Coal Mill Fires and Explosions

IEEE East Coast

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Agenda

- Introduction
- Common Causes
- Spontaneous Ignition
- Indications of Fire in the Grinding Circuit
- Prevention (Lessons Learned)
- Protection
- Closing Remarks
- Appendix A – Definitions
- Appendix B – Determinants
- Appendix C – Resources

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Introduction

Famous Last Words

- “We should be okay exceeding the recommended limits by just a hair.”
- “It’s too much trouble to change the way we operate the mill when we switch fuels.”
- “Direct, semi-direct, indirect… what’s the difference?”
- “We want the mill inlet temperature to be really hot so we can dry the coal… right?”
- “I don’t know when we last analyzed our coal.”
- “We’ll get to those repairs as soon as we can.”

And my all-time favorite…

- “We’ve never had an issue before.”

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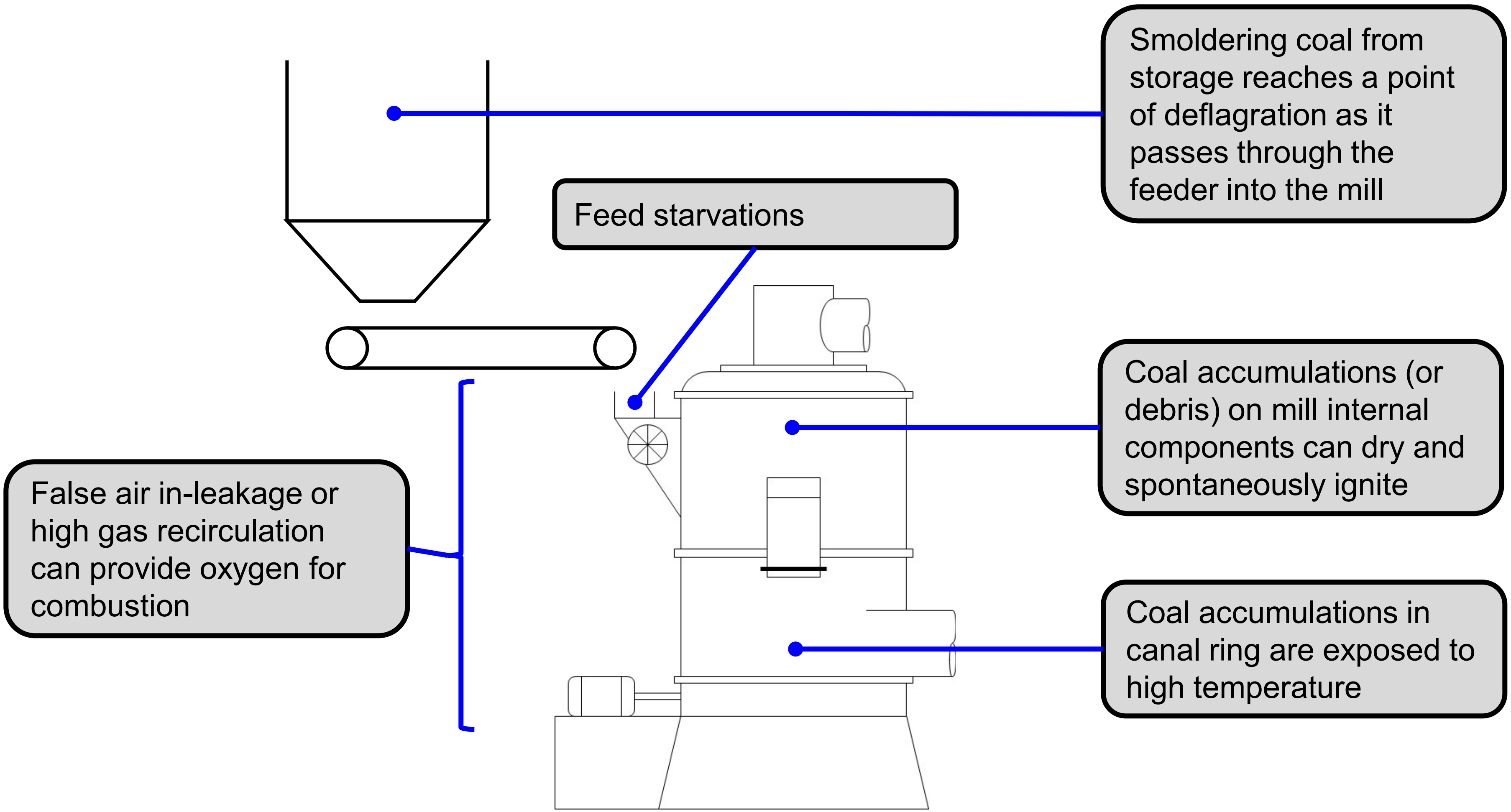
Common Causes



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Spontaneous Ignition

- Reactions that may generate heat:
  - Adsorption
    - Water vapor molecules adhere to pore surfaces in the fuel
  - Condensation
    - Water vapor condenses within the coal pores, usually as a result of multiple adsorption layers building up and filling the pores
  - Oxidation
    - Autoxidation – oxidation brought about by reactions with oxygen at normal temperatures, w/o the intervention of flame or electric spark
    - Primary mechanism for spontaneous ignition
    - Oxygen reacts with combustible elements on surface and in pores of fuel particles
    - Reaction is slow below 50 °C
    - Rate of reaction increases rapidly with increasing temperature
    - Carbon monoxide liberated at ~ 135 °C
    - Fire occurs at ~ 230 °C

Spontaneous Ignition (cont'd)

- Factors contributing to spontaneous ignition:
  - High fuel fineness
  - Over-drying of pulverized fuel
  - Oxidizing atmosphere
  - High temperature
  - Freshly pulverized fuel
  - Poor heat dissipation
  - Pyrites

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Common Indications of Fire in Circuit

- High or rapidly increasing mill outlet temperature without other cause
- Mill housing and/or piping glowing red or peeling paint
- Pungent sulfurous odor of smoldering coal
- Discharge of sparks or burning embers from the pyrite trap / rejects system

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Preventive Measures

- Prevention involves eliminating or controlling one or more of the combustion triangle / explosion pentagon components via:
  - Engineering design
    - Equipment selection and arrangement
    - Protection devices
  - Operating practices
  - Maintenance
  - Housekeeping

Have you learned your lesson?

- "It's okay to learn from mistakes, …

  …but it's a lot less painful if they're made by others."

- Most safety procedures, policies, protocols, etc., regrettably come about due to an unfortunate incident harming or killing someone
- The following is a compilation of "lessons learned the hard way" by others in the hope that history will not repeat itself

Best Practices

- Avoid smoldering stockpiles
  - Store different coal types in dedicated piles
  - Avoid contamination (rags, wood, etc.)
  - If feasible, only store coal for a period appropriate for the volatile matter content of the fuel
    - VM < 15 % (adb): < 4 mo
    - VM ≥ 36 % (adb): < 1 mo
  - For longer-term storage…
    - Two schools of thought…
      - For coals having a large proportion of fines, build pile in compacted layers (~ 1 ft each), i.e. try to prevent oxygen from reaching coal
      - For coals having predominantly coarse particles, build pile in horizontal, non-compacted layers with maximum pile height dependent on volatile matter content, i.e. try to allow the heat to dissipate to the atmosphere
  - Reclaim along vertical face to minimize exposed surface

Best Practices (cont'd)

- Minimize stored pulverized coal when long shutdowns are foreseen
- Minimize raw feed interruptions
  - Acceptance criteria for moisture
  - Covered storage
  - Heated air lock
  - Self-cleaning rotary feeder
- Minimize mill starts and stops
  - Especially in rapid succession
  - Avoid "hot starts"

Best Practices (cont’d)

- Analyze fuel properties
  - Routinely:
    - Moisture – raw fuel
    - Moisture – pulverized fuel
    - Fineness
    - Volatile matter
  - New fuel:
    - Volatile matter (adb)
    - Inherent moisture / Dewatering curve
    - Limiting oxygen concentration (LOC)
    - Pyritic sulfur

Best Practices (cont'd)

- Operate mill according to fuel properties
  - Stay below LOC
    - Minimize false air in-leakage
    - Utilize inlet duct water spray to reduce preheater off gases temperature, thereby reducing mill gas recirculation
    - Do not operate HGG by itself (i.e. no PH gases) if high VM coal
      - HGG combustion gases typically 18-19 % O_2
  - Maximum inlet and outlet temperatures
    - Don't over-dry pulverized fuel
  - Appropriate fineness targets

Best Practices (cont'd)

- Maintain recommended gas flow and velocities through mill and conveying lines
- Do not operate mill < 25 % of rated capacity
  - Possible flame instability due to poor air-to-fuel control
  - Likely emptying of mill if feed is interrupted
  - Both can result in momentary loss of flame, followed by restoration and delayed reignition of an accumulation

Best Practices (cont'd)

- Ensure interlocks are properly programmed and functional
  - DO NOT bypass safety interlocks!
  - Adequate purge time (fan, downstream conveying eqpt, …)
- Maintain monitoring equipment
  - O_2
  - CO
  - Temperature
    - Mill
    - Bins
    - Cyclone
    - Filter
    - Ducting
  - Filter Δp

Best Practices (cont'd)

- Maintain inertization equipment
  - Monitor CO_2 (N_2) tank level
    - Refill when reaches minimum acceptable level (typ. 50-60 %)
  - Vaporizer
  - Control cabinet
  - Temperature switches
  - Piping
  - Nozzles
  - Conduct annual inspection
- Maintain deflagration venting, isolation, and suppression devices
  - Explosion vents and rupture discs
  - Isolation dampers
  - Chemical suppressant system

Best Practices (cont'd)

- Maintain metal detection and extraction equipment
- Proper grounding
  - Lightning rods
  - Grounding straps
  - Filter media grounding
- Ensure pyrite trap / rejects system is operating properly
  - Make sure air lock is functional
  - Clear / empty routinely
  - Ensure no blockage
- Maintain scrapers
  - Clearance
  - Integrity

Best Practices (cont'd)

- Train operators, process assistants, and maintenance personnel
  - Coal firing hazards
  - Best practices
  - Emergency actions
- Conduct drills with local fire department
  - Familiarity with plant layout
    - Roads and buildings
    - Hydrant locations
  - Plant personnel to act as guides

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Protection

- Should an explosion occur, there are four approaches to protect personnel and equipment:
  - Venting
  - Containment
  - Isolation
  - Suppression
- Multiple (redundant) protection strategies are a best practice

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Venting

- Generally the most economical strategy
- Provides relief for an explosive force buildup inside a vessel
- Reduces damage and injury potential should an explosion occur
- Venting not permitted on mills
- NFPA 68 – *Standard on Explosion Protection by Deflagration Venting*

Source: Thorwesten Vent

Source: Fike

Containment

- Mill systems are designed to one of two standards:
  - Directed explosion (3 bar design) [50 psig]
    - Mills and vessels
    - Ducts not required to meet design standard
  - Contained explosion (10 bar design)
    - Solid fuel grinding circuits that are designed for containment need all elements capable of containing 10 bars of pressure
    - This is costly for indirect fired coal mills which are mostly designed for venting explosions

Isolation

- Mechanical, fast-acting valve system
- Stops “deflagration propagation”
  - … the spread of explosion from point of origin
- Pressure sensor-activated
- Used primarily in ductwork ≤ 24” diameter
- Often used as one of several redundant protection systems

Suppression

- Chemical agent injected under pressure into incipient explosion area
  - Inert gas (CO_2, N_2)
  - Sodium bicarbonate powder
- Stops “deflagration propagation”
  - … the spread of explosion from point of origin
- Pressure sensor-activated
- Used primarily in ductwork > 24” diameter

Source: Fike

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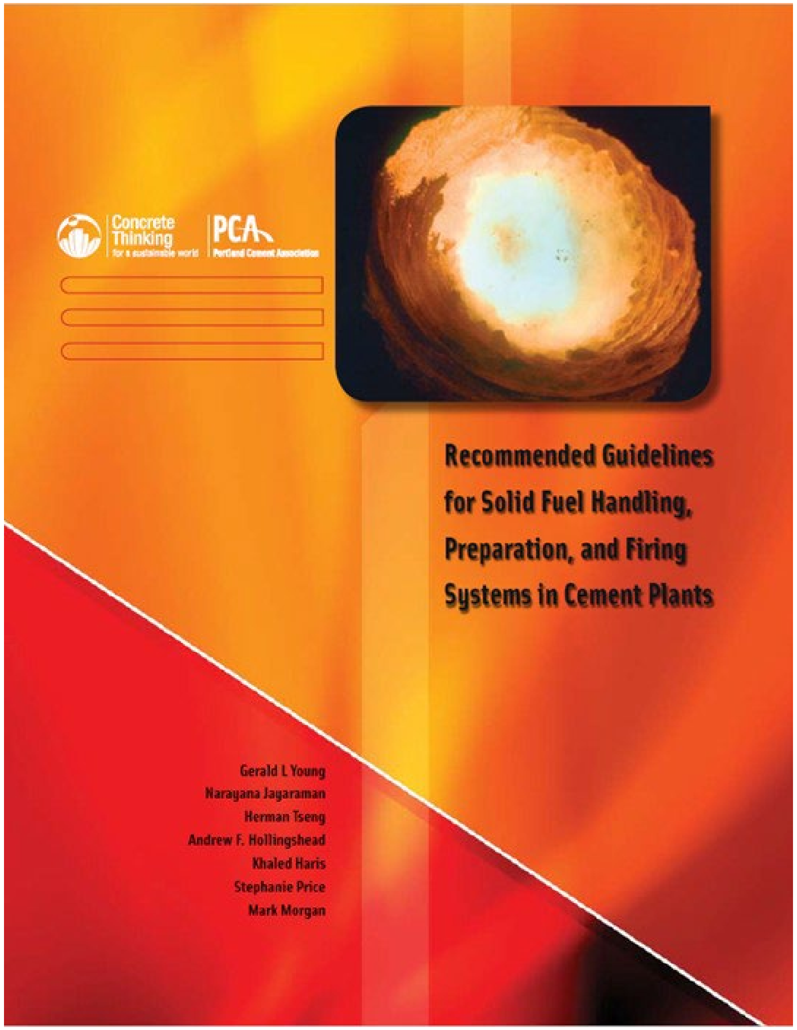
For more details…



- PCA guidelines (photo)
- ASTM standards
- NFPA standards and codes
- Et cetera

(see appendix for more exhaustive list)

Remember…

- Just because it hasn't happened yet doesn't mean that it can't
- Be vigilant and rigorous
- Let's all go home in the cab of our trucks… not in a pine box loaded in the bed

Thank you for your attention!

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Process engineering solutions and operations training for the cement, lime and gypsum industries

Appendix A

Definitions

Definitions

- Oxidation – the combining of elements with oxygen; it consists of the increase of positive charges on an atom or the loss of negative charges
- Autoxidation (auto-oxidation) – oxidation brought about by reactions with oxygen at normal temperatures, without the intervention of flame or electric spark

Definitions (cont'd)

- Burning – a process in which a substance reacts with an oxidant (e.g. oxygen) to give heat and light
- Combustion – the process of burning (rapidly); an exothermic reaction that takes place between a combustible substance and oxygen
- Combustible dust – any finely divided solid material that is capable of burning
  - Combustion occurs when the dust is dispersed in an oxygen-rich environment at a concentration falling within its explosive range[†] and is exposed to an ignition source

[†] Between lower (LEL) and upper explosive limits (UEL), typically btwn 30-7,000 g/m^3 for most coals

Definitions (cont'd)

- Smoldering – the process of burning slowly with smoke but no flame

Definitions (cont'd)

- Fire – the rapid oxidation of a material via the exothermic chemical process of combustion, releasing heat, light, and various reaction products
- Explosion – a rapid increase in volume and release of energy in an extreme manner, usually accompanied by high temperature generation and gas release
  - → Internal pressure ruptures container

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Definitions (cont'd)

- Explosion types:
  - Deflagration – an explosion which propagates subsonically, i.e. at a velocity less than the speed of sound
    - Can be mitigated by various means
      - Containment (i.e. design equipment for minimum pressure rating)
      - Inerting (i.e. dilution via gas or smothering with meal)
      - Suppression (i.e. application of powdered suppressant to smother fuel)
      - Isolation (e.g. use of isolation dampers)
      - Venting (e.g. pressure-relief valves or rupture discs)
  - Detonation – an explosion which propagates supersonically, i.e. at a velocity greater than the speed of sound
    - Occurs when the flame front of a deflagration ignites a pulverized fuel layer and/or buildup in its path, causing a secondary explosion, thereby increasing velocity and pressure
    - Cannot be effectively controlled, therefore must be avoided (via isolation and/or venting)

Appendix B

Determinants

Combustion Triangle

- All three components need to be present to initiate or sustain combustion
- Elimination of one of the three will prevent or stop the combustion process

Explosion Pentagon

- As with the combustion triangle, removal of one component prevents an explosion
  - Confinement is intrinsic to the system but check that safety devices (e.g. explosion vents, isolation dampers, etc.) are properly designed, maintained and operational; also check that ducting has adequate velocities to avoid settling
  - Dispersion incidents generally occur during start-ups and shutdowns → follow SOPs
  - Maintain an inert atmosphere (typically < 10-12 % O_2, wet volume basis‡)
  - Fuel fineness, volatile matter and moisture can all play a role in auto-ignition
  - Follow prescribed temperature guidelines and minimize risk of spontaneous ignition

‡ Fuel specific

Appendix C

Resources

Resources

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