your actions?
How will you ensure the implemented controls will continue to be effective over time?
How are workers involved in developing and implementing controls?
How do you know that workplace decisions related to safety are effective and sustainable?
How do you measure change to establish a new performance expectation?
When changes are made, how are interrelated procedures, programs, and policies updated effectively?
Is a strategy for continuous improvement in place? How does this process work?
If you have multiple locations, are lessons learned and continuous improvements shared with other locations? How does this process work?
Is the safety management system self-sufficient, or does it rely on specific individuals to make it function? How do you ensure the system remains self-sufficient?
Overall effectiveness of improvement actions

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: INVESTIGATION

April 2024

References

- Rayner Brown, K., Murray, G., Laturnus, B., Yazdanpanah, F., Cloney, C., Amyotte, P.R. (2024). Integrating Process Safety Management into Canadian Wood Pellet Facilities that Generate Combustible Wood Dust. (Manuscript in Progress)
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Appendix F. Self-Assessment Worksheet: Management of Change

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: MANAGEMENT OF CHANGE

April 2024

Management of change (MOC) aims to manage risks associated with changes to design, equipment, procedures, personnel, and the organization and includes temporary and permanent changes.

Management of Change Self-Assessment & Action Plan

When completing the Self-Assessment & Action Plan below:

- If you identify a gap in any of the questions, develop an action plan.
- When choosing due dates for the action plans, consider the following to determine priority:
  - The anticipated effort required to close the gap and make improvements,
  - The benefits expected from taking action and implementing change, and
  - The urgency (e.g., perceived risk) of the improvements needing to be made.

Key Resources

- PSM Implementation: How to Use the Self-Assessment Worksheets
- Process Safety Management on pellet.org
- CSA Z767 *Process safety management standard*

Visit Management of Change on pellet.org for:

- Self-Assessment & Action Plan Worksheets
- Improvement Tools & Resources
- Example of MOC Plan
- Example of MOC Form
- MOC Guidelines

Materials are being updated all the time - come back to pellet.org often.

Suggested Activities

- Define what constitutes a change and implement a system to identify changes prior to implementation
- Create a change review system that requires proposed changes to be documented
- Provide training to all personnel to identify changes
- Develop a practical process to notifying management of changes
- Provide resources to raise awareness on the process safety hazards that can be posed by changes.
- Educate personnel on what constitutes a replacement in kind
- Implement an authorization procedure to manage temporary changes, and establish time limits for temporary changes and define renewal requirements

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: MANAGEMENT OF CHANGE

April 2024

Suggested Deliverables

- Documented management of change procedure
- Documented management of change roles and responsibilities
- Documented procedures for change review and approvals
- Documented process for changing documentation, test and inspection frequencies, operating procedures, training records

1. Is a management of change (MOC) program in place? ☐ Yes (formalized) ☐ Yes (informal) ☐No ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
2. Does the MOC system manage risks associated with the following changes? Check all that apply: ☐Design changes ☐Equipment changes ☐Procedural changes ☐Organizational changes ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
3. If an MOC system is present, does it consider the following aspects? Check all that apply. ☐States what a change is. ☐States what type a given change is (emergency or temporary).	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: MANAGEMENT OF CHANGE
April 2024

☐States what replacement-in-kind (RIK) is (which is not included in MOC). ☐Considers changes in operating procedures or safe operating limits. ☐Considers changes in the structure of the organization and staffing. ☐A process for reviewing and approving changes. ☐Includes a risk assessment of the change. ☐Includes the communication of the change with relevant stakeholders before the change is made. ☐ Includes any necessary training of relevant stakeholders before the change is made. ☐ Includes a procedure for implementing an emergency change, as well as communicating with relevant personnel in a timely manner ☐ States the documentation needed for a change including: a. ☐ Explanation of proposed change, b. ☐ Change authorization, c. ☐ Training requirements, d. ☐ Up-to-date drawings, e. ☐ Confirmation that change was implemented as design intended ☐Not applicable.	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
4. Does the MOC system manage temporary changes? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: MANAGEMENT OF CHANGE
April 2024

5. Does the MOC system use any of the following considerations to manage temporary changes? Check all that apply. ☐ A time limit/timeframe is set ☐ A process for review and approval if the temporary change needs a time extension ☐ A process to return the equipment or system back to the original state when the temporary change has ended (e.g., removing any temporary installations). ☐ Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
6. If there have been instances of temporary changes being permanently implemented, are the following considerations made? Check all that apply. ☐ Changes for other lifecycles (e.g., maintenance turnaround) ☐ Changes to documents and procedures ☐ Changes to supporting programs ☐ Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
7. Is the hierarchy of controls and inherently safer design (ISD) options considered during management of change? ☐Yes (formalized process documented) ☐Yes (informal process) ☐No ☐Sometimes ☐Unsure ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: MANAGEMENT OF CHANGE
April 2024

Plans and actions needed to address gap or improve existing approach	

Review of Action Plan for Management of Change

Complete the following table after corrective actions have been implemented.

Improvement actions taken
How did you ensure the controls were implemented in a timely fashion? How did you prioritize your actions?
How will you ensure the implemented controls will continue to be effective over time?
How are workers involved in developing and implementing controls?
How do you know that workplace decisions related to safety are effective and sustainable?
How do you measure change to establish a new performance expectation?
When changes are made, how are interrelated procedures, programs, and policies updated effectively?
Is a strategy for continuous improvement in place? How does this process work?
If you have multiple locations, are lessons learned and continuous improvements shared with other locations? How does this process work?

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: MANAGEMENT OF CHANGE

April 2024

Is the safety management system self-sufficient, or does it rely on specific individuals to make it function? How do you ensure the system remains self-sufficient?
Overall effectiveness of improvement actions

References

- Rayner Brown, K., Murray, G., Laturnus, B., Yazdanpanah, F., Cloney, C., Amyotte, P.R. (2024). Integrating Process Safety Management into Canadian Wood Pellet Facilities that Generate Combustible Wood Dust. (Manuscript in Progress)
- WorkSafeBC. (2022). *Managing Risks in Manufacturing Workplaces: How to Use the Self-Evaluation Tool.* Last accessed April 2024.
- WorkSafeBC. (2023). *Enhancing Health & Safety Culture & Performance: Self-Evaluation Tool for Managing Risks in Manufacturing Workplaces*. Last accessed April 2024.

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Appendix G. Self-Assessment Worksheet: Key Performance Indicators

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS

April 2024

Key performance indicators (KPIs) focusses on the use of leading and lagging indicators that are selected and monitored to target for improvement. Leading indicators are process-focussed metrics that signify the function of operating discipline, processes, or safety barriers/controls. Leading indicators are selected to provide an early signal of potential issues or degradation of safety controls so proactive corrective actions can be conducted. Lagging indicators are outcome-focussed metrics that can signify recurring issues and include events that have taken place.

Key Performance Indicators Self-Assessment & Action Plan

When completing the Self-Assessment & Action Plan below:

- If you identify a gap in any of the questions, develop an action plan.
- When choosing due dates for the action plans, consider the following to determine priority:
  - The anticipated effort required to close the gap and make improvements,
  - The benefits expected from taking action and implementing change, and
  - The urgency (e.g., perceived risk) of the improvements needing to be made.

Visit Key Performance Indicators on pellet.org for:

- Self-Assessment & Action Plan Worksheets
- Improvement Tools & Resources
- Leading and Lagging Indicators Guidelines

Key Resources

- PSM Implementation: How to Use the Self-Assessment Worksheets
- Process Safety Management on pellet.org
- CSA Z767 *Process safety management* standard

Materials are being updated all the time - come back to pellet.org often.

Suggested Activities

- Develop leading indicators that measure the performance of work processes, procedures, and equipment that prevent incidents.
- Develop lagging indicators based on process safety incidents that measure weaknesses, defects or failures in processes, procedures, and equipment.
- Communicate process safety metrics to all personnel

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS

April 2024

Suggested Deliverables

- Established process to review and communicate key performance indicators, including target and actual, to management and employees on a routine basis

1. Have you identified leading and lagging key performance indicators (KPIs) for process safety at your facility?

☐ Yes (formalized and documented) ☐No ☐Unsure

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

2. Are unsafe behaviours or inadequate operational discipline measured? Operational discipline is defined as the performance of all tasks correctly every time.

☐ Yes (formalized and documented) ☐No ☐Unsure

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

3. Are process safety near misses tracked? These may include, for example, small fires, system failures or instrumentation failure that could lead to an incident.

☐ Yes (formalized and documented) ☐No ☐Somewhat ☐Unsure

Action owner	**Due date (yyyy-mm-dd):**

Plans and actions needed to address gap or improve existing approach

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS

April 2024

4. Are near misses collected and used for lessons learned, enhancing awareness, and improving process safety culture? ☐ Yes (formalized and documented) ☐No ☐Somewhat ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
5. When selecting key performance indicators, which of the following are considered? Check all that apply. ☐Not applicable - process safety key performance indicators have not been selected. ☐Indicators refer to process safety critical equipment and items that influence system performance. ☐Indicators advance process safety performance improvement and learning. ☐Indicators are relatively easy to implement, measure, and understood by stakeholders. ☐Indicators can be used for benchmarking. ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
6. Which of the following lagging indicators are tracked? Check all that apply. ☐Not applicable - process safety key performance indicators have not been selected. ☐ID (induced draft) fan fire ☐Silo fire ☐Pelletizer/extruder fire ☐Cooler fire	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS

April 2024

4. Are near misses collected and used for lessons learned, enhancing awareness, and improving process safety culture? ☐ Yes (formalized and documented) ☐No ☐Somewhat ☐Unsure	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
5. When selecting key performance indicators, which of the following are considered? Check all that apply. ☐Not applicable - process safety key performance indicators have not been selected. ☐Indicators refer to process safety critical equipment and items that influence system performance. ☐Indicators advance process safety performance improvement and learning. ☐Indicators are relatively easy to implement, measure, and understood by stakeholders. ☐Indicators can be used for benchmarking. ☐Not applicable	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
6. Which of the following lagging indicators are tracked? Check all that apply. ☐Not applicable - process safety key performance indicators have not been selected. ☐ID (induced draft) fan fire ☐Silo fire ☐Pelletizer/extruder fire ☐Cooler fire	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS
April 2024

☐Pipe fire ☐Dryer fibre silo fire ☐Conveyance fire ☐Fibre pile fire ☐Mobile equipment fire or deflagration ☐Hammer mill deflagration ☐Belt-dryer deflagration ☐Deflagration propagation (multiple equipment impacted) ☐Others (list):	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	
7. Which of the following leading indicators related to electrical upset conditions are tracked? Check all that apply. ☐Not applicable - process safety key performance indicators have not been selected. ☐Loss of power ☐Communication error or loss of communication between HMI/PLC (human-machine interface/programmable logic controller) ☐ID fan failure (loss of air flow) due to electrical loss/power outage ☐Deluge system failure due to electrical loss/power outage ☐Electric fire pump due to electrical loss/power outage ☐Fire or explosion detection systems malfunction due to electrical loss/power outage ☐Auto deluge malfunctions ☐Motor failure ☐Others (list):	
Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS

April 2024

8. Which of the following leading indicators related to mechanical upset conditions are tracked? Check all that apply.

☐Not applicable - process safety key performance indicators have not been selected.

☐Cyclone plug-ups/clogs

☐Conveyor plug-ups and breakdowns

☐Dryer infeed conveyor failure

☐Dryer outfeed conveyor failure

☐Drag chain breakage

☐Hammer mill shutdowns

☐Belt breakage (dryer or conveyor)

☐Dryer high temperature shutdowns (due to losing power or due to losing feed)

☐Motor failure

☐Others (list):

Action owner	**Due date (yyyy-mm-dd):**
Plans and actions needed to address gap or improve existing approach	

9. Which of the following leading indicators related to environmental/weather upset conditions are tracked? Check all that apply.

☐Not applicable - process safety key performance indicators have not been selected.

☐Deluge system failure due to freezing

☐Dryers having trouble with fluctuating fibre moistures (inconsistent speeds)

☐Sparks caused by combustion air fluctuating with ambient air

☐Freeze up in abort gates

☐Freeze up in utilities/compressed air system

☐Operational issues with pneumatic sensing/differential pressure lines/flow sensor due to cold temperatures

☐Freezing of incline conveyors

☐Blower intake screens plugging due to hoar frost

☐Building dry valve systems breaking the drain systems due to frost

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS
April 2024

☐Excursions of high-speed bearing temperatures, including hammermills and fans during hot ambient temperatures

☐Excursions of high pellet temperatures out of the coolers and into the rail cars during hot ambient temperatures

☐Issues with electrical drives, PDCs (power distribution centres), MCCs (motor control centres) during hot ambient temperatures

☐Others (list):

Action owner	Due date (yyyy-mm-dd):

Plans and actions needed to address gap or improve existing approach

10. Which of the following leading indicators related to operational upset conditions are tracked? Check all that apply.

☐Magnets filled with metal contaminants (not cleaned)
☐Rock traps full (not cleaned or emptied)
☐Worn hammers
☐Holes in hammermill screens
☐Pelleter roll and dies worn or out of adjustment
☐Bridging of material in surge bins
☐Failing bin level indicators or bindicators
☐Fibre too wet or too dry coming into pelleters
☐Decks bridging off or running empty
☐Mixing bin bridging
☐Cooler bins plugging up
☐Manual deluge malfunction
☐Burner will not relight
☐Others (list):

Review of Action Plan for Key Performance Indicators

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS

April 2024

Complete the following table after corrective actions have been implemented.

Improvement actions taken
How did you ensure the controls were implemented in a timely fashion? How did you prioritize your actions?
How will you ensure the implemented controls will continue to be effective over time?
How are workers involved in developing and implementing controls?
How do you know that workplace decisions related to safety are effective and sustainable?
How do you measure change to establish a new performance expectation?
When changes are made, how are interrelated procedures, programs, and policies updated effectively?
Is a strategy for continuous improvement in place? How does this process work?
If you have multiple locations, are lessons learned and continuous improvements shared with other locations? How does this process work?
Is the safety management system self-sufficient, or does it rely on specific individuals to make it function? How do you ensure the system remains self-sufficient?
Overall effectiveness of improvement actions

WOOD PELLET BC Forest Safety DALHOUSIE UNIVERSITY DUST SAFETY SCIENCE OBEXRISK

PSM INTEGRATION TOOL: SELF-ASSESSMENT & ACTION PLAN
ELEMENT: KEY PERFORMANCE INDICATORS

April 2024

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