Prevention of Fires and Dust Explosions when handling Biomass

Anders Bergström, Firefly AB
Mixing biomass into coal is a cost efficient way of reducing carbon dioxide emissions for coal fired power plants.

However, there are some technical issues related to it.

The increased risk for **Fires** and **Dust Explosions** is one of them.
Risks when handling Biomass

Dong Energy, DK (2012)
“One hot conveyor roller drops down and ignites accumulated wood dust, underneath the conveyor belt” - Dong Energy

Tilbury Power Station, UK (2012)
“The fire developed from a localized smoldering incident in one of the wood pellet bunkers that had almost certainly been initiated by hot dust and embers falling into the bunker...”

The fire started in a conveyor carrying wood chips “there was fire in both of the plant's silos and on three different conveyor belts spreading across hundreds of feet...”
Why higher Risks with Biomass compared to Coal?

- Biomass (wood or agriculture dust) has lower ignition temperature and is more “explosive” than coal.
- The self-heating properties of biomass increases the risk for spontaneous combustion.
- Increased dust emissions when handling biomass.

### TABLE 5-0A: Explosion Characteristics of Various Dusts

(Compiled from the following reports of the U.S. Department of Interior, Bureau of Mines: RI 5753, The Explosibility of Agricultural Dusts; RI 6516, Explosibility of Metal Powders; RI 6971, Explosibility of Dusts Used in the Plastics Industry; RI 6597, Explosibility of Carbonaceous Dusts; RI 7132, Dust Explosibility of Chemicals, Drugs, Dyes and Pesticides; and RI 7208, Explosibility of Miscellaneous Dusts.)

| Type of Dust          | Explosibility Index | Ignition Sensitivity | Explosion Severity | Maximum Explosion Pressure psig | Max Rate of Pressure Rise psi/sec | Ignition Temperature | Min Cloud Ignition Energy joules | Min Explosion Conc oz/cu ft | Limiting Oxygen Percentage $|$  |
|-----------------------|---------------------|----------------------|--------------------|-------------------------------|---------------------------------|----------------------|----------------------------------|-------------------------------|------------------------------|
| Agricultural Dusts    |                     |                      |                    |                               |                                 |                      |                                  |                               |                              |
| Cellulose             | 2.8                 | 1.0                  | 2.8                | 130                           | 4,500                           | 460                  | 270                             | 0.080                         | 0.055                        | C13                           |
| Cellulose, alpha      | >10                 | 2.7                  | 4.0                | 117                           | 8,000                           | 410                  | 300                             | 0.040                         | 0.045                        | —                             |
| Cocoa, natural 19% fat| 0.6                 | 0.5                  | 1.1                | 68                            | 1,200                           | 510                  | 240                             | 0.10                          | 0.075                        | —                             |
| Coffee, fully roasted | <0.1                | 0.2                  | 0.1                | 39                            | 150                            | 720                  | 270                             | 0.16                          | 0.085                        | C17                           |
| Corn                  | 6.9                 | 2.3                  | 3.0                | 113                           | 6,000                           | 400                  | 250                             | 0.04                          | 0.055                        | —                             |
| Cornstarch commercial product | 9.5 | 2.8                  | 3.4                | 106                           | 7,500                           | 400                  | 100                             | 0.04                          | 0.045                        | —                             |
| Cork dust             | >10                 | 3.6                  | 3.7                | 95                            | 7,500                           | 460                  | 210                             | 0.035                         | 0.035                        | —                             |
| Cotton linter, raw    | <0.1                | <0.1                 | 0.1                | 73                            | 400                            | 520                  | 1.92                            | 0.50                          | —                             | C21                           |
| Cube root, South American | 6.5         | 2.7                  | 2.4                | 69                            | 2,100                           | 470                  | 230                             | 0.04                          | 0.04                         | —                             |
| Grain dust, winter wheat, corn, oats | 9.2 | 2.8                  | 3.3                | 131                           | 7,000                           | 450                  | 230                             | 0.03                          | 0.05                         | —                             |
| Lycopodium            | 16.4                | 4.2                  | 3.9                | 75                            | 3,100                           | 480                  | 310                             | 0.04                          | 0.08                         | C13                           |
| Milk, skimmed         | 1.4                 | 1.6                  | 0.9                | 95                            | 2,300                           | 490                  | 200                             | 0.05                          | 0.05                         | N15                           |
| Rice                  | 0.3                 | 0.5                  | 0.5                | 47                            | 700                            | 510                  | 450                             | 0.10                          | 0.085                        | —                             |
| Soy flour             | 0.7                 | 0.6                  | 1.1                | 94                            | 800                            | 550                  | 340                             | 0.10                          | 0.06                         | C15                           |
| Sugar, powdered       | 9.6                 | 4.0                  | 2.4                | 109                           | 5,000                           | 370                  | 400                             | 0.03                          | 0.045                        | —                             |
| Wheat flour           | 9.6                 | 4.0                  | 2.7                | 97                            | 2,800                           | 440                  | 440                             | 0.06                          | 0.06                         | —                             |
| Wheat starch, edible  | 17.7                | 5.2                  | 3.4                | 100                           | 6,500                           | 130                  | 260                             | 0.025                         | 0.045                        | C12                           |
| Wood flour, white pine | 9.9               | 3.1                  | 3.2                | 112                           | 5,500                           | 470                  | 260                             | 0.040                         | 0.035                        | —                             |
| Carbonaceous Dusts    |                     |                      |                    |                               |                                 |                      |                                  |                               |                              |                               |
| Charcoal, hardwood mixture | 1.3         | 1.4                  | 0.9                | 83                            | 1,300                           | 550                  | 180                             | 0.020                         | 0.140                        | —                             |
| Charcoal, activated, from lignite | 0.11 | 0.11                 | —                  | 41                            | <100                           | 670                  | 370                             | #                             | 2.000                        | —                             |
| Pitch, petroleum      | 4.0                 | 2.8                  | 1.4                | 82                            | 3,800                           | 630                  | 320                             | 0.025                         | 0.045                        | —                             |
| Carbon black, acetylated | 0.1           | 0.1                  | —                  | 90                            | 0.11                           | 900                  | 180                             | 0.030                         | 0.05                         | —                             |
| Coal, Kentucky (Bituminous) | 4.1       | 2.2                  | 1.6                | 101                           | 4,000                           | 610                  | 180                             | 0.030                         | 0.05                         | —                             |
| Coal, Pennsylvania, Pittsburg (Experimental Mine Coal) | 1.0 | 1.0                  | 1.0                | 90                            | 2,300                           | 610                  | 170                             | 0.060                         | 0.05                         | —                             |
Why is dust dangerous?

- Dust from a leaking process will be spread and accumulated on all horizontal surfaces.
- For example, a mechanical failure in the process will create friction heat that can easily ignite these dust layers.
- Dust deposits in the facility will lead to a quicker spreading of a fire.
- Airborne dust creates a large risk for rapid fires (flame fronts) or even dust explosions.
Understanding dust explosions

The more finely divided the material is – the easier it is to ignite and the more “explosive” it will become.

From Dust explosions in the process Industries by Rolf K Eckoff
Confinement

A quick combustion will lead to a quick increase in temperature.

A quick temperature increase will lead to a quick expansion of the air.

If this quick expansion of the air occurs inside an enclosed volume = dust explosion.
Video – Effects of a dust explosion in a wood panel plant
Primary and secondary dust explosions

➢ Primary explosions
  - Often initiated by “ignition sources” inside the process

➢ Secondary explosions
  - Initiated by a primary explosion
  - Can be disastrous!

Illustration from ’Silo Fires’ by Henry Persson, SP
Secondary explosion in raw material storage
Root-causes of Fires in the fuel handling process

Common causes of fires are:

- Smoldering biomass from the transport
- Mechanical failure in conveyors
- Self heating of the biomass in the storage silos
- Ignition sources generated by Mills / Crushers or other equipment
- Hot works
Main Risk Zones in the material handling process

- Chutes
- Conveyors
- Silos / Storage areas / Bunkers etc
- Elevators
- Mill rooms
- Filters for dust extraction
How to prevent Fires or Dust Explosions

- Minimize dust leakages and dust accumulations
- Spark detection systems
- Protection of conveyors
- Protection of Silos
- Quick Suppression systems for high-risk areas
- Solid routines for housekeeping and maintenance of equipment
- Follow the code of practice for hot works
Minimize dust leakages and dust accumulations

- Follow best practices for dust emission & control
- Dust containment systems / enclosures
- Optimized transfer chute design
- Dust extraction systems
- Design floor, wall and platforms to prevent dust accumulations
- Proper cleaning and house keeping procedures
  - Document your housekeeping schedule
Spark Detection System

Detection and extinguishing of **ignition sources** inside the process **before** fire or explosion occurs
Principle of Spark Detection

System in Chute

Detection zone

Water Extinguishing zone

~500mm

System in Extraction Duct to Filter

Detection zone

Water Extinguishing zone

~4-8m
Important parameters for Spark Detection Systems

What is the Minimum Ignition Temperature – MIT of the fuel?
- MIT - Dust Cloud
- MIT - Dust Layer

What is the Minimum Ignition Energy – MIE of the fuel?

Make sure that the detection system can detect down to the right temperature and energy

Hot particles can be dangerous even if they do “glow” or emit any light
Where to locate spark detection systems in the process?

- In transfer chutes
- Infeed to bunkers / silos
- Outfeed of bunkers / silos
- Filter units
- Elevators
- After mills / shredders etc (Unless the fuel is sent right into the boiler after the mill)
Additional Protection of Conveyors – With Water Mist

New solutions are coming up, combining Spark Detection in chutes with water mist above the conveyors.

Detection
- Flame detection above the conveyors
- Temperature sensing cable around rollers
- Signal from Spark detection in the chutes can also be used

Extinguishing
- Water mist along the conveyors

Important to make sure that the water mist system is fire-tested and approved by a certified test laboratory.
Silos

Fire in a silo could be a worst case scenario if not handled correctly

Once a fire has started, extinguishing is very complicated and imply great risks for the fire fighters

There are ways to minimize the risk for a fire to happen, but the risk cannot be eliminated completely

Research and experimental studies of fire extinguishment in silos have been performed by SP Swedish National Testing and Research Institute SP Report 2006:47 with detailed firefighting methods for silo fires

Silo Protection

➢ Detection and extinguishing of hot particles **before** entering the silo

➢ MGD – Multiple Gas Detector in the top of the silo
  - Detection of combustion gases inside the silo

➢ Temperature sensors / Monitoring cables inside the silo
  - Detection of overheated material

➢ Detection and extinguishing of hot particles at the **outlet** of the silo

➢ Explosion Venting and/or Explosion Suppression
  - To mitigate the effects of an explosion

➢ Prepare the silo with injection points in the bottom for Nitrogen extinguishing
Quick Suppression Systems - for High Risk Areas

High Risk Areas in the plant can be protected with Quick Suppression Systems

- Quick Detection and Suppression of flames
  - System is based on Flame detectors and Water Mist Suppression

- The aim is to detect and extinguish quick enough to avoid damages and downtime in the plant

- Can be used for spot-protection of most types of machines or high risk areas

- A new test protocol - DFL TM170307-1261 to certify Quick Suppression Systems is available since 2017
Principle of Quick Suppression Systems

Example of applications for Quick Suppression Systems in Power Stations

- Unloading Stations / Receiving stations
- Mill rooms
- Conveyors / Elevators
- Turbines
- Transformer Stations
- Etc
Video of a Quick Suppression System in action

Firefly Quick Suppression System protecting a Tissue Machine
Conclusion

✓ Do not neglect the fire risk when handling Biomass

✓ Good process design is the first step to minimize dust emissions and reduce the risk for fires and dust explosions

✓ Use applicable methods to prevent fires and dust explosions in combination with methods to fight fires

✓ Solid routines for housekeeping and maintenance of equipment

If you think Safety is Expensive – Try an Accident!
Anders Bergström
General Manager – Industrial Applications
Firefly AB

anders.bergstrom@firefly.se
+46-70-229 38 84