Wood Dust in Sawmills

Compilation of Industry Best Practices

May 4, 2012

This document is dedicated to the memory of workers who have suffered and lost their lives from the hazards of combustible dusts. It is offered in the hope that it will help prevent such tragedies in the future.

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Introduction

Two recent catastrophic fires and explosions occurring at BC sawmills have prompted a series of followup actions by industry, government and organized labour. One key step was to quickly poll operations and key organizations on industry practices specific to wood dust cleanup, control and associated fire prevention and protection measures. This information has been compiled in the attached document and is available for your consideration. The materials cover a broad spectrum of fire prevention but do have a focus on combustible wood dust and specifically the cleanup and control of dust in sawmills.

When cleaning up combustible wood dust there is a potential to increase the risks associated with a variety of tasks and the potential for fire and explosion. The following introductory pages contain important considerations when addressing dust cleanup and control in your mill.

Of upmost importance ………

- Minimize the use of compressed air for cleanup. Airborne dust can explode when in contact with potential ignition sources.
- Limit your ignition sources when cleanup activity is underway. No hotwork.
- Wetdown and misting is effective but be aware of impact and interface with electrical equipment.
- Lockout and de-energized equipment will decrease risks of energy contacts and ignition points.
- Dust accumulates in awkward locations – be aware of workers entering restricted, confined and workspaces at heights.
- Review the considerations following before you direct workers or engage contractors to cleanup.

Key Items for Consideration

1. Responsibilities

- Supervisors (need to know..)
  - ☐ Knowledge of combustible dust conditions & controls.
  - ☐ Risk Assessment Process.
  - ☐ Monitoring Requirements (dust exposure, hotwork, permits, risk assessment etc.).
  - ☐ Requirements for first aid coverage during high risk activities.
  - ☐ Emergency evacuation and response procedures.
  - ☐ Control of ignition sources to prevent explosions:
    - ▪ Lockout equipment prior to starting work.
    - ▪ Elimination of 'Hot Work' and propellant-actuated tools (Hilti-guns) during cleanup activities.
    - ▪ Use appropriate electrical equipment and wiring methods.
    - ▪ Control static electricity, including bonding of equipment to ground.
    - ▪ Control smoking, open flames, and sparks.
    - ▪ Control mechanical sparks and friction.
    - ▪ Separate heated surfaces from dusts.

- Workers (need to know..)
  - Identification & reporting of combustible dust conditions.
  - Understanding of emergency response procedures.
  - Understanding of the job planning needed to perform the task safely.
  - Dust cleaning methods that do not generate dust clouds:
    - Clean in a manner that eliminates the generation of dust clouds. Blowing down with compressed air or even vigorous sweeping should be minimized.
    - Use combination air/water wands or water wash down. A hazard and risk assessment must be conducted when using water systems in and around electrical components.
    - Methods that create dust clouds should only be used if the following requirements are met:
      - Electrical power and other sources of ignition shall be shut down or removed from the area.
      - Only low gauge pressure 103 kPa (15 psi) compressed air should be used.
      - No open flames, sparks from spark-producing equipment, or hot surfaces capable of igniting dust cloud or layer exist.
      - All fire protection equipment should be in service.
      - If portable vacuum cleaners are used they shall be industrial vacuum cleaners designed for Class II Hazardous Locations or alternately a fixed pipe suction systems (non-pvc) with remotely located exhaust and air material separator dust collectors (cyclones or bag houses).

2. Pre-Work & Ongoing Hazard/Risk Assessment(s)

Pre-work considerations to identify hazards and develop controls. All field level hazard and risk assessments should be conducted by a qualified person before cleanup commences.

Assessments need to identify:

- Critical areas (Class II Hazardous Locations – see description at end).
- Identification of areas to clean, order & priority to clean and appropriate cleanup methods eg.,
  - Open areas
  - Hidden or enclosed areas
  - Dust "leaking" from dust capture systems
- Ventilation requirements (start-up procedures prior to work commencing, shut down procedures after dust clouds are gone).
  - NOTE: some lockout procedures may shut down area or machine specific ventilation systems.
- All ignition sources.
- Coordination of work activities (between cleanup , maintenance and/or contractors).
- Potential for changing conditions.
- Other things that might cause explosions (examples: propane, natural gas)

3. Lockout

Lockout procedures should be reviewed to address combustible dust issues. The act of pulling electrical cords from sockets and throwing energy isolating switches can produce ignition sources.

Class II Hazardous Location Lockout:

- All Class II Hazardous Locations should have the equipment locked out before the dust is cleaned up.
- Wear appropriate PPE (Arc Flash Rated Clothing and other PPE if required).
- At the end of the work activities wait until the dust cloud has dispersed before re-energizing the equipment or removing your electrical cords from sockets.

4. Hot Work

Hot Work is an ignition source.

- No Hot Work should take place in any Class II Hazardous Location without first performing a risk assessment.
- All Hot Work should be coordinated with the supervisor who signs all Hot Work permits.

5. Working At Heights

Combustible dust will most likely be found in areas that require working at heights. Some of these areas are:

- Structural members
- Dust collection systems
- Conduit and pipe racks
- Cable trays
- Above suspended ceilings
- Above interior offices
- Above operators booths
- On equipment
- Attics

When workers are working at heights a fall protection plan & system must be in place and workers need to be instructed in this system.

6. PPE

Almost all wood dust, especially if very fine, can cause allergic reactions in many people and can cause skin irritation, as well. Workers exposed to wood dust need to understand the potential health effects of such exposure and take precautions to reduce their exposure.

Appropriate PPE for cleanup activities in Class II Hazardous Locations are:

- Steel toed boots
- Hearing protection
- Gloves
- Goggles

- Coveralls
  - NOTE: Tyvek coveralls with a B suffix do not contain an antistatic agent. Styles like these can build a static charge and should not be used in areas where there is a potential for dust explosion.
- Respiratory Protection
  - Elastomeric half-face respirator with P100 cartridges, as a minimum.
  - Fit Testing needs to take place prior to starting work.
  - Single use respirator - Where an N95 filtering dust mask is used the requirement for fit testing would still apply.

7. Confined Spaces

Many confined spaces will also require cleanup and be classified Class II Hazardous Locations. All confined spaces need to be identified and assessed prior to work commencing. The company needs to have a confined space program and workers need to be trained in confined space entry procedures. Confined spaces and combustible dust hazards:

- The risk of combustible dust fire/explosion increases in confined spaces because of the confinement of the dust cloud.
- Workers must be properly trained to conduct this work and use the required controls.

8. Electrical Equipment Cleanup

Cleanup of electrical equipment, motor control centers (MCCs), electrical rooms, disconnects and power distribution centers should be performed by qualified electricians. A hazard and risk assessment must be performed prior to cleanup activities. Ensure that Arc Flash PPE is being used.

9. Water Misting Systems

Water misting can be used to decrease the combustible properties of wood dust.

- Existing water misting systems should be maintained and working during cleanup activities.
- Consider installing water misting systems in Class II Hazardous Locations such as:
  - Canter Bandsaws
  - Canter cutting heads
  - Outfeed of VAG
  - Outfeed of board edgers
  - Conveyor junctions
  - Chip screen areas
  - Any area that becomes a Class II Hazardous Location due to normal operating conditions.

10. Contractor Management

If companies choose to hire contractors to perform cleanup of Class II Hazardous Locations there needs to be management coordination of these activities. The company is responsible to ensure that the contractor has the ability to perform the work safely.

Items to consider for contractor management:

- Selection Criteria - contractors should be hired based on their ability to safely perform the task and not solely based on price. Contractors need to be in good standing with WorkSafeBC. The contractors have to supply appropriate supervision to ensure that all work activities are carried out according to the Occupation Health and Safety Regulation and company standards.
- Contractors must be supplied with combustible dust and risk assessments, as well as the company combustible dust control plan.
- Contractor work procedures must be reviewed by the company, before the work commences.
- Monitoring - contractors need to be monitored by a management representative to ensure that all work activities are being carried out according to company and regulatory standards.

11. Ongoing Dust Control

The elimination of dust buildup will greatly reduce the potential for a combustible dust explosion. Passive dust control systems, dust suppression systems and dust collections systems can be installed to reduce dust buildup. The areas identified as Class II Hazardous Locations should be equipped with engineering controls to reduce or eliminate dust issues.

Ventilation systems also need to be assessed for potential combustible dust explosions. Spark detection and deluge systems and explosion controls can be installed to reduce or eliminate these risks.

Definitions

Class II Hazardous Locations

The second type of hazard listed by the *National Electrical Code* are those areas made hazardous by the presence of combustible ***dust***. These are referred to in the Code as "Class II Hazardous Locations."

Combustible Dust Explosions

Five elements are necessary to initiate a dust explosion, often referred to as the "Dust Explosion Pentagon".

The first three elements are those needed for a fire, i.e., the familiar "fire triangle":

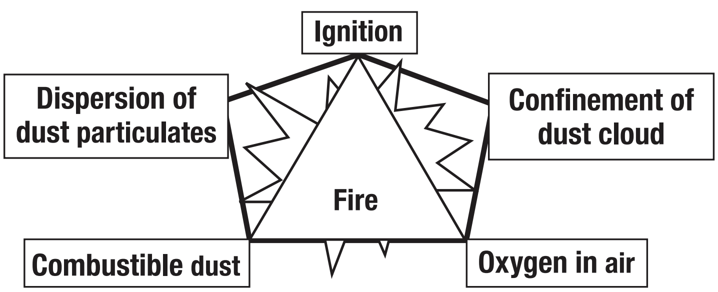
1. Combustible dust (fuel);
2. Ignition source (heat); and,
3. Oxygen in air (oxidizer).

An additional two elements must be present for a combustible dust explosion:

4. Dispersion of dust particles in sufficient quantity and concentration; and,
5. Confinement of the dust cloud.

If one of the above five elements is missing, an explosion cannot occur.

Dust Explosion Pentagon



Hot Work

'Hot work' means riveting, welding, flame cutting or other fire or spark-producing operations.

Deflagration

Deflagration is the propagation of a pressure wave (at a speed less than the speed of sound) from the ignition of a combustible dust, and includes both fires and explosions. An explosion can occur if the deflagration occurs in an enclosed space such as a dust collector, duct, or building.

Typical Ignition Sources Found in Sawmills

- Electrical equipment (examples: fixed and portable equipment, plugs, switches)
- Electrical rooms
- Static Electricity
- Hot Work
- Propellant-actuated tools (Hilti guns)
- Hydraulics systems
- Compressors

- Metal tools
- Mobile Equipment
- Smoking or open flames
- Hot surfaces (example: fixed and portable heaters, hot bearings)
- Lighting (fixed or portable)

Passive Dust Control

Prevents the escape of airborne dust through minimization, containment, and/or filtration. Typical areas to apply this would be: Canter lines, chippers and chip screens, vertical arbor gangs, barkers, board edgers, trimsaws and conveyor junctions.

Dust Suppression

Minimizes the escape of airborne dust by adding moisture to the material and/or the air.

Dust Collection

Removes solid particles from the air by moving dust-laden air through a filter.

Qualified Person

Being knowledgeable of the work, the hazards involved and the means to control the hazards, by reason of education, training, experience or a combination thereof.

INDUSTRY INPUT

Best Practices and Housekeeping

Canfor

Canfor Loss Prevention Manual: Fire Protection

Date published: Unknown

Canfor Loss Prevention Manual: Fire Protection

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Canfor – “Fire Free”

Loss Prevention is a Top Priority at Canfor

Loss Prevention Policy Statement

Canfor’s loss prevention objective is to minimize the potential for risk of asset loss by fire through strictly adhering to Company-wide Loss Prevention Standards for the following:

- Hot Work Control
- Housekeeping
- Thermal Imaging
- Fire Protection System Inspection and Maintenance
- Fire Protection System Impairment Management

These human element Loss Prevention Standards are considered critical for the prevention of fire loss and Canfor will adopt an aggressive approach to promptly deal with any deficiencies relating to these standards.

MANAGEMENT RESPONSIBILITY:

a. Promote awareness of the Loss Prevention Standards and the importance of loss prevention

b. Implement a company wide Loss Prevention measurement standard (Fire Incident Rating)

c. Report and investigate all loss incidents and further adhere to Canfor’s abnormality escalation process up to and including our Board of Directors

d. Maintain Company-wide Loss Prevention Manual detailing the standards relating to the five key human element programs

e. Implement a continuous improvement process for all human element programs

SUPERVISORS RESPONSIBILITY:

a. Ensure all employees under their direction receive proper loss prevention training, instruction and all work is performed safely according to Canfor’s Loss Prevention Standards

b. Initiate actions and follow-up to address any deficiencies identified in adherence to the Loss Prevention Standards within their areas of responsibility

c. Ensure contractors working on site follow Canfor’s Loss Prevention Standards

d. Maintain proper documentation to provide evidence of adherence to Loss Prevention Standards

EMPLOYEES RESPONSIBILITY:

a. Maximize property protection by following all Loss Prevention Standards found in Canfor’s Loss Prevention Manual

b. Take ownership for loss prevention and notify a Management representative of any potential loss prevention concerns or near misses

c. Report all loss incidents to Management

Components of the Loss Prevention Policy:

Hot Work Control
Implementing hot work standards will reduce the likelihood of fires starting at Canfor facilities.
Hot work fires account for nearly one quarter of all fires in the industry, representing the single leading cause of fires.

Fire Protection System Inspection and Maintenance
Ensuring fire protection equipment is maintained and operating will help ensure that fires that do occur will be controlled or suppressed before they cause significant damage.

Fire Protection System Impairment Management
Properly managing fire protection system impairments will significantly reduce the risk of a fire developing to where it is not controllable.

Housekeeping
Keeping Canfor's facilities as clean as possible will help reduce the risk of fire and the spread of fire.

Introduction

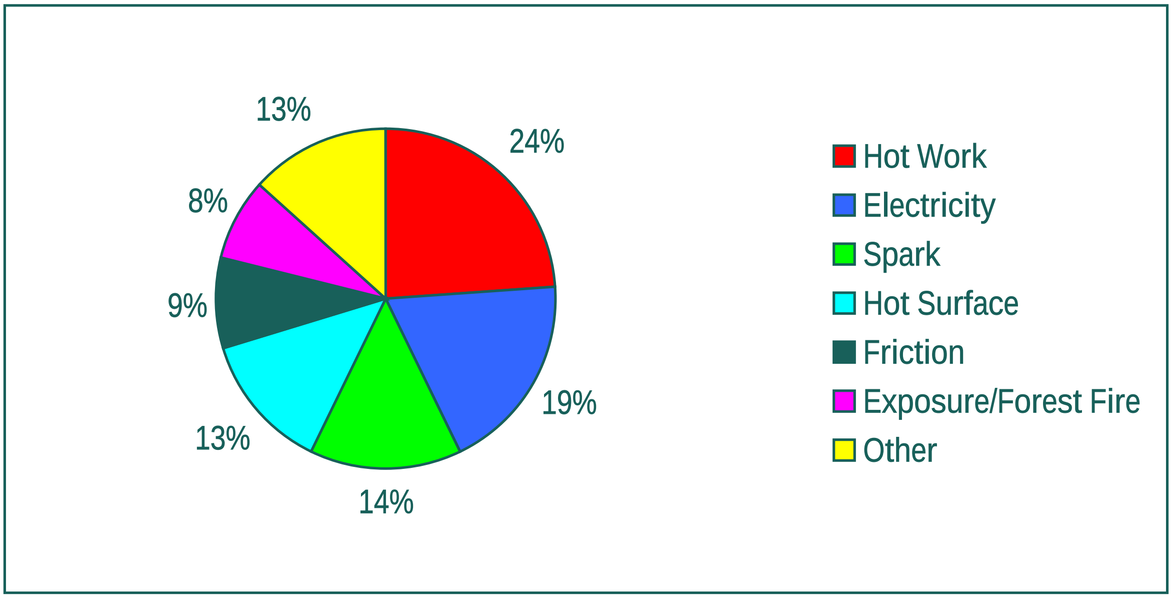
Purpose of the Loss Prevention Manual:

- Act as a resource for all operations as a guide to the company wide loss prevention standards.
- Identify additional resource material and training that can be accessed by contacting any one of the above people.

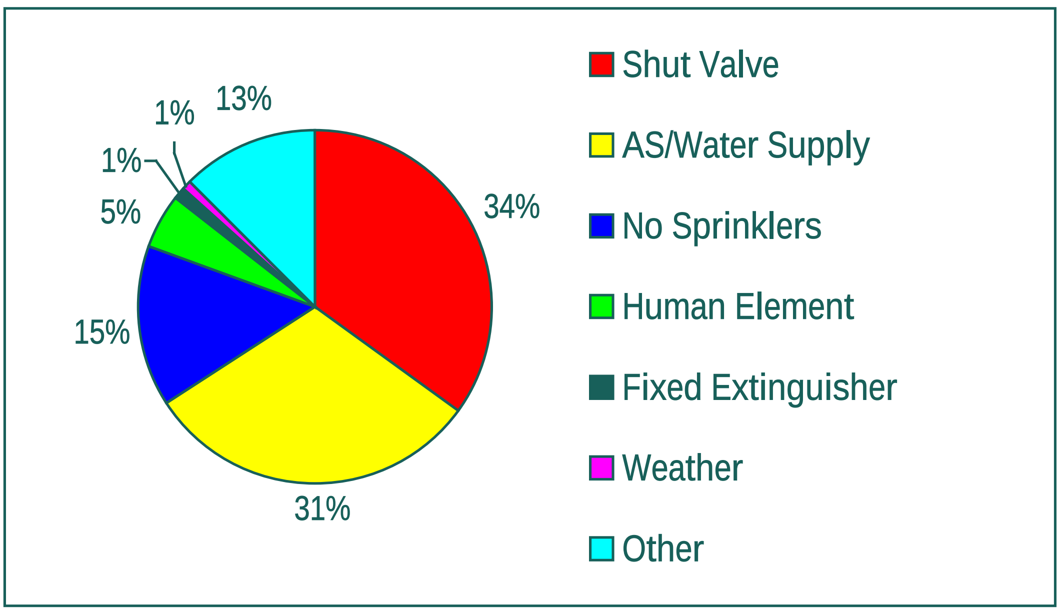
Loss Statistics in the Forest Products Industry:

- 79% of losses at woodworking facilities are from Fires/Explosions.

The Leading Causes of Fires at Woodworking Facilities are as follows:



The Key Factors in Fires that got out of control and resulted in significant losses are as follows:



Hot Work Management

Hot Work Defined:
Any temporary operation involving open flames or producing heat or sparks, including braising, cutting, grinding, soldering, arc welding, and torch-applied roofing.

The Importance of a Hot Work Program:

- Hot Work fires are preventable.
- Hot Work goes beyond just an exercise in paperwork. The permit is a tool to help with the overall process of managing Hot Work.

- Almost 25% of all fires at woodworking facilities have hot work as the cause.

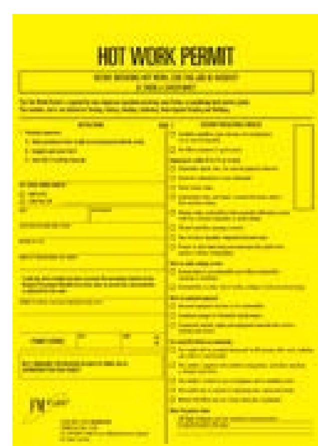
Objectives of Hot Work Program:
A solid hot work management program is characterized by good adherence to procedures and demonstrated by the consistent use of a permit system.

Permits should be properly filled-out. Proper precautions need to be consistently taken and an adequate fire watch must be included. There must be a process to ensure that sprinklers are in service before any hot work begins. The entire process needs to be audited regularly to help identify weak areas on which to improve. Education and feedback must be utilized as part of the audit process.

Common Pitfalls:
- Not considering alternatives to performing Hot Work
- Lack of time spent on executing the required precautions
- Lack of time spent on supervision
- Lack of adequate fire watch/monitoring for full 4 hours post hot work
- Not having contractors follow hot work standard processes
- Lack of a robust hot work permit system auditing program

Hot Work Management

Hot Work Program Review:
Use the following 13-point questionnaire to assess the hot work program at your site:


HOT WORK PERMIT

1. A written local standard hot work management system exists. The system also incorporates:

   a. Self audits
   b. Continuing education
   c. Mandates use of hot work permits
   d. Thermal Imaging

2. The Hot Work Permit System is used for all arc or torch welding/cutting, grinding, use of propane torches, soldering, use of portable open flame heaters, and applying roof coverings.

3. An acceptable procedure is followed for issuance of permits for any hot work conducted by employees.

4. An acceptable procedure is followed for issuance of permits for any hot work conducted by contractors and ensuring that contractors do not conduct unauthorized hot work.

5. A fire safety supervisor is available on every shift and is empowered to enforce necessary precautions.

6. Permit precautions are strictly adhered to:

a. Available sprinklers, hose streams and extinguishers are verified to be in service/operable.

b. The 35 ft. rule (see permit) is enforced in all cases as needed.

c. Combustibles are protected with fire-resistive tarpaulins or metal shields, all wall and floor openings are covered and fire-resistive tarpaulins suspended beneath work.

d. Enclosed equipment is cleaned of all combustibles, and containers purged of flammable liquids/vapours.

e. A continuous fire watch is provided during and for 60 minutes after work, including any coffee or lunch breaks.

f. Fire watch is supplied with suitable extinguishers and charged small hose.

g. Fire watch is trained in use of this equipment and in sounding alarm.

h. Fire watch may be required for adjoining areas, above, and below.

i. Following the 60 minute continuous watch, the hot work area is periodically monitored for an additional 3 hours, along with a thermal image of the area being taken and attached to the closed permit.

7. Hot work is prohibited on foam-insulated metal wall, roof, and ceiling panels (where applicable).

8. Alternatives to hot work are considered and encouraged at all times. The fire safety supervisor is required to review any such proposed work and determine if alternate methods are available.

9. Regular, properly documented use of the permit system is evident.

10. A ready-to-function emergency plan is available at all times.

11. Safe practices are incorporated into contracts with strict verification that they are followed.

12. A formal feedback mechanism is available for the responsible manager.

13. Employees demonstrate support for hot work procedures.

Fire Protection System Inspection and Maintenance

Fire Protection System Inspection and Maintenance Defined:
Fire protection systems that are not functioning cannot respond to a fire, which significantly increases the exposure to loss. Fire protection equipment inspection and maintenance consists mainly of the following:

- Valve inspection/testing
- Sprinkler flow testing, trip testing, and flushing investigations
- Fire pump inspection/testing

The Importance of a Fire Protection System Inspection and Maintenance Program:
There are three key factors that can lead to an inoperable or compromised fire protection system.

1. Malfunctioning components during a fire-event: Fire pumps that don’t start, valves that don’t operate properly, pipe obstructions preventing adequate water flow, etc…

2. System is shut down for known or unknown reasons: Shut values, fire pumps left in 'off' position, or any other component not returned to service after shutdowns.
3. Failure of a system component during a non-fire event: corroded piping leading to leaks and water damage, sprinkler heads knocked off causing system to trip, etc…

Objectives of Fire Protection System Inspection and Maintenance:
All inspections and maintenance items are completed properly and on-schedule.
Documentation should always be available to confirm that these are being done consistently.
Emergency response plans include a valve operator and fire pump operator where necessary.

Common Pitfalls:

- Insufficient documentation on testing/inspection work done (whether using in-house or contracted services)
- Lack of understanding or knowledge of the inspection standards
- Lack of trained personnel to perform the inspections and maintenance at times where the principal employee is absent (e.g. during vacations).

Fire Protection System Inspection and Maintenance

General Fire Protection Inspection Frequency Reference:

Frequency	*Component*	*Action*
Weekly	Sprinkler Valves	Visual Inspect
	Dry/Deluge/Pre-action Systems	Visual Inspect
	Fire Pump	Start-Test via Pressure Drop
	Water Tank	Inspect
	Open Water Supply Suction Screens	Inspect
	Pressure Reducing Valves	Inspect
	Special Protection Systems	Inspect
	Fire Prevention Inspection	Inspect
Monthly	Yard Post Indicator (PIV) type and Underground (T-bar) type sectional Sprinkler Control Valves	Physically Try

	Fire Pump Diesel Engine	Inspect Batteries
	Pressure Reducing Valves	Operational Test
Quarterly	Sprinkler Water Flow Alarms	Test
	Standpipes and Hose	Inspect
	Dry/Deluge/Pre-action Systems	Test Alarms
Semi-Annually	Freezer Protection Systems	Inspect
	Special Protection Systems	Check Agent Quantity
	Fire Pump Diesel Engine	Maintenance
Annually	Sprinkler Valves	Close and Reopen
	Dry/Deluge/Pre-action Systems	Full Flow Trip Test
	Fire Hydrant Control Valves	Inspect/Physically Try
	Main Drain	Test
	Fire Hydrants	Flow Test
	Back-flow Preventers	Flow Test
	Fire Pumps	Performance Flow Test
	Fire Pump Diesel Engine	Maintenance
	Open Water Supply Suction Screens	Inspect/Clean
	Pressure Reducing Valves Flow	Test
	All Special Protection Systems	Test Detectors and Actuators
	All Special Protection Systems	Inspect and Clean Nozzles
	Gaseous Protection Systems	Inspect Protected Area
Every 3 Years	Freezer Protection Systems	Internal Inspection
	Underground Main Loop	Flow Test
Every 5 years	Sprinkler Systems with an Open Reservoir Suction Source	Flushing Investigation
	Check Valves, Alarm Valves, and Backflow Preventers	Internal Inspection
	Steel Water Tanks	Internal Inspection
Every 10 Years	Dry/Deluge/Pre-action Systems [1]	Flushing Investigation
	Sprinklers	Inspect

[1] Increased to every 5 years after 20 years of service

Fire Protection System Inspection and Maintenance

Valve Inspection Frequency Reference:

Valve Type	*Action*	*Frequency*
Outside screw and yoke (OS&Y), Indicating butterfly valves (IBV's), Post indicator valve assemblies (PIVA's)	Visually inspect for the full open position and locked.	Weekly
	Full turn operation, return to and re-lock in the full open position, and conduct drain test. **Note 1 & 2**	Annually
Post indicator valve (PIV), Wall post indicator valve (WPIV), Inside screw gate valves	Visually inspect for the open position and locked.	Weekly
	Physically test for the full open position and re-lock in the full open position. These valves are open if you feel a spring or tension in the operating rod when you try to turn it beyond the wide-open position. **Note 1**	Monthly

	Full turn operation, return to and re-lock in the full open position, and conduct drain test. **Note 1 & 2**	Annually
Curb-box/roadway	Visually inspect cover and for accessibility.	Weekly
	Physically test for the full open position and leave in the full open position. These valves are open if you feel a spring or tension in the operating rod when you try to turn it beyond the wide-open position. **Note 1**	Monthly
	Full turn operation, return to the full open position, and conduct drain test. **Note 1 & 2**	Annually

Note 1: For the monthly physical tests, the valve only needs to be turned closed 3 -4 full turns, then re-open the valve fully (ensuring that the valve was and remains, fully open). Any physical test or full-turn operation will likely activate any tamper switch that is electrically supervised. Take proper precautions to ensure the alarm station is notified both before and after any operation of the valve(s).

Note 2: Annual full turn operation creates an impairment condition and needs to be handled as a planned impairment.

Fire Protection System Inspection and Maintenance

Dry-Pipe System Inspection Frequency Reference:

Frequency	*Action*
Weekly **Note 1**	1. Check to ensure system air and water pressures are adequate. 2. Verify that air supply valves to accelerators and exhausters are open, accelerator/ exhauster air pressure is equalized with system air pressure, and excess water is drained off. 3. Make sure the valve room/house temperature is at a minimum of 40°F (5°C).
Monthly	1. Verify that the automatic drain (ball drip valve) from the intermediate chamber is free to move. 2. Check the level of priming water above the clapper and drain any excess water. 3. Make sure no air leakage is occurring. 4. Check the operability of accelerators and exhausters without tripping the dry pipe valve. 5. Check the condition of air compressors and air dryers (if required). Follow manufacturers recommended maintenance schedule for these components. 6. Before and during cold weather check the sprinkler systems low point drains and drain as

	necessary.
Annually **Note 2**	Full Flow Trip Test — Record air and water pressure. With the water control valve fully open perform a full flow dry pipe valve trip test using the inspectors test connection to exhaust the air. Record the time and air pressure at which the system trips and compare to previous tests. If the time has increased, investigate and fix the deficiency. Be sure to record both the time when the valve initially trips open, and the total time for water to reach the inspector's test connection, to enable troubleshooting in the event the trip test yields an excessive time. Ensure that the valve trips and water arrives at the inspectors test connection within 60 seconds. Observe condition of the water. Conduct a flushing investigation if scale or debris sufficient to clog a sprinkler is evident. Drain the system and inspect internal dry pipe valve components. Clean, repair and replace components as necessary. Reset the dry pipe valve per the manufacturers instructions, making sure the water and air pressures are normal and that the air supply system is working properly. Check and service the air dryer (if provided) based on the manufacturer's guidelines. Perform a 2 in. (51 mm) drain test after the dry pipe valve is placed back in service.
Every 10 Years **Note 2, 3, 4, & 5**	Perform a flushing investigation on plain (black) steel pipe systems. See Note 5 below for galvanized piping systems.

Note 1: During extreme cold weather (-20°F [-11°C] below normal low temperature) check the temperature of the valve room/house and the air and water pressures daily.

Note 2: This test can create an impairment condition and needs to be handled as a planned impairment.

Note 3: Reduced to every 5 years after 20 years of service.

Note 4: Systems in service for 20 years or longer with no history of flushing investigation maintenance are likely obstructed and a full flushing is required.

Note 5: For internally galvanized piping systems flushing investigations are only required if the suction source is an open water supply or if obstructions are suspected.

Fire Protection System Inspection and Maintenance

Flushing Investigation Frequency Reference:

Type of System and Conditions	*Piping Type*	*Frequency*
Dry Pipe and Preaction fed from Clean Water Supply	Uncoated Ferrous Sprinkler Piping	After in service for 10 years, after 20 years, and every 5 years thereafter.
Dry Pipe and Preaction fed from Clean Water Supply	Internally Galvanized Ferrous Sprinkler Piping	Flushing investigations for galvanized piping systems are only needed when the water supply is from an open body of water or when obstructing materials are suspected
Wet, Dry Pipe or Preaction fed from Open Water Supply (e.g., ponds, rivers, etc.)	Any	Every 5 years
Dry Pipe or Preaction fed from Open Water Supply (e.g., ponds, rivers, etc.) where system is tripped more	Any	Annually

than 2 times per year.		
When any of the following conditions exist: • Discharge of obstructive material is noted during a yard main water test. • Foreign material is noted in fire pumps, dry pipe valves or check valves. • Plugging of pipe or foreign material noted coming from Inspector's Test Connection. • Failure to flush underground piping or surrounding public mains following new installations or repairs. • Plugged sprinklers or piping found during building alterations or after a fire. • Defective intake screens for fire pumps taking suction from open bodies of water.	Any Sprinkler System or Underground Piping	As soon as the condition is discovered.

Fire Protection System Inspection and Maintenance

Flushing Investigation Process:

Before starting, send in impairment report to Marsh Risk Consulting (see Appendix "8") to report the system that will be impaired.

Flushing Investigation Equipment/Materials List:

- Manpower (2 persons minimum)
- Fork lift or manlift and operator
- Pipe wrenches, etc.
- Spare gasket for replacement in DPV (if necessary)
- Strut replacement for accelerator (if applicable)
- Two 2 ½ in. hose gate valves
- Four 1 ½ in. hose gate valves
- Two 2 ½ in. hoses in sufficient length to discharge outside
- Minimum of two 1 ½ in. hoses in sufficient length to discharge outside
- Bushings to connect the 1 ½ in. hose gate valves to ends of the branch lines
- Four 1 ½ in. elbows
- Burlap bag to collect foreign material from water discharge

Flushing Investigation Procedure:

1. Trip and flood the system. Maintain the system full of water for a minimum of 24 hours to allow any pipe scale to soften.
2. Shut the sprinkler control valve and drain the system that was flooded.
3. Check the piping visually with a flashlight while it is being dismantled. Attach hose valves and 2½ in. hoses to the end of the crossmains to be tested.
4. Shut these valves and have air pressure restored on the system and the control valve reopened.
5. Open the hose valve on the crossmain allowing the system to trip in simulation of normal action. Any obstructions should be cleared from the crossmain before proceeding with further tests.
6. After flowing water through the crossmain, shut its hose valve and test the branchlines by discharging water through a 1½ in. fire hose. Again, collect any foreign material in a burlap bag. Only a representative number of branchlines need to be tested.
7. After the test, the dry-pipe valve should be internally cleaned and reset. Its control valve should be locked open and a drain test made.

Fire Protection System Inspection and Maintenance

Flushing Investigation Procedure Continued:

Key Points:

- The system should be flooded a minimum of 24 hours prior to flushing – this is a good opportunity to conduct a trip test.
- All low drain points should be bled off to ensure maximum water is distributed throughout the system.
- Depending on the annunciator panel, the sprinkler waterflow switch on the alarm trim should be by-passed so the panel can be reset to monitor any other sprinkler waterflow alarms.
- Fire pumps should be used to provide maximum waterflows. Please refer to the chart below which provides the minimum recommended waterflows for the given pipe diameter.
- The sprinkler piping should be visually inspected while it's being dismantled.
- Flow water from the crossmains first, then through the branch lines.
- Labelling test points will prevent future tests being conducted at the same points.
- If ball valves are used, they should be the Full Bore Type valves.
- Connect a 2 ft. length of 1½ in. pipe with 1½ in. couplings on both ends to the ends of the 1½ in. discharge hose – this will prevent the hose from closing in on itself and provides a mechanism useful for gripping.

Table 1. Waterflow Recommended for Flushing Piping

Size of pipe,		*Flow*		*Size of pipe,*		*Flow*	
in.	*(mm)*	*gpm*	*(dm³/min)*	*in.*	*(mm)*	*gpm*	*(dm³/min)*
¾	(19)	17	(65)	3½	(89)	300	(1,135)
1	(25)	27	(100)	4	(100)	390	(1,475)
1¼	(32)	47	(180)	5	(125)	620	(2,345)
1½	(38)	63	(240)	6	(150)	880	(3,325)
2	(50)	105	(395)	8	(200)	1,560	(5,895)
2½	(64)	149	(565)	10	(250)	2,440	(9,225)
3	(76)	220	(830)	12	(300)	3,520	(13,305)

Impairment Management

Fire Protection System Impairment Management Defined:
Impairment management is closely tied to the overall system of managing the fire protection system. It specifically relates to a formalized program for taking the fire protection system out of service for any reason, either planned or unplanned.

The Importance of a Fire Protection System Impairment Management Program:
Gives formal notification to Canfor and Marsh Risk Consultingl and allows for a second opinion to understand and advise on the process being used. Notification helps ensure supervision and a secondary source for follow-up. The impairment management program also provides a visual indicator of the impairment.

Objectives of Fire Protection System Impairment Management:
All inspections and maintenance items are completed properly and on-schedule.
Documentation should always be available to confirm that these are being done consistently.
Emergency response plans include a valve operator and fire pump operator where necessary.

A good program is in place to manage impairments should they occur. A permit system is used to supervise occurrence. Strict adherence to the Impairment Permit process including promptly notifying Marsh Risk Consulting of the impairment by fax.

Common Pitfalls:

- Not considering all 3 phases of a fire protection system shutdown
    1. Pre planning before impairment
    2. During Impairment
    3. After Impairment
- Not considering alternatives to impairing the fire protection system

Impairment procedures should be used whenever fire protection water supplies, sprinklers, fire pumps or special protection systems are impaired for any reason, where an unusual fire protection hazard exists, and when specific fire prevention procedures are necessary. Note that routine testing of fire protection equipment can create an impairment to the system, and even these brief impairments need to be properly managed. The follow procedures outlined below to ensure complete precautionary measures are taken and ignition sources are controlled.

Impairment Management

System Impairment Precautions

1. Is any hot work (i.e., cutting, welding, brazing, grinding) being allowed in an unprotected area? If so, cease this potential ignition source while fire protection is impaired.
2. Is smoking allowed in the unprotected area? If so, stop all smoking until fire protection has been restored to service.
3. Are there hazardous operations in the impaired area? If so, can this operation be stopped until fire protection is back in service? This could include flammable or combustible liquids and dusts in the area.
4. If this is a planned impairment, is all the pre-work completed prior to impairing the fire protection? This includes having all piping laid out for new underground work; ensure all piping and sprinklers needed for a job is on site and available, etc., and that all piping/connections/equipment be installed/completed to the extent possible before impairing the protection system. If not, can any planned work be completed on a priority basis so that the amount of time of impaired fire protection is minimized?
5. Ensure that the work being done will be carried out without interruption until completion.
6. Can temporary protection be provided by using fire hoses to the sprinkler system and/or fire hydrant? Ensure there are charged small hoses and fire extinguishers available in the area that is impaired.
7. If at all possible, schedule any impairment work to be done during idle hours when fewer ignition sources are present.
8. Contact (either by telephone, fax or e-mail), the FM Global Customer Service Desk to inform them of fire protection impairments. Explain the impairment in detail, and depending upon what type of fire protection is impaired, the following information should be provided:

   a) What type of system is being impaired (i.e., sprinklers, halon, CO2, Inergen, AFFF, Fire Pumps, Gravity Tanks/Reservoirs, etc.).

   b) If a sprinkler control valve is closed, provide the following information: What valve is being closed, what area does this fire protection valve protect, the reason why it is being shut, and approximately how long will this system be impaired. If the fire protection will be impaired for some time, look into capping off the affected area and reopening the sprinkler control valve so at least partial protection can be restored to service. Also, look into tying the impaired sprinkler system into a "live" adjacent system using fire hoses if applicable.

   c) If a fire pump is impaired, provide the following information: Type of fire pump (diesel or electric), is there another fire pump provided that will remain in service; is there still city water pressure available with the pump impaired; the reason why it is out of service; can the pump be started manually in an emergency and if so, will there be someone on site 24 hr./7days per week that knows how to start this pump in an emergency; and the expected duration of this impairment.

Impairment Management

System Impairment Precautions (continued)

d) If special protection (i.e., Halon, CO2, Inergen, etc.) is impaired, provide the following information: Type of system that is impaired; what area does this system protect; is there automatic sprinkler protection available and in service; can this system be manually tripped in an emergency situation and if so, would personnel be instructed/allowed to do this; reason why this system is being impaired and an estimated timetable for restoration.

e) If fire alarms are impaired, provide the following information: Is automatic sprinkler protection still in service; is special protection (i.e., halon, CO2, Inergen, etc.) impaired when these fire alarms are impaired; if only fire alarms are impaired, ensure there are key personnel assigned to the duty of calling the public fire service in an emergency; the reason why the alarms are impaired and the expected duration of this impairment.

f) If a gravity tank, reservoir, etc., is impaired, provide the following information: Is this the only water supply available for fire protection. If so, is there a way to obtain water from other sources nearby (i.e., river, lake, etc.). Could the public fire service park a pumper truck at the facility while they water supply is impaired?

9. Contact the public fire service and inform them of the impaired fire protection.

10. Provide ongoing fire watch patrols of the unprotected area(s).

11. Have someone assigned to respond or stand by the closed valve so it can be opened immediately in an emergency situation. This is also true of an impaired fire pump that can still be manually started. Once the above has been provided/obtained, discuss the following:

Obtain and properly fill out the impairment form. The person assigned to close the sprinkler control valve needs to ensure they count the number of turns it took to close this valve. This is done so that when facility personnel are reopening this valve (when work is completed), they ensure the valve is completely reopened the same number of turns it took to close. The tag should then be attached to the "closed" valve so that anyone walking by will see and know that the fire protection is impaired. DO NOT LOCK ANY CLOSED SPRINKLER CONTROL VALVES. They should only be locked after they have been fully reopened and fire protection restored to service.

The original impairment document should be kept by the person responsible or the person who authorized the impairment, so that they in turn can confirm, and ensure, that all valves have been fully reopened, when the fire protection is restored to service.

Impairment Management

System Impairment Precautions (continued)

Once work has been completed, do the following:

1. After completion and restoration of fire protection equipment, pertaining to the restoration of automatic sprinkler protection, perform a 2 in. drain test on the downstream side of each valve that was closed. This test is very important as the final check to ensure that all control valves have been left in the wide-open position.

   To do this test, fully open the drain valve and observe the pressure gauge. A quick return of pressure after the drain valve is closed indicates the valve is open to allow good flow. A slow return means there is a partial obstruction. No return means the valve is either totally shut or completely obstructed. Investigate immediately if drain tests are unsatisfactory.

2. If work was being done to install new underground mains, the new mains should be hydrostatically tested at 200 psi for 2 hr. (or 50 psi greater than the working pressure of the system). This will ensure there are no leaks in the underground main. Furthermore, any time either a new underground main is installed or an existing underground main has been repaired, full flushing of the underground is recommended to ensure there are no rocks or other obstructions in the mains.
3. Ensure the fire pump(s) are in full automatic operation.
4. Ensure all sprinkler control valves are locked in the wide-open position.
5. Ensure that all control actuators are replaced and that all control panels/alarm systems are placed back in full service.

Confirm with Marsh Risk Consulting that the impairment is completed and all fire protection has been restored to service.

Housekeeping

Housekeeping Defined:

Housekeeping is the process of organizing, cleaning, and maintaining a facility, keeping hazards in check and goods out of aisles, removing dust, and handling storage properly. Good housekeeping is key component of any loss prevention program and involves all employees. Effective housekeeping is an ongoing operation: it is not a hit-and-miss cleanup done occasionally.

The Importance of a Housekeeping Program:

The main purpose of good housekeeping in loss prevention is to prevent the spread of fire. It is also linked to employee safety and accident prevention. Good housekeeping sets the tone for all property loss prevention and control efforts.

Objectives of Housekeeping Management:

Effective housekeeping results in:

- decreased fire and explosion hazards
- safer work environment for all employees
- lower employee exposure to hazardous substances (e.g. dusts, vapours)
- more efficient equipment cleanup and maintenance
- better control of tools and materials, including inventory and supplies

Key Components of Housekeeping Management:

A good housekeeping program identifies and assigns responsibilities for the following:

- clean up during the shift
- day-to-day cleanup
- waste disposal
- removal of unused materials
- inspection to ensure cleanup is complete and address deficiencies

Housekeeping

Elements of an Effective Housekeeping Program

1. Regular Dust and Wood Waste Removal

Strive for no more than 1/8-inch dust accumulation on overhead building members and equipment by providing and maintaining dust collection equipment and supplementing as necessary with scheduled clean up.

2. Maintenance

The maintenance of buildings and equipment may be the most important element of good housekeeping. Maintenance involves keeping buildings, equipment and machinery in safe, efficient working order and in good repair. A good maintenance program provides for the inspection, maintenance, upkeep and repair of tools, equipment, machines and processes.

3. Clear Aisles and Stairways

Aisles should be wide enough to accommodate people and equipment comfortably and safely. Aisle space allows for the movement of people, products and materials. Warning signs and mirrors can improve sight lines in blind corners. Arranging aisles properly encourages people to use them so that they do not take shortcuts through hazardous areas.

Keeping aisles and stairways clear is important. They should not be used for temporary "overflow" or "bottleneck" storage.

4. Spill Control

The best way to control spills is to stop them before they happen. Regularly cleaning and maintaining machines and equipment is one way. Another is to use drip pans and guards where possible spills might occur. When spills do occur, it is important to clean them up immediately. Absorbent materials are useful for wiping up greasy, oily or other liquid spills. Used absorbents must be disposed of properly and safely.

5. Organized Tools and Equipment

Tool housekeeping is very important, whether in the tool room, on the rack, in the yard, or on the bench. Tools require suitable fixtures with marked locations to provide orderly arrangement, both in the tool room and near the workbench. Returning them promptly after use reduces the chance of being misplaced or lost. Workers should regularly inspect, clean and repair all tools and take any damaged or worn tools out of service.

6. Adequate Lighting and Maintenance of Light Fixtures

7. Waste Disposal

The regular collection, grading and sorting of scrap contribute to good housekeeping practices. Allowing material to build up on the floor wastes time and energy since additional time is required for cleaning it up. Placing scrap containers near where the waste is produced encourages orderly waste disposal and makes collection easier. All waste receptacles should be clearly labelled (e.g., recyclable glass, plastic, scrap metal, etc.).

Housekeeping

8. Storage

Good organization of stored materials is essential for overcoming material storage problems whether on a temporary or permanent basis. The location of the stockpiles should not interfere with work but they should still be readily available when required. Stored materials should allow at least one metre (or about three feet) of clear space under sprinkler heads.

Stacking cartons and drums on a firm foundation and cross tying them, where necessary, reduces the chance of their movement. Stored materials should not obstruct aisles, stairs, exits, fire equipment, emergency eyewash fountains, emergency showers, or first aid stations. All storage areas should be clearly marked.

Flammable, combustible, toxic and other hazardous materials should be stored in approved containers in designated areas that are appropriate for the different hazards that they pose. Storage of materials should meet all requirements specified in the fire codes and the regulations of environmental and occupational health and safety agencies in your jurisdiction.

Avoid storage of combustible materials in utility rooms such as MCC, PDC, compressor, and mechanical rooms.

Appendix "1"

Fire Protection Inspection Form

Account Number: Index Number:

Sample Only	No one form can be designed to fit all conditions. Use this sample as a basic guide in developing your own form. Items that do not apply can be omitted; other items can be expanded or added as desired.
Instructions to Inspector:	*Complete this form while inspecting fire protection. Send the completed form to your supervisor for necessary action.*

Facility:	Location:	Date:

Valve Inspections

Visually inspect all locked valves weekly and physically try them monthly as required.* Record both weekly and monthly inspections.

*Physically try gate valves, including nonindicating and indicator-post-gate valves. Post-indicator-valve assemblies (PIVAs), indicating-butterfly valves (IBVs) and standard outside-screw-and-yoke (OS&Y) valves do not have to be tried, but should be checked visually at close range.

All inside and outside valves controlling sprinklers or fire protection water supplies are listed below. Check the condition of the valve. Do not report a valve open unless you have personally inspected it.

	Valve Location	Area Controlled	Open	Shut	Locked	Physically Turned
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						

The impairment system is used to guard against delayed reopening of valves. The impairment form should be used every time a sprinkler control valve is closed. When the valve is reopened, the 2-in. (51-mm) drain should be flowed wide-open to ensure there is no obstruction in the piping. The valve then should be relocked.

Were any valves closed since the last inspection?	☐ Yes	☐ No
Was impairment documentation used?	☐ Yes	☐ No
Was the valve(s) reopened fully and a 2-in. (51-mm) drain test conducted before the valve(s) was relocked?	☐ Yes	☐ No

Comments:

Inspect These Items At Least Weekly

SPRINKLERS	**Automatic Sprinklers**	Spare heads available? ☐ Yes ☐ No	Obstructed by high piling (18- to 36-in. [46- to 91-cm] clearance)? ☐ Yes ☐ No
		Heat adequate to prevent freezing (40° F [4° C] min.)? (Note broken windows, etc.) min. temp.	Water Pressure: Psi at yard level:
	Any heads disconnected or needed:		Comments:

DRY-PIPE VALVES	**Valve Room Properly Heated?**	No. 1 Min.: 42° F/6° C Measured: F/C	No. 2 Min.: 42° F/6° C Measured: F/C	No. 3 Min.: 42° F/6° C Measured: F/C	No. 4 Min.: 42° F/6° C Measured: F/C
	Air Pressure	No. 1 Min.: psi/bar Measured: psi/bar	No. 2 Min.: psi/bar Measured: psi/bar	No. 3 Min.: psi/bar Measured: psi/bar	No. 4 Min.: psi/bar Measured: psi/bar

WATER SUPPLIES	**Fire Pump**	Fire pump pressure: Start Stop		Packings cool? ☐ Yes ☐ No
		Jockey pump pressure: Start Stop		Fuel tank level ($^3/_4$ min.)
		Pump room properly heated? (° __F/C min.) Temp. ° F/C	Properly ventilated? ☐ Yes ☐ No	Fire pump started on automatic? ☐ Yes ☐ No
	Tank or Reservoir	Full? ☐ Yes ☐ No	Time to overflow tank: Mins.	Heating system in use? ☐ Yes ☐ No
		Temp. at cold water return (should be 42° F [6° C] min.):		Circulation good? ☐ Yes ☐ No
	Inside Hose	In good condition? ☐ Yes ☐ No		Accessible? ☐ Yes ☐ No

Fire Doors	Condition:	Close properly? ☐ Yes ☐ No	Obstructed? ☐ Yes ☐ No	Blocked open? ☐ Yes ☐ No

OCCUPANCY	**General Order Neatness**	Good? ☐ Yes ☐ No	Combustible waste removed on schedule? ☐ Yes ☐ No	How often?	
		Presence of combustible dust, lint or oil deposits on ceilings, beams, machines? ☐ Yes ☐ No If yes, arrange for cleaning and investigate the source.		List areas needing attention, Including yard:	
	Electrical Equipment	Defects noted? ☐ Yes ☐ No			
	Flammable Liquid	Safety cans used? ☐ Yes ☐ No	Low-level vent fans on? ☐ Yes ☐ No	Flammable liquid cabinets used? ☐ Yes ☐ No	Grounding straps, self-closing faucets and safety buns in use? ☐ Yes ☐ No
	Smoking Regulations	Locations where violations noted:		Corrective action taken:	
	Hot Work	Permits issued for all hot work applications? ☐ Yes ☐ No		Listed precautions taken? ☐ Yes ☐ No	
	Storage	Well-arranged? ☐ Yes ☐ No	Aisles clear? ☐ Yes ☐ No	Clear of lamps, heaters (36 in. [91 cm] min.)? ☐ Yes ☐ No	

Other items:

Inspect These Items At Least Monthly

MANUAL PROTECTION	**Extinguishers**	Charged? ☐ Yes ☐ No	Any missing? ☐ Yes ☐ No	Accessible? ☐ Yes ☐ No	Location of extinguishers needing attention:
	Yard Hydrants and Hose	Condition: No. 1 / No. 2	No. 3 / No. 4	No. 5 / No. 6	No. 7
		Hydrants drained? ☐ Yes ☐ No	Remarks:		

Other items:

Inspect These Items At Least Quarterly

Sprinkler Alarms	Tested? ☐ Yes ☐ No Time for alarm	Operation satisfactory? (If no, comment below.) ☐ Yes ☐ No

Other items:

Appendix “2”
DRY PIPE VALVES

Caution: Do not use grease or pipe compounds on valve seats.

Dry-pipe valves should be tripped, cleaned and reset annually

Instructions: Use one card for each dry-pipe valve. Post securely in dry-pipe valve enclosure.
Record the data each time the valve trips or is tripped.

VALVE MANUFACTURER’S NAME	MODEL NUMBER	YEAR INSTALLED	VALVE NO./AREA CONTROLLED

DATE TRIPPED	CAUSE OF TRIPPING OR BY WHOM TRIPPED	STATIC WATER PRESSURE	SYSTEM AIR PRESSURE	TRIP POINT AIR PRESSURE	TRIP TIME MIN. – SEC.	DATE RESET	RESET BY	RED TAG PERMITS USED?	
								YES	NO
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
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								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐

Appendix “3”
DELUGE OR PRE-ACTION VALVES

Caution: Do not use grease or pipe compounds on valve seats.

Valves should be tripped, cleaned and reset annually

Instructions: Use one card for each valve. Attach securely to valve. Record the data each time the valve trips or is tripped.

VALVE MANUFACTURER’S NAME	MODEL NUMBER	YEAR INSTALLED	VALVE NO./AREA CONTROLLED

DATE TRIPPED	CAUSE OF TRIPPING OR BY WHOM TESTED	DETECTION SYSTEM NUMBER	TIME TO TRIP	TRIP POINT AIR PRESSURE	TRIP TIME MIN. – SEC.	DATE RESET	RESET BY	RED TAG PERMITS USED?	
								YES	NO
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐
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								☐	☐
								☐	☐
								☐	☐
								☐	☐
								☐	☐

Appendix "4"
FLUSHING INVESTIGATION RECORD

Building Number	System Number	Wet	Dry	Date Installed	Date Last Flushed	Investigated By	Date	How Investigated	Type of Material Found	Rec. Flush?

Appendix "5"
Weekly Fire Pump Test Form

Test all fire pumps weekly. Enter correct settings in shaded column. Make sure all test results are within normal limits. If you find that repairs are needed, make them immediately and follow manufacturer's instructions.

Pump Manufacturer **Year installed**

Manufacturer's model no. **gpm/psi rating** **gpm** ☐ **psi** ☐ **rpm** ☐

Pump on ________ psi/bar/kPa **Pump off _________ psi/bar/kPa**
Jockey pump on _______ psi/bar/kPa **Jockey pump off ______ psi/bar/kPa**

Date tested							
By Whom							
Pressure at pump startup method of start							
Motor running time (min)							
Suction pressure							
Discharge pressure							
Temp and tightness of stuffing box glands							
Level of water supplies suction tanks should be overflowed							
Temperature of water							
Pump room temperature							
Engine instrument readings RPM							
Oil pressure							
Temperature							
Last oil change ___________ Next oil change ___________							
Amps							
Fuel tank level should be at least three-fourths full							
Condition of crank case oil							
Condition of battery charger Last time battery charged _________ **Battery Electrolyte Level Normal** _________							
Cooling system temperature							
Cooling system strainer condition							

Annual pump flow test results satisfactory _______ Yes _______ No

Explain findings:

Provide a work order for immediate repair.

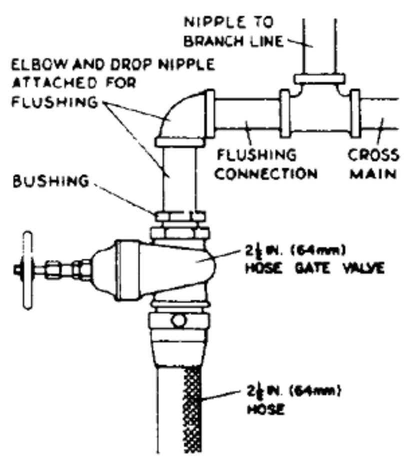
Follow impairment procedures

Keep records on file for review by appropriate personnel.

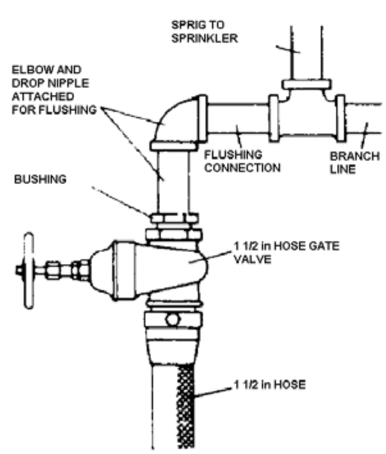
Sign off when pump is restored to automatic:

Appendix “6”
FLUSHING INVESTIGATION
MATERIALS LIST

- Manpower (minimum of 1 person, ideally 2 people)
- Forklift-mounted safety cage or "Manlift"
- Proper wrenches and other tools
- Flashlight
- Gasket replacement for Dry Pipe Valve (if needed)
- Strut replacement for accelerator (if applicable)



- 2½ in. hose gate valve *
- Three 1½ in. hose gate valves *
- 2½ in. hose in sufficient length to discharge outside
- 1½ in. hose in sufficient length to discharge outside
- Bushing to connect the 2½ in. hose gate valve to the ends of the cross main
- Bushings to connect the 1½ in. hose gate valves to the ends of the branch lines
- 2½ in. elbow



- Three 1½ in. elbows
- Burlap bags

** If ball valves are used, they should be the Full Bore Type valve.*

Dry-pipe system FLUSHING INVESTIGATION
PROCEDURE SUMMARY

DAY 1

1. **Use the Red Tag Permit System**.

   Notify Emergency Organization, monitoring station, and Marsh Risk Consulting that the sprinkler control valve will be closed and that testing will take place.

2. Close sprinkler control valve, isolate compressor line and bleed air from systems

3. Select the cross main(s) to be investigated.
   Select a representative number of branch lines to be investigated (minimum of 3).
   Choose branch lines at the remote end of the system or areas where there is little flow from the riser to the inspectors test connection. On multi-zone/multi-floor/multi-height ceiling sprinkler systems, it may be necessary to select 3 branch lines from each zone/floor/etc. plus more than one cross main.

4. Check the piping (cross mains and branch lines) visually with a flashlight while it is being dismantled.
   Look for obstructing material such as coupons, stones or large pieces of scale. If any of these are observed either manually remove or visually re-check after flowing water to ensure that piping is clear.

5. Connect all hose gate valves to the cross-mains and branch lines to be tested. Shut these valves.

6. Re-pressurize system and reopen sprinkler control valve

7. Lock the sprinkler control valve in the open position

8. Do full trip test through the inspector's test connection (ITC). Record the following:
   - Water pressure acting on the valve: ________
   - Air pressure before test: ________
   - Dry-Pipe Valve trip pressure: ________
   - Dry-Pipe Valve trip time: ________
   - Water delivery time to ITC: ________

   If the water delivery time to ITC exceeds 60 seconds inform Marsh Risk Consulting promptly and ask for guidance.

   See "Troubleshooting" below for some possible causes.

9. Leave system wet for a minimum of 24 hours (over night).

   This is important to allow any pipe scale to soften.

   You will need to bypass the alarm line.

Dry-pipe system FLUSHING INVESTIGATION
PROCEDURE SUMMARY

DAY 1 (continued)

10. Notify the following that the sprinkler control valve has been reopened and that the system will be wet with no alarm capability:
    - Emergency Organization
    - Fire Department
    - Monitoring station
    - Marsh Risk Consulting

11. Provide more frequent watchman rounds if possible.

TROUBLESHOOTING an excessive water delivery time to ITC

Dry pipe sprinkler systems are required and designed to deliver water to the Inspector's Test Connection (which is the most remote sprinkler on the system) in the shortest time possible but never more than 60 seconds.

If the water delivery time exceeds 60 seconds, the sprinkler system can be expected to take longer to control the fire and open up more sprinklers, resulting in greater fire damage, more water and more smoke.

If the water delivery time reaches and exceeds 90 seconds, it is expected that the sprinkler system may be unable to control the fire, resulting in uncontrolled spread of fire!

Possible causes of an excessive water delivery time to ITC:

1. *The air pressure in the system is excessive. – Consult the manufacturer's documentation for the valve model to determine the acceptable pressure range. – If this is the cause a simple adjustment of this pressure will resolve the issue.*
2. *Scale or other obstructing material within the piping is restricting the flow of water through the system. – The Flushing Investigation should reveal if this is the case via the quantity and size of material collected. – If this is the cause a full flushing of all the piping of that system will be needed.*
3. *The way the system was designed, modified or added-to has resulted in a volume of air too great to be pushed out in time by the water. – The valve trip time will help reveal if this is the case. – Modification of the system or the addition of an accelerator are possible solutions.*

Dry-pipe system FLUSHING INVESTIGATION
PROCEDURE SUMMARY

DAY 2

1. **Use the Impairment System**.
   Notify Emergency Organization, monitoring station, and Marsh Risk Consulting that the sprinkler control valve will be closed and that flushing investigation will take place.

2. Do flushing investigation. Maintain any fire pumps in service to ensure maximum water flow during the investigation.
   a. Test the cross mains first:
      i. Attach a burlap bag securely to the end of the 2 ½ in hose.
      ii. Open the hose valve on the cross main.
      iii. Flow for a good 10 minutes to allow any obstructions to be cleared from the cross main.
      iv. Shut the hose valve on the cross main.
      v. Retrieve and analyze the material collected in the burlap bag.

      If already more than ½ cup OR if particle size is large enough to plug a sprinkler head (any dimension greater than the orifice size per the table on the next page), a full system flush is needed. Immediately arrange for a full flush of the system. Keep the material collected.

      If less than ½ cup and if particle size is NOT large enough to plug a sprinkler head, proceed with investigation of branch lines. Keep the material collected.

   b. Similarly test the branch lines selected by discharging water – one branch line at a time – through a 1½ in. fire hose into a burlap bag.
      i. Flow each branch line for 2 to 3 minutes to allow any obstructions to be cleared from the branch line.
      ii. If flow appears obstructed, note which line so that piping can be checked visually as soon as the system is drained.
      iii. Retrieve the material collected in the burlap bag.

3. Analyze all the material collected in the burlap bag.

   If the total collected from the cross-mains and branch lines is more than ½ cup OR if particle size is large enough to plug a sprinkler head (any dimension greater than the orifice size per the table on next page), a full system flush is needed. Immediately arrange for a full flush of the system. Keep the material collected.

Dry-pipe system FLUSHING INVESTIGATION
PROCEDURE SUMMARY

DAY 2 (continued)

4. Drain piping, including all low points, and remove hose gate valves

5. Visually check (with a flashlight) any piping that appeared obstructed during testing

6. Replace gasket in Dry Pipe Valve (if it does not seal properly)

7. Reset accelerator (if applicable)

8. Reset Dry Pipe Valve, pressurize system and reopen the sprinkler control valve

9. Lock the sprinkler control valve in the open position

10. Return all alarms to service, including the alarm line that was bypassed on Day 1.

11. Perform an alarm test to confirm that alarms are functioning correctly

12. Perform a 2 in Drain test to confirm valve is open

13. Notify the following that the sprinkler control valve has been reopened and that the system alarms are back in service:
    - Emergency Organization
    - Fire Department
    - Monitoring station
    - Marsh Risk Consulting

Orifice Size of sprinklers

K factor	***Orifice Size (in.)***
5.6	*0.5*
8	*0.53*
11.2	*0.64*
14	*0.70*

K factor	***Orifice Size (in.)***
16.8	*0.77*
19.6	*0.82*
22.4	*0.87*
25.2	*0.95*

Appendix “7”
FULL FLUSHING
MATERIALS LIST

- Manpower (2 or 3 people)
- Forklift-mounted safety cage or "Manlift"
- Proper wrenches and other tools
- Flashlight
- 2½ in. hose in sufficient length to discharge outside
- 1½ in. hose in sufficient length to discharge outside

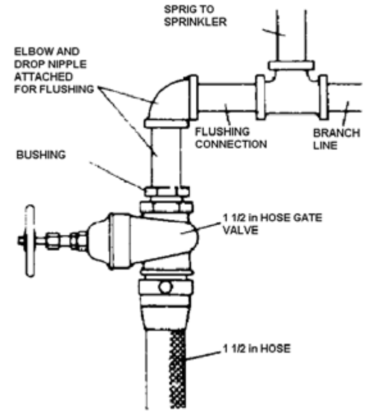


Fig 13a

For gridded systems – Fig 15 below:

- Flexible couplings with short nipple for branch lines
- Nipples and caps for ends of cross mains

For 4, 5, 6 and 8 in. pipes (in risers, feed mains or cross mains):

- Reducer from 8, 6 or 5 in. to 4in.
- Y or Siamese connection, or 4in. Tee with 2 ½ in. outlets
- Two 2½ in. elbows
- Two 2½ in. hose gate valves
- Bushings to connect the 2½ in. hose gate valve to the ends of the main

For risers, feed mains or cross mains with pipes < 4 in. (ideally 1 set per cross main to minimize the number of times the system is drained and refilled during flushing) – Fig 13a:

- 2½ in. elbow
- 2½ in. hose gate valve
- Bushing to connect the 2½ in. hose gate valve to the ends of the cross main

For branch lines (ideally more than 1 set, to minimize the number of times the system is drained and refilled during flushing) – Fig 13b:

- 1½ in. elbow
- 1½ in. hose gate valves (use 2 ½ in. valves for larger branch lines)
- Bushing to connect the 1½ in. hose gate valve to the ends of the branch lines

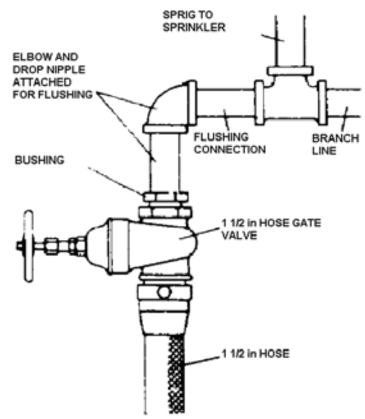


Fig 13b

Fire protection system FULL FLUSHING

PROCEDURE SUMMARY

Thoroughly flush yard mains before flushing any interior piping**.**

FLUSHING YARD PIPING

1. If divisional or other valves are to be closed, use Impairment System. Notify Emergency Organization, monitoring station, and Marsh Risk Consulting that fire protection control valves will be closed and that flushing will take place.

2. Flush yard piping through hydrants, allowing the water to run until clear.

   Use the flow specified in Table 9a or the maximum flow available for the size of the yard main being flushed.

   Table 9a. Waterflow Recommended for Flushing Piping

Size of pipe	Flow	Size of pipe	Flow	Size of pipe	Flow	Size of pipe	Flow
in.	gpm	in.	gpm	in.	gpm	in.	gpm
1	27	2	105	4	390	8	1,560
1-¼	47	2-½	149	5	620	10	2,440
1-½	63	3	220	6	880	12	3,520

   If the water is supplied from more than one direction or from a looped system, close divisional valves to produce a high-velocity flow through each single line.

   If there are no yard hydrants flush yard piping and sprinkler feeds together as per Step 3 (below).

3. To flush underground feeds from yard mains to sprinkler risers, follow one of the approaches below:
   a. Use the fire service connections on sprinkler risers as flushing outlets by removing or inverting the check valve.
   b. Install a temporary fitting on the end of riser manifolds. See Fig 14a for suggested connection and hose sizes.
   c. Install a temporary fitting on the riser, above or below the control and alarm valves. Suggested connections are illustrated in Fig. 14a.

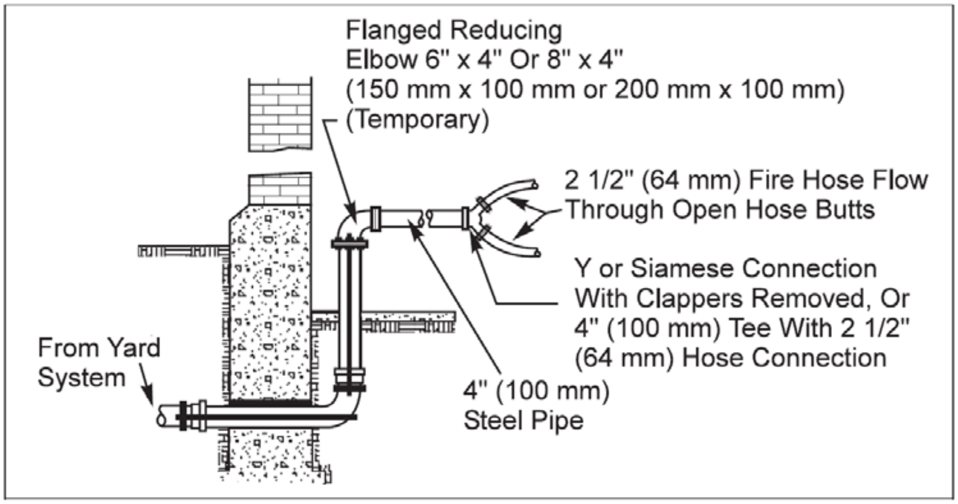


Fig. 14a. Arrangement for flushing of sprinkler riser underground lead-in piping.

FLUSHING SPRINKLER PIPING (using the hydraulic method)

General Instructions – all sprinkler systems

1. Flush feed mains, cross mains and finally the branch lines

   To ensure that sufficient water will be discharged to scour the largest pipe in the line, **remove small end piping and connect hose valves to a larger section, if necessary**. This will ensure that the flow specified in Table 9a will be achieved.

   Table 9a. Waterflow Recommended for Flushing Piping

Size of pipe	Flow	Size of pipe	Flow	Size of pipe	Flow	Size of pipe	Flow
in.	gpm	in.	gpm	in.	gpm	in.	gpm
1	27	2	105	4	390	8	1,560
1-¼	47	2-½	149	5	620	10	2,440
1-½	63	3	220	6	880	12	3,520

2. Dismantle and clean by rodding or other means any piping found solidly obstructed or with material adhering to pipe walls
3. For systems with pendent sprinkler heads, remove several sample sprinklers per system and inspect until it can be concluded that all sprinklers are free of obstruction material

Instructions for Flushing Dry/Pre-action Systems

DAY 1

1. Flood the system and leave wet. (This will soften pipe scale and deposits to facilitate removal.)
2. Use Impairment System. Notify Emergency Organization, Fire Department, monitoring station, and Marsh Risk Consulting that the system will be wet with no alarm capability. Provide more frequent watchman rounds if possible.

DAY 2

1. Use Impairment System. Notify Emergency Organization, monitoring station, and Marsh Risk Consulting that sprinkler control valves will be closed and that a flushing will be conducted.
2. Equip riser feed and cross-mains with hose valves and flush individually.
3. Equip branch lines with hose valves and flush individually.
4. Visually inspect and clean smaller piping and sprinkler heads as per General Instructions above.
5. Drain piping, including all low points, and remove hose valves
6. Reset Dry Pipe Valve (and accelerator – if applicable), pressurize system and reopen the sprinkler control valve
7. Notify Emergency Organization, Fire Department, monitoring station, and Marsh Risk Consulting that the sprinkler control valve has been reopened and that the system alarms are back in service.

Instructions for Flushing <u>tree-type Wet Systems</u>

1. Use Impairment System. Notify Emergency Organization, monitoring station, and Marsh Risk Consulting that sprinkler control valves will be closed and that a flushing will be conducted.
2. Equip riser feed and cross mains with hose valves and flush individually.
3. Equip branch lines with hose valves and flush individually.
4. Visually inspect and clean smaller piping and sprinkler heads as per General Instructions above.
5. Notify Emergency Organization, Fire Department, monitoring station, and Marsh Risk Consulting that sprinkler control valve has been reopened.

Instructions for Flushing <u>gridded Wet Systems</u> (Fig 15)

(north, south, east and west references below refer to Fig 15)

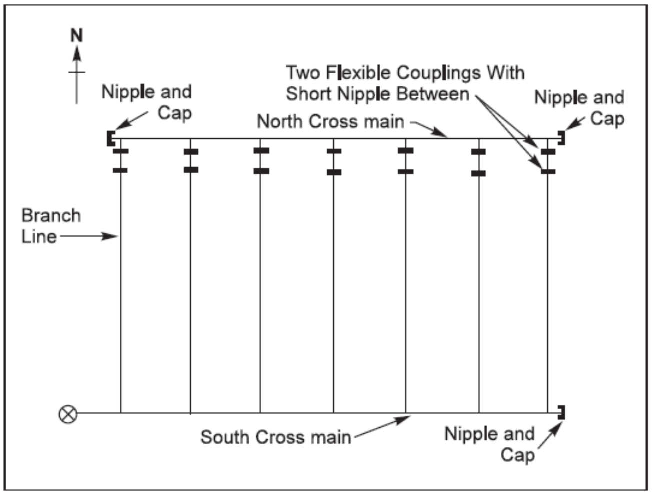


Fig. 15. A typical gridded piping arrangement prior to flushing.

1. Use Impairment System. Notify Emergency Organization, monitoring station, and Marsh Risk Consulting that sprinkler control valves will be closed and that a flushing will be conducted.
2. Disconnect all branch lines and cap all open ends.
3. Remove the cap from the east end of the south cross main, flush the main and replace the cap.
4. Remove the cap from branch line 1, flush the line, and replace the cap.
5. Repeat Step 3 for the remaining branch lines.
6. Reconnect enough branch lines at the west end of the system so the aggregate cross-sectional area of the branch lines approximately equals the area of the north cross main. For example, three 1-1⁄4 in. branch lines approximately equal a 2-1⁄2 in. cross main. Remove the cap from the east end of the north cross main, flush the main and replace the cap.
7. Disconnect and recap the branch lines. Repeat Step 5 except reconnect branch lines at the east end of the system and flush the north cross main through its west end.
8. Reconnect all branch lines and recap the cross main.
9. Notify Emergency Organization, Fire Department, monitoring station, and Marsh Risk Consulting that sprinkler control valve has been reopened.

Appendix "8"

Send the following message IMMEDIATELY by Fax or Email for any Fire Protection Impairment:

Date: ______________________________

TO:	Warren Paolucci, Marsh Canada	**Fax Number:**	1-604-633-5289
		Email:	Warren.Paolucci@marsh.com
SITE:		**SITE Contact Phone Number:**	
		SITE Contact Name:	
SITE Fax #:		**SITE Phone #:**	

AN IMPAIRMENT TO THE FIRE SYSTEM HAS OCCURRED TO:

☐	FIRE MAIN	
☐	SPRINKLER SYSTEM	
☐	FIRE PUMP	Location:
☐	CO2 SYSTEM	
☐	NOVEC	
☐	OTHER:	

Reason for Impairment:

Impaired By: **Phone:**

PRECAUTIONS TAKEN (check as appropriate):

☐	Shift Management Notified	☐	Continuous Work Authorized
☐	Fire Chief Notified (or equivalent)	☐	Ongoing Patrol Of Area
☐	Hazardous Operations Stopped	☐	Hydrant Connected To Sprinkler Riser
☐	Cutting & Welding Prohibited	☐	Pipe Plugs On Hand
☐	Other:	☐	Fire Hose Laid Out

Date Closed:	☐ Faxed	☐ Emailed
Time Closed:	Estimated Duration of Impairment:	

RESTORATION OF THE ABOVE NOTED SYSTEM IS COMPLETE

Date Opened:	☐ Faxed	☐ Emailed
Restored By:		

Canfor

Industry Best Practices/Processes for Wood Dust Control

Date published: April 30, 2012

From: Smith, Duncan [Duncan.Smith@canforpulp.com]
Sent: Monday, April 30, 2012 10:07 AM
To: Walker, Dale
Subject: RE: Industry Best Practices/processes for Wood Dust Control

Hi Dale,

Here is what Canfor Pulp Limited Partnership has done for control of wood dust:

- Ongoing capital program to control dust at drop points with enclosures and skirting on conveyor belts.

- Installation of water misting systems at drop points. These systems run from May to October but can't be run in the winter months.

- Thermal surveys on conveyor bearings to identify and correct potential ignition sources.

Duncan Smith
Human Resources Superintendent
Northwood Pulpmill
Canfor Pulp and Paper
250-962-3630

-----Original Message-----
From: Kerry.Douglas@westfraser.com [mailto:Kerry.Douglas@westfraser.com]

Sent: Thursday, April 26, 2012 11:18 AM
To: JBulcock@westernforest.com; lorraine.ducharme@conifex.com; Morris Ettinger; jgiene@lakelandmills.bc.ca; Ryan Johnson; Ed.Ma@tolko.com; mmeyer@carrierlumber.bc.ca; tmogus@dunkleylumber.com; david.murray@interfor.com; Scott, David; Butow, Gus; 'Brad Evans'; Ian Fillinger; Grimm, Mike; Coburn, Kathy; don.banks@tolko.com; Smith, Duncan
Cc: Dale.Walker@worksafebc.com
Subject: Industry Best Practices/processes for Wood Dust Control
Importance: High

Subsequent to the meeting yesterday with the Ministry of Labour, WSBC, Industry and Labour.

WSBC will be assisting in compiling Combustible Wood Dust Best practices, processes or procedures

Pls forward details on best practices, processes and procedures to Dale Walker at WSBC at the above e-mail address

WSBC is looking for all the detailed information we can provide on equipment, systems, tools, equipment, practices or procedures that you have
employed in your operations to control wood dust and ignition sources.

Pls ensure that the information provided to Dale. Please ensure the information forwarded to Dale has worked in you operations and has improved
the control of wood dust and the potential ignition sources.

Yours submissions should include the detailed information on any product names, part numbers etc.

Dale and his group will compile the information provided and provide a working Draft to the working group of industry representatives by Thursday
May 3 2012.

Pls have all submissions to Dale by Noon May 1, 2012 at the latest so that
the draft information can be compiled for the working group.

If you have any questions Pls call

Thx

In addition there will likely be a meeting in Vancouver with WSBC, industry
representatives (including representatives from MAG) and labour sometime late next week to provide some information on what has been ruled out in the Babine incident hopefully by the time we have the conference call tomorrow we will have a date and time.

Kerry Douglas
Corporate Safety-Canada
Office 250-992-0828
Cell 250-255-0805
Fax 250-992-3027

"Safety is a core value and business priority"

FM Global

Prevention and Mitigation of Combustible Dust Explosion and Fire

Date published: March, 2009

PREVENTION AND MITIGATION OF COMBUSTIBLE DUST EXPLOSION AND FIRE

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1.0 SCOPE

This data sheet describes recommended preventive measures to reduce the frequency of combustible dust explosions, and protection features to minimize damage from a combustible dust explosion. The hazards of dust fires can be found in other data sheets containing detailed occupancyspecific recommendations. However, an overview of loss history related to dust fires is included in this document.

This data sheet does not include dust explosion prevention and protection schemes unique to grain handling, storage, and processing. Loss prevention recommendations for these occupancies are covered in Data Sheet 7-75, *Grain Storage and Milling*. However, recommendations in this data sheet do apply to hazards at grain handling facilities that are not unique to those facilities.

The technology of dust explosion hazard evaluation is primarily discussed in metric (SI) units and those are the units used in this data sheet.

1.1 Changes

March 2009. Minor editorial changes were made for this revision.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 General

2.1.1 Treat all equipment that handles combustible dusts, as well as any rooms or buildings where combustible dusts can be present and might be put into suspension, as having a dust explosion hazard.

2.1.2 Implement a management-of-change process in all facilities handling combustible dusts to be certain that no changes occur that could increase the severity or consequence of an existing dust hazard or introduce a dust hazard where none previously existed. Examples of such changes include the following:

- Adding new equipment such as blenders, grinders, cutting tools, dust collectors, cyclones, etc.
- Increasing temperatures in the process that could result in drier material being handled
- Adding new materials
- Changing product formulation by adding combustible materials or reducing the proportion of inert materials
- Making process changes that reduce the particle size of in-process materials

2.1.3 Where process, equipment, raw material, or product changes are planned that could significantly change the dust properties, retest the dust for its explosibility.

2.1.4. Ensure your management-of-change process has the following minimum characteristics:

a) Provides a method for identification of changes that should be subject to the management-of-change process

b) Provides documentation of the proposed change

c) Provides a formal analysis of the loss prevention considerations involved in the proposed change

d) Identifies the need for updated personnel training

e) Provides for communication of the change and the loss prevention consequences to appropriate personnel such as maintenance, operators, safety, and emergency responders

f) Establishes any administrative procedures needed (documentation, checklists that cover hazards, training, etc.)

g) Identifies any required authorizations

2.1.5 Where potential for a dust explosion exists, eliminate the potential or minimize the consequences using one of the following methods:

a) Control fugitive dust releases using enclosures, collection systems and equipment design.

b) Locate dust producing operations in areas separated from different hazard occupancies by construction (dust-tight and explosion-resistant barriers) or distance.

c) Minimize chances for dust accumulation by arranging building elements and equipment to reduce the likelihood of dust accumulations. Employ features such as smooth, easily cleaned walls, boxed in or covered horizontal surfaces (beams, joists, etc.), and surfaces sloped a minimum of 60° from the horizontal.

d) Where fugitive dust release and accumulation exist in buildings, design the structure to safely vent the potential explosion using damage-limiting construction.

e) Locate dust collection and transfer equipment outside, away from important buildings and utilities.

f) Construct equipment that processes or transfers combustible particles to contain or safely vent a potential explosion.

g) Where explosion venting or containment in equipment is not possible, eliminate the oxygen in the system by inerting, or install an explosion-suppression system.

2.1.6 Practice effective maintenance of production and protection equipment. An effective maintenance program will:

a) Identify and eliminate fugitive dust sources continually.

b) Test and maintain spark detection and extinguishing systems, explosion isolation devices, and relief vents to ensure they are in working order per manufacturer's guidelines, or at least monthly.

c) Test and maintain metal and non-metal detection and extraction equipment to ensure they are in working order, at least quarterly.

d) Check belts and rotating equipment for alignment at least quarterly to prevent these becoming a source of friction heating.

e) Lubricate bearings and rotating equipment (fans, blowers, size-reduction equipment) in accordance with manufacturer's guidelines, or at least quarterly

f) Remove accumulated dust on rotating equipment bearings and components to insure free movement and prevent friction heating, at least quarterly.

g) Assign accountability and keep accurate records.

2.1.7 Ensure a comprehensive dust fire and explosion awareness program exists at all sites where combustible dust exists either within closed processing systems or as fugitive dust within buildings. Include the following:

a) Basic education to promote awareness and understanding of the hazards of combustible dusts

b) Instruction of new employees on the particular hazards and on precautions relevant to their departments

c) A minimum of annual instruction, drill, and familiarization of the local public fire service and/or internal firefighting teams

d) Periodic refresher training for all facility personnel

2.1.8 Strictly control potential dust ignition sources where combustible dusts may be present.

a) Ensure all electrical equipment is rated Class II, Division 1 or 2, or Zone 20, 21, or 22 per NFPA 70, the National Electric Code, Articles 500, 502, and 506, as appropriate, or international equivalent. (Refer to Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*, for additional details regarding area classification and equipment selection.)

b) Use a hot work permit system to manage all hot work operations. (See DS 10-3, *Hot Work Management*, and *Hot Work Management Kit*, P9601)

c) Prohibit smoking and open flames.

d) Provide grounding and bonding of metal components with a resistance of less than 1 x 10^6 ohms to ground. (See DS 5-8, *Static Electricity*.) At least annually, check for continuity of the metal components and security of any bonding connections.

e) Subject all electrical equipment to an initial infrared (IR) scan and then at a frequency as dictated by results and DS 5-20, *Electrical Testing*.

2.1.9 Prohibit recycling of air material separator exhaust to buildings or rooms, except where either “a” or all of “b through h” apply:

a) The return air duct discharges into an area that does not contain fugitive dust, combustible equipment or storage, combustible construction, high-value equipment, or equipment that is critical to production, OR

b) Install a filter downstream of the dust air separators that prevents return of dust to the enclosure with a minimum efficiency of 99.9% at 10 microns AND

c) Install a device to measure pressure-drop across the filter with an alarm to indicate when the filter needs to be cleaned or replaced AND

d) Provide support for the filter with a wire mesh screen or other method that allows the filter to withstand a pressure equal to or exceeding the value of P_{red} for the piece of equipment directly upstream from it AND

e) Provide explosion isolation between the building and the last dust collector in the system (the one furthest downstream) AND

f) On explosion-isolation system activation, shut down any connected dust- collection equipment AND

g) Combustible vapors, gases, or hybrid mixtures are not involved AND

h) The dust-collection system meets the protection requirements in other sections of this data sheet.

Where these features are present, the recycling of air material separator exhaust would not cause the building/room to require explosion protection features such as venting, etc. (other factors present in the building/room could create that need, however).

2.2 Room/Building Explosion Hazards

2.2.1 Construction and Location

Isolate areas handling combustible dusts from other less hazardous occupancies by separation with construction or distance to minimize damage from the potential explosion or fire. Areas needing isolation would be where fugitive dust is not readily controlled for example, grinding, sanding, sawing, open conveying, filing open bins, etc. Excluded would be for example, rooms containing properly vented dust collectors, spray dryers, fluid bed dryers, etc.

In new construction where some fugitive dust is likely, maximizing explosion venting beyond that calculated by DustCalc, can provide future flexibility for process or material changes, and often can be done with little additional cost.

2.2.1.1 Isolate areas handling combustible dusts using the methods listed below in order of preference (also see Figure 1, Table 1):

a) Detached outside location at least 50 ft (15 m) away from an important building or facility (Fig. 1, Location 1)

b) Along an exterior wall of an important building, preferably at a corner to limit exposure (Fig. 1, Location 2)

c) Inside an important building on the first floor, either at an exterior corner or along an exterior wall. Avoid locations on upper floors of multistory buildings. Where above-grade locations are unavoidable, ensure the floor and ceiling of the room have the same pressure resistance as the walls. (Fig. 1, Locations 3 and 4)

Where confirmed using DustCalc software, the spacing can be reduced to less than recommended in ″a″ above or Distance X in Table 1.

2.2.1.2 Avoid below-grade locations that cannot be equipped with adequate explosion venting.

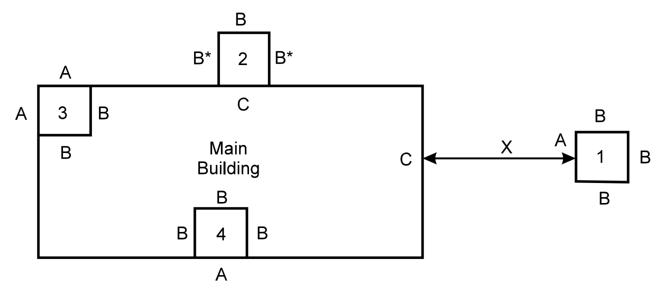

Fig. 1. Preferred locations for processes or equipment handling combustible dusts

Table 1. Construction for Dust Handling Occupancies

Location	*Distance X, ft (m)*	*Room/Building Construction*				*Construction of Exposed Wall*
		A	B		Roof	C
1 (note 3)	> 50 (15)	PV	PV		PV or LW	Any
	10 – 50 (3 – 15)	PR	PV		PV or LW	Any
	< 10 (3)	PR	PV		PV or LW	PR for 10 ft (3 m), horizontally & vertically beyond exposing structure
2	Abutting	DNA	B	B*	PV or LW	PR for 10 ft (3 m), horizontally & vertically beyond abutting structure
			PV	PV		
	Abutting	DNA	B	B*	PR	PR for 10 ft (3 m), horizontally beyond abutting structure
			PV	PV		
	Abutting	DNA	B	B*	PR	PR for Abutting wall only
			PV	PR		
3 (note 5)	Inside	PV	PR		PR	DNA
4 (note 5)	Inside	PV	PR		PR	DNA

1. This table addresses only protection against explosion hazard.
2. The types of construction are defined as follows:
   PR = Pressure resistant
   PV = Pressure venting
   LW = Lightweight, noncombustible
3. Where confirmed with calculations by the DustCalc software, location 1 distance X may be less than those listed above.
4. PR construction is also needed for floors and ceilings that have spaces below or above that contain less-hazardous occupancies.
5. Where adequate venting can be provided using the walls alone, roofs (not ceilings) do not need to be pressure-venting.

2.2.1.3 Construct buildings in which a combustible dust hazard exists of noncombustible or FM Approved Class 1 materials.

2.2.1.4 Ensure physical barriers that isolate dust hazard areas are sealed dust tight using noncombustible materials. Where the barriers have a fire resistance, ensure the seals maintain that rating.

2.2.1.5 Use door seals, window seals, positive room pressurization, etc. to prevent dust from entering and accumulating in adjacent areas that otherwise do not have their own sources of fugitive dust.

2.2.1.6 Ensure physical barriers that isolate dust hazard areas have explosion resistance sufficient to prevent failure before the pressure can be safely vented.

2.2.1.7 Do not allow openings in explosion-resistant walls. Where openings cannot be avoided, keep all doors in these walls normally closed and make sure they have the same explosion-resistance as the walls themselves. (See DS 1-44, *Damage-Limiting Construction*, for design and installation of explosion resistant doors and windows.)

2.2.1.8 Provide pressure resistance and vent area in accordance with calculations conducted using FM Global DustCalc software.

2.2.1.9 In buildings where some fugitive dust is likely despite process design and equipment upkeep, arrange building elements and equipment to reduce the likelihood and amount of dust accumulation by any or all of the following, as appropriate:

a) Provide smooth interior walls with minimal ledges.

b) To the extent practical, provide horizontal surfaces such as girders, beams, ledges, and equipment tops with a sloped cover having a smooth finish, to shed dust settling out of the air.

c) Slope covers at an angle of 60° from horizontal, unless a lesser slope is known to be sufficient.

d) Box in overhead structural steel that is out of the reach of normal vacuuming or sweeping operations and that has horizontal ledges (such as Ibeams or Ushaped channels in the up or sideways position) with a noncombustible material to eliminate pockets for dust accumulation.

2.2.2 Occupancy

2.2.2.1 Buildings can be considered as not having a combustible dust hazard if they contain combustible dust-handling equipment that is designed and protected to control or safely vent an internal explosion, in accordance with the pertinent sections of this data sheet.

2.2.2.2 Take any or all of the following steps, as needed, where quantities of fugitive dust could be expected in new operations or are excessive in existing operations:

a) Survey process equipment to identify the sources of dust release.

b) Modify, repair, or replace equipment to eliminate or at least reduce dust escape.

c) Provide permanent vacuum pickup points at the locations that release dust, such as grinding, buffing, bag dumping, open transfer points in conveying systems, and other equipment/locations where large quantities of dust are liberated frequently. In some cases this may require construction of a ventilated hood or containment enclosure for existing equipment.

d) Operate closed dust-handling systems under a slight negative pressure to reduce dust escape.

e) Conduct extra housekeeping in existing operations while equipment is being modified (see Section 2.2.4).

2.2.2.3 Existing buildings containing small, localized amounts (less than 5% of the building area and in no case exceeding 1,000 ft^2 [93 m^2]) of fugitive combustible dust can be considered tolerable without explosion damage-limiting construction, if the following conditions exist:

a) The fugitive dust escape and accumulation rate is very low, i.e., less than 1⁄16 in. (1.6 mm) for a dust with an approximate bulk density of about 36 lb/ft^3 (580 kg/m^3) per three month period AND

b) The cleaning frequency is high enough to permit one scheduled cleaning to be missed without allowing dust accumulations to reach the unacceptable level of 1⁄16 in. (1.6 mm) noted above.

2.2.3 Protection

2.2.3.1 Construct pressure-relieving and resistant walls in accordance with Data Sheet 1-44, *Damage-Limiting Construction.*

a) Design the explosion vent relief pressure (P_{stat}) as low as the wind-resistance design will permit. In a low-wind area, P_{stat} can be as low as 20 psf (0.01 bar), whereas in higher wind areas 30 to 40 psf (0.015 bar) is more typical.

b) Provide pressure resistance and vent area in accordance with calculations conducted using FM Global DustCalc software.

2.2.3.2 Do not use explosion vents in the roof to provide explosion relief.

2.2.3.3 Where a thorough engineering study shows that explosion-venting walls alone cannot provide the needed explosion venting area, roof vents may be used to provide a portion of the needed vent area if snow and ice are not allowed to build up on the vent. Any of the following are acceptable methods:

a) Position the explosion vents at a minimum 60° angle, either on a roof pitched at that angle or as a projection above the roof line (see Figure 2). For vents projected above the roof line, the effective vent relief area to be used in vent sizing calculations is the smallest cross sectional area the combustion gases would have to flow through.

b) Provide heat tracing along the perimeter and across the surface area of the explosion vent.

1. Leave heat tracing on permanently, or automatically actuate the system whenever the outside temperature drops to 0°C (32°F) or lower.

2. Ensure the wiring for the heat trace cabling incorporates enough slack to allow the explosion vent to deploy as intended.

3. Use FM Approved heat-tracing equipment.

c) Provide explosion venting panels without insulation to allow building heat to melt away snow or ice. Expect condensation under the explosion vent and take measures to ensure condensation does not cause problems.

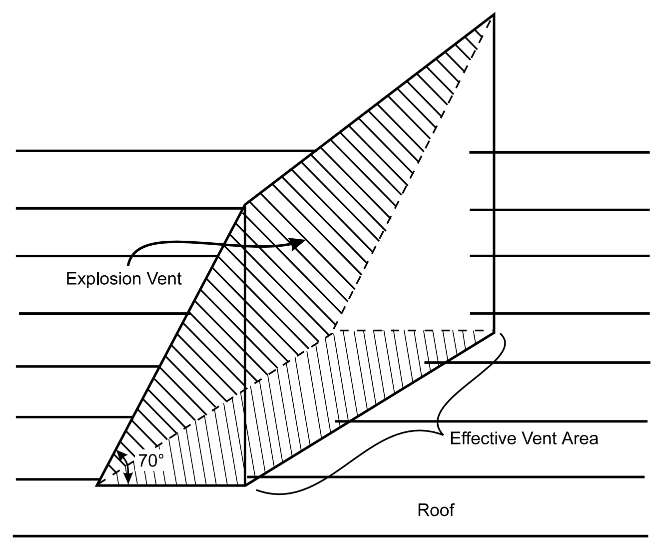

Fig. 2. Schematic of rooftop explosion vents that project above the roof line

2.2.3.4 Where explosion venting devices swing out of the way rather than rupture, use gravity or mechanical devices to ensure they cannot reclose. (3.1.9)

2.2.3.5 To prevent uncontrolled release of explosion vent panels where they could become missile hazards, take the following steps:

a) Provide tethering cables to limit the vent movement.

b) Attach tethering cables to no more than two corners, making sure the tethered corners are adjacent.

c) To prevent the tethered panels from swinging back into the vent opening after the explosion, make connections at the side or bottom of the panel rather than the top. This allows the panels to completely swing out of the way of the vent opening, leaving an unobstructed path for the combustion gases to flow along during the explosion, and for fresh air to flow into the protected enclosure after the explosion.

d) Set minimum tether length to that determined by the following equation:

$$l \geq \frac{a \times b}{2 \times (a+b)}$$

where

l = length of tethering cables
a, b = side dimensions of explosion vent

e) Where the tether length is less than that determined above, consider the explosion vent as a hinged panel when performing calculations to determine the vent area and vented explosion pressure (P_{red}). This will account for the hindrance to the venting process created by the short tethers.

f) Where tethers are located at all four corners, this can be considered tolerable where the cable length exceeds the minimum set in d, above. Any less and the vent area is restricted to the annular space determined by the cable length and the dimensions of the panel, rather than on the size of the panel itself.

2.2.3.6 Do not attach sprinkler system piping to any wall, ceiling, or roof that could be displaced by the pressure of a room or building explosion.

2.2.4 Operation and Maintenance

2.2.4.1 In buildings where fugitive dust is released despite process design and equipment upkeep, incorporate the following actions into a fugitive-dust-control program:

a) Assign accountability and keep records.

b) Commit time and resources regularly.

c) Create a maintenance schedule and review it periodically to ensure it is adequate.

d) Pay particular attention to eliminating accumulations above floor level, such as equipment tops and building structural members because this dust is more likely to become suspended (airborne) and create an explosible cloud if it is disturbed.

e) Use vacuum removal wherever possible using a central, portable, or truckmounted vacuum system as appropriate.

f) Where vacuuming is impractical, sweeping or water wash-down are other acceptable options.

g) Where compressed air blow-down is the only practical method for cleanup, use the following precautions:

1. Perform air blown-down frequently enough to prevent hazardous accumulations of dust.

2. Limit the extent of blow-down to small areas at a time with as low a volume and pressure of air as possible.

3. Shut down electrical equipment not suitable for Class II, Division 2 hazardous locations.

4. Prohibit open flames and hot work, and ensure no hot surfaces exist.

2.2.4.2 Any accumulations of fugitive dust present a potential for a secondary explosion and must be eliminated in buildings without damage-limiting construction (DLC), and controlled in those with DLC (3.1.1).

a) Base dust-cleaning frequency on preventing accumulations of more than 1⁄16 in. (1.6 mm) thickness over more than 5% of the room floor area.

b) Use fugitive dust exceeding the above, either in thickness or area, as a trigger to initiate cleanup.

c) Ensure the total area of accumulation does not exceed 1,000 ft^2 (93 m^2).

d) The thickness of 1⁄16 in. (1.6 mm) is based on a typical wood or agricultural dust with a bulk density of about 36 lbs/ft^3 (580 kg/m^3). The thickness of dust of different density can be based on a ratio of the bulk densities.

2.2.4.3 Inspect explosion venting devices periodically to prevent their condition or mobility from being impaired. Possible impairments include the following:

a) Corrosion

b) Improper painting of movable parts or rupture membranes

c) Icing

d) Snow accumulation on or in front of vents

e) Obstruction by pipes, wires, or other utilities

f) Permanent or temporary equipment located next to the venting device

Any of these can increase effective vent-relief pressure (P_{stat}) and cause explosion-resisting walls to fail and/or damage the building structure during an explosion.

2.3 Equipment Explosion Hazards

2.3.1 General

2.3.1.1 Locate all equipment having an explosion hazard outdoors whenever practical (3.1.2).

2.3.1.2 Where equipment has an explosion hazard, take one of the following steps:

a) Eliminate the explosion hazard using any of the techniques detailed in Section 2.3.2,

OR

b) Mitigate the explosion hazard using explosion venting, suppression, containment, or vacuum operation, or a suitable combination of these, as detailed in Section 2.3.3.

2.3.2 Explosion Hazard Elimination

2.3.2.1 Where equipment handles coarse material, prevent dust from being generated during material handling by suitable methods or preclean the coarse material to remove all fines from most of the process equipment.

2.3.2.2 Where equipment handles coarse material, prevent dust from being generated during material handling by eliminating airborne dust inside the processing equipment using a liquid mist (water or other compatible liquid) as follows:

a) Apply the liquid suppressant at a point in the process that involves substantial turbulence, e.g., at a discharge spout, to ensure the suppressant is thoroughly mixed in with the material stream.

b) Install an interlock that will shut down the solid process stream on suppressant spray-system malfunction if this system is being relied upon as the sole means of hazard control.

c) Confirm the effectiveness of the system to eliminate dust in the equipment by visually checking equipment while it is running, for example, by opening access or inspection ports.

d) Develop a maintenance and inspection program with written procedures and records of completion to ensure the dust-suppressant spray system is functioning properly whenever the solid process stream is being handled.

2.3.2.3 Inert the combustible dust by mixing it with a noncombustible dust (known as ‘‘phlegmatization’’) on the following basis (3.1.3):

a) Perform a test to determine the mixture is non-explosible per ASTM E1515, *Standard Test Method for Minimum Explosible Concentration for Combustible Dust* or international equivalent.

b) Ensure the noncombustible dust does not separate from the combustible dust during further material handling.

2.3.2.4 Reduce the oxygen level in the process with an inert gas in accordance with recommendations in Data Sheet 7-59, *Inerting and Purging of Equipment*.

2.3.2.4.1 If values of the Limiting Oxygen Concentration (LOC) are not available from Data Sheet 7-59 for the particular material being handled, arrange for laboratory testing of materials to determine the LOC.

2.3.2.4.2 Where an inert atmosphere is to be used to safeguard pneumatic conveying of freshly ground or freshly manufactured light metal powder (aluminum, magnesium, titanium, zirconium):

a) Provide a minimum oxygen concentration of at least 1% to ensure a stable oxide layer can be formed to passivate the dust.

b) Where the metal powder is not to be exposed to air, or where testing has shown a lower oxygen level is acceptable, concentrations lower than 1% are acceptable.

2.3.2.4.3 The metal powders titanium, magnesium, zirconium, uranium, and thorium, will ignite in pure carbon dioxide. Use argon, helium, or nitrogen (except for titanium, which can be ignited in pure nitrogen) for inerting processes handling these materials.

2.3.2.5 As an alternative to an inert atmosphere for handling freshly manufactured light metal powder (aluminum, magnesium, titanium, zirconium) take the following steps:

a) Use wet collectors (water wash) rather than dry type.

b) Remove the accumulated sludge and dispose of it in a safe manner before shutting down the collection system.

c) Continue collector ventilation at all times until the metal/water sludge is removed from the collector.

Aluminum particularly has a very low MIE (as low as 0.1 mJ) making it easily ignitable and metal powders in general can have high K_{st} and be very difficult to provide adequate explosion venting. Aluminum powder when damp with water can form small amounts of hydrogen so it needs to be kept wet at all times.

2.3.3 Explosion-Hazard Mitigation

2.3.3.1 Venting

2.3.3.1.1 Provide a vent area in accordance with calculations conducted using FM Global DustCalc software (3.1.4).

2.3.3.1.2 Where indoor equipment with an explosion hazard cannot be relocated outside, provide explosion venting in one of the following ways:

a) Locate the vessel next to an exterior wall and vent the explosion to the outdoors via a short vent duct.

b) Vent the explosion to the surrounding area through an FM Approved explosion quench pipe (3.1.5).

1. A vent area increase (compared to an open or unobstructed vent) will be needed to accommodate reduced venting efficiency caused by the quench pipe.

2. Use the venting efficiency for FM Approved quench pipes as listed in the Approval Guide, a publication of FM Approvals.

Where the above is not practical, implement other explosion hazard mitigation methods described in 2.3.1.2.b.

2.3.3.1.3 For calculations of vent area where equipment design strength data is not available, use the following values of P_{red} (maximum allowable pressure) for normally constructed equipment with an assumption that some vessel deformation may occur in a safely vented explosion:

a) Weak rectangular vessels (e.g., bag-type dust collector): 0.2 barg (2.9 psig)

b) Cylindrical vessels (e.g., cyclone) or strong (reinforced) rectangular vessels: 0.3 barg (4.4 psig) (3.1.6)

2.3.3.1.3.1 For vessels where deformation is not acceptable, obtain the design strength of the equipment or assume ½ the values given above for P_{red}.

2.3.3.1.4 Set the explosion vent relief pressure (P_{stat}) as low as possible in accordance with the following criteria:

a) Not exceeding 0.05 barg (0.7 psig) when vessel operates below this pressure, OR

b) At least 0.1 barg (1.4 psig) below the assumed P_{red} for higher operating pressure

2.3.3.1.5 For calculations of vent area where equipment design strength data is available, set the value of P_{red} according to the following criteria:

a) Where vessel deformation is acceptable, use a value equal to twice the design strength.

b) Where vessel deformation is to be prevented, use a value equal to the design strength (3.1.6).

2.3.3.1.6 Construct explosion vents of material that is as light in weight (mass per unit area) as possible to minimize the vent area required. Explosion vents that are rupture membranes (e.g., prefabricated rupture disks, aluminum foil, etc.) have virtually no inertia, and require no adjustment to the required explosion vent area (3.1.7).

2.3.3.1.6.1 Where venting devices are heavier than light-weight membranes, calculate the effect on the vent area using FM Global DustCalc software.

2.3.3.1.7 Install vent ducts that redirect the combustion products from the vent to a safe area in accordance with the following:

a) Route the vent to a safe outdoor area.

b) Permit no bends in the duct.

c) Limit the length to diameter ratio (L/D*) of the duct to 1.

d) Ensure the vent duct is at least as strong as the P_{red} design of the vessel.

e) Permit no closures on the discharge end of the duct that obstruct the free venting of the discharged material.

f) When the above conditions cannot be met, quantify the effect on the vent area using FM Global DustCalc software (3.1.8).

* calculate the equivalent diameter (D_{eff}) of a non-circular duct as follows:

$$D_{eff} = \sqrt{\frac{4A_d}{\pi}}$$

where A_d is the cross sectional area of the duct (m^2 or ft^2)

2.3.3.1.8 Where a wire mesh screen or other obstruction is to be provided between an explosion vent and the free atmosphere, adjust the effective area of the explosion vent for the reduction in venting efficiency as follows:

a) If the screen or obstruction is less than 15% of the explosion vent area, no adjustment is required.

b) If the screen or obstruction is between 15% and 40% of the explosion vent area, calculate the effective explosion venting area using:

$$A_{v,eff} = A_{v,actual} \text{ X } \frac{115\text{-\% } blockage}{100}$$

c) If the screen or obstruction exceeds 40% of the explosion vent area, blockage is excessive. Replace the screen or obstruction with something that causes a smaller blockage.

2.3.3.1.9 Where explosion venting devices swing out of the way rather than rupture, use gravity or mechanical devices to ensure they cannot reclose and create vacuum conditions that can collapse/implode the protected equipment (3.1.9).

2.3.3.1.9.1 Where explosion vents can reclose and there are no other openings that could draw in air, provide vacuum breakers. (See German engineering standard VDI 3673 for sizing information.)

2.3.3.1.10 To prevent the free release of explosion vent panels where they could become missile hazards, provide tethers in accordance with 2.2.3.5.

2.3.3.1.11 Do not locate objects subject to fire or pressure damage in the path of explosion vents (3.1.10.1 and 3.1.10.2).

2.3.3.1.12 For new installations, provide a distance of at least two explosion vent diameters between an explosion vent outlet (face of explosion vent or vent duct) and any large, fixed, flat obstruction (e.g., a wall). For explosion vent outlets having cross sections other than circular, use the hydraulic diameter as calculated below (3.1.11).

Hydraulic diameter = 4A/p, where
A = cross-sectional area of vent
p = perimeter of the cross-section

2.3.3.1.13 Where a weather protection cover (''rain hat'') is provided over the end of an explosion vent duct, estimate the effect on the venting efficiency as follows:

a) If there is a distance of at least one explosion vent diameter between the end of the duct and the weather cover, there is no effect on efficiency.

b) If the distance is between ¼ and 1 explosion vent diameter, consider the weather cover as a 90° bend in the vented flow when calculating the effect of the vent duct.

c) A distance of less than ¼ explosion vent diameter away from the vent duct is unacceptable unless it is designed to fly off in the event of an explosion.

For non-circular ducts, use the hydraulic diameter for these calculations (2.3.3.1.12).

2.3.3.1.14 Do not provide explosion venting if the dust or its combustion products are poisonous, radioactive, corrosive to nearby equipment or structures, or for any other reason should not be released from an otherwise closed system. Use alternatives to venting, such as explosion hazard elimination, explosion suppression, explosion containment, or high vacuum operation.

2.3.3.1.15 Where a vessel requiring explosion venting contains significant obstructions to the free flow of gases, provide several distributed vents at different places on the vessel rather than one large vent of the same area (3.1.12).

2.3.3.1.16 Where a vessel contains both suspended combustible dust and flammable liquid vapors or gases (a hybrid mixture), the reactivity of the mixture will require larger vent areas than the combustible dust on its own.

a) The presence of a flammable vapor or gas can be ignored if the concentration is at or below 5% of its Lower Explosive Limit (LEL).

b) Where the gas concentration exceeds 5% of its LEL, determine the reactivity of the mixture by testing.

2.3.3.1.17 The required explosion venting area for a vessel with a dust explosion hazard operating at pressures exceeding 0.1 barg (1.5 psig) requires special consideration and needs to be carefully analyzed. FM Global DustCalc software can handle initial pressure up to 4 barg (58 psig) for full-volume explosions.

a) Set the vent-relief pressure, P_{stat} above the normal maximum operating pressure by at least 0.1 barg (1.5 psig) (3.1.13).

b) Obtain vent sizing criteria from experts familiar with high initial pressure venting.

2.3.3.1.18 Recoil forces from the venting of an explosion can dislodge even large vessels that are not properly anchored. Implement one of the following to control recoil forces:

a) Provide equal-sized vents at opposite sides of the vessel.

b) Calculate the magnitude and duration of the dynamic recoil force (or an equivalent static force) from a vent, and provide anchorage to resist those forces (3.1.10.3).

2.3.3.2 Isolation

Avoid multiple pieces of interconnected equipment containing a dust explosion hazard. Properly protected equipment can fail when an explosion propagates from another piece of equipment. Isolation systems can prevent that condition (3.1.14).

2.3.3.2.1 Provide explosion isolation on all connections of vessels (or vessel groups) designed to contain the explosion pressure (explosion-resistant design).

2.3.3.2.2 Provide explosion isolation on all connections between vessels (or vessel groups) individually protected by explosion venting (or other mitigation method) but subject to unacceptable property damage or business interruption by a propagating event.

2.3.3.3 Isolation Systems

This section includes acceptable forms of explosion isolation and the features needed to ensure the systems serve as effective flame barriers.

2.3.3.3.1 Chemical Explosion Blocking Systems

a) Install the system in accordance with Data Sheet 7-17, *Explosion Protection Systems.*

b) Install FM Approved equipment.

c) These systems may be inappropriate under the following conditions:

1. Process flow rates are high.
2. The primary explosion is in a very large vessel.
3. The primary explosion is in a vessel protected by explosion containment.

2.3.3.3.2 Rotary Air Locks

Install devices as follows:

a) Ensure the angle between adjacent vanes and the shape of the housing allows two vanes per side to be engaged (near the housing wall) at all times.

b) Ensure the vanes (including the tips) are made of metal and have a thickness of at least ⅛ in. (3 mm).

c) Ensure the gap between the tips of the vanes and the housing between 0.2 and 0.25 mm (less or equal to 0.1 mm for aluminum dust). Consult reference 17 in Appendix D if additional information on the allowable gap is required.

d) Interlock the rotary air lock to automatically stop in the event of an explosion, to prevent the passing of burning matter. An interlock is not required if burning matter would not cause a second fire or explosion of any significance.

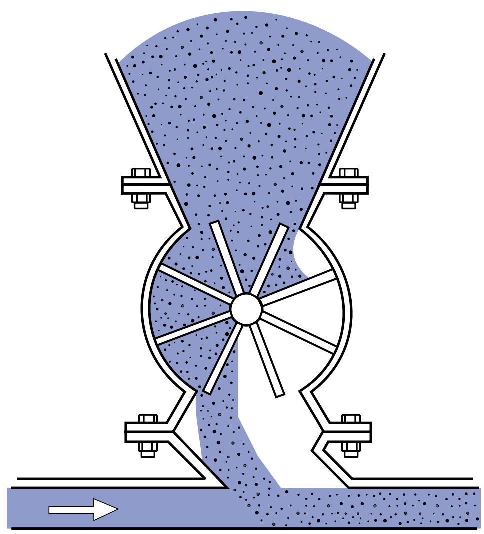

Fig. 3. Rotary Air Lock

2.3.3.3.3 Chokes

Chokes provide explosion isolation by providing an accumulation of powder through which an explosion cannot propagate.

a) Rotary air locks that don't meet all the criteria in 2.3.3.3.2, can serve as a choke if the height of powder above the air lock is equivalent to the diameter of the discharge opening and is always present.

b) Screw conveyors can serve as chokes where part of the screw is removed or a baffle is in place that ensures a plug of material is always in the screw.

2.3.3.3.4 Rapid Action Valves, Gate- Or Butterfly-Type

Ensure the distance between the explosion detection device and the rapid action valve is sufficiently long to allow the valve to fully close before the arrival of the dust flame front. (See Section 3.1.15 for how to estimate the flame front travel time.)

Fig. 4. Rapid-action valve (gate type)

2.3.3.3.5 RapidAction Valve (Float Type)

An example of this type of valve is the Ventex ESI (3.1.16).

a) Locate the valve at least 5 m (26 ft) and no more than 12.5 m (41 ft) from the equipment where the explosion initiates.

b) Ensure the value of P_{stat} (the vent opening pressure) for explosion vented equipment upstream or downstream of the float-type valve exceeds the differential pressure required to shut the valve, typically about 0.1 barg (1.5 psig).

c) Where the value of P_{stat} must be below the required differential pressure, arrange an alternate closing mechanism by installing an optical detection system at the explosion source that will trigger the high-speed release of compressed gas near the float valve to force it to close.

d) Do not locate a float-type valve in an air stream that has a significant loading of abrasive dust that would prematurely wear down the surfaces of the moving float.

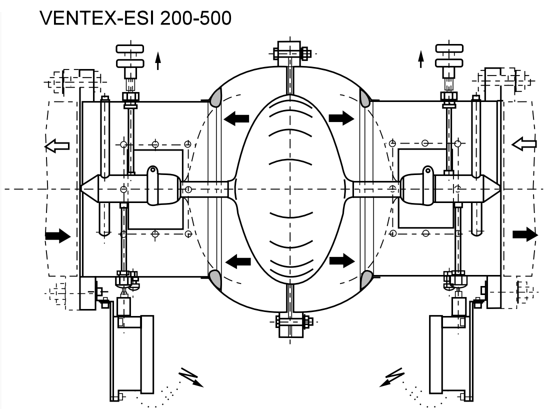

Fig. 5. Rapid action float valve (Ventix ESI ®)

2.3.3.3.6 Flame Front Diverter or Explosion Diverter

a) Do not install this device upstream of an air-moving fan because an explosion originating upstream of the diverter will propagate past the diverter.

b) Do not use explosion diverters in air streams that have a significant loading of abrasive dust that would eventually erode through the pressure-relieving diverter cover.

c) Do not use explosion diverters for hybrid mixtures where the flammable vapors exceed the LEL.

d) Flame-front diverters built commercially or inhouse according to design guidelines in Figure 6 are acceptable.

e) Ensure a prefabricated rupture disk used for the pressure-venting opening has a release pressure equal to or less than 0.1 barg (1.5 psig).

f) Where the diverter is constructed in house and a prefabricated rupture disk is not used, ensure the device meets the following criteria:

1. When providing a solid cover, ensure it will quickly and easily release during an explosion.

2. When providing a rupture membrane, use a weak weather-resistant material, such as aluminum foil or tar paper.

3. Confirm the rupture pressure is at or below 0.1 barg (1.5 psig) by calculations or pressure testing. Base this calculation on the ultimate tensile strength of the material.

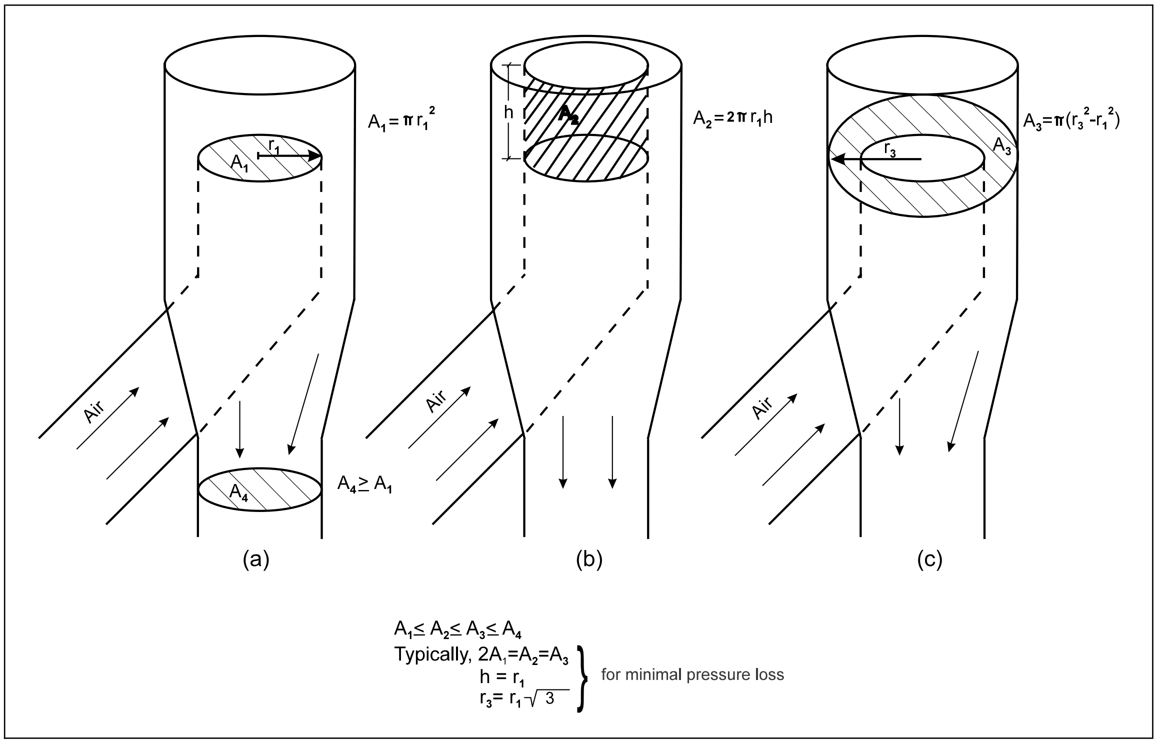

Fig. 6. Acceptable design parameters for explosion diverters

2.3.3.3.7 High Speed Abort Gate

a) Actuate the high-speed abort gate by either pressure detection or infrared explosion detection in the upstream vessel expected to experience the explosion.

b) Ensure the detection system and abort-gate responses are fast enough to completely close the abort gate before the dust flame front reaches it. (See Section 3.1.15 for how to estimate the flame front travel time.)

Fig. 7. Explosion diverter

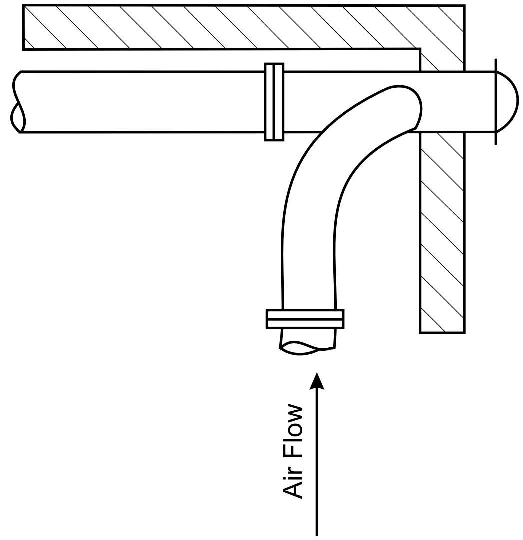

Fig. 8. Indoor installation of explosion diverter

c) Ensure the abort-gate reset is manual. Automatic reset is not acceptable.

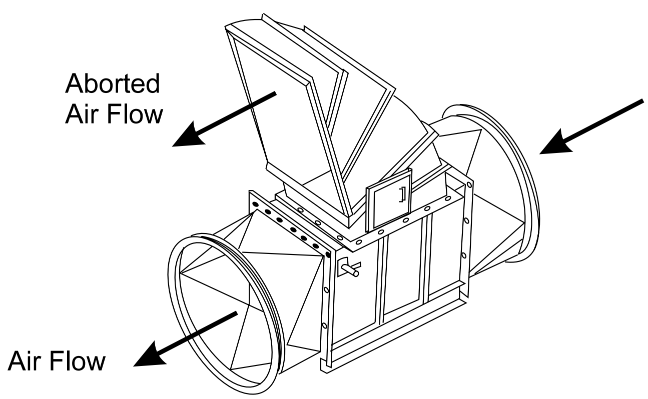

Fig. 9. High-speed abort gate

2.3.3.3.8 Double-Dump Valve

Provide an interlock to ensure both valves do not open simultaneously.

2.3.3.3.9 Back-Blast Damper

This is essentially a check valve that is effective in stopping explosion propagation in the opposite direction of normal flow. Ensure the device is provided with an explosion vent downstream from the normal flow in the system.

2.3.3.4 Suppression

2.3.3.4.1 Where explosion suppression is the chosen explosion hazard mitigation method:

a) Install explosion suppression systems in accordance with Data Sheet 7-17, *Explosion Protection Systems*.

b) Install FM Approved equipment in accordance with its listed limits of application.

2.3.3.5 Containment

2.3.3.5.1 Where explosion containment is the chosen explosion hazard mitigation method, use the explosion-resistant-design method. Existing, shock-resistant vessels are tolerable for providing explosion containment.

a) Explosion-resistant design is any vessel with a design pressure of 6 barg (87 psig) or more that would not be deformed by a dust explosion that occurs at an initial (pre-explosion) pressure of less than 0.1 barg (1.5 psig).

b) Shock-resistant design is any vessel having 3 barg (43 psig) design pressure or more when designed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, or yield strength of 6 barg (87 psig) or more according to other codes. With this design, the vessel may deform but not rupture in the event of a dust explosion that occurs at an initial (pre-explosion) pressure of less than 0.1 barg (1.5 psig).

c) To prevent damage to other equipment connected upstream and downstream of the vessels protected by explosion containment, provide explosion isolation.

2.3.3.6 High Vacuum (3.1.17)

2.3.3.6.1 Where high vacuum is the chosen explosion hazard mitigation method, use the following criteria:

a) Operate the dust-handling system at a sub-atmospheric pressure of less than 0.1 bar absolute (1.5 psi absolute)

b) Provide an interlock to automatically inert or shut down the process upon a loss of vacuum.

2.3.4 Ignition Source Control

2.3.4.1 Where a process or system has a high frequency of dust explosions implement the following:

a) Operate the equipment that is the source of sparks or hot/glowing particles in an inert atmosphere, OR

b) Install a spark-detection system combined with either a spark-extinguishing system or a high-speed abort gate, AND

c) Locate the spark-extinguishing system or high-speed abort gate upstream of the first piece of equipment having an equipment explosion hazard, AND

d) On activation of the spark-detection system shut down any connected dust collection equipment.

Installation of spark control as above doesn't eliminate the need for explosion hazard mitigation features (3.1.18).

2.3.4.1.1 The following are considered to have a high frequency of dust explosions:

a) Woodworking industry: rotary dryers, flash dryers, sanding equipment, particleboard milling equipment (see Data Sheet 7-10, *Wood Processing and Woodworking Facilities*, for additional fire and explosion protection requirements related to this industry)

b) Any mechanical milling equipment with connected equipment such as a downstream cyclone (exceptions: coal pulverizers and human food-product milling are not considered to have a high frequency of explosions for the purposes of this recommendation.)

c) Processes that routinely produce sparks or glowing embers (e.g., due to grinding or friction) that can enter a dust-collection system

d) Any process or system that has experienced two or more explosions within a 10 year period

2.3.4.2 To minimize dust-cloud ignition due to static electricity accumulation and discharge, implement the following:

a) Apply all applicable recommendations in Data Sheet 5-8, *Static Electricity*, to minimize the probability of ignition. Where plastic ducts are used to transfer material, they do not need bonding or grounding because the insulating properties of plastic do not normally allow large capacitive charges to discharge in a hazardous spark. The insulating properties also prevent metal grounding wires touching the duct from draining charges away from the overall duct surface.

b) If materials are very easily ignitable (Minimum Ignition Energy less than 10 mJ), operate any equipment with an explosion hazard under an inert environment (see 2.3.2.4) (3.1.19).

2.3.4.3 Provide magnetic separators upstream of all size-reduction equipment e.g., grinders, pulverizers, hammer mills, or other equipment involving mechanical impact with the process material (3.1.20).

2.3.4.3.1 Separators other than magnetic (e.g., air separators, grates, coarse screens) may be used if nonferrous metal or other objects (e.g., rocks) could enter the product stream and cause an ignition hazard.

2.3.4.4 Fans and blowers in the fugitive dust-air stream can become an ignition source. Install these devices as recommended below:

2.3.4.4.1 In negative pressure systems, locate the fan on the discharge side (i.e., clean side) of the dust collector.

2.3.4.4.2 In positive pressure systems, locate the blower upstream of the dust injection point.

2.3.4.4.3 Where, for design reasons, the fan must be located in the dirty air stream, and the dust/air stream concentration is higher than the 25% of the MEC:

a) install fans and blowers of Type A or B spark-resistant construction per AMCA 99-0401-86, *Classifications for Spark Resistant Construction*

b) comply with the appropriate criteria in 2.5, Connecting Ducts, below.

2.3.4.4.4 Ordinary fans and blowers may be used in a dust-air stream of unlimited concentration if the dust has been shown by test to be hardtoignite.

2.3.4.4.5 Systems handling wood dust can use ordinary fans upstream of bagtype dust collectors if a cyclone collector (primary dust collector) is upstream of the fan.

2.3.4.4.6 Ordinary fans and blowers may be used if a high-speed abort gate or FM Approved spark-extinguishing system is provided between the fan and any important or valuable downstream equipment.

2.3.4.5 Prevent materials subject to spontaneous heating from becoming an explosion initiation source by implementing the following:

a) Prevent accumulation in ductwork by maintaining sufficient transport velocity.

b) Prevent accumulation in equipment by performing frequent cleaning.

c) Do not allow moisture to contact such material; however, automatic sprinklers or spark-extinguishing systems can be used in ducts, when needed.

d) Clean collectors handling residues subject to spontaneous heating daily or as needed to prevent heating and hazardous accumulations.

2.3.4.6 Avoid using mechanical drives with high rpm or power as they can cause dust ignition due to heat generated by friction or sparks.

2.3.4.6.1 Use the following guidelines to determine the potential for hazardous conditions based on the tangential velocity (v) of the rotating component:

a) When $v < 1$ m/s (3.3 ft/s): there is no danger for ignition.

b) When $1 < v < 10$ m/s, ($3.3 < v < 33$ ft/s): judge each case separately considering the product and material specific characteristics such as MIE and particle size (for each, the lower value will tend to be more susceptible to ignition).

c) When $v > 10$ m/s (33 ft/s): there is always an ignition potential.
Note: To convert rpm to tangential velocity, use $v = rpm \times 2\pi r \times 1/60$, where
v = length (same units as r) per second
r = length of the rotating part, from shaft center to outer tip

2.3.4.6.2 Where low-velocity, high-power equipment is used, usually in grinding operations or screw conveyors and blenders, the potential for uncontrolled heating due to excessive residence time, accumulations at bearings, foreign objects, etc., needs to be considered and protected against by using shear pins, overload detection and alarm, proper maintenance and cleaning, and screens and separators.

2.4 Dust Collectors and Cyclones

In addition to the requirements presented above and in DS 7-73, *Dust Collectors*, the following are some specific requirements for dust collectors and cyclones.

2.4.1 Construction and Location

2.4.1.1 For new installations, use separate dust-collection systems for each process area to minimize the chance of one dust explosion involving many operations. For example, for an operation involving sawing rough lumber in one area and sanding finished lumber in another, each involving multiple saws and sanding stations, two separate dust collectors could reduce downtime from a single event. This will be more reliable than using explosion-isolation devices throughout a manifolded system.

2.4.2 Protection (3.1.21)

2.4.2.1 When determining the explosion venting area for a mediatype dust collector, (e.g., cloth bags, paper filter sheets or cartridges) include both the clean and dirty air side to calculate the volume of the collector.

2.4.2.2 For mediatype dust collectors, locate explosion vents entirely on the dirty side of the collector volume.

2.4.2.2.1 Where it is necessary to install some venting on the clean side, use the following equation to calculate the minimum amount of the total explosion venting area that must be provided on the dirty side:

$$A_{v,dirty,min} \geq (V_{dirty}/V_{total})^{2/3} \times A_{v,total}$$

where:
$A_{v,total}$ is the total vent area required
$A_{v,dirty,min}$ is the minimum explosion venting area that should be on the dirty side of the dust collector
V_{dirty} is the volume of the dirty side of the dust collector
V_{total} is the total volume of the dust collector

2.4.2.3 Cyclone dust collectors can be considered to have adequate explosion relief without any additional explosion vents if they meet ALL of the following criteria:

a) The dust being processed has a K_{st} of 80 bar m/s or less, and

b) The exhaust goes directly to atmosphere via the gas outlet at the top of the cyclone, and

c) The gas outlet diameter is at least 45% of the diameter of the cyclone itself, and

d) The free outflow of gases is not obstructed by screening.

1. A ''rainhat'' located above the gas outlet hole does not violate this criteria as long as its distance above the gas outlet is not less than one half the diameter of the gas outlet (3.1.22).

2.4.2.3.1 Calculate explosion vent sizing for all other situations (higher K_{st}, a smaller gas outlet, gas outlets with a duct attached exceeding L/D = 1, a duct with a bend, etc.) using FM Global's DustCalc software.

2.4.3 Ignition Source Control

2.4.3.1 Bag-type collectors do not need any type of special ''conductive'' bag material to dissipate static electric charges.

a) Where these special ''conductive'' bags have been provided, initiate a schedule of inspection and maintenance to ensure the straps used to ground the bags are always well-attached to the dust collector structure.

b) Regardless of the type of bags used, provide a reliable grounding connection for the bag cages (metal wire supports) (3.1.23).

2.5 Connecting Ducts (3.1.24)

Ducts connecting pieces of a process or collection system can provide a route for spreading an initial explosion and may contain enough dust to propagate an explosion of their own. This section does not apply to clean air ducts downstream of air-material separators or pneumatic transfer of process materials at rates well in excess of the MEC (dense phase transfer).

2.5.1 Occupancy

2.5.1.1 Control the dust concentration in a fugitive-dustcollection system to prevent a continuous, explosible atmosphere from developing in the duct using the following methods:

a) When the dust-generation rate is variable, keep the dust below an average concentration of 25% of the minimum explosible concentration (MEC). Limit peak dust-emission rates above 100% of the MEC for only a few seconds at any time.

b) When the dust-generation rate is steady without significant peaks, keep the dust concentration to no more than 90% of the MEC.

2.5.1.2 Where the concentration in a duct regularly exceeds the MEC, provide protection for the additional in-duct explosion hazard (2.5.2.3).

2.5.1.3 In ducts transporting combustible dusts, maintain an air velocity that exceeds the settling velocity for the material being transported.

Note: The velocity for typical industrial dusts (e.g., saw dust) can be from 3500 to 4000 ft/min (1070 to 1220 m/min). Where the settling velocity of a material is unknown, consult Data sheet 7-78, *Industrial Exhaust Systems*, for generic transport velocity recommendations.

2.5.2 Protection

2.5.2.1 On ducts containing combustible dust in concentrations that are always less than the MEC and that carry dust at velocities where dust settling out is unlikely, provide explosion-isolation devices as follows:

a) On connections to important pieces of equipment

b) On duct running back to buildings that contain expensive equipment or important processes that could be damaged, that might contain fugitive dust.

If the value of MEC is not available, an estimate of 30 grams/m^3 (0.03 oz/ft^3) can be used.

2.5.2.2 Arrange ducts containing combustible dust in concentrations that always or frequently exceed the MEC, or that carry dust at velocities where dust settling out might be expected, as follows:

a) Route the ducts outside.

b) Provide an explosion-isolation device at each point of connection between the duct and a piece of equipment.

c) Protect the duct from an explosion propagating in the explosible mixture by one of the following:

1. Provide venting for the duct in accordance with 2.5.2.3.

2. Design the duct to fail at pressures as low as practical but not more than 0.3 barg (4.4 psig).

2.5.2.2.1 Where the duct containing dust above the MEC or conveyed at less than the dust-settling velocity must be located indoors, take the following precautions:

a) Provide an explosion-isolation device at each point of connection between the duct and a piece of equipment, AND

b) design the duct to contain the explosion (shock resistant), OR

c) provide venting for the duct in accordance with 2.5.2.3 but route the vents outdoors.

2.5.2.3 Provide explosion venting along the length of a duct on the following basis:

a) Compute the maximum distance between explosion vents (L_{max}) as follows:

$L_{max} = 7.5\ D^{1/3}$, D and L in meters, OR
$L_{max} = 16.5\ D^{1/3}$, D and L in feet.

For noncircular ducts, calculate the effective diameter for the above equation by:

$$D_{eff} = \sqrt{\frac{4A_d}{\pi}}$$

where: A_d = cross sectional area of the duct (m^2 or ft^2)

b) Provide the vent area at each location at least equal to the cross sectional area of the duct.

c) Provide a full-size vent no more than 2 diameters away from the point of duct connection to a piece of equipment.

d) Set the explosion vent relief pressures (P_{stat}) as low as possible, with a maximum value of 0.1 barg (1.5 psig).

e) Provide an explosion vent at all elbows and end flanges (see Figure 10).

f) When located inside, route the explosion products outside via a short duct (L/D less or equal to 1).

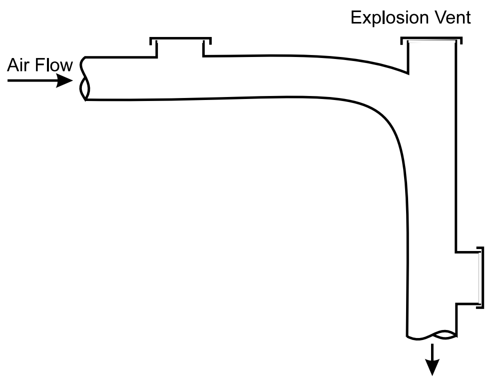

Fig. 10. Example of duct explosion venting at an elbow

2.6 Silos (3.1.25)

2.6.1 Protection

2.6.1.1 When a dust storage silo has a dust collector (other than a simple vent sock) on the breather vent, provide explosion protection as follows:

a) Treat the collector/silo combination as a single unit if either of the following conditions exist:

1. The duct connecting the silo to the dust collector has an L/D ratio less than 2, OR

2. The cross-sectional area of the connecting duct is at least as large as the explosion-venting area needed to protect the volume of the dust collector alone.

b) Provide explosion venting for the silo/collector combination based on the total volume of the two units.

c) Install part of the explosion venting on the dust collector if possible, not to exceed the cross sectional area of the connecting pipe, although all of the explosion venting can be on the silo.

2.6.1.2 Where the dust collector/silo combination does not meet the criteria of a single unit:

a) Provide explosion venting for each component based on their individual volumes.

b) Provide explosion venting for the connecting duct itself in accordance with 2.5.2.3.

2.6.1.3 Ensure the explosion venting area provided for a silo does not exceed its cross- sectional area ($A_{x\text{-}sect}$). Any explosion venting in excess of this value will not help to decrease the explosion pressure.

2.6.1.3.1 If calculations show the explosion venting area required is more than the cross-sectional area, use an explosion-suppression system or reinforce the silo so it can withstand the value of P_{red} corresponding to $A_v = A_{x\text{-}sect}$.

2.6.2 Equipment and Processes

2.6.2.1 Do not use air cannons to break bridges in silos handling combustible materials if there are particles smaller than approximately 500 microns within the material.

2.7 Bucket Elevators (3.1.26)

2.7.1 Construction and Location

2.7.1.1 Enclosed bucket elevators handling combustible dusts present an explosion hazard and need to be installed in accordance with one of the following:

a) Locate bucket elevators outdoors.

b) Locate indoor bucket elevators adjacent to an exterior wall so explosion venting can be directed to the outside via short ducts.

c) Provide the indoor bucket elevator with either explosion suppression or explosion venting through FM Approved quench pipes.

2.7.2 Protection

2.7.2.1 For enclosed bucket elevators handling dusts with K_{st} from 100 to 200, provide explosion venting based on the following design:

a) Locate explosion vents no more than 20 ft (6.1 m) apart along the height of the bucket elevator.

b) Size each explosion vent at least as large as two thirds of the cross sectional area of the elevator leg enclosure.

c) Vent the head section (i.e., top) of the bucket elevator leg based on a ratio of 1 ft^2 of venting for every 20 ft^3 of head section volume (1 m^2 per 6.1 m^3).

d) Provide explosion venting for the up and downside leg casings.

e) Set the explosion vent relief pressure to less than 1 psi (0.07 barg) and construct vents of lightweight material.

Note: Because this recommendation is based on fullscale tests in a bucket elevator, use it only for this application.

2.7.2.2 Where the elevator head or boot feeds into equipment or areas that have an explosion hazard (e.g., a dusty conveyor gallery), provide an explosion-blocking system using explosion-suppression devices or other types of physical barriers, such as a product ‘‘choke’’ or air lock between the head or boot and adjacent areas or equipment.

2.7.3 Ignition Source Control

2.7.3.1 To help prevent bucket-elevator explosions from occurring:

a) Provide belt driven elevators with a mechanical or electromechanical device to cut the power to the drive motor and sound an alarm if the belt slows downs more than 20%.

b) Do not locate or expose bearings within the elevator casing.

c) Provide belt-alignment interlocks to shut down the elevator if the belt misaligns.

2.7.3.2 Use the following preventive measures where practical:

a) Use antifriction bearings on all elevator legs.

b) Maintain all bearings per manufacturer's recommendations and keep them free of dust, product, and excessive lubrication.

c) Limit the use of combustible linings (e.g., plastic, rubber, wood) to impact points, wear surfaces, and connected hoppers.

d) Install drive belts (e.g., Vbelts, timing belts, and flat belts) that are electrically conductive at 1 megaohm or less, as well being as fire and oil resistant.

e) Design the drive train with a 1.5 service factor to stall the drive without slipping.

f) Install belts in elevator legs that have a surface resistivity of less than 100 megaohm per square, and are fire and oil resistant (oil resistance is not needed in flour mills).

g) For elevator legs inside a building whose belt speeds exceed 500 ft/min (2.6 m/sec) provide bearing-temperature monitoring or vibration detection.

2.8 Spray Dryers

2.8.1 Protection

2.8.1.1 Spray dryers often operate with much of the dryer at less than the MEC. Provide explosion protection in accordance with the following:

a) Obtain accurate calculations to confirm the average dust concentration within the cylindrically shaped portion is below the MEC of the material being handled. On this basis, only the conical section at the bottom of the dryer and any downstream equipment (e.g., cyclones, bag collectors) have an explosible mixture.

b) Use FM Global's DustCalc software for determining the explosion venting area required where a combustible cloud exists in only a fraction of the total vessel volume.

c) Distribute explosion vents uniformly throughout the dryer surface although vents only near the conical section are recommended.

2.8.1.2 For protection against fire, see DS 6-9, *Industrial Ovens and Dryers*, in the section "spray dryers handling dust."

2.9 Bulk Raw-Grain Handling

2.9.1 Equipment and Processes

2.9.1.1 Bulk grain handling presents a dust explosion hazard that can be controlled or eliminated if the following are implemented:

a) Use oil mist (or other liquid) dust suppression to reduce the dust explosion hazard in rooms or buildings and equipment used to handle bulk raw grain.

1. The explosion hazard can be considered eliminated in rooms if the oil mist can successfully reduce fugitive dust emissions low enough to allow normal housekeeping to keep accumulations below dangerous levels. (See 2.2.4.2 to determine when dust accumulations are at hazardous levels.)

2. The explosion hazard can be considered eliminated from equipment if the oil mist can successfully prevent any dust from becoming airborne inside the equipment. Confirm this by visually observing equipment while it is running (i.e., by opening access or inspection ports). Completely eliminating airborne dust inside the processing equipment can only be done by very thoroughly applying mist to all of the material being handled.

b) Apply the oil or other liquid suppressant to the grain at a point in the process that includes substantial turbulence, e.g., at a discharge spout, to ensure the suppressant is thoroughly mixed in with the grain.

1. Do not apply suppressant in bucket elevators as this could lead to slipping of the rubber belts and possible friction heating.

c) Develop a maintenance and inspection program to guarantee the dust suppressant spray system is functioning properly whenever grain is being handled.

d) Install an interlock that will shut down grain handling on suppressant spray system malfunction where this system is being relied upon as the sole means of explosion protection.

2.10 Dust Fire Hazards

In addition to the explosion hazard addressed by this document, combustible dusts can present a fire hazard that must be controlled. The following data sheets cover protection and prevention of dust fires in various equipment or processes:

a) Inside spray dryers: Data Sheet 6-9, *Industrial Ovens and Dryers*

b) Wood processing and wood working facilities: Data Sheet 7-10, *Wood Processing and Woodworking Facilities*

c) Dust collectors: Data Sheet 7-73, *Dust Collectors and Collection Systems*

d) Grain handling facilities: Data Sheet 7-75, *Grain Storage and Milling*

e) Ducts: Data Sheet 7-78, *Industrial Exhaust Systems*

f) Wood dust storage: Data Sheet 8-27, *Storage of Wood Chips*

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Comments and Technical Support

3.1.1 Is There a Housekeeping Problem? (2.2.4.2)

The fundamental rule is that any dust accumulations outside of equipment present a potential for a secondary explosion and should be removed and the source of the release eliminated. Provide DLC for areas that are subject to such uncontrolled releases that can't be resolved.

As a rule of thumb, 1⁄16 in. (0.0625 in., 1.6 mm) of dust is a cause for cleanup. (This assumes wood dust with approximate bulk density of about 36 lb/ft^3 [580 kg/m^3]). This is about the thickness of a US quarter.

Where dusts of different bulk density are used, the thickness of the equivalent mass of 1⁄16 in. (1.6 mm) wood dust would be inversely proportional to their bulk densities. For example, for a dust with a bulk density of about 60 lb/ft^3 (950 kg/m^3), a layer of about 0.04 in. (1 mm) thick would be equivalent.

Equivalent thickness = 1.6 mm x (580 kg/m^3/950 kg/m^3) or 1 mm

Any dust accumulations in a small room (200 ft^2, 19 m^2) would present a severe secondary explosion hazard. In a larger room, for example 20,000 ft^2 (1860 m^2), dust covering an area of 200 ft^2 (19 m^2) would be a less-severe event.

For practical purposes, some dust accumulations in small parts of large areas without DLC can be considered tolerable with frequent cleanup and actions to remove the source of the dust. Consider 5% of the area with 1⁄16 in. (1.6 mm) dust capable of being thrown into suspension as the limit of "tolerable." In any building of ordinary construction, any area of dust accumulations exceeding about 1,000 ft^2 (93 m^2) is considered unacceptable.

Any dust that is elevated above floor level in joists, beams, equipment tops, etc., should be considered as being capable of being thrown into suspension. Dust that has agglomerated by age, heat, moisture, etc., should not be considered as capable of being thrown into suspension but may suggest an ongoing housekeeping problem or source of uncontrolled release. Dust on the floor could be suspended but is less of a risk than elevated accumulations.

Pay close attention to dust adhering to walls since this is easily dislodged. Also consider other projections, such as light fixtures, that can provide surfaces for dust accumulation.

The available surface area for dust deposits on bar joists or steel beams can be roughly estimated at 5% of floor area. However, some steel beams might have an equivalent surface area as high as 10% of floor area, such as when spans between columns are longer than average for a given geographical area, or when a large building elevation difference requires a stronger roof structure due to anticipated snow drift loadings.

For reference, the following represents typical bulk density data.

Table 2. Typical Dust Bulk Density

Material	*lb/ft³*	*kg/m³*
Coal, bituminous, smaller than 420 microns	50	800
Flour, wheat	35-40	560-640
Starch	25-50	400-800
Sulfur, powdered	50-60	800-960
Wood flour	16-36	260-580
Source: Appendix D, Reference 15		

3.1.2 Relocating Explosion Hazards Outdoors (2.3.1.1)

A frequent objection to locating dust handling equipment outdoors is that condensation will form on the inside walls of the vessel during cold weather and introduce moisture into the dust stream. Moisture may be a process problem if it causes particle agglomeration or offspec product. It can be a hazard with some material subject to spontaneous heating. Moisture can be eliminated by providing insulation on the dust handling equipment. However, explosion vents must properly deploy without being affected by the insulating cover. Prefabricated rupture-type explosion vents are available that have a foam-insulated core to prevent condensation on the inside of the vent. Additional insulation does not have to be applied over such a vent, thus ensuring insulation does not hinder vent deployment.

3.1.3 Inerting (Phlegmatization) (2.3.2.3)

Combustible and noncombustible dusts must be intimately mixed to truly create a safe non-explosible product. Typically, inert dust ranging from 50% to 75% by weight of the total is required.

Carbonates, phosphates, and salts are sometimes used for inerting. In the coal-mining industry, rock dust is used because it is in abundant supply. Unfortunately, no mathematical correlations can predict the required limiting inert powder concentration. All mixtures must be tested to establish the inertness of the mixture.

3.1.4 FM Global Explosion Effects Calculations – DustCalc (2.3.3.1)

Many recommendations suggest using FM Global's DustCalc software for any calculations involving predicting explosion pressures based on the specifics of a given situation. This is a proprietary expert system developed by FM Global and considers the variables listed below to calculate various explosion effects. The mathematical models are based on years of research by FM Global and others on dust explosions. Some of the relations have been shared with NFPA and have been adopted in part in NFPA 68 starting with the 2002 edition. To get the full advantage of FM Global's methods, the DustCalc software must be used.

The vessel variables that will have an impact on explosion effects are as follows:

- Vessel volume (V)
- Dust explosibility constant (K_{st}) and maximum unvented pressure (P_{max})
- Explosion-vent area (A_v)
- Explosion-vent relief pressure (P_{stat})
- Explosion-vent panel mass and orientation
- Explosion-vent duct length (L_d) and area (A_d), if present
- Fraction of vessel volume containing an explosible mixture
- Pre-explosion equipment pressure (P_o)

This data sheet does not include any explosion vent sizing equations, nor does it have any dust-testing results to characterize previously tested materials. First, the mathematical correlations developed by FM Global to predict the outcome of explosions are complex and would be difficult to apply using only a calculator. This could easily cause computational errors. Generic data could be useful for preliminary evaluation of existing venting systems, but data for the specific dust being processed may be different and only specifically developed test data should be used in design.

DustCalc software is available in all FM Global offices worldwide, but is limited to personnel who have been trained in the details of its basis and use. This will ensure the results are developed recognizing all the factors that are important in the design.

A detailed description of the analytical and experimental work leading to the FM Global methodology has been published in an article in a special dust explosion issue of the Journal of Loss Prevention in the Process Industries (Spring 1996). The FM Global article from that journal is included as Appendix C, Section C.1.

FM Global has not adopted the German VDI (Verein Deutscher Ingenieure) calculation methods (VDI 3673). Since much of the data used to develop the VDI guideline was used in developing the FM Global guidance, in many cases DustCalc and VDI answers are similar. However, due to improvements made to VDI's methods by FM Global, in addition to other calculation tools developed or improved by FM Global, the DustCalc software expands on the capabilities of VDI.

For the 2002 version of NFPA 68, FM Global submitted, and the NFPA committee accepted, much but not all of the FM Global equations and methods. The implementation is with numerous equations and nomographs. The 2007 edition maintains much of the same methods, but with some additional adjustments.

The other major difference with NFPA 68-2007 was changing from a Guideline to a Standard. This is now in language that can be adopted as legally binding by local authorities having jurisdiction. As a Guideline, no AHJ could implement the requirements as binding.

The DustCalc software program can also provide solutions based on the NFPA or VDI methods and will indicate where, and often why, there are differences with the FM Global method.

3.1.5 Explosion Quench Pipes (2.3.3.1.2)

An explosion quench pipe (Fig. 11) is like a flame arrester fitted onto a rupture membrane-type explosion vent. As a result there is a reduction in the effective vent area compared to an open vent.

As the explosion is vented through the quench pipe, any burned or unburned dust is retained, combustion gases are cooled, and no trace of flame exits the quench pipe. In addition, the nearfield blast (pressure) effects outside the vent are greatly reduced. Thus, the quench pipe can safely vent an explosion to the indoors without the fear of igniting nearby combustibles or creating damaging pressure in the room. However, the exit gases are hot (approximately 212°F [100°C]).

The actual pressure effect of the released gases can be conservatively estimated based on an approximate gas-exit temperature of 212°F (100°C) and the following equation:

$$\Delta p = 1.74\ p_0 \frac{V_1}{V_0}$$

where:

V_0 is the building volume (m^3 or ft^3)
V_1 is the vented equipment volume (m^3 or ft^3)
p_0 is the ambient pressure (14.7 psia or 1.01 bara)
Δp is the pressure increase created by the vented gases (psi or bar)

For example, where the equipment volume is 1/100 of the building volume, V1/V0 is 1/100, the pressure increase is about 37 psf (18 mbar, 1.8 kPa). This would not cause any significant building damage.

The listing of all FM Approved devices includes their vent efficiency, which is the factor by which the effective vent area of the device is reduced. This is different than the pressure effect calculation above.

3.1.6 Strength of Vessels (2.3.3.1.3)

When the explosion vent design is based on P_{red} values that allow for vessel deformation, this will prevent catastrophic vessel failure and allow the forces and products of an explosion to move safely through the explosion vent. However, this could make the vessel unfit for future use.

If data on vessel strength is unavailable and the assumed values 3 to 4.4 psig (0.2 to 0.3 barg) of P_{red} are used for explosion vent sizing, then the vessels will likely not be deformed in the event of an explosion, if

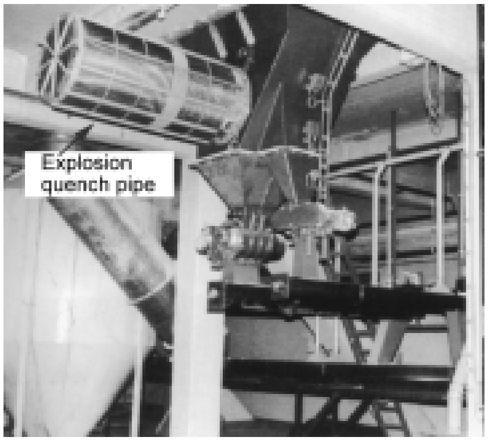

Fig. 11. FM Approved explosion quench pipe (Photo courtesy of Rembe GmbH)

they are of typical design. However, the possibility of deformation does exist. The innumerable variations in equipment design can make a vessel weaker than other seemingly comparable vessels. In most cases, the assumed values will be sufficiently conservative to prevent vessel rupture. Estimates of the pressure that a generic type of vessel can withstand involve uncertainties. It is always best to try to get actual design information for any vessel whose protection is being evaluated or planned.

3.1.7 Effects of Explosion Vent Mass (Inertia) (2.3.3.1.6)

A heavy explosion vent relief panel takes longer to move out of the way than a similarly sized lightweight panel and can produce higher pressures inside the vented enclosure. Because the delay is a continuous function of the panel's weight, its effect needs to be evaluated whenever a panel's inertia is greater than zero.

Rupture membranes, which are typically very thin sheets of metal or plastic film, are zero-inertia devices. However, the effect of any other type of vent panel cannot be neglected and should be calculated.

An extensive review of experimental data generated by numerous organizations worldwide has allowed FM Global to correlate the data along a theoretical framework to produce an effective predictive tool.

3.1.7.1 Typical Vent Panel Mass (Inertia)

The following are examples of materials that might be used as venting panels or wall construction and their mass:

- Single-layer metal panels: 10 kg/m^2 (2 lb/ft^2)
- Insulated metal sandwich panels: 15 to 20 kg/m^2 (3 to 4 lb/ft^2)
- FM Approved Explovent: 12 kg/m^2 (2.5 lbs/ft^2)
- FM Approved Kalwall panel: 12 kg/m^2 (2.5 lbs/ft^2)

Note: the following materials have an additional dimension of inch (cm) of thickness.

- Gypsum board: 8 kg/m^2/cm (4 lb/ft^2/in.)
- Steel: 77 kg/m^2/cm (40 lb/ft^2/ in.)
- Aluminum: 27 kg/m^2/cm (14 lb/ft^2/in.)
- Glass: 29 kg/m^2/cm (15 lb/ft^2/in.)
- Concrete: 23 kg/m^2/cm (12 lb/ft^2/in.)

3.1.8 Effect of Explosion Vent Ducts (2.3.3.1.7)

The effect of the vent duct must be anticipated in the sizing of explosion vents. Placing a duct at the discharge of an explosion vent can significantly affect the pressure inside the enclosure. Depending on the length and diameter of the vent duct, the value of P_{red} can be increased by as much as an order of magnitude (10 times), which is usually enough to completely destroy the protected vessel.

Two factors are most important when considering the effect of vent ducts on the venting process: (a) combustion of dust within the duct during the explosion, and (b) the inertia of the air mass inside the duct before the explosion.

During the early part of the venting process, unburned dust is ejected into the duct ahead of the flame front from the vessel. When the flame front moves into the duct, dust starts to burn within the duct and generate additional combustion products. Those combustion products expand in ALL directions, thus slowing down or even reversing the flow out of the vessel and the pressure builds up within the vessel.

Inertia of the air within the duct also increases explosion pressure within the protected vessel. When the explosion vent opens and combustion gases first start flowing into the duct, those gases must push all of the air out of the duct. During the time required to eject the air, the pressure continues to grow within the vessel because the combustion gases are obstructed from reaching the open atmosphere. In a long duct, that mass of air can delay the venting of combustion gases enough to significantly increase the pressure in the vessel.

Friction effects from gas flowing through the duct generally have little effect on the explosion, except possibly from bends or other geometric discontinuities, compared to the previously noted effects of in-duct combustion and air inertia.

Because P_{red} sharply rises as vent duct length increases, vessels with a low strength generally cannot be protected by venting through ducts if the L/D of the vent duct exceeds a value of 1 to 2 unless the vent size is proportionately increased.

Although fitting an explosion vent duct having a cross-section smaller than the explosion vent will increase the value of P_{red} (i.e., create a worse situation), using an explosion vent duct with a cross section larger than the explosion vent area will not lower the P_{red}.

FM Global's DustCalc software readily calculates the effects caused by vent ducts.

3.1.9 Re-Closing Explosion Vents (2.2.3.4 and 2.3.3.1.9)

After the combustion of dust inside of a room or vessel has ended and gases are no longer being produced to generate pressure, explosion vents that can reclose by gravity will do so. The very hot combustion gases trapped within the room or vessel begin to cool and, unless fresh air moves into the enclosure fast enough (e.g., via an appropriately-sized vacuum breaker), this will produce a vacuum. This vacuum can result in vessel damage or equipment implosion. In rooms or buildings, vacuum damage is less severe, but is still possible.

3.1.10 Pressure and Fireball Effects from an Explosion (2.3.3.1.11)

A dust explosion results in short duration pressure and fireball effects outside of the enclosure. There are limited studies that allow these effects to be estimated, and suggested equations are shown below:

Estimate the pressure effects close to, and in a direction normal to, the vent using the following equations:

Step 1: Calculate the maximum overpressure ($P_{blast,max}$) generated by the explosion outside of the vented enclosure using the following equation:

$$P_{blast,max}\text{ (barg)} = 0.2\, A_v^{0.1}\, V^{0.18}\, P_{red}$$

Where

A_v is the explosion vent area, m^2
V is the volume of vented enclosure, m^3
P_{red} is the reduced pressure in the enclosure during venting, barg

Step 2: Calculate the perpendicular distance (R_{max}) from the vent opening to $P_{blast,max}$ using the following equation:

$$R_{max}\text{ (meters)} = 0.25\, L_{f,max}$$

Where

$L_{f,max}$ = maximum flame jet length, m

Step 3: For distances R larger than Rmax, calculate the distance-specific blast pressure by the following equation:

P_{blast} (barg) = $(R_{max}/R)^{1.5}$ $P_{blast,max}$

Note 1: These calculated pressures are very localized near the fireball ejected from a vented explosion. This is not the same as the overall explosion pressure (P_{red}) created throughout the enclosing room or building. In a large building, this shock pressure might be the largest pressure that the walls located close to exploding equipment will feel, but, usually, the pressure on the walls of a room enclosing the vented equipment depends on the quantity of combustion gases produced by the explosion and vented into the room. Such pressure is essentially uniform throughout the room, regardless of distance of the walls from the vented vessel.

Note 2: The equations for predicting pressure effects are valid only for a single explosion vent. For multiple vents that open in the same direction, calculate $P_{blast,max}$ for each vent, then add the values to estimate the combined, conservative pressure effect.

3.1.10.2 Estimate the maximum flame jet length in a direction normal to the vent using the following equation:

$L_{f,max} = 8\ V^{(1/3)}$

where

$L_{f,max}$ = maximum flame jet length, m
V = Volume of vented enclosure, m^3

This equation is valid only for ST1 dusts (i.e., $K_{st} \leq 200$) with $P_{red} \leq 1$ barg (14.5 psig) and $P_{stat} \leq 0.1$ barg (1.5 psig). There are no published correlations for situations outside the stated limits. It is believed that changes in P_{stat} will change the size of the predicted fireball; however, current estimation methods have not quantified that effect.

3.1.10.3 Estimate the recoil force from an explosion using the following equations (2.3.3.1.18):

a) For dynamic recoil force, use the following formula:

$F_R = 119\ A_v\ P_{red}$
Units: F_R (kN), A_v (m^2), P_{red} (barg)

$F_R = 1.2\ A_v\ P_{red}$
Units: F_R (lb), A_v (in^2), P_{red} (psig)

b) For duration of this recoil force, use the following formula (applies only to enclosures without vent ducts):

$t_f = 10^{-4}\ K_{st}\ V/(P_{red}\ A_v)$
Units: K_{st} (bar m/s), V (m^3), P_{red} (barg), A_v (m^2), 10^{-4} (s^2m^{-2}) a constant

c) As an alternative to dynamic force anchoring design, use an equivalent static force (F_s) as calculated using the following formula:

$F_s = 0.52\ F_R$
Units: kN or lb as in the original equation

3.1.11 Fixed Obstructions near the Face of Explosion Vents (2.3.3.1.12)

A fixed obstruction located too close to an equipment explosion vent opening creates significant resistance to the free outflow of combustion products from the vented equipment. This is believed to be mainly due to dust burning after being ejected from the protected equipment. Since the combustion occurs in the semiconfined area between the vessel and the obstruction, a condition similar to a secondary explosion occurs. This has significant backpressure effects on the equipment explosion. The state of knowledge regarding this phenomenon is limited, and it is impossible to quantify the effect. It is also not possible to provide any guidance on safe distances to nonflat obstructions, due to the complexity of the effects of different geometries producing partial confinement. The only safe course of action is to locate and orient explosion vents so they do not point to nearby surfaces.

3.1.12 Distribution of Explosion Vents (2.3.3.1.15)

If a protected vessel has significant obstructions within it, there are two principles of explosion that make it important to provide well-distributed explosion venting.

First, if the gases heading toward an explosion vent at one end of the vessel have to flow through obstructed areas, the gases will not flow out as fast as they would if the volume was unobstructed. Because of this, the vented explosion pressure P_{red} can rise above the expected level.

Second, if the gases heading toward the explosion vent flow over any significant obstructions, turbulence will increase substantially within the vessel. Because the rate of pressure rise of an explosion increases with increasing turbulence, the obstacles can worsen the explosion.

Vents distributed throughout an entire enclosure will help ensure the gases vented during the explosion take the shortest path out of the enclosure.

3.1.13 Dust Collector Operating Pressures (2.3.3.1.17)

The normal operating pressure range for dust-collecting and dust-handling systems is +40 to 40 mbar (+16 in. H_2O to 16 in. H_2O). In this pressure range, no adjustments to the standard explosion venting guidelines are necessary.

3.1.14 Explosion Isolation (2.3.3.2)

When an explosion occurs in an enclosure protected by pressure containment, both pressure and flame (i.e., burning dust) propagate down any open, connected ductwork to another enclosure. If that second vessel also has a pressure-resisting design, it is likely to be insufficient due to an effect often referred to as ‘‘pressure piling.’’ The pressure in the second vessel will increase before the source of ignition (i.e., burning material) arrives, as the pressure disturbance travels from the first vessel to the second at the speed of sound, which is generally greater than the speed of the flame front. Therefore, at the moment when a dust explosion is ignited within the second vessel, the initial pressure will be well above the normal (ambient) pressure.

For a given fuel-to-air ratio, the final, unvented pressure of an explosion is directly proportional to the initial pressure. For example, if the first explosion prepressurizes the second vessel to 3 bar (44 psi) absolute, then the final pressure of the explosion in the second vessel would increase by a factor of 3. For a dust with a P_{max} value of 9 bara, the final unvented pressure in this example would be 27 bara, well above the strength of even the most sturdy vessel designed for dust explosion pressure containment. Thus, where explosion containment is used as a protection method, it is important to provide explosion isolation to prevent pre-pressurizing a vessel by another explosion.

When one vessel protected by explosion containment is connected to a second vessel protected with explosion venting, a protection problem exists that is not related to pre-pressurization, but rather to the turbulence created by the pressure front and a very strong ignition source from the flame front. The result is a more rapid explosion in the second vessel, unaccounted for in the vent design, with failure of the second vessel likely.

These effects occur to a lesser extent if the connected vessels are both protected with explosion venting.

Thus, where explosion venting is used as a protection method, it is important to provide explosion isolation to separate the vented vessel from any connected vessels protected by explosion containment.

3.1.15 Explosion Isolation: Use of Active Devices (2.3.3.3.4)

When using active (as opposed to passive) devices for explosion isolation, the maximum speed the explosion flame front travels from the point of detection to the isolation device is an important consideration.

An equation has been proposed correlating the speed of flame propagation in a duct as a function of the pressure developed in the duct. (The duct is filled with an initially quiescent mixture.)

$$V_a = \frac{p - p_o}{\rho c}\left(\frac{p_o}{p}\right)^{1/\gamma}$$

where:

V_a is the speed of flame propagation (m/s)
p is the maximum pressure in the duct, absolute (Pa) (1 psia = 6897 Pa)

p_o is ambient pressure, absolute (Pa)
ρ is density of ambient air (1.18 kg/m^3)
c is the speed of sound in air = 347 m/s
γ is the specific heat ratio = 1.4

This formula is valid for flame speeds up to 500 m/s (1640 ft/s).

To estimate the speed of flame propagation down a duct connected to a vessel in which an explosion has originated, (p - po) is assigned the value of P_{red} for vented explosions or P_{max} for vessels protected by explosion containment.

If the flame is propagating in a system where air has been flowing before the time of ignition, add the velocity of the flow, or subtract it (as appropriate) from the value given by this equation.

As an example, a vessel protected with explosion venting with a P_{red} value of 0.21 barg (3 psig) has a duct flame front propagation velocity of approximately 45 m/s (148 ft/s).

3.1.16 Rapid-Action Float Valves (2.3.3.3.5)

These devices actuate either on a differential pressure caused by the approaching flame front or the gas velocity in the duct. As a result, the vent relief pressure (P_{stat}) of the equipment experiencing the explosion must be high enough, about 0.2 barg (3 psig), to ensure the valve will shut. Where a lower P_{stat} is needed to protect the equipment, an additional explosion sensor and helper gas are needed to actuate the valve.

Data on the Ventex device indicate that specified minimum and maximum separation distances are needed to ensure the device closes properly and no transition to detonation has occurred. These distances are determined by test but are approximately valid for a broad range of operating conditions. If hybrid mixtures are involved, both distances will be reduced and the exact figure depends on the valve/pipe size. Manufacturer's data would supersede this general guidance.

Ventex valves are either uni- or bi-directional, i.e., will actuate from a pressure event coming from one direction only or from either direction. Once closed, they lock in that position and need to be manually reset.

3.1.17 Vacuum Operation (2.3.3.6)

Because the final pressure after an explosion is proportional to the initial (pre-explosion) pressure, a dust explosion occurring in an environment that is at less than 0.1 bara (1.5 psia) will produce an absolute explosion pressure of less than 1 bara (14.5 psia). Thus, damage potential from that explosion does not exist.

In addition, if a process operates at a pressure of less than 50 mbar (0.73 psi) (absolute), usually, an explosion could not be ignited.

3.1.18 Spark Extinguishing Versus Explosion Suppression (2.3.4.1)

Losses have revealed that a misconception might exist as to the capabilities of a spark-extinguishing system. Spark-extinguishing systems are very effective in reducing the frequency of combustible dust explosions. However, they do not affect the severity of an explosion, and are not an alternative to explosion venting, explosion-blocking systems, or explosion-suppression systems.

A spark-extinguishing system, also known as a spark-suppression system, detects and extinguishes sparks or glowing embers upstream of dust-collection equipment, to prevent these ignition sources from traveling to the dust collector(s) and initiating an explosion. The detection system uses an infrared sensor to look for particles passing by at elevated temperatures. The extinguisher is a water spray located downstream from the detector.

The detector is expected to function regardless of the size of the hot particles passing by. It detects hot particles as small as sparks or as large as a piece of broken sander belt. However, the extinguisher might not work if the particles are large. Sparks should all be extinguished, but a large burning or smoldering piece of material might not be, in which case an explosion could occur if there is an ignitable dust cloud in the downstream dust-collection equipment.

The spark-extinguishing system will not decrease the severity of the resulting explosion, so the same level of explosion protection or mitigation needs to be provided for the equipment with the dust explosion hazard.

A spark-extinguishing system extinguishes an ignition source but cannot suppress an explosion once it has begun. By preventing an explosible cloud from ever igniting, spark-extinguishing prevents the explosion altogether.

An explosion-suppression system detects the early phases of an explosion and quenches the explosion to prevent pressure from rising to a level at which equipment may be damaged or destroyed.

The explosion-suppression system reduces the severity of an explosion, whereas the spark-extinguishing system only reduces the frequency.

A spark-extinguishing system is only intended to eliminate one ignition scenario: small, hot particles conveyed to a dust collector where a combustible dust cloud can be ignited. There are other ignition scenarios which the spark-extinguishing system cannot influence. For example:

- Tramp metal (e.g., a screw or nail) aspirated into the dust collection system. The metal creates sparks as it impacts against ductwork or metal equipment downstream of the spark-extinguishing system.
- Ignition sources produced downstream of the spark-extinguishing system; for example, hot surfaces, cutting and welding on/around dust collection equipment.

For most processes, conveying small, hot particles from the dust-producing process to the dust-collection system is by far the most common potential dust-explosion ignition source. Installed spark-extinguishing systems can actuate weekly or more often without incident. This attests to the system's ability to consistently detect and extinguish even the smallest hot particles.

There are losses where burning material passed through the spark-suppression zone into the dust collection equipment and triggered an explosion. The burning material possibly got through because of its size or form or because of a defect in the spark-extinguishing equipment or its installation. Because other damage-limiting features, such as explosion venting or blocking systems may have been lacking or were not fully adequate, the ensuing explosions damaged the collection equipment. In addition, burning material was forced (ejected) into the work area either forwards through a warm air return or backwards to the dust pickup points. Adequate explosion venting combined with safeguards on the warm-air return (recommended here and in Data Sheet 7-73, *Dust Collectors and Collection Systems*) could have prevented any burning material from being ejected into the facility.

3.1.19 Minimum Ignition Energy (MIE)(2.3.4.2)

The vast majority of dusts have MIE values above 10 Mj, so it is not necessary to routinely have dusts tested for MIE. Such testing is normally pursued only when there are reasons to suspect a dust might be particularly susceptible to ignition from static. There are currently at least two recognized test standards for MIE, ASTM E2019 and EN BS 13821. Any test result reporting an MIE of 10 mJ or less should be interpreted as proving static ignitability.

3.1.20 Foreign Material Separators, Magnetic or Other (2.3.4.3)

Using separators upstream of all equipment that mechanically impacts with the process material prevents metal and other foreign objects from entering the equipment. Without the separators, tramp metal or other material entering the equipment can create impact or friction sparks capable of igniting a dust cloud.

3.1.21 Clean Versus Dirty Side of Dust Collectors (2.4.2)

The distinction between the clean and dirty air sides is not important when considering explosion scenarios. The pressures generated in an explosion frequently rupture the filter media as the explosion propagates throughout the clean and dirty sides. In addition, there may be a breach of the filter media even before an explosion (e.g., a bag break), thus allowing dust to enter the clean side.

The issue of where to locate vents relative to the clean and dirty side is both theoretical and practical. Most testing is based on an enclosure with no internal obstructions and with the vent remote from the ignition. Bags or other obstructions can change the explosion and the venting process. Bags generally fail early in the explosion and have a minor effect on the venting process, but the tube sheet dividing the clean and dirty sides can be more of an impediment. The equation specifying the minimum amount of explosion venting that must be on the dirty side is based on providing fully adequate explosion venting for a dirty-side explosion if the bags do not get damaged and do not allow any gases to vent out through the clean side of the collector.

3.1.22 Cyclone Explosion Venting (2.4.2.3)

Calculations for explosion venting a cyclone based on typical design proportions show that the typical gas outlet whose diameter is one half the diameter of a cyclone provides an adequate explosion venting area for dusts with K_{st} values up to 80, based on the assumption of a pressure resistance of about 0.3 barg (4.4 psig). Dusts with K_{st} values as low as 80 are typically rather coarse (e.g., sawdust, corn meal), have a very low volatiles content (e.g., charcoal), or have very low combustion energy (e.g., iron dust, FRP with high inert fibers content).

The adequacy of explosion venting cannot be assumed if the cyclone has a duct with L/D>1 extending above the gas outlet. As with any vessel provided with a duct on the explosion vent, explosion pressure calculations will be needed to quantify the effect.

Due to significant backpressure effects produced by bends in vent ducts, any gas outlet provided with a 180° duct (gooseneck) will not likely have adequate explosion venting. If practical, replace the gooseneck with a rainhat over an open gas outlet.

Typical cyclone proportions include a diameter D, cylinder height and cone height each 2D and gas outlet diameter of ½ D.

3.1.23 "Conductive" Dust Collector Bags (2.4.3.1)

''Conductive'' bags typically have fine wire woven or fastened into their cloth. The grid of conductive wires is connected to one or more grounding straps/wires, which must be attached to the dust-collector structure. Because there is no dependable mechanism to migrate charges from the surface of the nonconductive bag material to the nearest grounded wire, measurable (and sometimes substantial) potential differences between the bag surface and wires can exist.

The need for any kind of special bag to prevent dust ignition due to static has never been established. With ordinary, nonconductive bags, static electricity may build up over the entire surface of a bag, but a static discharge can only release the energy built up over a very small area. This energy release is not likely to be enough to ignite even the most ignitionsensitive dusts.

There is another concern related to ''conductive'' bags. There is the possibility of the grounding straps detaching and turning the bag into a giant capacitor. All the embedded wires collecting charges from the bag surface could suddenly release enough static electricity to ignite a dust cloud. The repeated shaking or air blasts to clean the bags could cause one or more ground straps to break or disconnect. Maintenance and inspection activities are needed to prevent this from happening.

3.1.24 Connecting Ducts (2.5)

Dusts are transferred in ducts either as part of a fugitive-dust-control system or to move the product from one part of the process to another. Fugitive-dust transfer is almost always at much less than the MEC, while process transfer may be at much greater than the MEC. Process transfer might be referred to as dense phase transfer.

To properly understand the hazard, the transfer conditions need to be known. This can be determined by knowing the amount processed/collected over some period of time, or measured by sampling or monitoring the actual flow in the duct. Sometimes this data can be obtained by occupational safety and health professionals on staff.

The hazard in the duct can be affected by the actual transfer rates or by dust that settles out and accumulates from insufficient flow velocity in the duct. It is important that this not occur; it can be controlled by maintaining sufficient airflow typically on the order of 3500–4000 ft/min (1070–1220 m/min). Dust that has accumulated can be re-entrained by the pressure wave from an explosion and create localized combustible concentrations, moving with the pressure wave and ignited by the trailing flame front. After considerable propagation, this turbulent jet flame becomes a very strong ignition source that destroys seemingly properly protected equipment.

A remarkably small amount of deposited dust can propagate an explosion. For a circular duct of diameter "D" with a dust layer of thickness "h" settled on ¼ of its inner circumference (i.e., at the bottom), the concentration of dust dispersed homogeneously throughout the cross section of the duct would be $C = \rho_{bulk}$ h/D. As an example, a dust with a bulk density of 31 lb/ft^3 (500 kg/m^3), a layer thickness of only 1/125 in.

(0.2 mm), and a duct of 8 in. (0.2 m) diameter, could generate a dust concentration of 500 g/m^3. This concentration is well above the MEC of virtually any dust, and therefore can propagate an explosion.

The settled dust is most likely not homogenously dispersed throughout the duct, but research by the US Bureau of Mines has shown that explosions can propagate through ducts even at average dust concentrations that are as little as half the MEC. All that is required for propagation is a continuous path of mixture that is above the MEC. This condition can be satisfied even though there is not enough dust to fill the entire volume of the duct with a mixture above the MEC. Thus, even very small amounts of dust can be sufficient to create a propagating explosion so the air velocity through the duct should be sufficient to prevent any settling of the transferred dust.

Explosion venting in duct work is not provided to save the duct, usually of low value and easily replaced, but to reduce the violence of a potential explosion propagating down its length. This would not stop the explosion propagation but would expose connected equipment containing suspended dust to a less energetic ignition source. Designing the duct to fail at low pressure rather than installing explosion vents could be an acceptable alternative approach where there is no exposure to equipment.

Explosion isolation systems may be needed for connecting ducts where the consequence of an unprotected event in equipment or flash-back to a building is unacceptable. For example, a large panel sander might have six dust pickup points, three on the top and three on the bottom, all joining into a common duct. Each pickup pipe would not need an isolation device. Explosion isolation would best be provided on the main duct after it leaves the building to prevent an explosion in the dust collector from propagating back towards the sander.

3.1.25 Silos (2.6)

Silos can also have a dust explosion hazard, even when they are used with granular material having a very small portion of fines. As the course material continually transfers into the silo, it will fall to the bottom of the silo, but the finest, most explosible material will remain in suspension. If transfer operations continue long enough, the airborne combustible dust concentration will exceed the MEC and create an explosion hazard.

When a dust collector is mounted directly onto a silo (i.e., with a short connecting pipe of sufficiently large diameter), any explosion igniting in the dust collector will create the same silo explosion effects as if the explosion had originated within the silo, so the dust collector can be considered part of the silo. As long as any explosion venting provided on the silo and dust collector assembly are sized on the basis of the sum of both volumes, explosion venting should be adequate, regardless of whether the explosion originates in the silo or the attached dust collector.

When the dust collector is separated from the silo via a small or elongated pipe, the silo and dust collector no longer act as a single volume during an explosion. If an explosion originates in a dust collector that has no explosion venting of its own, the jet flame will propagate down the connecting pipe, igniting any combustible dust cloud within the silo. This would cause a much more violent explosion in the silo than if the silo explosion was ignited by a conventional (weaker) ignition source.

Air cannons used to break up bridging material can disperse fines in the bulk material into the silo headspace. Even if the percentage of fines is very small (e.g., 1%-2%), repeated air blasts will concentrate the fines at the top of the bed. Repeated air-cannon operation creates more fines at the top of the bed and a higher concentration of dust in the head space at every air cannon firing. Only an ignition source is needed for a potentially severe dust explosion.

Additionally, certain combustible materials such as coal, grain, and wood are susceptible to spontaneous heating, and introducing air over an extended period of time can increase the probability of such spontaneous heating. Air introduced to glowing combustion could fan it into flame or ignite a dust explosion.

Alternative solutions to air cannons include using vibratory wands inserted temporarily or permanently into the bottom portion of the silo or using acoustic horns and lances.

3.1.26 Bucket Elevators (2.7)

Even though bulk combustible material may have a very small percentage of fines mixed in with material too coarse to constitute a dust explosion hazard, handling that bulk material will likely create an explosion hazard in a bucket elevator enclosure. Because of the high degree of turbulence within the bucket elevator enclosure, any fines will be easily picked up into suspension. Because more fines are continuously added to the air space in the elevator with very little are falling out, the concentration can exceed the MEC and create a dust explosion hazard.

An example of this involves unground soybean extraction grouts, which are not explosible. Most of this product is very coarse material (median particle size approx. 1000 microns) but about 3% of fines are smaller than 63 microns. In one instance, after conveying this product in a bucket elevator for several minutes, the fines were liberated and an ignition and explosion occurred.

3.1.27 Size-Reduction Equipment (Grinders, Pulverizers, Hammer Mills, etc.)

Size-reduction equipment presents the inherent hazard of mechanical impact in the presence of combustible dusts. The mechanical impact can create frictional and impact heating. Sparks may occur if unintended metal enters the machine. The result can either be glowing particles leaving the equipment to become an ignition source in downstream equipment or actual ignition of the dust cloud in the equipment. These machines are most frequently of substantial construction and able to withstand an internal explosion without damage. Explosion venting or other protection techniques are not needed.

Maintain these devices regularly to ensure adequate lubrication is provided, proper clearances are maintained, and dust and debris don't accumulate and become ignited or impair proper operation.

3.2 Loss History

Loss history was surveyed for dust explosion losses for the period 1983 through 2006. A total of 166 losses at FM Global client locations resulted in a gross loss of US$284 million (all figures indexed to 2007 dollars). The losses by industry group are shown in Table 3. In five of the top six categories there was one event that was substantially larger than typical in terms of gross loss. This will skew any estimate of average loss based on the total number of losses. In fact, the top 2 losses account for almost 60% of the loss cost.

Loss history is best used to help prioritize what materials, processes, and equipment should be the focus of protection efforts.

Table 3. Losses by Industry (by Number of Losses)

Industry Type	*No. Losses*
Woodworking	64
Food	26
Metals	18
Chemical/Pharmaceutical	14
Pulp/Paper	12
Mineral	11
Utility	7
Plastics	5
Rubber	5
Printing	1
Textile	1
Other	2
Total	166

Table 4 examines the loss data for the ignition source that caused the event. Friction and sparks have been commonly considered the major ignition source and the loss data shows that. Hot work is also a significant contributor.

Table 4. Losses by Cause (Ignition Source)

Cause Type	*No. Losses*
Friction	50
Spark	38
Chemical Action	16
Hot Work	13
Burner Flame	10
Electricity	6
Static Electricity	6
Overheating	4
Hot Surface	2
Unknown/No Data	21
Total	166

Another informative approach to investigate would be the dust group involved in the loss. Table 5 shows that the wood group is by far the most significant by number of losses.

Table 5. Losses by Dust Type

Dust Group	*No. Losses*
Wood	70
Food	25
Chemical	17
Metal	15
Coal	14
Plastic/Rubber/Resin	13
Paper	8
Various	4
Grand Total	166

Looking at the equipment type involved, the losses in Table 6 clearly show that dust collectors are by far the leading piece of equipment to experience explosions. Obviously, a dust collector has dust that is suspended in air. Also, because a dust collector is designed to handle material produced elsewhere, the ignition source does not have to come from within the dust collector. A source picked up in the dust production area can ignite an explosion in the dust collector.

Explosions in impact equipment are also frequent. The data shows 22 incidents involving grinders, sanders, pulverizers, ball and hammer mills, chippers, shredders, etc. The mechanical energy expended in these processes can translate into the generation of heat or spark energy required to ignite a dust cloud.

In Table 6, the “various” category consists of 30 single-occurrence items.

Table 6. Losses by Equipment Type

Equipment Type	*No. Losses*
Dust Collector	66
Impact Equipment	22
Storage Silo	8
Processing Equipment	7
Oven	5
Conveyor	4
Grain Elevator	4
Spray Dryer	4
Dryer	3
Boiler	3
Storage Silo/Dust Collector	3
Waste Bin	3
No Data	2
Storage Bin	2
Various	30
Total	166

The data was also analyzed to see the effect of adequate damage-limiting construction on the size of the average loss. For buildings, the protected loss was about 45% of the unprotected. For equipment, the protected loss was about 25% of the unprotected loss.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-44, *Damage Limiting Construction*
Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*
Data Sheet 5-8, *Static Electricity*
Data Sheet 5-20, *Electrical Testing*
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 7-10, *Wood Processing and Woodworking Facilities*
Data Sheet 7-17, *Explosion Protection Systems*
Data Sheet 7-32, *Flammable Liquid Operations*
Data Sheet 7-59, *Inerting and Purging of Tanks, Process Vessels and Equipment*
Data Sheet 7-73, *Dust Collectors and Collection Systems*
Data Sheet 7-75, *Grain Storage and Milling*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 10-3, *Hot Work Management*

Hot Work Management Kit (P9601)

4.2 Other

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Verein Deutscher Ingenieure (VDI). VDI Guideline 3673, Part 1, ''Pressure Venting of Dust Explosions.'' Latest edition.

APPENDIX A GLOSSARY OF TERMS

A_v: Explosion venting area

Air material separator: A broad term for a device designed to separate powders from the air in which it is transported. Most commonly, this would be a cyclone or dust collector.

Bara: bar, absolute (unit of pressure).

Barg: bar, gauge (unit of pressure)

Bonding: Electrical connection between two electrically-conductive objects that minimizes any difference in electrical potential between them.

Damage-limiting construction (DLC): Construction designed to minimize the damage from a deflagration (explosion) in equipment or building. This can be pressure resistive, pressure relieving, or some combination of the two. Most commonly this would be vent panels on enclosures (buildings or equipment) releasing at a pressure below the strength of the enclosure.

Deposit velocity: The minimum air (or other gas) velocity needed to prevent dust-particle fallout during pneumatic-material conveying and to pick up any dust particles deposited during airflow interruption. The velocity varies with particle weight, density, and aerodynamic properties.

Design strength: Pressure to which a vessel can be exposed without any risk of damage (because a safety factor has been applied to the yield strength).

Double dump valve: An arrangement of two gate or butterfly valves in series. Only one is open at a time. This valve is often used where material discharged from one vessel is gravity fed to another vessel (i.e., not pneumatically conveyed) such as a dust collector discharging into a hopper below it or a material blender or grinder discharging into a pneumatic conveying system.

Dust: Any sample of solid particles with a median size smaller than 500 microns. For the purposes of this data sheet, it refers only to combustible dusts.

Dust, combustible: Established by tests that expose the material to ignition sources of various intensities, such as a spark, a match flame, a Bunsen burner, or a Meker burner. Any organic material, unoxidized metal particles, or other oxidizable materials (e.g., zinc stearate) should be considered combustible unless testing proves otherwise. A combustible dust is not always an explosible dust.

Dust, explosible: Established by ASTM test E1226 (Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts) or E1515 (Test Method for Minimum Explosible Concentration of Combustible Dusts), or National/International equivalent (e.g., ISO 6184/1, Explosion Protection Systems – Part 1: Determination of explosion indices of combustible dusts in air). Dust with a median particle size greater than 500 microns can be assumed to be non-explosible as long as particles smaller than 500 microns cannot be segregated during material handling.

Explosion isolation: System or single device that prevents the propagation of explosion effects from one volume to an adjacent volume.

Explosion mitigation: Methods used to reduce damage from the explosion after the explosion has started.

Explosion prevention: Methods used to prevent an explosion by controlling either the air, fuel, ignition source, or a combination of these.

FM Approved: References to ''FM Approved'' in this data sheet mean the product or service has satisfied the criteria for FM Approval. Refer to the Approval Guide for a complete listing of products and services that are FM Approved.

Grounding: Electrical connection between a conductive object and the ground that minimizes the difference in the electrical potential between the object and ground.

K_{st}: The dust explosibility constant, defined as the maximum rate of pressure rise of a dust explosion in a 1 cubic meter vessel. The units are bar meter per second (bar m/s). The test method used to obtain this constant is standardized worldwide. This value (K_{st}) is used in all modern dust explosion vent sizing to characterize the reactivity (i.e., explosibility) of a particular dust. Only metric units are used for this constant.

MEC: Minimum explosible concentration, the lowest concentration of dust that can support a self-propagating explosion. (The terms LEL [lower explosible limit] or LFL [lower flammable limit] mean the same, but are not often used in the context of dust explosions.)

Media type collector: A device (enclosure) that separates dry, solid material from air by passing the air through a dry filtering medium. Examples are enclosures with bag-type filters, cartridge-type filters (normally a pleated filter arranged in a cylindrical shape, similar to automobile air filters), rotary drum filters, and panel filters. (See Data Sheet 1-45, *Air Conditioning and Ventilating Systems*, and Data Sheet 7-73, *Dust Collectors and Collection Systems*, for information on filter types.)

MIE (minimum ignition energy): The minimum amount of thermal energy released at a point in a combustible mixture to cause indefinite flame propagation under specified test conditions. The lowest value of MIE, known as LMIE, is found at a certain optimum mixture. It is this value that is usually reported as the MIE.

Phlegmatization: The process of mixing inert dusts with combustible dusts to reduce or eliminate the explosion hazard.

$P_{blast,\ max}$: The localized pressure as a result of the fireball and pressure from a vented explosion.

P_{max}: The maximum pressure developed in the 20-liter sphere when testing dust for explosibility characteristics by ASTM E1226 method. It is factor used to help size explosion vents.

P_{red}: Highest explosion pressure in a vessel protected with explosion vents; usual units are barg or psig.

P_{stat}: Explosion vent relief pressure; usual units are barg or psig.

Psia: Pounds per square inch, absolute (unit of pressure).

Psig: Pounds per square inch, gauge (unit of pressure).

Strong ignition source: A strong ignition can provide more than approximately 100 Joules of energy.

a) Examples of a strong ignition source include open flame, welding arc, gas or dust explosion, and electric arc/short.

b) Consider the presence of combustible building construction or large amounts of combustible storage along with unacceptable levels of fugitive dust as presenting the possibility of a dust cloud coincident with a flame (strong ignition source).

c) Conversely, examples that would not be considered a strong ignition source include frictional sparks, mechanical impact sparks, static sparks, cigarettes, hot surfaces, overheated electrical components.

Strong vessel: A vessel that can withstand explosion pressures in excess of 0.2 barg (3 psig) without being damaged or destroyed. This includes most process vessels constructed or used in Europe.

Tube sheet: The mounting plate for cartridge-type filters or bag-type filter tubes and cages.

Ultimate strength: Pressure at which an enclosure will be torn open (i.e., ruptured).

Weak vessel or enclosure: A structure that cannot withstand explosion pressures in excess of 0.2 barg (3 psig) without being damaged or destroyed. This includes most rooms, buildings, and many North American process vessels.

Yield strength: Pressure at which an enclosure will be deformed without rupturing.

APPENDIX B DOCUMENT REVISION HISTORY

March 2009. Minor editorial changes were made for this revision.

January 2009. Correction to the equation in Section 2.4.2.2.1 was made.

May 2008. Reformatted the document for clarity and ease of use, especially the recommendations.

Added more construction and location guidance on preferred locations for dust hazard occupancies.

Emphasized explosion-hazard elimination and mitigation features.

Added chokes as an isolation method.

Refined the criteria on fans and blowers located in fugitive dust – air streams where they can become an ignition source in an atmosphere that may exceed the MEC.

Simplified the criteria for protection of vessels of unknown strength.

Resolved inconsistencies with other data sheets, especially Data Sheet 7-73, *Dust Collectors.*

Simplified the Support for Recommendations section.

May 2006. Minor editorial changes were done for this revision.

New section 3.2.3.9.1, Typical Vent Panel Mass (inertia) was added.

May 2005. Added recommendations to implement a management of change program.

January 2005. Minor editorial changes

May 2004. Minor editorial changes

May 2003. Minor editorial changes

January 2001. The document was reorganized to provide a consistent format.

August 1995. Major revisions implementing K_{st} based vent sizing technology and abandoning the prior method of vent area to protected volume method.

This data sheet includes many new recommendations which were not in the 1976 edition but many locations will require less protection than the previous version required. The following exceptions have been made to the general explosion protection requirements:

- Explosion venting is not needed for cyclones handling dusts with a K_{st} less than 80 (weakly explosible) and having an open gas outlet on top whose diameter equals or exceeds 45% of the cyclone diameter.
- Systems operating at a pressure below 0.1 bara (1.5 psia) require no protection.
- Spray dryers operating at below the minimum explosible concentration (MEC) require a reduced amount of explosion venting compared to other equipment with the same volume. Note: the explosion venting area for spray dryers and for other equipment is now calculated using the FM Global Research DustCalc software.

APPENDIX C RESEARCH INFORMATION ON DUST EXPLOSION HAZARDS

C.1 Reprint from *Journal of Loss Prevention in the Process Industries: Improved Guidelines for the Sizing of Vents in Dust Explosions*

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Improved guidelines for the sizing of vents in dust explosions

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Current vent sizing guidelines, developed both in Europe (VDI 3673) and in the United States (NFPA 68) for the protection of equipment and buildings from dust explosions, rely on statistical regressions of test data. This leads to limitations in the range of applicability of the design methods, and, in some cases, to questionable scaling of the results. Analysis of available experimental information with knowledge derived from models of vented explosions offers a suitable alternative which can overcome these problems. An effort based on this approach has produced significant improvements in several aspects of explosion vent sizing, including: vent duct and panel inertia effects, partial volume deflagrations, venting of equipment inside buildings, and explosions at initial elevated pressure. The output of this work has been incorporated in revised vent sizing guidelines which are used by Factory Mutual Engineering Association (FMEA) loss prevention consultants in the development of loss prevention recommendations for industrial and commercial properties. This paper discusses the development of the guidelines, with emphasis on the aspects in which they significantly differ from the guidance provided by other published methods.

Keywords: venting; dust explosions; engineering guidelines

The need for explosion protection of dust-handling equipment and buildings has been satisfied through the use of several approaches, among which the provision of venting is arguably the most widespread. The underlying concept is quite simple: a portion of the physical boundary that defines the volume to be protected is intentionally made weaker than the rest of the structure, so that it will fail in the early stages of an explosion; the size of the resulting opening is chosen such that the outflow of gases through the area is sufficient to prevent the pressure in the protected volume from reaching values that would cause damage to the structure.

This seemingly simple technology presents serious engineering challenges in its practical implementation, due to the need to account properly for the effect of the reactivity of the exploding mixture, the characteristics of the ignition source and the details of the geometry of the system on the rate of volume expansion associated with the explosion. Extensive research, both experimental and theoretical, has been carried out for unvented and vented dust-explosion situations to shed light on these issues[1–5]. However, most of the design information found in current engineering guidelines amounts to statistical regressions of results from large-scale tests, with little if any recognition of the implications of theoretical considerations. While the ultimate reliance on large-scale data may remain an unavoidable cost, at least until more advanced modelling tools are developed to predict the progress of explosions, it is no longer justifiable to make use of test results in a manner that does not take advantage of the guidance provided by a modelling perspective.

At present, there are two published documents, one in Europe (VDI 3673)[6] and the other in the United States (NFPA 68)[7], that provide guidelines for the protection of equipment and buildings from dust explosions (NFPA 68 also contains guidance for dealing with gas explosions). With regard to dust explosions, the technology behind the vent sizing methods in both documents has essentially been based on tests carried out in Europe (mostly Germany and Switzerland). As a result, the most recent developments have consistently been incorporated in the VDI guideline first and then, only with some delay, in NFPA 68. This is in fact the existing situation, with the current edition (1994) of the NFPA document still containing the vent sizing recommendations of the earlier version of VDI 3673 (this document having also been revised in 1994). Despite the quantitative differences, essentially due to the offset in the revision cycles, these two documents are conceptually equivalent in their reliance on empirical correlations of test data, and they have similar ranges of applicability.

Work carried out at Factory Mutual Research Corporation (FMRC) has sought to remedy some of the perceived limitations or inadequacies of the VDI and NFPA guidelines. The goal has been pursued with the recognition that no single organization can possibly generate all the data or hold all the knowledge that is necessary to address the different facets of such a complex problem. Accordingly, extensive use has been made of data available in the literature, and correlations have been developed with the help of results obtained from modelling work. Because of this approach, these correlations have a range of applicability that is broader than that of their empirical equivalents. These model-based correlations also ensure proper scaling to conditions different from those of the tests. Where data were not available, the missing information was obtained by designing and carrying out specific test work. This effort has culminated in a set of revised guidelines that are being distributed to Factory Mutual Engineering Association (FMEA) loss prevention consultants worldwide for use in evaluating dust explosion protection at commercial and industrial properties insured by Allendale Insurance, Arkwright and Protection Mutual Insurance. More specifically, the paper describes the progress made in the following areas: explosion vent sizing, vent duct and panel inertia effects, partial volume deflagrations, venting of equipment inside buildings, and explosions at initial elevated pressure.

Current design basis for dust explosion venting

The following description of the design basis which is common to all current vent design guidelines, including the one developed at FMRC, should be helpful to provide a point of perspective and will be used at the end of the paper in the discussion on the needs for future improvements. The severity of a dust explosion is a function of many parameters, some of which represent fundamental properties of the fuel (chemical composition, particle size distribution, reactivity characteristics, such as burning velocity and peak unvented pressure at various concentrations), others which give a measure of the response of the fuel to environmental conditions (moisture content, entrainability when subjected to a disturbance, settling velocity, etc.), and others which define significant aspects of the event (ignition source, dust distribution in the volume, presence of turbulence) or details of the geometry. While the importance of these parameters is generally understood, at least in a qualitative sense, engineering tools to take them into account in a predictive model are currently not available. Moreover, the conditions that prevail in a specific piece of industrial equipment or building are not quantitatively defined, further hindering the application of such tools, even if they were available, to practical cases.

In the absence of a more complete solution to the problem, the approach has been to postulate a near worst-case dust explosion scenario and use it as a design basis for vent sizing. A vent which is correctly sized according to this method will provide adequate protection for most situations, but will not guarantee total protection under all circumstances. The fact that actual explosions are strongly dependent on many factors is illustrated by results obtained by Eckhoff in a large silo[8]. This study underscored the differences in explosion severity due to the dust cloud generation conditions (turbulence, concentration gradients) in actual industrial equipment. The case of pneumatic dust injection into a silo offers an example of a situation where the explosion severity is normally not expected to reach the levels corresponding to the near worst case used as a design basis for standard situations. This fact is recognized by the current VDI 3673 guideline[7] through a special set of recommendations that relax the venting requirements for this situation (which is referred to as an inhomogeneous dust cloud). Unfortunately, the form used for the correlation that accounts for this effect raises questions as to the applicability of the predicted vent areas to conditions that are different from those of the tests on which the formula is based.

The fact that dust explosions can be more severe than the near worst case used for design purposes was confirmed by tests done at FMRC where the turbulence at the time of the explosion was varied and quantified[9]. In practice, severe explosions can be expected to occur in situations where there is an opportunity for development of high levels of turbulence and strong ignition sources. One scenario which can cause this condition to arise is presented by the case of an explosion propagating through a duct into a piece of equipment or a building. The flow ahead of the flame front contributes to generation of turbulence in, and possible pre-pressurization of, the receiving volume; the flame front itself then provides a very strong distributed ignition source when it enters the volume. This results in an explosion which is more severe than the near worst case considered as the design basis. Because of the cited effects, the sizing of vents for interconnected equipment generally falls outside the range of applicability of standard vent sizing methods and still requires special treatment[10].

As indicated, the improvements discussed in this paper are contributed within the framework of a vent sizing approach that postulates a near worst-case explosion as a basis for the design. In addition, characterization of this design condition for a given dust is still based on the result of standardized laboratory-scale testing of the dust in a 20 litre sphere, in a manner identical to that followed in the two referenced guidelines. It should be reiterated, however, that real progress in the area of customized design of explosion protection will have to take proper account of the factors that define the specific explosion scenario of interest. This will require the development of more advanced computer models and further progress along the lines of the work (theoretical and experimental) carried out by FMRC and others on the effects of turbulence on dust explosions and on the characterization of turbulence levels in different types of equipment.

Vent sizing correlation

As indicated by the preceding discussion, the selection of a suitable model of vented explosions was the starting point in the development of a vent sizing correlation. Several theoretical treatments of the complexities of vented dust and gas explosions have appeared in the literature[11–17], while some of FMRC's own experimental and theoretical work has focused on the question of the effects of turbulence on flame propagation[18–20]. The results of this modelling effort[20], which includes a two-

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stage description of the combustion process and takes into account the production of turbulence by jet flow injection, are quite relevant to the dust explosion problem and represent a starting point for future advances. In addition, this model can make a claim of reasonable physical realism, and, as such, can be considered to have predictive capabilities. The level of included detail, however, is greater than that appropriate for the development of a vent sizing correlation, given the choice of a standardized near worst-case scenario as a design basis.

For the narrowly defined purpose of interest here, a simplified formulation of vented explosions has been used in place of the more detailed modelling of the turbulent flame just described[21]. This simpler model, implemented in program ISOVEX (ISOthermal Vented EXplosions), is based on the concept of a spherical flame propagating at a constant velocity. Other assumptions are introduced to minimize the formal complexity of the equations. While these simplifying assumptions do limit its predictive capabilities, the model has proven to be a more than adequate tool to correlate experimental data and to clarify the relationships among the parameters that characterize explosions in enclosures.

The model assumes the flame to propagate from a central ignition point as a front of infinitesimal thickness. Unburnt material is ahead of this front, while totally burnt material lies behind it. The temperatures of these two regions are uniform and constant in time. Pressure is uniform throughout the volume. In the formulation, the reactivity of the mixture is characterized through the value of the rate of propagation of the flame front, i.e. the burning velocity. If turbulence is present, its effect is taken into account by appropriately modifying the value of this velocity. Due to this simplification, the model makes no distinction between gas/air and dust/air mixtures. It is therefore applicable to both. Venting starts when the pressure in the enclosure has reached a preset threshold. The composition of the vented flow, namely the split between burnt and unburnt mass, is assumed to be the same as that of the material inside the enclosure.

A modification to the constant burning velocity assumption is introduced as a way to make the calculated pressure reproduce an important feature of experimental profiles. If the flame propagates at a constant burning velocity, the pressure in an unvented enclosure is found to increase at a continuously increasing rate. In the absence of heat losses, the maximum rate of pressure rise is then calculated to occur at the time when the flame reaches the enclosure wall, corresponding to the time of maximum pressure. This is in contrast with experiment, where the peak rate of pressure rise is normally observed before the explosion pressure reaches a maximum. In actuality, this effect results from a combination of heat losses, departure from perfect spherical geometry (parts of the flame reaching the wall before others), and flame quenching.

Since the model is not set up to simulate any of these effects, the observed feature of the pressure curve is reproduced by arbitrarily relaxing the constant burning velocity assumption. This is done by assuming that the velocity starts to decrease after the flame reaches a certain radius, to become zero at the wall. This artifact introduces a new parameter, the location of the point at which the flame starts to decelerate, which is adjusted so that the position of the inflection point in the calculated pressure curve is in rough agreement with experiment. This choice fixes the relationship between burning velocity and peak rate of pressure rise. This is important because a normalized form of the latter quantity (see equation (3) below) is normally used to characterize the reactivity of the exploding mixture.

Analytical manipulation of the model equations and approximations of the numerical results have shown that model predictions can be generalized by plotting a normalized pressure rise, Π, versus a normalized vent parameter, Γ, defined as

$$\Pi = \frac{p_r - p_0}{p_m - p_0} \tag{1}$$

and

$$\Gamma = a_{cd} \frac{A_v}{V^{2/3}} \frac{p_m - p_0}{K} \tag{2}$$

The quantity a_{cd} is a constant, with the dimensions of a velocity, that depends on the vent flow coefficient, the temperature and molecular weight of the unburnt mixture, the universal gas constant, and the specific heat ratio. In equations (1) and (2), p_0 is the initial pressure of the mixture, $p_r - p_0$ is the pressure rise in the vented explosion, $p_m - p_0$ is the maximum pressure rise under unvented conditions, A_v is the vent area, V is the volume of the vented enclosure, and K is the normalized peak rate of pressure rise defined as:

$$K = V^{1/3} \left(\frac{dp}{dt}\right)_{max} \tag{3}$$

The model is not fully predictive due to the presence of a parameter that, in practice, is adjusted to obtain best agreement with experiment. Once this is done, however, the model predictions can be used as a sort of yardstick to characterize experimental results and to compare data from different experiments. This process was applied to the data which are the basis for the correlation in VDI 3673[22], for the purpose of determining the effective reactivity corresponding to the reduced pressures measured in vented dust explosions carried out in different size vessels (V = 2.4, 10, 20, 25, 250 m^3) for two dusts of nominal reactivities K_{st} = 206–220 and 301–322 bar m s^{-1}, as measured in a standardized test apparatus of 20 litres or greater volume. The result of this operation is shown in *Figure 1*.

In plotting the data shown in the figure, the value of the reactivity, K, which appears in the denominator of the vent parameter, Γ (cf. equation 2), was chosen for each data set so as to achieve best agreement between the data and the theory. The values of K determined through this procedure are reported in the legend to *Figure 1*. From the expanded plots presented in *Figure 2*, one can see that the model provides an accurate simulation of the variation of reduced pressure with vent area for each data set. A change in the selected value of K causes a horizontal translation of the data and therefore has no impact on the trend. In summary, the point being made here is that, while the absolute values derived for the effective reactivity, K, may be somewhat affected by

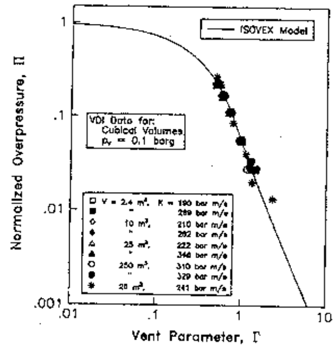

Figure 1 Use of the predictions of the ISOVEX model to determine the effective reactivity implied by the VDI data for cubical volumes and homogeneous dust distribution

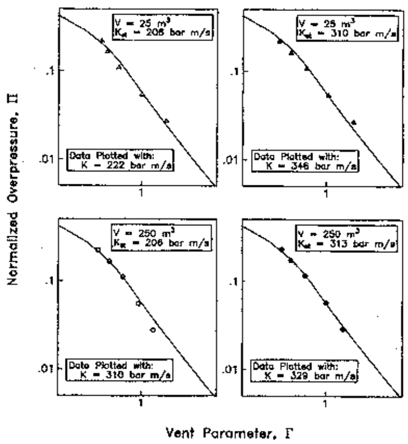

Figure 2 Comparison of experiment with the prediction of the ISOVEX model after matching of the effective mixture reactivity. VDI data for volumes of 25 and 250 m³

limitations of the model, the variations of K from one data set to the other are real and should be considered a meaningful measure of the dependence on volume of the effective reactivity of the vented mixture. This can be better appreciated by considering the data summary presented in *Table 1*.

Table 1 Comparison of reactivity from closed-vessel tests with calculated effective reactivity (K) under venting

Reactivities K_{st} and K (bar m s^{-1})		Vessel volume, V (m³) 2.4	10	20	25	250
Dust A	K_{st}	206	206	220*	206	206
	K	190	210	241*	222	310
Dust B	K_{st}	322	301	NA	310	313
	K	269	282	NA	346	329

*Data for cornstarch

As can be seen from the values given in the table, the calculated effective reactivity, K, of the mixture is not constant but appears to be a function of the volume of the test vessel. A graphical presentation of the numbers in *Table 1* is provided in *Figure 3*. This figure shows how the data for the lower K_{st} (206–220 bar m s^{-1}) dusts display a continuous increase in the effective reactivity, K, calculated from the vented tests. The data for the high-K_{st} case, on the other hand, display an initial rise, but the point corresponding to the largest volume (250 m³) is found to be unexpectedly low. With this exception, the two data sets support the empirical finding that K increases as about the 0.11-power of vessel volume. The lines corresponding to this correlation are also shown in the figure. Note that, at a volume of about 10 m³, the calculated reactivities are in rough agreement with the K_{st} values reported for the two dusts.

The analysis reported here has generalized the VDI experimental data[22], in the sense that each set has been reduced to a value for the effective reactivity, K, displayed by the mixture during venting from a particular vessel volume. The fact that K is generally seen to increase with vessel volume does not necessarily mean, however, that scale has an effect on the rate of flame propagation itself. The result may be due to other effects that are not included in the model on which the analysis is based, such as the dynamic blockage of the vented flow associated with the occurrence of an external explosion.

The conclusion of the validation from comparison with experimental data is that the relationship between reduced pressure and vent area defined by the model can now be used for vent sizing purposes. Unlike empirical fits, the theoretical curve displays the correct trends: for example, the reduced pressure tends to the unvented pressure (Π = 1) when the vent area becomes very small. This gives a basis for use of the correlation beyond the range of conditions for which data are available. In addition, empirical adjustments, such as the previously mentioned volume dependence of the reactivity, are made in a manner that provides for better segregation of the effect, rather than leaving it mixed with other factors in an empirical formula.

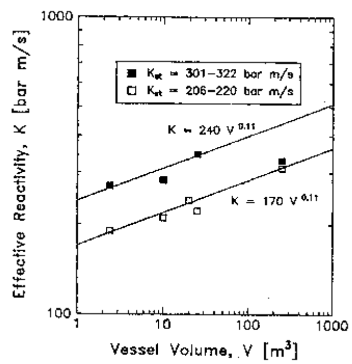

Figure 3 Effective reactivity inferred from the VDI data for homogeneous mixtures as a function of vessel volume

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The timing of vent deployment affects the subsequent development of the explosion by causing higher reduced pressures for higher vent relief pressures, p_v. Here again, the simplified explosion model suggests that this effect can be taken into account as an increase in the effective reactivity of the mixture. However, while the model predictions are qualitatively correct, they tend to underestimate the magnitude of the reduced pressure increase corresponding to increasing values of p_v. As a practical solution to the problem, the values of effective reactivity reported in *Table 2* were calculated from the data obtained by Lunn in an 18.5 m^3 vessel[23]. An empirical correction was then developed for the dependence of K on p_v. As a result of this correction, for most dusts, the FMRC method enforces a significantly lower p_v effect when compared with the analogous adjustment implied by the vent sizing correlation in the VDI 3673 guideline[6]. The corrections from the two methods are approximately equivalent for dusts whose K_{st} is about 500 bar m s^{-1}. It is conceivable that this part of the VDI vent sizing correlation may have been biased by the inclusion of data for high-K_{st} dusts. The practical implication is that the VDI method may overpredict the effects of vent relief pressure in the case of most dusts, for which K_{st} is less than 200 bar m s^{-1}.

Explosions at initial elevated pressure

Available vent sizing methodologies[6,7] are typically restricted, at least in the case of dusts, to mixtures that are initially at (or near) ambient pressure. While this is the most common situation, process conditions may be encountered in which the unignited mixture can be under normal conditions at pressures well above atmospheric, requiring modifications of standard procedures for the sizing of explosion vents. A possible approach for the handling of these circumstances when gaseous fuels are involved is provided in NFPA 68[7], but with little explanation of its foundations. No guidance is provided by this document for dust explosions at initial pressure above ambient. The theoretical framework discussed in the preceding section has been used to review critically this aspect of the NFPA guideline, with the general conclusion that the effects associated with elevated initial pressure are better taken into account by an empirical correction to the effective reactivity of the gaseous mixture[24].

With regard to this aspect, the case of dusts appears to be somewhat simpler than that of gases, since data from experiments with dust/air mixtures at initial elevated pressure[25] are consistent with an increase in reactivity which is proportional to the pressure. It should be noted, however, that this result may in fact have been determined by the procedures followed in running the tests, particularly with regard to the details of the dust injection process and the choice of the ignition delay. The question of how the turbulence of the mixture should be adjusted, as a function of initial pressure, still remains to be settled. The observed linearity and the results from model calculations lead to simple scaling of the effects on reduced explosion pressure due to high initial ambient pressures, p_0. Through a combination of analytical derivations and generalization of numerical results, the model shows that these effects can be approximately correlated by changing the definition for the normalized reduced pressure rise from the expression given as equation (1) to:

$$\Pi_p = \frac{p_r - p_{eff}}{p_m - p_{eff}} \qquad (4)$$

where p_{eff} is an effective external pressure, which is calculated as a linear combination of the pressure (p_e) outside the vented volume and the initial pressure (p_0).

A comparison of the correlation with the limited data obtained by Siwek *et al.*[25] is shown in *Table 3*. These data were obtained in a 10 m^3 vessel with a vent relief pressure set at 0.2 times the absolute initial pressure. Note that, in the cited paper (and in *Table 3*), gauge pressures are referenced to the initial pressure of the mixture. Also included in the table are results predicted on the basis of the VDI guideline, and on the assumption that both the vent relief and the reduced gauge pressures scale proportionately to initial pressure. As can be seen, in three of the ambient pressure tests, the VDI correlation is used beyond its valid range, which is limited to a maximum value of $p_r - p_0$ of 2 barg (@ p_0 = 1 bar). While the predictions from the VDI and from the FMRC method are both acceptable, the cited limitations of the VDI correlation lead to overestimates of the required vent area when the method is used beyond its defined range.

A question still exists concerning the effect of the vent release pressure, p_v, on the correlation. With elev-

Table 2 Calculated effective reactivity (K) as a function of vent relief pressure (p_v) from Lunn's data

Dust [K_{st} (bar m s^{-1}) – p_m (bar)]	Vent area (m^2)	Measured $p_r - p_0$ (barg) @ $p_v - p_0$ (barg)				Calculated K (bar m/s) @ $p_v - p_0$ (barg)			
		0	0.1	0.2	0.5	0	0.1	0.2	0.5
Coal (144–8.5)	0.95	0.12	0.21	0.25	0.61	138	176	190	274
	0.636	0.25	0.24	0.64	1.24	127	125	187	253
	0.385	0.80	0.58	1.56	1.38	124	109	177	163
	0.196	1.55	2.44	2.58	3.77	89	127	134	212
Aspirin (254–8.3)	0.95	0.58	0.71	0.94	1.04	264	286	324	341
	0.636	1.10	—	—	—	235	—	—	—
	0.385	—	2.45	2.96	3.10	—	250	302	321
Toner (236–8.8)	0.636	1.05	—	—	—	237	—	—	—

Table 3 Reduced explosion pressures from tests at initial pressure above ambient

Dust reactivity K_{st} (bar m s^{-1})	Initial pressure p_0 (bar)	Relief pressure $p_v - p_0$ (barg)*	Vent area A_v (m^2)	Reduced explosion pressure, $p_r - p_0$ (barg)* Experimental	VDI 3673	FMRC method
190	1.0	0.2	0.64	0.45	0.53	0.44
190	1.0	0.2	0.38	1.4	1.37	1.31
190	1.0	0.2	0.28	2.1	2.40†	2.16
190	2.38	0.48	0.38	3.0	3.33	3.34
290	1.0	0.2	0.64	0.75	0.91	1.09
290	1.0	0.2	0.38	2.2	2.35†	2.53
290	1.0	0.2	0.28	3.6	4.09†	3.56
290	2.0	0.4	0.64	1.65	1.82	2.18
290	3.0	0.6	0.64	3.0	2.73	3.52

*Gauge pressures are referenced to the initial pressure, p_0, of the mixture.
†Value exceeding the upper range of the VDI correlation (2 barg @ p_0 = 1 bar).
All test results from vented explosions in a 10 m^3 vessel and dusts with unvented maximum pressure $p_m - p_0$ = 8.5 barg (@ p_0 = 1 bar).

ated initial pressure, the model results indicate this effect to be stronger than in the case of explosions starting at near-ambient conditions. Accordingly, the empirical correction used for the standard case has been modified to incorporate the magnitude of the increase given by the calculations. This aspect of the method, however, is still based on incomplete understanding of the effects of vent relief pressure on explosions and will have to be improved as better knowledge is developed.

Partial-volume deflagrations

In the typical situation encountered in most explosion venting problems, the explosive mixture occupies the entire volume of the vented enclosure. This is the case normally considered by models of explosion venting, including the one presented here. Conditions exist, however, where only a portion of the volume (a small fraction, at times) is actually within the explosive range. Examples of partial-volume deflagrations (PVDs) are offered by accidental explosions in spray-drying equipment or in buildings, where the dust cloud is created by deposits or by material ejected from a piece of equipment venting inside the building volume. In these situations, one expects that less venting should be adequate relative to the full-volume case, even though it will be seen that the reduction in vent area is often not as large as intuition might have led one to believe.

The question of the effect of filled fraction on explosion severity has been addressed by several experimental studies. These have included test programmes carried out by CERCHAR[26] (now INERIS) in a 100 m^3 vessel, by Ciba-Geigy[27] in a 6.5 m^3 vessel, and by the TNO Prins Maurits Laboratory[28,29] in a 38.5 m^3 chamber. A careful analysis of these data has revealed inconsistencies that cannot be fully explained. An example is offered by one of the Ciba-Geigy tests[27], where the pressure measured in a vented test is reported to be 25% higher than the maximum pressure that could be reached at the stated filled fraction under unvented conditions. It appears that tests of partially filled enclosures are often plagued by difficulties in controlling the fraction of the volume occupied by the explosive mixture.

Results from vented PVD tests have generally been interpreted through scaling of the vent area by the volume of the exploding cloud[27]. Other than representing a seemingly logical extension of existing correlations for full-volume explosions, this approach has no conceptual justification. Its limitations have already been recognized by other studies[28] and have been quantified by the results of a detailed analysis carried out at FMRC based on an extension of the simplified model to include PVDs[30]. This is discussed further below. The most obvious pitfall of volume scaling is the prediction of the need for venting even in situations where the explosion can be contained. An illustrative example is provided by the case of a vessel with a strength of 1 barg, handling a dust that can produce a peak unvented pressure $p_m - p_0$ = 8 barg. No venting of the vessel is necessary if a worst-case concentration of the dust occupies less than 12.5% of the vessel volume. Simple thermodynamic considerations indicate that the peak unvented pressure rise is approximately proportional to the filled fraction. Therefore, an explosion producing an unvented pressure rise of 8 barg when the explosive mixture fills the entire volume, can produce only 1 barg if the mixture occupies 1/8th of the volume.

The FMRC analysis of the PVD variation on the standard explosion problem has been based on an extension of the full-volume deflagration (FVD) model described earlier, modified to restrict the reacting mixture to a fraction of the enclosure volume. It should be noted that, in making this extension, it has been necessary to introduce additional assumptions. In particular, the model implicitly assumes that the partial volume occupied by the explosive mixture is centrally located inside the vented enclosure. As a result, peculiarities of the geometry of the system cannot be taken into account. Since a description of the details of the model is beyond the scope of the present discussion, only the final result of the generalization of the FVD model is given here.

To a degree of approximation which is adequate for engineering calculations, it can be shown that the same vent sizing curve which applies to FVDs can be used for PVDs by making a simple change to the correlating parameters. This involves introducing the filled fraction, X_r, into the two variables of the 'universal' vent sizing correlation developed from the FVD model, leading to the modified normalized reduced pressure, Π_r:

$$\Pi_r = \frac{1}{X_r}\frac{p_r - p_0}{p_m - p_0} \quad (5)$$

and the modified vent parameter, Γ_r:

$$\Gamma_r = a_{cd}\frac{A_v}{V^{2/3}}\frac{p_m - p_0}{K}X_r^{1/3} \quad (6)$$

This empirical result can be used to evaluate the dependence of the reduced pressure on the filled fraction, X_r, by noting that, over a narrow range of Γ_r values, the relationship between the normalized overpressure, Π_r, and the vent parameter, Γ_r, given by the PVD model can be written as a power-law approximation using:

$$\Pi_r = c\,\Gamma_r^n \quad (7)$$

From the definitions of the two normalized parameters given by equations (5) and (6), a relationship can be obtained for the dependence of the reduced pressure rise, Δp_r ($= p_r - p_0$), on the filled fraction, X_r:

$$\frac{\Delta p_r}{\Delta p_m} = c\,X_r^{\,1+\frac{n}{3}}\left(a_{cd}\frac{A_v}{V^{2/3}}\frac{\Delta p_m}{K}\right)^n \quad (8)$$

For conditions where the vent parameter is small ($\Gamma_r < 0.3$–0.4), the dependence of Π_r on Γ_r is relatively weak, and the reduced pressure becomes roughly proportional to the filled fraction, X_r, raised to a power in the range 2/3 to 1 (since n assumes values between -1 and 0). If conditions are such that $\Gamma_r \gtrsim 1$, then X_r is roughly raised to the 1/3rd power ($n \cong -2$). In this latter case, the analysis indicates that the reduced pressure is a relatively weak function of the filled fraction. Equation (8) leads to analogous conclusions, when written so as to express the dependence of the vent area, A_v, on the filled fraction, X_r.

A numerical example is illustrated in *Table 4*, by considering the case of a vented vessel with a volume of 500 m^3, handling a dust with $p_m - p_0 = 8$ barg and $K_{st} = 140$ bar m s^{-1}. If a worst-case concentration of the dust occupies the entire volume ($X_r = 1$), and the vessel is assumed to withstand an overpressure (Δp_r) of 1 barg, the required vent area predicted by the PVD model is 6.1 m^2. If the volume is only 25% filled with this explosive mixture, the required area is less than half, 2.9 m^2. If the filled fraction is further reduced to 0.125, no venting of the vessel is necessary. If the vessel is 'weak', as defined by a maximum allowable pressure of 0.2 barg (about 3 psig), a reduction in the filled fraction has a lesser impact on the venting requirements, with vent areas from 12.3 to 9.2 and 7.0 m^2 for respective filled fractions, X_r, of 1, 0.25 and 0.125. In this case, the point where no venting is needed is reached at a filled fraction of 0.025%.

Areas predicted on the basis of volume scaling, which has been advocated by some researchers[27], are also shown in the table. With the exception of the previously mentioned anomaly of indicating that venting is required even in situations when the explosion can be contained, the areas predicted by this method are seen to be smaller than those based on the PVD model, particularly in the case of the weak enclosure. These numerical examples show that the effect of reductions in the fraction of the enclosure volume occupied by the explosive mixture depends on the conditions of the vented system. On the other hand, scaling by the volume of the explosive cloud generally leads to underestimates of the vent areas needed in both examples. This conclusion is supported by analysis of test results and expresses a trend that would apply to most practical cases.

While these results represent a significant improvement over current treatments of the effects of partial filling of a vented volume, the PVD model introduced here does not offer a final solution to the general problem of PVDs. The inability of the model to account for the position of the exploding cloud inside the volume will need to be corrected before this approach can be used to deal with partial-volume effects in systems where stratification is important, such as in the case of vapour/air explosions produced by flammable liquid spills. For the dust explosion problems considered here, the PVD model will generally yield slightly conservative predictions and is therefore believed to be adequate in most situations.

Vent duct effects

The effect of vent ducts on dust explosion development has much practical importance because of the use of ducts in those situations where the vented flow needs to be directed outside the building that contains the protected equipment. It is generally accepted that the presence of the duct causes a reduction in the effectiveness of the vent. However, a critical examination of the guidelines that have been developed to estimate the magnitude of the effect (VDI 3673[6], NFPA 68[7], UK IChemE[31]) shows that there is much room for improvement in the way available data have been put to practical use. It will be shown, for example, that the recommen-

Table 4 Required vent area as predicted by the PVD model and by volume scaling

	'Strong' equipment		'Weak' equipment	
Reduced explosion pressure, $p_r - p_0$ [barg]	1.0		0.2	
Scaling of vent area	PVD	Volume scaling	PVD	Volume scaling
	Required vent area, A_v (m^2)			
Full volume ($X_r = 1.0$)	6.1	6.1	12.3	12.3
Partial volume when $X_r = 0.25$	2.9	2.1	9.2	4.2
$X_r = 0.125$	0	1.2	7.4	2.4
$X_r = 0.025$	0	0.34	0	0.70

Calculated vent areas obtained for $p_m - p_0 = 8$ barg, $K_{st} = 140$ bar m s^{-1}, $V = 500$ m^3, $p_v - p_0 = 0.1$ barg.

dations published in VDI 3673 and NFPA 68 have limited applicability, because of improper scaling of the problem variables. The work by Lunn *et al.*[23] at the Health and Safety Executive, on the other hand, while arguably offering the most extensive data currently available in the open literature, has been converted into engineering guidelines that appear to be properly presented but are somewhat cumbersome to use[31]. FMRC work in this area has been carried out with the goal of overcoming the perceived limitations of these methods.

The physical phenomena involved in the problem of unsteady flame propagation through a heterogeneous turbulent mixture reacting in a duct are complex and probably beyond the capabilities of most models, with the possible exception of advanced codes which are still mainly in the research domain. For this reason, earlier work carried out at FMRC on this problem[32] has relied on a simplified approach to the treatment of the duct dynamics, and has resulted in a model which is suitable for a limited range of applications. Unfortunately, use of this model to address more general vent sizing problems is restricted by the need for the user to make somewhat arbitrary selections for values of unknown parameters which have a significant impact on the calculated answer.

The correlation presented here is the result of an even more elementary treatment of the problem. It was developed using the same simplified conceptual framework of the model in Ref. 32, for the more limited purpose of identifying the parameters that characterize the effects of the duct. Essentially, gas inertia, friction losses, and density changes due to combustion in the duct are assumed to be the only controlling processes. Wave propagation effects are neglected and the characteristic time scale for the combustion in the duct is assumed to be the same as that of the combustion in the vented enclosure. Obstacles or bends in the duct are taken into account through an appropriate increase in frictional losses, while their impact on the combustion process itself is effectively neglected. Additional details on the development of the correlation have been given elsewhere[33]. The conclusion of the analysis is that the vent duct effects are found to be described by three parameters: the vent parameter, Γ, introduced in equation (2); the duct inertia parameter, Φ_d, described by:

$$\Phi_d = \frac{L_d V^{1/3}}{A_d}\frac{M}{RT_0}\left(\frac{K}{p_m - p_0}\right)^2 \tag{9}$$

and the friction loss parameter, Ψ_d, given by:

$$\Psi_d = \left(c_f\frac{P_d L_d}{A_d} + c_\alpha\right)\frac{V}{L_d A_d} \tag{10}$$

The additional variables introduced in equations (9) and (10) are: vent duct length, L_d; duct cross-sectional area, A_d; duct perimeter, P_d; friction factor, c_f; head loss factor, c_α (to account for the presence of bends in the duct); temperature and molecular weight of the mixture, T_0 and M; and the universal gas constant, R. Under the assumption that there is no mixing of excess fuel with additional air in the duct during the venting process, combustion effects are represented by the ratio of the volume of the vessel to that of the duct, which already appears as the last term in the right-hand side of equation (10).

The approach taken for the identification of the parameters of the problem does not yield the functional relationship that links them to a dependent variable of interest such as, for example, the reduced pressure developed by the explosion. An empirical relationship was therefore developed by fitting the test results obtained by Lunn *et al.*[23] to obtain an expression for the variation of the effective vent area as a function of the identified controlling parameters. This interpretation of the experimental data has the advantage of reducing problems involving ducted explosion vents to the same vent sizing curve that applies to the case of ductless vents. An example of the success of this correlation in bracketing the test data is shown in *Figure 4* as a plot of the reduced explosion pressure measured in the experiments against the values predicted by the correlation, for the case of data from vented dust explosions in an 18.5 m^3 vessel fitted with straight ducts of various lengths. The correlation, which can be seen, with a very few exceptions, to provide an upper bound to the data, is just as successful in dealing with the other data obtained by Lunn *et al.* for ducts with one 45° or 90° bend, data (also obtained by Lunn) for a 20 litre vessel, and the 1 m^3 sphere data that constitute the basis for the design guidelines in VDI 3673[22].

The correlation is not applicable to ducts of cross-sectional area greater than that of the vent. Recent results[34], also from the Health and Safety Executive (HSE) in the UK, have indicated that an increase in the duct diameter can bring about a reduction in explosion pressure. There are, however, some aspects of these results that caution against a generalized acceptance of the potential increase in vent effectiveness associated with large vent ducts. Another factor that is not explicitly addressed by the correlation is the location of the ignition source. The previously cited work from the HSE reports some results which show that greater vent duct effects can be expected when the ignition source is away from the vent opening. While this is not surprising, a proper treatment of this variable is beyond the reach of current design methods, including the one presented here.

The formula developed by FMRC lends no support for the form of the vent duct correction in VDI 3673[6] (or NFPA 68[7]), which uses the physical length of the

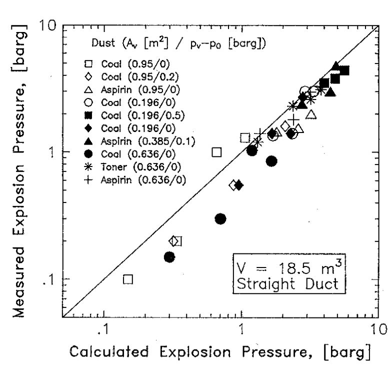

Figure 4 Measured explosion pressures versus values calculated from the FMRC correlation. Data from Lunn *et al.*[24] for an 18.5 m^3 vessel:straight duct

duct as a correlation variable. On the other hand, the dependence of the effectiveness of the vent on the *L/D* ratio of the duct (among other variables), as used in the graphic correlation of Lunn's data[31], is validated by the model. A practical consequence of the failure of the VDI and NFPA guidelines to use appropriately scaled variables is that the design method presented in those standards should be considered approximately correct only for equipment volumes close to that of the vessel (1 m^3) used to obtain the data on which the correlation is based. The numerical examples shown in *Table 5* illustrate this point. The table considers the particular cases of venting situations for two vessel volumes (V = 1 and 50 m^3), two effective dust reactivities (K = 150 and 300 bar m s^{-1}), and three reduced pressures in the absence of a vent duct ($\Delta p_{r,0}$ = 0.1, 0.5 and 2.0 barg), the first and the last representing the two extremes of the range of validity of the VDI correlation. Required vent areas are reported through the vent diameter, D_v.

The table shows the values of reduced pressure calculated by the VDI guideline and by the FMRC correlation for different duct lengths. In the case of the 1 m^3 vessel, the two methods are in approximate agreement. For the larger vessel (50 m^3), however, the pressures calculated according to the VDI method are consistently higher than those predicted by the FMRC correlation. The VDI predictions represent clear overestimates, as indicated by the cases of high reduced pressures calculated for situations where the *L/D* of the duct is less than 1 (see underlined figures in the table). The effect on the explosion from these low aspect ratio ducts is expected to be very low. In fact, there is evidence that indicates that ducts of low aspect ratio may in some cases actually make the vent more efficient. While the FMRC correlation neglects this possible beneficial factor, it does predict small effects, so that the omission has limited practical relevance. Still according to the VDI method, ducts with length greater than 6 m fall outside the range of the published correlation and are claimed to require expert treatment. More realistically, the FMRC correlation shows that even a 6 m duct can have a relatively modest impact on the explosion if the vent is large, meaning that the *L/D* of the duct is small (cf. case for V = 50 m^3, K = 150 bar m s^{-1}, $\Delta p_{r,0}$ = 0.1 barg, where a 6 m duct causes an increase in the reduced pressure from 0.1 to 0.22 barg).

The fact that the VDI guideline systematically and in some cases grossly overestimates the effect of the duct raises serious questions with respect to its practical use for vented volumes that are much different than 1 m^3. The FMRC correlation, on the other hand, has been developed on the basis of a theoretical analysis that has identified the appropriate scaling parameters, has the support of experimental data used to validate it which span a range of scales, and can therefore be relied upon for extrapolation to conditions that are different from those for which test results are available.

Panel inertia effects

The effects associated with the finite inertia of vent panels would appear to be ideally suited to some sort of analytical treatment. It is therefore somewhat surprising to find that the previously cited vent sizing guidelines address this aspect either by including a recommendation on the maximum mass per unit area that is acceptable for the vent panel (NFPA 68) or else by suggesting that the reduction in panel effectiveness due to inertia effects be determined experimentally on a case-by-case basis (VDI 3673).

The analysis of vent panel dynamics carried out by Rust[35] represents an early attempt to predict the dependence of the explosion pressure on the inertia of the panel. The relative obscurity to which these results have been relegated may be due to the fact that they were inadequately generalized, making them difficult to understand. A more recent attempt at addressing the same problem has been made by Harmanny[36]. Model results are used to analyse experimental data and some general conclusions are presented. These include the observation that the mass per unit area of the panel is

Table 5 Influence of vent ducts on the reduced explosion pressure (calculations by the VDI method and by the FMRC correlation)

				Reduced explosion pressures with duct, $\Delta p_{r,d}$ (barg)							
				VDI for L_d (m)		FMRC correlation for L_d (m)					
V (m^3)	K (bar m s^{-1})	$\Delta p_{r,0}$ (barg)	D_v (m)	0–3	3–6	1	2	3	4	5	6
50	300	0.1	2.23	0.41	1.00	0.13	0.16	0.19	0.23	0.27	0.32
50	300	0.5	1.60	1.17	2.15	0.61	0.74	0.86	1.00	1.14	1.28
50	300	2.0	1.11	2.90	4.18	2.25	2.49	2.73	2.95	3.16	3.36
50	150	0.1	1.58	0.41	1.00	0.12	0.13	0.15	0.18	0.20	0.22
50	150	0.5	1.13	1.17	2.15	0.57	0.65	0.73	0.81	0.90	0.98
50	150	2.0	0.79	2.90	4.18	2.16	2.32	2.48	2.63	2.78	2.93
1	300	0.1	0.61	0.41	1.00	0.22	0.38	0.60	0.85	1.12	1.40
1	300	0.5	0.43	1.17	2.15	0.96	1.48	2.01	2.51	2.98	3.40
1	300	2.0	0.30	2.90	4.18	2.88	3.63	4.24	4.74	5.16	5.51
1	150	0.1	0.43	0.41	1.00	0.17	0.26	0.37	0.51	0.66	0.82
1	150	0.5	0.31	1.17	2.15	0.79	1.11	1.45	1.79	2.13	2.46
1	150	2.0	0.21	2.90	4.18	2.59	3.12	3.59	4.00	4.37	4.69

Underlined reduced pressures refer to ducts for which $L_d/D_v < 1$.
FMRC correlation applied assuming a peak unvented pressure of 9 barg.
Variables in first four columns are: V, vessel volume; K, effective reactivity; $\Delta p_{r,0}$ reduced explosion pressure without duct; and D_v vent diameter.

Dust explosion vent sizing: F. Tamanini and J.V. Valiulis

not a quantity that should be considered in isolation, since the volume of the enclosure is also an important parameter. However, Harmanny's analysis fails to identify the effect of other important variables, such as the reactivity of the mixture.

This problem was revisited by FMRC, taking as a starting point the simplified explosion model used to develop the vent sizing correlation already discussed in this paper. The model was modified to take into account the motion of the panel as it accelerates away from the vent opening under the pressure differential produced by the explosion. During the initial stages of the process, the area available for venting is given by the surface between the edges of the panel and the vent opening as defined by the motion (translation or rotation) of the vent cover. Full deployment is achieved when this surface reaches an area equal to that of the vent opening. The model was used to study the effects on the first and second peaks of the explosion (see the discussion of the pressure curves presented in *Figure 5*), including consideration for the presence of opposing gravity and for different panel arrangements (hinged vs. translating).

Since a detailed description of the analytical development is beyond the scope of this paper, only the main conclusions will be presented. After normalization of the equation of motion, using the scales identified by the explosion model, the effects associated with the inertia of the panel are found to be fully characterized by the following parameter:

$$\sum_{*}^{*} = \frac{\sigma_v \, K^{5/2}}{n^{1/2} \, c_s \, a_{sd}^{1/2} \, p_e^{1/2} \, p_0^{3} \, V^{4/3}} \qquad (11)$$

where σ_v is mass of the vent per unit area; n is the number of equal panels on the vented volume; c_s is the panel shape factor; and p_e is the external pressure.

This parameter establishes the correct relationship between three important variables: the surface density of the panel, σ_v; the volume of the enclosure, V; and the reactivity of the mixture, K. It shows that panel inertia effects are more important the more reactive the mixture and the smaller the volume. Other variables also appear in the definition of Σ_*^*, such as the shape factor, c_s, which assumes the value 1 in the case of a square panel. Different values for c_s are calculated to deal with the cases of circular or rectangular vents. The correction to the mass of the panel introduced by this shape factor accounts for the effect of the perimeter-to-area ratio. From the inertia point of view, a round shape is the least efficient because it has the smallest perimeter per unit area. This condition implies that the panel needs to move farther to provide the full vent area than one with a greater perimeter-to-area ratio. A long and skinny vent, on the other hand, is more efficient for the opposite reason. Similarly, inertia effects are reduced if the total vent area is divided over multiple vents. When the vents are all of the same shape and size, and have no adjoining sides, the correction to the mass of the panel is simple and is given by the $n^{1/2}$ factor in the denominator of equation (11). The more general case of vents of unequal sizes/shapes cannot be handled in a simple way.

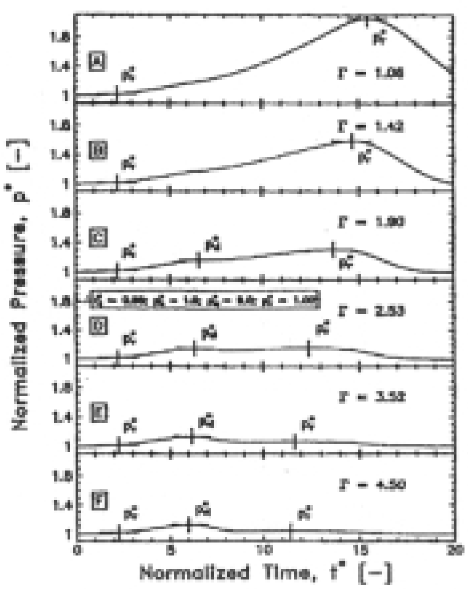

Figure 5 Pressure development in vented explosions predicted for different vent ratios and constant panel inertia ($\Sigma_i = 0.03$)

The model does not account for the effect of the shape of the panel on the discharge coefficient of the vent, and it assumes that the discharge coefficient is the same for the full vent area and for the annular space around the panel during deployment. This is an approximation which is not believed to introduce significant errors, at least in the sense of underestimating the inertia effects. An interesting result which, after careful inspection, can also be found hidden in the formulae in Rust's paper[35], is produced by the model for the case of hinged panels. In terms of its deployment in a vented explosion, a hinged panel is equivalent to a translating panel with a mass one-third greater.

By manipulation of the numerical results, the effect of the unvented explosion pressure, p_m, can be included by dividing the parameter defined in equation (11) by $(p_m/p_0 - 1)^{5/2}$. This approximate generalization introduces the inertia parameter, Σ_i, which will be used, with sufficient accuracy for engineering purposes, to characterize fully the inertia of the panel. The expression for Σ_i is given by:

$$\sum_{i} = \frac{\sigma_v}{n^{1/2} \, c_s \, a_{sd}^{1/2} \, p_e^{1/2} \, p_0^{1/2} \, V^{4/3}} \left(\frac{K}{p_m - p_0} \right)^{5/2} \qquad (12)$$

The different situations that can arise when dealing with panel inertia effects are illustrated by the pressure traces calculated by the model for different values of the vent and inertia parameters, Γ and Σ_i (*Figure 5*). The six pressure traces shown in the figure are all for a constant inertia parameter ($\Sigma_i = 0.03$), but correspond to increasing venting from top to bottom. At the two lower values of Γ (traces 'A' and 'B'), deployment of the vent at pressure p_v^* ($= p_v/p_0$) is followed by a continuous increase of the pressure, until a maximum is reached p_r^* ($= p_r/p_0$). As the venting is increased (trace 'C'), a first maximum starts to appear. This is labelled p_{r1}^* in the figure (the presence of the asterisk indicates that the pressure is normalized relative to the initial pressure, p_0) and will be referred to as the effective vent relief pressure attributable to panel inertia effects. With further vent area increases, the magnitude of the second peak decreases, until p_r^* becomes less than p_{vi}^* (cf. traces 'E' and 'F').

The qualitative behaviour displayed by the traces in *Figure 5* is strongly dependent on the fact that the model assumes that the flame propagates throughout the entire event at a constant effective burning velocity. This is probably a fair approximation in dust explosions (the case addressed in this paper) where turbulence generally dominates the combustion process. However, it is not true for most situations involving gaseous mixtures, where the venting process itself is known to cause the flame to accelerate. This interaction results in a progress of the explosion which is characterized by slower rates in the early stages (initial panel deployment, first pressure peak), and is followed by enhanced burning as the flame approaches the vessel walls (second pressure peak). For these combustion situations, the detailed distinctions made in *Figure 5* should not be expected to be applicable.

The maximum pressure reached by the vented explosion, either as a first or second peak (p_{vi}^* or p_r^*) is presented in *Figure 6* as a function of the vent parameter, Γ, for different values of vent panel inertia, Σ_i. The labelled vertical lines in this figure indicate the conditions of the six pressure traces presented in *Figure 5*. The break in the curve corresponds to the point at which the vent parameter, Γ, is sufficiently large such that p_{vi}^* is greater than p_r^*. Furthermore, a distinct first peak is predicted by the model only for values of the vent parameter, Γ, that are greater than about 1.5–2.0. Detailed analyses of model predictions have resulted in the development of power-law correlations for the increase of the vent relief pressure (effective over static, $p_{vi}^* - p_v^*$) and of the reduced pressure, p_r^*, as a function of the combined inertia and vent parameters, Σ_i and Γ.

A point of comparison is offered by data obtained by Siwek and Skov[37] from dust explosions using hinged doors in vessels from 2.4 to 25 m^3 in volume. This is an important reference since the results documented in the paper constitute the basis for the technical recommendations contained in the current edition of VDI 3673 on this matter. Analysis of these data is complicated by the fact that a direct comparison between the burst disk and the hinged explosion door results is not possible because of the presence of a transition section in the case of the latter vent device. Unfortunately, since the flow disturbance caused by the transition section introduces additional effects, separation of those which are directly associated with the inertia of the door required elaboration of the data and the introduction of assumptions in the analysis. The task, however, was made possible by information provided in the paper on the effect of the transition section alone, in the form of data from experiments where this section was fitted with a burst disk.

The result of the evaluation of Siwek and Skov's data is given in *Figure 7*. The ordinate in the plot is the normalized increase in reduced pressure above the value, p_{r0}, obtained in the absence of inertia effects (vent fitted with a burst disk), due to the finite mass of the panel. The agreement between the values for this quantity inferred from the experiment (data points) and those calculated from the correlation (dashed line) is quite satisfactory. As can be seen, the values of the vent parameter, Γ, are all less than 1.5, indicating that the conditions of the tests were such that the pressure curves should not have displayed a distinct first peak. The correlation curve is seen to represent a good approximation of the data and could be made to provide an upper bound by appropriately increasing one of the coefficients in the formula. It should be noted that the four cases where the experiment indicated a zero reduced pressure increase are all for the smallest vent area, with resulting reduced pressures in excess of 4 barg. For these four cases, the correlation predicts a reduced pressure increase due to panel inertia of 0.07–0.14 barg, an amount which is probably too small to be resolved from the data.

In summary, the analysis has shown that vent panel inertia effects are described by the parameter, Σ_i, which has been defined in equation (12). If the panel is hinged, its mass per unit surface must be multiplied by 4/3 before it is substituted for σ_v to calculate Σ_i. Panel shapes other than square are taken into account through the shape factor c_s, and the presence of more than one equal panel through the variable *n*.

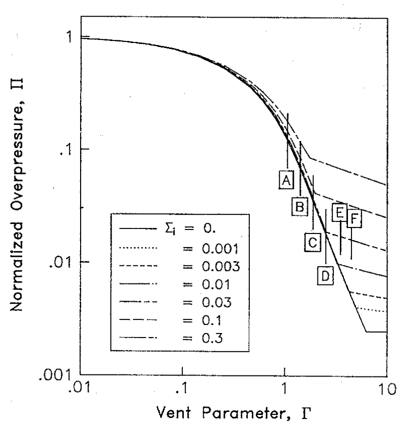

Figure 6 Effect of vent panel inertia on the reduced pressure from a vented explosion

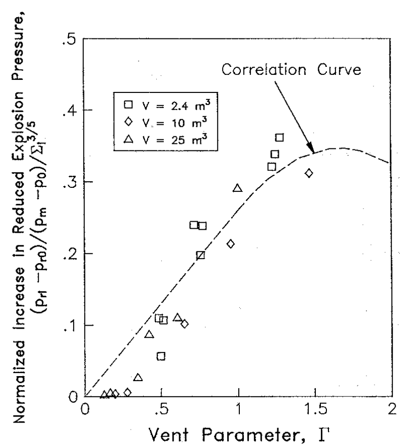

Figure 7 Predicted and experimental increase in reduced explosion pressure due to panel inertia effects. Data from Siwek and Skov[37]

In vented dust explosions, a distinct first pressure peak is observed only if the vent area is sufficiently large. This situation has been found to correspond to values of the vent parameter, Γ, which are approximately greater than 1.5. In this case, the inertia of the panel manifests itself mainly as an increase in the effective vent relief pressure, p_{vi}. A correlation including the effects of opposing gravity has been developed to calculate this increase.

If the amount of venting is small (Γ less than about 1.5), then the pressure curve displays only one maximum, for the reduced pressure, p_r. A correlation has been developed for this situation also in the form of an expression for the increase in reduced pressure, $p_{r1} - p_{r0}$, as a function of the vent and inertia parameters, Γ and Σ_i. Opposing gravity is not taken into account by this correlation, but the neglected effect is in most cases very small. The calculation procedure used to obtain p_{r0} (the reduced pressure reached in an explosion with a zero-inertia vent panel) must include the effects of the static vent deployment pressure and those associated with any transition section attached to the vent. Extensive comparisons with experimental data have shown these correlations to yield somewhat conservative estimates of panel inertia effects.

Venting of equipment inside buildings

Situations where buildings contain equipment fitted with explosion relief vents directed to the inside of the building, or with no venting at all, are of concern because of the potential consequences even in the case where the building is clear of dust deposits. Currently, there is uncertainty on the protection requirements for buildings housing dust-handling equipment which is not vented to the outside. If an explosion takes place in the equipment, unburnt dust is released and then reacts in the surrounding space. In general, however, the cloud created by the ejected dust is not expected to fill the entire volume of the building with a uniform explosive mixture, and is likely to occupy only a portion of the available volume. From the building's perspective, this results in a partial-volume deflagration (PVD) producing a fraction of the pressure that would be developed by a full-volume explosion involving the entire building.

Reference to studies of dust explosions in partially filled volumes, related to the venting of spray dryers[26] and confined plant areas[27–29], has already been made in this paper. In the analysis of those results, the volume scaling approach, which calculates the vent area on the basis of the 2/3 power of the volume of the exploding cloud, has been found to lead to serious underestimates of the vent area. An additional problem in establishing the severity of the PVD produced by the venting of equipment is associated with the uncertainty in predicting the fraction of the building volume filled by the explosive dust cloud. Since no systematic approach appears to have been proposed to deal with this question, unpublished test work has been carried out at FMRC to develop answers.

Instead of relying on visual observations of the dust cloud ejected by the equipment, the consequences of the explosion external to the equipment were measured directly. Data were obtained for the pressure rise in a sealed 2250 ft^3 (63.7 m^3) chamber produced by vented dust explosions in a 22.5 ft^3 (0.64 m^3) enclosure located inside the chamber. The maximum pressure developed by the dust in laboratory-scale, full-volume explosions was used to calculate the equivalent volume of the exploding cloud under the various conditions of the large-scale tests. This was done by assuming proportionality between this equivalent volume and the pressure rise measured in the unvented 2250 ft^3 chamber.

To establish a point of reference, a simple analysis was also carried out to determine the volume over which a given amount of dust would have to be dispersed in order to produce the highest pressure rise when exploding inside a confinement. When related to this theoretical upper limit, the effective volumes measured in the experiments were found to depend on the conditions of the vented explosion in the simulated equipment and, more specifically, on the size of the vent, on the vent relief pressure, and on the fraction of the total dust charge that was pre-dispersed in the small enclosure. Effective volumes as large as 50–75% of the theoretical maximum were measured for situations where much of the dust in the simulated equipment was ejected in bulk instead of being pre-dispersed. Smaller vent areas tended to produce dust clouds with smaller effective volumes (as low as 10–15% of the theoretical maximum).

A secondary objective of the project was to determine the venting requirements of the building containing the vented equipment. The data obtained for this situation were somewhat limited, but they nevertheless allowed validation of the predictions generated by the PVD model discussed previously. In addition, they provided further confirmation of the fact that scaling by the volume of the exploding cloud would have grossly underestimated the vent requirements. On the basis of these results, it is possible to identify situations where venting of equipment inside a building may be tolerated, at least from the perspective of potential pressure damage to the building structure. In practice, this option is not considered acceptable for new installations or when personnel safety issues are present.

Conclusions

The paper has reviewed recent results from work carried out at FMRC to develop advanced vent sizing guidelines for dust explosions. The contributions have been of different types, ranging from new results on partial volume deflagrations and on the effects of equipment explosions vented inside buildings, to a re-interpretation of data obtained by others, as in the case of the correlation for the effects of vent ducts. The recurrent element in all of the work is the use of theoretical models either in a predictive mode (treatment of vent panel inertia effects, for example), to support data extrapolations (as in the case of the generalized vent sizing curve), or to simply identify the controlling parameters of the problem (correlation of vent duct effects).

The main conclusion to be drawn from this effort is that the impact of experimental results is greatly diminished by the absence of a conceptual framework to assist in the interpretation. The fact that such framework need not be particularly sophisticated is certainly made evident by the applications discussed in the paper.

Of course, there is the potential for losing much of the acquired gains if this integrated approach is used to support unwarranted conclusions. An example of a situation where this might happen is the correlation for the effect of vent ducts. While providing a significant advance over existing methods, the correlation is empirical and relies on parameters which are based on a simplified theory that leaves out potentially important effects (wave propagation and enhancement of combustion in the duct, for example). Therefore, extrapolation of empirical results to conditions where such effects may become important should be done with great care. In practice, to avoid use of the correlation beyond its limits of applicability, restrictions have been set for the maximum *L/D* ratio allowed for ducts, so that conditions where transition to detonation may be possible are avoided.

Real improvements in the management of the risk presented by explosion hazards will eventually require removal of the current assumption of a near worst-case situation as the basis for design. This means that the conditions that are specific to a certain process and accident scenario will need to be taken into account in the sizing of the protection. While it is difficult to imagine how this could be done, based on correlations of experimental data alone, it is doubtful that detailed models will be developed that can account for all the complexities of practical systems. It would therefore appear that the best prospects for progress will come from a judicious combination of the results from advanced computational fluid dynamics codes and from phenomenological models, designed to provide support in the interpretation and extrapolation of experimental results.

An obvious condition for the success of any kind of modelling is the inclusion of adequate treatment of the important physical phenomena. This consideration has inspired much of the work currently in progress at FMRC. An example is provided by the research devoted to the effects of turbulence, since this parameter plays a dominant role in defining the severity of gas and dust explosions. Ultimately, standard guidelines should allow for more accurate tuning of protection systems depending on the identified hazards and should provide guidance to predict the damage caused by events that exceed the design basis. Much remains to be done, involving contributions from several organizations, before these goals can be reached. Development times will be shortened if there is a consensus on the desired state and on the type of effort needed to achieve it.

Acknowledgements

The results presented in this paper represent a compendium of long- and short-range projects, carried out over a period of several years as part of internally sponsored research on dust and gas explosions. While ultimately beneficial in advancing the overall understanding of explosion phenomena, this work has been aimed at the development of improved explosion protection guidelines for use by FMEA loss prevention consultants. The authors gratefully acknowledge the support of the Factory Mutual Research Corporation, Allendale Insurance, Arkwright, and Protection Mutual Insurance.

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Nomenclature

a_{cd}	Constant (m s^{-1}) (cf. equation 2)
A_d	Vent duct cross section (m^2)
A_v	Nominal vent area (m^2)
c_f	Friction factor
c_s	Vent panel shape factor
c_α	Head loss factor
K	Effective normalized peak rate of pressure rise (bar m s^{-1})
K_{st}	Normalized peak rate of pressure rise from laboratory tests (bar m s^{-1})
L_d	Vent duct length (m)
M	Molecular weight of unburnt mixture (= 28.8 kg/kg mole)
n	Number of equal panels on the vented volume
p_e	External pressure (bar)
p_{eff}	Effective external pressure (bar) (cf. equation 4)
p_m	Maximum pressure in unvented explosion (bar)
p_r	Maximum explosion pressure following full vent deployment (bar)
p_{r0}	Value of p_r without panel inertia (bar)
p_{rI}	Value of p_r with panel inertia (bar)
p_v	Vent relief pressure (bar)
p_{vi}	Effective vent relief pressure due to panel inertia (bar)
p_0	Initial pressure in the enclosure (bar)
P_d	Duct perimeter (m)
R	Universal gas constant (= 8314 kg m^2/s^2/kg mole/K)
T_0	Temperature of unburnt mixture (K)
V	Enclosure volume (m^3)
X_r	Filled fraction
Σ_i	($= \Sigma_v^*/(p_m/p_0 - 1)^{5/2}$ inertia parameter (cf. equation 12)
Σ_v^*	Normalized panel mass (cf. equation 11)
Γ	Vent parameter (cf. equation 2)
Γ_r	Vent parameter modified for partial volume effects (cf. equation 6)
Δp_m	($= p_m - p_0$) maximum pressure rise under unvented conditions (barg)
Δp_r	($= p_r - p_0$) pressure rise in vented explosion (barg)
$\Delta p_{r,0}$	Pressure rise in vented explosion without duct (barg)
$\Delta p_{r,d}$	Pressure rise in vented explosion with duct (barg)
Π	Normalized pressure rise (cf. equation 1)
Π_p	Normalized pressure rise modified for initial pressure effects (cf. equation 4)
Π_r	Normalized pressure rise modified for partial volume effects (cf. equation 5)
σ_v	Vent mass per unit area (kg m^{-2})
Φ_d	Duct inertia parameter (cf. equation 9)
Ψ_d	Friction loss parameter (cf. equation 10)

APPENDIX D BIBLIOGRAPHY

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Interfor

Dust Control Method Chart

Date published: April 30, 2012

INTERFOR	Dust Control Method Chart		Last Revision Date: April 30, 2012
Dust Control Method	**Pro**	**Con**	**Best Use/Location**
1. Water misters	• Knocks down airborne dust • Can be timed to work in conjunction with dust source activity	• Water freezing limits use to seasonal • Water pooling/housekeeping issues	• Fine dust at the source • Contained area • Seasonal
2. Water log storage	• Prevents drying-out of logs	• Storage/process imitations based on operation	• Those operations that have ample water storage
3. Sprinklers on log decks	• Wets/washes dust off logs	• Water freezing limits use to seasonal • Water pooling/housekeeping issues	• Log decks and infeeds
4. Wall/Roof fans	• Keeps air moving, so reduces dust settlements • May be constantly run; does not require scheduling	• Ineffective in large areas • Brings in outside conditions (cool: winter, hot: summer)	• Enclosed areas
5. Blow downs	• Immediate, targeted • Can be used to reach most locations, including at elevations	• Labor intensive; slow process • Sweep and shovel must be done as much as possible prior • Ignition sources must be controlled (hot work, etc) • Does not remove dust, just moves it to lower areas • Increases atmospheric dust concentrations during the blow down • Regulate air pressure as appropriate	• High build-up • Elevated horizontal levels and walls
6. Water Hose Down	• Immediate, targeted • Can be used to reach most locations, including at elevations • Wets the dust, lowers airborne dust concentrations compared to blow down	• Labor intensive; slow process • Does not remove dust, just moves it to lower areas • Water freezing limits use to seasonal • Water pooling/housekeeping issues • Electrical equipment restrictions	• Seasonal • High build-up • Elevated horizontal levels • Restricted from electrical equipment

Dust Control Method	Pro	Con	Best Use/Location
7. Sweep/Shovel	• Immediate, targeted • Limits risk of aerating dust	• Labor intensive; slow process	• Areas noted that have build-up that do not reach a level of priority for an engineered control
8. Contract Vacuum Truck	• Immediate, targeted • Can be used to reach most locations, including at elevations • Removes dust without increasing airborne dust concentrations	• Slow process • Limited access • Cannot reach higher locations without extensive scaffolding	• Specific, enclosed small areas
9. Dust Collection Systems	• Removes most volume of dust without the need for manpower/scheduling • Gracon spark detectors • Added cleanout doors the facilitate easier and more frequent cleanout which increasing the efficiency of the system	• Capital required • Not absolute fix • Removes heat	• At source
10. Suction/vacuuming	• Equipment dust vacuuming	• Smaller, higher risk areas	• Electrical equipment
11. Smaller Enclosures	• Contains dust around source, away from larger areas.	• Does not remove dust, only contains • Must work in conjunction with other dust control means (misters, suction, etc) to ensure the airborne dust concentration is within limits	• Around machines
12. Enclosing and skirting conveyors	• Contains dust around source and prevents dust aeration	• Custom design often required	• At drop-off and transfer junctions
13. Sloping horizontal structures	• Keeps dust from settling on horizontal surfaces	• Custom design often required	• High concentration, elevated areas • Limited access
14. Circulating Fans	• Keeps dust from settling so larger exhaust fans or suction may remove dust	• Unproven • Difficult access for maintenance	• Rafter structure
15. Education	• Ensuring the cleanup crew knows the expectations and the risks of not meeting requirements. • Stress to all people on the plant-site to all help with clean-up, controlling risk	• Procedural not engineered control	• All workers

Norbord

Norbord's Combustible Dust Experience

Date published: March 29, 2011

Norbord

Norbord's Combustible Dust Experience

March 29, 2011

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Norbord

- Approximately 2,000 employees
- Based in Toronto, Canada
- North America
  - 9 OSB mills (7 US, 2 Quebec)
- Europe/United Kingdom
  - 2 OSB mills
  - 3 PB/MDF lines
  - 1 added value plant – lamination and RTA furniture

Agenda

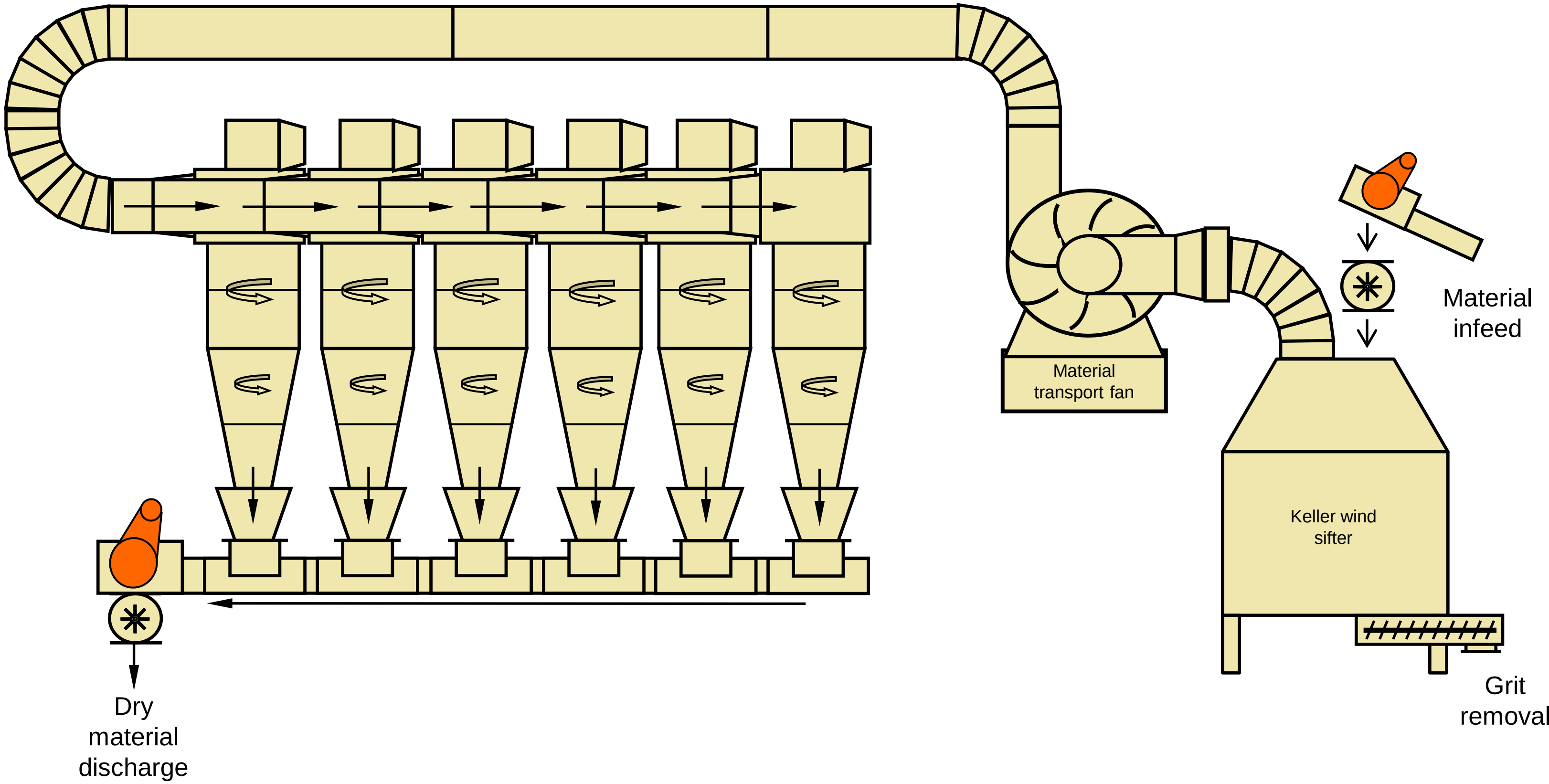
- Norbord’s dust explosion experience – South Molton, England
- Our overall approach to reducing combustible dust risks
- Examples of quick wins in a Minnesota OSB plant
- Experience with vacuum systems in European panel mills

The South Molton PB explosion
A wake-up call

Norbord

PB line explosion - 2004

The South Molton PB explosion
How did it happen?



The South Molton PB explosion
What was the consequence?

Norbord

- Risk to employees
- Prohibition notice from the UK Health and Safety Executive
- Extended downtime – business continuity risk
- Cost - £1.4M to bring the plant back on line
- Immediate ban on the use of compressed air for cleaning and dry brushing
  - Prohibition extended to other Norbord UK facilities

The South Molton PB explosion
What contributed to the explosion?

- Wood dust has the ability to be explosive
- Contamination in the material
- Maintenance was poor
- Philosophy to keep running at all costs
- Housekeeping standards were poor
- No protection systems fitted to the plant to safely vent pressure
- Process interlocking poor

The South Molton PB explosion
What did we do about it?

Norbord

- Plant blow downs replaced with wash downs or vacuum systems
- Dust leak management program put in place
- Explosion protection systems installed
- Process interlocks improved
- Employee awareness training rolled out

- Similar action plans also implemented in Norbord's other EU mills

Norbord's general approach… So far

Norbord

- Treat all dust as potentially explosive
- Increase awareness and training – assign champions
- Keep as much wood in the systems as possible
  - Eliminate historic accumulations
  - Understand where dust is coming from
  - Systematically identify sources
- Reduce or eliminate use of compressed air for cleaning
  - Set guidelines for use
  - Explore and encourage vacuum alternatives
- Developed clear and documented program expectations

Addressing the source of dust
Quick wins in Minnesota OSB

Norbord

- First we developed a Dust Recognition Form
  - Trained employees what to look for and to use the form
- Then we identified the areas that were the largest dust contributors that could be a "Quick Win"
- We created a list of projects that would produce the best results for containment or capturing fugitive dust
- With the help of contractors we are maximizing the use of our air systems
- Within a year we have been able to complete about 20 of our heavy hitters!

Norbord

- **Belt cleaner on the outfeed conveyor for the dryer**, this cleaner has reduced the amount of dust by 75% going to the take up pulley which normally would end up falling on the floor

- **Below the take up pulley**, the amount of dust here has been reduced from one and a half bobcat buckets to a shovel full in 8 hours

- **Outfeed end of the flatline dryer,** we installed the hood from “K” air system to collect the dust from the outfeed end of the dryer

- **Blower for the outfeed end of the dryer**, this is used for separating the dust from the wafers so the hood in the previous slide can collect the dust

- **Rotary dryer outfeed conveyor take up pulley** has been fully enclosed. Clean up now is done from the bottom door, it's just shoveled into a wheel barrow. This keeps a lot of dust from being blown around when doors are open on the building

- **Woodroom tail ends of the wet wafer conveyors**, they have been fully enclosed to keep the dust contained inside

- **Mat conveyor return pan**, this has been closed up and the dust is directed to the bin below. Prevents the dust from being blown around

Vacuum Systems

Norbord

- Inverness OSB
  - Gotland BagVac
  - Portable
  - 12"HG, 1200m^3/hr
  - 4" (100mm) flex hose connection
- Dedicated area specific 4" collection network
- Direct dump to hopper or bag

Vacuuming has its advantages

- Does not compromise existing extraction systems or reduce negative pressure from bunkers/conveyors
- Reduces risk of contaminants from floor making it into floor pick-ups etc.
  - Reduces ignition sources in extraction equipment
- Handles materials only once

… there is much more to do.

Norbord

- Reinforce housekeeping and leak detection routines
  - Continue training and communication
  - Develop habit to identify and fix leaks
  - Establish "acceptable" housekeeping expectations
- Quantify residual risk
  - Characterize/test remaining dust
  - Classify areas
- Plan investments for improvement (dust extraction etc.)
- Review suitability of fire protection and control
  - Review engineering for explosion venting, etc.
  - Limit propagation - explosion detection, inerting systems, etc.

Weyerhaeuser

Combustible Dust Awareness

Date published: Unknown

Combustible Dust Awareness

COMBUSTIBLE DUST

EVERY DAY, DUST IS CREATED AS A BYPRODUCT OF MANY WORK PROCESSES.

WHEN CONDITIONS ARE RIGHT, VERY SMALL PARTICLES OF DUST CAN CATCH ON FIRE AND CAUSE AN EXPLOSION.

EVEN SMALL AMOUNTS OF COMBUSTIBLE DUST CAN BE EXTREMELY DANGEROUS.

SOURCES OF COMBUSTIBLE DUST

AT WEYERHAEUSER'S SITES, POTENTIAL SOURCES OF COMBUSTIBLE DUST INCLUDE:

- WOOD DUST
- PAPER DUST
- PULP DUST
- FLY ASH
- PET COKE

OSHA EMPHASIS

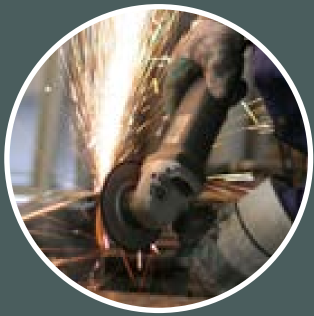
OSHA HAS RENEWED EMPHASIS ON COMBUSTIBLE DUST BECAUSE OF INCIDENTS:

- PET COKE MASSACHUSETTS FOUNDRY DUST FIRE AND EXPLOSION IN 1999 KILLED 3 AND INJURED 9
- COMBUSTIBLE DUST ABOVE SUSPENDED CEILINGS IN A NORTH CAROLINA PHARMACEUTICAL PLANT FUELED A 2003 EXPLOSION THAT KILLED 6 AND INJURED 38
- ANOTHER FATAL DUST EXPLOSION IN 2003 AT A KENTUCKY ACOUSTICS INSULATION MANUFACTURING PLANT LEFT 7 DEAD AND 37 INJURED
- A DUST EXPLOSION AT A SUGAR REFINERY IN GEORGIA TOOK THE LIVES OF 14 WORKERS AND INJURED 10 OTHERS IN FEBRUARY 2008

COMBUSTIBLE DUST HAZARDS

IF YOU WORK IN A SITE WHERE COMBUSTIBLE DUST MAY BE PRESENT, YOU SHOULD BE AWARE OF THE HAZARDS OF COMBUSTIBLE DUST AND THE CONTROL MEASURES TO ELIMINATE BUILD UP OF HAZARDOUS LEVELS OF COMBUSTIBLE DUST.

COMBUSTIBLE DUST EXPLOSION (TYPICAL EVENT SEQUENCE)



INITIAL FIRE STARTS WHEN IGNITION SOURCE CONTACTS DUST BUILD-UP

INITIAL FIRE LEADS TO A SMALL EXPLOSION

SHOCK FROM INITIAL EXPLOSION KNOCKS DUST OFF OF ELEVATED HORIZONTAL SURFACES

DUST FROM ELEVATED SURFACES IGNITES, EXPANDING THE FIRE AND LEADING TO A BIGGER EXPLOSION

MEASURED IN MILLISECONDS !

HAZARDOUS CONDITIONS

CONDITIONS THAT CAN POTENTIALLY TRIGGER A COMBUSTIBLE DUST EXPLOSION INCLUDE DUST THAT IS:

- SMALL IN SIZE (LESS THEN 420 MICRONS)
- DISPERSED IN THE AIR IN SIGNIFICANT CONCENTRATION
- IN THE PRESENCE OF AN IGNITION SOURCE
- CONFINED WITHIN A BUILDING OR EQUIPMENT

HAZARDOUS CONDITIONS—SIZE

- SIZE MATTERS: SMALLER FUEL PARTICLES TAKE LESS ENERGY TO IGNITE (STARTING A FIRE)
- PARTICLES 420 MICRONS OR SMALLER ARE PRIME FOR BEING COMBUSTIBLE DUSTS

Common Material	Size (microns)
Table salt	100
White granulated sugar	450-600
Sand	50+
Talcum (baby) powder	10
Mold spores	10-30
Human hair	40-300
Flour	1-100

SOURCE: FILTERCORP INTERNATIONAL LTD.

CONDITIONS—DISPERSION

WHEN PARTICLES ARE DISPERSED (SPREAD THROUGH THE AIR) FIRES AND EXPLOSIONS CAN BE MUCH MORE SEVERE.

WHY? COMBUSTIBLE DUST EXPLOSIONS TYPICALLY INVOLVE TWO PHASES:

- AN INITIAL SMALLER EXPLOSION AT THE IGNITION SOURCE THAT BLOWS FINE, DRY, SETTLED DUST OFF ELEVATED HORIZONTAL SURFACES, MAKING IT AIRBORNE
- A MORE CATASTROPHIC SECONDARY EXPLOSION WHEN THE NEWLY AIRBORNE FINE, DRY, DUST IGNITES, RESULTING IN AN EXPANDING FIREBALL

CONDITIONS—DISPERSION

TO PREVENT DISPERSION (AND POTENTIAL SECONDARY, MORE CATASTROPHIC EXPLOSIONS) DUST ACCUMULATIONS MUST BE MINIMIZED, ESPECIALLY AT HIGHER LOCATIONS SUCH AS BEAMS, PIPES, OR DUCTS

CONDITIONS—DISPERSION

KNOWING HOW MUCH DUST ACCUMULATES AND COULD BE DISPERSED IS IMPORTANT:

- OSHA CONSIDERS ANY DUST ACCUMULATION IN EXCESS OF 1/32 INCH, COVERING MORE THAN 5% OF THE SURFACE AREA OF THE ROOM, TO BE EXCESSIVE AND A COMBUSTIBLE DUST HAZARD
- WEYERHAEUSER'S BEST PRACTICE IS TO LIMIT DUST BUILD-UP TO 1/8 INCH OR LESS DUE TO THE LIGHTER BULK DENSITIES OF OUR DUSTS

CONDITIONS—IGNITION SOURCES

IGNITION SOURCES CAN START THE INITIAL FIRE. COMMON IGNITION SOURCES AT OUR SITES CAN INCLUDE:

- ELECTRICAL EQUIPMENT
- STATIC ELECTRICITY
- MECHANICAL SPARKS & FRICTION
- OPEN FLAMES
- HEATING SYSTEMS & HOT SURFAC
- TOOLS & VEHICLES
- MAINTENANCE ACTIVITIES, SUCH AS GRINDING AND WELDING

CONDITIONS—CONFINEMENT

CONFINEMENT OF DUST INCREASES THE EFFECT OF AN EXPLOSION.

A SMALL DUST EXPLOSION, WHEN CONTAINED, GENERATES EXTREME PRESSURE THAT CAN LEAD TO A CATASTROPHIC AND DESTRUCTIVE EXPLOSION.

IF DUST CLOUDS ARE IGNITED WITHIN CONFINED AREAS SUCH AS BUILDINGS OR EQUIPMENT, DANGEROUS PRESSURES CAN BE GENERATED, POSSIBLY EXCEEDING THE BUILDING OR EQUIPMENT'S DESIGN STRENGTH.

BEST PRACTICES—HOUSEKEEPING

MAINTAIN A STRONG EMPHASIS ON HOUSEKEEPING AT ALL TIMES TO ELIMINATE THE BUILD-UP OF DUST.

HOUSEKEEPING PRACTICES INCLUDE:

- LIMIT DUST BUILD-UP TO 1/8TH INCH OR LESS ON ANY SURFACE
- CLEAN ACCUMULATED DUST IN A TIMELY MANNER
  - ABOVE-FLOOR-LEVEL AREAS SUCH AS ON MACHINE TOPS, BEAMS, JOISTS, DUCTS, PIPES AND CABLE TRAYS SHOULD BE CLEANED REGULARLY
- INSPECT HIDDEN AREAS FOR DUST RESIDUES AT REGULAR INTERVALS
  - BE CERTAIN TO INSPECT FOR DUST ON AND WITHIN ELECTRICAL EQUIPMENT, SUCH AS ON THE SURFACE OF AND INSIDE MCC CABINETS

BEST PRACTICES—HOUSEKEEPING

- USE CLEANING METHODS THAT DO NOT GENERATE DUST CLOUDS, ESPECIALLY IN AREAS WHERE IGNITION SOURCES ARE PRESENT. VACUUM, WATER WASH, USE WET RAGS OR SOFT BRISTLE BROOMS.
  – EVALUATE THE HAZARDS OF USING WATER NEAR ELECTRICAL EQUIPMENT AND MCC'S (MOTOR CONTROL CENTERS) BEFORE USING WET METHODS
- MINIMIZE USE OF HIGH-PRESSURE COMPRESSED AIR TO CLEAN (BLOWDOWN) DUST ACCUMULATIONS
  – IF DUST IS TO BE BLOWN OFF OVERHEAD AREAS, DE-ENERGIZE ALL ELECTRICAL EQUIPMENT IN THE AREA, AND USE A HOT WORK PERMIT SYSTEM

BEST PRACTICES—HOUSEKEEPING

CONSIDER USING CONTRACTORS THAT SPECIALIZE IN INDUSTRIAL VACUUMING.

CONSIDER INSTALLATION OF A CENTRAL VACUUM SYSTEM.

FOLLOW REQUIRED HOT WORK PROCEDURES INCLUDING REMOVING COMBUSTIBLES FROM THE AREA, PREVENTING SPARKS FROM REACHING UNPROTECTED AREAS, AND POSTING A FIRE WATCH- ALWAYS FOLLOW ALL HOT WORK PERMIT REQUIREMENTS.

BEST PRACTICES—EQUIPMENT INSPECTION

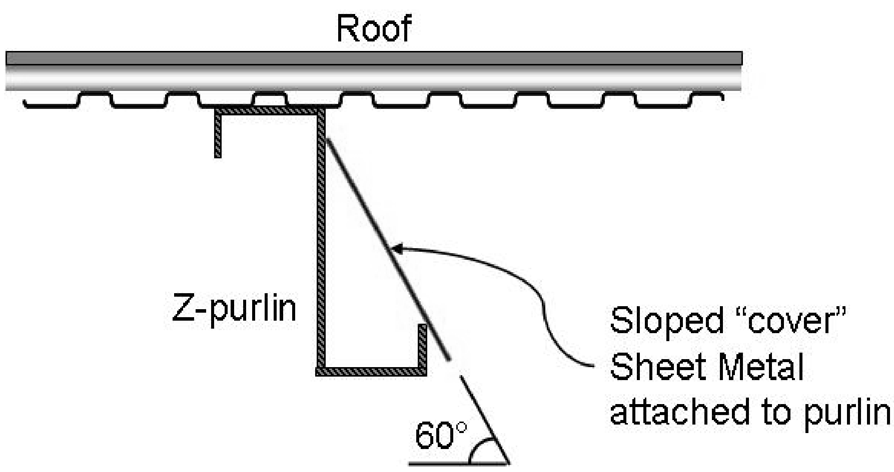
- ENSURE YOUR PROCESS DUST-CONTROL/VENTILATION SYSTEMS ARE PROPERLY MAINTAINED AND REGULARLY INSPECTED, INCLUDING:
  – SOURCE VENTILATION HOODS, BLOWPIPES, DUCTING, CYCLONES, BAG HOUSES, AND ASSOCIATED FIRE, SPARK, AND EXPLOSION SUPPRESSION SYSTEMS

- DUST ESCAPING FROM THESE SYSTEMS INDICATES IMPROPER DESIGN, INSUFFICIENT CAPACITY, BLOCKAGE AND/OR INADEQUATE MAINTENANCE
  – PLACE THESE SYSTEMS ON REGULAR PREVENTIVE MAINTENANCE (PM) INSPECTIONS USING MAXIMO OR SAP

CONTROL MEASURES

IN AREAS WHERE IT IS DIFFICULT TO CONTROL FUGITIVE DUST, TO PREVENT DUST FROM COLLECTING:

- TO THE EXTENT PRACTICAL, PROVIDE HORIZONTAL SURFACES SUCH AS GIRDERS, BEAMS, LEDGES, AND EQUIPMENT TOPS WITH A SLOPED COVER HAVING A SMOOTH FINISH, TO SHED DUST SETTLING OUT OF THE AIR
- SLOPED COVERS SHOULD BE AT AN ANGLE OF AT LEAST 60 DEGREES FROM HORIZONTAL



CONTROL MEASURES

- SEPARATOR DEVICES ARE USED TO REMOVE FOREIGN MATERIALS CAPABLE OF IGNITING COMBUSTIBLE DUSTS, SUCH AS A PIECE OF METAL THAT COULD CREATE A SPARK
- MSDSS FOR MATERIALS THAT COULD BECOME COMBUSTIBLE DUST UNDER NORMAL OPERATIONS ARE AVAILABLE TO EMPLOYEES
- EMPLOYEES ARE EDUCATED ON THE EXPLOSION HAZARDS OF COMBUSTIBLE DUSTS AND THE EDUCATION IS DOCUMENTED

CONTROL MEASURES

- DUST CONTAINING EQUIPMENT SUCH AS CYCLONES BAG COLLECTORS, BINS, FORMERS, AND SILOS ARE LOCATED OUTSIDE OF BUILDINGS WHENEVER POSSIBLE
- BUILDINGS AND EQUIPMENT HANDLING COMBUSTIBLE DUST ARE DESIGNED TO WITHSTAND DUST EXPLOSIONS OR VENT EXPLOSIONS—EXPLOSION VENTING IS DIRECTED TO A SAFE LOCATION AWAY FROM EMPLOYEES
- DUST COLLECTOR SYSTEMS HAVE SPARK DETECTION AND EXPLOSION/FIRE SUPPRESSION SYSTEMS
- THE SITE HAS ISOLATION DEVICES TO PREVENT SUDDEN AND INTENSE FIRES FROM SPREADING BETWEEN PIECES OF EQUIPMENT CONNECTED BY DUCTWORK

CONTROL MEASURES

- A CURRENT EMERGENCY ACTION PLAN IS REVIEWED WITH ALL EMPLOYEES ANNUALLY
- SITE USES A HOT WORK PERMIT PROGRAM
- NON-SMOKING AREAS ARE POSTED WITH "NO SMOKING" SIGNS
- EMERGENCY EXIT ROUTES ARE MAINTAINED PROPERLY AND DESIGNATED WITH SIGNS
- SITE SELECTS AND USES POWERED INDUSTRIAL TRUCKS (E.G. FORKLIFTS) THAT ARE APPROVED FOR COMBUSTIBLE DUST LOCATIONS
- EMPLOYEES ALWAYS USE APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT (PPE)

Additional Resources

- Weyerhaeuser's Combustible Dust website
- Health & Safety Network, 9.6 Fire and Explosion Risk Reduction (Combustible Dust)
- OSHA Combustible Dust Website
- iLevel Combustible Dust Best Practice website

Wood Machinery Manufacturers of America

NFPA 664 Combustible Dusts – Overview

Date published: February 21, 2011

NFPA 664 Combustible Dusts – Overview – does *not* cover hybrid mixtures or gas

The National Fire Protection Association - NFPA® has issued several standards and it can be quite difficult to get a good overview of these standards. WMMA Dust Task Force has developed this tool to help you to get a simplified way to get an overview of the requirements set out in the NFPA standards. It is important for the user to understand that in each case the user must consult with the applicable standard to assure the particular facility/process being assessed comply with the correct standard.

Link to NFPA

Instructions of how to navigate the guide

Click on green arrow to start

Other hyperlinks instructions

Click this link to get back to this page

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If you want to view this guide page by page you can use PgDn and PgUp on you computer

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WMMA companies who can assist

Click on logo to visit website

The requirements of the NFPA standards are complex. The standards have a lot of interrelated references and often segments are confusing and subject to interpretation.

The ultimate responsibility for compliance is the responsibility of the Owner/Operator.

Some issues have to be managed by the Owner/Operator and others he can be supported by a qualified Supplier/Vendor.

To help the Owner/Operator get an overview of the issues and costs related to compliance with NFPA 664 the WMMA Dust Task Force has developed this tool

Owner/Operator		Supplier/Vendor	
1	Awareness and Education	1	Collector Location
2	Housekeeping	2	Isolation
3	Compressed Air Cleaning	3	Spark Detection
4	Maintenance & Repair	4	Enclosureless Dust Collectors
5	Documentation	5	Equipment Documentation – Operating and Maintenance manual
6	OSHA - NEP	6	Designer Qualifications
7	Hot Work Permit	7	Return Air – High Speed Abort
8	Forklifts	8	Return Air – Chemical Isolation
9	Dust Layer	9	Ductwork and Duct Design
10	Authority Having Jurisdiction	10	Hazardous Location
Dust Testing		Resource Material	

Click on subject you want to get more information about

Each rectangle is a hyperlink

Click

on each page to get back here

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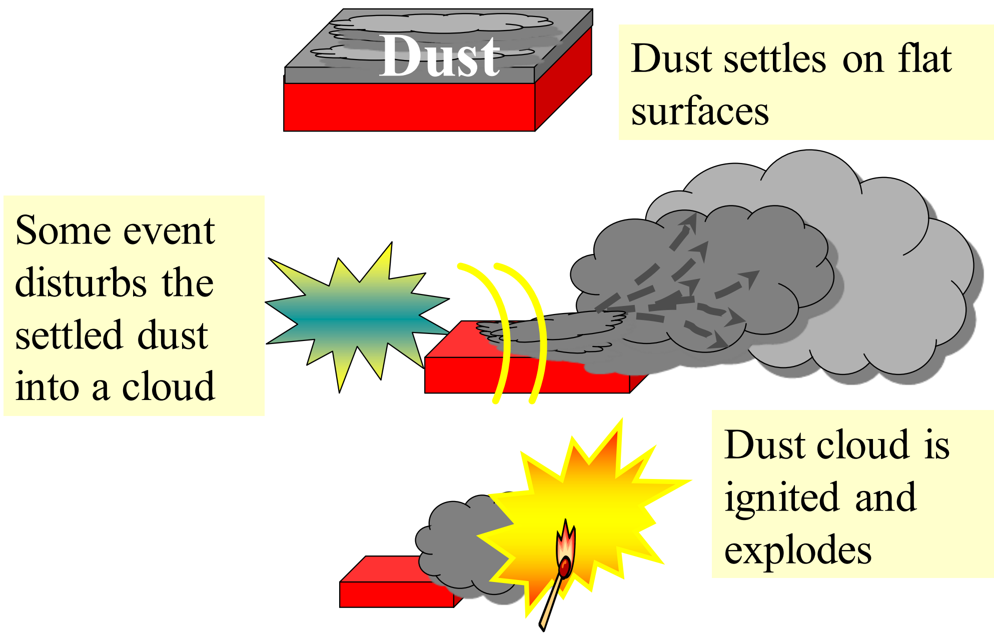
Awareness and Education



Employees need to know

- The safe work practices applicable to their job tasks,
- The overall plant programs for dust control and ignition source control.

Employee training must be

- Before he/she initially start work
- Periodically to refresh their knowledge
- When reassigned
- When hazards or processes change

Lack of awareness of the danger of fires and explosions in wood dust can cause this to happen

Only thing left intact of the plant was the dust collector

Housekeeping

See details in NFPA 664 – Chapter 11
(click here for NFPA 664)

Housekeeping is your first line of defense.

- Work area must be kept clean for dust accumulation
- Machinery should be equipped with engineered dust collection hoods
- Dust accumulation must be kept below minimum layer thickness
- Remove dust from up-facing surfaces i.e. beams, piping and ductwork, machine enclosures etc
- Watch out for hot surfaces and or potential ignition sources

Use proper equipment for housekeeping

- Do not use compressed air for cleaning

Click here for rule on compressed air cleaning

- All hot sources must be shut down and cooled off before commencement of cleaning
- Use only vacuum cleaners certified to work in dusty environment
- Alternative install central vacuum system with vacuum device placed outside

Electric
Explosion proof

Cost:
$8,000 +up

Air
Explosion proof

Cost:
$5,000 +up

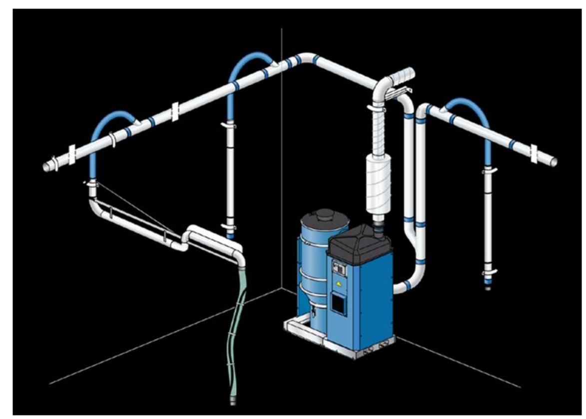
Electric
General duty

Cost:
$3,000 +up

Electric
General duty

Cost:
$4,000 +up

Fixed system



Cost:
$20,000 +up

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Compressed Air Cleaning

Compressed air cannot be used for cleaning.

Exemption

- the area first has been cleaned by vacuum up all accessible areas
- All heat producing components has been turn off
- All lighting fixtures are rated Class II division 2G
- Air pressure is reduced to 15 PSIG (30 PSI)

Maintenance and Repair

Record and maintain for each event

Inspection and Maintenance.

An inspection, testing, and maintenance program shall be developed to ensure that fire and explosion protection systems are in accordance with NFPA 664 Chapter 9.

The inspection, testing, and maintenance program shall be a documented program detailing the equipment inspected, testing performed, test results formulated, and maintenance or repair requirements.

Process controls, equipment, and machinery shall be inspected, tested, and maintained in accordance with the manufacturer's recommended guidelines and safe practices.

In addition to inspecting the fire and explosion protection systems that could be in place, such a program should include, but not be limited to, inspections of dust collection system components, electrical transformers, switchgear and switches, large motors (e.g., greater than 200 hp), hydraulic and lubricating systems, rotating machinery (e.g., debarkers, chippers, mills, refiners, dryers, roll presses, planers, sanders etc.), and deficiencies with electrical devices (e.g., arcing, lighting, and damaged wiring) in and around dust-producing processes. Arcing switches, worn bearings, worn belts, damaged wiring, and misaligned parts, including gears, pulleys, guards, and fairings, have all been identified as being sources of ignition.

Record Retention.

Records of inspections, tests, and maintenance of fire protection equipment and components shall be retained and made available to the authority having jurisdiction upon request.

All records required to be kept shall be retained until their usefulness has been served or until no longer required by the applicable standard or authority having jurisdiction.

Records shall be maintained on-site by the owner/Operator.

Retained records shall indicate the procedure performed (e.g., installation, inspection, testing, training, or maintenance), the organization that performed the work, the results, and the date the work was performed.

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Documentation

- Owner must have complete set of **Drawings and Specifications** for his facility and process – on file for the life of the process

- A **Process Hazard Analysis (PHA)** must be done for the process and updated when changes to the process made – procedural changes or equipment changes – and at least every 5 years.

- Owner must have a **Management of Change Procedure** documented and executed for each facility and process change

- Owner must have **Training** procedures documented - regular re-training at least annually – each activity must be documented

- Owner must have **Inspection and Maintenance** procedures documented - each activity must be documented

- Owner must have **Housekeeping** procedures documented – each activity must be documented.

OSHA - NEP

OSHA Combustible Dust National Emphasis Program

- OSHA implements National Emphasis Program(NEP) for combustible dust. CPL 03-00-008 – Provides policies and procedures for inspecting workplaces that create or handle combustible dusts that could cause deflagration, fire or explosion
- 800 inspections Oct. 2007 – October 2009
  - –164 in wood
  - –123 in food
  - –103 in chemical
- Issued 4,900 violations
  - –74% serious
  - –Average violations per visit – 7
  - –Average $1,300 per serious violation
  - –Only 20% were in compliance
  - –80% dust collectors inside building
- Selection by Industry Type .
  - –Or Employee Complaint
  - –Or Incident

Home

Hot Work Permit

HOT WORK PERMIT ____ **(company name)**

Date __________________ Time___________________________

Name of Person(s) Performing Work ____

Specific Location of Work ____________________________________

Yes No

___ ___ Cutting or welding permitted in an area that has been made fire safe.
___ ___ All movable fire hazards in the vicinity have been taken to a safe place.
___ ___ Guards used to contain the heat, sparks and slag if fire hazards cannot be removed.
___ ___ Floor or wall openings or cracks, open doorways and windows protected or closed.
___ ___ Fire extinguisher available for instant use.
___ ___ Fire watch in areas where other than a minor fire might develop such as around combustible material.
___ ___ Floors swept clean of combustible material for a radius of 35'.
___ ___ Combustible floors have been kept wet, covered with damp sand or protected by fire resistant shields.
___ ___ Welding/cutting done only in areas authorized by management. No welding/cutting in sprinkled building when sprinkler system is impaired or in presence of explosive atmosphere, or in area of storage of readily ignitable material.
___ ___ Dusts and conveyor systems that might carry sparks to distant combustibles protected or shutdown.
___ ___ Cutter/welder is trained in safe operation of equipment and the safe use of the process.
___ ___ Any on-site contractors advised about flammable material or hazardous conditions of which they may not be aware.
Welding or cutting containers:
___ ___ Container thoroughly cleaned and ventilated;
___ ___ Any pipe lines or connections to containers disconnected or blanked.
___ ___ PPE used as needed– e.g., eye protection, helmet, protective clothing, respirator, gloves.
___ ___ Warning sign posted to warn other workers of hot metal.
___ ___ Appropriate ventilation provided.
___ ___ When working in confined spaces a permit has been issued as per 1910.146.

For specific requirements refer to General Industry Standards 1910.146; 1910.252; .253;, .254 and .272 and Construction Standards 1926.803; .350; .352 and .353.

____
Authorized Signature – Supervisor

CSB 5/28/05 Rev 1

Forklifts

OSHA 29 CFR 1910.178 regulates powered industrial trucks in dust areas

When powered industrial trucks are used in CLASSIFIED AREAS they must be rated in accordance with the link below

Link to OSHA
Powered Industrial Trucks

Dust Layer

Deflagration Hazard
– potential for flash fire and explosions

A deflagration hazard shall be determined to exist when either of the two following conditions exists:

1. Layer of accumulated fugitive dust exceed 1/8th inch over 5% of the area or 2,000 ft^2, whichever is smaller.

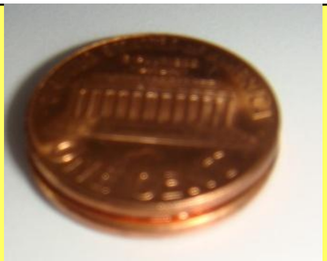
   This layer thickness can be adjusted for "settled" bulk density (on dry weight bases) using following formula:

   $$\text{Allowable thickness, } T_p = \frac{0.125 \times 20\ (lb/ft^3)}{\text{Measure Bulk Density } (lb/ft^3)} \text{ inch}$$

2. Deflagrable wood dust in the air at a concentration in excess of 25% of MEC (Minimum Explosive Concentration) under normal operating conditions

NFPA 664
- 3.2 mm (1/8") thickness

(Bulk density 20 lb/ft^3)



< OK
> NO

Authority Having Jurisdiction - AHJ

See details in NFPA 664 – Chapter 3.2.2
(click here for NFPA 664)

Who makes the final decision about compliance?
It is the Authority Having Jurisdiction or AHJ.

The problem for the Owner/Operator is that the authority is held by several entities and they may work from different guidelines and codes.

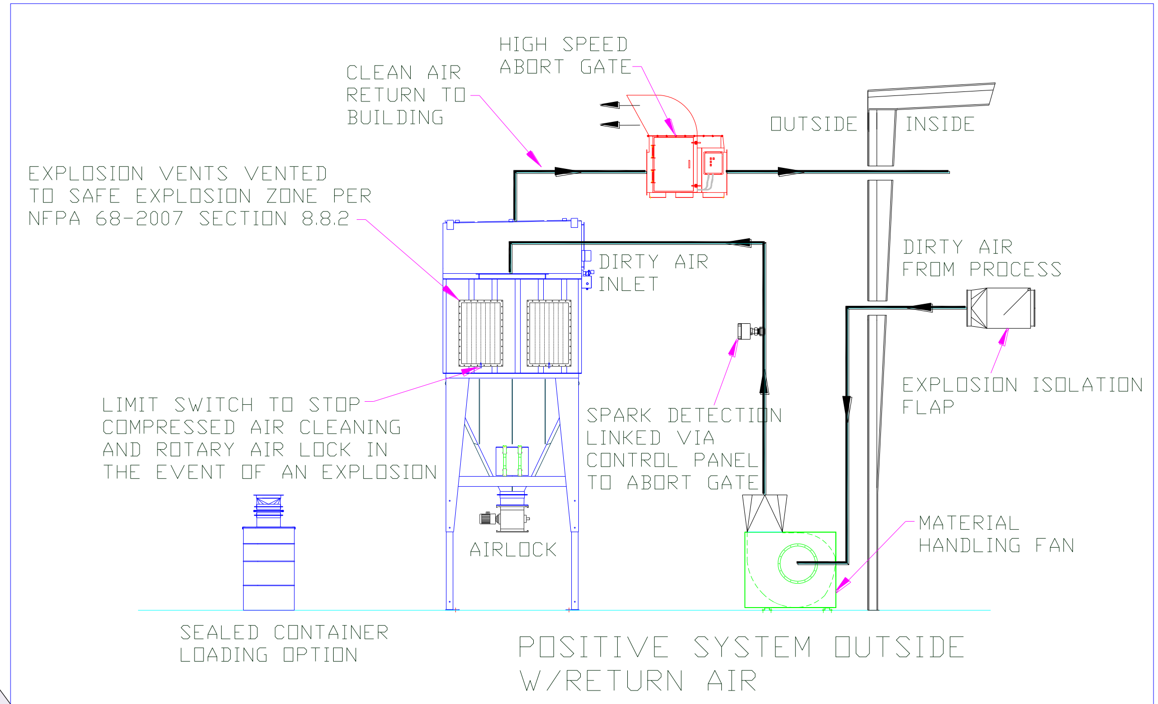
Here are some of the authorities that may apply:

- **OSHA**
- **Local Fire Marshall**
- **Local Building Inspector**
- **Insurance Company**
- **Corporate Mandate or Guidelines**

Ultimately it is the Owner/Operator that must assure and document that he has a safe workplace.

Collector Location

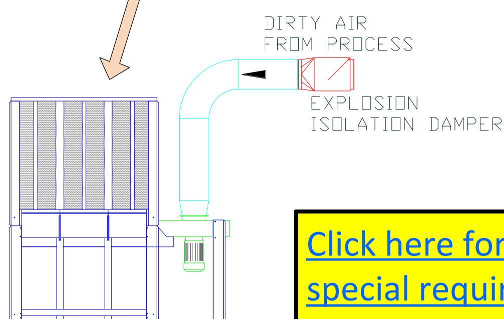
Dust collectors shall always be installed outside with explosion vents exhausting to a safe area

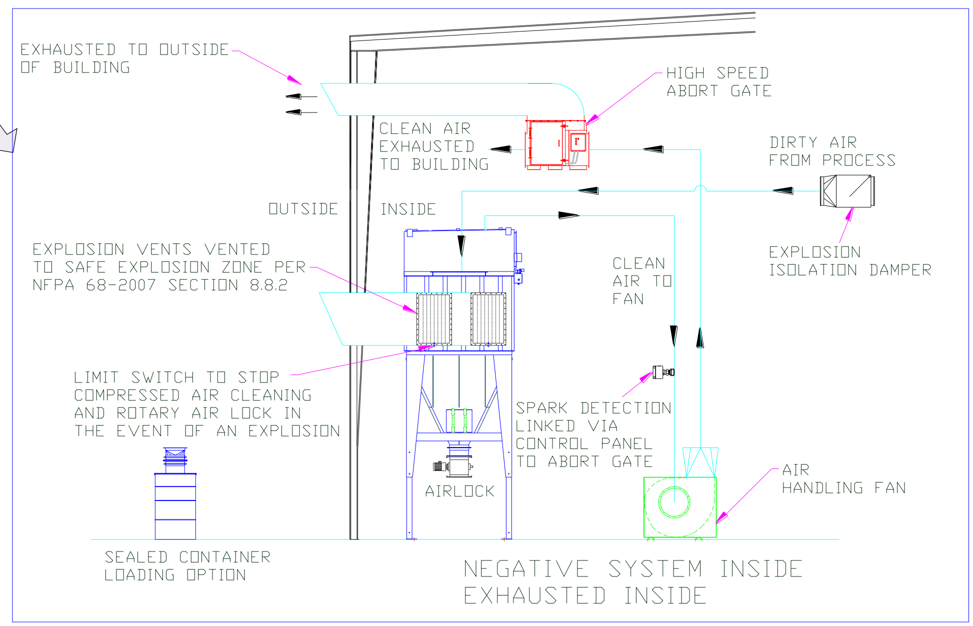


Exemptions:

1. Inside with explosion vent exhausting to and outside safe area (See NFPA 68)

2. Enclosureless dust collector meeting specific requirements





Click here for special requirements for Enclosureless Dust collectors

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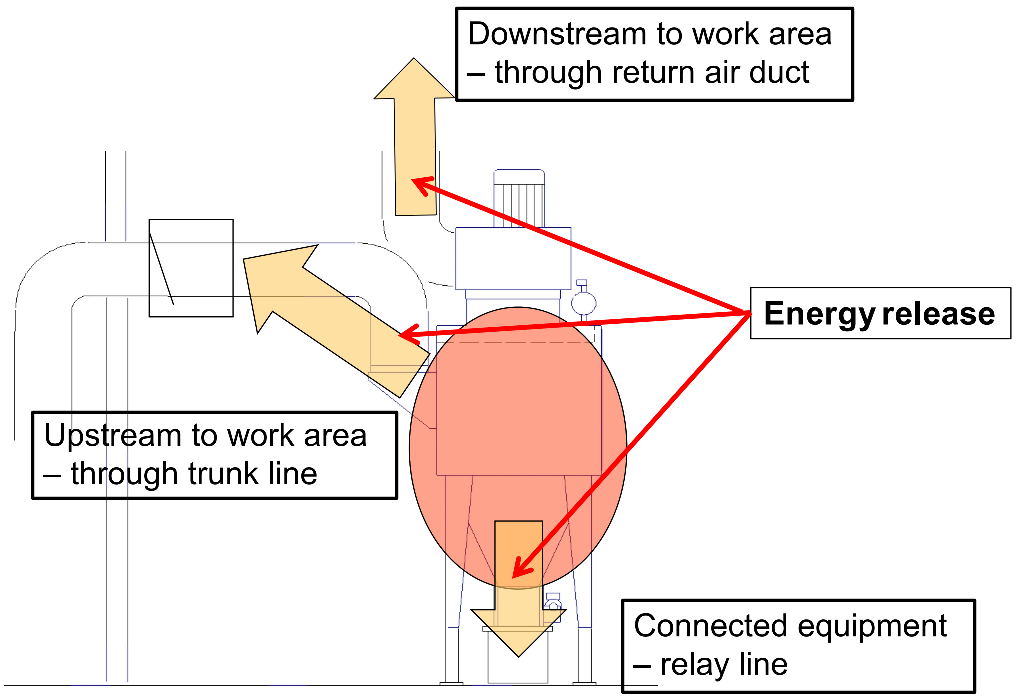
Isolation

If an explosion happen in a dust collector the system must be designed to prevent the transfer of energy to upstream and downstream areas and equipment



Trunk line isolation methods:

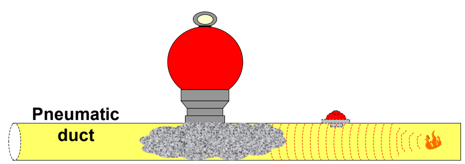
- Explosion Isolation Flap
- Chemical Isolation
- Fast acting Valve

Return air duct isolation methods:

- High speed abort gate
- Chemical Isolation
- Fast acting Valve

Downstream equipment isolation methods:

- Install compliant rotary valve on collector
- RV must stop immediately on event
- Chemical Isolation
- Fast acting Valve
- Note: If enclosed vessel is downstream special engineering required.



Explosion Isolation Flap
Cost:
$2,500 - $8,000

High Speed Abort Gate
Cost:
$8,000 - $20,000+

Chemical Isolation
Cost:
$12,000 - $25,000+

High Speed Gate Valve
Cost:
$20,000 +up

Compliant Rotary Valve
Cost:
$3,000 +up

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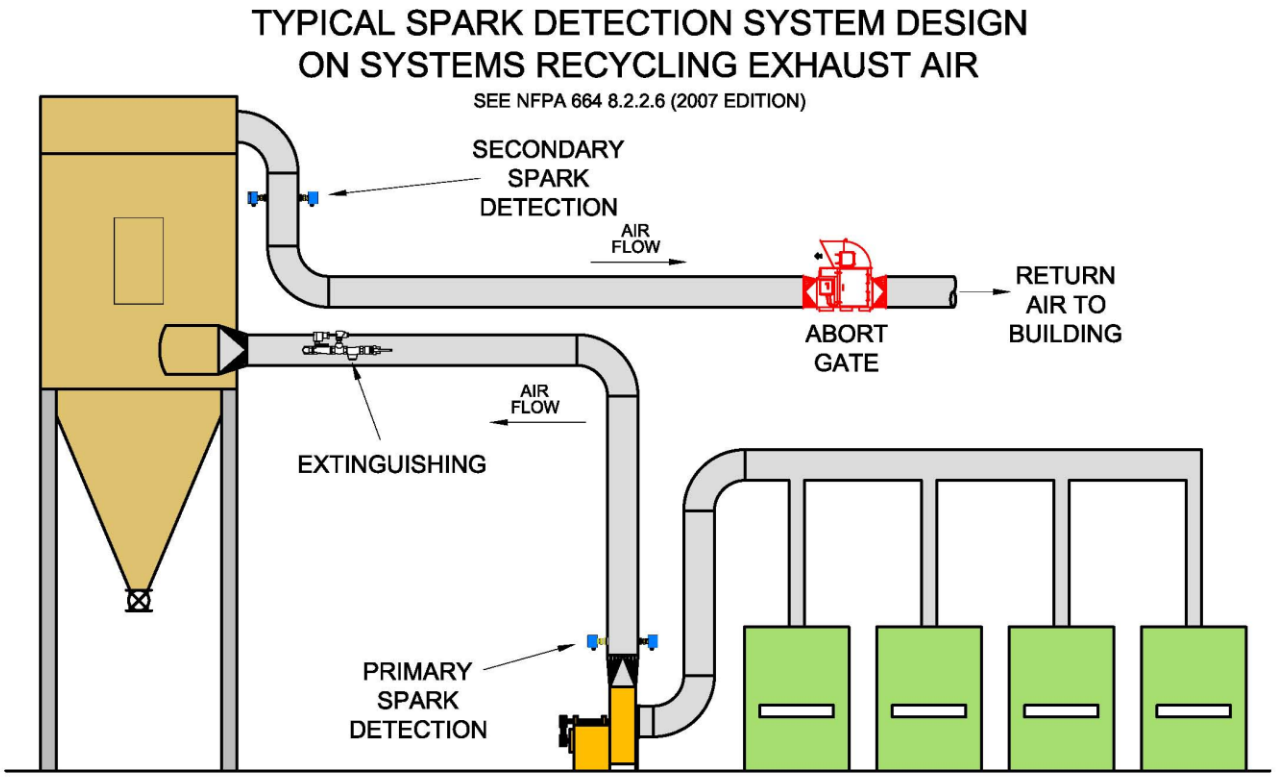
Click here for more info on abort gate

Click here for more info on chemical isolation

Spark Detection



Cost:
$5,000 to $8,000 per zone/duct (<30")+pump if required

Home

Enclosureless Dust Collector

If your dust collection requirement is **below 5,000 cfm** then an enclosureless dust collector that complies with the NFPA664 design practices can be used inside your facility as long as;

- Your are collecting just wood dust – no metal – no lacquers.
- You empty the waste containers at least once daily.
- It is 20' away from where people egress.
- It is 20' away from any other enclosureless dust collectors
- The fan is a TEFC design.
- The collector will not be extracting from wide-belt sanders or other machinery with a mechanical feed.

Equipment Documentation -Operating and Maintenance Manual

Design and submittal documentation:

- Mfg. data sheet & instruction manuals
- Design calc. inc. final reduced (P_{red}) pressures
- General specifications
- Explosion prevention system equipment list
- Sequence of operation for each system
- End user inspection and maintenance forms
- User conformity with applicable standards and the appropriate chapter of this standard
- Combustible material properties and source of data
- Process hazard review
- Process plan view including protected process, placement location of all explosion prevention devices, and personnel work locations
- Process elevation view
- Electrical wiring diagram, including process interlock connection details
- Mechanical installation drawings and details
- Electrical installation drawings and details
- Process interlocks identifying each equipment interlock and function (P&ID)
- Employee training

Mechanical Installation:

- Must follow drawings as system requirements are location sensitive
- Manufacturer's requirements must be followed related to environmental conditions and process material handled
- Safe access for inspection, service and maintenance

Electrical Installation:

- Must comply with NFPA 70, National Electrical Code
- Hazardous areas identified in accordance with NFPA 70, 497 and 499 must be documented and information kept on file for life.
- Wiring and control circuits must be properly isolated and shielded from other circuits
- Control systems shall be installed, maintained, and isolated from the basic process control system
- Minimum functional testing must be performed
- Special requirements for type A and B circuits as described in NFPA 72
- An reliable source of electrical energy shall be used that meets the requirements of the manufacturer

Installation Checkout and Commissioning:

- Prior to start up and use of a protection system following steps are applicable:
- Walkthrough and inspect that the right equipment is installed in the location
- Inspect each components for mechanical and electrical integrity
- Conduct control unit function test
- Make point-to-point wiring checks of all circuits
- Ensure continuity and conditions of all field wiring
- Inspect sensing pathway and calibrate initiating devices
-

- Verify installation of all system components
- Verify system sequence of operation by simulating activation to verify system inputs and outputs
- Conduct pre-validation testing. verify systems interlock, and shutdown circuits
- Complete record of system commissioning inspection, including hardware serial numbers, operational data, air flow readings, power readings, as appropriate
- Conduct user training
- Turn system over to Owner/Operator

Designer Qualifications

Designer and Installer Qualifications – systems to be designed and installed under supervision of qualified engineers who are knowledgeable of these systems and their associated standards

WMMA companies who can assist

Click on logo to visit website

See details in NFPA 664 – Chapter 4.4
(click here for NFPA 664)

Home

Return Air – High Speed Abort Gate

Recycling of exhaust from dust collectors to buildings shall only be permitted if following are met:

1. it is from wood dust only and the collector efficiency is greater that 99.9% at 10 µm

2. the system is equipped with a listed spark detection system installed in accordance with NFPA 72

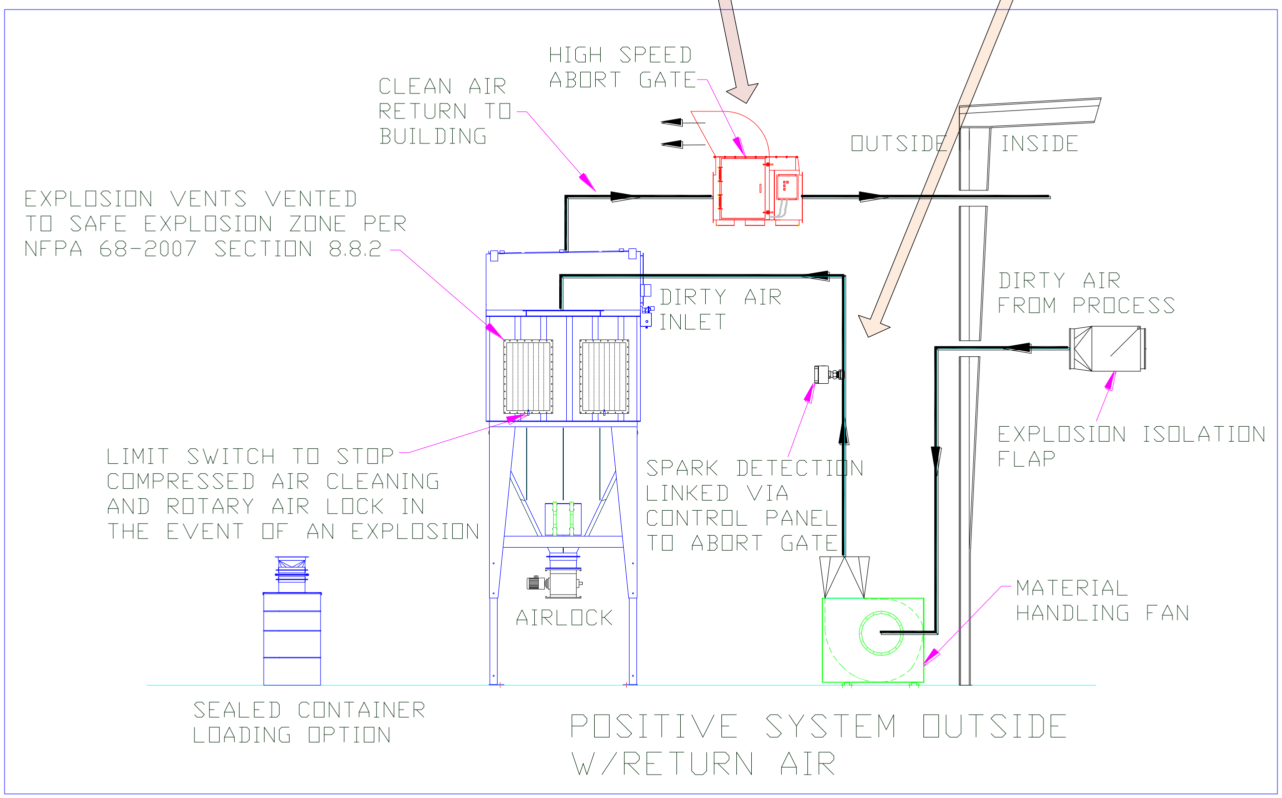
3. the exhaust air duct conveying the recycled air back to the building is equipped with a high speed abort gate w/ manual reset

Click here for more Information on Spark Detection

High Speed Abort Gate Cost:
$8,000 - $20,000+

Alternatively chemical isolation can be used in return air ducting

Click here for more Information on Chemical isolation



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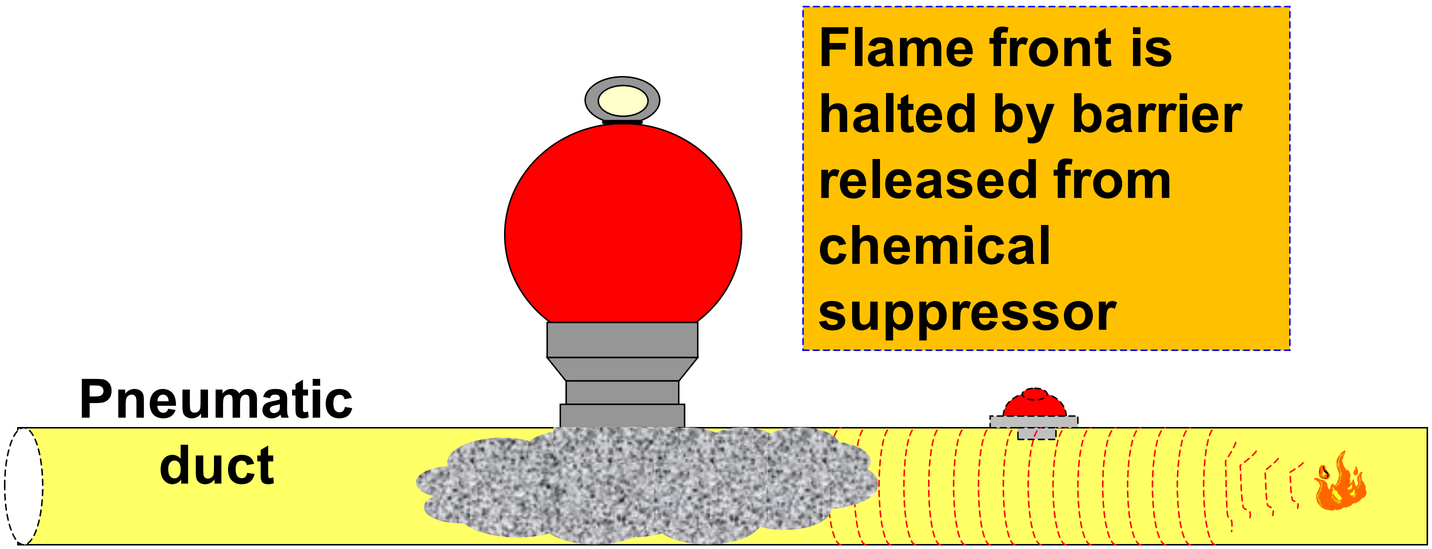
Chemical isolation



Chemical Isolation Cost:
$12,000 - $25,000+

Ductwork and Duct Design

- Processes that generates sparks, flames or hot material i.e. grinding wheels, welding, sanding shall not be manifolded into ducts conveying flammable or combustible material.

- An exhaust system shall be “inherently” balanced – <u>or a means shall be provided to balance the system</u>
  - Inherently balanced means it is designed using the “velocity pressure method”

- The velocity must be high enough to keep the duct interior clean and free of residual material

- Branch ducts shall not be added or removed without redesign of the system.

- Removal of branch duct also require redesign of system to assure required velocity is maintained.

- If the dust is combustible determine the concentration of combustible dust and compare it to the MEC for the product conveyed. (if >25% of MEC explosion relief may be required).

- Changes in duct sizes shall be designed to prevent accumulation of material by utilizing tapered transition with the included angle of taper not more than 30 degrees (preferred) or 45 degrees if necessary.

- When duct passes through physical barriers that is erected to segregate dust deflagration hazards, physical protection shall be provided to prevent propagation of deflagration between segregated spaces.

- Ductwork shall be metallic. Exception: Flexible duct is only permitted at an inlet when movability or portability is required.

- Ductwork shall be bonded and grounded

- Ducts shall be isolated to prevent propagation of deflagration to other vessels.

Home

Hazard Locations

- **The NEC (National Electrical Code) establishes the criteria for electrical safety for "Hazardous Locations" in Article 500 through 504.**
- **The sole concern of NEC is preventing the electrical service from serving as an ignition source or electrical shock hazard.**
- **"Class I Hazard Locations" are areas containing gasses and vapors**
- **"Class II Hazard Locations" are areas containing combustible dusts**

Class II Division 1 areas

A location where:

Combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitable mixtures

Mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitable mixtures to be produced and might also provide a source of ignition through simultaneous failure of electrical equipment, through operation of protection devices, or from other causes

Group E (combustible metals) combustible dusts may be present in quantities sufficient to be hazardous

Class II Division 2 areas

A location where:

Combustible dust may be present in the air in quantities sufficient to produce explosive or ignitable mixtures, due to abnormal operations

Combustible dust accumulations are present but are normally insufficient to interfere with normal operation of electrical equipment or other apparatus, but could become suspended in the air as a result of infrequent malfunctioning of handling or process equipment

Combustible dust accumulations on, or in vicinity of electrical equipment could be sufficient to interfere with the safe dissipation of heat from electrical equipment, or could be ignited by abnormal operation or failure of electrical equipment

None Hazardous areas are "Unclassified" or "general purpose" areas

Home

Resources

Click on subject you want to view

OSHA – Occupational Safety and Health Administration

Combustible Dust

OSHA Advanced Notice of Proposed Rulemaking

NFPA – National Fire Protection Association

NFPA 664 – Standard for the Prevention of Fire and Explosions in Wood Processing and Woodworking Facilities

NFPA 654 – Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and handling of Combustible Particulate Solids

NFPA 68 – Standard on Explosion Protection by Deflagration Venting

NFPA 69 – Standard on Explosion Prevention Systems

FM Global – Insurance Company

Loss Prevention Data Sheet 7-73, Dust Collection Systems

Loss Prevention Data Sheet 7-76, Prevention and Migration of Combustible Dust Explosions and Fires

Congress

US Chemical Safety Board

Linkedin – The Combustible Dust Forum

Building Code Reference Library

Combustible Dust Policy Institute

Imperial Sugar Company Dust Explosion and Fire

Dust Testing

As part of the Process (Hazard) Analysis as outlined in NFPA 664 Chapter 4.2 the Owner/Operator must establish the severity of a potential explosion in the materials handled in the process.

Chapter 4.2.2 says:
"The design of systems and facilities that handles combustible particulate solids shall address the physical and chemical properties and hazardous characteristics of the materials in the hazard area"

This means that sampling of potentially Combustible Dusts must be taken and analyzed and tested to establish its characteristics.

This information is required and used by the designer of the dust handling systems.

The data is established through testing at specialized laboratories using test methods established by ANSI.

OSHA may require its own standardized tests if you are inspected under the NEP program.

Typical tests required on wood dust	
Explosion Severity Test (P_{max}, dP/dt_{max}, K_{St})	Cost: $1500 - $2,500
Minimum Explosible Concentration (MEC)	Cost: $900 - $1,500
OSHA Combustible Dust NEP Testing	Cost: $4,000 - $5,000

Multiple test may be required for each facility/process.

Owner/operator should engage professional assistance for Process (Hazard) Analysis and dust testing

Home

Equipment

Buffalo Turbine

Monsoon Atomizing Misters

Date published: Unknown

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BUFFALO TURBINE

Monsoon Atomizing Misters

Products	Model #
Monsoon Gasoline KB w/ 2 wheel trailer and tongue	BT-CKB4M
Monsoon Diesel KB w/ 2 wheel trailer and tongue	BT-DCKB3M
Monsoon Gasoline KB – Skid Mount (No Trailer)	BT-CKB4SM
Monsoon Diesel KB – Skid Mount (No Trailer)	BT-DCKB3SM
Monsoon Electric Skid Mount	BT-EL08M
Monsoon Skid Steer Hydraulic	BT-HYSS1M
Monsoon 8000	BT-CYC8KM
Monsoon PTO	BT-CPTOM
Monsoon Electric Complete	BT-MEC
Monsoon Gasoline Complete	BT-MGC
Monsoon Diesel Complete	BT-MDC
Monsoon Hydraulic w/ Oscillation	BT-MHO

*Purchase and Rental rates do not include freight and packaging charges.

Purchasing Financing available.

Pricing subject to change

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ISRI
Institute of Scrap Recycling Industries, Inc.
Voice of the Recycling Industry

IHRA MOTORSPORTS
OFFICIAL DEBRIS BLOWER

Horschel COMPANIES

SYSTEM CERTIFICATION
ISO 9001:2000 SGS

Why the Buffalo Turbine Debris Blower?

•BUFFALO TURBINE
Since 1945 Buffalo Turbine has utilized high volume, high velocity turbine style fan for spraying, debris blowing, dust suppression and odor control.

•PERFORMANCE AND RELIABILITY
Designed and Built for the harshest environments while exceeding our customer’s demanding expectations every day

•VALUE
Over 10 different models, Strategically priced, offering great value giving the you the opportunity to utilize the right misting system for your desired application.

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BUFFALO TURBINE MONSOON

Industry First

- ❑Industry First Turbine Style Blower / Sprayer for Dust Control
- ❑Industry First Gasoline Engine Sprayer for Dust, Smoke, Odor Control
- ❑Industry First Diesel Engine Sprayer for Dust, Smoke, Odor Control
- ❑Industry First Air Driven Atomizing Nozzle for Dust, Smoke, Odor Control
- ❑Industry First Wireless Remote Nozzle Control
- ❑Industry First Wireless Remote Throttle Control

ISRI Institute of Scrap Recycling Industries, Inc.
Voice of the Recycling Industry

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BUFFALO TURBINE MONSOON

DUST SMOKE ODOR CONTROL

Applications

- ❑Demolition
- ❑Metal Scrap Recycling
- ❑Waste Transfer
- ❑C&D Scrap Recycling
- ❑Raceways
- ❑Aggregate Crushing
- ❑Aggregate Processing
- ❑Aggregate Recycling
- ❑Landfills
- ❑Torch Areas
- ❑Concrete Crushing
- ❑Asphalt Recycling
- ❑Mining
- ❑Asphalt Milling
- ❑Wood Recycling
- ❑Wood Processing
- ❑Port Loading / Unloading
- ❑Coal Handling
- ❑Excavation
- ❑Controls Most Airborne Fugitive Dust

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BUFFALO TURBINE MONSOON

GYRATORY ATOMIZING NOZZLE "GAN"

Why It Works

1. Driven by high velocity wind generated by Turbine style Blower, at speeds over 5000 rpm.

2. Fluid passes through a Mesh screen at perimeter of rotating hub that immediately pulverizes fluid into uniform spectrum of atomized droplets.

3. <50 – 200 micron size droplets are broadcast 90-150 ft. in neutral wind conditions and begin collecting and trapping dust and other particulates resulting of an immediate reduction of airborne fugitive dust pollution on site.

Benefits of utilizing Fluid for Airborne Dust Suppression

1. **Currently one of the best available control technologies for airborne fugitive dust is to utilize an atomized mist wet suppression method.**

2. **Smaller atomized fluid particles have a greater ability to attract to fugitive airborne dust particulates than larger water droplets.**

3. **Utilizing water based dust control makes it easier and more cost effective to add many types of dust control suppressants and agents if fluid is atomized properly.**

Why "GAN" Better Than Spray Nozzles

- **Spray nozzles, Tee Jets , and other small orifice spraying equipment needs to filter out very small particulates from all water sources and will tend to plug very easily reducing efficiency well before replacement is required.**
- **Buffalo Turbine Monsoon GAN will not plug as long as fluid is prescreened for larger particulates when drawn from non-potable sources. No screening is necessary if drawn from Potable water source.**
- **Spray Nozzles require higher pressures of fluid to cause proper atomization. This is done with booster pumps and other methods which adds expense to purchase and maintain.**
- **Buffalo Turbine Monsoon GAN runs effectively at lower pressures and does not require high pressure pumps. The GAN is easily cleaned in less than 10 minutes as compared to the expense of fine mesh filters and nozzle tips which can be time consuming to clean and costly to replace.**

Monsoon Compared Stationary Spray Systems

- **Stationary spray systems require a large investment for installation, repairs, and once installed are mostly permanent. They use small orifice nozzles that are not effective as pointed out in the previous section on nozzle tips.**

- **Buffalo Turbine Monsoon is very portable and can be moved easily by a single person or by towing. The Oscillation and angle of pitch can be adjusted in accordance with changing wind and other conditions.**

- **The ease of portability of the Buffalo Turbine Monsoon system makes it possible to safely and easily maneuver around a jobsite as it is needed or to relocate to an entirely different jobsite making it the most versatile Dust Suppression system available today.**

Monsoon Compared to Water Trucks and Fire Hoses.

- **Fire Hoses and Water trucks are very effective for saturating areas on the ground or on piles, however not effective for removing particulates from the air.**

- **Will utilize more water than necessary and usually require a laborer to operate which can be time consuming and costly.**

- **Buffalo Turbine Monsoon is very portable and can be operated with an attendant nearby performing other tasks while inspecting the unit periodically.**

- **Buffalo Turbine Monsoon will generate many millions of particulate trapping droplets utilizing much, much less fluid on a daily basis.**

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BUFFALO TURBINE

Gasoline / Diesel Monsoon KB

- Gasoline: 27 HP Kohler Command Engine
- Diesel : 17.4hp Kohler Diesel
- Gyratory Atomizing Nozzle for Spraying
- 12” Round Blower Nozzle for Debris Blowing
- Wireless Throttle and 360° Nozzle Control
- Ability to Skid Mount
- DOT Trailer available
- Two Position Tongue

Gasoline KB Model # – BT-CKB4M
Diesel KB Model # – BT-DCKB3M

www.buffaloturbine.com BUFFALO TURBINE

Monsoon Gas Complete Model # BT-MGC

- 27 HP Kohler Command Engine
- Gyratory Atomizing Nozzle for Spraying
- 12” Round Blower Nozzle for Debris Blowing
- Wireless Throttle and 360° Nozzle Control
- Heavy Duty Steel Construction
- Oscillating Stand w/Three Settings 30-55-80 Degrees
- 12 Volt Oscillation Motor
- 3 Wheel Off Road Removable Trailer package
- Fork Pockets for Moving and Lifting

BT-MGC (Contains Part Numbers)

BT-CKB4SM	Gasoline Monsoon KB Skid Mount
BT-OS12-28.5	12 Volt Oscillation Stand
1695	3 Wheel Trailer Package

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BUFFALO TURBINE

Monsoon Diesel Complete Model # BT-MDC

- 17.4 HP Kohler Diesel Engine
- Gyratory Atomizing Nozzle for Spraying
- 12” Round Blower Nozzle for Debris Blowing
- Wireless Throttle and 360° Nozzle Control
- Oscillating Stand w/Three Settings 30-55-80 D
- 3 Wheel Off Road Removable Trailer package
- Heavy Duty Steel Construction
- 12 Volt Oscillation Motor
- Fork Pockets for Moving and Lifting

BT-MDC (Contains Part Numbers)

BT-DCKB3SM	**Gasoline Monsoon KB Skid Mount**
BT-OS12-28.5	**12 Volt Oscillation Stand**
1695	**3 Wheel Trailer Package**

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BUFFALO TURBINE

Monsoon Electric Complete Model # BT-MEC

- 460 Volt 3 Phase 15 HP Emerson Electric Motor
- Gyratory Atomizing Nozzle for Spraying
- Manual pitch adjustment up to 45 degrees
- Oscillating Stand w/Three Settings 30-55-80 Degrees
- 3 Wheel Off Road Removable Trailer package
- Heavy Duty Steel Construction
- 460 Volt Oscillation Motor
- Fork Pockets for Moving and Lifting

BT-MEC (Contains Part Numbers)

BT-EL08M	Electric Monsoon Skid mount
BT-OS460-22	460 Volt Oscillation Stand
1695	3 Wheel Trailer Package

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BUFFALO TURBINE Monsoon PTO

- Gyratory Atomizing Nozzle
- Garden Hose Connection
- 12 volt Remote Nozzle Control w/ 12ft cable
- Direct Drive Gearbox
- 12” Round Blower Nozzle for Debris Blowing
- Cost Effective
- Lightweight Heavy Duty Steel Construction
- Low Maintenance
- Minimum 20 HP required at the PTO
- Anti Skid Roller

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BUFFALO TURBINE

Monsoon 8000

- Great For Portable Applications with Small Coverage Area
- Gyratory Atomizing Nozzle
- Garden Hose Connection
- 12” Round Blower Nozzle for Debris Blowing
- Cost Effective
- 12.75 HP Kohler Engine or Honda GX320
- 12 volt Remote Nozzle Control w/12ft cable
- Lightweight Heavy Duty Steel Construction
- Two Position Stub Axle
- Two Position Tongue
- Ability to skid mount

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BUFFALO TURBINE

Monsoon Squared

- Industry First Twin Turbine Style Blower For Misting Applications
- Gyratory Atomizing Nozzles for Spraying
- 12” Round Blower Nozzles for Debris Blowing
- 40 HP Kohler Engine
- Independent Nozzle Control
- Wireless Remote Throttle Control
- Wireless Remote Nozzle Control
- Aerospace Polymer Nozzles
- Heavy Duty Steel Construction
- Two Position Tongue
- Ability to skid mount
- Garden Hose Connection

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BUFFALO TURBINE

Hydraulic Monsoon

- Hydraulic Debris Blowers for Skidsteers and Utility Vehicles with Skidsteer quick mount plate.
- Will Quickly Mount to most Makes of Skidsteers.
- Hydraulically driven Blower runs off of any existing equipments auxiliary Hydraulics.
- Minimum 14gpm and Max 25gpm Hydraulic GPM required.
- Available in Basic skid mount
- Gyratory Atomizing Nozzle
- 12 volt Oscillation stand is available.

Monsoon Skidsteer Hydraulic

Hydraulic Monsoon w/ Oscillation

FM Global

Wood Processing and Woodworking Facilities

Date published: May, 2010

WOOD PROCESSING AND WOODWORKING FACILITIES

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1.0 SCOPE

This data sheet gives guidelines for protecting wood processing and wood working facilities. Wood processing facilities manufacture basic construction materials (lumber, veneer, plywood and composite panels such as particleboard, fiberboard, hardboard and oriented strand board). Woodworking facilities remanufacture these basic products into other consumer products such as doors, windows, cabinets, furniture, paneling, etc.

NFPA 664 also covers these occupancies, and is in general agreement with this standard.

1.1 Changes

May 2010. Minor editorial changes were done for this revision.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 Noncombustible construction is preferred.

2.1.2 Process areas which are susceptible to wide-spread dust or resin accumulations on roof framing members should have draft curtains to define the sprinkler operating area. Typical areas with this problem are particleboard raw material screening and storage buildings, wood waste fuel houses, and ceiling areas above hot presses and plywood veneer dryers. Draft curtains should be at least 4 ft (1.2 m) deep, and fit flush with the underside of the roof. For laminated wood beam roof framing with decking flush with the top of the structural members, additional draft curtains are not needed.

2.1.3 Refer to Data Sheet 7-76, *Prevention and Migration of Combustible Dust Explosions and Fires*, for other general construction criteria for facilities which have a dust explosion potential.

2.2 Protection

2.2.1 Water supply quantity, flow, and pressure requirements will vary according to yard storage and special hazard protection needed at each facility. Thorough review of this and other referenced data sheets should be done to determine the greatest demand.

2.2.2 Two-way hydrants should be located throughout the plant site in accordance with Data Sheet 3-10, *Installation and Maintenance of Private Fire Service Mains and Their Appurtenances*. All hydrants should have repair gate valves, and hydrants in high traffic or yard storage areas should have substantial barriers to help prevent physical damage. Refer to Recommendation 2.2.8 for hydrant protection of log storage and chip pile areas.

2.2.3 Provide automatic sprinkler protection according to Table 1 throughout all general manufacturing areas (i.e., areas not identified elsewhere in this data sheet as needing special sprinkler protection). Refer to Section 2.3, Equipment and Processes, for sprinkler design criteria for lumber dry kilns, lumber sorters, hardboard humidifying and tempering ovens, or areas containing significant quantities of flammable liquids such as press pits, thermal oil process heating systems, and coating/spraying finishing operations.

Table 1. Sprinkler Demand for General Manufacturing Areas

Density[1,2] gpm/sq ft(mm/min)	*Type System*	*Head Temp[3] °F (°C)*	*Area[2] sq ft (sq m)*
.20 (8)	Wet	286 & 212 (141 & 100)	3000 (280)
		165 (71)	4000 (370)
	Dry	286 & 212 (141 & 100)	4000 (370)
		165 (71)	5000 (460)

NOTES:

[1] Sprinkler spacing should not exceed 100 sq ft (9.3 sq m). Calculations should include 500 gpm (1900 l/min) for hose streams. Duration is two hours.

[2] This table anticipates the presence of scattered, small hydraulic units (100 gal [378 cu dm/min] or less), localized dust accumulations, etc. which can result in sprinkler demands larger than those for low-piled product storage areas. Refer to Data Sheet 7-98, *Hydraulic Fluids*, if large hydraulic systems are present.

When draft curtains are needed (e.g., particleboard raw material screening and storage buildings, wood waste fuel houses, and ceiling areas above hot presses or plywood veneer dryers), the area to be calculated should be the curtained area if larger than the area in this table. When laminated wood beam roof framing is used in lieu of draft curtains, use the area defined by the major laminated beams (2 ft [0.6 m] or more in depth) as the curtained area.

[3] Roof areas over major equipment subject to cyclical heating (e.g., veneer dryers, hot presses, thermal oil systems, large ovens or dryers, etc.) should have sprinklers with glass bulb-type thermal elements. If maximum ambient temperatures are expected to exceed 150°F (66°C), use 286°F (141°C) rated heads. If these high temperatures are accompanied by high moisture content (e.g., dryer and hot press areas, etc.), *do not* use galvanized pipe.

2.2.4 Provide automatic sprinkler protection for indoor wood product storage areas according to Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*, using the commodity classifications listed in Table 2.

Table 2. Commodity Classification of Wood Products

Class I	All GREEN wood products (moisture content = 20 percent or more)[1]
Class II	All DRY wood products (moisture content less than 20 percent)[1]
Class III	All FLAMMABLE-COATED wood products (regardless of moisture content)[2]

[1] The storage configuration (e.g., stuck lumber vs. solid-piled) has little effect on the degree of hazard. The moisture content is the primary factor. If green wood products might be stored for extended periods allowing them to dry (one to three months, depending on climate), design protection for dry wood products (Class II).

[2] Typical products in this category are timbers treated with creosote or oil-based preservatives, asphalt saturated fiberboard (insulation board), etc.

2.2.5 Outdoor storage of wood products (e.g., lumber, veneer, etc.) should be arranged and protected as follows (See Recommendation 2.2.8 for chip and log storage areas):

a) The water supply from all sources combined, including fire department pumpers, should be able to provide the following demand flows at a residual pressure of 80 psi (5.5 bar):

Total yard storage (bd. ft×1000)	*Waterflow (gpm)*	*Waterflow (cu dm/min)*	*Duration (hrs)*
up to 1000	1000	3800	2
1000 to 2000	1500	5700	3
over 2000	2000	7600	4

b) Keep blocks of storage as small as possible so that all areas are accessible for manual fire fighting. Contiguous stack areas should be limited to approximately 10,000 sq ft (920 sq m) with 20 ft (6 m) separation between adjacent stack areas.

c) Provide clear space between large aggregate blocks of storage arranged as above so that no more than 2.5 million board feet is in any one aggregate area. Use Data Sheet 1-20, *Protection Against Exterior Fire Exposure (From Buildings or Yard Storage)*, to determine suitable separation distances between large aggregate blocks of storage.

d) Yard storage should not be located under important structures (e.g., conveyors). Storage is considered to be ‘‘under’’ a structure if it is less than 20 ft (6 m) away horizontally. Where this is unavoidable, provide automatic sprinkler protection beneath the structure on ordinary hazard pipe schedule using 165°F (74°C) heads located 12 ft (3.7 m) on centers. Yard storage should never be located below power lines.

e) Keep separation spaces and areas adjacent to storage free of weeds or other combustibles.

f) Mobile equipment should not be parked or refueled in storage areas.

2.2.6 Large wood chip and fine storage silos or bins should be protected according to Data Sheet 8-27, *Storage of Wood Chips*. Automatic water spray protection is an acceptable alternative to automatic sprinklers, and is preferred if there is a dust explosion potential. Small bins which can quickly dump their contents (e.g., ‘‘clam shell’’ type truck dump bins) do not need internal protection.

For important detached bins or silos where it is not economically practical to provide automatic protection, a fixed manual water spray system connected to a dry standpipe should be provided. A hose connection from the standpipe to a nearby hydrant can provide quick, effective fire fighting capability which is particularly beneficial if the stored material has a dust explosion potential.

Waterspray nozzles in dusty bins or silos should be protected from plugging (e.g., dust caps, plastic bags, or ‘‘poppet valve’’ style nozzles).

2.2.7 Buildings or other important structures should be protected from yard storage exposures by applying Data Sheet 1-20. A minimum separation of 5 ft (2 m) between large blocks of storage and important buildings should be maintained at all times for fire fighting access, even if Data Sheet 1-20 will permit less separation.

2.2.8 Refer to Data Sheet 8-27, *Storage of Chips* and Data Sheet 8-28, *Pulpwood and Outdoor Log Storage*, for protection recommendations for outdoor storage of wood fractions (chips, sawdust, shavings, bark, etc.) and logs, respectively. When storage separations are less than recommended in those data sheets, Data Sheet 1-20 can be used as an alternative method of exposure evaluation. Consider chips and similar materials as a Class I commodity, and logs as a Class II commodity.

2.3 Equipment and Processes

2.3.1 Lumber Sorters

The following recommendations should be completed:

1. Provide automatic sprinkler protection beneath sorters when the floor below is combustible, when the area is not kept clear of combustible debris or when there is a potential for a flammable liquid spill (e.g., hydraulic fluid). Use 165°F (74°C) rated heads on 100 sq ft (9.3 sq m) maximum spacing and ordinary hazard pipe schedule. To prevent damage from falling lumber, locate heads and piping under sorter structural members. Sidewall heads can be used if necessary. These heads do not need to be included in any calculations for ceiling sprinklers.

2. Provide 1½ in. (38 mm) small hose stations in all sorter buildings so that all sides of the sorter can be reached. If the sorter is under an open-sided canopy, adequate hydrant protection will suffice in lieu of small hose stations.

3. Sorters should be emptied as much as is practical during idle periods and debris on the floor below sorters should be removed regularly. Sorters should also be emptied, if practical, if a fire should occur in or adjacent to the sorter.

2.3.1.1 Horizontal Tray Sorters

2.3.1.1 Provide additional sprinkler protection for horizontal tray sorters according to one of the following options (see Fig. 1):

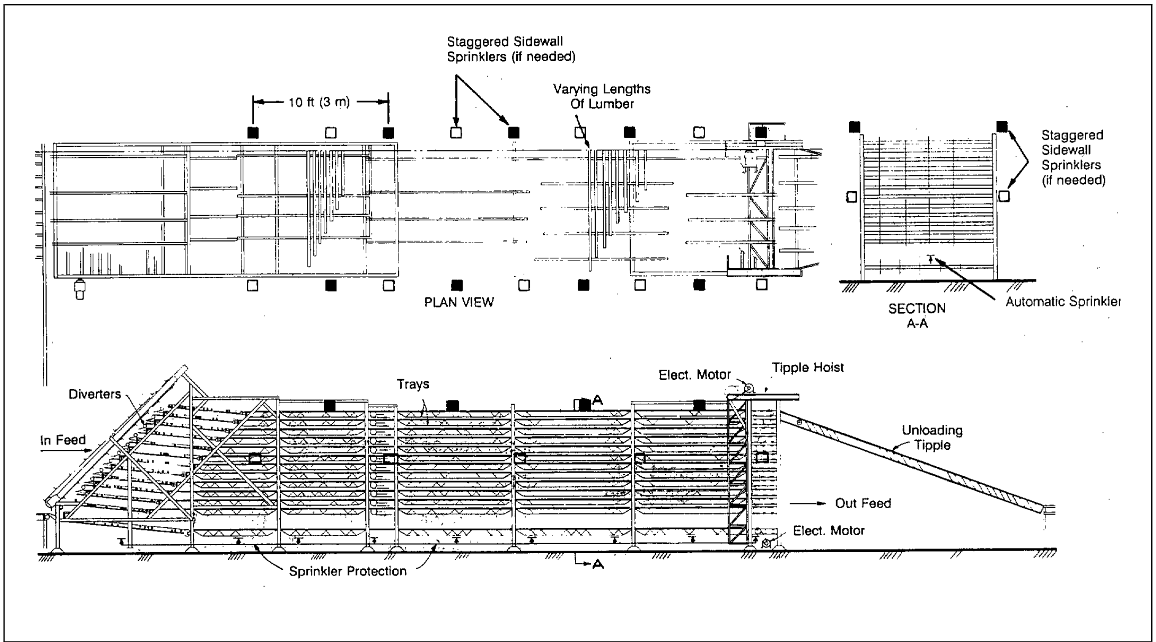


Fig. 1. Horizontal tray sorter.

a) Provide automatic sprinklers at ceiling level designed to protect an ''equivalent'' height of lumber storage (see Section 2.2). An ''equivalent'' height is defined as one foot (0.3 m) for each tray. Use the appropriate commodity classification according to the type of lumber (green or dry) being sorted. In no case should this density/area be less than that recommended for general manufacturing areas as defined in Table 1.

OR

b) When the ''equivalent'' height in part a, above, is the limiting case and the required ceiling density cannot be met, provide ceiling sprinklers designed for general manufacturing areas per Table 1, and supplement them with automatic sprinklers along both sides of the sorter. Each side should have one line of heads at the top tray level, and additional lines spaced every six to eight trays vertically. Use ½ in. (12.7 mm) orifice, 165°F (74°C) rated, horizontal sidewall heads spaced no more than 10 ft (3 m) on lines and staggered vertically and side-to-side. Hydraulically design the sidewall heads to provide a minimum pressure of 20 psi (1.4 bar) when flowing the 10 most remote heads (five on each side). Balance this demand with the ceiling sprinkler demand.

c) The above ceiling protection should extend over and for 20 ft (6 m) beyond the sorter.

2.3.1.2 Diagonal and Vertical Bin Sorters

2.3.1.2.1 Provide ceiling-level automatic sprinkler protection designed to protect indoor lumber storage the same height as the maximum height of lumber which can accumulate in the vertical or diagonal bins (see Fig. 2). In no case should the ceiling density/area be less than that recommended for general manufacturing areas as defined in Table 1.

2.3.2 Dry Kilns

2.3.2.1 Provide automatic sprinklers throughout dry kilns as follows (see Fig. 3):

a) Provide sprinklers over the lumber loads to protect an *equivalent* height of dry indoor lumber storage. An *equivalent* height is the actual height of the lumber (excluding the kiln cart). The area of operation should be the entire kiln. Heads should be located such that the top and sides of the lumber loads are

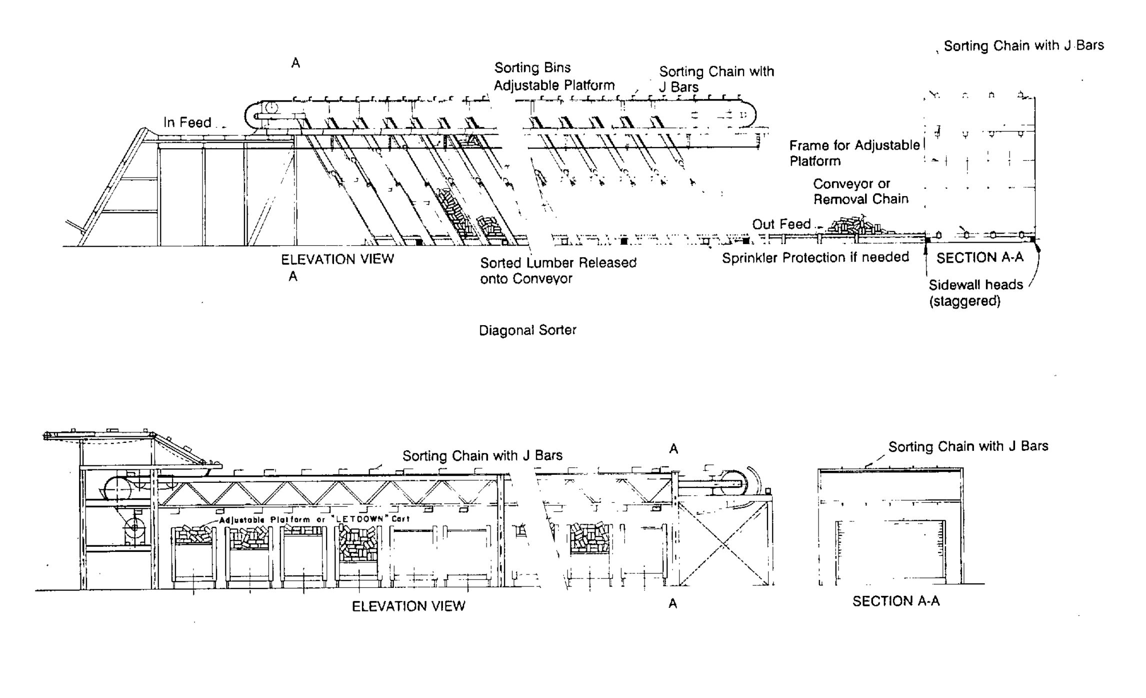


Fig. 2. Diagonal and vertical bin sorters.

wetted. Consideration must be given to obstructions such as heating coils and movable airflow baffles which could block sprinkler discharge when the kiln is in operation. In no case should the density be less than .15 gpm/sq ft (6 mm/min).

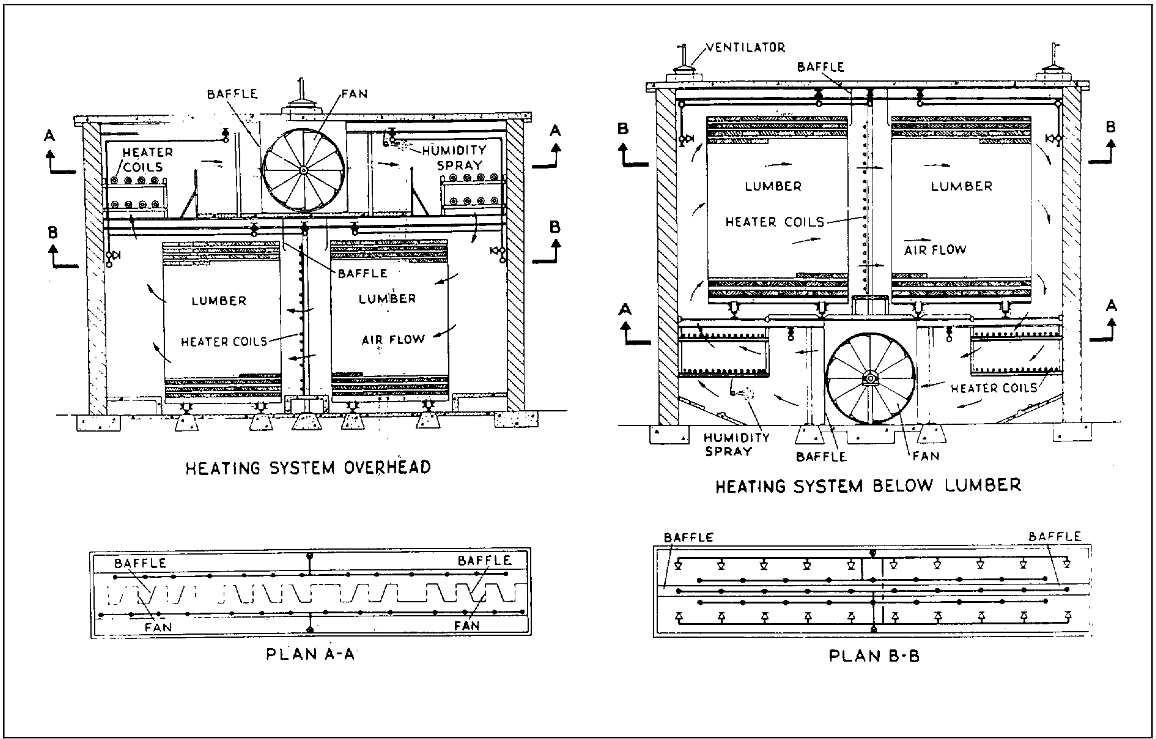


Fig. 3. Typical indirect-heated dry kilns.

Exception: If the kiln is heated by a thermal oil system and the lumber load area is subject to an oil spill or spray fire, a .25 gpm/sq ft (10 mm/min) density should be used. Flow of thermal oil to the kiln should be automatically stopped on sprinkler waterflow or detection of oil loss in the kiln heating loop. Manual shutoff is acceptable where alarms for sprinkler waterflow and loss of oil annunciate at an on-site constantly attended location, the oil isolation valve is readily accessible and not exposed by a kiln fire, and the emergency response team includes a person assigned to this task.

b) Provide automatic sprinklers throughout the fan plenum space on 130 sq ft (12 sq m) maximum spacing. Hydraulically calculate these heads to provide .15 gpm/sq ft (6.1 mm/min) over the entire kiln.

Exception: If the kiln is heated by a circulating thermal oil system and the plenum space is subject to an oil spill or spray fire, a .25 gpm/sq ft (10 mm/min) density should be used.

Interlock flow of thermal oil to the kiln as described in Part a., above.

c) Assume simultaneous operation of the heads over the lumber and in the fan plenum space. Hydraulic calculations should be balanced for the two operating areas.

d) Calculations should include 500 gpm (1900 cu dm/min) for hose streams. Duration is 1½ hours. It is acceptable to include more than one pump or source to meet the total demand, if necessary.

e) A dry pipe system should be used if sprinkler piping is subject to freezing when the kiln is idle. *Do not* use galvanized piping since the high temperature and humidity will lead to accelerated pipe deterioration.

f) Use sprinkler heads with glass bulb-type thermal elements rated for approximately 50°F (nominal 30°C) above the maximum normal operating temperature.

2.3.2.2 Combustion controls and interlocks should be provided for burners supplying kiln heat in accordance with Data Sheet 6-9, *Industrial Ovens and Dryers*.

2.3.2.3 Roofs or canopies over kiln outfeed cooling areas (dry lumber) and infeed areas (green lumber) should have the same automatic sprinkler protection as indoor lumber storage of the same height. If no roof exists, evaluate the exposure to the kiln the same as any other yard storage.

2.3.3 Veneer and Fiberboard Dryers

2.3.3.1 Provide automatic deluge water spray protection for all multi-tiered (more than two tiers) dryers processing plywood veneer, fiberboard, etc., where the moisture content of the material being dried is reduced to 40 percent or less, or where fines and other combustible residues can collect on interior surfaces. (Small veneer dryers with only one or two tiers and good internal housekeeping do not need internal protection.) The following design criteria should be used (see Figs. 4 to 14):

a) Design systems to provide a minimum pressure of 20 psi (1.4 bar) for the end ¼ in. (6.4 mm) nozzles to ensure an adequate spray pattern. For the ½ in. (12.7 mm) orifice open sprinklers normally provided in air plenums and in exhaust stacks the end sprinkler pressure should be at least 7 psi (0.5 bar). Design by density is impractical because of the multi-tier nozzles arrangement in most dryers.

b) Where two or more deluge systems are provided in long units the water demand should be designed for two systems operating at one time. These units may have water demands in excess of 2000 gpm (7570 cu dm/min).

c) Provide strainers before the deluge valves for nozzles with orifices smaller than ⅜ in. (9.5 mm) to remove wood sawdust, chips or fibers. This is particularly important for system supplied from penstocks, flumes, ponds or rivers.

d) Provide heat detectors or a pneumatic pilot head system to actuate the deluge system. Figures 5, 6, 8 and 9 show suggested locations of the detectors or pilot heads. A pneumatic pilot system is preferred where moderate or heavy accumulation of resin is experienced and routine washdown is made using the deluge system or hoses.

e) Interlock the dryer fans and heat source to shut down when the deluge system(s) trip.

f) Provide water traps (Figs. 5, 6 and 9) to prevent air movement from plugging deluge piping with dust and resin.

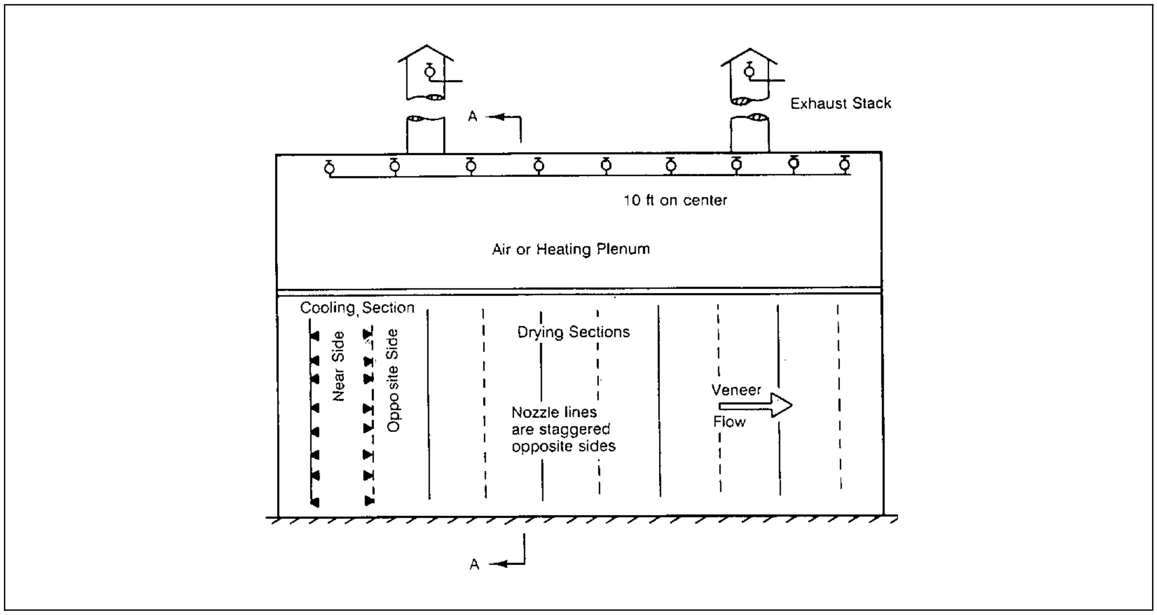


Fig. 4. Typical arrangement of deluge protection for standard veneer dryer. See Fig. 5 for additional protection details.

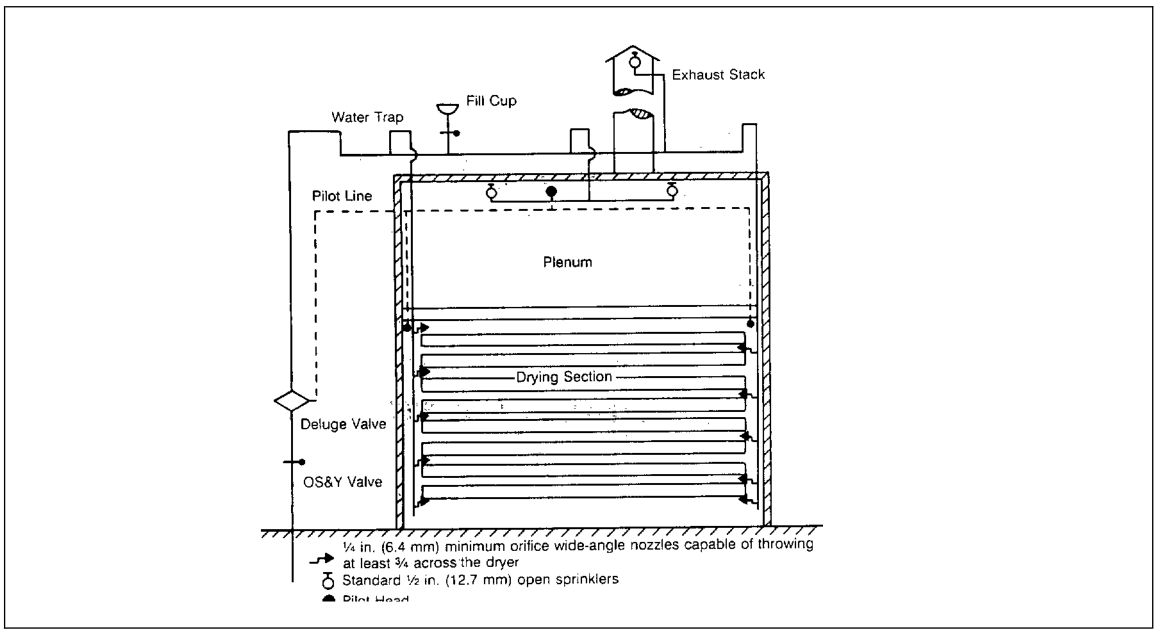


Fig. 5. Typical arrangement of deluge protection for standard veneer dryer. (Section A-A of Fig. 1.)

g) Provide inspection and fill top openings in the traps for weekly inspection of the water level. A mill-use hose should be provided for refill of the traps.

h) Provide open sprinklers in the exhaust stacks supplied by the deluge system.

i) For all deluge systems, locate the control valves for ready access by the operator.

j) Trip test the deluge system regularly to remove accumulated lint and resins in the piping. This should preferably be done weekly as part of the dryer cleaning program, but may be extended to monthly as long as the tests show that nozzle plugging is not occurring.

k) Provide manual-pull stations for the deluge system on both sides of the dryer near opposite ends.

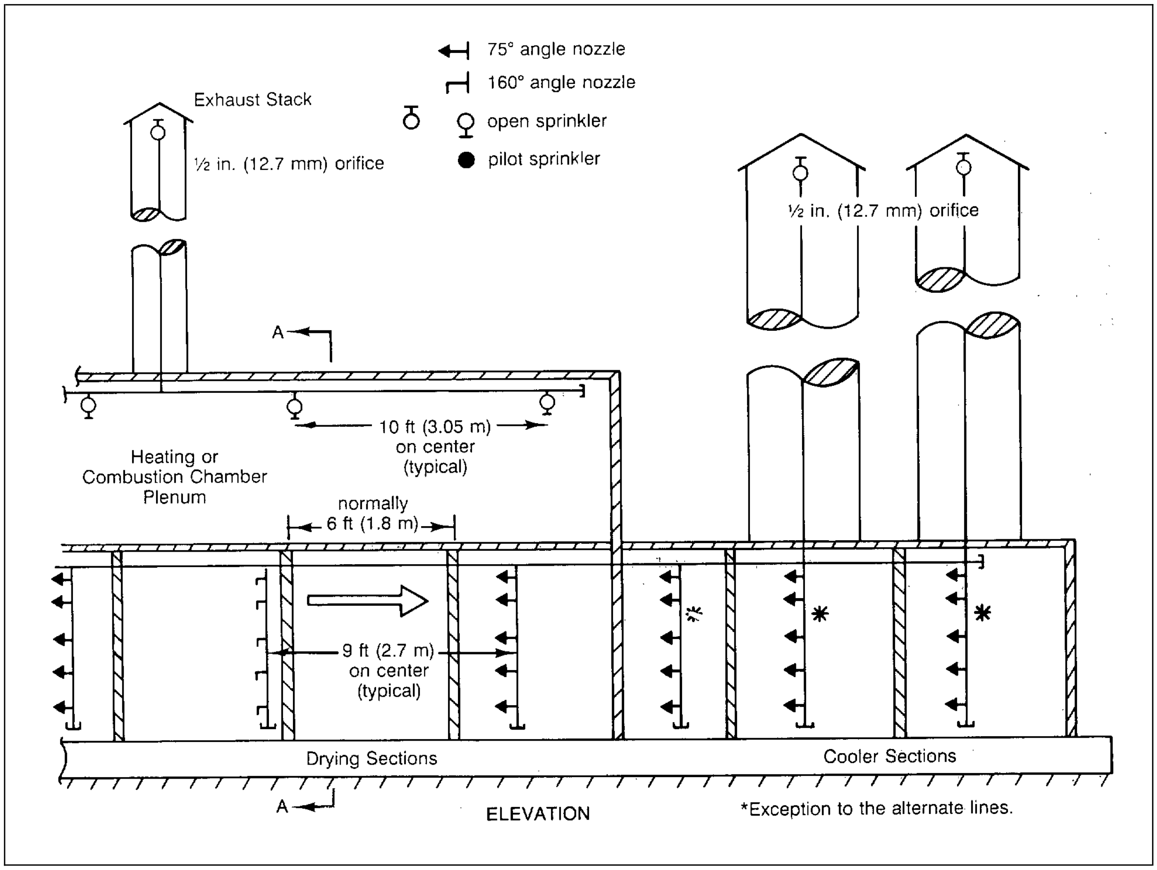


Fig. 6. Typical arrangement of deluge protection for vertical jet-type dryer. See Fig. 7 for additional protection details.

2.3.3.2 Standard multi-tier dryers (Fig. 4) should have nozzles on both sides so that one nozzle on each vertical line is at alternating tier levels and below the bottom tier. The nozzles should be arranged to spray at least ¾ of the way across the tier providing dual coverage in the middle of the unit. Nozzles should be wide angle spaced along the side of the unit providing overlapped coverage in the center of the dryer. The cooling section should have nozzles on each tier level.

2.3.3.3 Where nozzles are arranged to discharge from only one side of a vertical jet type dryer, one nozzle on each vertical line should be located at each tier and below the bottom tier. See Figures 6 and 7. Provide the same type of nozzle on each vertical line, with wide-angle nozzles on one vertical line and narrow-spray nozzles on the alternating line.

2.3.3.4 Provide standard upright open sprinklers in the top and side plenum chambers of both standard and vertical jet-type dryers spaced approximately 9×13 ft (3×4 m) or 120 sq ft (11 sq m) maximum.

2.3.3.5 Provide spray nozzle and open sprinkler deluge system for special vertical jet-type dryers as shown in Figures 8 and 9.

2.3.3.6 Provide roof level sprinkler systems for Wicket type dryers (see Fig. 10).

2.3.3.7 The ceiling areas above these dryers should receive regular cleaning to eliminate accumulations of dust and resin buildup. Particular attention should be given to ceiling exhaust fan openings since these areas will have the largest accumulations, and the fan drives are frequent ignition sources.

2.3.4 Humidifying and Tempering Ovens

Provide automatic waterspray deluge protection throughout the oven. Design the system similar to that used for standard veneer dryers.

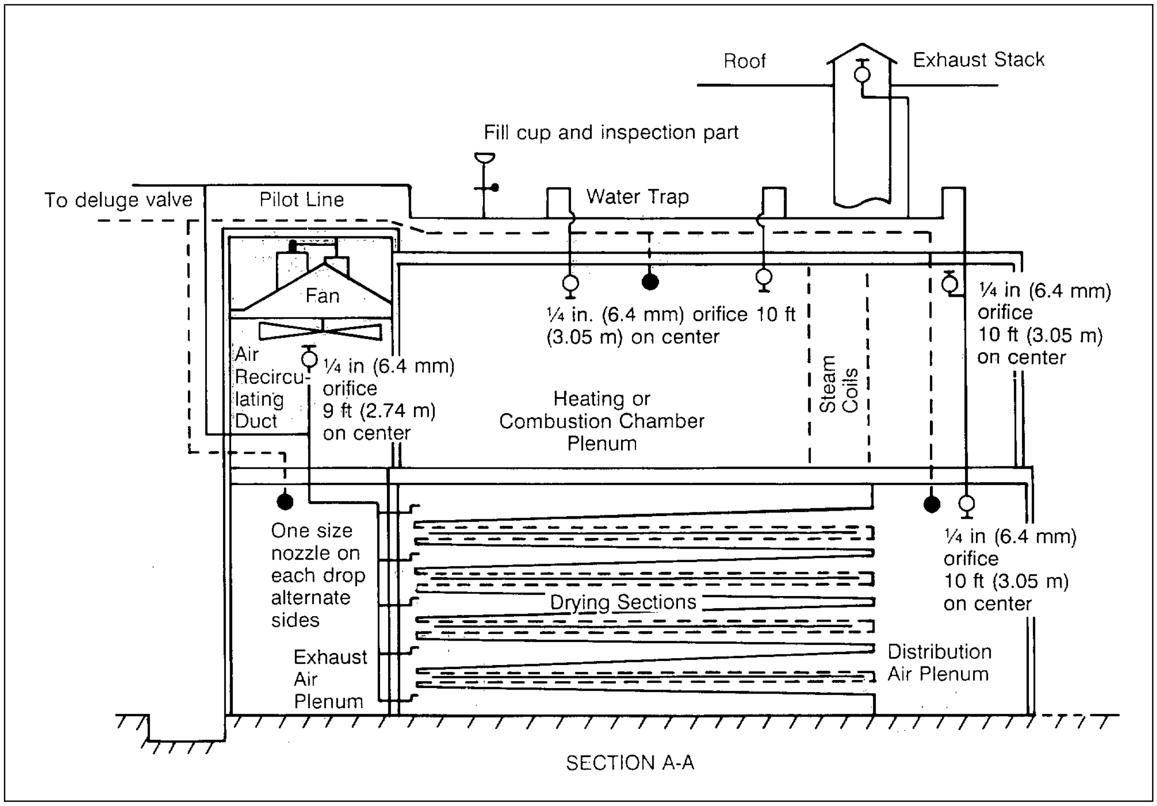


Fig. 7. Typical arrangement of deluge protection for vertical jet-type dryer. Section A-A of dryer shown in Fig. 6.

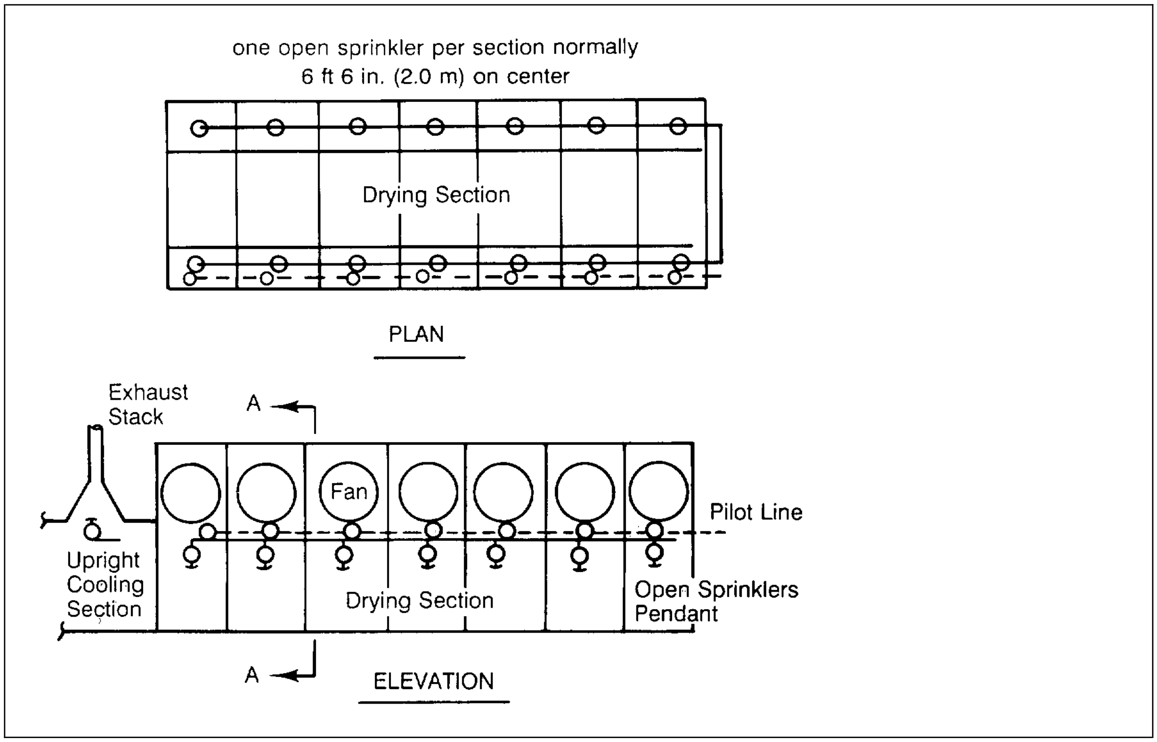


Fig. 8. Typical arrangement of deluge protection for special vertical jet-type dryer. See Fig. 9 for additional protection details.

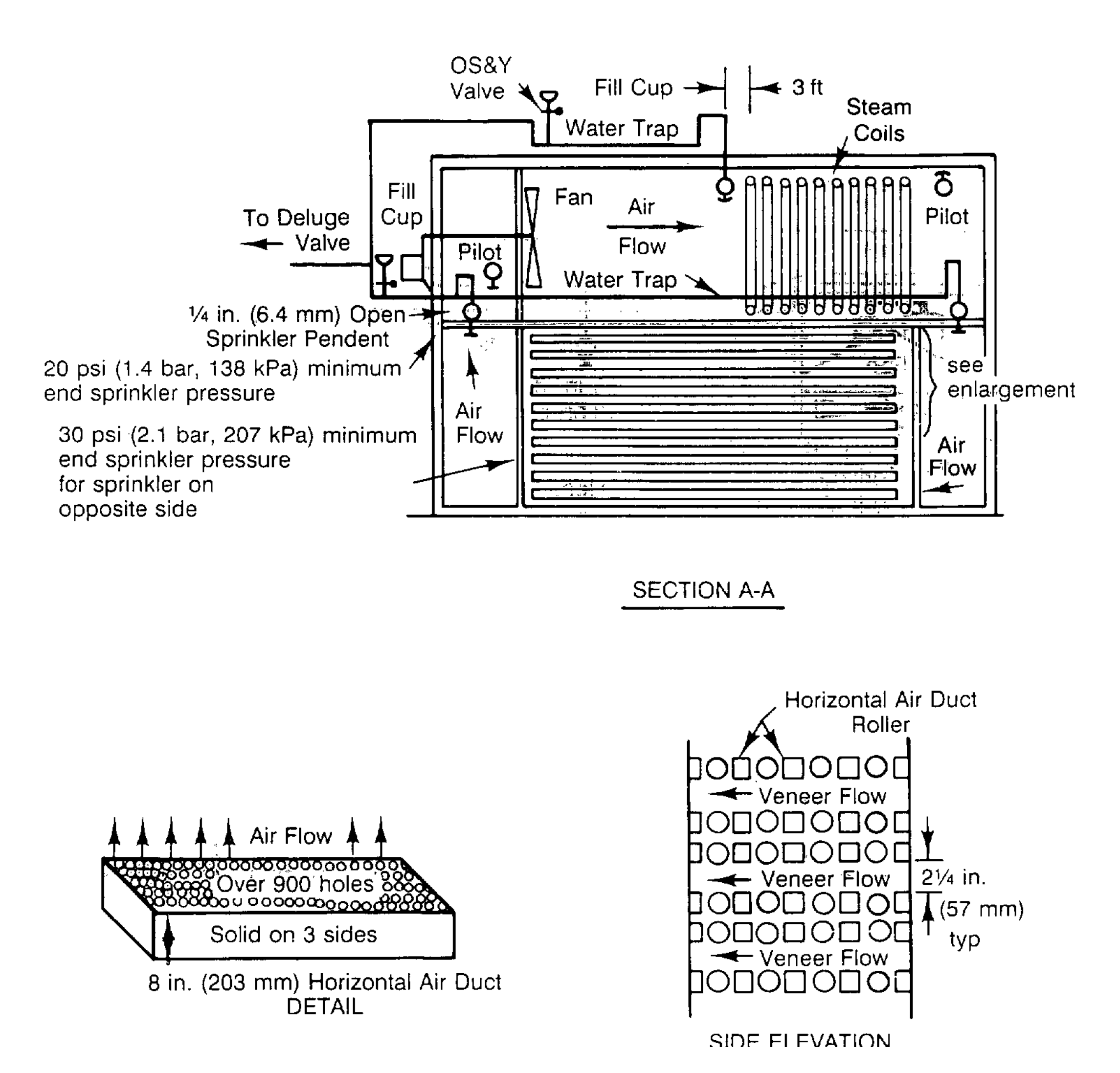


Fig. 9. Typical arrangement of deluge protection for special vertical jet-type dryer.

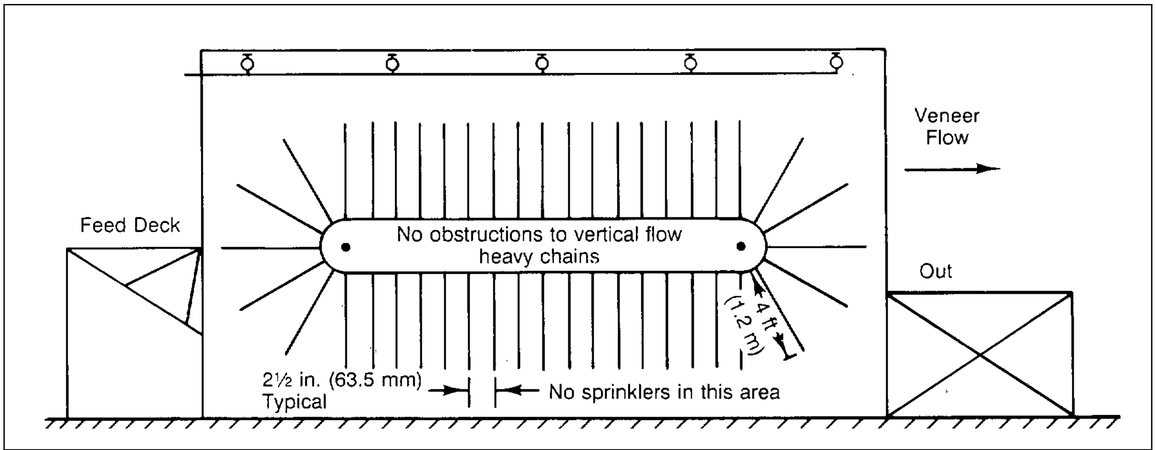


Fig. 10. Typical arrangement of automatic sprinkler protection for wicket-type veneer dryer.

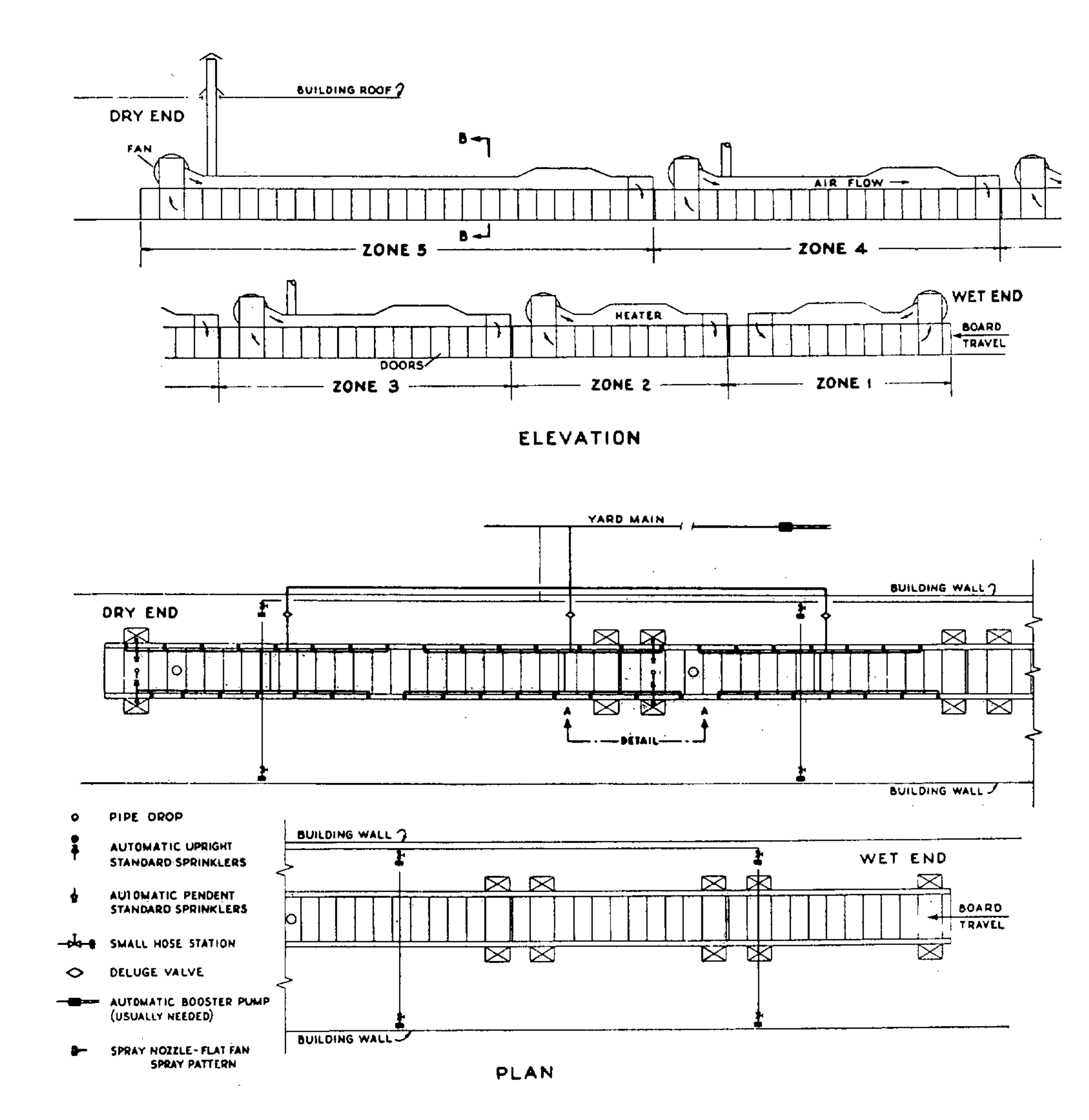


Fig. 11. Typical arrangement of spray nozzle protection for multi-tier wood fiberboard or veneer dryer. Dryers, especially fiberboard dryers, can be up to 500 ft (153 m) long. Symbols apply also to Figs. 12–14 showing additional protection details.

2.3.5 Hot Presses

2.3.5.1 Refer to Data Sheet 7-98, *Hydraulic Fluids*, for protection guidelines for the hydraulic oil reservoir and pumps. Water-based (nonflammable) or FM Approved less-flammable hydraulic fluids should be used where feasible.

2.3.5.2 Provide automatic deluge sprinkler protection for all new press pits which utilize either flammable hydraulic fluid which is not FM Approved or thermal oil heat transfer fluid. Activation should preferably be by combination fixed temperature/rate-of-rise heat detectors, although wet or dry pilot lines are also acceptable. Provide manual trip stations on the operating floor on both sides of the press.

2.3.5.3 Automatic sprinklers on a closed head system are acceptable for existing or new press pits when water-based non-flammable or FM Approved less-flammable hydraulic fluid is used, there is no thermal oil heating, and the sprinkler design is otherwise in accordance with this standard.

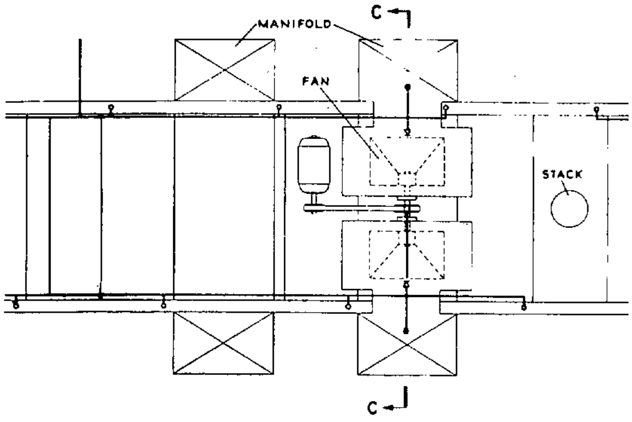


Fig. 12. Detail A-A of dryer shown in Fig. 11.

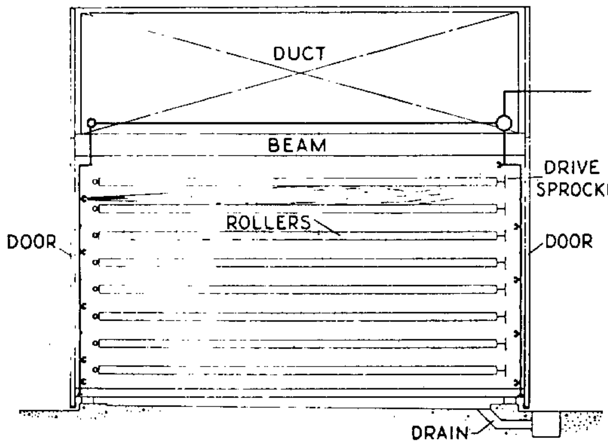


Fig. 13. Section B-B of dryer shown in Fig. 11.

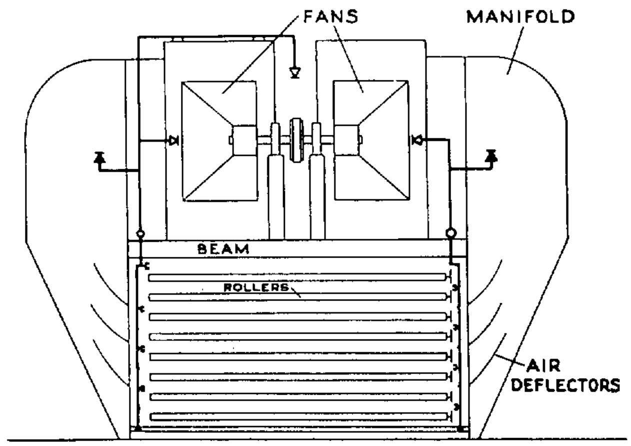


Fig. 14. Section C-C of dryer shown in Fig. 11.

2.3.5.4 Provide sidewall heads spaced 8 to 10 ft (2.4–3 m) apart around the perimeter of the press pit. Horizontal sidewall heads may be needed for larger pits to assure coverage at the center of the pit.

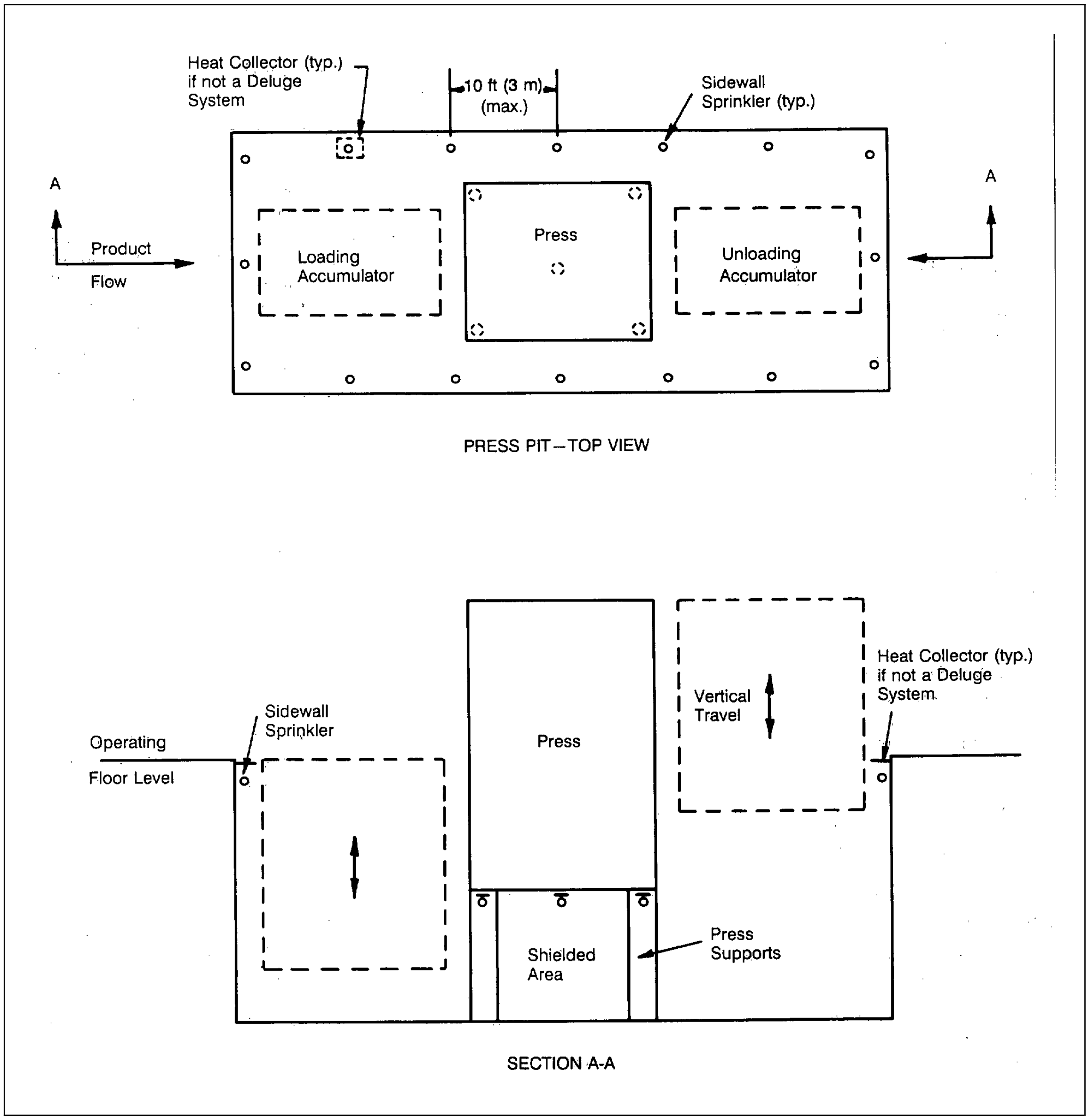


Fig. 15. Wood panel press pit protection.

Provide additional heads in shielded areas under the press which cannot be protected by perimeter sprinklers (see Fig. 15). Open heads on deluge systems should be protected against plugging (e.g., loose fitting plastic bags).

2.3.5.5 Sprinklers should be hydraulically calculated to provide a minimum density of .20 gpm/sq ft (8 mm/min) over the entire pit area. If the press is heated by thermal oil, increase the density to .25 gpm/sq ft (10 mm/min). Include 500 gpm (1890 cu dm/min) in the calculations for hose streams. Duration is two hours.

Note: Presses utilizing flexible wire cauls can have very large pit areas and many shielded areas due to the caul return conveyor system. In these cases, the area requiring this special protection would be defined by the size of a potential oil spill, giving consideration to floor slope, curbing, drainage, etc.

2.3.5.6 Presses supported on steel columns should have column protection in the form or a sidewall sprinkler head pointing inward at the top of each steel column under the press or FM Approved fire resistive coating. Nearby adjacent heads cannot be relied upon to provide column protection.

2.3.5.7 Interlock the press hydraulic system to shutdown on sprinkler waterflow. Presses which will try to open via gravity can maintain pressure on the hydraulic system if the hydraulic pumps are shut off while the press is closed. In these cases it is acceptable to first open the press before the hydraulic system is shut off, but the sequence should be automatic and initiate without delay on waterflow.

Exception: Presses utilizing water-based nonflammable hydraulic fluids do not need this interlock.

For pits protected with dry pipe sprinkler systems, an acceptable alternative to interlocking on waterflow would be to use thermal detection in the pit. This should preferably be combination fixed temperature/rate-of-rise heat detectors, but other simple methods can be used. One such method is spring-loaded switches held open by cables routed around the press pit and under the press. The cables have fusible links no more than 10 ft (3 m) on centers. If a link fuses, the cable releases the spring-loaded switch and shuts down the press hydraulic system.

2.3.5.8 Interlock the press heating system to shut off on sprinkler water flow (i.e., stop flow of steam or thermal oil to the press, or de-energize RF energy heating systems). When the pit is protected by a dry pipe sprinkler system, the alternative methods for interlocking mentioned in Recommendation 2.3.5.7, above, can be used.

2.3.5.9 Press pits should be cleaned regularly to eliminate accumulations of wood waste or oil. Oil leaks should be promptly repaired.

2.3.5.10 The ceiling areas above presses should receive regular cleaning to eliminate accumulations of dust, oil and resin build- up. Particular attention should be given to exhaust fan openings since these areas will have the largest accumulations, and the fan drives are frequent ignition sources.

2.3.6 Thermal Oil Heating Systems

2.3.6.1 Refer to Data Sheet 7-99, *Heat Transfer by Organic and Synthetic Fluids*, for recommendations for thermal oil heating systems.

2.3.7 Rotary Dryers

2.3.7.1 Dryers should preferably be located outdoors. If they must be inside, they should be in a separate building from the main production line, and the cyclone collection system should be located outdoors.

2.3.7.2 Provide a spark detection/extinguishing system and process interlocks arranged as follows:

a) Provide a spark detection/extinguishing system on the main airflow duct between the dryer drum and cyclone. The extinguishing system should activate every time a single spark is detected. It will reset after a few seconds (if no additional sparks have been detected) and the dryer can continue to operate. The spark counting features available in some Approved extinguishing systems can be used to shut down dryers when an excessive number of sparks are encountered, but should never be used as a measure of when to actuate the extinguishing spray.

b) Provide a second "fail-safe" detection point on the duct between the spark extinguishing nozzles and the cyclone collector. Detection at this location should be interlocked to safely shut down the dryer as follows:

i) Isolate the dryer cyclone outfeed to prevent smoldering material from being conveyed into downstream process areas. This should be accomplished by stopping rotary feeders or diverting material to a fire dump via reversing conveyors or diverter gates. Refer to Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*, for effective isolation techniques.

ii) Stop material infeed to the dryer and shut off all dryer heating sources.

iii) Initiate an automatic waterspray deluge in the dryer cyclone. Flush mounted, spring-loaded "poppet" nozzles (similar to those on the spark extinguishing system) are preferred because they are resistant to plugging and do not protrude into the airflow where dried material can collect or cause damage. Automatic sprinklers are less desirable but can be accepted on existing installations. The second detection zone is still needed for isolation purposes, however. Be sure the water has a way to drain out if the cyclone and its supports cannot handle the weight of accumulated water. Steam should not be used as the sole extinguishing medium.

iv) The dryer conveying fan and dryer drum drive should be left running to purge material from the system and help prevent warping of the drum.

c) Rotary dryers which incorporate a ‘‘wind box’’ on the dryer outlet where the majority of the conveyed material drops out should have an additional spark detection zone, isolation measures, and waterspray deluge protection similar to the main cyclone.

d) When the dryer duct on which spark detectors are mounted is subject to resinous accumulations, test lights should be mounted across the duct from each detector. This will permit remote testing to be sure the detector lens has not become blinded by accumulations.

2.3.7.3 Provide high temperature limit switches on the inlet and outlet of the dryer drum interlocked to initiate all of the functions in 2, above, as well as actuate waterspray deluge in the dryer inlet and outlet.

2.3.7.4 For dryers processing particleboard furnish or other material having a similar high concentration of fines, provide explosion venting on the cyclone if it does not exhaust directly to atmosphere and on the windbox (if provided). A vent area equal to the full cross sectional area of the exhaust duct is normally sufficient for cyclone venting. Use Data Sheet 7-76 for windbox venting guidelines. Venting is not required on dryers processing furnish for waferboard or oriented strand board.

Figures 16 to 19 show typical protection schematics and interlock logic for rotary dryers.

2.3.8 Flash Dryers

2.3.8.1 Dryers should preferably be located outdoors. If they must be inside, they should be in a separate building from the main production line, and the cyclone collection system should be located outdoors. Dryer tube explosion vents should have relief ducts extending through the roof or walls to safely vent an explosion outdoors.

2.3.8.2 Protect flash dryers with spark detection/extinguishing systems, isolation methods, and automatic deluge systems in cyclones similar to Recommendation 2.3.7.2 for rotary dryers. Flash dryer protection differs only in that there is no dryer drum. The ‘‘fail-safe’’ detector should also initiate a waterspray deluge at the head end of the dryer tube in addition to the cyclone.

2.3.8.3 Provide high temperature limit switches on the dryer duct at the material inlet and entrance to the cyclone. These detectors will act as backup detection to the ‘‘fail-safe’’ spark detector and should initiate the same functions.

2.3.8.4 Flash dryers should have explosion venting on the dryer tube and cyclone. Vents should be smooth and flush fitting on the inside to prevent material build-up. Refer to Data Sheet 7-76 for venting guidelines.

2.3.8.5 If fiber buildup inside the dryer duct (and subsequent ignition) is a problem, a diverter on the fiber injection pipe to direct fiber to a dump area on initial startup of the material feed may help solve the problem.

2.3.8.6 The dryer duct should be regularly checked for fiber accumulations, and cleaned if needed.

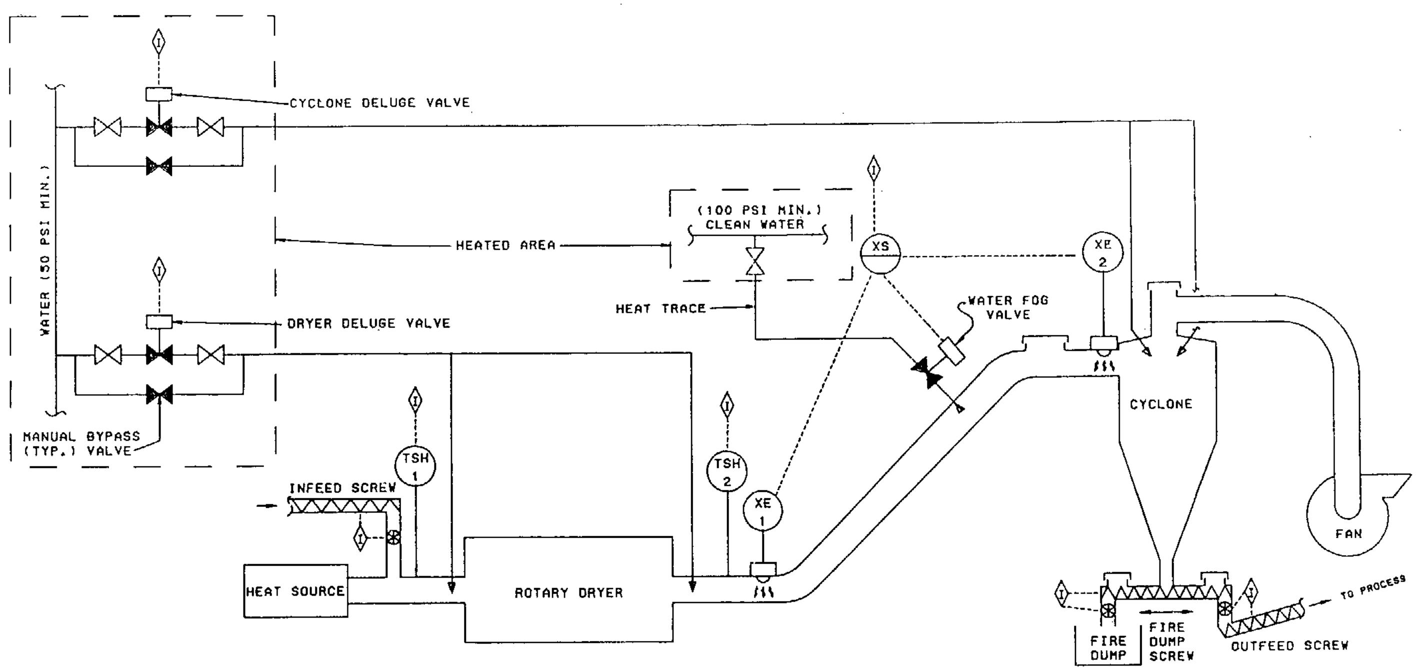
2.3.9 Particleboard Milling Equipment

2.3.9.1 Locate milling equipment in a building separate from the main production forming line building. It is acceptable to incorporate milling and drying equipment in a common facility, but the milling area should be separate from the drying area.

2.3.9.2 Provide explosion protection on each flaker, knife hog or hammermill used in particleboard, medium-density fiberboard, or dry process hardboard material preparation.

Exception: Disk refiners and steam aspirated flakers will not normally warrant this protection.

Protection should consist of either explosion suppression systems or explosion venting combined with spark detection to initiate process shutdown. Protection should extend upstream and downstream from this equipment to the point where a ‘‘choke’’ (e.g., rotary airlock) is provided to isolate the explosion. Refer to Data Sheet 7-76 for additional details.



SYMBOL	DESCRIPTION	LOCATION	SYMBOL	DESCRIPTION	LOCATION
XS	CONTROLLER; INFRARED RADIATION DETECTION/SUPPRESSION SYSTEM	DRYER OPERATOR'S CONTROL ROOM	TSH 1	TEMPERATURE SWITCH, HIGH LIMIT	DRYER INLET
—	NOZZLE, WATER FOG	DUCT BETWEEN DRYER AND CYCLONE	TSH 2	TEMPERATURE SWITCH, HIGH LIMIT	DRYER OUTLET
XE 1	INFRARED RADIATION (SPARK) DETECTOR	DRYER OUTLET	→	NOZZLE, WATER SPRAY	DRYER INLET AND OUTLET, CYCLONE
XE 2	INFRARED RADIATION (SPARK) DETECTOR	CYCLONE INLET		EXPLOSION VENT	CYCLONE INLET & EXHAUST OUTLET, FIRE DUMP SCREW
I	SYSTEM INTERLOCK	NUMEROUS			

Fig. 16. Dryer without windbox.

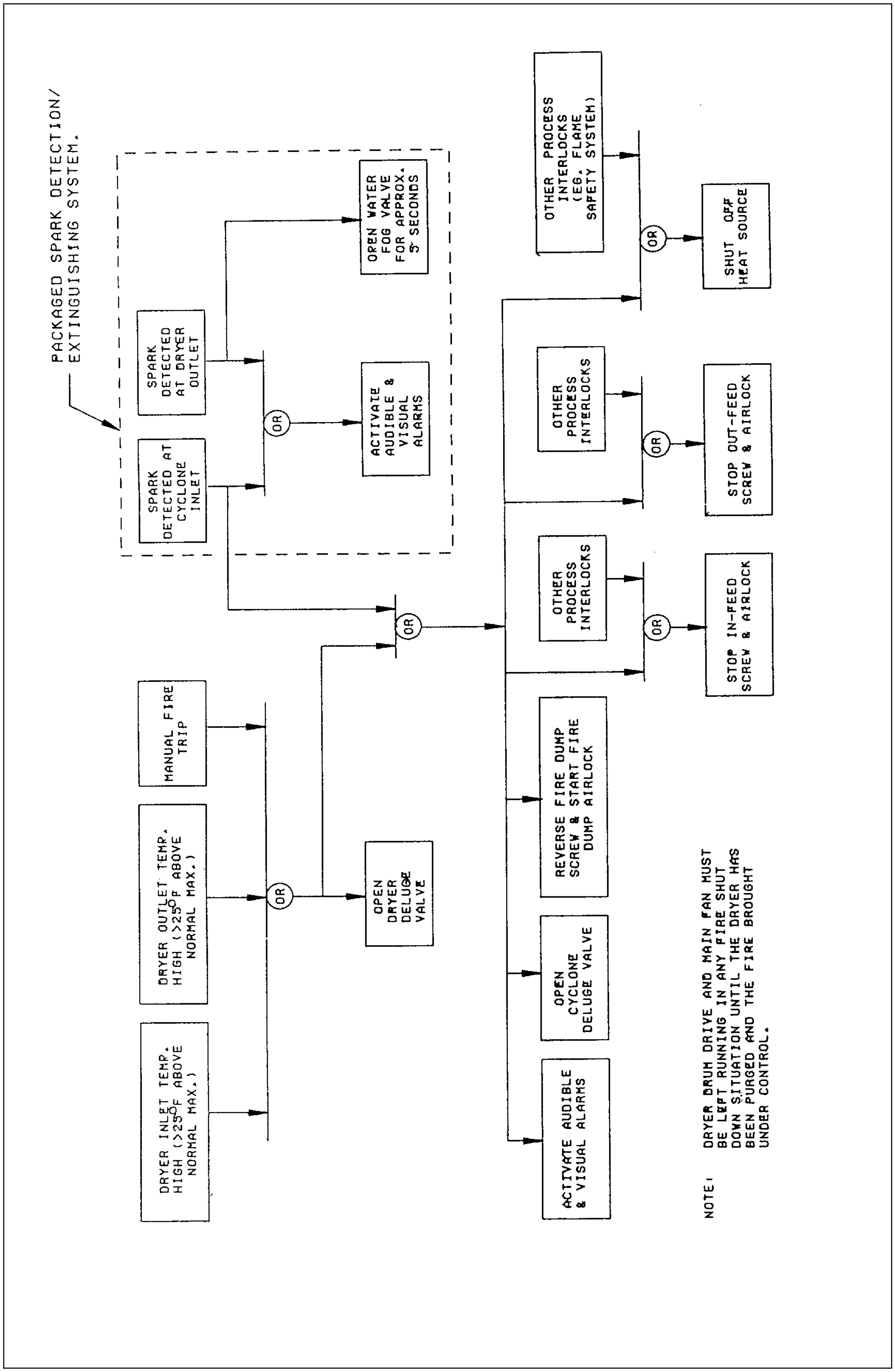


Fig. 17. Dryer without windbox-interlock logic.

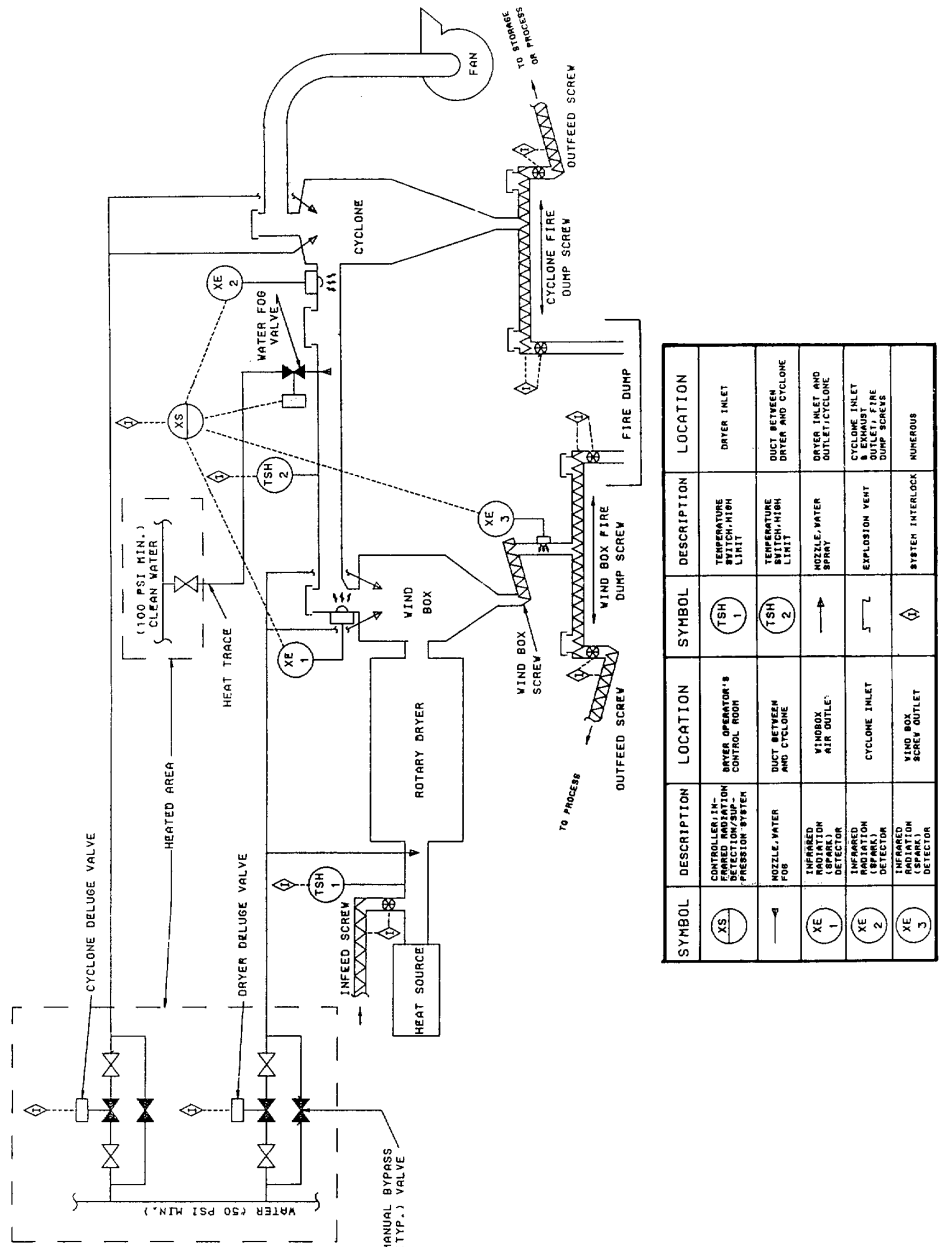


Fig. 18. Dryer with windbox.

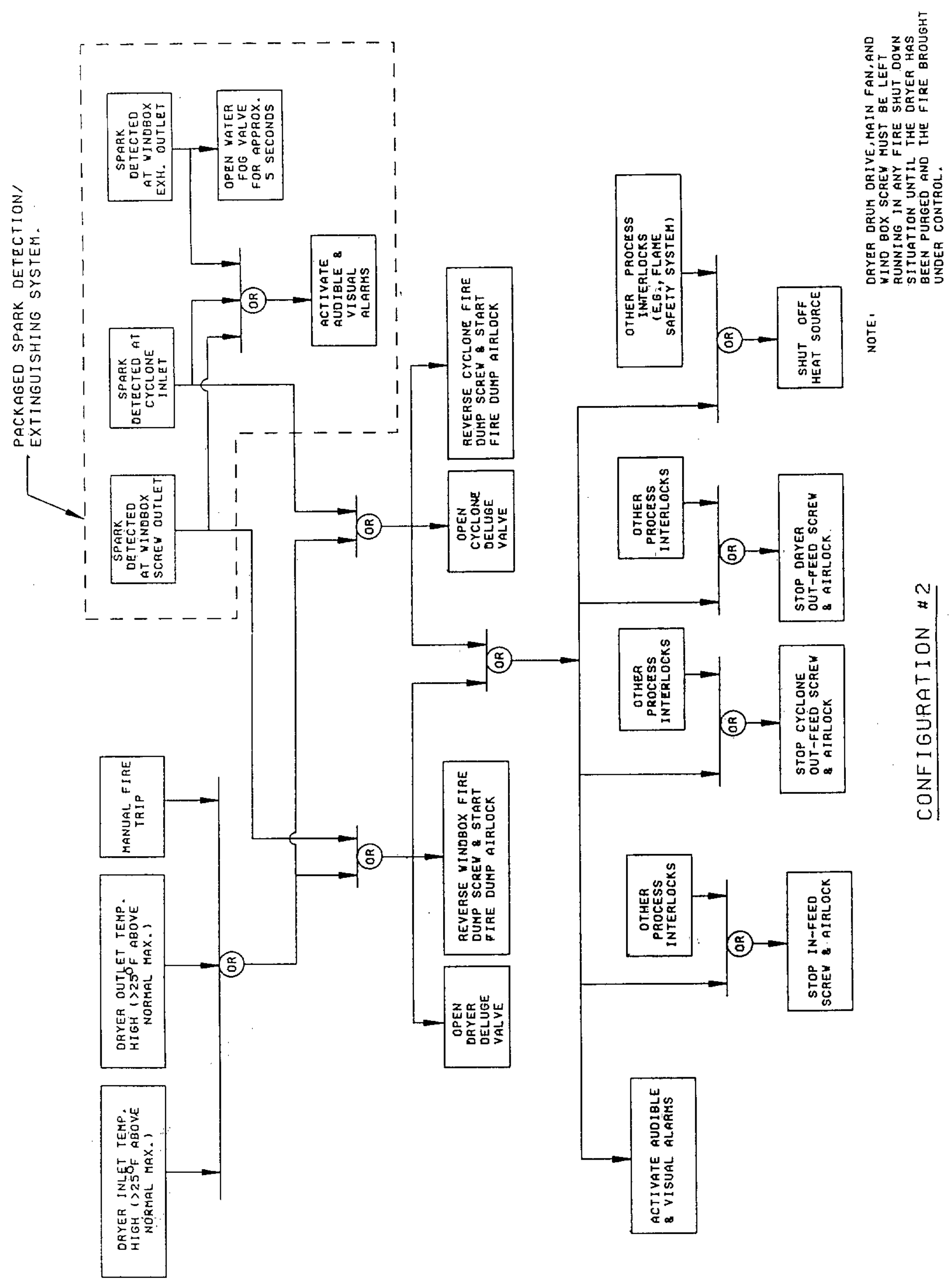


Fig. 19. Dryer with windbox-interlock logic.

2.3.10 Composite Panel Formers

2.3.10.1 Install automatic sprinklers or waterspray nozzles to protect the inside of formers. Heads should be located at the top of the former. When the formers are in view of an operator who is properly trained to respond, manual waterspray systems are acceptable.

2.3.10.2 Install explosion suppression systems on formers (felters) used to produce medium-density fiberboard and dry-process hardboard.

2.3.11 Hazardous Dust Collection and Dust Handling Systems

Refer to Data Sheet 7-73, *Dust Collectors and Collection Systems,* and Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*.

2.3.12 Raw Material and Wood Waste Fuel Storage Buildings

2.3.12.1 Provide explosion-relieving construction for new buildings. Venting should be designed in accordance with Data Sheet 7-76. Conventional lightweight, pre-engineered metal panel on steel frame buildings will meet the intent of this recommendation.

2.3.12.2 Construction should minimize horizontal ledges where dust can accumulate.

2.3.12.3 Sprinkler piping should be protected against explosion damage according to Data Sheet 2-8N, *Installation of Sprinkler Systems*.

2.3.12.4 Buildings which store *only green* wood waste should have electrical equipment suitable for Class II, Div. 2 hazardous areas.

Any areas handling *dry* wood waste should have Class II, Div. 1 electrical equipment.

2.3.12.5 Diesel powered front-end loaders used for material reclaim in Class II, Div. 1 classified buildings should have the following provisions:

a) Protect the engine and hydraulic oil compartments with fixed, automatic dry chemical extinguishing systems.

b) Loaders rated for use in ''DY'' classified hazardous areas should be used, but are not readily available and may not be practical if the loader must have electrical equipment such as lights for night-time operation. As an alternative, the following safeguards are acceptable:

i) Only essential electrical equipment should be used, and wiring should be in metal conduit. Air operated starting is preferred, but batteries may be used if they are mounted in enclosures rated for Type EX hazardous areas.

ii) Where practical, a water-cooled manifold and muffler should be used.

iii) Loaders which are certified to meet the Mining Enforcement and Safety Administration's Schedule 31 criteria are also acceptable in lieu of i & ii above.

c) Loaders should have a high degree of maintenance and cleaning. Frequent cleaning (daily in some cases) of the engine compartment with compressed air may be necessary. Periodic steam cleaning should also be done.

d) Loaders should never be parked or left unattended in the storage building.

2.3.13 Wood Waste Burners (Incinerators)

2.3.13.1 Wood waste burners should be located as far as practical from yard storage and important buildings of combustible construction. A separation of 400 ft (120 m) is desirable.

2.3.13.2 The screen on the burner top should be kept in good repair to minimize the chance of escaping embers.

2.3.13.3 Where sparks from wood waste burners could reach roof areas of important combustible buildings that are not readily accessible using hydrant hose streams, provide 1½ in. (38 mm) hose stations in each building on a dry pipe system so that all such areas can be reached.

2.3.13.4 When dry wood fines, such as planer shavings or sander dust, are burned in wood waste burners, the burner should be at full operating temperature before the fines are introduced. This can be accomplished by manual observation if an operator is present at the burner to control the introduction of fines. If fines can be introduced into the burner by remote control without a local operator to confirm the status of the burner, a temperature interlock should be provided to assure the burner is ready to receive the material. This will assure an explosive dust cloud cannot form in the burner and be subsequently ignited.

2.3.14 Finishing Operations Using Flammable Liquids

2.3.14.1 Finishing operations using flammable sealers, coatings, paints, etc. should be protected in accordance with the applicable parts of Data Sheets 7-9, *Dip Tanks, Flow and Roll Coaters and Oil Cookers*; 7-32, *Flammable Liquid Operations*; and 7-27, *Spray Application of Flammable and Combustible Materials*. These operations should be cut off from other manufacturing areas, preferably in a separate building.

2.3.14.2 Ovens or dryers used in these operations should be protected in accordance with Data Sheet 6-9, *Industrial Ovens and Dryers.*

2.4 Operation and Maintenance

2.4.1 Sprinkler System Flushing

Dry-pipe sprinkler systems that are prone to frequent nuisance tripping (several times per year) should receive the following routine maintenance:

a) Perform annual trip tests by opening the inspector's test connection with the control valve wide open, allowing the water to flow until it is clear (one minute minimum).

b) Sprinkler systems fed from open water supplies (e.g., ponds, rivers, etc.) should have flushing investigations every five years. Based on the results of the investigations, flushing frequency should be adjusted as needed to assure piping does not become obstructed. In no case should the flushing frequency be longer than that for systems with clean water supplies.

c) Sprinkler systems fed from public water systems or other clean supplies should have flushing investigations on the following frequencies after being placed in service:

Galvanized Pipe	*Plain Pipe*
15 years	10 years
25 years	20 years
every 5 years thereafter	every 5 years thereafter

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

Recent losses involving wood processing facilities utilizing thermal oil heat transfer fluids have illustrated the need for adequate separation, protection and interlocks. A recent loss exceeded $10 million.

During the period 1980–1989, there were 1,583 F&EC/DIC losses. They totaled $178.5 million net insurance company liability (indexed to 1990 dollars). There were 725 fire losses that amounted to $113.6 million. A complete breakdown of losses involving wood processing facilities is provided in Table 3 and Figure 20.

Table 3. 1980–1989 Wood Processing/Working F&EC/DIC Losses By Engineering Peril (1990 $)

Engineering Peril	*No. of Losses*	
	No.	*%*
Fire	725	45.8
Collapse	57	3.6
Explosion	89	5.6
Wind or Hail	198	12.5
Flood	10	0.6
Riot & Civil Commotion	25	1.6
Water Damage	40	2.5
Miscellaneous	74	4.7
Sprinkler Leakage	114	7.2
Lightning	54	3.4
Impact	5	0.3
Vehicle	45	2.8
Burglary & Theft	56	3.6
Transportation	36	2.3
Rigging	11	0.7
Other	44	2.8
Total	1,583	100.0

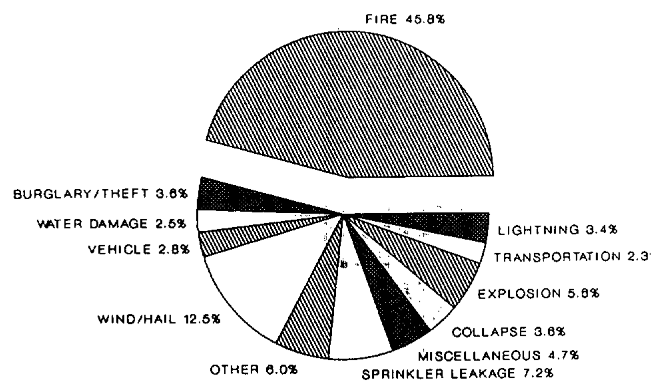


Fig. 20. Wood processing/working F&EC/DIC losses by peril (percent number of losses [1583]).

Lacking or obstructed sprinkler systems or defective water supplies were considered a prime factor in 27.6 percent of the losses. These losses represent 80 percent of the total reported loss amount (over $88 million). A complete breakdown of prime factors in fire losses is provided in Table 4.

Table 4. 1980–1989 Wood Processing/Working Fire By Prime Factor (1990 $)

Prime Factor	No. of Losses	
	No.	%
Sprinklers Needed[1]	109	21.0
Sprinklers Out-of-Service (ICVs)[2]	10	1.9
Sprinkler System Defects[3]	19	3.7
Water Supply Defects[4]	5	1.0
Inadequate Housekeeping	57	11.0
Combustible Building Construction	6	1.2
Miscellaneous Human Element	67	12.9
Inadequate Cut/Weld Procedures	16	3.1
Inadequate Dust Handling	30	5.8
Defective Electrical Equipment	23	4.4
Inadequate Flammable Liquid Handling	11	2.1
Inadequate Maintenance	40	7.7
Defective Protective/Safety Equip.	11	2.1
Other	115	22.1
Total—Factors Recorded	519	100.0
Unknown/No Data	206	
Total—All Losses	725	

Cutting and welding activities were considered the probable cause of 10 percent of the reported fires. These losses represent 33 percent of the total reported loss amount (over $36 million). A complete breakdown of reported probable causes is provided in Table 5 and Figure 21.

Table 5. 1980–1989 Wood Processing/Working Fires By Cause (1990 $)

Cause	No. of Losses	
	No.	%
Cutting/Welding	56	10.5
Misc. Electricity	121	22.8
Incendiarism	48	9.0
Firebox Spark	12	2.3
Smoking	10	1.9
Spont. Ignition/Chem. Action	39	7.3
Gas Burner Flame	6	1.3
Chimney Spark	9	1.7
Hot Electric Motor Surface	2	0.4
Overheated Dryer, Kiln, Oven	15	2.8
Manufacturing Process Friction	40	7.5
Lightning	8	1.5
Exposure	13	2.4
Mechanical Spark	28	5.3
Other	124	23.3
Total—Cause Recorded	531	100.0
Unknown/No Data	194	
Total—All Losses	725	

Table 6 provides a comparison of losses with sprinkler system presence and effectiveness. For example, fires involving out-of-service sprinkler systems resulted in an average insurance company liability of $1,986,000. Fires controlled by adequate sprinkler protection resulted in an average liability of $168,000.

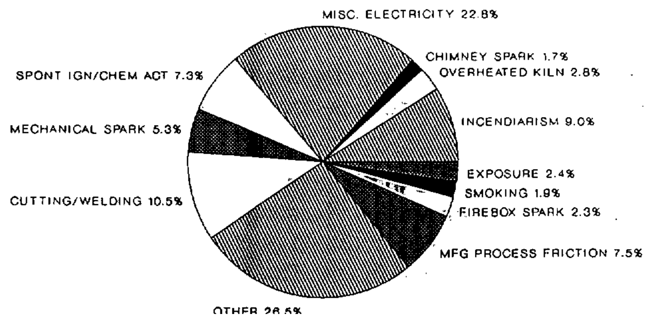


Fig. 21. Wood processing/working fires by cause (percent number of losses [531]).

Table 6. 1980–1989 Wood Processing/Working Fires Sprinkler Protection Analysis (1990 $)

Sprinkler Protection	*No.of Losses*
Out-of-Service (ICV)[1]	13
Sprinkler Equipment Deficiency	23
Water Supply Deficiency	11
None—Sprinklers Needed	65
Yes—More Sprinklers Needed	76
Yes—Protection Adequate	180
None—None Needed	7
Total	375

[1]Improperly closed valves.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-20, *Protection Against Fire Exposure (From Buildings or Yard Storage)*.
Data Sheet 2-8N, *Installation of Sprinkler Systems (NFPA)*.
Data Sheet 3-10, *Installation/Maintenance of Private Service Mains and Their Appurtenances*.
Data Sheet 6-9, *Industrial Ovens and Dryers*.
Data Sheet 7-9, *Dip Tanks, Flow/Roll Coaters and Oil Cookers*.
Data Sheet 7-27, *Spray Application of Flammable and Combustible Materials*.
Data Sheet 7-32, *Flammable Liquid Operations*.
Data Sheet 7-73, *Dust Collectors and Collection Systems*.
Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*.
Data Sheet 7-98, *Hydraulic Fluids*.
Data Sheet 7-99, *Heat Transfer by Organic and Synthetic Fluids*.
Data Sheet 8-9, *Storage of Class 1, 2, 3, 4 and Plastic Commodities*.
Data Sheet 8-27, *Storage of Wood Chips*.
Data Sheet 8-28, *Pulpwood and Outdoor Log Storage*.

4.2 NFPA Standards

NFPA 664 *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*.

APPENDIX A GLOSSARY OF TERMS

Approved: references to ''Approved'' in this data sheet means the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, a publication of FM Approvals, for a complete listing of products and services that are FM Approved.

Composite Panels: comprise a wide range of products manufactured from wood fractions bonded with resin and pressed into panels. The term ''particleboard'' has been used as a generic name for many of these products; however, this is misleading. There is not even consistency within the industry in defining these various products, but the following descriptions give a general differentiation of the major products:

Particleboard: a non-structural pressed panel product made primarily from small, non-fibrous wood particles or flakes such as planer shavings, sawdust, and wood scrap processed through hogs, hammermills, or special ''flakers.'' Particle size runs from wood dust up to flakes of about ¼ in. (6.3 mm) across and 1/16 in. (1.6 mm) thick. The boards are usually formed with the coarser material in the core and finer material on the surface layers, with finished boards ranging from ¼ in. (6.3 mm) to 1½ in. (3.8 mm) thick. Principal uses include floor underlayment in wood frame construction and core stock to be laminated with a veneer (wood or plastic laminate) for furniture, cabinets, paneling, etc. Panel density ranges from 25 to 70 lbs/cu ft (400–1120 kg/cu m) and may also be referred to as flakeboard or chipboard.

Waferboard: a structural pressed panel product made of wafers cut from logs by special rotating knife chippers, or ''waferizers''. Wafers can be rectangular or nearly square shaped, about an inch long (25 mm) and 1/16 in. (2 mm) thick, with the grain running in the plane of the wafer, like a small piece of veneer. The boards are usually homogeneous with random wafer orientation, although they may be formed in layers. Rectangular wafers may be somewhat aligned to give higher strength. Typical uses are for underlayment, soffits, or as a substitute for plywood sheathing for the stronger waferboards.

Oriented Strand Board (OSB): a structural pressed panel product similar to waferboard except the strands are longer and narrow, nearly finger-sized in dimension. Forming is in three or five layers, with strands on the surface layers oriented along the long dimension of the finished board, and internal layers at 90° orientation to adjacent layers. The orientation of layers give this product greater strength than waferboard, and equivalent to plywood in most cases. Typical uses are similar to softwood plywood.

Fiberboard: a non-structural light-weight panel manufactured from small needle-like resinated wood fibers produced by defiberization of wood chips in rotating disc refiners. Panels are formed by flowing a thick fiber slurry onto a moving forming wire. Panels have a finished density of 10 to 30 lbs/cu ft (160–180 kg/cu m) with 4 by 8 ft (1.2×2.4 m) by ½ in. (12.7 mm) thick being a standard size. The most common use is insulating sheathing for standard wood frame construction. Fiberboard is sometimes coated with hot asphalt to act as a vapor barrier.

Medium-Density Fiberboard (MDF): a non-structural pressed panel product formed from fibers similar to those in fiberboard, however the panels are formed dry in formers like particleboard, and pressed to final thickness in a hot press. Density ranges from 31 to 55 lbs/ft^3 (496–880 kg/m^3). Most common end uses are in furniture and cabinet manufacture. This product is commonly referred to as MDF within the industry.

Hardboard: non-structural dense pressed panel product which can be formed in a wet process like fiberboard or in a dry process like medium-density fiberboard. Density ranges from 31 to 90 lbs/ft^3 (486–1440 kg/m^3). Common end uses are for paneling and siding in standard wood frame construction. Panel thickness is commonly between ⅛ and ½ in. (3.2–13.0 mm). Specialty products can be made by in special presses to produce molded products such as decorative door skin panels.

Plywood: a structural panel made by gluing together multiple layers of wood veneer. A primary use for softwood plywood is sheathing for walls, floors, and roofs in conventional wood frame construction. Another common use is for furniture, cabinets, decorative wall panels, etc., where hardwood veneers may be used for appearance. The standard size is a 4×8 ft (1.2×2.4 m) sheet.

Sawmill: a plant which reduces logs to standard-sized dimensional lumber and timbers for use in conventional wood frame joisted construction, or into boards for other construction or specialty use. Dimensional lumber is usually made of conifer softwood species such as fir and pine. Boards for construction use are also made of similar species, while hardwood such maple and oak may be cut into boards to be used in furniture manufacture, wood trim, or other specialty uses.

Wood Processing: manufacture of basic construction materials (lumber, veneer, plywood and composite panels such as particleboard, fiberboard, hardboard and oriented strand board) from whole logs.

Woodworking: remanufacture of basic construction products from wood processing plants into a wide variety of consumer products such as doors, windows, cabinets, furniture, paneling, or other commodities which use wood components as the basic construction material.

APPENDIX B DOCUMENT REVISION HISTORY

May 2010. Minor editorial changes were done for this revision.

September 2000. This revision of the document has been reorganized to provide a consistent format.

April 1991. Complete rewrite.

September 1998. Reformatted.

APPENDIX C MAJOR OCCUPANCIES AND PROCESS HAZARDS

This section gives descriptive information of typical processes and special equipment found in sawmills and panel products (plywood and composite panels) manufacturing facilities. Wood working facilities which re-manufacture these basic commodities into consumer products are too numerous and varied to describe here, but some of the process hazards are similar to those found in the facilities described below. This is especially true for dust collection systems used on all the specialty finishing planers, molders, sanders, etc.

Flammable liquid operations such as paint spraying and roll or flow coating are much more prevalent in wood working facilities than in wood processing facilities. This is perhaps the most significant loss exposure, but is not covered in detail here since protection for the various hazards are covered in other FM Global data sheets.

C.1 Process Descriptions

C.1.1 Sawmills

Older softwood sawmills were designed to cut very large logs, up to 6 ft (1.8 m) in diameter in some cases. Modern softwood forestry practices harvest trees at a fairly young age to get maximum yield. Southern softwood trees grow very fast, and may be cut after only 20 years of growth. Newer sawmills are designed to cut only small logs of about 18 in. (457 mm) maximum diameter. Common sizes of dimensioned lumber runs from 2×4 in. (51×102 mm) up to 2×14 in (51×356 mm). Common timbers run from 4×4 in. (102×102 mm) up to 6×14 in. (152×356 mm). All dimensions are nominal, and actual sizes are about ½ in. (13 mm) less than nominal. Laminated wood beams are a specialty product made by gluing standard lumber together. Special sizes, shapes and strengths can be engineered to order.

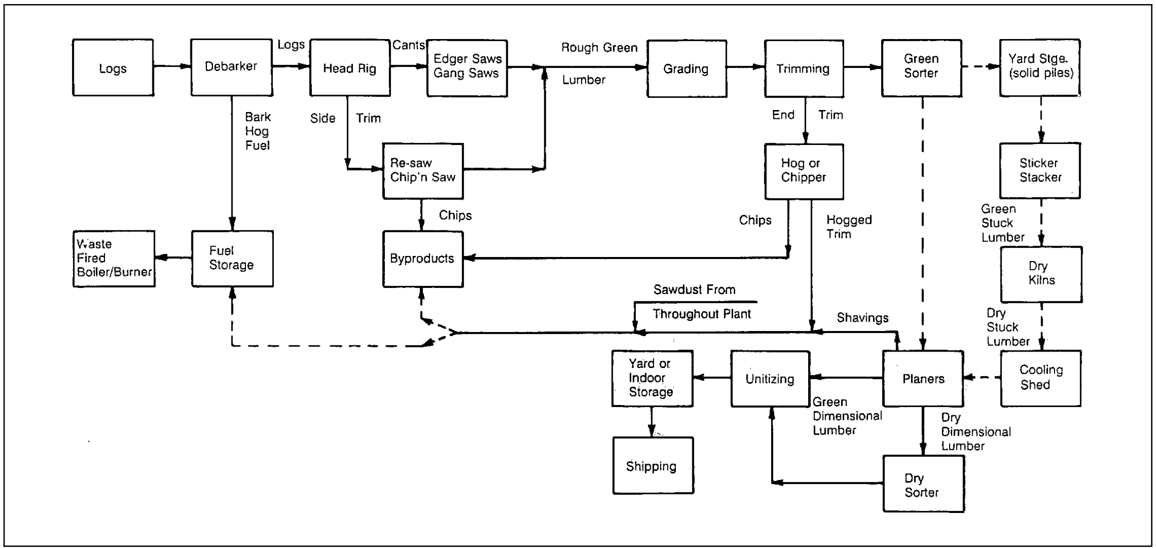


Fig. 22. Typical sawmill process flow schematic.

Figure 22 shows a process flow schematic of a typical sawmill producing both green and dry dimensional lumber. Logs are reclaimed from yard storage by large mobile stackers and fed into the debarker. Debarkers remove bark from the logs either mechanically via rotating rings with toothed claws or hydraulically via jets of high pressure water. Slasher saws cut the logs to the desired length. Bark is reduced in size by mechanical ''hogs'' to be burned as ''hog fuel'' in waste fired boilers or incinerated in ''tepee'' burners.

Debarked logs move to the ''head rig'' which cuts them longitudinally into large rectangular ''cants.'' Head rigs are usually large band saws, but rotary saws may be used for smaller logs. In older mills, logs are positioned in the head rig manually by skilled sawyers. Modern facilities use laser scanning equipment to do this automatically. The side trim from the head rig is re-sawn to recover usable lumber with the remainder reduced to chips for pulp/paper mills. Special equipment (Chip 'n Saw is a common term) can do this in one operation. Cants are further reduced by edger saws and then ''gang'' saws which produce several pieces of lumber cut to rough final dimension in one pass.

Rough cut lumber is graded (usually manually) according to species and quality, then cut to length. Trimmed ends are either chipped to be sold as by-product, or hogged for use as fuel or by-product for composite panels raw material. Green lumber is sorted to length and sent to the planer operation for final dimensioning or to yard storage to await processing through the dry kilns.

Lumber sorters convey lumber on chain conveyors, detect the length of each piece, and divert it into a bin or tray with similar sized pieces. Figure 1 shows a horizontal tray sorter. Figure 2 shows both diagonal bin and vertical bin sorters, also referred to as ''drop'' sorters or ''J-bar'' sorters in the industry. Another variety of vertical bin sorter is the ''sling'' sorter which collects lumber in fabric slings.

Lumber which is to be dried is first prepared by stacking in uniform loads with each layer of lumber separated by a ''sticker'' of wood approximately 1 in. (25.4 mm) square. The loads of ''stuck lumber'' are stacked on wheeled carts which run on tracks to convey the loads into each dry kiln. Kilns may be heated indirectly by steam or thermal oil heat exchangers, or directly by fossil fuel or wood dust fired burners (refer to Data Sheet 7-99, *Heat Transfer by Organic and Synthetic Fluids*, for a discussion of hot oil systems).

Figure 3 shows two typical indirect heated dry kilns. Once the drying cycle is complete, kiln loads are removed and placed in a cooling shed (usually just a canopy) to cool before the stickers are removed. Some plants may dry lumber by ''air drying'' rather than kilns. This is done by simply leaving the stuck lumber outside until it is dried to the desired moisture content. This typically takes from one to three months, depending on the ambient temperature, humidity and rainfall.

Following drying, lumber is passed through rotating knife planers for final dimensioning. Sometimes high-speed belt sanders similar to wood panel sanders are used for final dimensioning. This is most common on boards such as pine where the knots tend to be chipped out by conventional knife planers. Planer shavings are collected for use as fuel or as a by-product material for composite panel products.

Lumber is sorted again, if necessary, prior to ''unitizing'' for final shipment. Lumber loads are usually secured with a metal band, and an end sealer applied to the exposed lumber ends to prevent water penetration. Dry lumber may also be wrapped if it is to be stored outside. Handling by mobile equipment usually limits storage to about 16 ft (5 m) in height. Indoor storage using cranes can reach 30 ft (9 m) in height before pile stability becomes a concern.

C.1.2 Panel Products

Panel products include both plywood and composite panels made of small wood fractions held together by resin binders. The processes which manufacture these products have as many similarities as they do differences. The pressing and finishing operations are very similar for all panel products. The forming of the panels constitutes the primary differences. Figure 23 shows typical process flows for all these products on one schematic to highlight these similarities and differences.

C.1.3 Plywood

Logs are debarked in equipment similar to the debarking operation of a sawmill. Slasher saws cut the logs to length, usually just over 8 ft (2.4 m) long. These ''peeler logs'' are thawed (in cold climates) and/or softened in steam or hot water vats. Once softened, the peeler logs are conveyed to the veneer lathe. In older mills, the lathe operator uses his or her experience to position the log in the lathe spindle for maximum yield. Modern facilities use laser scanning equipment to assist in the positioning. Veneer from the lathe is trimmed to square up the edges. The peeler core remaining from each log after all usable veneer is removed is either

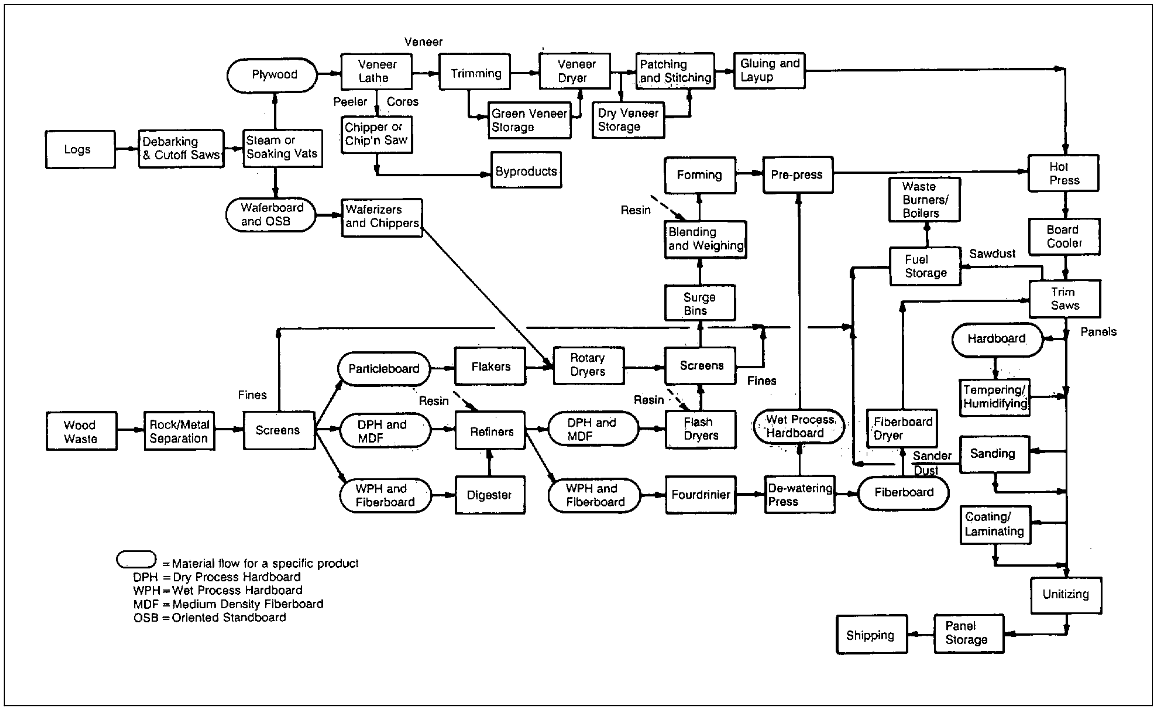


Fig. 23. Typical panel products process flow schematic.

chipped or processed through a Chip ’N Saw to recover lumber from the center and chips from the sides. Green veneer may be stored to await drying. Piles are usually flat on-side, up to a height about 12 ft (4 m), but occasionally veneer may be stacked vertically.

Refer to the Section 2.3.3, Veneer and Fiberglass Dryers, for a description of veneer dryers.

Dried veneer may be stored before further processing such as patching and gluing or stitching to join smaller pieces together. The layup process prepares the veneer for pressing. Successive layers of veneer are coated with glue and laid on top of each other, with the veneer grain alternately placed lengthwise and crosswise for panel strength. The quality of outside face sheets of veneer depends of the end use for the panels. Plywood to be used for furniture or cabinetry may have a solid lumber core. Plywood glue is typically urea formaldehyde resin for indoor applications and phenol formaldehyde resin for exterior grades, although new resins are being sought to eliminate consumer concerns (such as formaldehyde emission) with the finished products. The glued veneer is then conveyed to the hot press to cure the resin, forming rigid panels.

Refer to the Section 2.3.5, Hot Presses, for a discussion of hot presses.

Pressed panels may be processed through a board cooler which is little more than a hood with a high induce airflow. The hood area creates a shielded space, which usually warrants automatic sprinkler protection. Panels are trimmed to final dimension, and if their end use dictates, sanded to final thickness or surface smoothness. Panel sanders are large high-speed belt sanders causing frequent sparks and fires in their dust collection systems due to belt breakage, jammed panels, and bearing failure. Further machining (e.g., tongue-and-groove edging, face grooving for paneling, decorative painting) may be done depending on end use. Finished products are unitized, usually by metal banding, and stored flat up to 20 ft (6 m) in height.

C.1.4 Particleboard

Dry wood waste material (called ‘‘furnish’’) is stored in large silos or open bay buildings, often referred to as RMS (raw material storage) buildings. RMS buildings have an inherently dusty atmosphere due to the free-fall formation of piles from over head conveyors or pneumatic conveying systems. ‘‘Green’’ sawdust may be stored outside. Diesel front end loaders are commonly used to reclaim material from the piles. Magnets and air separators are used to remove foreign material from the furnish prior to milling.

Screens may be also be used to remove the very fine dust for use as fuel. Special rotating-ring knife flakers are used to reduce the furnish to acceptable size. The furnish is then dried to the desired moisture content, usually less than 10 percent (dry basis), in rotary drum dryers.

Dried material is screened again to remove additional fines, and conveyed to surge bins. Material from the surge bins is convey to blenders where resin, and sometimes wax, is added. Urea formaldehyde is the common resin, but like plywood, alternate resins are being sought which do not have an emission problem. The blended resin is weighed and metered into formers which distribute the free-falling furnish onto a moving belt. There are usually at least three formers, two for surface material and one for core material. The material is normally deposited on metal ‘‘caul’’ plates to carry the furnish into the hot press, but is sometimes done without using a using a caul and pre-press roll instead to help the mat stay together as it's loaded into the hot press.

Refer to Section 2.3.5 for a discussion of hot presses. Following pressing, the finishing line is similar to that described for plywood.

C.1.5 Waferboard

Whole logs are the primary raw material in waferboard manufacturing. Log preparation is identical to that described for plywood. Waferboard is commonly produced in the northern United States and Canada in areas where softwood is less prominent, allowing local hardwoods (aspen is a common species) to be used. Hot water soaking vats are common to thaw logs and soften then prior to processing in special wafer chippers called ‘‘waferizers.’’ Following waferizing, the furnish is processed through rotary dryers, forming, pressing, and finishing similar to particleboard as described above. Because large wafers are used as furnish, the process is much less dusty than particleboard. Once fines are screened out of the furnish, the process has about the same hazard as plywood manufacturing.

C.1.6 Oriented Strand Board (OSB)

The process and its hazards are virtually identical to waferboard. Oriented is the newest composite panel product in North America. Powdered resins (usually phenol formaldehyde, a combustible dust) are sometimes used instead of liquid resins. The handling of powdered resins can present some additional dust explosion hazards. Also, this process usually forms and presses very large panels (nominally 8 ft wide by 24 ft [2.4×7.3 m] long) which are subsequently cut into standard 4 by 8 ft (1.2×2.4 m) sheets.

Refer to the Section 2.3.5 for a discussion of hot presses.

C.1.7 Fiberboard

Like particleboard, wood waste is the primary raw material. Since fiberboard is formed in a wet process, the material does not need to be dried and can be stored outdoors. The initial removal of foreign material and screening is similar to particleboard. Processing of the furnish is different in that it passes through a pressurized steam digester to help soften the furnish, and then is reduced to fibers in rotating disk refiners, which may also be pressurized. Resin is added during the refining process. The fiber flows from the refiners as a wet slurry, similar to thermo-mechanical pulp. Also like pulp, the slurry is formed into a mat on a moving-wire former (‘‘Fourdrinier’’ is a common former manufacturer). Water is removed from the formed mat by vacuum and de-watering press rolls.

The mat is then cut into individual panels and dried in a multi-tier dryer (see Section 2.3.3, Veneer and Fiberglass Dryers, for a discussion of these dryers.) The dried fiberboard is trimmed to final size, usually 4 by 8 ft (1.2×2.4 m) panels, and unitized for storage prior to shipping. Some fiberboard products are coated with hot asphalt in a roll-coating process (refer to Data Sheet 7-9, *Dip Tanks, Flow Roll Coaters, and Oil Cookers,* for hazards and protection details).

C.1.8 Medium-Density Fiberboard (MDF)

MDF furnish is also formed from wood waste, but the forming process is dry and raw material which is not ‘‘green’’ is usually stored in large open bay buildings like particleboard. Reclaim using diesel front-end loaders is also common. Following the usual foreign material separation and screening, raw material is broken down into fibers by rotating disc refiners, which are usually steam pressurized. The damp fibers are dried to final moisture content (usually less than 10%) in ‘‘flash’’ dryers (see Section 2.3.8, Flash Dryers, for a discussion of these dryers.) Some processes inject resin (usually urea formaldehyde) into the furnish as it is enters the flash dryer. This is known as *blowline blending*.

Dried fiber may be further screened before it is conveyed (usually pneumatically) to surge bins. Fiber is conveyed from the surge bins (again, commonly by pneumatic blowlines) to blenders for resin addition (unless resin was added in the drying process), then to weigh belts before dropping into formers (commonly called *felters* in this process). Like other dry formers, the material free-falls onto a moving belt. In this process, the belt is usually a wire mesh with suction applied to the underside to help form the mat. Although the mat is usually formed by at least three felters laying down successive layers of fiber, there is usually little difference between the surface and core material, resulting in a homogeneous board. The fiber used in this process is typically fine enough to be explosive.

From the forming line, the mat is cut in panel lengths and run through pre-press rolls before entering a hot press for final pressing and resin curing (see Section 2.3.5 for a discussion of hot presses). The finishing line operations are similar to those described above for particleboard.

C.1.9 Hardboard

The raw material preparation and forming of wet process hardboard is similar to fiberboard as described above, except that the mat is processed through a hot press rather than a multi-tier dryer. Dry process hardboard manufacturing is virtually identical in equipment and hazards to medium-density fiberboard.

The finishing process for hardboard products usually has one additional step to temper or stabilize the moisture content in the panels. This consists of processing the panels in steam heated batch humidifying ovens which are similar in size to lumber dry kilns. Panels are typically placed horizontally separated by thin ‘‘stickers’’ on wheeled carts much like stuck lumber. Carts are loaded into the ovens in very close arrays, such that sprinkler penetration into the loads is difficult. The hazard is more like a multi-tier fiberboard or veneer dryer, and waterspray deluge protection should be used for that reason. Additional cutting of hardboard panels may be done to make lap-siding products.

C.2 Special Hazards

C.2.1 Veneer and Fiberboard Dryers

Dryers and ovens having multi-tiers are used for drying plywood veneer and fiberboard as well as other similar combustible material. The tiers very from three to twelve inches apart.

Generally, dryers have one or two zones and are protected by a single deluge system. Long units where the water demand is high (e.g., 2000 gpm or 7560 cu dm/min) may require two or more deluge systems. Figure 11 (top) shows the elevation view of a typical five zone dryer. Figure 11 (bottom) shows a general plan view. Detailed sketches of the deluge system installation are shown in Figures 12 to 14.

In wicket type veneer dryers (see Fig. 10), sheets are placed on horizontal arms, lifted to a vertical position, dried passing through the unit and then fall out when the arms slope downward. There are no obstructions to roof level sprinkler protection.

Vertical jet-type dryers have airflow plenum arm extensions which extend across the dryer. These extensions have openings along their length which cause jets of hot air to impinge vertically on the top and bottom of the veneer. This airflow can help support the veneer sheet and assist its travel through the dryer. The normal design will only accommodate spray nozzles along one side of the dryer (see Figs. 6 and 7). One special design is very similar to an airborne pulp dryer, with such restricted internal configuration that it is only practical to locate deluge heads in the main inlet and outlet plenum on both sides of the dryer (see Figs. 8 and 9).

C.2.2 Hot presses

Hot presses are used to cure the resins in panel products and press them to their approximate final thickness. The most common presses have multiple openings, perhaps 15 or more, to press many boards in one press cycle. Single opening continuous presses utilizing top and bottom platen segments on revolving tracks (much like the tracks on a bulldozer) exist, but are rare in North America. Presses (and the forming line equipment) are commonly of European manufacture, with lead time for replacement of a year or more.

Press platens were traditionally heated by flowing steam through them, but newer presses are using hot oil instead of steam. Some presses do not heat the platens at all, but rather use radio-frequency energy to heat and cure the resin (much like a microwave oven).

Hot presses typically have loading and unloading panel accumulators which move vertically to quickly load and unload boards from the press. Sprinkler protection in these portions of the pit are practical around the perimeter only. Horizontal sidewall heads may be needed to reach the center pit areas. Solid metal caul plates used in composite panel manufacturing usually progress through the press along with each panel. They are separated from the panels upon unloading and are returned to the forming line at operating floor level along the side of the press. Newer presses which use flexible wire cauls recirculate them underneath the press. This can result in very long, deep pit areas below the press with areas shielded by the caul conveyors.

Multi-opening presses are closed during the press cycle by large hydraulic cylinders in the pit directly below the press. The hydraulic system contains thousands of gallons of hydraulic fluid on larger presses. The press pit provides natural containment for an hydraulic or thermal oil spill, but exposes the press to a severe fire hazard.

C.2.3 Rotary Dryers

Rotary dryers used in composite panel manufacturing consist of steel drums which are oriented horizontally and rotate on trunion bearings, similar to a kiln. Dryer drums are commonly 8 to 10 ft (2.4–3 m) in diameter and 30–50 ft (9–15 m) long. The drums have internal baffles, or ''flights'' which lift the material and advance it through the dryer as the drum rotates. Dryers are either *single-pass* or *triple-pass* design. In single-pass designs, the material enters one end and exist the other end after traversing the dryer once. Triple-pass types have a labyrinth of drum passages inside the outer drum, such that material enters one end and traverses the length of the dryer three times before exiting the far end. Heated air is induced through the dryer to dry the furnish and assist movement through the system.

Material exiting the drum is collected in a fall-out chamber called a *wind box* (if the dryer has one), or in a cyclone. Dryer exit temperature is used to control the firing rate of the burner. Direct firing of the dryer is typical, with gas, oil, or wood dust used as fuel. Occasionally, waste heat from boilers or thermal oil heaters may be ducted to rotary dryers as a base-load heat source.

C.2.4 Flash Dryers

Flash dryers used in composite panels manufacturing are little more than pneumatic transport blowpipes 3–5 ft (0.9–1.5 m) in diameter, with the conveying air heated to dry the material as it is conveyed. Occasionally, vertical sections of duct with increased diameter may be used to increase the dwell time in the dryer (similar to pulp flash dryers). Fuel and firing rate control are similar to rotary dryers, with the exception that indirect heating using steam or hot oil heat exchangers are sometimes used.

FM Engr. Comm. April 1991

Norbord

Norbord's Combustible Dust Experience

(see document in "Best Practices and Housekeeping" section)

Date published: March 29, 2011

Sinclair Forest Products Ltd

Possible solutions – dust removal systems

Date published: April 30, 2012

From: Walker, Dale
Sent: Monday, April 30, 2012 8:29 AM
To: Walker, Dale
Subject: FW: Possible solutions - dust removal systems

Forwarded by Kerry Douglas/CRP/WestFraser on 04/30/2012 07:52 AM

http://www.qair.com/

Here's what seems to be the most plausible site I've found so far.

Thanks Kerry

Michel Richard MBA CEC
Operations Manager
Sinclar Forest Products Ltd
Tel: (250) 614-7655
Cell: (250) 612-9317
Fax: (250) 562-0914

Van-Ed Equipment

Air Mister

Date published: Unknown

AIR MISTER

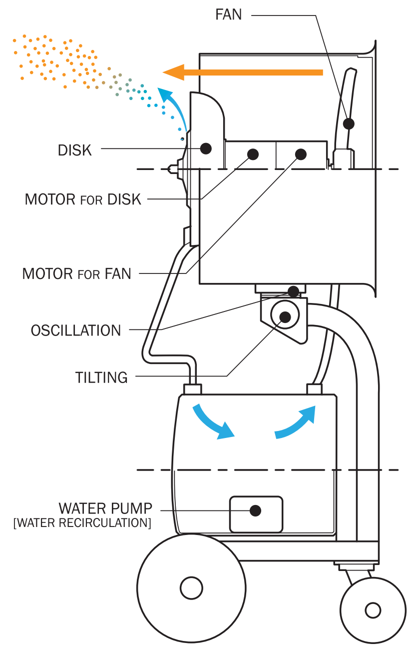
VAN-ED
Heavy Duty Attachments
604.888.9020
vanedequipment.com

HOW IT WORKS - The Air Mister uses simple air assisted centrifugal water supply system that atomizes water into microscopic droplets. Water is supplied through a standard hose and the unit is powered by 110 volts. Spray volume is completely adjustable from 1 to 10 gallons per hour.

DURABLE - The Air Mister comes in epoxy coated steel housing. Motors and fans are duty rated for consistent performance and reliability.

PORTABLE - The unit is lightweight with an optional mobile package [AMP model].

APPLICATION - Dust suppression, Odor control, Humidity and Temperature control.
- Waste management facilities, Recycling plants, Mills, Agriculture facilities, Poultry farms, Food processing plants, Outdoor leisure events, Restaurants, and Pubs.



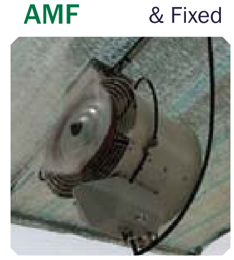
SPECIFICATION

Description		Metric		Imperial	
Fan Diameter		560	mm	22	inch
Air Volume		5,880	m^3/hr	208,000	ft^3/h
Mist Size		20	microns	←	
Covering Area	Max	320	m^2/unit	3,500	ft^2
Mist Throw *	Max	35	m	110	ft
	Min	20	m	65	ft
Required Water Pressure	Max	6	bar	87	psi
	Min	1	bar	15	psi
Water Consumption	Max	40	liter/hr	10	gph
	Min	4	liter/hr	1	gph
Fan RPM		3,420	RPM	←	
Disk RPM		1,710	RPM	←	
Power		110V AC, 60Hz, 620W		110V AC, 60Hz, 0.8hp	
Weight **		33	kg	73	lb
Shipping Dim **		65X65X57	cm	26X26X23	inch

* Results may vary depending on application
** AMP model

AMP Portable & Fixed

AMF Ceiling Mounted & Fixed



AMO Ceiling Mounted & Oscillation

Authorized Dealer

THE SCIENCE OF DUST SUPPRESSION :

What is the particle size of the dust?

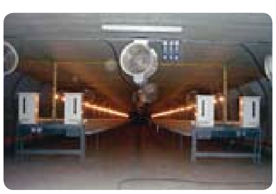
Dust capture is most effective when dust particles collide with water drops of an equivalent size.
Drops that are too large won't collide with the smaller dust particles and drops that are too small evaporate too quickly and release the captured dust particles.
Understanding the particle size of the dust is critical in effective system design.

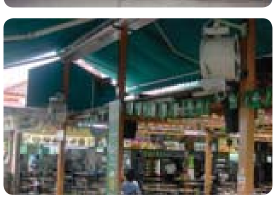
You can use these general guidelines regarding dust particle size. However, further research may be necessary depending on the material and stage of the material in processing.

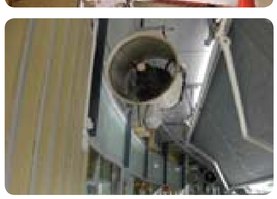
Particle diameter in microns:

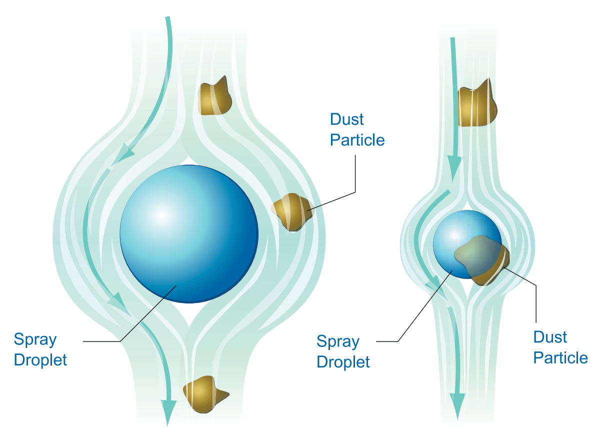
- Ground limestone: 10 to 1000 μm
- Fly ash: 10 to 200 μm
- Coal dust: 1 to 100 μm
- Cement dust: 3 to 100 μm
- Carbon black: 0.01 to 0.3 μm
- Pulverized coal: 3 to 500 μm

Capturing airborne dust with water sprays is most effective in areas with little air turbulence. Depending on the environment, enclosures may be required.









If the drop diameter is larger than the dust particle diameter, the dust particle will follow the air stream around the drop. (Shown left.) If the diameters of the drop and the dust particle are comparable, the dust particle will follow the air stream and collide with the drop. (Shown right.)

Wood Machinery Manufacturers of America

NFPA 664 Combustible Dusts – Overview

(see document in "Best Practices and Housekeeping" section)

Date published: February 21, 2011

Risk Assessments and Audits

Aon

Aon Safety Information Bulletin – Combustible Wood Dust in Sawmills: Preventing and Mitigating the Effects of Fire and Explosions

Date published: April 26, 2012

Aon Safety Information Bulletin — April 26th, 2012

Combustible Wood Dust in Sawmills: Preventing and Mitigating the Effects of Fire and Explosions

Two separate, recent catastrophic events affecting sawmills in BC have served as a critical reminder of how large a role strong risk management practices play in this industry segment. Aon is committed more than ever to our clients in the management of risk with a strong focus on safety and property conservation.

The most recent provincial developments in BC included the Labour Minister, Margaret MacDiarmid, instructing WorkSafeBC to take the "extraordinary step" of sending orders to sawmill employers in BC to conduct "full hazard identification, risk assessment and safety reviews, with particular focus on sawdust accumulation and potential ignition sources."

On April 25th, 2012, WorkSafeBC informed to the media that inspection officers will be conducting on-site follow-ups at each sawmill within two weeks to ensure compliance.

On the same date, the union representing sawmill workers in B.C. has reported to be in talks with the Ministry of Labour to create regulations that will require employers to deal with sawdust accumulation in their mills.

Purpose

This Safety Information Bulletin highlights:

- Hazards associated with wood combustible wood dusts;
- Work practices and guidelines that reduce the potential for a wood combustible dust explosion, or that reduce the danger to employees if such an explosion occurs; and,
- Training to protect employees from these hazards.

Background

Dust Fire and Explosion

Combustible dusts are fine particles that present an explosion hazard when suspended in air in certain conditions. A dust explosion can be catastrophic and cause employee deaths, injuries, and destruction of entire buildings.

Regrettably, in many combustible dust accidents, employers and employees were unaware that a hazard even existed.

According to a report issued by the Occupational Safety and Health Administration of the US in October 2009, there have been nearly 280 dust fires and explosions at industrial sites across North America over the prior 25 years. Those accidents have caused 130 fatalities and about 780 injuries. Like most fires, a dust fire occurs when fuel (the combustible dust) is exposed to a source of ignition in the presence of oxygen. Removing any one of these elements of the fire "triangle" eliminates the possibility of a fire.

For dust explosions, two additional conditions are required: dispersion and confinement. Suspended dust burns more rapidly and confinement allows for pressure build-up. Incidents of dust explosions can sometimes reveal a pattern of multiple subsequent explosion. The initial explosion can disturb dust that has settled over a period of time causing it to become airborne resulting in a secondary explosion that propagates throughout the plant often with catastrophic results. On occasions, there have been more than one subsequent explosion.

In addition to sawmills and wood working operations, various other industries are at risk of dust explosions including but not limited to: wood product manufacturing; combustible metal processing; chemical manufacturing; food and pharmaceutical production; grain storage, sugar mills, fabrication of rubber and plastic products; and coal-fired power plants.

Combustible materials which have been implicated in some dust explosions include: wood dust; coal; chemicals; rubber; grain dust; sugar; flour; and a number of metals such as aluminum.

Causal factors usually listed in incident forensic investigation reports include inadequacies in the following areas:

- Housekeeping to control dust accumulations;
- Ventilation system design;
- Maintenance of ovens, driers and furnaces;
- Equipment safety devices.
- Hazard assessment, and
- Hazard communication.

Elements Needed for a Fire (the "Fire Triangle")

1. Combustible dust (fuel);
2. Ignition source (heat); and,
3. Oxygen in air (oxidizer).

Additional Elements Needed for a Combustible Dust Explosion

4. Dispersion of dust particles in sufficient quantity and concentration; and,
5. Confinement of the dust cloud.

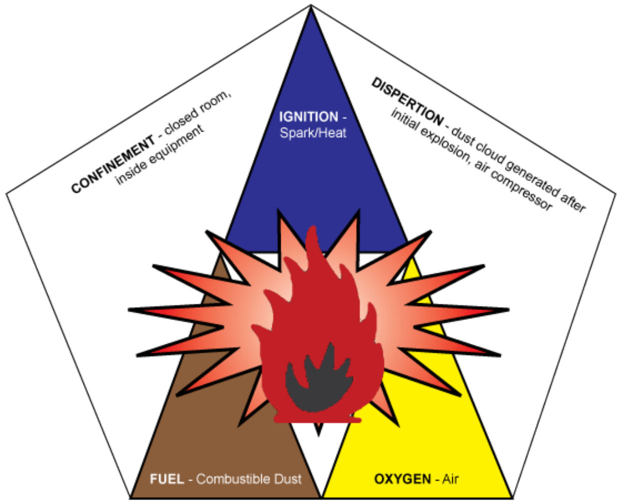


Figure 1. Explosion Pentagon

The addition of the latter two elements to the fire triangle creates what is known as the "explosion pentagon" (see Figure 1). If a dust cloud (diffused fuel) is ignited within a confined or semi-confined vessel, area, or building, it burns very rapidly and may explode. The safety of employees is threatened by the ensuing fires, additional explosions, flying debris, and collapsing building components.

An initial (primary) explosion in processing equipment or in an area where fugitive dust has accumulated may shake loose more accumulated dust, or damage a containment system (such as a duct, vessel, or collector). As a result, if ignited, the additional dust dispersed into the air may cause one or more secondary explosions (see Figure 2). These can be far more destructive than a primary explosion due to the increased quantity and concentration of dispersed combustible dust.

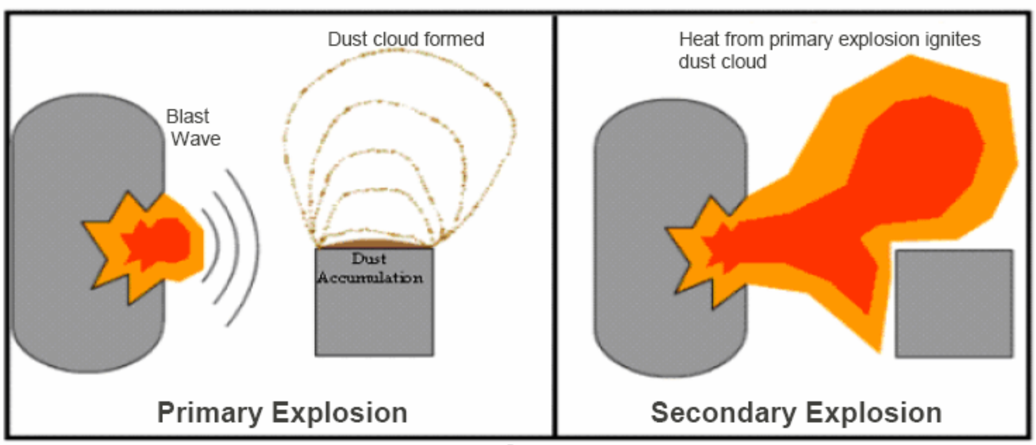


Figure 2

If one of the elements of the explosion pentagon is missing, a catastrophic explosion cannot occur. Two of the elements in the explosion pentagon are difficult to eliminate: oxygen (within air), and confinement of the dust cloud (within processes or buildings). However, the other three elements of the pentagon can be controlled to a significant extent, as it is discussed further in this document.

Facility Dust Hazard Assessment

A combustible wood dust explosion hazard may exist in your plant. Aon has devised a Facility Sawdust Hazard Assessment specifically tailored to address concerns in sawmills and wood working plants. It produces effective risk control recommendations that will help you manage your exposure while keeping your total cost of risk at a bay. Contact your Aon representative for more information. See list of contacts at the end of this bulletin.

Facility Analysis Components

Facilities should carefully identify the following in order to assess their potential for dust explosions:

- Materials that can be combustible when finely divided;
- Processes which use, consume, or produce combustible dusts;
- Areas where combustible dusts may build up;
- Hidden areas where combustible dusts may accumulate;
- Means by which dust may be dispersed in the air; and
- Potential ignition sources.

Dust Combustibility

The primary factor in an assessment of these hazards is whether the dust is in fact combustible. Any "material that will burn in air" in a solid form can be explosive when presented in finely divided particulates.

Combustible dust is defined by NFPA 654 as: "Any finely divided solid material that is 420 microns or smaller in diameter (material passing a US No. 40 Standard Sieve) and presents a fire or explosion hazard when dispersed and ignited in air."

Different dusts of the same wood material may have different ignitability and explosibility characteristics, depending upon many variables such as particle size, shape, and moisture content. Additionally, these variables can change while the material is passing through process equipment. For this reason, published tables of wood dust explosibility data may be of limited practical value. In some cases, dusts will be combustible even if the particle size is larger than that specified in the NFPA definition (especially if the material is fibrous). Also, industrial settings may contain high-energy ignition sources such as welding torches or open flame devices that can provide the ignition energy necessary to ignite larger particulate sizes.

The pine beetle epidemic in BC has had an impact on raw timber supply for many sawmills. Some mills that process these logs may have experienced a noticeable increase in combustible dust generation which, in turn, significantly increases the overall hazard associated with dust management and the need for adequate housekeeping practices that are commensurate with the exposure.

Electrical Classification

The facility analysis must identify areas requiring special electrical equipment classification due to the presence (or potential presence) of combustible dust. Detailed requirements for equipment and for electrical installations in hazardous areas are in NFPA 70, the *National Electrical Code.*

Further guidance on area classification is contained in NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*. The overall dust hazard designation for electrical requirements is Class II. This is further broken down into Divisions which represent the probability of dust being present at any given time. Additionally, each dust is assigned a group (E, F, or G), representing the dust types (metal, carbonaceous, organic and other, respectively) with different properties. For instance, group G dusts includes atmosphere that may present combustible dusts of wood, flour, grain, plastic, and some chemicals.

For Class II locations, Groups E, F, and G, the classification involves the tightness of the joints of electrical assembly and shaft openings to prevent the entrance of dust in the dust-ignition proof electrical enclosure, the blanketing effect of layers of dust on the equipment that may cause overheating, and the ignition temperature of the dust. It is necessary, therefore, that equipment be identified not only for the class but also for the specific group of dust that will be present.

Sections 500.7(A) through (L) of the NFPA 70 provides acceptable protection techniques for electrical and electronic equipment in hazardous (classified) locations.

Other Hazard Analysis Considerations

The amount of dust accumulation necessary to cause an explosive concentration can vary greatly. This is because there are so many variables – the particle size of the dust, the method of dispersion, ventilation system modes, air currents, physical barriers, and the volume of the area in which the dust cloud exists or may exist. As a result, simple rules of thumb regarding accumulation (such as writing in the dust or visibility in a dust cloud) can be subjective and misleading. The hazard analysis should be tailored to the specific circumstances in each facility and the full range of variables affecting the hazard.

Many locations need to be considered in an assessment. One obvious place for a dust explosion to initiate is where dust is concentrated. In equipment such as dust collectors, a combustible mixture could be present whenever the equipment is operating. Other locations to consider are those where dust can settle, both in occupied areas and in hidden concealed spaces. Fugitive dust can occur where conveying systems change direction or at transfer points. For sawmill operations, areas that must specifically be considered include (but are not limited to) the following:

- Debarking operations;
- Primary breakdown operations (saws);
- Chipper enclosures;
- Chip screening operations; and,
- Conveying and transfer points.

A thorough analysis will consider all possible scenarios in which dust can be dispersed, both in the normal process and potential failure modes.

After hazards have been assessed and hazardous locations are identified, one or more of the following prevention, protection and/or mitigation methods may be applied.

Dust Control

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, contains comprehensive guidance on the control of dusts to prevent explosions. The following are some of its recommendations:

- Minimize the escape of dust from process equipment or ventilation systems;
- Use dust collection systems and filters;
- Utilize surfaces that minimize dust accumulation and facilitate cleaning;
- Provide access to all hidden areas to permit inspection;
- Inspect for dust residues in open and hidden areas, at regular intervals;
- Clean dust residues at regular intervals;
- Use cleaning methods that do not generate dust clouds, if ignition sources are present;
- Only use vacuum cleaners approved for dust collection;
- Locate relief valves away from dust hazard areas; and
- Develop and implement a hazardous dust inspection, testing, housekeeping, and control program (preferably in writing with established frequency and methods).

Ignition Control

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, also contains comprehensive guidance on the control of ignition sources to prevent explosions. The following are some of its recommendations:

- Use appropriate electrical equipment and wiring methods;
- Control static electricity, including bonding of equipment to ground;
- Control smoking, open flames, and sparks;
- Control mechanical sparks and friction;
- Use separator devices to remove foreign materials capable of igniting combustibles from process materials;
- Separate heated surfaces from dusts;
- Separate heating systems from dusts;
- Proper use and type of industrial trucks;
- Proper use of cartridge activated tools; and
- Adequately maintain all the above equipment.

The use of proper electrical equipment in hazardous locations is crucial to eliminating a common ignition source. The classification of areas requiring special electrical equipment is discussed in the Facility Dust Hazard Assessment section above. Once these areas have been identified, special Class II wiring methods and equipment (such as "dust ignition-proof" and "dust-tight") must be used as required by NFPA 70 Article 500. It is important not to confuse Class II equipment with Class I explosion-proof equipment, as Class II addresses dust hazards, while Class I addresses gas, vapor and liquid hazards.

Damage Control

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, contains comprehensive guidance to minimize the danger and damage from an explosion. The following are some suggested protection methods:

- Separation of the hazard (isolate with distance);
- Segregation of the hazard (isolate with a barrier);
- Deflagration venting of a building, room, or area;
- Pressure relief venting for equipment;
- Provision of spark/ember detection and extinguishing systems;
- Explosion protection systems (also refer to NFPA 69, Standard on Explosion Prevention Systems);
- Sprinkler systems; and
- The use of other specialized suppression systems.

Training

Employees

Workers are the first line of defense in preventing and mitigating fires and explosions. If the people closest to the source of the hazard are trained to recognize and prevent hazards associated with combustible dust in the plant, they can be instrumental in recognizing unsafe conditions, taking preventative action, and/or alerting management. All employees should be trained in safe work practices applicable to their job tasks, as well as on the overall plant programs for dust control and ignition source control. They should be trained before they start work, periodically to refresh their knowledge, when reassigned, and when hazards or processes change.

Management

A qualified team of managers should be responsible for conducting a facility analysis (or for having one done by qualified outside consultants*) prior to the introduction of a hazard and for developing a prevention and protection scheme tailored to their operation. Supervisors and managers should be aware of and support the plant dust and ignition control programs. Their training should include identifying how they can encourage the reporting of unsafe practices and facilitate abatement actions.

* Aon has developed an effective sawmill dust hazard assessment survey that has been proven to help sawmills and woodworking facilities control these exposures while keeping the total cost of risk management under check. Contact your Aon representative for more information.

Aon has designated team of experts that will be readily available to look after your needs for sawdust risk control including full hazard identification, risk assessment and safety reviews, with particular focus on sawdust accumulation and potential ignition sources.

Aon Contacts

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Limiting Conditions

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BC Forest Safety Council

Base Audit – Draft Guidelines Version 2.1: Pellet Industry Addendum

September 13, 2011

BC Forest Safety Council
Unsafe is Unacceptable

BASE AUDIT

DRAFT GUIDELINES Version 2.1

Pellet Industry Addendum

Designed for

- **Wood Pellet Mills**

420 Albert Street, Nanaimo, BC V9R 2V7
Phone: 250-741-1060 | Toll Free: 1-877-741-1060 | Fax: 250-741-1068 | www.bcforestsafe.org

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BASE Audit Application

The BASE (Basic Audit and Safety Evaluation) Audit Pellet Industry Addendum standard applies to companies involved in the manufacturing of wood pellets, regardless of the size of the company.

Company certification follows the same protocol as the main BASE audit. The initial audit for the Addendum must be performed by a certified external BASE audit with pellet industry competency. Successful completion of a BASE audit is a co-requisite (i.e. the company must already be certified to the BASE standard or simultaneously complete the main BASE audit with the pellet addendum.)

BASE Audit Instructions

The BASE Audit Guidelines provide instructions and interpretation for the 'BASE Audit Questions'. Please refer to that document for the exact question text.

Audit Scoring

Scoring for the audit is very prescriptive. Auditors are given very particular instructions and there must be valid reasons for awarding or not awarding points. Scoring is discussed further in the audit guidelines. Scoring is important. As a basic requirement, every company that undertakes an audit must meet a minimum standard as determined by the sector through the Council.

- **Companies must obtain at least 51% in <u>each</u> of the applicable 9 elements PA-PJ and an overall mark of 80% to meet the addendum standard.**

Contact the BC Forest Safety Council (Toll Free: 1-877-741-1060) at any time for assistance or go the Council's website at www.bcforestsafe.org for safety audit advisor staff contact information.

Individual Question Guidelines

PA. Raw Fibre Storage

This section of the audit deals with the storage of raw material from receipt until drying/sizing. Storage may be indoors or outdoors and the stored fibre may be in any form, such as chips, shavings, hog fuel, whole log and/or non-tree biomass. Both wet and dry storage is to be considered.

Applies only at manufacturing sites with storage facilities. Does not apply with direct-feed from adjacent mills if stockpiles are not present on site.

PA. Raw Fibre Storage (Wet and/or Dry)	
PA1. Fibre Piles	
Question	**Guideline**
PA1.1	**O -** If all raw fibre (shavings, hog fuel, sawdust, logs or other wood) is stored in piles or a building, structure or silo that is 30m or more away from all major buildings and 10m away from any access roads, award 5 points..
PA1.2	**O-** If 100% of observations of fibre piles are less than 150m long, 100m wide and 20m tall, award 5 points
PA1.3	**O-** If all piles or structures or silos of fibre separated by a distance of not less than 10m, award 5 points.
PA1.4	**D –** If program documents specify a maximum safe thermal limit in piled materials (excluding logs) of 60C or less, award 4 points. If the program documents specify a warning limit of 40C followed by a 10C rise in 24 hours, or a more stringent limit, award an additional point. **D-** If documents show that the internal temperature of piles is monitored at least weekly, award 5 points. **I-** Award up to 5 points based on % of interviewed supervisors able to explain how they are ensuring piles are rotated regularly and managed on a FIFO (First In, First Out) basis for piles of the same type of material. It is recognized that blending recipes may draw down piles of some materials faster than others.
PA1.5	**O-** Award up to 5 points based on the % of buildings and silos used for dry fibre storage that are equipped with automatic sprinkler or other automatic fire suppression system. If all fibre is stored outside, then score this question as 'Not Applicable' and deduct 5 points from the available score.
PA1.6	**O –** Award up to 5 points based on the % of raw fibre stored on a paved, cement or otherwise sealed surface that will not introduce debris into the process.
PA2. Mobile Equipment	
Question	**Guideline**
PA2.1	**O –** Award up to 5 points based on the % of mobile equipment used to transport raw fibre that is equipped with fire suppression systems using the following formula *(% of equipment equipped with a fixed suppression system with or without a portable system) * 5 +* *(% of equipment with a portable system only) * 2*

PA. Raw Fibre Storage (Wet and/or Dry)	
PA2.2	**D –** Award up to 5 points based on the % of mobile equipment used for fibre handling that has daily records of inspection for cleanliness and/or cleaning. **I –** Award up to 5 points based on the % of operators of mobile equipment used for fibre handling that report completing daily inspection or cleaning forms. The inspection must specifically include cleanliness.

PB. Primary Building Construction

This section of the audit applies to manufacturing, storage, transportation and end-user

PB. Primary Building Construction	
PB1. Construction Materials	
Question	**Guideline**
PB1.1	**O-** If all primary manufacturing buildings are of non-combustible construction, award 20 points
PB1.2	**O-** Award up to 5 points based on the % of combustible components (open wood truss roof structures, open wood framed walls, etc.) that are enclosed in a non-combustible material. If there are no combustible components, score this question as 'Not Applicable' and deduct 5 points from the available total.
PB2. Dust Isolation	
Question	**Guideline**
PB2.1	**D-** Award up to 10 points based on the % of building features that allow for the accumulation of wood dust (i.e. wall ledges, horizontal structural members, horizontal piping, roof trusses, etc.) enclosed or shielded with sheet metal angled at least 60 to shed dust. **D –** If less than 5% of the floor area of the plant has dust accumulations of greater than 3mm (1/8"), award 5 points.
PB2.2	**O-** If all mechanical and electrical rooms are separated from the main manufacturing area, award 2 points. If the separation is a 2 hour fire rated enclosure on all walls, floor, ceiling and self-closing doors as applicable, award a further 2 points, provided that no mechanical or electrical room door was found to be blocked or left open. If the mechanical room is at positive pressure, award 1 point.

PC. Fire Suppression Systems

Applies to all sites

PC. Fire Suppression Systems	
PC1. Sprinklers	
Question	**Guideline**
PC1.1	**O-** If all primary manufacturing buildings are sprinkler protected, award 4 points. If all separate support buildings (i.e, office, shop, etc.) are sprinkler protected, award an additional 1 point.
PC1.2	**D-** If the annual sprinkler system testing and service was performed by a qualified person in the last 12 months award 2 points. If there were no corrective actions, or if all corrective actions are completed, award an additional 3 points.
PC2. Hoses and Hydrants	
Question	**Guideline**
PC2.1	**O-** If fire hose stations are provided throughout the interior of production buildings, award 5 points.
PC2.2	**O-** If fire hydrants (private or municipal) spaced not less than 100m apart and 100m from manufacturing buildings, storage silos and fire storage piles, award 5 points
PC3. Water Supply	
Question	**Guideline**
PC3.1	**D-** If the company can show that the water supply volume calculation, as performed by a qualified engineer, is sufficient to satisfy the hydraulic demands of the sprinkler system and the hose stream allowance, award 5 points.
PC3.2	**D-** If there is documentation to show that the water supply has a minimum duration of 90 minutes, award 5 points. The duration must be for both the sprinklers and the hose stream allowance simultaneously. Public utility water connections are to be considered as sufficient unless documentation to the contrary exists. Private water supplies (fire reservoir, lake, pond, etc.) must have documentation on site.
PC4. Pumps	
Question	**Guideline**
PC4.1	**O-** If fire pumps are required, award 5 points if they are approved (UL or FM) pumps with either • Dual system (electric driver and diesel driver) or • Electric with an on-site diesel generator to provide a back up power supply Fire pumps are required for private water supplies or where specified by the qualified engineer who provided the water supply volume calculation.
PC4.2	**D-** If there are records showing that the fire pump (whether diesel or electric) is started weekly in at least 90% of the weeks in the scope of the audit and the records indicate the date, result, and identify the personnel performing the test, award 2 points. If there were no corrective actions, or if all corrective actions are completed, award an additional 3 points.

PC. Fire Suppression Systems	
PC4.3	**D-** If there are records showing that the fire pump annual performance test has been performed by a qualified person in the last 12 months, award 2 points. If there were no corrective actions, or if all corrective actions are completed, award an additional 3 points.
PC5. Spark Detection and Suppression	
Question	**Guideline**
PC5.1	**D-** If maintenance records all support that spark detection and suppression systems are inspected, cleaned and tested internally by trained personnel on a regular basis in accordance with the manufacturer's instructions, award 5 points.
PC5.2	**D-** If there are records showing that all annual inspections and tests of • Spark detection systems • Spark suppression systems • Back draft dampers • High speed abort gates have been performed by a qualified person in the last 12 months, award 2 points. If there were no corrective actions, or if all corrective actions are completed, award an additional 3 points.
PC6. Operational Programs	
Question	**Guideline**
PC6.1	**D-** If documentation supports that the responding fire department has completed pre-incident planning and site visits of the mill within the last 3 years or since the last major process change, whichever is more recent, award 5 points. The responding fire department may be salaried, volunteer or a company fire brigade, provided the brigade meets NFPA 1081 standard. Documentation may include posted Fire Department inspection results.
PC6.2	**D-** If there are records showing that all annual thermographic scanning inspections and tests of the electrical distribution system has been performed by a qualified person in the last 12 months, award 2 points. If there were no corrective actions, or if all corrective actions are completed, award an additional 3 points.

PD. Fibre In-Feed

Covers in-feed into the manufacturing process, as opposed to in-feed into the property.
Applies to all sites.

PD. Fibre In-Feed	
PD1. Screening	
Question	**Guideline**
PD1.1	**I-** If the supervisor can describe a reasonable process for raw fibre screening or sorting prior to processing that is designed to remove any oversized materials or foreign contaminants such as rocks or tramp metal, award 10 points
PD2. Training and Education	
Question	**Guideline**
PD2.1	**O-** If there is observed to be an effective magnetic separation and/or other metal detection process at the in-feed into the process, award 5 points **D-** If records support regular inspection and removal of the metal from the separation / detection process, award 5 points. **I** – If all qualified operators interviewed can describe how the metal is removed from the process stream, including the method and frequency of inspection of the separation equipment, award 5 points.

PE. Fibre Sizing

Fibre Sizing covers both pre- and post-drying sizing of the fibre.
Not applicable if no sizing on site (i.e. at a transportation / storage facility)

PE. Fibre Sizing	
PE1. Foreign Object Removal	
Question	**Guideline**
PE1.1	**O-** If the fractionating equipment (hammer mill, hogger, etc.) is equipped with magnetic separation and/or interlocked ferrous material detection, award 5 points.
PE1.2	**O-** If rock drops and/or other means of removing non-ferrous contaminants are present on all fractionating equipment, award 5 points.
PE1.3	**D-** If there is a policy / program on the inspection and cleaning of the magnets or other apparatus in the magnetic separation / detection equipment, award 2 points **D** – If there are records supporting that the equipment is inspected and cleaned daily, award 3 points. **I -** If at least 90% of interviewed qualified operators state that they follow the prescribed protocol, including the maintenance of records, award 5 points.
PE1.4	**D-** If there is a policy / program on the inspection and cleaning of the fractionating equipment, award 2 points **D** – If there are records supporting that the equipment is inspected and cleaned daily, award 3 points. **I -** If at least 90% of interviewed qualified operators state that they follow the prescribed protocol, including the maintenance of records, award 5 points.
PE2. Fire Detection	
Question	**Guideline**
PE2.1	**O-** If an approved (UL or FM) spark detection and suppression system, including, but not limited to • Clarkes • GreCon • Flamex • Firefly Is installed following the fractionating equipment, award 15 points. D – If the design documents indicate that the system has multiple spark detection that will shut down the equipment if limits are exceeded, award 10 points

PE. Fibre Sizing	
PE2.2	**O –** If the device used for bearing temperature monitoring has a current calibration on or with it, award 5 points. **D** – If a readout shows the current bearing temperature or daily logs indicate the temperature readings for all fractionating equipment bearings, award 5 points. **I-** If at least 80% of sampled qualified operators state the fractionating equipment is provided with bearing temperature monitors or that a hand-held remote thermometric device is used on a daily basis to examine bearing temperatures, award 5 points.
PE3. Equipment Location	
Question	**Guideline**
PE3.1	**O-** If the fractionating equipment is either • Located outside the main manufacturing facility, or • Isolated in a 2 hour fire enclosure within the main plant Award 5 points
PE3.2	**O-** If the equipment AND the ductwork leading from the equipment has explosion-relieving panels that vent to the exterior of the building in an area or location where pedestrians are excluded by physical design (elevation, barriers, etc.) or by administrative controls (signage), award 5 points.
PE3.3	**O –** Award up to 5 points based on the % of observable electrical wiring, fittings and other devices that are properly sealed and maintained (i.e. no open electrical boxes, no connections outside of junction boxes, no frayed wires, no portable heaters in manufacturing areas, etc.) **D –** if the electrical wiring and lighting is marked for use as per National Electrical Code and NFPA 70, award 5 points • Enclosed location – Class III, Division II, Group G • Exterior location – (need the reference for exterior weather protection rating)

PF. Fibre Drying

Covers horizontal drum driers, single, triple and other pass styles

(Not applicable if site is a transportation / storage site or otherwise has no drying)

PF. Fibre Drying	
PF1. Incident Reports	
Question	**Guideline**
PF1.1	**D-** If there is an approved (UL or FM) spark detection and suppression system provided on the outfeed of the dryer, award 5 points.
PF1.2	**O-** If both the internal and out-feed temperatures of the dryer are continuously monitored in a control room, award 2 points. **D** – If system design documentation indicates that the dryer will shut down or purge material to a fire dump at a safe location if the monitored temperature exceeds the limit value, award 3 points. Emergency shutdown must include shutting down and/or diverting heat from the dryer as well as stopping the material in-feed.
PF1.3	**O-** If there is an automatic water deluge system (with or without a manual system) on both the dryer in-feed and out-feed award 5 points. If there is a manual system without automatic activation, award 3 points.
PF1.4	**D-** If the operating instructions describe how the feed of materials into the dryer is monitored and interlocked to shut off or divert heat from the burner if the feed of material is interrupted, award 5 points.
PF1.5	**O-** If there is a fire dump or other safe area provided for the purging of dryer contents if high temperature limit switches are exceeded, award 5 points. The area must be location where pedestrians are excluded by physical design (elevation, barriers, etc.) or by administrative controls (signage).
PF1.6	**O-** If there is a backup generator or secondary driver (with an independent power source) for the drum rotation drive, award 5 points. The backup system needs to be able to maintain drum rotation during emergency shut down or power failure to prevent warping of the drum.
PF3. Inspections	
Question	**Guideline**
PF2.1	**O-** If the dryer operation monitored with programmable logic controllers (PLC), award 5 points. **D-** If records show that the annual logic testing of the dryer PLC system has occurred in the last 12 months, award 2 points. If there were no deficiencies, or all deficiencies have been corrected, award an additional 3 points.
F3.2	**D-** If there are records showing the duct work after the dryer is inspected for creosote build up and cleaned on a quarterly basis, award 5 points. **I-** If interviews with at least 80% of sampled qualified operators describe a cleaning frequency and method that is at least quarterly and compliant with operating instructions, award 5 points.

PG. Pelletizing

(not applicable at a site without pelletizing, such as a transportation or storage facility or at a final user)

PG. Pelletizing	
PG1. Load Sensing	
Question	**Guideline**
PG1.1	**O-** If the pellet presses are all equipped with PLC to monitor their operation, award 5 points. **D-** If the control room readouts include load sensors or electrical current monitoring with both high and low limits, award 5 points
PG2. Reserve Hopper	
Question	**Guideline**
PG2.1	**O-** If there is a reserve hopper for either each press or for all presses proved for material being fed into the presses to prevent the presses from running out of feed stock, award 5 points. If the hopper is equipped with both high and low level material sensors, award 5 additional points. **I-** If 80% of the interviewed qualified operators can correctly describe how the low material sensor alerts the operator and automatically suspends operations of the press(es) connected to that hopper, award 5 points. If there is no hopper and/or no low level material sensor, score the interview portion as zero. Do not deduct 5 points from the total.
PG3. Auxiliary Materials	
Question	**Guideline**
PG3.1	**D-** If documentation shows that 100% of any additives used in the pelletizing process have an ignition temperature above the maximum operating temperature of the press, award 5 points. If no additives are used, score this portion as 'N/App' and deduct 5 points from the available total. D – If documentation shows that 100% of any die cleaners (ie diesel fuel, waste oil, vegetable oil, etc.) used in the pelletizing process have an ignition temperature above the maximum operating temperature of the press, award 5 points. If no die cleaners other than air and mechanical effort are used, score this portion as 'N/App' and deduct 5 points from the available total. Documentation reviewed for this question should include the operating control limits of the press and product specification or material safety data sheets (MSDS).

PH. Pellet Cooling

Pellet cooling can be using individual or common coolers.
(Not applicable if at a transportation, storage or end-user site)

PH. Pellet Cooling	
PH1. Cooler Equipment	
Question	**Guideline**
PH1.1	**D-** If there is a clear display in the control room indicating temperature of the cooler that will alert the operator and automatically stop the process in-feed and out-feed from each affected cooler, for all coolers, award 5 points.
PH1.2	**O-** If there is an automatic water deluge system (with or without a manual system) within all coolers, award 5 points. If there is a manual system without automatic activation, award 3 points.
PH1.3	**O-** If all coolers vent to atmosphere outside the building in a safe location, award 5 points. The system must not capture residual heat for use anywhere else in the process or for seasonal heating.
PH1.4	**D-** If there is an approved (UL or FM) spark detection and suppression system provided on the ventilation system of the cooler, award 5 points.
PH1.5	**O-** If the duct from the cooler to the baghouse contains a high speed abort gate, award 5 points. If there is no baghouse, score this question 'Not Applicable' and deduct 5 points from the available total.

PI. Finished Product Storage

This portion of the audit only applies if the company has storage silos for finished product. The entire section of the audit is to be scored 'Not Applicable' if the company produces solely bagged product and the storage volume of product between cooled pellet and bag is one shift or less. If the intermediate storage is a greater volume than one shift, then this portion of the audit applies.
Applies at transportation, storage and end-user sites.

PI. Finished Product Storage	
PI1. Silo Construction	
Question	**Guideline**
PI1.1	**O-** If silos are all located outside of manufacturing building and provided with a clear space of at least 10m on all sides for firefighting efforts, award 10 points.
PI1.2	**O-** If there is explosion-relief venting at the top of the silos that is directed away from buildings or where personnel congregate, award 5 points.
PI2. Silo Emergency Response	
Question	**Guideline**
PI2.1	**D-** If there is a clear display in the control room indicating temperature of the silo that will both audibly and visually alert the operator and automatically stop the process in-feed to each affected silo, for all silos, award 5 points. **D** – If the system documentation specifies a maximum safe limit of 60C or less, award 4 points. If the program documents specify a warning limit of 40C followed by a 10C rise in 24 hours, or a more stringent limit, award an additional point.
PI2.2	**O-** If there is an automatic water deluge system (with or without a manual system) within all silos, award 1 point. If the system is a pre-action, water mist or inert gas system, award 4 points
PI2.3	**D-** If the written emergency response procedure for an actual or suspected silo fire includes fully emptying the silo with due consideration to avoid bottom-feeding a silo fire with air, award 5 points

PJ. Dust Collection and Ventilation

Applies at manufacturing, storage and end-user sites

PI. Finished Product Storage	
PH1. Bag Houses	
Question	**Guideline**
PJ1.1	**D-** If dust collection equipment and ductwork from the collection equipment to the bag house is grounded, award 5 points
PJ1.2	**O-** If the dust collection system is located outside the building more than 10m from the building or separated by a minimum 2 hour fire wall, award 5 points. A location on the roof of the building is acceptable if the roof is also fire rated for a minimum of 2 hours.
PJ1.3	**O -** Are cyclones or bag house type collectors that are connected to process equipment with a potential to produce sparks or embers; • Equipped with an approved spark detection system (1 point) • Equipped with an approved sprinkler system both above and below the collector bags (1 point) • Equipped with a high-speed abort gate (1 point) • Provided with counterweighted back draft dampers on in-feed duct work (1 point) • Provided with explosion-relief panels directed away from buildings where personnel congregate (1 point) Process equipment with a potential to produce sparks or embers includes, but is not limited to: • Fractionating equipment • Rotary drum driers • Pellet coolers
PJ2. Procedures	
Question	**Guideline**
PJ2.1	**D-** If there is a written program defining the frequency of inspection of the bag house structure, the bags and unit grounding as being annual or more frequent, award 5 points. I – If all interviewed qualified operators state that replacement bags are on-site or available off-site in less than 24 hours, award 5 points.
PJ2.2	**I-** If all interviewed qualified operators can correctly describe the automatic sequential shut down of process equipment and activation of an audible and visual alarm on baghouse shut down, award 5 points.
PJ2.3	**O –** If the primary method of dust cleanup is observed to be vacuum (as opposed to air wand), award 10 points. It is recognized that some equipment, such as the internals of pelletizers, cannot be vacuumed due to impacted materials. Vacuums may be any combination of portable, fixed and centralized.

Definitions

Word or Phrase	Definition
Any definitions specific to pellets??	Ready for definitions if there are any

Louisiana Pacific

Fire Prevention Assessment

Date published: September 2010

Fire Prevention Assessment

Dust

Mill Location:	
Auditor(s):	
Date:	

RATING	PROCESS OWNER	PRIORITY
NE = No evidence of any action/process/procedure or training VE = Visible evidence but no documentation / documentation but no visible evidence VEP = Visible evidence and partial documentation CED = Clear evidence of compliance with thorough documentation	Operations Maintenance Safety Fire Technician	Level 1 (High Priority) - Situations that may present substantial risk to employees, stockholders, the company or reputation. Level 2 (Priority Action) - Does not meet the criteria for level 1, but is more than an isolated or occasional situation. These actions should not continue past the short term. Level 3 (Action Required) - May be administrative in nature or involve an isolated or occasional situation.

Instructions for completing 1st Party Fire Assessments

1. 1st Party Fire Assessments should be done with a small team of people at each location.
2. Each element must be covered annually. All annual evaluations are to be complete by the end of the third quarter.
3. Review each question in detail.
4. Rate each element of each question (Documentation, Training, Execution). It is acceptable for certain questions to answer some elements as NA.
5. List a Process Owner for each item.
6. Answer all questions in narrative form in the findings section.
7. Provide detailed information for each question (where information is located, how it is documented and maintained, who performs required checks/inspections, how often checks/inspections are completed, how verified).
8. Once complete, cover the responses and recommendations with the site staff and personnel responsible for recommendations.
9. For each item that does not score CED there should be a recommendation to strengthen the element. Recommendations should be detailed and specific to allow auditing. Recommendations should be transferred to CAP Tracker.
10. Send a copy of the completed assessment to your corporate safety contact.

The documentation for the following areas may be contained in one or more documents.

	Areas	Rating: Documentation	Rating: Training	Rating: Execution	Process Owner	Finding	Recommendation	Priority
1	Is there a process in place to assure the process areas will be free of dust buildup in excess of 1/8"?							1
2	In buildings or areas fugitive combustible dust is released, are the following actions incorporated into a housekeeping/dust control plan? Guidelines should be established as appropriate:							2
3	Regular cleaning frequencies shall be established and a person assigned responsibility for executing for walls, floor, and horizontal surfaces, such as equipment, ducts, pipes, hoods, ledges, beams, and above suspended ceilings and other concealed surfaces, to minimize dust accumulations within operating areas.							2
4	Is there evidence of fugitive dust leaks around fire dump vault/bunker areas?							1
5	Is it ensured that all covers, infeeds and distributions are closed, sealed and in good repair to prevent any leaks or dust build-up (level sensor holes closed and sealed to prevent leaks)?							1
6	Are all lids closed, sealed and in good repair to prevent any leaks or dust build-up? No leaks are acceptable.							1
7	Are conveyor pulley areas kept clean?							2
8	Has a comprehensive dust mitigation and fire awareness program where combustible dust exists either within closed processing systems or as fugitive dust within building areas been developed with LP Safety/Marsh Risk Consulting to coordinate the training?							1
9	Is process in place to assure process areas will be free of leaking flake, wood dust/fines from piping?							1

Fire Prevention Assessment

Dust

Mill Location:	
Auditor(s):	
Date:	

RATING	PROCESS OWNER	PRIORITY
NE = No evidence of any action/process/procedure or training	Operations	Level 1 (High Priority) - Situations that may present substantial risk to employees, stockholders, the company or reputation.
VE = Visible evidence but no documentation / documentation but no visible evidence	Maintenance	Level 2 (Priority Action) - Does not meet the criteria for level 1, but is more than an isolated or occasional situation. These actions should not continue past the short term.
VEP = Visible evidence and partial documentation	Safety	Level 3 (Action Required) - May be administrative in nature or involve an isolated or occasional situation.
CED = Clear evidence of compliance with thorough documentation	Fire Technician	

Instructions for completing 1st Party Fire Assessments

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5. List a Process Owner for each item.
6. Answer all questions in narrative form in the findings section.
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8. Once complete, cover the responses and recommendations with the site staff and personnel responsible for recommendations.
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10. Send a copy of the completed assessment to your corporate safety contact.

The documentation for the following areas may be contained in one or more documents.

	Areas	Rating: Documentation	Rating: Training	Rating: Execution	Process Owner	Finding	Recommendation	Priority
10	Are superstructure/framework and support beams, decking and stairs, guarding, drop chutes (infeed and outfeed) seals, doors clean?							1
11	Cable trays?							1
12	Storage (tools, etc.)?							1
13	How does the facility check and account for forces in the PLC's that control alarms or safety trips?							1
14	Is the cleaning method used in this order of preference - 1. vacuum, 2. sweeping, 3. water wash, 4. air blow down?							
15	Use brooms and brushes first for layers exceeding 1/8" in depth.							2
16	Vacuum removal suitable for Class II, Division II (This includes appropriate grounding and bonding) should be used wherever possible using a central, portable, or truck mounted vacuum system as appropriate.							3
17	Is compressed air being used in areas where alternative cleaning methods are practical?							2
18	In overhead blow down areas, are electrical devices within 10 feet dust tight to prevent dust entry?							2
19	Has a list been developed of where compressed air can be used for cleaning?							3
20	Has a sample of the material that accumulates in the ductwork of the multi-cyclones been tested for minimum ignition temperature (MIT) annually?							3
21	Are corrective actions identified and tracked to completion in the CAP Tracker?							3

United Steelworkers

Resource Handout: Controlling Hazards

Date published: Unknown

UNITED STEELWORKERS
USW
UNITY AND STRENGTH FOR WORKERS

Resource Handout

CONTROLLING HAZARDS

Once hazards have been identified, the next step is to control the hazards. Hazard controls are methods used to eliminate or limit workers' exposure to a hazard. While there are many different types of hazards (such as toxic chemicals, unguarded machinery and equipment, working in high places), there are certain principles guiding hazard control that apply to all hazards.

The Hierarchy of Hazard Controls

The best way to control a hazard is to eliminate it. If a hazard can not be eliminated all together, there are several other ways to limit worker exposure to the hazard. Some of these ways are more effective than others. When all of these different hazard control methods are put in a chart, going from the most effective to the least effective way to control the hazard, the chart portrays the "hierarchy of hazard controls." It is considered good occupational safety and health practice to follow the hierarchy of controls.

HIERARCHY OF HAZARD CONTROLS

Most Effective	**1.**	**Elimination**
↓	**2.**	**Substitution**
	3.	**Engineering Controls (Safeguarding Technology)**
	4.	**Administrative Controls (Training and Procedures)**
Least Effective	**5.**	**Personal Protective Equipment**

Examples of Each Step in the Hierarchy of Hazard Controls

1. Elimination

The best way to control a hazard is to eliminate it and remove the danger. This can be done by changing a work process in a way that will get rid of a hazard;

substituting a non-toxic chemical for a toxic substance; having workers perform tasks at ground level rather than working at heights; implementing needle-less IV systems in health care facilities to eliminate needles; and other methods that remove the hazard all together.

2. Substitution

The second best way to control a hazard is to substitute something else in its place that would be non-hazardous or less hazardous to workers. For example, a non-toxic (or less toxic) chemical could be substituted for a hazardous one.

3. Engineering Controls (Safeguarding Technology)

If a hazard cannot be eliminated or a safer substitute cannot be found, the next best approach is to use engineering controls to keep the hazard from reaching the worker. This could include methods such as using noise dampening technology to reduce noise levels; enclosing a chemical process in a Plexiglas "glove box"; using needles that retract after use; using mechanical lifting devices; or using local exhaust ventilation that captures and carries away the contaminants before they can get in the breathing zone of workers.

4. Administrative Controls (Training and Procedures)

If engineering controls cannot be implemented, or cannot be implemented right away, administrative controls should be considered. Administrative controls involve changes in workplace policies and procedures. They can include such things as:

- Warning alarms,
- Labeling systems,
- Reducing the time workers are exposed to a hazard, and
- Training.

For example, workers could be rotated in and out of a hot area rather than having to spend eight hours per day in the heat. Back-up alarms on trucks that are backing up are an example of effective warning systems. However, warning signs used *instead* of correcting a hazard that can and should be corrected are *not* acceptable forms of hazard control. For example, it is neither effective nor acceptable to post warning signs by an unguarded machine cautioning workers to work carefully.

5. Personal Protective Equipment

The use of personal protective equipment (PPE) is a way of controlling hazards by placing protective equipment directly on workers' bodies. Examples of personal protective equipment include: respirators, gloves, protective clothing, hard hats, goggles, and ear plugs.

Personal protective equipment is the *least* effective method for protecting workers from hazards. PPE should be used only while other more effective controls are being developed or installed, or if there are no other more effective ways to control the hazard. This is because:

- The hazard is not eliminated or changed.
- If the equipment is inadequate or fails, the worker is not protected.
- No personal protective equipment is fool-proof (for example, respirators leak).
- Personal protective equipment is often uncomfortable and can place an additional physical burden on a worker.
- Personal protective equipment can actually create hazards. For example, the use of respirators for long periods of time can put a strain on the heart and lungs.

While there are some jobs, such as removing asbestos, where wearing adequate personal protective equipment is absolutely essential, there are many jobs where employers hand out personal protective equipment when in fact they should be using more effective hazard control methods.

A Word of Caution

When planning for hazard controls, remember that the control selected must not eliminate one hazard while creating another. For example, it is not acceptable to remove air contaminants from one area by venting them to another area where another group of workers will be exposed. Hazard control measures should eliminate or reduce hazards for all who are potentially exposed to them.

Hazard Control: Whose Responsibility?

The ability and responsibility to design jobs safely in the first place, or redesign them when a hazard is detected, lies with management. It is the role of workers and unions to promote the use of the "Hierarchy of Controls," making sure that employers are providing the most effective methods for hazard control possible. Remember: fix the workplace, not the worker!

Weyerhaeuser

Combustible Dust Control Program

Date published: November 6, 2009

Combustible Dust Control Program

1. Objective

The objective of the combustible dust control program is to reduce the risk of deflagrations, explosions and fires caused by combustible dust. Risk reduction will be achieved by effectively controlling wood dust and other dust accumulations by following the reliable processes identified in this program. This program also identifies training to protect employees from combustible dust hazards.

2. Definitions

Combustible Dust - Any finely divided solid combustible material that presents a deflagration or explosion hazard when dispersed and ignited in the air.

Deflagration - A technical term describing subsonic combustion that usually propagates through thermal conductivity. Hot burning material heats the next layer of cold material and ignites it. Most fire found in daily life, from flames to explosions, is technically deflagration.

Explosion - The bursting or rupture of an enclosure or a container due to the development of internal pressure from deflagration.

3. Background

A deflagration may occur when the right concentration of finely divided dust suspended in air contacts a source of ignition. An explosion could result if the combustible dust is dispersed within a confined enclosure such as a vessel, storage bin, ductwork, room, or building and the confined enclosure does not contain sufficient deflagration venting capacity to safely release the pressures.

A initial deflagration can disturb and suspend dust which has accumulated in the workplace, which could then serve as the fuel for a secondary (and often more damaging) deflagration or explosion. Combusting dust can also ignite other fires in the surrounding area.

In Wood Products mills combustible dust is most often composed of wood ground into very small particles. This dust is usually generated by the manufacturing processes and equipment. It accumulates in the workplace if it is not collected, transported and stored by a dust collection system.   Dust that is not collected by the dust collection system must be manually removed.

The **site** has developed procedures to identify areas where combustible dust may be generated, where it may accumulate, and where it could potentially become airborne and come in contact with an ignition source. When an area is identified the site will develop a plan to control, remove or prevent hazardous accumulations of combustible dust.

4. <u>Identification of Hazardous Areas</u>

The **site** has completed a thorough review of its manufacturing process to identify:

- Areas where there is the potential for combustible dust accumulation
- Process equipment that collects, transfers and stores combustible dust
- Work practices that might cause combustible dust accumulations to become airborne
- Sources of ignition that may come into contact with combustible dust

The site has also reviewed Incident investigation reports of fires that have occurred in the past 3 years. Root causes of the fires have been reviewed and implementation of the corrective actions to prevent reoccurrence has been confirmed.

The **site** has identified the following areas of the site where there is a potential of accumulation of dust greater than 1/8th of an inch.

Likely areas of dust accumulations within the site are:

- *Structural members in both planer and sawmill.*
- *Pipe racks and cable trays in sawmill basement*
- *Cable trays in planer sorter area*
- *Main floor in planer and sawmill*
- *Above ceilings*
- *On and around equipment*

Additionally the site has identified the following areas that either collects, transfers or stores combustible dust:

- *Planer infeed area, including under decks*
- Planer room
- PDC room in planer room
- *Planer chipper room*
- *Sawmill chipper area*
- *Underneath sawmill chip screens*
- Planer Chip screen room - wall ledges
- MSR room - plastic on wall
- *Hog building and Hog infeed.*
- *#4 chip tower.*
- *The area under the barkers and between the Barker / COS refuse conveyors.*

5. <u>Procedures to Minimize the Risk Associated with Combustible Dust</u>

Sources of Ignition
The **site** maintains effective electrical grounding and bonding methods, for dissipating electrostatic charges that could be generated.

The **site** follows a strict permitting procedure when hot work is performed in areas where combustible material may be present. The Hot Work permitting process requires removal of combustible material in the area where the hot work will occur and the appropriate level of fire watch during and after the hot work has been completed.

Fire and Property Insurance Investigation
The **site** utilizes Weyerhaeuser's incident investigation process to investigate process and building fires to root cause. Corrective actions are identified and assigned to a competent employee to ensure completion.

The site also utilizes the services of its property/casualty insurance carrier (FM Global) or its designate (Global Risk Consultants) to conduct periodic (minimum annually) fire insurance inspections. High-priority findings will be addressed as soon as possible, if not immediately, following the site's receipt of the audit report.

Dust Collection Systems (Engineering Controls)
The **site** maintains a system to collect dust generated in the manufacturing process. The dust collection system includes source exhaust ventilation hoods, ductwork (blowpipes), dust collectors (cyclones) with technology to minimize a dust fire or exposure inside the system. Such technology includes explosion venting and spark detection and suppression equipment in the ducting and a deluge system in the bag cyclone themselves to suppress fires and explosions. To keep these systems operating efficiently and as designed, this equipment is on a regular preventative maintenance (PM) schedule which includes inspection, cleaning and servicing. Specific information includes

Fugitive Dust Control
The **sites** housekeeping program establishes regular cleaning frequencies for floors and horizontal surfaces, such as ducts, pipes, hoods, ledges, and beams, to minimize dust accumulation. The housekeeping programs also inspects equipment that may generate or leak dust (such as sanders and dust collectors) to ensure they are maintained in a manner that minimizes dust accumulation.
Housekeeping inspection tours are held regularly to ensure the effectiveness of the program. Inspection findings are documented and presented to the site's leadership team. Corrective actions are assigned and tracked through completion.

Work Practices
Whenever feasible, the **site** uses cleaning methods that do not generate dust clouds, especially in areas where ignition sources are present. Vacuum, water wash or soft bristle brooms are the preferred approaches. The site minimizes use of high-

pressure compressed air to clean (blow down) dust accumulations. If dust is to be blown off overhead areas, all electrical equipment in the area is de-energized and appropriate respiratory protective equipment (such as disposable dust masks) is used, when necessary.

Contractors that specialize in industrial vacuum cleaning will be used for large dust-cleaning jobs. Capturing the majority of the dust at the source, before it is distributed throughout the work area, is the desired standard. Twice annually we will use the contractors to do a site wide cleanup.

6. Training

All leaders are expected to complete the Weyerhaeuser online training module: Combustible Dust Awareness, which was developed to inform facility personnel of the hazards of combustible dust and how to minimize the potential for a combustible dust fire or explosion.

Revision #	Revision Details	Date
01	Using developed the Combustible dust Plan for the Site	**Nov 6, 2009**

Sampling Results

Wood Pellet Association of Canada

Testing of Explosibility and Flammability of Airborne Dust from Wood Pellets

Date published: November 2, 2008

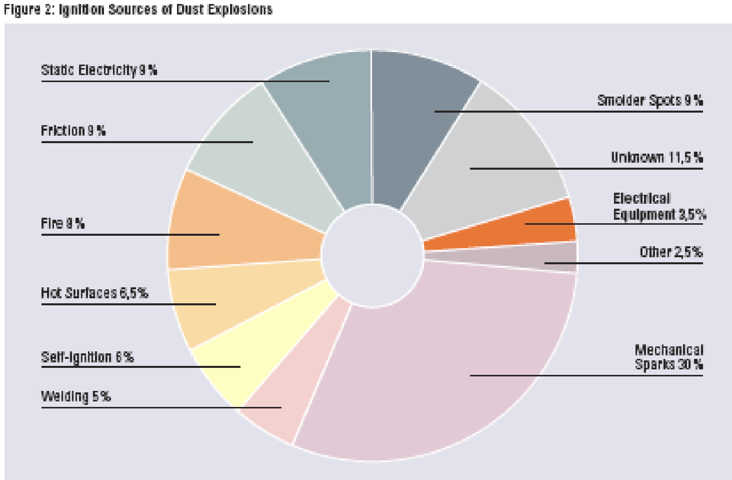
Testing of Explosibility and Flammability of Airborne Dust from Wood Pellets

Staffan Melin
Research Director
Wood Pellet Association of Canada
November 2, 2008

1. Introduction

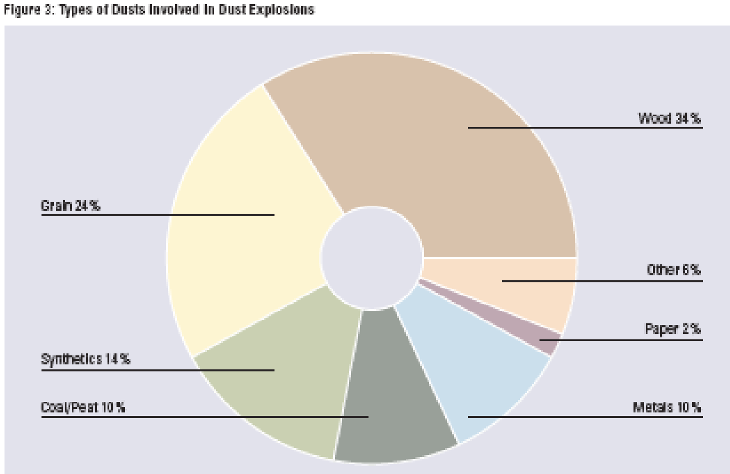
This report is a summary of the findings from physical characterization and testing the explosibility and flammability of dust collected during handling of white pellets as well as bark pellets. Explosions and fires are quite common in the industry processing wood, including the wood pellet industry, as can be seen in the diagram on the right hand side illustrating the officially recorded incidents in USA. It is of interest to notice the relatively small rate of incidents in the coal mining industry which traditionally has had a reputation of having many serious incidents.

Figure 2: Ignition Sources of Dust Explosions



To better understand the significance of dust generated during handling, the report includes some rudimentary particle physics to give a perspective on the behavior of dust suspended in air since it is the basics of much of the procedures for testing explosibility.

Figure 3: Types of Dusts Involved in Dust Explosions

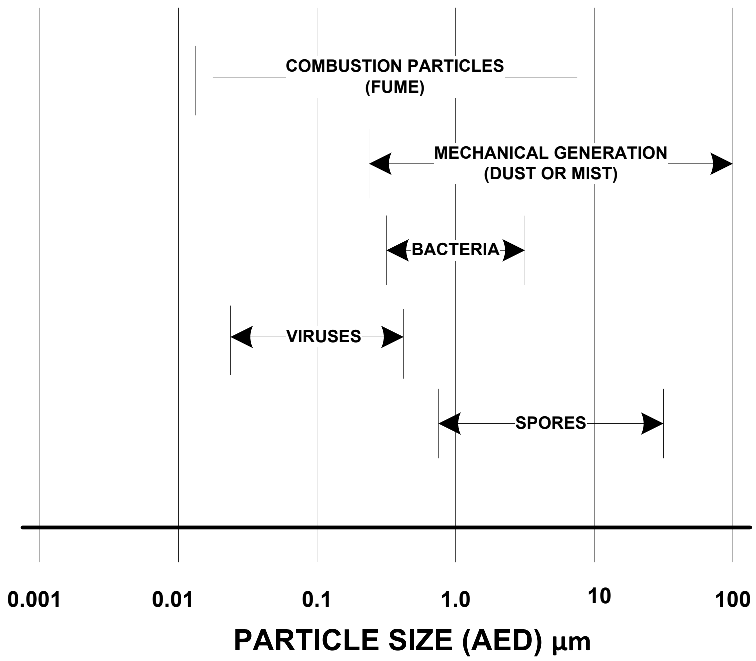


(Courtesy R. Stahl Schaltgeräte GmbH)

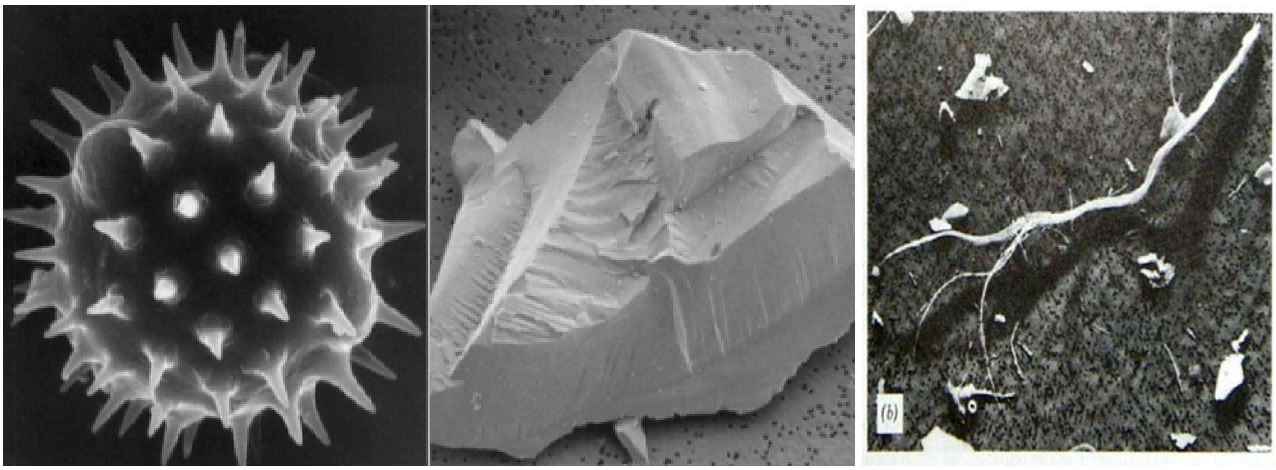
2. Particulate Physics Orientation

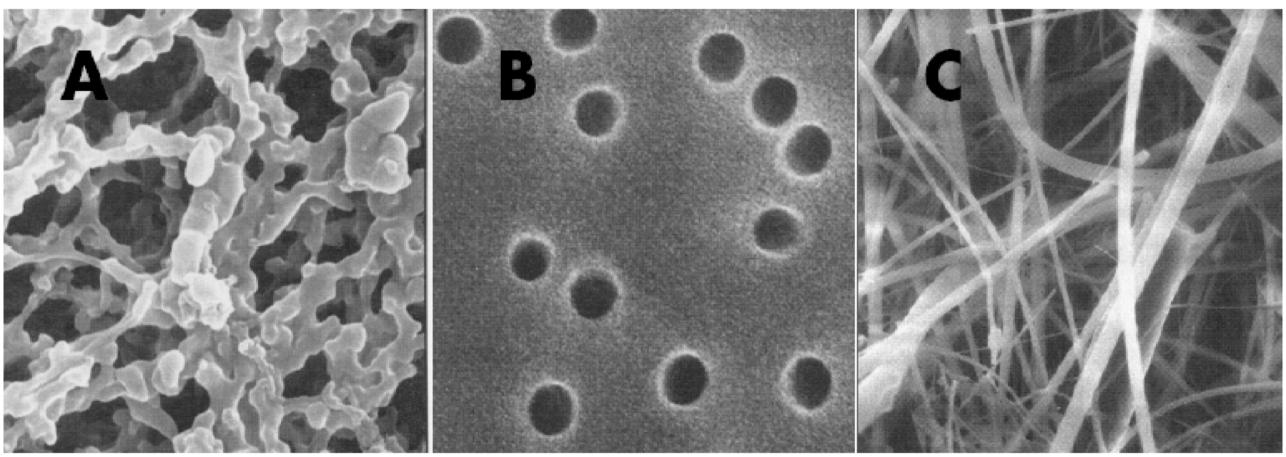
Airborne dust from wood pellets is the cause of many fires and explosions when exposed to ignition source or heat and often results in substantial damage and injuries. Airborne dusts are part of the wide spectrum of aerosols and are classified in the following main categories with typical size range indicated in the diagram below;

- Combustion generated particles
- Mechanically generated particles
- Spores
- Bacteria
- Viruses



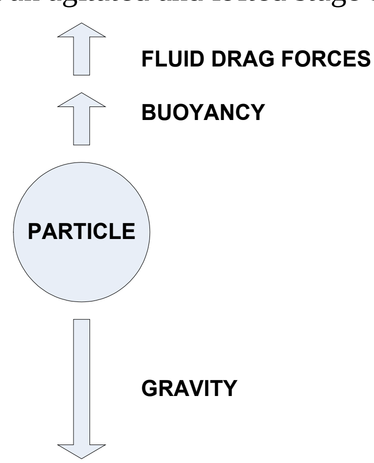
Particulates smaller than 425 µm (screen 40) are classified by OSHA as dust. To give a perspective on the size of particulates, cement dust range from 2-100 µm, diesel exhaust 0.001-1 µm and a human hair 20-180 µm. The actual size of particles is difficult to measure with any accuracy since they almost always appear in large numbers with individual shapes and sizes and each particle is almost always irregular in shape, often with porosity. The shape and size is often also affected by changes in moisture and temperature. In the industry the size is often determined by mechanical sieving with results affected by the geometry and duration of the vibrations of the sieving equipment. The result of mechanical sieving is often in question since the mesh through which the material is passing has no way of discriminating particles of different density and particles with non-spherical (ideal) shape or particles smaller than a certain diameter. Particles such as fibers with an aspect ratio larger than 1:5 are particularly difficult to classify by mechanical sieving.





An alternative method of classifying particles is machine vision using a high resolution scanner and image processing software. Both methods are approximations although the machine vision should be considered more accurate.

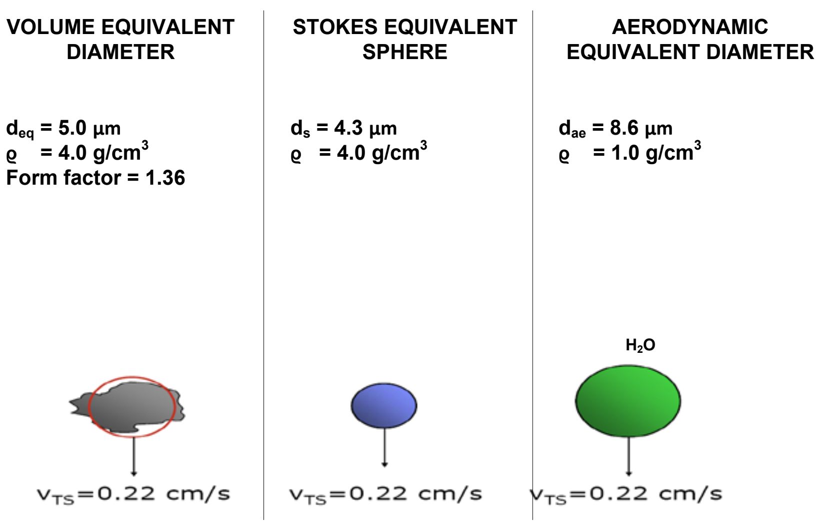
Particles which are not in the sediment state are often in an agitated and lofted stage by the media in which they habitate. The agitation is due to external forces acting on the particles such as turbulence, buoyancy, fluid drag, static electricity, Brownian forces, Van der Waal forces and gravity. The dynamics of how particles propagate in a media, such as air, is of fundamental importance in dust control. Practically all particles are non-uniform in shape and have different density depending on material and porosity and therefore are transported at different speed in air due to the forces of gravity, buoyancy and fluid drag forces as illustrated to the right.



Some of the critical factors with all aerosols is the concentration in any given area and the speed at which concentrations may occur. An understanding of the net effect of the forces exerted on the particle is essential and is quantified in terms of sedimentation (settling) speed of the particles under still as well as turbulent conditions. The sedimentation speed is primarily affected by the physical size, surface structure and density of the particle. The concept of **Aerodynamic Equivalent Diameter (AED)** is a way to relate the particle characteristics to the sedimentation speed at normal temperature and atmospheric pressure (NTP). One method is based on a determination of the projected area of the particle and the other is based on the volumetric determination of the particle, both normalized to an equivalent droplet of water with density 1,000 kg/m^3. The two methods results in an (AED). The sedimentation speed is then calculated using Stokes formula.

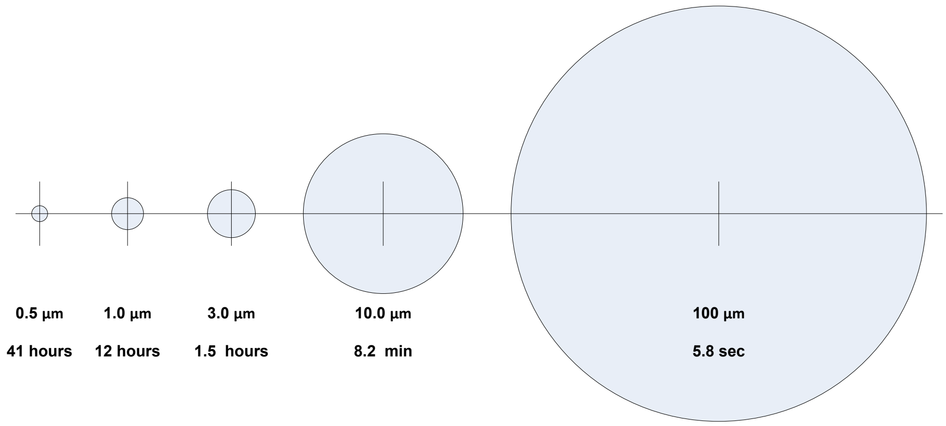
The two methods are illustrated below with parametric values to arrive at the same sedimentation speed.

THREE METHODS OF ESTIMATING PARTICLE DIAMETER BASED ON SEDIMENTATION SPEED



In turbulent air particles remain airborne for a longer period of time, particularly smaller particles. The sedimentation time has a direct impact on the concentration of particles in a given containment as well as the time it takes to build up a sediment layer. In still air larger particles settle much quicker than smaller particles as illustrated in the figure below.

PARTICLE SEDIMENTATION TIME IN STILL AIR



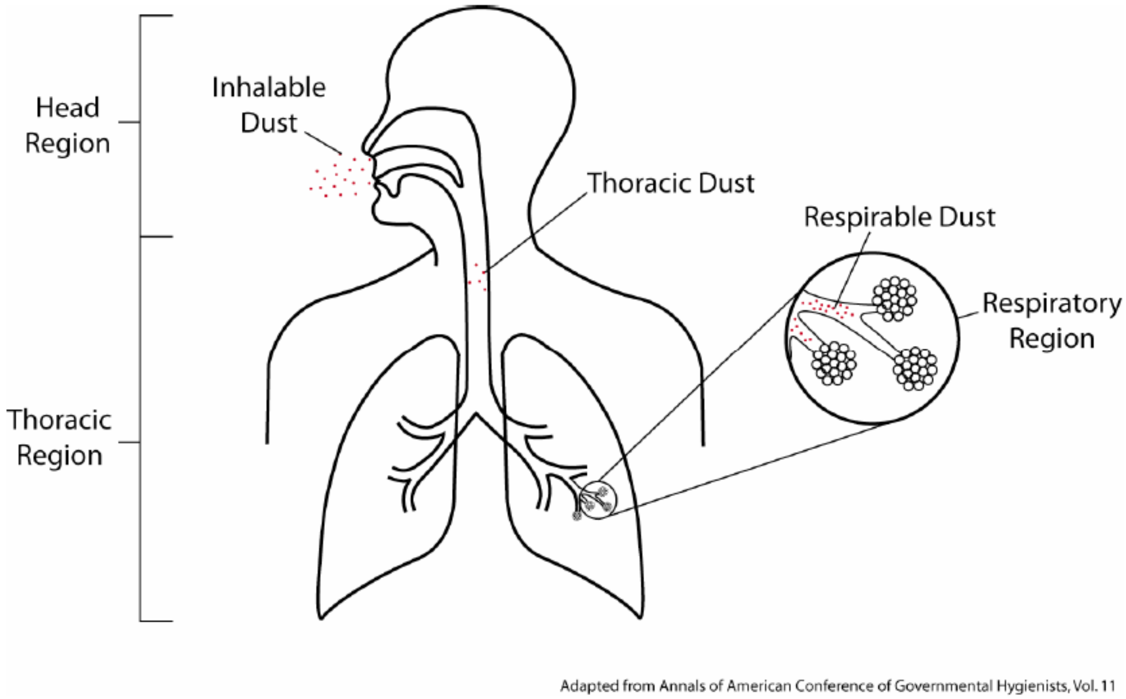
TIME TO SETTLE 5 FEET BY UNIT DENSITY SPHERES Source: NIOSH

The airborne dust generated during handling of pellets range in size from 500 to a few micron (see section on Samples below). The above figure indicates a sedimentation (settling) time from a few seconds to several hours in still air. The time is even longer in turbulent air.

The smaller the particle is the larger the relative surface area, which means increased exposure to the oxygen in the air. The larger the oxygen exposure is of combustible material the higher the risk is for open flame combustion in the presence of an igniting source or a source of heat.

Aside from the safety and infectious aspect of some particles we are also concerned with **health effects** from exposure to particles with an AED less than 100 µm. Depending on size, aerosol particles easily deposit in various parts of our airways as we inhale and subsequently causes illnesses such as acute reactions, chronicle reactions or tumors. The most serious damage is done by particles less than 10 µm AED which are able to enter our bloodstream through the alveolars where the gas exchange (oxygen uptake) takes place in our lungs. The medical field is using the following classifications for particles with penetration illustrated in the figure below;

- Inhalable particulates < 100 µm AED
- Thoracic particulates < 25 µm AED
- Respirable particulates < 10 µm AED



Regional Particle Deposition in the Airways

As a curiosum, it is estimated that during a lifetime an average person is inhaling over 10 m^3 of air per 24 hours which translates in to about 4,000 m^3 per year or 320,000 m^3 during an 80 year lifespan. A typical outdoor particle concentration is about 3 $\mu g/m^3$ inhaled. This translates in to about 3 g of particulates inhaled during a lifetime, which is about 3 teaspoons full of particles[1]. The surface of the head region exposed to air is about 0.5 m^2, the bronchial-thoracic region about 2 m^2 and the respiratory alveoli region about 100 m^2.

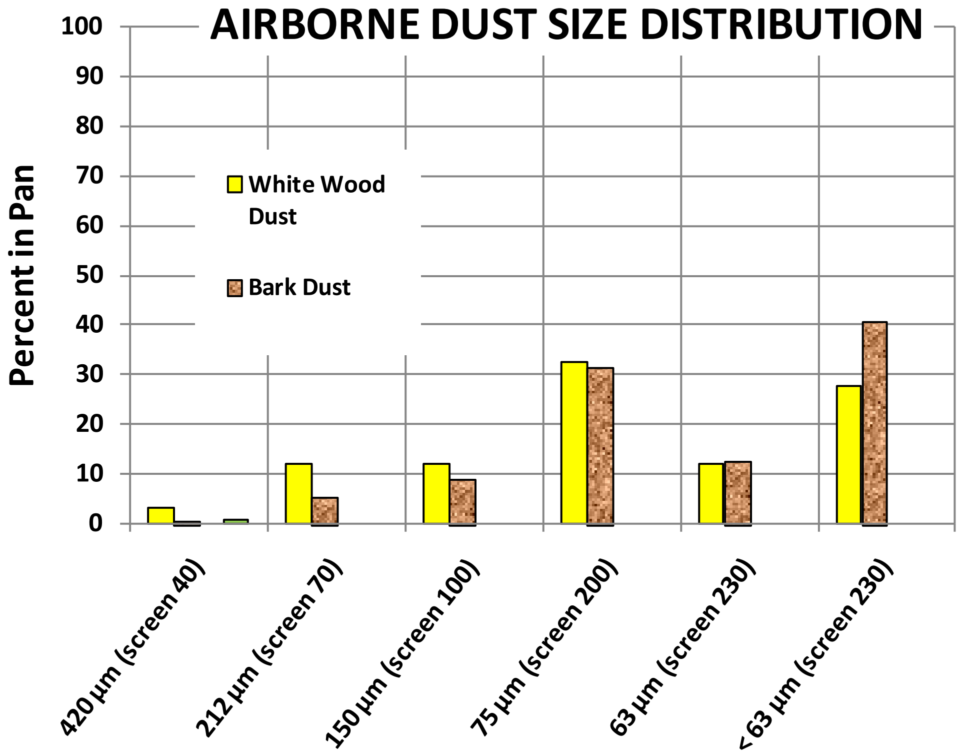
3. Dust Samples Tested

Samples of dust from wood pellets used in the testing of explosibility and flammability in this report were collected in areas where the dust had settled which means that the particles were representative of the entire spectrum of sizes encountered in a typical working environment for bulk handling of pellets. The particles had been airborne and transported a distance before settling and therefore can be classified as passing through a band pass filter. Sample A from white pellets was collected at a downstream transfer point between conveyors at a shiploading terminal. Sample B from bark pellets was collected at girts, ledges and bin tops on the production floor inside a pellet mill. No grinding or hammer milling of the material was done after sampling. The samples were kept in sealed plastic bags until opened at the lab immediately before testing.

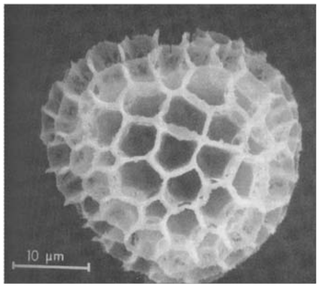
The particle size spectrum for the two samples was established by means of wire cloth sieving as well as by use of a new machine vision system developed at University of British Columbia. The result of the size determination is shown in diagram below. For comparison,

[1] Partiklar och Hälsa, Gudmundsson, 2008.

the diagram is also including typical particle size distribution for Pittsburgh coal and Lycopodium spores.



The Lycopodium spores are often used as a reference since the spores have very predictable and consistent particle size of 20-30 µm and is naturally suspended in air (see picture to the right). The spore also has a large surface area and therefore has a high level of explosivity.



In comparison, the dust generated during coal mining operations varies from 1 to 200 µm depending on the mineral composition and the mining process. The particle size distribution is very similar to the dust from wood pellets.

For this report the ASTM Standards have been followed. Similar testing standards are also published under ISO, EN and some national standards in Europe. The tests have been performed on screen 230 materials (particles 63 µm or less) since over 80 % of the dust particles are 75 µm or less and about 50 % or more is 63 µm or less. Based on the size distribution the most representative particle size would be somewhere between screen 200 and 230 (see diagram above). The ISO Standards recommend 63 µm as the norm for testing purposes.

4. Explosibility

Explosion is used as a general characterization of a violent event emitting sound and light and often immediately followed by fire. There are two main categories of explosions. **Detonation** generated from a sudden expansion of gas in to a supersonic shock wave (molecular speed is higher than the speed of sound). An example is nuclear explosions such Castle Romeo 2 nuclear test 1954 (to the right). The other is **deflagration** generated by an initial violent oxidation followed by a frontal combustion propagating outward as long as fuel and oxygen is present in sufficiently high concentrations (see deflagration flame supported by fuel to the right).

Explosions occur in dust suspended in air as well as dust sediments on hot surfaces. The explosibility is a function of particle concentration, oxygen concentration, energy of the ignition source or the temperature of the heat exerted on the dust. In order to emulate real live conditions as close as possible a number of Testing Standards are available. The following table summarizes the results of the tests which have been conducted on dust from white pellets as well as bark pellets.

Standards tests are conducted on **Dust Clouds** as well as **Dust Layers**. The result of the tests generates a **Dust Classification** which is used as a guideline for how the product generating the dust should be handled and how the handling facility should be designed.

Table 4.0 Results from testing dust from white pellets and bark pellets

Test Mode	Test Parameter (dust <63 µm)		Measure	White Dust	Bark Dust	Coal Dust	Lycopodium Spores	Testing Standards
Dust cloud	Auto-ignition Temp (Godbert-Greenwald)	T_c	°C	450	450	585	430	ASTM E1491
	Min Ignition Energy	MIE	mJoule	17	17	110	17	ASTM E2019
	Max Explosion Pressure	P_{max}	bar	8.1	8.4	7.3	7.4	ASTM E1226
	Max Explosion Pressure Rate	dP/dt_{max}	bar/sec	537	595	426	511	ASTM E1226
	Deflagration Index	K_{St}	bar.m/sec	146	162	124	139	ASTM E1226
	Min Explosible Concentration	MEC	g/m^3	70	70	65	30	ASTM E1515
	Limiting Oxygen Concentration	LOC	%	10.5	10.5	12.5	14	ASTM E1515 mod
Dust Layer	Hot Surface Ignition Temp (5 mm)	T_s	°C	300	310			ASTM E2021
	Hot Surface Ignition Temp (19 mm)	T_s	°C	260	250			ASTM E2021
	Auto-ignition Temp	T_L	°C	225	215			USBM (Bureau of Mines) RI 5624
	Dust Class (>0 to 200 bar.m/sec)			St 1	St 1	St 1	St 1	ASTM E1226
	Dust Class (Explosion Severity (ES > 0.5)			Class II	Class II			OSHA CPL 03-00-06

The smaller the particle is the higher the explosibility. The bark dust contains noticeably higher percentage smaller particles compared to the white dust. This translates in to higher explosion pressure.

The minimum explosivity concentration (MEC) for coal dust is practically the same as for dust from wood pellets. Coal dust explosions can be mitigated partly by injection of incombustible mineral dust (e.g. limestone) at air intakes in order to keep the dust concentration below the critical 65 g/m^3 level of coal dust. This option is not practical for operations handling wood pellets.

The following sections describe each test in principle. These methods were used in 2008 for testing dust from pellets manufactured in British Columbia and Nova Scotia in August 2008. The results are the basis for the data documented in the MSDS. For more information, see the actual Standards and the related reference documentation. It should be noted that the data obtained from the testing as outlined in the Standards is not necessarily intrinsic to the tested material but may be used for assessing the risk for explosions and fires together with local conditions and sizing of explosion vents.

The moisture of the samples to be tested shall not exceed 5 % in order to avoid a substantial influence from the moisture on the results.

4.1 Minimum Auto-Ignition Temperature in Dust Cloud - T_C (ASTM E1491-06)

The general principle of this testing is to have dust disbursed in to a cloud and expose the cloud to radiated heat. The minimum auto-ignition temperature is defined as the temperature at which the cloud ignites. The detailed requirement to achieve reproducible results is found in the ASTM E1491 Standard. There are several apparatuses recommended in the Standard as illustrated below (courtesy ASTM E1491-06 Standard).

The Godbert-Greenwald apparatus (see schematic to the right) was used for the testing of material from British Columbia and Nova Scotia in August 2008. The Pyrex tube has a volume of 0.27 Liter (diameter 3.8 cm and length 30.5 cm) and is feed from the top with a predetermined amount of dust cascading down, injected by an air bust from the exit at the bottom is an

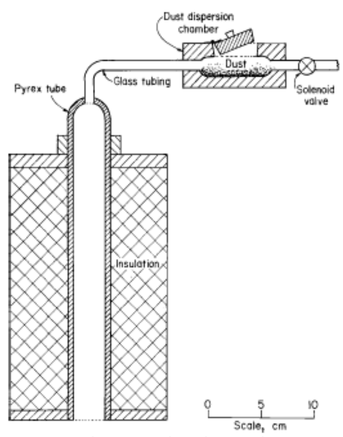


FIG. X1.1 Vertical Cross Section of the Godbert-Greenwald Furnace

top. A flame observed at the indication of ignition. The furnace temperature is measured with type N thermocouples.

The apparatus on the right called BAM is defined by Bundesanstalt für Materialforschung und Prüfung. A predetermined amount of dust is fed horizontally in to the oven from the right and dispersed by the deflection surface inside the oven with the flame exiting on the left hand side upon ignition.

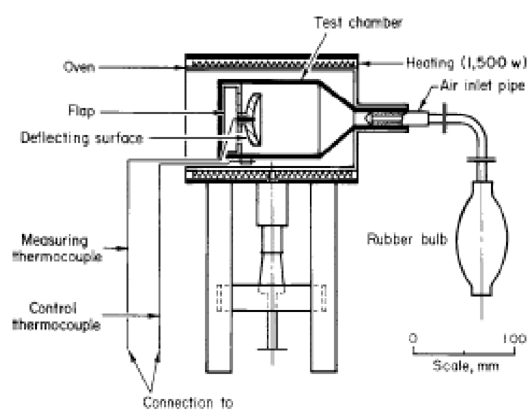


FIG. X2.1 Manually Operated Version of the BAM Oven

The apparatus on the right is defined by the US Bureau of Mines with a volume of 1.2 Liter is fed from the bottom. When the dust ignites the burst diaphragm at the top will break and a flame will appear at the top.

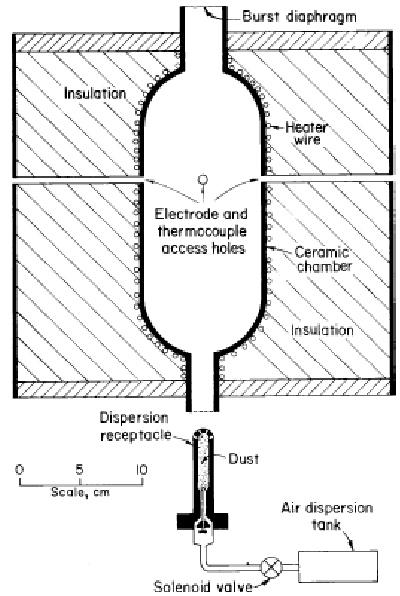


FIG. X3.1 Vertical Cross Section of the Bureau of Mines 1.2-L Furnace

The different methods produce results within ± 5 % with an increasing variance for materials with higher minimum temperature. A typical result from testing a material is illustrated in the graph to the right. Obviously, the concentration of particulates in the cloud is an important variable.

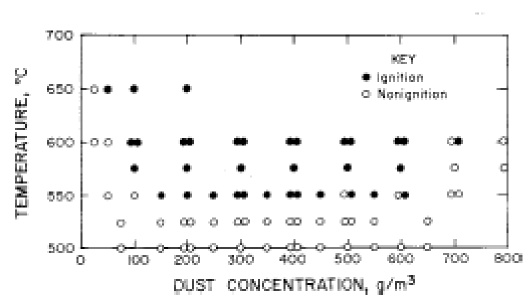
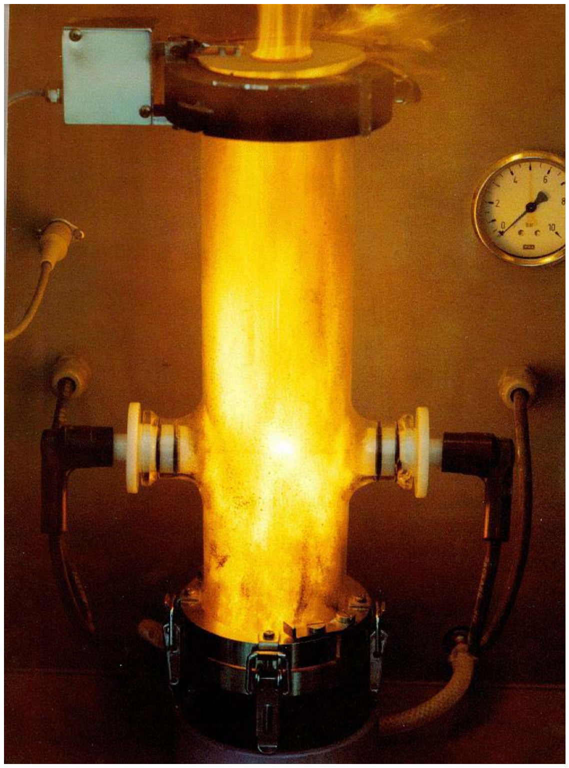


FIG. 2 Typical Detailed Data for the Minimum Autoignition Temperature of a Coal Dust

4.1 Minimum Ignition Energy in Dust Cloud – MIE (ASTM E2019-03)

The general principle with this test is to estimate the energy required to ignite a dust cloud by means of an electrical discharge. Since the ignition of the dust is dependent on the concentration of the dust, dust-air turbulence and the discharge energy the test is iterative to find the least concentration in combination with the least energy in the discharge spark. A typical apparatus consists of a chamber, spark electrodes and a spark generation circuit. The idea is to create a non-turbulent dust-air mixture with a known dust concentration by means of a delayed discharge after the dust has been injected into the chamber from the bottom. A 1.2 or 0.5 Liter Hartmann tube may be used as a chamber. The spark gap shall be 2-6 mm and a gap resistance of 10^{12} Ω is required for a minimum ignition energy (MIE) of 1 mJ and 10^{10} Ω for an MIE of 100 mJ and the discharge voltage is several thousand volts (see ASTM Standard for further details). The apparatus discussed in Section 4.2 may also be used for this test.



(Courtesy Adolf Kühner AG)   (Courtesy Physikalische-Technishe Bundesanstalt PTB)

Electrostatic discharge from person to a metal surface during summertime is typically 20 mJ and about 60-80 mJ during wintertime when the humidity in the surrounding air is lower.

The relation between product moisture and MIE is illustrated in the diagram on the right hand side.

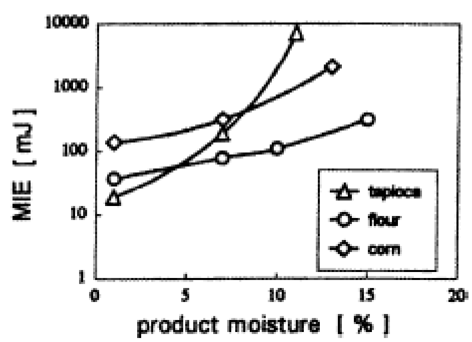
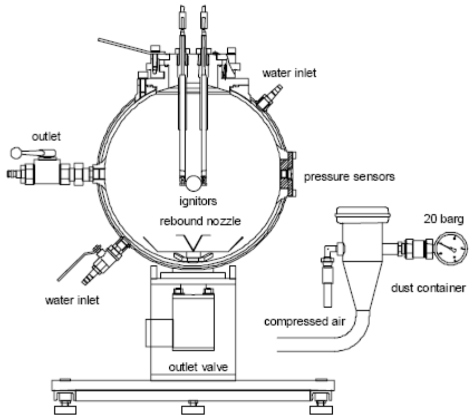
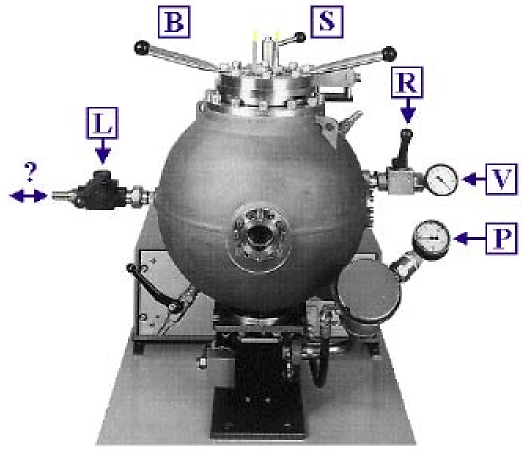


FIG. 2 Influence of the Humidity (Water Content) of Combustible Dusts (5)

4.2 Maximum Explosion Pressure (P_{max}), Pressure Rate (dP/dt_{max}) and Deflagration Index (K_{st}) in Dust Cloud – (ASTM E1226-05)

The general principle is to test the severity of explosions in a dust-air mixture in a closed spherical chamber with a volume of 20 Liter. The maximum pressure and the maximum rate of pressure rise are measured. The most common apparatus used is the spherical 20 Liter Siwek explosion chamber as depicted below.





(Courtesy Adolf Kühner AG)

The Pressure is measured in bar (usually called bar-g meaning gauge reading) and designated P_{max}, the Pressure Rate in bar/second dP/dt_{max} and the Deflagration Index K_{St} in bar.m/s measured at maximum dust concentration. The K_{St} is extracted from the following formula normalized to 1.0 m^3:

$$K_{St} = \left({}^{dP}/_{dt}\right)_{max} V^{1/3}$$

where P is pressure in bar
t is time in seconds
V is Volume in m3
K_{st} is bar meter per second

The results of the testing is very much dependent upon the concentration of dust, particle size, turbulence in the chamber, geometry of the vessel, energy dissipated by the ignition source, homogeneity of the air/dust mixture, initial pressure and initial temperature. The following diagrams illustrate typical recordings of explosions with the single explosion data on the left hand side and the iterative data on the right hand side as a function of dust concentration.

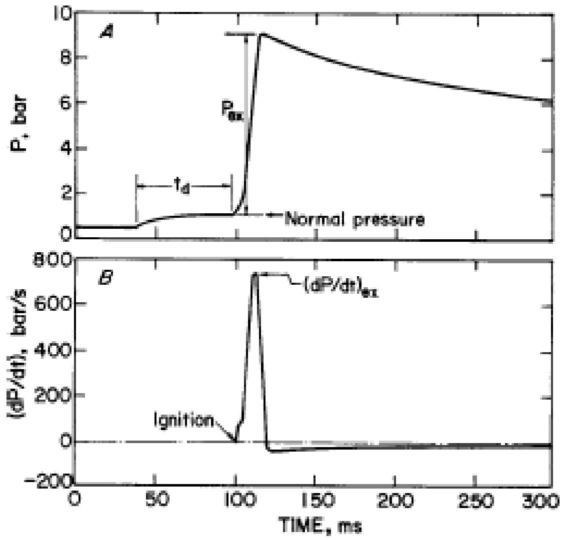


FIG. 1 Typical Recorder Tracings of Absolute Pressure, *P*, and Rate of Pressure Rise, *dP/dt*, for a Dust Deflagration in a 20-L Chamber

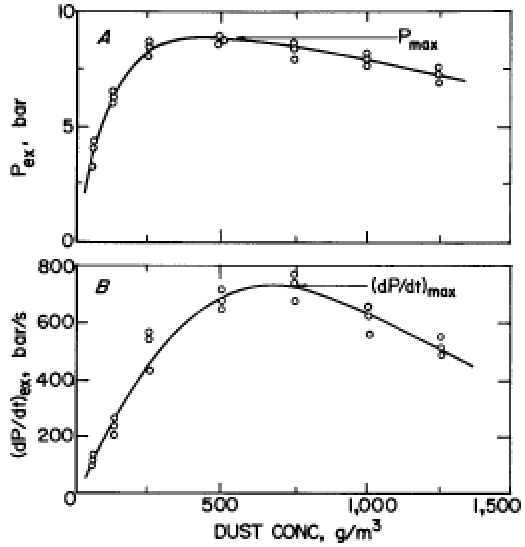


FIG. 2 P_{max} and $(dP/dt)_{max}$ as a Function of Concentration for a Typical Dust in a 20-L Chamber

(Courtesy ASTM E1226-05 Standard)

In case of mild deflagration of less than 150 bar/s the pressure curve for the ignitor may impact the interpretation of the result. As an example, with an ignitor energy of 10,000 J the pressure tangent for the dust under test may be drawn after 50 ms to minimize the effect of the ignitor as illustrated in the diagram below (Courtesy ASTM E1226-05 Standard).

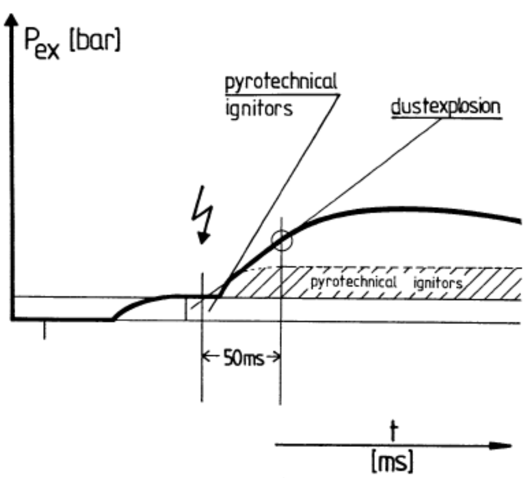


FIG. X1.7 Mild Dust Explosion

The K_{St} is the basis for Dust Explosibility Classification in the following three ranges;

Dust Explosibility Class	K_{max} [bar.m/s]
St 1	>0 - 200
St 2	201 - 300
St 3	>300

The value obtained from the Siwek apparatus is normalized to 1 m^3 by using a formula in order to be compatible with the nomograms in NFPA 68 Standard for sizing of deflagration vents. The calibration of the values between the ISO chamber and the Siwek chamber are made by means of explosibility of certain well known compounds such as Lycopodium Spores and Pittsburgh Seam Bituminous Coal Dust with a maximum variance of ± 20 %.

In case the deflagration is difficult to achieve in a 20 Liter chamber using a 5,000 or a 10,000 J ignitor, it is recommended that a 1 m^3 chamber is used as specified in the ISO 6184/1 Standard using a 10,000 J ignitor.

4.3 Minimum Explosible Concentration in Dust Cloud – MEC (ASTM E1515-07)

The Minimum Explosible Concentration (MEC) is also referred to as Lower Explosibility Limit (LEL) or Lean Flammability Limit (LFL). Data from this test provides a relative measure of the minimum concentration of well dispersed dust capable of propagating a deflagration. The Siwek apparatus as described in Section 4.2 is used for the MEC testing. A less common alternative is a chamber specified by US Bureau of Mines may be used as illustrated below.

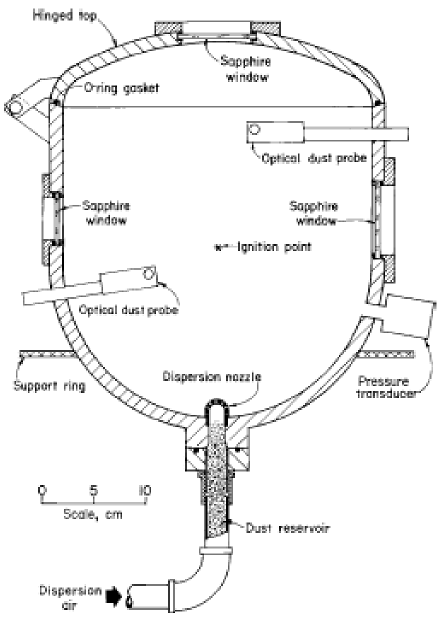


FIG. X1.1 Vertical Cross Section of Bureau of Mines 20-L Chamber

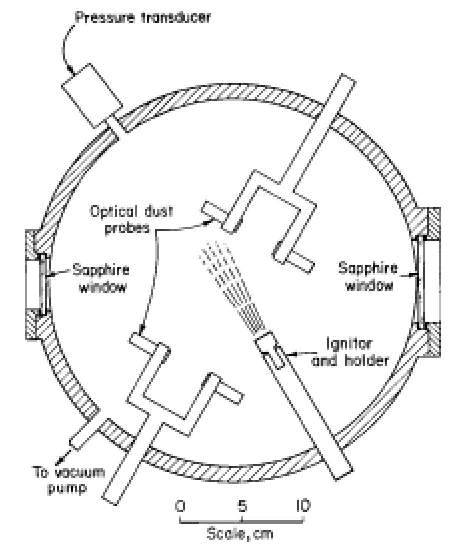


FIG. X1.2 Horizontal Cross Section of Bureau of Mines 20-L Chamber

(Courtesy ASTM E1515-07 Standard)

Attention has to be given when dust with low explosibility limit is tested to make sure the pressure from the ignitor is not confused with the pressure generated by the dust explosion. The following diagrams illustrate the pressure recording for a weak and a moderate dust deflagration.

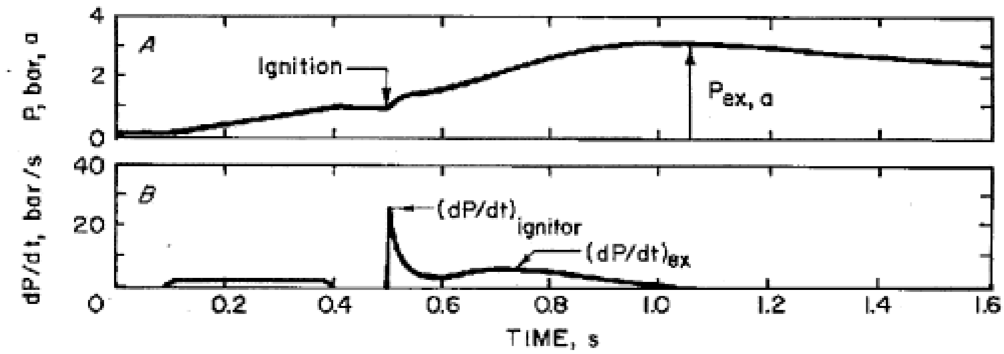


FIG. 1 Typical Recorder Tracings for a Weak Dust Deflagration in a 20-L Chamber, using a 2500 J Ignitor

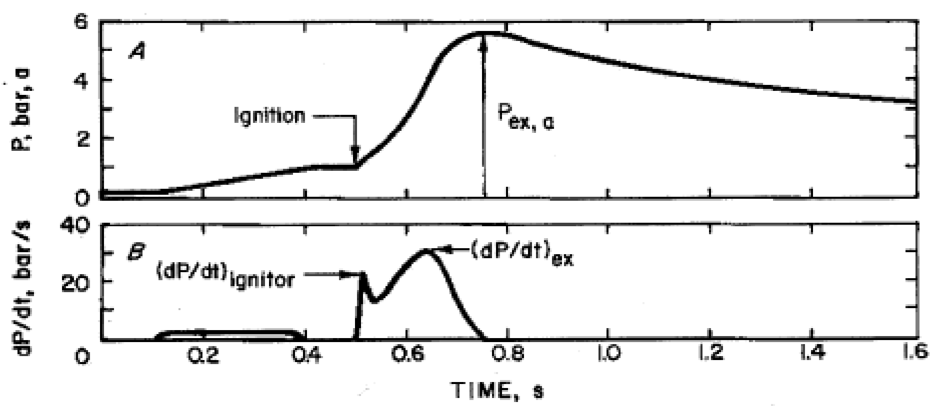


FIG. 2 Typical Recorder Tracings for a Moderate Dust Deflagration in a 20-L Chamber, using a 2500 J Ignitor

4.4 Limiting Oxygen Concentration in Dust Cloud – LOC (ASTM E1515 mod.)

The general principle of this test is similar to the MEC described above using the same equipment with a slight modification to the procedure of operating the unit. The oxygen concentration in the chamber is successively adjusted by injection of nitrogen and the pressure prior to injection of dust is lowered to -0.6 bar. The pneumatic injection of dust brings the pressure up to 1 bar followed by the ignition. The lowest value of oxygen is reached close to the lowest cloud density.

4.5 Hot Surface Ignition Temperature of Dust Layers – T_S (ASTM E2021-06)

The general principle for this test is to establish the temperature at which a layer of dust with a certain thickness will ignite or self-heat when residing on a hot surface. The test is conducted by placing a ring of metal with a diameter of 100 mm and a certain depth on a hot plate and the ring is filled with dust. The temperature of the hot plate is set at different temperatures and the temperature within the dust layer is measured with a thermo-couple. The depth of the ring may be selected to mimic realistic thicknesses found in the area of concern in a location where dust accumulates. In the case of the testing reported in this document a ring with a depth of 5 and 19 mm respectively were used. The test setup is depicted below.

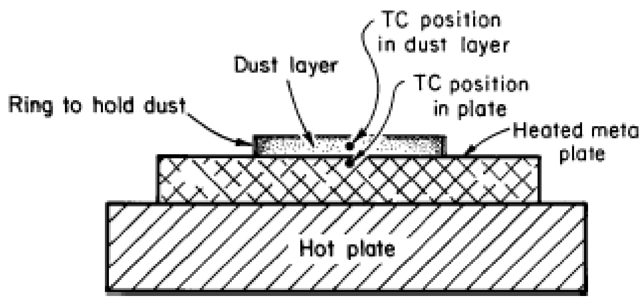


FIG. 1 Schematic of Hotplate Layer Ignition Apparatus

(Courtesy ASTM E2021-06 Standard)

Ignition is deemed to have occurs if within a 60 minute period the sample temperature rises to 50 ^oC, or more above the hot plate temperature, or a red glow or a flame is observed in the sample. The following diagram illustrates the definition of ignition at +290 ^oC but not at +280 ^oC.

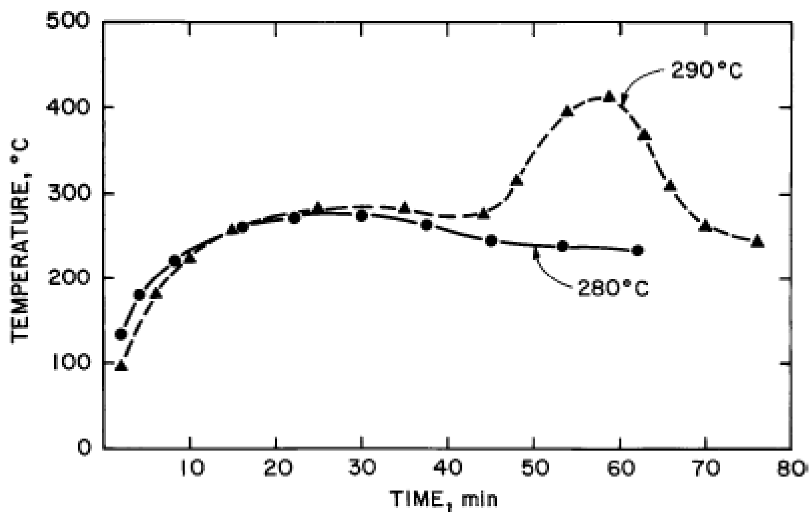


FIG. 4 Test Data Showing Nonignition at Set Temperature of 280°C and Ignition at Set Temperature of 290°C

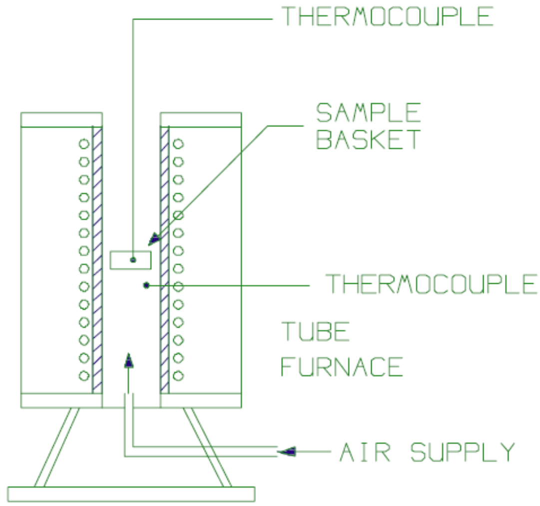
(Courtesy ASTM E2021-06 Standard)

The ignition temperature for other thickness of dust layers can be estimated using extrapolation or interpolation based on a minimum of two experimental numbers using a linear relationship within a certain constraint.

This method of measuring the ignition temperature is assuming no or very little movement of air in the immediate vicinity of the sample. The method outlined in Section 4.6 on the other hand is based on a steady flow of air in the space immediately surrounding the sample.

4.6 Auto-ignition Temperature in Dust Layer – T_L (Bureau of Mines RI 5624)

The general principle for this test is to establish the temperature at which a layer of dust with a certain thickness will ignite or self-heat when residing on a hot surface. The test is conducted by placing a sample basket (2.54 cm in diameter) in the center of a vertical tube furnace with a diameter of 3.6 cm and a length of 22.9 cm as illustrated below.



(Courtesy Kidde-Fenwal)

The furnace temperature as well as the sample temperatures are measured by thermo-couples and a steady flow of air at a rate of 1.3 Standard Liter per minute is fed from below to make sure the sample has sufficient supply of oxygen at all times.

This method is less accurate than the method presented in Section 4.5. The minimum ignition temperature is considered reached if the sample temperature reaches 25 ^{o}C above the temperature of the furnace within 5 minutes, or 50 ^{o}C without time restriction. The reporting criteria for Auto-ignition Temperature is defined as follows;

> The minimum ignition temperature of a dust layer is the temperature which causes ignition after approximately 5 minutes (25 ^{o}C above furnace temperature) or, the average of the lowest temperature which causes ignition in less then 30 minutes and the highest temperature which fails to cause ignition in 30 minutes.

<u>4.7 Safety Classification – (29 CFR 1910.307)</u>

The US Code of Federal Regulations 29 CFR 1910.307 stipulate certain standards for equipment located in locations where hazardous dusts are present under normal operating conditions. The US National Fire Prevention Association guidelines NFPA 70 *National Electrical Code* defines the conditions in more detail. The US National Materials Advisory Board NMAB 353-3-80 *Classification of Combustible Dusts in Accordance with the National Electrical Code* defines dusts having Ignition Sensitivity (IS) greater than or equal to 0.2, or Explosion Severity (ES) greater than or equal to 0.5 to be appreciable explosion hazards requiring electrical equipment suitable for Class II locations.

$$\text{Explosion Severity (ES)} = {(P_{max} x R_{max})_2}\big/{(P_{max} x R_{max})_1}$$

where

- subscript 1 refers to Pittsburgh seam bituminous coal dust (3,110 bar^2/s)
- subscript 2 refers to the dust under evaluation

The data obtained from testing dust cloud from white pellets manufactured in BC and dust from bark pellets manufactured in Nova Scotia forming the base for Table 4.0 is summarized in the following Table 4.7.

Table 4.7

Parameter	Measure	White Pellets Dust	Bark Pellets Dust
P_{max}	bar - g	8.1	8.4
R_{max}	bar/s	537	595
P_{max} x R_{max}	bar^2/s	4,350	4,998
ES		1.40	1.61
Dust Classification		Class II combustible	Class II combustible

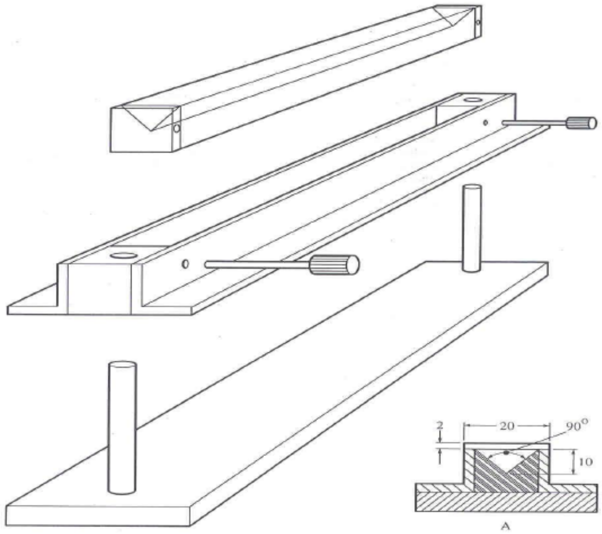
Dust Classification Criteria according to the OSHA Directive CPL 03-00-06 is defined as follows;

Test Results	Dust Classification
ES > 0.5	Class II combustible
ES < 0.4	Not Class II combustible
0.4 < ES < 0.5	Combustible but not Class II
P_{max} < 1 bar	Not combustible

Concluding from the test data, installations exposed to the white pellet dust as well as the bark pellet dust require equipment classified as Class II compatible. In daily language, such dust is often called Class II dust although the classification refers to the equipment.

5. **Flammability (UN Test N.1 – Class 4 Division 4.1 Substances)**

The objective of the test is to establish if the material under test shall be classified as flammable or not under the criteria stipulated by the Standard. A material burning a distance of 200 mm in 2 minutes or less, is classified as flammable. The flammability or burning rate of dust is investigated using an elongated mould 250 mm long with a triangular cross section with an inner height of 10 mm and width of 20 mm as depicted in the schematic below.



(Courtesy UN Manual of Tests and Criteria, rev. 3, 2000)

The mould is loosely filled with dust and the top of the mould is leveled off by a ruler. The material in one end of the mould is heated by a torch until it ignites and the time for burning to the opposite end of the mould is clocked. If less than 2 minutes the material is considered flammable. If the opposite end of the mould is not reached within 2 minutes the material is considered not flammable. The results of the tests conducted on dust “as received” as well as sieved with mesh 230 (<63 μm) are summarized in the following Table 5.0.

Table 5.0 Burning Rate of Dust from Pellets	
Material	**Burning Rate**
White Pellet Dust as received	20 mm/2 min
Bark Pellet Dust Received	22mm/2 min

Obviously the two types of dust tested are not classified as flammable as it relates to the UN MTC criteria. Classification of flammability is relevant for packaging requirement during transportation and is regulated by for example 49 Code of Federal Regulation.

6. **<u>Pyrophorocity (UN Test N.4 – Class 4 Division 4.2 Substances)</u>**

The ability of the material to ignite on contact with air is tested by exposure to air and determining the time to ignition. One or two ml of the powdery substance to be tested should be poured from about 1 m onto a non-combustible surface and it is observed whether the substance ignites during dropping or within 5 minutes of settling. This test is primarily of interest for metallic materials. No pyrophoric reaction was observed for the materials tested.

Obviously, the two types of dust tested are not classified as pyrophoric as it relates to the UN MTC criteria.

Classification of pyrophorocity is relevant for packaging requirement during transportation and is regulated by for example 49 Code of Federal Regulation.

WORKSAFEBC INFORMATION

Combustible Dust Strategy – Phase 1 (Sawmills) (Handout)

Combustible Dust Strategy – Phase I (Sawmills)

Table of Contents

Reference Material

OHSR Guideline G5.81 – Combustible Dust – Sawmill facilities

Issued April 25, 2012; Editorial Revision May 1, 2012

Regulatory excerpts

Section 5.81 of the OHS Regulation ("Regulation")

Combustible dust

If combustible dust collects in a building or structure or on machinery or equipment, it must be safely removed before accumulation of the dust could cause a fire or explosion.

Section 5.71 of the Regulation

Flammable air contaminants

(1) If an operation or work process produces a combustible or flammable air contaminant in concentrations that may present a risk of fire or explosion, the employer must provide a separate exhaust ventilation system for the operation or work process.

(2) Electrical components of an exhaust ventilation system required by subsection (1) must comply with Class I Division I requirements of CSA Standard C22.1-94, Canadian Electrical Code, Part 1 if the components contact the air stream.

(3) A dust collector having an internal volume greater than 0.6 m3 (20 ft3) and being used to control combustible dusts must be located and constructed so that no worker will be endangered in the event of an explosion inside the collector.

Section 115 of the Workers Compensation Act ("Act")

General duties of employers

(1) Every employer must

(a) ensure the health and safety of

(i) all workers working for that employer, and

(ii) any other workers present at a workplace at which that employer's work is being carried out, and

(b) comply with this Part, the regulations and any applicable orders.

(2) Without limiting subsection (1), an employer must

(a) remedy any workplace conditions that are hazardous to the health or safety of the employer's workers.

Section 3.5 of the Regulation

General requirement

Every employer must ensure that regular inspections are made of all workplaces, including buildings, structures, grounds, excavations, tools, equipment, machinery and work methods and practices, at intervals that will prevent the development of unsafe working conditions.

Introduction

Combustible dusts are fine particles that present an explosion hazard when suspended in air under certain conditions. A dust explosion can cause catastrophic loss of life, injuries, and destruction of buildings. In many cases, employers and workers may be unaware of the potential for dust explosions, or fail to recognize the serious nature of dust explosion hazards.

This guideline provides information about the mitigation of hazards associated with combustible dusts, including the conduct of risk assessments, development of a dust control program and training of workers at workplaces. The focus of the guideline is on combustible dusts at sawmills and related facilities.

Ventilation for flammable air contaminants

Section 5.71 of the *Regulation* provides requirements for exhaust ventilation systems and dust collection where operations or work processes present a risk of fire or explosion. Refer to *G5.71(3) Location and construction of dust collectors* for guidance on locating and constructing dust collectors used to control combustible dusts so that workers will not be endangered in the event of an explosion inside the collector.

Combustible dust program

Hazard mitigation

Hazard mitigation strategies for combustible dust at sawmills should include the following elements discussed in more detail herein:

- Facility risk assessment
- Written combustible dust control program
- Implementation of program, including training

Facility risk assessment

The factors that should be identified and included in assessing the potential for dust fires/explosions include the following:

- Materials that can be combustible when finely divided
- Consideration of the physical properties of dust including, moisture content, particle size and combustibility
- Processes which use, consume, or produce combustible dusts
- Open areas where combustible dusts may build up
- Hidden or enclosed areas where combustible dusts may accumulate
- Means by which dust may be dispersed in the air
- Potential ignition sources such as, hot work locations, friction points, electrical equipment, static charges, and confinement areas
- Mechanisms of dispersion of air including, discharge from saws, equipment vibration, compressed air use
- Areas with risk of secondary deflagration (adjacent dust is dispersed by initial combustion and creates conditions for rapid propagation).

Written combustible dust control program

The combustible dust program should be in writing and include the following elements:

ELEMENT	NOTES
• List of all combustible dust sources, locations and control equipment	
• Engineering controls including,	• Local exhaust ventilation, use of appropriate electrical equipment, grounding of material conveyance systems, and misting systems
• Housekeeping inspection schedules and procedures for preventative maintenance including inspection of	• Equipment that may act as an ignition source (produces heat or sparks if not properly maintained) • Elevated horizontal surfaces such as machine tops • Beams, joists, purlins, ducts, pipes and cable trays • Vertical surfaces (walls, etc.) • Hidden areas • On the surface of, and within electrical equipment (e.g., motor control cabinets)
• Description of dust clean-up program including methods of removal such as,	• Vacuums, compressed air, water, specialized tools
• The criteria or thresholds that have been established	• As a guide, limit surface to accumulation of 1/8 inch or less
• Specific safe work procedures including,	• Hot permit program, smoking control and emergency preparedness, equipment de-energized during clean-up activities
• Third party inspections (e.g., insurance inspections and findings)	

Implementation of program, including training

The training of workers must include making workers aware of all known or reasonably foreseeable hazards to which they are likely to be exposed, and making workers aware of their rights and responsibilities under the *WCA* and the *Regulation*. The dust control program should be communicated to all workers and include training on the program elements, including hazard awareness, specific safe work procedures, hazcom documentation and emergency preparedness.

Further resources

RESOURCE	LINK
NFPA 664 Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities (2007)	http://www.nfpa.org/
OSHA - Combustible Dust National Emphasis Program	http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=directives&p_id=3830
Combustible Dust: An Insidious Hazard (video)	http://www.csb.gov/videoroom/detail.aspx?vid=30&F=0&CID=1&pg=1&F_All=y

OHSR Guideline G4.42 Cleaning with Compressed air – Hazards of Combustible Dusts

Regulatory excerpt

The OHS Regulation states:

> 4.42 (1) Compressed air or steam must not be used for blowing dust, chips, or other substances from equipment, materials and structures if any person could be exposed to the jet, or to the material it expels or propels and an injury or health hazard due to fire, explosion or other cause is likely to result.

Purpose of guideline

This guideline is intended to set out the circumstances under which cleaning equipment or work areas with compressed air is permitted, and the controls that need to be put in place in order to ensure that cleaning with compressed air does not create a hazard due to fire, explosion or other cause.

Discussion

Cleaning equipment with compressed air provides a convenient and effective way of removing small particulate matter from inaccessible areas in and around equipment and other contained work areas.

Cleaning with compressed air, however, can release combustible dusts into the air, creating an explosion hazard. Combustible dusts are fine particles that present an explosion or fire hazard when suspended in air under certain conditions. A dust explosion can cause catastrophic loss of life, injuries, and destruction of buildings.

While cleaning with compressed air can present serious risks if done incautiously, the OHS Regulation does permit it, provided it is done in a way that does not create an explosion or fire hazard. Cleaning with compressed air should be minimized, however, and should only be done where other methods of cleaning are not practicable.

Managing combustible dusts

Combustible dust explosions occur when dusts are dispersed into the air in concentration and come into contact with an ignition source, including potential static charge dissipation of the dust cloud. Cleaning with compressed air must be done in a way that ensures that these risk elements are controlled. Cleaning must occur in a way that minimizes the amount of dust that is dispersed into the air, does not allow dusts to spread, and ensures that dusts do not come into contact with any potential source of ignition. Prior to undertaking cleaning with compressed air, employers should consider the nature of the dust created by the work process and its combustibility.

Necessary controls include:

1. Minimizing dust

    - The work area, equipment and other areas near the cleanup area (e.g. floors, sills and other surfaces) should be swept and/or vacuumed prior to cleaning, and dust removed from the cleanup area as much as possible

2. Minimizing dispersion

    - Cleaning with compressed air should only occur in localized or isolated areas; cleaning of a number of work areas should occur in stages
    - Where practicable, the area should be washed with water or a water mist should be applied
    - Compressed air pressure must be kept as low as practicable to complete the cleaning. NFPA Standard 664 Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities sets out a maximum of 15 psi for the use of compressed air for blowing down equipment
    - Compressed air must not be used to consolidate dust into piles or clean open areas
    - Care must be taken to ensure that the compressed air stream does not contact a dust deposit containing a "smoldering nest", which occurs when a dust deposit or layer rests on a heated surface. Dust in a deposit that has not yet burnt can form an explosible dust cloud.

3. Eliminating Sources of Ignition

    - Machinery and equipment in recent operation must be allowed to cool prior to blowdown, and other hot surfaces must be identified and cooled or removed
    - Electrical equipment in the area must be de-energized and locked out,
    - Sources of open flame, sparks or static discharge must be identified and eliminated

4. Emergency Response

    - Fire protection equipment must be readily available and in service.

The NFPA Standard 654 *Standard for the Prevention of Fire and Dust Explosions form the Manufacturing, Processing, and Handling of Combustible Particulate Solids* provides more information on managing combustible dusts in all phases of the manufacturing, processing, blending, pneumatic conveying, repackaging and handling of combustible particulate solids or hybrid mixtures, and also provides more detail on cleaning with compressed air.

OHSR Guideline G5.71(3) – Location and Construction of Dust Collectors

Issued April 27, 2010

Regulatory excerpt

Subsection 5.71(3) of the OHS Regulation ("Regulation") states:

> A dust collector having an internal volume greater than 0.6 m^3 (20 ft^3) and being used to control combustible dusts must be located and constructed so that no worker will be endangered in the event of an explosion inside the collector.

Purpose of guideline

This guideline explains terms used in Regulation subsection 5.71(3) and provides guidance for locating and constructing dust collectors used to control combustible dusts so that workers will not be endangered in the event of an explosion inside the collector.

Background

WorkSafeBC considers the relevant National Fire Protection Association (NFPA) standards to provide acceptable guidance with respect to combustible dust collectors. There are a series of NFPA standards that are relevant to the control of fire and explosion hazards from combustible dusts and an employer should review the standard(s) relevant to the application in question. Information in this guideline references mainly the following NFPA standards, which are available for review online at http://www.nfpa.org/.

- NFPA 61 Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities (2008)
- NFPA 484 Standard for Combustible Metals (2009)
- NFPA 654 Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids (2006)
- NFPA 655 Standard for Prevention of Sulfur Fires and Explosions (2007)
- NFPA 664 Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities (2007)

In addition, there are specifications in the BC Building Code (e.g., edition 2006, articles 3.3.1.20 and 6.2.2), BC Electrical Code Regulation (2009) - Chapter 18, and the BC Fire Code, (e.g., edition 2006 article 5.3) with respect to protection from fires and explosions of combustible dust.

Employers should not rely solely on the generic information in this guideline to minimize hazards that could lead to a dust explosion. The entire relevant standard(s) or code(s) should be consulted for complete information.

What is a "dust collector having an internal volume greater than 0.6 m^3 (20 cu. feet)?"

A dust collector is one component of a dust collection system. The collection system is a pneumatic conveying system that is specifically designed to capture dust at the point of generation, sometimes from multiple pieces of equipment, and convey the particulate to a point of collection. The system includes the collection hood, conveyance ducting, and flexible hoses, exhaust fan, motor, and dust collector. The dust collector, also called an air-material separator, is a device used to separate the particulate material from the air stream, and includes but is not limited to cyclones, baghouse and media-type filter collectors, wet-type collectors, electrostatic precipitators, and enclosureless units.

A cyclone is defined in NFPA 664 as a cylindrical type of dust collector used to separate particulate from the air stream by centrifugal force, having an enclosure of circular cross-section, a tangential air and material inlet, an air exhaust outlet, and a material discharge. In order to determine whether subsection 5.71(3) is applicable, the internal volume of the dust collector needs to be determined. The internal volume of a cyclone is considered to be the volume of the collector from the tangential inlet through the cylindrical and conical area, and includes the chute and dust container that holds the captured dust.

A baghouse dust collector is an air-material separator designed and used to remove dust from the transport air through a filter medium of suspended bags that are contained within an enclosure. The internal volume is considered to be the total volume inside the enclosure from the entrance point of the air-particle mixture, and includes the volume of the container designed to hold the captured dust.

NFPA 664 defines an enclosureless dust collector as an air-material separator where filtration is accomplished by passing dust-laden air through filter media, collecting the dust on the inside of the filter media and allowing cleaned air to exit to the surrounding area (Note: See also Regulation section 5.70 and guideline G5.70 for information about requirements for discharged air). The filter medium is not enclosed, is hand shaken and is under positive pressure during use. Removal of the collected dust is not continuous or mechanical. The internal volume of an enclosureless dust collector is considered to be the air volume inside all the bags plus the air volume of the container designed to hold the captured dust.

If the manufacturer's specifications for a dust collector do not include the internal volume of the dust collector, this volume can be calculated from measurements of height and area.

What is a combustible dust?

NFPA 654 defines combustible dust as a combustible particulate solid that presents a fire or deflagration* hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape. This definition replaces a previous definition that required the particles to be, on average, less than 420 micron (0.017 inch) diameter (capable of passing through a U.S. No. 40 Standard Sieve). The newer definition applies more broadly to include elongated particles such as paper dust and some agglomerates, for which particle diameter is not a useful concept.

*NFPA Standards and this guideline use the term "deflagration." Deflagration is the propagation of a pressure wave (at a speed less than the speed of sound) from the ignition of a combustible dust, and includes both fires and explosions. An explosion can occur if the deflagration occurs in an enclosed space such as a dust collector, duct, or building.

Not all dusts are combustible. For example, substances that are stable inorganic oxides (e.g., silicates, sulphates, phosphates, and carbonates) are not combustible. Therefore dust clouds of Portland cement, sand, limestone, etc. are not combustible.

Materials that are combustible and that can give rise to dust explosions include, but are not limited to

- Food products (e.g., grain, cellulose, powdered milk, sugar, flour, starch, etc.)
- Natural organic materials (e.g., wood dust, wood flour, textiles such as cotton dust and nylon dust, biosolids, etc.)
- Synthetic organic materials (plastics such as phenolics and polypropylene, resins such as lacquer and phenol-formaldehyde, organic pigments, pharmaceuticals, pesticides, etc.)
- Coal and peat
- Metals (e.g., aluminum, magnesium, zinc, iron, etc.)

Combustible dusts have varying limits of flammability. These are usually expressed in terms of grams per cubic metre. For example, aluminum dust may be listed as requiring an airborne concentration of 30 grams per cubic metre for a combustible atmosphere to exist whereas coal dust may require 60 grams per cubic metre. A layer of dust as thin as a dime dispersed throughout a room can create an explosion hazard.

NFPA 499 Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas (2008) includes a table of selected combustible materials. This is not a comprehensive list and a dust should be considered to be combustible unless it is known otherwise. For certain, substances that are combustible as particulates should be considered as combustible dusts. OSHA also publishes a list of substances for which there is a risk of combustible dust explosion, at http://www.osha.gov/Publications/combustibledustposter.pdf.

What is a dust explosion?

A dust explosion/deflagration is essentially the very rapid combustion of a dust cloud or suspension of dust in air, during which heat and pressure is generated at a very high rate. The conditions necessary for an explosion are a sufficiently dense dust cloud of combustible dust in an enclosed area, adequate oxygen/air to support combustion, and an ignition source.

Dust explosions can be very destructive. Often there is a series of explosions in which the primary explosion/deflagration is relatively small. The pressure from the primary explosion can be intense enough to dislodge dust off walls, beams, ledges, machines, and other surfaces. This dislodged dust then mixes with air, creating a much larger dust cloud which can then be ignited and react explosively creating a secondary catastrophic explosion. This secondary explosion/deflagration can be much larger than the primary explosion.

Location and construction of dust collectors

The guidance in this guideline is taken mainly from the five NFPA standards listed above in the Background section. Information provided here represents some of the control measures from the NFPA standards. In addition, *NFPA 69 Standard on Explosion Prevention Systems (2008)* provides information on preventing and controlling deflagrations.

The NFPA standards also contain specifications not directly related to location or construction of the dust collector (e.g., electrical protection, ventilation, control of ignition sources, spark detection and arrest, isolation devices, ductwork, partitioning, preventing dust accumulations on horizontal surfaces, sprinkler and other fire suppression systems, relief venting, etc.). These specifications are not directly related to Regulation subsection 5.71(3) but many are related to other regulatory requirements. Employers should not rely solely on the generic information in this guideline to minimize hazards leading to dust explosions. The entire relevant standard(s) should be consulted for complete information.

Location of a dust collector

Regulation subsection 5.71(3) specifies that a dust collector used to control combustible dust be located so that no worker will be endangered in the event of an explosion inside the collector. Dust collectors used for collection of combustible dust are appropriately located outdoors - this is usually the preferred location with respect to compliance with this section of the Regulation. Under certain circumstances and conditions, it is acceptable to locate a dust collector indoors. The relevant B.C. Codes and NFPA standard(s) should be consulted for complete information on these circumstances and conditions, but some general guidance is provided here.

The *BC Fire Code* (2006) specifies in Division B Section 5.3 that a dust collector having a flow capacity greater than 0.5 m3/s be located outside of a building and be equipped with explosion venting to the outdoors of not less than 0.1 m2 of vent area for each cubic metre of dust collector enclosure volume.

The *BC Fire Code* allows a dust collector to be located inside a building if it is

a) Provided with explosion venting to the outdoors

b) Equipped with an automatic explosion venting system

c) Located in a room with fire separations having a fire-resistance rating of not less than 1 hr and provided with explosion venting to the outdoors

The *BC Fire Code* also requires, when exhausted air is returned to the building, that the dust-collection system be designed so that the exhaust fan and ancillary equipment are automatically shut down in the event of a fire or an explosion inside the dust collector. Construction of a dust collector should also include isolation devices where ductwork returning to a building from the dust collector can provide a path for a fireball and a pressure wave to enter the building.

A number of NFPA standards also provide guidance for the location of a dust collector, and this guidance is acceptable as long as it does not contradict British Columbia code requirements such as the *BC Fire Code*. For example, *NFPA 61* Chapter 10 specifies location criteria for dust collectors used in agriculture and food processing facilities, including operations involving dry agricultural bulk materials and their by-products, and dusts that include grains, oilseeds, agricultural seeds, legumes, sugar, flour, spices, feeds, and other related materials. An outside location of the dust collector is required, with several exceptions listed in the standard.

NFPA 484 describes specific dust collector location criteria for a number of combustible metals and has specific chapters for control of combustible dust hazards from alkali metals, aluminum, magnesium, niobium, tantalum, titanium, zirconium, and other combustible metals.

NFPA 654 provides specifications for control of dust explosions from materials not specifically addressed by another more specific NFPA standard. This standard specifies that, where an explosion hazard exists, air-material separators be located outside of buildings. The standard provides some exceptions to this specification in Chapter 7.

NFPA 655 provides general specifications for control of fires and explosions from processes involving sulfur dust, and includes specific location criteria for the dust collector.

NFPA 664 provides specifications for selecting the location for a dust collector in wood processing and woodworking facilities. Outdoor locations are recommended. The standard recommends that dust collectors not be located on the roof of a building. Indoor locations are permitted by the standard under special circumstances, which are listed in the standard for enclosed and enclosureless dust collectors.

Construction of a dust collector

Dust collectors used for combustible dust need to be designed and constructed entirely of non-combustible material suitable for the use intended (Note: the use of aluminum paint on the inside of a metal dust collector increases the fire hazard and should be avoided. If the aluminum flakes off or is struck by a foreign object, the heat of impact could be sufficient to cause ignition of the aluminum particle, thereby initiating a fire). However, filter bags and explosion vent panels fabricated from combustible material are acceptable. Dust collectors need to be constructed to prevent leakage of dust into the rest of the workplace and to minimize internal ledges or other points of dust accumulation (e.g., hopper bottoms should be sloped; surfaces and seams should be smooth). This is important since an accumulation of as little as 0.8 mm (1/32 inch) thick of combustible dust on horizontal surfaces (both inside and outside the dust collector) may lead to a secondary and more damaging explosion following any primary explosion. Dust collectors need to have independent supporting structures capable of supporting the weight of the collector, the material being collected, and any water from extinguishing systems that will not readily drain from the system.

NFPA 61 Chapter 10 specifies criteria for construction of a dust collector used for agricultural and food processing operations.

NFPA 484 describes construction criteria for dust collection in metal operations.

NFPA 655 provides general specifications for control of fires and explosions from processes involving sulfur dust, and includes specific construction criteria.

NFPA 664 describes location and construction criteria for wood processing and woodworking facilities (see especially section 8.2).

Explosion relief venting and suppression

Explosion relief vents are panels or doors that are deliberate points of weakness. If they are of the correct size and construction, and properly positioned, they can help to safely vent an explosion in a dust collector so that workers are not endangered. These relief vents should be designed and constructed by experts. *NFPA 68 Standard on Explosion Protection by Deflagration Venting (2007)* addresses the design, location, installation, maintenance, and use of devices and systems that vent the combustion gases and pressures resulting from a deflagration within an enclosure. The standard specifies that deflagration venting be arranged to avoid injury from the vent discharge and that the material discharged from an enclosure during the venting of a deflagration be directed outside to a safe location.

NFPA 654 includes information on deflagration venting, suppression systems, mechanical and chemical isolation systems, flame front diverters, and abort gates to lower the risk to workers in the event of

Definitions

Class II locations. Class II locations are those that are hazardous because of the presence of combustible dust.

The following are Class II locations where the combustible dust atmospheres are present:

LOCATION	DESCRIPTION
Group E	Atmospheres containing combustible metal dusts, including aluminum, magnesium, and their commercial alloys, and other combustible dusts whose particle size, abrasiveness, and conductivity present similar hazards in the use of electrical equipment.
Group F	Atmospheres containing combustible carbonaceous dusts that have more than 8 percent total entrapped volatiles (see ASTM D 3175, Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke, for coal and coke dusts) or that have been sensitized by other materials so that they present an explosion hazard. Coal, carbon black, charcoal, and coke dusts are examples of carbonaceous dusts.
Group G	Atmospheres containing other combustible dusts, including flour, grain, wood flour, plastic and chemicals.

The following is a partial listing of definitions based on NFPA standards and 29 CFR 1910.399, the definitions provision of Subpart S—Electrical, that relate to combustible dust.

TERM	DEFINITION
Combustible dust	A combustible particulate solid that presents a fire or deflagration hazard when suspended in air or some other oxidizing medium over a range of concentrations, regardless of particle size or shape.

TERM	DEFINITION
Combustible Particulate Solid	Any combustible solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition.
Hybrid Mixture	A mixture of a flammable gas with either a combustible dust or a combustible mist.
Deflagration	Propagation of a combustion zone at a speed that is less than the speed of sound in the unreacted medium.
Deflagration Isolation	A method employing equipment and procedures that interrupts the propagation of a deflagration of a flame front, past a predetermined point.
Deflagration Suppression	The technique of detecting and arresting combustion in a confined space while the combustion is still in its incipient stage, thus preventing the development of pressures that could result in an explosion.
Detonation	Propagation of a combustion zone at a velocity that is greater than the speed of sound in the unreacted medium.
Dust-ignition proof	Equipment enclosed in a manner that excludes dusts and does not permit arcs, sparks, or heat otherwise generated or liberated inside of the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specified dust on or in the vicinity of the enclosure.
Dusttight	Enclosures constructed so that dust will not enter under specified test conditions.
Explosion	The bursting or rupture of an enclosure or a container due to the development of internal pressure from deflagration.
Lower Flammable Limit (LFL)	The lowest concentration of material that will propagate a flame from an ignition source through a mixture of flammable gas or combustible dust dispersion with a gaseous oxidizer.

TERM	DEFINITION
Upper Flammable Limit (UFL)	The highest concentration of a combustible substance in an oxidizing medium that will propagate a flame.
Minimum Explosible Concentration (MEC)	The minimum concentration of combustible dust suspended in air, measured in mass per unit volume that will support a deflagration.
Minimum Ignition Energy (MIE)	The lowest electrostatic spark energy that is capable of igniting a dust cloud.
Minimum Ignition Temperature (MIT)	The lowest temperature at which ignition occurs.

Areas of Dust Build Up

The use of air wands for scheduled clean-up and clearing machinery quickly of debris during routine or break down maintenance is probably the single largest contributor to the accumulation of fine dust particles in a sawmill. Typically air lines used for clean-up are simply tapped into main mill air lines that run at 80 to 120 PSI straight from the compressor. It would be rare to see such a line equipped with a regulator to step down the pressure. Materials coming from any of the process machines in a sawmill are generally a mix of large chips and splints, coarse sawdust and shavings and a component of fine and very fine sawdust. Any circular saw that cuts thick material such as cants can create a large amount of fine sawdust mixed with the coarser sawdust. This is because some of the initial sawdust contained in the gullet of the saw does not have enough time to fully exit the gullet before the tooth re-enters the cut. Sawdust carried thru the cut is reduced further to finer sawdust. Cross cutting perpendicular to the grain also creates very fine sawdust.

When high pressure air is used to clear machines or clean up accumulations of cutting material, the heavier coarser material remains on or just above the floor and the employee is able to direct the bulk of materials to a waste chute or other collection area by blowing down with an air wand. Smaller particles are raised into the air and settle in a short time. Often they are too large to cling to vertical or angular surfaces and fall back to the floor level. The very fine dust is suspended in air and can remain that way for several minutes or longer. This dust moves about throughout the mill and eventually settles in areas with little or no air movement. This fine component of dust is generally the most volatile and accumulates over time. When something disturbs this dust, it may create a dense mixture of very combustible material suspended in air. Under the right conditions, this material can explode with disastrous consequences.

Any horizontal surfaces and some vertical surfaces if the texture is rough such as plywood walls and wooden beams will hold dust. Vertical corrugated sheeting can also hold wood dust.

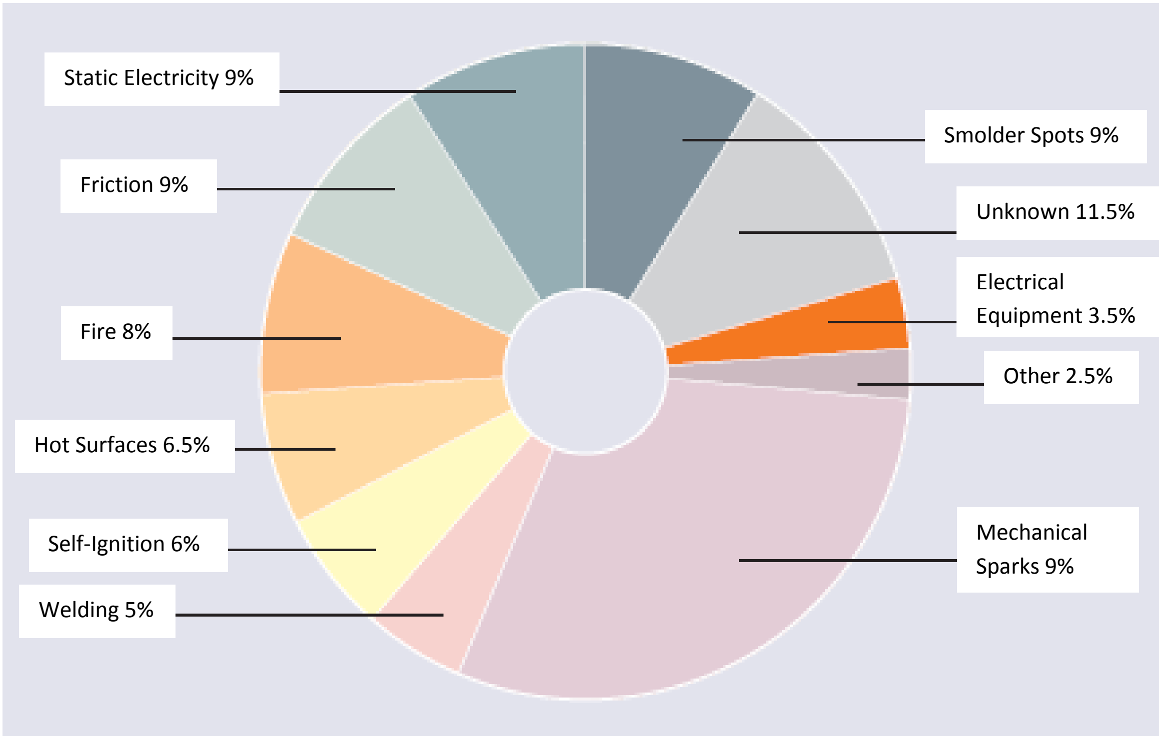
Roofs contained within the mill canopy such as lunch rooms, washrooms, offices, air compressor rooms, maintenance shops etc. are generally out of the main operating areas where there is minimal air flow and disturbance. Good areas for fine materials to settle. The roofs of these structures collect sawdust over a long period which can be disturbed by the shock wave of an initial explosion and introduce a huge amount of fuel into the atmosphere very quickly. Because these surfaces are fairly high above the mill floor, they tend to accumulate the finest sawdust that has floated up to that level due to normal mill processes or as a result of clean up or maintenance personnel using air wands to clean up below.

Beams, piping and electrical trays are all potential dust traps and should be inspected for obvious dust accumulations.

Trim saws, chippers, hoppers, chip screening rooms, canter lines and edger’s generate significant volumes of fine dust. Inspections of surfaces in the vicinity of these machines should be a priority.

Ignition Sources

The following chart is from the OSHA Combustible Dust Training Program (C-DuST) which depicts possible ignition sources.



Additional information on possible ignition sources

A number of ignition sources are equipment and process related. A control program should include inspection and maintenance to ensure potential ignition sources are managed. Below are examples of items to consider

Motor control centers (MCC's). Potential sparks inside cabinets when various relays and contacts are energized. When inspecting a mill, look for door panels that have inadvertently been left open after resetting switches that have kicked out or other trouble shooting activities associated with maintenance.

Inspection plates on electrical motors. The plates are not always replaced, this exposes wiring to potential arcing if a metal object comes into contact. Inspect these areas to ensure cover plates are in place and secure.

Fixed guards on power transmission components. Often fixed guards around belt and pulley assemblies are removed for various reasons and not replaced properly. Sometimes they are not properly aligned with mounting points which can result in a belt or part of a sheave or sprocket rubbing on the metal guard. Another issue with these type of guards is deformation. If an object strikes and deforms the guard, it can push the mesh into the moving parts resulting in friction. Inspect guards for clearance to moving parts and proper installation. Also, lumber and other objects can fall onto unguarded power transmission components and create friction.

V-belts. Worn or loose drive belts can slip on sheaves when a load is imposed on the drive such as a jam up in a conveyor or a heavy load in the conveyor. Slipping belts create huge friction and often burn right off the sheave. These should be regularly inspected and on maintenance program

Hogs and chippers. Friction caused by sawdust build up or other materials pushing against chipper discs and hog screens can ignite and cause fires. Dull chipper knives will not feed material properly and will often heat up causing a fire. Inspect for general housekeeping, proper maintenance (knife changes at regular intervals) and evidence of heat. If a chipper or hog catches on fire, it will fill the mill with smoke quickly.

Unprotected lighting. Old style filament bulbs and large, high intensity mercury / sodium vapour bulbs are a potential ignition source if they are broken when struck by an object. This type of lighting is more common in older mills and inspection should focus on cages or other means of protecting an exposed bulb.

Extension cords and welding cables. Worn and abraded welding cables will arc when they come into contact with steel. Extension chords should be GFCI or maintained in an assured grounding program but can easily be cut when dragging to a location or through conveyors where sharp surfaces exist. Inspect for obvious wear and stripped off insulation. They should also be properly stored and not left laying strung out in the mill. A steel wheeled cart crossing a cable could cut through and arc.

Dust Handling Systems

The following information provides some examples of dust generating equipment in saw mills have been associated with dust explosions.

The following information are excerpts summarized from the OSHA 'Dust Handling Equipment' presentation.

Types of Equipment Used in Dust Handling

There are several types of equipment, dust transportation systems and containers that are used in the storage and handling of combustible dusts. The following are some of the types of equipment used at combustible dust handling facilities:

- Dust Collectors
- Silos and Hoppers

Dust Collectors

Dust emitted from the handling and processing of combustible dusts is generally controlled by dust collectors which include cyclone separators, electrostatic precipitators, Fabric filters, (Baghouses) and wet scrubbers.

Dust emitted from handling and processing can be collected and controlled by the following equipment.

- Cyclone Separators- less susceptible to fires and explosions; proper grounding and bonding critical to avoid static build-up
- Electrostatic Precipitators- used where high collection efficiency is required, less likely to see around sawmills.
- Fabric Filters – most common, presence of easily ignitable fine dust and high turbulence
- Wet Scrubbers-usually do not pose a fire or explosion hazard because the particles are wet. If the scrubbing liquid flow (water) is stopped there is an increased potential

Baghouses are composed of number of compartmented filter bags, and a bag cleaning mechanism. These are enclosed in a shell and provided with a hopper to receive collected dust. There are several types of baghouses; Shakers, reverse flow, pulse-jet, etc..

Locate baghouses outside – **see WorkSafeBC guideline G5.71 (3) for additional information regarding explosion prevention in dust collectors.**

Silos and Hoppers

Normally Silos (or bins) are very large vessels used for long term storage.

Fires and explosions can occur: from dust clouds generation from powders mechanically conveyed or pneumatically conveyed into the hoppers or silos.

Prolonged storage can cause smoldering from self heating.

While Smoldering is still limited to a small portion of the interior of the pile, the detection of the possibility of smoldering can be achieved by the use of thermal monitoring devices. This can be achieved by: **infrared system** or by installing some type of **temperature monitor** (thermistors) within the pile interior.

- Silos and hoppers shall be located outside the buildings with some exceptions
- Air cannons not to be used to break bridges in silos

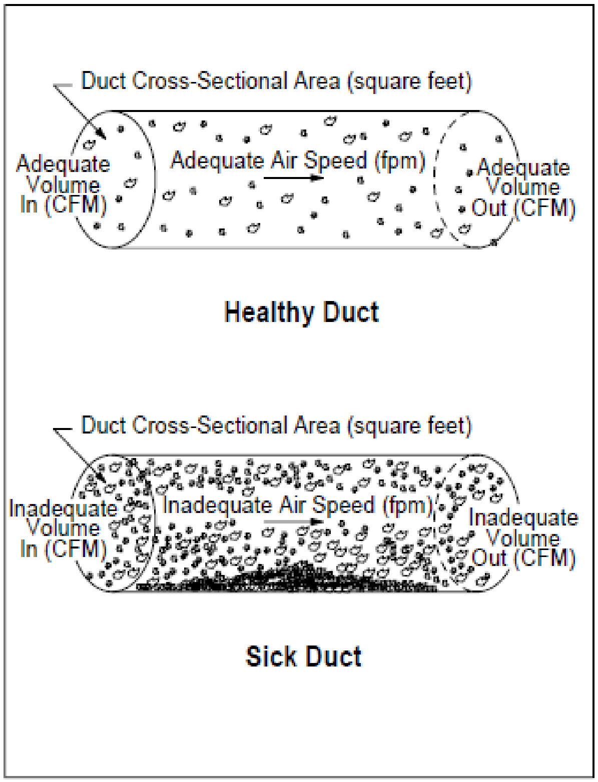
Detection of smoldering fires in bunkers, silos and enclosed dust collectors can be achieved with either CO or hydrocarbon vapor detector, or with infrared monitoring of silo wall temperature. In the case of coal bunkers, NFPA 850 recommends alarming at concentrations of 1.25%.

- Pressure containment, inerting, and suppression systems can also be used protect against explosions
- Venting is the most widely used protection against explosions.

Enclosed spaces and ducts

Look for enclosed spaces around the machines where dust can accumulate.

To maintain a “healthy” duct system, make sure there is the correct air speed in the duct system to prevent fallout of wood dust and avoid explosive dust-air mixtures. Also look for clean out point/doors in the ductwork. They should be used to clean ducts in case they get clogged.



Adequate air speed inside of the duct is 3,500 to 4,000 fpm to prevent dust settling.

Cutting operations

Cross cutting timber can produce very fine sawdust. The type of equipment normally used for this includes trim saws, chop saws, finger jointers.

There are a few factors that relate to the production of fine sawdust in these processes. Most significant is cutting perpendicular to the structure of the wood cells. This creates shorter (finer) particles.

Trim saws and cut off saws generally have a higher tooth count than saws designed to rip wood parallel to the grain due to cell orientation. Higher tooth count in the saw blades results in a smaller bite per tooth. In addition, these saws are generally run at high speed to produce a clean fine finish in the cut.

Chip screening rooms and trim block chippers - particularly in planer mills where trim ends are often kiln dried also tend to generate a lot of fine sawdust.

Efforts to provide local exhaust ventilation on these saws should significantly reduce accumulation of fine sawdust on adjacent surfaces.

Clean-up of Hazardous Combustible Dust

Wood dust is a combustible dust. If the dust is disturbed and a sufficient amount becomes airborne and a source of ignition is present, then the dust may explode. Uncontrolled cleaning activities may generate a dust cloud that could explode.

In order to clean safely, use cleaning methods that do not generate dust clouds, especially in confined areas where ignition sources (flames, sparks, and static electricity) are present. These cleaning methods would include:

- Vacuuming, using a vacuum approved for dust collection
- Water wash or wet rags (do not use water near live electrical equipment). First apply a water mist and then increase the flow to a high velocity water stream. Be cautious not to plug the drain piping.
- Soft bristle brooms on telescopic poles (to clean high areas)
- Compressed air pressure must be kept as low as practicable to complete the cleaning. NFPA Standard 664 Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities sets out a maximum of 15 psi for the use of compressed air for blowing down equipment

Likely areas of dust accumulations may include:

- Structural members
- Conduit and pipe racks
- Cable trays
- Floors
- Above the ceiling (if a suspended ceiling is present)
- On and around dust collection equipment
- The interior of a dust collector and ductwork

Horizontal and vertical surfaces should be cleaned (where dust could settle). Dust and wood waste must be cleaned up at regular intervals:

- At least once per shift, or
- Sooner, if dust and wood waste accumulates quickly, or
- Immediately, if dust spills from a machine or device (this information should be reported to a supervisor or manager

Disposal of waste dust must be conducted safely.

The cleaned area should be inspected to ensure the cleaning is complete and any deficiencies addressed. Tools and equipment for clean-up should be kept in a designated area.

Workers cleaning up hazardous dust must wear personal protective equipment that includes eye goggles and a respirator (elastomeric half-face respirator with P100 cartridges, as a minimum).

Frequently Asked Questions (FAQs)

QUESTION	ANSWER
1. What is a combustible dust?	Any combustible material (and some materials normally considered noncombustible) can burn rapidly when in a finely divided form. A combustible dust is particulate solid that presents a fire or deflagration hazard when suspended in air over a range of concentrations, regardless of particle size or shape. For wood dusts the combustibility increases as the particle size decreases and the moisture content is reduced.
2. What is secondary deflagration?	Deflagration is a rapid propagation of combustion. It occurs when the pressure from an initial combustion event disturbs other combustible dusts and causing a mixture of dust air that readily supports the propagation of the combustion. The propagation can continue as long as there is the fuel and air to support it. It is important to keep in mind that the initiating source of combustion may not be dust related.
3. Are all wood dusts and shavings a problem?	No. The potential for explosion is based on the characteristics and composition of the material. While most wood wastes are a combustible material, for an explosion to occur the material must be easily dispersed and suspended in air. The risk is with the finer dry dust fractions which can settle out on, or adhere to elevated surfaces.
4. Is there a maximum allowable airborne concentration or combustible limit and can it be measured?	Given the variable characteristics of wood dusts in terms of species, particle size, moisture content and combustibility properties, minimal explosive concentrations can vary dramatically. There is no established standard for a maximum concentration of combustible dust in air. Explosive mixtures of dust in air occur at fairly high concentrations that will be found

QUESTION	ANSWER
	only in isolated locations or as a result of an activity or event which creates this condition. In addition, these conditions may exist only for short instances. Therefore, the measurement of an explosive concentration is neither practicable nor reliable. The focus should be on identifying and evaluating the dust sources, sources of ignition and dust dispersion mechanisms.
5. We have assessed dust exposure levels for respiratory hazards and found them to be acceptable. Are we okay?	Exposure monitoring is not representative of potentially explosive conditions. As mentioned above explosive mixtures of dust in air occur at very high concentrations and will be found only in isolated locations or as a result of an activity or event which creates this condition.
6. Are all wood dusts and shavings explosive?	No. The potential for explosion is based on the characteristics and composition of the material. While most wood wastes are a combustible material, for an explosion to occur the material must be easily dispersed and suspended in air. The risk is with the finer dry dusts which can settle out on, or adhere to elevated surfaces.
7. Should I focus on cleaning up the mill as a first step?	The order was to conduct a risk assessment and develop a control plan. It is very important that the clean-up activities are carefully planned and consider not only the risks associated with the combustible dusts but also the other risks such as working at heights, safe access, confined space and the need for protective equipment.
8. Is blow down of dusts prohibited?	Section 4.42 states that blowdown with compressed air is prohibited where it is likely to result in an injury or health hazard due to fire or explosion or other cause. As a result, blowdown is permitted where it is managed adequately to ensure that the risk of fire or explosion and any other risk of injury is eliminated or minimized to the extent practicable. Many mills use blow down to

QUESTION	ANSWER
	clean machines and elevated areas that are otherwise difficult to access. Employers must ensure that specific written procedures are put in place that minimize the use of blowdown, and that eliminate the risks of fire and explosion, by eliminating sources of ignition and minimizing dust dispersion from the process. Reference the 4.42 guideline for more information.
9. Where do we start on the risk assessment and develop the control plan?	A guideline has been established in relation to OH&S 5.81. This guideline identifies a number of items which need to be considered when conducting the risk assessment, and developing and implementing the control plan. The guideline focus is on identifying and controlling the elements or conditions that are necessary to support a dust explosion (fuel sources, ignition sources, conditions and mechanisms were the dust can be dispersed in air). There are also links to additional resources (NFPA and OSHA) provided with in this Guideline. Employers should be looking closely at their processes including all product and waste processing streams and work activities including clean up and maintenance work which could potentially create the conditions necessary for a fire or explosions.
10. Does the risk assessment and dust control program need to be documented?	There is no explicit requirement for documentation in the OH&S Regulation, but the guideline calls for a written control program. This is a complex issue and it is extremely unlikely the employer could demonstrate that an effective control program is established and implemented without documentation.
11. When do we stop work?	Work should stop when there is a high probability that all conditions necessary for a

QUESTION	ANSWER
	dust explosion exist or are likely to exist. i.e. a significant accumulation of dry, finely divided dust is or will likely be dispersed in air within an enclosed environment with uncontrolled ignition sources present.
12. What regulations relate to the control of fires and explosion hazards?	A list of other requirements that may apply is attached.

Other Regulations to Consider

REGULATION	EXCERPT
4.42 Cleaning with compressed air	(1) Compressed air or steam must not be used for blowing dust, chips, or other substances from equipment, materials and structures if any person could be exposed to the jet, or to the material it expels or propels and an injury or health hazard due to fire, explosion or other cause is likely to result.
5.23 Permitted quantities	(1) The amount of a hazardous substance in a work area must not exceed the quantity reasonably needed for work in progress, normally in one work shift. (2) Bulk or reserve quantities must be stored in a designated area separate from the work area.
5.24 Incompatible substances	Substances which are incompatible must not be stored in a manner that would allow them to mix in the event of container leakage, breakage or other such circumstance.
5.25 Storage practices	A hazardous substance must be stored in a designated area, in a manner which ensures that it will not readily fall, become dislodged, suffer damage, or be exposed to conditions of extreme temperature.
5.26 Storage area	The designated storage area for a hazardous substance must be (a) designed and constructed to provide for the safe containment of the contents, (b) clearly identified by signs, placards or similar means, (c) designed and maintained to allow the safe movement of workers, equipment and material, (d) provided with adequate ventilation and lighting, and (e) in a location not normally occupied by workers, and not in a location such as a lunchroom, eating area, change room, clothing storage locker or passenger compartment of a vehicle.

REGULATION	EXCERPT
5.27 Ignition sources	(1) When a flammable gas or a flammable liquid is handled, used or stored, all sources of ignition must be eliminated or adequately controlled. (2) For the purposes of subsection (1) sources of ignition include open flame, spark-producing mechanical equipment, welding and cutting processes, smoking, static discharge and any electrical equipment or installation that is not approved for hazardous locations, as specified by the Electrical Safety Act. (3) If the work involves more than one employer, the principal contractor or, if there is no principal contractor, the owner must ensure that sources of ignition resulting from the work of one employer are eliminated or adequately controlled in any work area where a flammable gas or a flammable liquid is handled, used or stored by any other employer.
5.28 Grounding or bonding	Metallic or conductive containers used to transfer flammable liquids must be electrically bonded to each other or electrically grounded while their contents are being transferred from one container to the other.
5.29 Electrostatic charge	If glass, plastic or other non-conductive container with a capacity of 23 litres (5 imp gal) or more is used to transfer a flammable liquid, the accumulation of electrostatic charge near the surface of the liquid must be eliminated or controlled by (a) limiting the flow velocity of the liquid to less than 1 m/s (200 fpm), (b) using a grounded lance or nozzle extending to the bottom of the container, (c) limiting free fall, (d) using anti-static additives, or (e) other effective means.

REGULATION	EXCERPT
5.30 Dispensing (G)	If a flammable liquid is dispensed or transferred inside a flammable liquids storage room, (a) the storage room must be mechanically ventilated at a rate of at least 18 m3/hr per square metre of floor area (1 cfm/sq ft), but not less than 250 m3/hr (150 cfm), (b) exhaust air must be discharged to the outdoors, and makeup air provided, (c) any makeup air duct passing through a fire separation must be equipped with an approved fire damper, and (d) doors must be self-closing.
5.31 Flammable gas or vapour	If it is not practicable to maintain the airborne concentration of a flammable gas or vapour below the applicable exposure limit, for example, in a temporary situation or an emergency, (a) only the minimum number of workers necessary for the work may be exposed, (b) every worker exposed must be adequately trained and equipped to safely perform the required duties, (c) the concentration of the flammable gas or vapour must not exceed 20% of the lower explosive limit (LEL), and (d) in a life-threatening emergency only, exposure of emergency response workers is permitted above 20% of the LEL, provided that only those qualified and properly trained and equipped workers necessary to correct the unsafe condition are exposed to the hazard and every possible effort is made to control the hazard while this is being done.

REGULATION	EXCERPT
5.32 Manual cleaning	A flammable liquid must not be used as a manual cleaning solvent unless (a) a thorough review of alternative solvents by the employer indicates that a suitable non-flammable substitute is not available, (b) appropriate written safe work procedures are implemented to effectively control flammability and health hazards, (c) the quantity of liquid used is minimized, (d) the worker is instructed and trained in the safe work procedures, and (e) the work procedures have been submitted to the Board.
5.33 Permitted quantities	Except for the quantity reasonably needed for immediate use, or that is present for display or sale in public areas of a mercantile facility, the quantity of combustible and flammable liquids stored outside an approved storage cabinet, storage room or storage area in any fire compartment (2 hour fire separation) of a building must not exceed (a) in closed containers, 600 litres (132 imp gal) of liquids having a flash point below 93.3°C (200°F) of which not more than 100 litres (22 imp gal) may be liquids having a flash point below 22.8°C (73°F) and a boiling point below 37.8°C (100°F), and (b) in storage tanks or portable tanks, 5,000 litres (1,100 imp gal) of liquids having a flash point below 93.3°C (200°F) and a boiling point at or above 37.8°C (100°F).
5.34 Combustible materials	Except for packaging used to contain flammable or combustible liquids, combustible shelves, racks and other materials are not permitted inside a flammable or combustible liquids storage room or storage cabinet unless required as part of a fire separation.

REGULATION	EXCERPT
5.35 Cabinet vent	If a flammable liquids storage cabinet is vented, the vent must be a steel pipe at least 5 cm (2 in) in diameter which is connected directly to the outdoors.
5.36 Containers	(1) A tank, cylinder, bottle or other vessel containing a substance under pressure, together with any associated pressure or flow regulator and piping or conveyance system, must be (a) protected from sparks, flames, excessive heat, physical damage, electrical contact or corrosion, and (b) equipped with suitable pressure relief mechanisms installed so that no worker will be endangered in the event of discharge. (2) Hand-held aerosol spray cans are exempt from the requirements of subsection (1)(b).
5.37 Pressure testing	A compressed gas container which requires pressure testing must bear a valid and current indication that it has been pressure tested.
5.38 Handling and securing cylinders	(1) A compressed gas cylinder must not be hoisted by a sling or magnet, dropped, subjected to impact, handled by the regulator or used as a roller or work support. (2) A compressed gas cylinder must be secured to prevent falling or rolling during storage, transportation and use, and where practicable, must be kept in the upright position.
5.39 Cylinder markings	A compressed gas cylinder must be marked to indicate its rated pressure and the type of gas it contains.

REGULATION	EXCERPT
5.40 Cylinder valves	(1) The valve on a compressed gas cylinder must be kept closed when the cylinder is empty or not in use. (2) A worker must not stand directly in front of a regulator attached to a compressed gas cylinder when the cylinder valve is being opened. (3) Any valve, regulator or fitting connected to a compressed gas cylinder must be a standard fitting, designed and manufactured for the type of cylinder and compressed gas for which it will be used, and must include provisions for flashback arresters where necessary. (4) Unless a compressed gas cylinder is equipped with an integral valve guard, the valve cover must be in position when the cylinder is not connected for use.
5.41 Fittings	Only standard fittings designed for the specific compressed gas service may be used with a compressed gas system.
5.43 Empty cylinders	An empty compressed gas cylinder must be identified as being empty and must be stored separately from other compressed gas cylinders.
5.44 Acetylene cylinders	(1) A compressed gas cylinder containing acetylene must be used only in the upright position. (2) If the cylinder has been stored or transported in a horizontal position, it must be placed in the upright position for at least 1 hour before it is used. (3) A suitable device for closing the valve on an acetylene cylinder must be immediately available when the cylinder is connected for use.
5.45 Restriction on use of copper	A fitting or tube made of copper or any alloy containing more than 67% copper must not be used in a system carrying acetylene gas, except for copper torch tips and lengths of copper tubing 30 cm (1 ft) or less in length which are open to the atmosphere.

REGULATION	EXCERPT
5.46 Restriction on use of oxygen	(1) Oxygen gas must not be used in any circumstance where it can contact a substance that oxidizes readily, such as a petroleum product, natural fibre or metal powder. (2) Oxygen gas must not be used to (a) operate a pneumatic tool, (b) start an internal combustion engine, (c) clean equipment or clothing, (d) create pressure in a container, or (e) ventilate a workplace.
5.47 Cleanliness	A worker must not permit oil or grease to contact an oxygen cylinder valve, regulator, or fitting.
5.71 Flammable Air Contaminants	(1) If an operation or work process produces a combustible or flammable air contaminant in concentrations that may present a risk of fire or explosion, the employer must provide a separate exhaust ventilation system for the operation or work process. (2) Electrical components of an exhaust ventilation system required by subsection (1) must comply with Class I Division I requirements of CSA Standard C22.1-94, Canadian Electrical Code, Part 1 if the components contact the air stream. (3) A dust collector having an internal volume greater than 0.6 m3 (20 ft3) and being used to control combustible dusts must be located and constructed so that no worker will be endangered in the event of an explosion inside the collector.
5.81 Combustible Dust	If combustible dust collects in a building or structure or on machinery or equipment, it must be safely removed before accumulation of the dust could cause a fire or explosion.

REGULATION	EXCERPT
5.98 Inventory	(1) An inventory must be maintained which identifies all hazardous substances at the workplace in quantities that may endanger workers in an emergency including controlled products covered by WHMIS, explosives, pesticides, radioactive materials, hazardous wastes, and consumer products. (2) The inventory must identify the nature, location, and approximate quantity of all such substances, and the location of MSDSs.
5.99 Risk assessment	An employer must ensure that an assessment is conducted of the risks posed by hazardous substances from accidental release, fire or other such emergency.
Part 12 Welding and Painting related	

WorkSafeBC Bulletin:
Clean-up of Hazardous Combustible Dust

Clean-up of Hazardous Combustible Dust

Wood dust is a combustible dust. If the dust is disturbed and a sufficient amount becomes airborne and a source of ignition is present, then the dust may explode. Uncontrolled cleaning activities may generate a dust cloud that could explode.

In order to clean safely, use cleaning methods that do not generate dust clouds, especially in confined areas where ignition sources (flames, sparks, and static electricity) are present. These cleaning methods would include:

- Vacuuming, using a vacuum approved for dust collection
- Water wash or wet rags (do not use water near live electrical equipment). First apply a water mist and then increase the flow to a high velocity water stream. Be cautious not to plug the drain piping.
- Soft bristle brooms on telescopic poles (to clean high areas)
- Compressed air should only be used as a last resort. Vacuum all accessible dust first. Use a maximum 15 psig compressed air to move dust out of inaccessible areas. Ensure that any electrical equipment in the area is locked out and de-energized, and any hot equipment or other surfaces are cooled down and no open flames exist.

Likely areas of dust accumulations may include:

- Structural members
- Conduit and pipe racks
- Cable trays
- Floors
- Above the ceiling (if a suspended ceiling is present)
- On and around dust collection equipment
- The interior of a dust collector and ductwork

Horizontal and vertical surfaces should be cleaned (where dust could settle). Dust and wood waste must be cleaned up at regular intervals:

- At least once per shift, or
- Sooner, if dust and wood waste accumulates quickly, or
- Immediately, if dust spills from a machine or device (this information should be reported to a supervisor or manager)

Disposal of waste dust must be properly and safely.

The cleaned area should be inspected to ensure the cleaning is complete and any deficiencies addressed. Tools and equipment for clean-up should be kept in a designated area.

Workers cleaning up hazardous dust should wear personal protective equipment that includes eye goggles and a respirator (elastomeric half-face respirator with P100 cartridges, as a minimum).

REFERENCES AND RESOURCES

References for WorkSafeBC Documents

National Fire Protection Association (NFPA)

Title: NFPA 68: Standard on Explosion Protection by Deflagration Venting
Date: 2007 Edition
URL: http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp?cookie%5Ftest=1

National Fire Protection Association (NFPA)

Title: NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
Date: 2006 Edition
URL: http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp?cookie%5Ftest=1

National Fire Protection Association (NFPA)

Title: NFPA 655 Standard for Prevention of Sulfur Fires and Explosions
Date: 2007 Edition
URL: http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp?cookie%5Ftest=1

National Fire Protection Association (NFPA)

Title: NFPA 664 Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities
Date: 2007 Edition
URL: http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp?cookie%5Ftest=1

Oregon Occupational Safety and Health Association (OSHA)

Title: Hazard Alert – Combustible Dust
Date: June 2008
URL: http://www.orosha.org/pdf/hazards/2993_05-2008_combustdust.pdf

US Chemical Safety and Hazard Investigation Board

Title: Combustible Dust: An Insidious Hazard
Date: July 2009
URL: http://youtu.be/3d37Ca3E4fA

US Chemical Safety and Hazard Investigation Board

Title: Investigation Report: Combustible Dust Hazard Study
Date: November 2006
URL: http://www.csb.gov/assets/document/Dust_Final_Report_Website_11-17-06.pdf

US Department of Labor – National Emphasis Program

Title: Status Report on Combustible Dust
Date: October 2009
URL: http://www.osha.gov/dep/combustible_dust/combustible_dust_nep_rpt_102009.html

U.S. Department of Labor – Occupational Safety and Health Administration

Title: OSHA Instruction: Combustible Dust National Emphasis Program (Directive # CPL 03-00-008)
Date: March 11, 2008
URL: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=directives&p_id=3830

U.S. Department of Labor – Occupational Safety and Health Administration

Title: Safety and Health Information Bulletin – Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions
Date: July 31, 2005
URL: http://www.osha.gov/dts/shib/shib073105.html

U.S. Department of Labor – Occupational Safety and Health Administration

Title: Hazard Communication Guidance for Combustible Dusts
Date: 2009
URL: http://www.osha.gov/Publications/3371combustible-dust.html

US National Archives and Records Administration

Title: Federal Register: Department of Labour Occupational Safety and Health Administration – Combustible Dust; Proposed Rule
Date: October 21, 2009
URL: http://www.gpo.gov/fdsys/pkg/FR-2009-10-21/pdf/E9-25075.pdf

Weyerhaeuser

Title: Combustible Dust Risk and Hazard Mitigation in Lumber Operations – Weyerhaeuser Experience
Date: May 26, 2010 (for Forest Products Industrial Hygiene Forum at AIHce Denver 2010)
URL: N/A (See document in Appendices section)

Suggested Additional Resources

American Industrial Hygiene Conference and Expo (AIHce)

Title: NFPA 654, 2011 Edition – Key Changes/Issues/Impacts (by Brice Chastain, CIH, Georgia-Pacific)
Date: May 26, 2010 (for Forest Products Industrial Hygiene Forum at AIHce Toronto 2010)
URL: N/A (See document in Appendices section)

Chemical Engineering Transactions, Volume 19

Title: State of the art: Promotion of early inherently safer design against dust explosions
Date: 2010
URL: http://www.aidic.it/cet/10/19/060.pdf

CNA

Title: Risk Control Bulletin: Combustible Dust – Wood Dust Exposures & Controls
Date: 2010
URL: http://www.cna.com/vcm_content/CNA/internet/Static%20File%20for%20Download/Risk%20Control/PropertyProtection/RC_Property_BUL_combustibledust_CNA.pdf

Factory Mutual Insurers

Title: Combustible Dust Hazard Recognition – an Insurer's View
Date: May 13-14, 2009
URL: http://www.nfpa.org/assets/files/PDF/Foundation%20proceedings/Combustible_Dust_Hazard_Recognition.pdf

FIKE

Title: EPIC: Explosion Protection Integrated Components
Date: Unknown
URL: http://www.fike.com.br/pdf/epic.pdf

FIKE

Title: Explosion Protection Application Profile: Bucket Elevators
Date: April 2010
URL: http://www.fire-protection.com.au/files/BucketElevators.pdf

Health and Safety Executive

Title: Safe Handling of Combustible Dusts: Precautions against explosions
Date: October 2003
URL: http://www.hse.gov.uk/pubns/books/hsg103.htm

Health and Safety Executive

Title: Safe collection of wood waste: Prevention of fire and explosion
Date: June 2011
URL: http://www.hse.gov.uk/pubns/wis32.pdf

New Zealand Department of Labor

Title: Dust Explosions in Factories: Precautions required with combustible dusts
Date: 1985
URL: http://www.osh.govt.nz/order/catalogue/archive/dustexplosions.pdf

Ontario Office of the Fire Marshal

Title: Ontario Fire Code: Section 5.10 — Combustible Dust Producing Processes
Date: August 27, 2010
URL: http://www.ofm.gov.on.ca/en/Legislation%20Directives%20and%20Technical%20Guidelines/fire%20code/Archived%20Documents/Illustrated%20Commentary/pdf/processes.pdf

Unknown Original Source

Title: Sawdust Cannon YouTube video
Date: August 3, 2007
URL: http://vimeo.com/260680 <http://vimeo.com/260680

US Chemical Safety and Hazard Investigation Board

Title: Inferno: Dust Explosion at Imperial Sugar
Date: October 2009
URL: http://youtu.be/Jg7mLSG-Yws

U.S. Department of Labor – Occupational Safety and Health Administration

Title: Combustible Dust Expert Forum Meeting Summary Report – Prepared by Eastern Research Group, Inc.
Date: Forum held on May 13, 2011; Report prepared on July 20, 2011
URL: http://www.osha.gov/dsg/combustibledust/expert_forum_summary_report.pdf

APPENDICES

American Industrial Hygiene Conference and Expo (AIHce)

NFPA 654, 2011 Edition – Key Changes/Issues/Impacts
(by Brice Chastain, CIH, Georgia-Pacific)

NFPA 654, 2011 Edition
Key Changes / Issues / Impacts

Brice Chastain, CIH
Georgia-Pacific

Forest Product IH Forum
AIHCE - Toronto
26 May 2010

NFPA 654

- Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids – 2006 Edition
- 2011 Edition pending issue June/July 2010

NFPA 654 Revision Cycle Summary

- Report on Proposal (ROP) developed (January 09 - Atlanta and March 09 - via teleconference)
- Proposals voted on by committee members in April 09
- Report of Proposals (ROP) presented on NFPA website for review & comment by Public - June 09
- Public comments submitted for review- Sep 09
- Committee met Sep 24-25, 2009 in Baltimore with several subsequent teleconferences through Nov 09 to review public comments & finalize proposed 2011 edition
- NITMAMs filed April 10, 2009 to address issues with document for floor vote at NFPA Convention in Las Vegas June 7-10
- If NITMAMS fail; 2011 edition issued by NFPA Standards Council in June/July 2010
- New 2011 edition effective (July – Aug 2010)

Key Changes / Issues

- Dust hazard area identified by:
  - Fire Hazard Criterion (people protection (95%); mass basis)
  - Explosion Hazard Criterion (structure protection; mass basis)
- Mechanical and chemical isolation devices replace abort gates and diverters as only reliable protection for AMS supply & return ducts

Dust Accumulation Allowance - *Present 2006 Edition Density Equation*

Allowable Thickness (inches) =

[(75 lbs/ft^3)(1/32 inch)] / settled bulk density, lbs/ft^3

Density		Allowance
75 lbs/ft^3	=	1/32 inch
18-20 lbs/ft^3	=	1/8 inch
2 lbs/ft^3	=	1.2 inches
1 lb/ft^3	=	2.3 inches

New Dust Allowance Criteria

- Two new criteria proposed– 2 simple / 2 complex “theoretical” equations
  (1) Protect Structure (Dust Explosion Hazard)
  (2) Protect Personnel from Fire (Dust Fire Hazard)
- Mass/area - based (kg/m^2) vs Density (lbs/ft^3) - thickness based (inches)
- Both complex equations require dust explosivity tests (~$2K)
- Complex “Fire” equation includes “Entrainment Factor” of 0.25
- Complex “Building” equation includes “Dynamic Load Factor” addressing weakest component in building not intended to fail
- Equations are theoretical and not validated with no loss history to support their use
- Will be more difficult for general industry and regulators to use than existing settled bulk density equation & thickness criteria

Two Simple Equations

Threshold mass establishing a building or room as a dust explosion hazard volume (building damage criterion):

$$M_{basic\text{-}exp} = 0.004 \times A_{floor} \times Height$$

Threshold dust mass establishing a building or room as a dust deflagration hazard volume (personnel fire explosion criterion):

$$M_{basic\text{-}fire} = 0.02 \times A_{floor}$$

Two Simple Equations

- Extremely conservative (reduces allowable dust mass by 40% for paper dust)
- Lumps all dust types (plastics, paper, starch, coal, petcoke, etc) together as if they have the same deflagration / explosion risks

Two Complex Equations

(alternate equations to the two simple equations)

Personnel Fire Hazard Equation

$$M_{fire}=0.05[Cw\ ][P_{initial}/(P_{initial}+P_{max})][(A_{floor}xD)/\ \eta_d]$$

- M_{fire} = allowable threshold dust mass (kg) based on personnel damage criterion (5% of occupants on floor not protected)
- Cw = worst case concentration(kg/m^3) at which max rate-of-pressure-rise results per ASTM E1226
- Pinitial = 1 bar absolute
- Pmax = max pressure developed during MEC tests
- A_{floor} = lesser of floor enclosure area (sq m) or 2000 m2
- D = personnel height (1.93 m [6 ft - typical person height])
- η_d = entrainment fraction (e.g. 0.25 – 1.0 unless determined; default 0.25*)

* Note: 0.25 entrainment fraction not validated; presently validated methodology for determining EF non-existent; development ~ 3-5 years away)

Building Damage/Explosion Equation

$$M_{exp} = [P_{es}/DLF]\ [Cw/Pmax]\ [(A_{floor} \times H)]\ /\ \eta_d$$

- Mexp = allowable threshold dust mass (kg) based on building damage criterion
- Pes = the enclosure strength evaluated based on static pressure calculations for the weakest building structure element not intended to fail (per NFPA 68)
- DLF = dynamic load factor, the ratio of maximum dynamic deflection to static deflection (per NFPA 68)
- Cw = worst case concentration (kg/m^3) at which max rate-of-pressure-rise results per ASTM E1226
- Pmax = max pressure developed during ASTM E1226 tests
- A_{floor} = lesser of floor enclosure area (sq m)
- H = height of enclosure ceiling (m) not to exceed 12 m
- η_d = entrainment fraction (e.g. 0.25 – 1.0 unless determined; set at 0.25)

New Isolation Requirements Eliminate Abort Gates/Diversion Devices in Supply/Return Ducts

- Based on vendor laboratory tests indicating abort gates are 0.25 seconds slower than isolation devices in reacting to deflagration
- Committee considered no loss history or actual case histories in deliberation
- Abort gates have served the Wood Products Industry well over the past 30 years
- Replacement costs can double cost of existing abort gate/diversion device ($15K to 25K)

OPPORTUNITY TO AFFECT OUTCOME OF NFPA 654 - 2011 EDITION

- Notice to File a Motion (NITMAMs) will be presented as challenges to elements of the new revised proposed standard on NFPA convention floor – 1-5 PM, Wednesday, June 9, 2009
- Majority vote of members on convention floor in favor of NITMAMs sends NFPA 654 back to committee for rework and resolution of issues
- NITMAMs supported by AF&PA, Paper Shredders/Recyclers, and Edison Electric Institute (representing Private Power Generation Facilities), John Cholin, expert consultant & past chair of NFPA 664 and member of NFPA 654

Successful NITMAM Impacts

- Delays issue of NFPA 654, 2011 Edition for 6-12 months or longer
- New equations likely will be reworked or possibly presented in annex as alternate method to settled bulk density method for establishing dust allowance criteria
- “Issues” with new equations & return air isolation/diversion become more visible to OSHA possibly affecting rulemaking process

QUESTIONS

Brice Chastain

bchasta@gapac.com

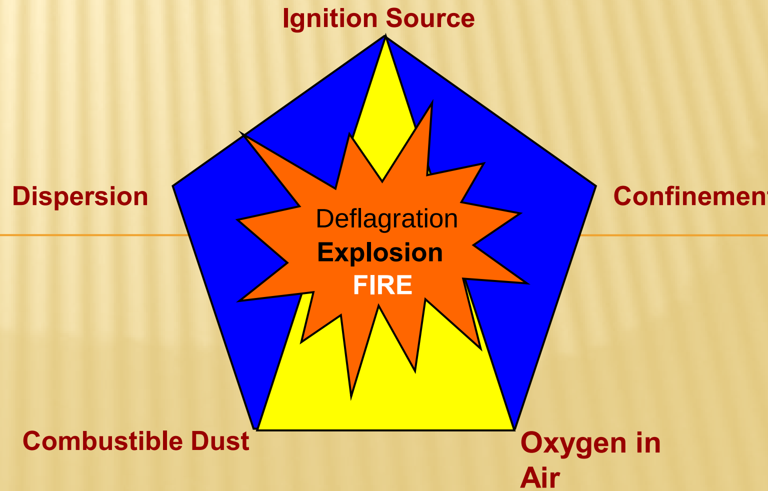
Weyerhaeuser

Combustible Dust and Hazard Mitigation in Lumber Operations – Weyerhaeuser Experience

Combustible Dust Risk and Hazard Mitigation in Lumber Operations — Weyerhaeuser Experience

Forest Products Industrial Hygiene Forum
May 26, 2010
AIHCE Denver 2010

Greg K. Ellisor, CIH, CSP
Corporate Health & Safety Manager

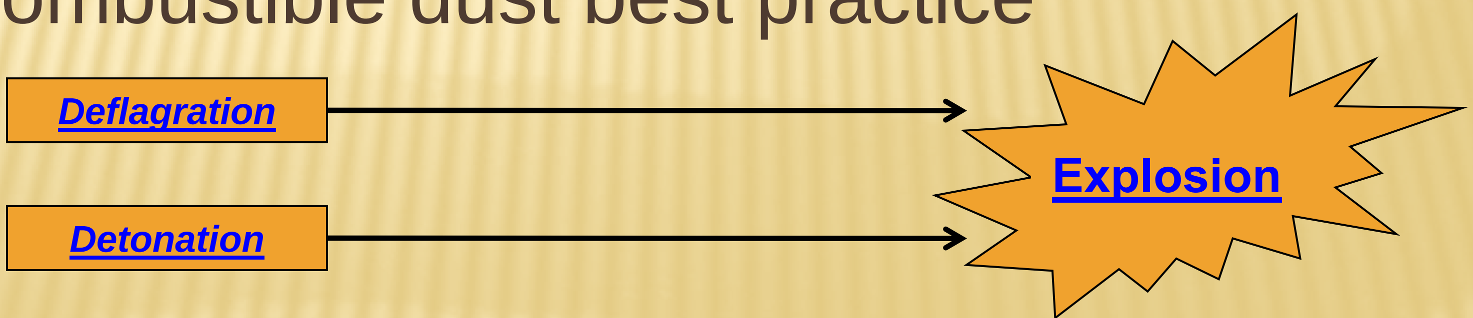


OUTLINE

- Response to the Combustible Dust NEP
- Weyerhaeuser hazard mitigation strategies and best practices
  - Administrative controls
  - Engineering controls
- Lumber experience with OSHA combustible dust inspections

RESPONSE TO THE COMBUSTIBLE DUST NEP

- Task team including corporate safety, industrial hygiene and property insurance/fire protection manager
- Does the NEP apply to our operations?
  - Cellulose Fibers (Kimberly-Clark)
  - Wood Products (Deltic Lumber)
- Combustible dust intranet site
- iLevel combustible dust best practice



WEYERHAEUSER HAZARD MITIGATION STRATEGIES AND BEST PRACTICES

- Facility dust hazard assessment
- Hazard communication, training
- Written combustible dust control program
- Housekeeping, physical conditions inspections
- Equipment inspection and maintenance
- Third-party property/fire insurance inspections and follow up
- Hot work permit program, smoking control and emergency preparedness

FACILITY DUST HAZARD ASSESSMENT

Facilities should carefully identify the following in order to assess their potential for dust fires/explosions:

- Materials that can be combustible when finely divided
- Processes which use, consume, or produce combustible dusts
- Open areas where combustible dusts may build up
- Hidden areas where combustible dusts may accumulate
- Means by which dust may be dispersed in the air
- Potential ignition sources and confinement areas

SURFACE DUST ACCUMULATION LIMITS

NFPA 654 Equation →

$$\text{Allowable thickness (in.)} = \frac{(1/32)(75)}{\text{bulk density } (\text{lb/ft}^3)}$$

- NEP does not consider differences in dust bulk density
  - Assumes heavy bulk density of 75 lb/ft^3 (typical of metals)
  - Uses 1/32-inch surface accumulation limit for all dusts
- Wood dust bulk density = 16–50 lb/ft^3
- 1/8th inch — NFPA wood dust accumulation limit (BD: 20 lb/ft^3)
- 1/16th inch — FM wood dust accumulation limit (BD: 36 lb/ft^3)
- Cellulose/pulp dust bulk density = 2.5–15.5 lb/ft^3
- 1/4th inch — FM pulp dust accumulation limit (BD: 10 lb/ft^3)

HAZARD COMMUNICATION

- Train employees on the explosion hazards of combustible dusts
  - On-line course developed by task team
  - Focused on employees' role in minimizing risk of CD fire/explosion
    - Hot work, smoking, housekeeping, cleaning methods, etc.
- Provide MSDS on combustible dust to employees
- Review a current emergency action plan with all employees annually

WRITTEN COMBUSTIBLE DUST CONTROL PROGRAM

- List of all CD sources and control equipment
- Housekeeping inspection schedules and procedures
- Preventive maintenance schedules and job plans
- Awareness training and hazcom documentation
- Safe work practices
- Property/casualty/fire insurance inspection findings and corrective actions

Insurance Evolved FM Global

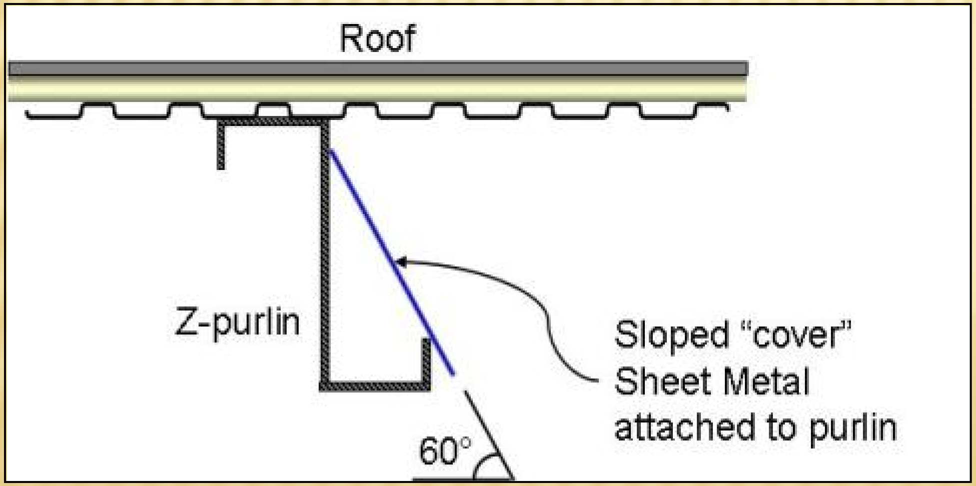
HOUSEKEEPING PRACTICES

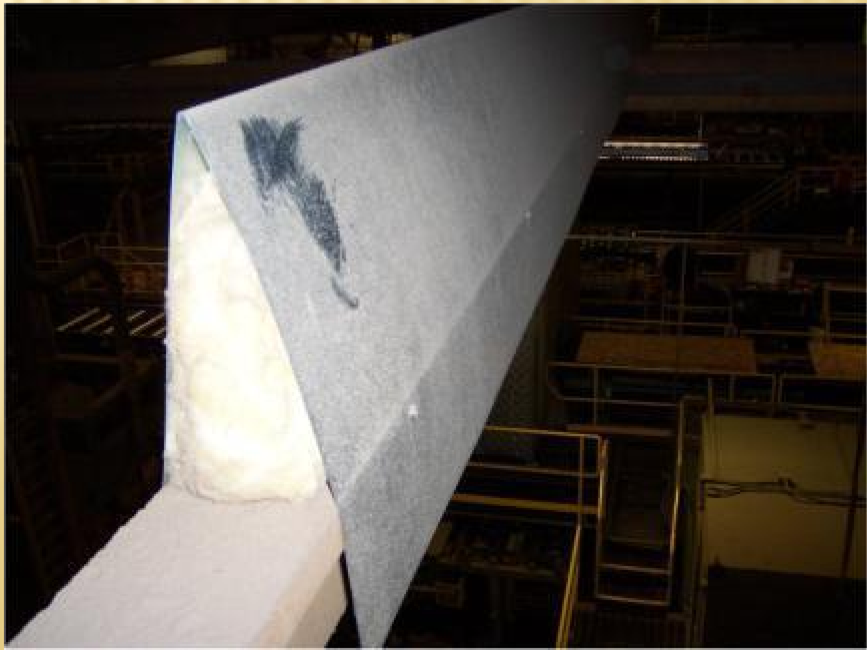
- Limit surface dust accumulation to 1/16-inch or less
- Pay particular attention to elevated horizontal surfaces such as machine tops, beams, joists, purlins, ducts, pipes and cable trays
  - Can make up 5-10% of total surface area of facility
- Don't neglect vertical surfaces (walls, etc.)
- Inspect hidden areas for dust residues regularly
- Be certain to inspect for dust on and within electrical equipment, such as on the surface of and inside motor control center (MCC) cabinets


CBP-9
LIGHTS & RECPT
OFFICE
A/C UNIT
Master
39 A
B
Master
40 A
B

SLOPED LEDGE COVERS

- Provide horizontal surfaces such as girders, beams, ledges, and equipment tops with a sloped cover having a smooth finish, to shed dust settling out of the air
- Sloped covers should be at an angle of at least 60 degrees from horizontal





HOUSEKEEPING CLEANING METHODS

- Use cleaning methods that do not generate dust clouds, especially in confined areas where ignition sources are present
  - Vacuum, water wash, use wet rags or soft bristle brooms
- Evaluate the hazards of using water near electrical equipment and MCC's before using wet methods
- Minimize use of high-pressure compressed air to clean (blow down) dust accumulations
- If dust is to be blown off overhead areas, de-energize and cover all electrical equipment in the area, and use a hot work permit system

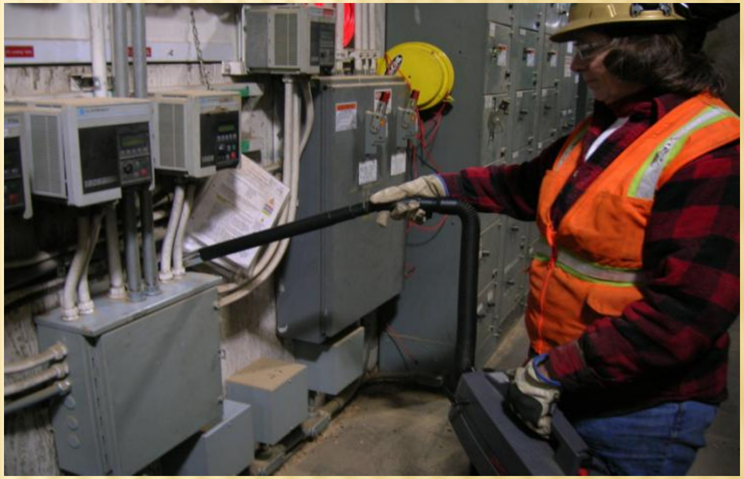
MANUAL CLEANING TOOLS – BLOW DOWN ALTERNATIVE

Bendable brush

Stationary brush

Feather Duster

http://www.ungerglobal.com/professional/products/highaccess/



EQUIPMENT INSPECTION & MAINTENANCE

- Ensure process dust-control/ventilation systems are regularly inspected and properly maintained
  - Source ventilation hoods, blowpipes, ducting, cyclones and bag houses
- Dust escaping from these systems indicates improper design, insufficient capacity, blockage and/or inadequate maintenance
- <u>Associated fire, spark, and explosion suppression systems – when operating properly – can save a facility from a catastrophic fire and/or explosion</u>
- Place all these systems on regular preventive maintenance (PM) inspection schedules

OSHA CD INSPECTIONS — WY EXPERIENCE

- Several CD-focused OSHA inspections in the past 2 years in Lumber operations
- Inspection activity higher in Northwest U.S. vs. South
- No particular emphasis on planer mills vs. sawmills
- Common findings
  - Dust samples collected, typically from elevated horizontal surfaces where dust is fine and dry
  - Explosion tests completed (K_{st})

OSHA CD INSPECTIONS — WY EXPERIENCE

- Common findings (continued)
  - Dusts are confirmed as “combustible”
  - Citations typically against housekeeping standard, general duty clause, NFPA 654, NFPA 664
    - Accumulations >1/16-inch over 5% surface area
  - Non-serious to serious in nature with penalties relatively low
  - Willingness to lower penalty amounts with quick resolution of violations

RESOURCES

- OSHA Combustible Dust website
- FM Data Sheet 7-76 – Prevention and Mitigation of Combustible Dust Explosions and Fire
- NFPA 654 – Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids
- NFPA 664 – Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities
- NFPA 499 – Classification of Combustible Dust
- NFPA 68 – Deflagration Venting Systems
- NFPA 69 – Explosion Prevention Systems
- NFPA 91 – Exhaust Systems

Comments, questions?

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THE END

THANK YOU !!!