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Safer Operation of Direct Heated

Belt Dryers

Final Report

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The belt dryer working group (BDWG) was composed of 25 members with representatives from **Wood Pellet Association of Canada** (WPAC), **BC Forest Safety Council** (BSFSC), **dryer manufacturers** (Stela and Prodesa), **pellet producers**, **safety equipment suppliers**, **consultants**, **academia**, and **technology providers.**

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These are the learnings of the working groups as it relates to specific but common dryers in the facilities they are installed.

This report was designed to be a helpful document for those either purchasing new dryers, or with existing dryers, as a way of **increasing safety and reducing the possibility of safety incidents**.

It goes through common safety issues and hazards related specifically to **direct heated dryers**, but a lot of the information can be applied to most dryers in the wood products industry.

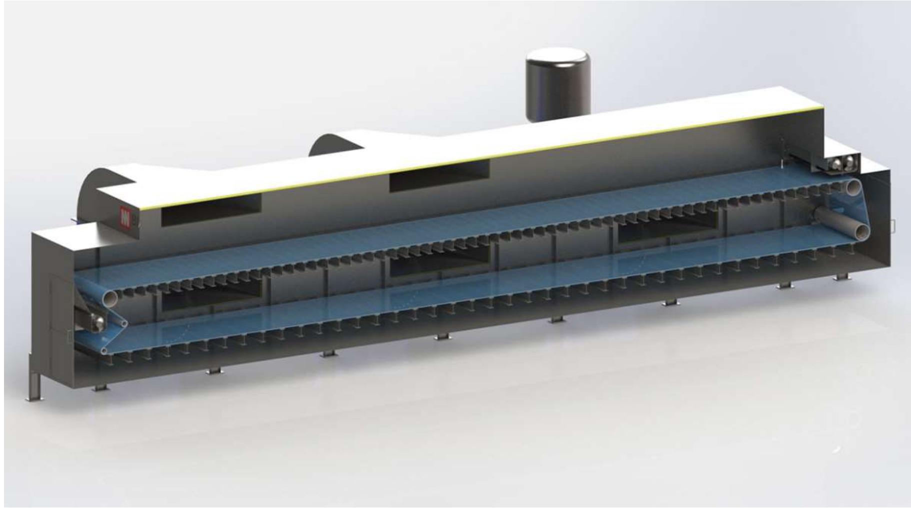
While comprehensive and helpful, this report and guidance contained within does not negate the need to independently evaluate the hazards and protection strategies in your facility.

Background

Most Canadian wood pellet plants use rotary drum dryers for moisture removal. However, some newer pellet plants have begun using direct heated belt dryers. Belt dryers generally provide:

- more flexibility in feedstock type, and
- have lower operating temperature

Thus result in lower emissions of volatile organic compounds.



There have been **several safety incidents** over the past few years in direct fire dryers. WPAC held a symposium on Belt Dryer in November 2020 and this Belt Dryer Working Group (BDWG) was formed after the symposium to **review the current practices and discuss controls and procedures for safer operations** of direct heated belt dryers. The working group also reviewed the positive aspects in safety, operations, and efficiency of indirect heated systems.

This slide shows a simplified explanation of

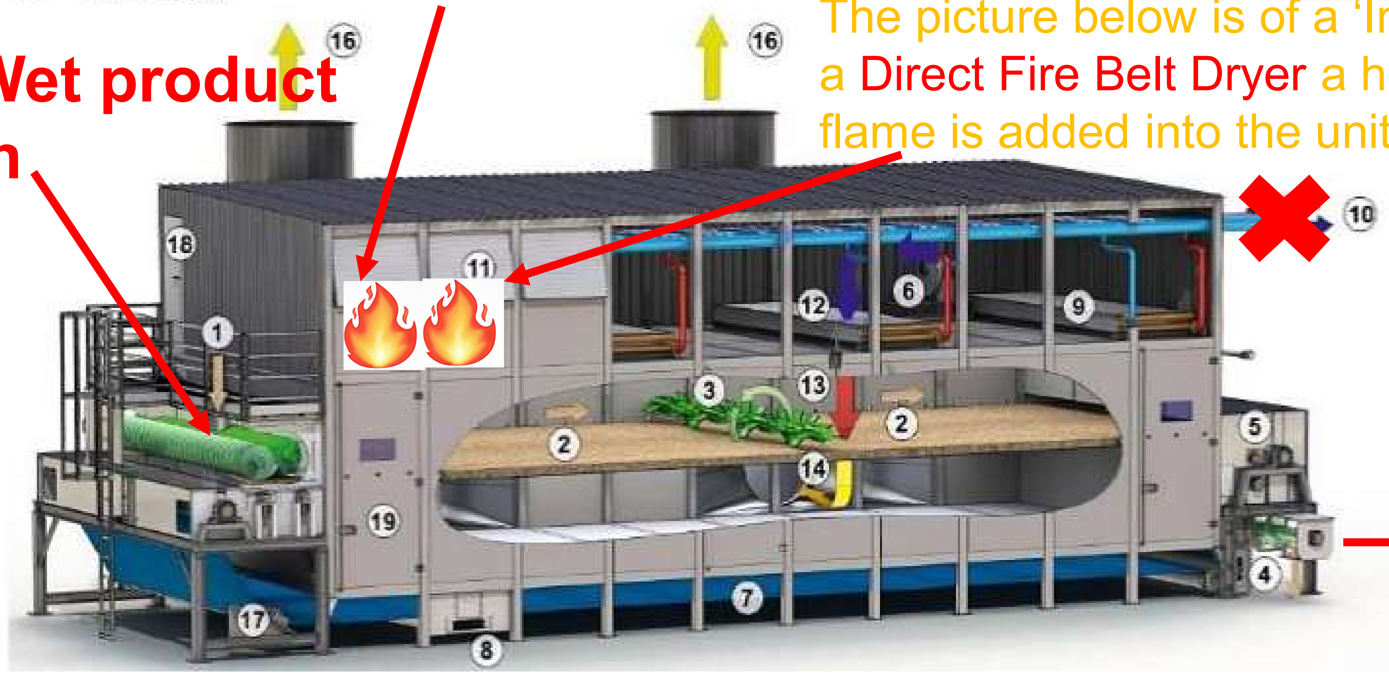
The basics of a Bed Dryer System

1 = feeding station
2 = product layer
3 = turning device
4 = discharge screw
5 = belt cleaning system (dry)
6 = fan for belt cleaning system
7 = web belt
8 = belt cleaning system (wet)
~~9 = heat exchanger~~
10 = heat supply (located inside for direct fire)

11 = fresh air intake
12 = fresh air
13 = heated air
14 = exhaust air
15 = exhaust air fan
16 = exit air
17 = belt alignment
18 = access housing for heat generation
19 = door for inspection

The picture below is of a 'Indirect Belt Dryer', in a Direct Fire Belt Dryer a heater with open flame is added into the unit.

Wet product in



Dry product out

One of the main recommendations by BDWG was:

The **removal of infeed contaminants** and the urge to ensure clean feedstock enters dryers.

Belt dryer manufacturers assumption is that the infeed fibre arrives at the belt dryer **free of contaminants** (planer shavings & dried residuals typically are free of contaminants) and thus the risk assessments and **design of the internal safety controls are based on this assumption from the OEM**. This is no longer the case.

As pellet plants diversify their infeed fibre to wider sources besides local sawmills and more external feedstock such as **bush grind** and **hog fibre** are added to the infeed mix, the **amount of contaminants increases**. Some pellet plants' infeed systems are not designed to process the full range of infeed types and remove contaminants completely from the infeed.

Sawdust

A sawmill residue that is produced from sawing, milling, planing and routing processes. It is composed of small chippings of wood.

In general, sawdust is clean and contains mostly white wood. It may contain some bark and small pieces of chips.

Some specific characteristics:

- Calorific value is between 17.9 - 19.4 (MJ/kg)
- Moisture content is between 44 – 54 (% wb)
- Ash content is between 0.2 – 2.5 (% db)
- Bulk density is between 195 - 254 (kg/m^3)

Shavings

A sawmill residue that is produced from planning wood. It usually comes after the kiln-drying process. The very thin pieces are dry and a by-product of planers.

Some specific characteristics:

- Calorific value is between 18.2 – 19.2 (MJ/kg)
- Moisture content is between 8 – 12 (% wb)
- Ash content is between 0.3 – 0.8 (% db)
- Bulk density is between 41 - 117 (kg/m^3)

Hog grind

A sawmill residue that is produced from debarking and scalping oversized materials from sawmill in-feed. It has a high content of bark and soil minerals. More contaminated hog, stored for a long period, is named "legacy hog grind."

Some specific characteristics:

- Calorific value is between 18.8 – 20.2 (MJ/kg)
- Moisture content is between 32 – 63 (% wb)
- Ash content is between 0.4 – 4.7 (% db)
- Bulk density is between 198 - 366 (kg/m^3)

Bush grind

A forest residue that is chipped in the logging area. It has high fraction of oversize materials, such as branches, bark pieces and chips.
When the forest was burned in a wildfire, the resulting forest residue is named "fire kill bush grind".
Some specific characteristics:

- Calorific value is between 18.9 – 19.0 (MJ/kg)
- Moisture content is between 21 – 45 (% wb)
- Ash content is between 0.2 – 3.0 (% db)
- Bulk density is between 137 - 276 (kg/m^3)

Wood chips

Produced from whole log or lumber chippers.
If the log is kiln-dried, it is named “kiln-dried chips.”
If it is micro-ground, the resulting chip is called “micro grind.”
Some specific characteristics:

- Calorific value is between 18.6 – 19.6 (MJ/kg)
- Moisture content is between 12 – 39 (% wb)
- Ash content is between 0.4 – 0.5 (% db)
- Bulk density is between 178 - 303 (kg/m^3)

Mix pile, green infeed, or infeed mix

A mixture of coarsely ground materials before entering the dryer. This in-feed mixture consists of sawdust, shavings, chips, hog and forest residues.
Some specific characteristics:

- Calorific value is between 18.3 – 19.3 (MJ/kg)
- Moisture content is between 33 – 45 (% wb)
- Ash content is between 0.3 – 1.5 C (% db)
- Bulk density is between 197 - 377 (kg/m^3)

Contaminants

A variety of foreign objects, which are mixed with the in-feed materials. The examples are rocks, lighters, batteries, aluminum foils, sandpaper, rifle brass, concrete, asphalt, dirt, etc.

Infeed Composition

Samples were collected and analysed from four plants. The table below lists the composition of the six most common types of infeed materials from those plants in BC. It shows an indication of the significant shift from clean dry infeed material to alternative infeed stock with higher potential amounts of contaminants.
In this the share of feedstock from sawdust and shavings is low as 12%.
Hog was as high as 58%

Highest Combine For 75%

Lowest 0%

Feedstock Type	Plant 1	Plant 2	Plant 3	Feedstock Type	Plant 4
Shavings	29.7%	22.8%	35.1%	Shavings Sawdust	12.0 %
Sawdust	45.6%	18.6%	20.2%		
Hog	3.3%	0.0%	9.4%	Hog	58 %
Grind – Bush, Yard, Mix	11.0%	2.4%	33.5%	Grind – Bush, Yard, Mix	0.01 %
Logs – Chipped, Ground	0.0%	36.5%	0.0%	Chips Other	30 %
Other	9.0%	19.7%	1.8%		

Typically upon its arrival biomass is separated into piles in open and closed storage depending upon the available facilities.

It should be assumed in most cases that some of the biomass feedstock arriving at the plant contains contamination that needs to be separated from infeed fibre.

These contaminants **can and will cause sparks** inside the drying unit unless they are separated and removed from the infeed materials. (Sparks can and will cause fires and explosions)

Both biomass **and air flow** should be free from sources that may introduce spark into the dryer.

Equipment and Controls

The standard equipment used to eliminate contaminants before entering the dryers includes:

- **Scalpers/Grizzly Rolls/Disk Screens**: this equipment removes large, oversized material which can include rocks, metal, and other foreign items. These types of devices are common in forest product manufacturing. The equipment is relatively easy to maintain. Note: This equipment allows **smaller contaminants to remain in the infeed flow**.
- **Density Separators**: a density separator **removes higher density material** from the infeed. Heavy contaminants such as **rocks, metal and man-made items fall out of the flow** of the infeed fibre in the separator. Note: **Smaller lighter contaminants can still make it into the infeed fibre stream** based on the set-up and feed speed of the density separators. Density separators either work based on screen vibration or by using an air flow or a combination of the two.

Equipment and Controls

- **Rock Drops/Vibration Screens**: drops and vibratory screens remove contaminants and larger items as they pass over rock drops or screens. **Screen opening sizes are managed to allow the optimum sized particles to stay** in the infeed stream while larger contaminants are separated out. Note: **Smaller rocks, pieces of metal and small man-made items can fall through the screens and stay in the infeed streams**.
- **Magnets:** magnets are deployed in various infeed locations to **remove ferrous metals**. Note: Non-ferrous metals remain in the infeed streams.

The existence of metals in the feed is one of the most critical contributors to creating sparks and fires in the dryer. The ferrous objects must be completely removed before the feed enters the dryer and come in contact with feed rollers.

Additional Infeed Equipment

- **Green Hammermills**: hammer mills are used to reduce the infeed fibre size to optimize dryer efficiencies. Magnets located on green hammermills help to remove ferrous metals.
- **Loader Driver Visual Screening of Fibre:** loader operators **visually inspect** incoming fibre loads for contaminants. The operators identify the suppliers who deliver contaminated feedstock to the plant and report this to the supervisor.
- **Small & Dry Particle Diversion**: Small and/or dry particles may by-pass in feed equipment and dryer. This bypass helps to minimize loading clean and over-dried material on the dryer. Thus increasing throughput and efficiency.

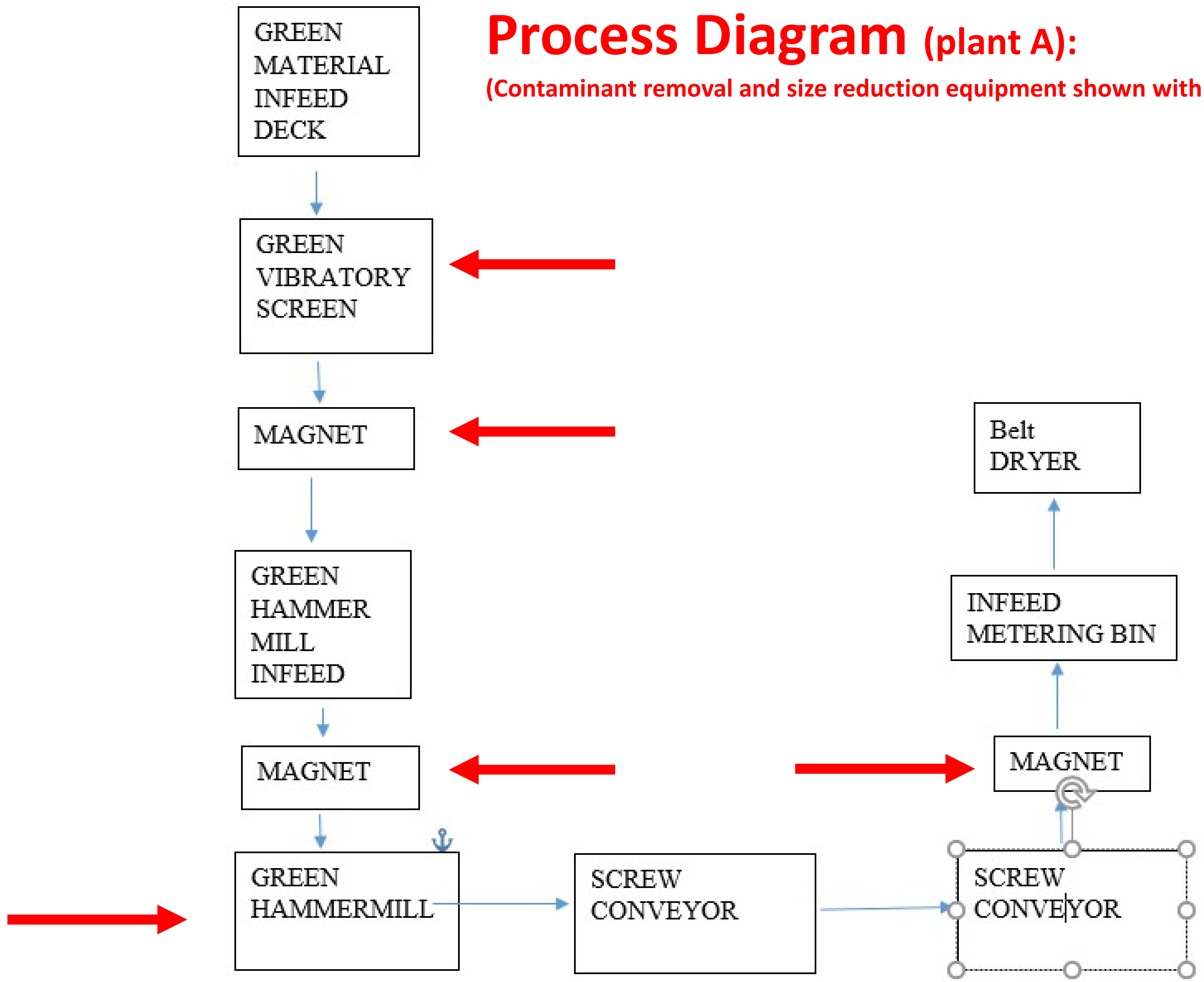
Additional Infeed Equipment

Controls used in other industries – possible upgrades?

- Equipment for Contaminant Identification and Removal: an on-line device is used in panel manufacturing prior to the press. This technology identifies contaminants such as rocks, metal and other high-density foreign materials. The real-time detection and elimination capabilities of such systems were discussed for potential consideration as an infeed control.
- Optical Chip Analyzer for Contaminant Identification and Removal: Optical chip analyzer was discussed to determine if this type of technology can be used to identify and remove contaminants from belt dryer infeed systems.

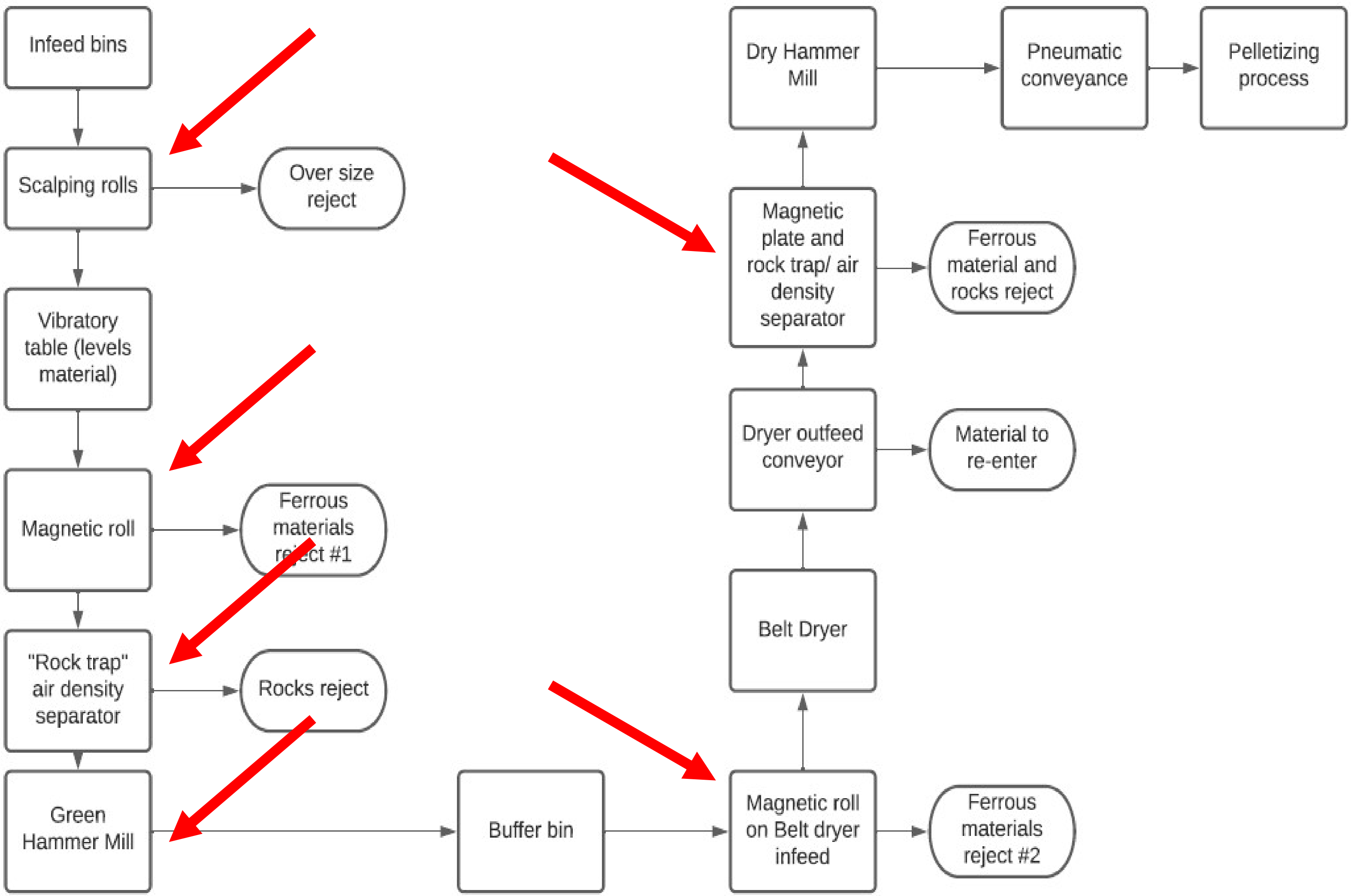
Process Diagram (plant A):

(Contaminant removal and size reduction equipment shown with red arrows)



Process Diagram (plant B): :

(Contaminant removal and size reduction equipment shown with red arrows)



This table summarizes:

1) Range of moisture contents,
2) Ash content
3) Bulk density
4) Range of on-set smoking temperature.

Highest Moisture Content

Lowest Moisture Content

Process line	Type	m.c. (% wb)[1]	Ash (% db)[2]	Bulk density (kg/m^3)	Smoking temperature (°C)[3]
Woody biomass feedstock at plant gate	Sawdust	44-54	0.2-2.5	195-254	155-171
	Shavings	9-12	0.3-0.8	41-117	154-170
	Chips	12-39	0.4-0.5	178-303	155-168
	Hog grind	32-63	0.4-4.7	198-366	154-170
	Bush grind	21-45	0.2-3.0	137-276	165-177
Infeed to the dryer	Feedstock mix	33-45	0.3-1.5	197-377	158-172

Smoking temperature is when a particle of feedstock exposed to hot air or in direct contact with a hot surface starts making smoke prior to burning. The lowest smoking temperature was 154°C. Exceeding temperature at any point within the dryer may be a sign that fire may be imminent.

Bulk density varied from a low of 41 kg/m^3 (4 lb/ft^3) to 366 kg/m^3 (22 lb/ft^3). This wide range of bulk density shows the challenge that a loader operator would have in preparing uniform loads for the dryer. A low bulk density feedstock occupies more volume.

Particle Size

This table lists the mass fraction of particles of the infeed material that passed through a **0.5 mm screen**. This is important because according to dryer manufacturers **particles less than 0.5 mm are not desired as these particles are easily entrained in the drying air** (which creates the right environment for an **explosion**) as well as tend to **fall through the dryer belt perforations**.

This shows that a large fraction of hog grind and shavings may be smaller than 0.5 mm. According to our measured data the particles less than 0.5 mm in size constitute 4.1% to 13.3% of the mass of the infeed to the dryer.

Process line	Type	Mass fraction of particles smaller than 0.5 mm (%)
Woody biomass feedstock at plant gate	Sawdust	10.4 - 15.2
	Shavings	5.7 - 23.7
	Chips	0.7 - 3.8
	Hog grind	6.0 - 13.3
	Bush grind	3.4 - 4.7
Infeed to the dryer	Feedstock mix	4.1 - 13.2

Feedstock Takeaways

Uneven loads, high moisture content disparities, and heating product above smoking points can all cause fires and worse in the dryer, steps should be taken to minimize / eliminate the possibility of each of these hazards.

Additionally, having a good understanding of **infeed quality, contamination levels and fibre composition** helps the operation with their **production rates, pellet quality and general safety.**

The BDWG determined that increased knowledge and management of infeed quality can play a **significant role in the overall success of the operation including safety.** Developing and implementing effective operational controls such as a formal infeed fibre quality control program as well as well maintained equipment controls can minimize infeed fibre contaminants.

Dryer: Standard Controls (Typically supplied by the manufacturer)

These include

- **Preventing hotspots by optimal air turbulence**
- **Spark elimination technology with grating**
- **Increased length of burner outfeed channel to achieve optimal air mixture and reduce spark energy**
- **Internal Deluge systems**
- **Belt Alignment control**
- **Monitoring of the distribution screw (amperage)**

Optional Controls

- **Spark detection and suppression in burner channel**. This control is included as a standard control in some direct heated belt dryers.

Spark detection with suppression/extinguishment **between burner and dryer belt** ideal

- **Below belt internal deluge**

Deluge systems (dry pipe) installed below the belt use rises in temperature to detect ignition events and trigger a deluge to extinguish the event. This controls reacts to fire events that have already started and does not prevent the event from happening. This system can only minimize the damages of a fire incident.

- **Infra-Red (IR) thermal detection above and below belts**

IR cameras detect hot spots or smolders and activate water deluge or fast-acting water mist above and below belts, it may also involve operator manual activation of water deluge.

Optional Controls

- **Controlling contaminants from entering the burner (air intake not feed)**

Control the intake of air-borne particles from entering the burner with a screen. This control helps to minimize burner sparks, but it does not eliminate the risk if housekeeping activities are not maintained and the screens are not regularly cleaned out.

The **elevated risk of fire events in direct heated belt dryers due to sparks generated in the burners can not be adequately addressed with the standard or optional controls supplied by the manufacturers**.

Operations should continue to explore further controls such as spark detection and suppression in the burner channels, but please note after all control measures for direct heated belt dryers, **a residual fire risk will remain**.

Fire risk can be lowered effectively by using the indirect heated dryer.

Risk Management and Control

Safety systems including prevention and mitigation

The working group discussed and reviewed safety systems associated with direct heated belt dryers, primarily using **Bow Tie analysis** that assessed combustible wood dust hazards and controls that are present in a direct heated belt dryer. The Bow Tie analysis allowed the group to systematically identify barriers and controls and how these safety systems can degrade or fail. In addition, the measures that must be taken to ensure that safety controls will perform as intended when needed were explored.

The analysis was performed over 6 sessions (1.5 hours per session) and involved a diverse group of subject matter experts (SMEs), including representatives from numerous explosion protection equipment suppliers, wood pellet facilities, as well as health and safety associations (HSA). It should be noted here that the dryer manufacturers also conduct their risk analysis and management according to EU-regulations and it is based on ISO standards (Machine Directive 2006/42/EG; Risk management system acc. ISO12100:2010 and risk assessment acc. Iso 13849-1:2015).

Safety Systems

Numerous existing and recommended safety systems were identified, including the following critical safety systems:

- **deflagration suppression/isolation (e.g., chemical suppression/ isolation)**,
- **Explosion venting, and passive isolation**
- **effective combustible dust housekeeping programs to remove dust in surrounding areas, as well as fixing leaks/sources of dust.**

Degradation factor controls that were identified include:

- **prescribed preventative maintenance and inspections of safety systems**,
- identifying as many opportunities to **automate** as possible, and
- considering the use of **micro-mist deluge systems that could extinguish fires quickly with very little residual water**.

Safety Controls, Procedures, Maintenance, and Cleaning Practices

- **Tracking amperage** of ID fans where a drop in amps **indicates a hole in the belt.** A drop of amperage may require an operator to check the belt for holes or any other damage.
- Visual **cameras** located **above or below the belt** allow operators to monitor belt levels and ignition events.
- **Auto shutdown** before and after dryer during events in the dryer.
- **Temperature monitoring in stacks** to trigger a water deluge in the stack or under the belt.

Procedures & Maintenance

- When the dryer goes down for **scheduled maintenance for two or more hours**, **the dryer must be completely empty of infeed materials**,
- If the **belt stops for any reason, the burners should be automatically shut off**,
- **Any “empty” running of the dryer must be prevented – the dryer should only be heated with completely material filled belt surface**
- **Exterior fire risks, such as smolders coming into the dryer, should be mitigated before the dryer,**
- **Direct heated dryers should be cleaned more frequently and have shorter maintenance cycles.** Indirect heated dryers will have significantly longer cycles than direct heated dryers.

The maintenance steps and topics reviewed by the group include:

- **Belt/dryer/fans cleaning** should be performed **every two to three weeks– not more than 500h (includes pressure washing or the use of fire hose),**
- **Visual inspection** of burner chambers and heat shields **should be done daily** during the commissioning and first weeks of operation, and weekly during the first months. After that, the frequency of the cleaning works can be decided. It is recommended that burner chambers and **heat shields be cleaned** of fibre and particulates **every three months or more often – not longer than 2000h.**
- **Stack cleaning should be performed every six months– not longer than 4000 hours**
- When cleaning an **emphasis should be made to remove all accumulations of combustible dust in all areas**
- Operator education, training, and competency should be **regularly reviewed.**
- Assessing these controls on an **annual basis** and as part of a fire event investigation will help improve the overall safety of the operation.

It is highly recommended that all producers review their current procedures and update their procedures looking for any missing step on infeed fibre quality and dryer operation using the report and bow ties developed.

Assessing the current controls, housekeeping, and maintenance schedule for effectiveness at eliminating or minimizing ignition sources or sparks will help to reduce or eliminate fire events.

In spite of all indicated measures mentioned, a residual risk in the operation of direct heated dryers remains compared to indirect heated systems working under similar conditions and material composition.

This report these findings and the bowtie analysis is available on the WPAC website.

Thank You!