

# Mill Inerting and Pulverizer/Mill Explosion Mitigation

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# Coal Mills are the Heart of a Coal Fired Plant

Maximum capacity, reliability and performance of your operation rely on the critical roles that your coal mills perform:

- Conditioning coal for proper combustion. (Fineness, fuel distribution, throughput)
- Delivering 100% of fuel to the boiler.
- Profoundly influencing ability to generate power economically.

## *There are risks.....*

- Firing high-moisture & highly-reactive sub-bituminous coals exposes your plant to risks of:
  - Unsafe working conditions, possible threat to worker safety.
  - Damage & repair cost (Primary air inlet ducts, PA fans, mill internals, feeders, etc.)
  - De-rates, forced outage, shut down.
- Loss of availability of certain mills can cause slagging, problems with environmental compliance, high exit gas temperatures, non-optimum steam temperatures and other adverse consequences.
- Downtime may extend to weeks or months, backup generation can be sparse or expensive.



# Mill inerting is regarded as the principal approach or engineering control to prevent mill fires & explosions

- People working in our industry use the term “inerting” loosely and sometimes incorrectly when describing systems that prevent mill explosions, puffs or fires.
- Systems often named as “inerting systems” by coal fired power plant personnel include:
  - Steam Inerting Systems
  - Water fogging or deluge systems
  - CO<sub>2</sub> inerting systems
  - N<sub>2</sub> Inerting (Not common in power plants)
  - Explosion Suppression Systems



## Steam, CO<sub>2</sub> and N<sub>2</sub> Inerting Systems

- Technically speaking it is generally accepted that achieving an “inert” environment inside a coal mill, the O<sub>2</sub> level should fall below 14% O<sub>2</sub>.
- Technically speaking, only Steam, CO<sub>2</sub> and N<sub>2</sub> (Rare) systems are true inerting systems.
- Steam is the most common inerting media. To know with confidence that an inerting environment is achieved, an O<sub>2</sub> probe is needed. They’re easily plugged, high maintenance and/or unreliable.
- Alternative is characterization testing to determine flow and time required to achieve an inerting environment and maintain it as steam condenses inside the mill.
- Not effective at washing away coal residues, fines and dust that can be combustible or explosive.
- Inerting systems are expensive



# Water Fogging/Deluge

- Water fogging and deluge systems are essentially mill internal combustible dust suppression systems and they also suppress or extinguish burning or smoldering coal.
- The majority of burning or smoldering coal more often occurs under the grinding zone where the hot primary air flow enters the mill. This area is often described as the under-bowl, under-table, reject area, pyrite area or primary air inlet wind box depending on the type of mill. Fogging and deluge systems can be very effective at “washing” away hazards under the grinding zone. Flooding this zone is also effective at extinguishing burning coal.
- Water fogging can be temperature driven to enhance effectiveness.



**All of these systems can be effective in reducing the risk of mill fire/explosion or limiting damage (explosion suppression systems). Each has strengths and weaknesses.**

- **Some plants have operated safely with and without these systems.**
- Coal characteristics profoundly influence risk.
  - Lower rank coals are generally more easily ignited inside the coal mill.
  - High volatile matter and highly reactive coals encourage pre-ignition inside the mill.
  - Higher moisture content requires temperature extremes inside the mill.
  - High moisture, high volatile matter and highly reactive coals are prone to self heating and can spontaneously ignite due to rewetting.
    - Rehydration is exothermic and dried coal that is stagnate anywhere in the coal mill can begin to smolder and burn.
    - Smoldering coal inside an idle mill can evolve into a big problem when the mill is started, agitating these accumulation combined with a high air to fuel ratio environment
- **PRB is one of the most difficult coals with respect to mill fires and explosions.**
- Mill internal temperatures are generally high enough somewhere to ignite any type of coal. Some bituminous coals ignite in the range of 315° to 350°F.



All of these systems can be effective in reducing the risk of mill fire/explosion or limiting damage (explosion suppression systems). Each has strengths and weaknesses.

- Some plants operate **with and without** these systems. Coal characteristics profoundly influence risk, PRB coal is one of the most difficult coals with respect to mill fires/explosions with greater magnitude explosions.

The  $K_{st}$  (Explosibility Constant or Deflagration Index) value for sub-bituminous coals are higher than for bituminous coals. Sub-bituminous coals have a higher rate of pressure rise if an explosion (deflagration) occurs.

Type of Coal	$K_{st}$
Sub-Bituminous <sub>1</sub>	200 bar-m/sec
Bituminous <sub>1,2,3</sub>	55-154 bar-m/sec
Lignite <sub>3</sub>	123 bar-m/sec

1 Options for Biomass Fuels Utilization in Power Plants, 2011, Don Koza

2 NFPA 68 Guide for Venting of Deflagration, 1998

3 Dust Explosions in the Process Industries, 1991, R.K. Eckhoff



## **Some units without these systems have prevented or managed fire and explosion risks by:**

- Mechanical Blue-printing and optimization (maintenance practices)
- Proper and optimum airflow management.
- Proper operation and plant staff awareness. Ability to identify common causes of mill fires and understanding of coal characteristics that promote fires.
- Coal mill system design and configuration.

## **Protective systems provide forgiveness and additional protection by addressing risks of mill fire explosion that develop that are not operator controlled or when maintenance and operation control measures fail.**

- High inlet or outlet temperatures
- Foreign Material (trash, wire, rope, rags, wood, etc.)
- Coal accumulations – below or above the grinding zone.
- Abnormal conditions
  - Component failures; dampers, slide gates, feeder belts, etc.
  - Feed interruptions caused by wet or frozen coal.



- **PRB is one of the most difficult coals with respect to mill fires and explosions.**
- **PRB coals are high moisture and highly reactive coals.**
- **Utilization of some type of protection system is prudent and widely accepted as a necessary best practice when firing PRB and other sub-bituminous coals.**



An understanding of what causes mill fires and explosions is required for safe operation and optimal results with any type of system that inhibit mill fires or explosions.

- It is important to remember that a mill fire, whether it be flaming, smoking or smoldering coal inside the mill means a mill explosion could be occur at any time.
- Any burning or smoldering material inside the mill can evolve into an explosion because they provide an ignition source if the air to fuel (coal) ratio is elevated or higher than desired.
- Air to fuel ratio inside the mill is always elevated during mill start-up, shutdown, mill trips and interruptions in raw coal feed.
  - Its well known the the risk of mill explosion is highest during these times of high air to fuel ratio.
  - Because of this, these events are the “triggers” that start mill inerting systems.



## **Most utility boiler coal mills do and should operate at primary air to coal ratios of 2:1 or less.**

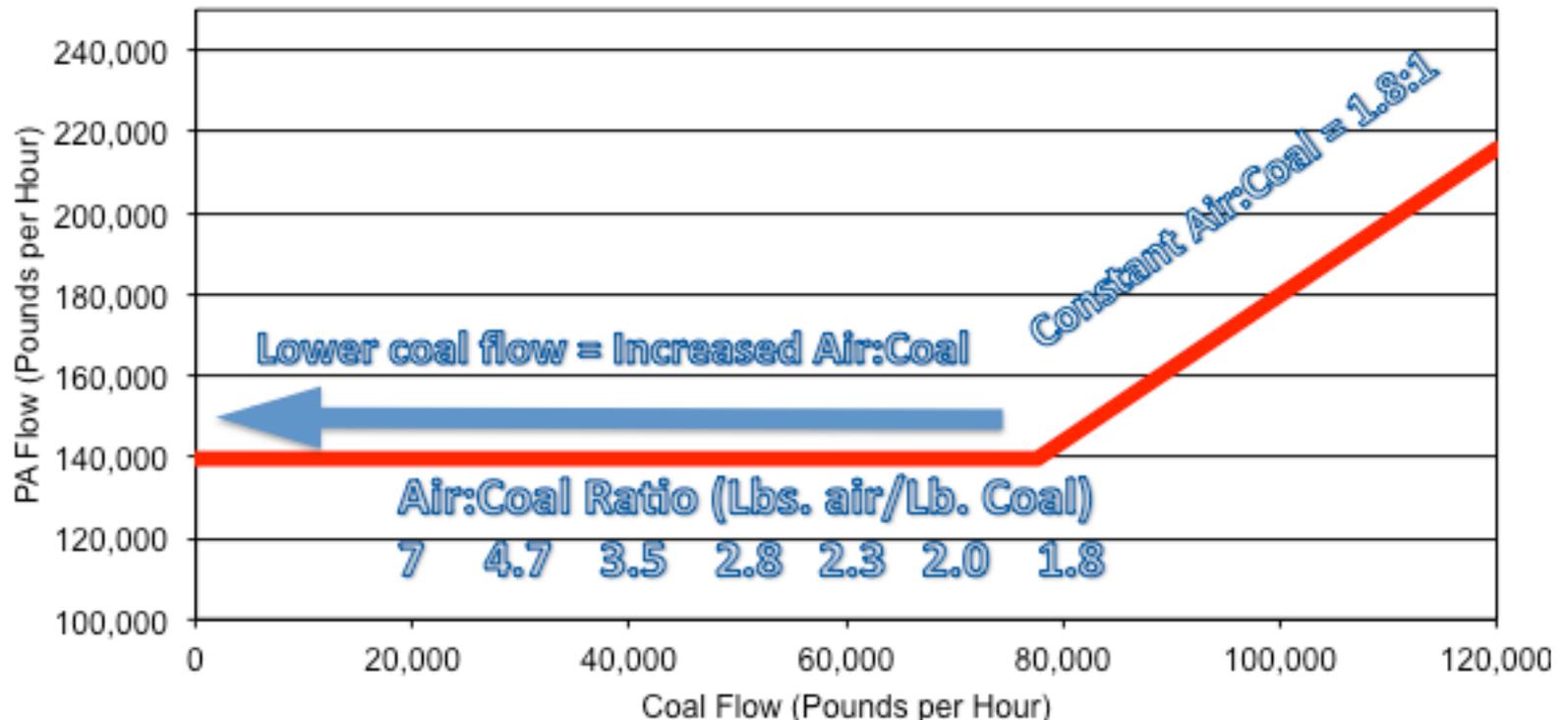
Coal Mill Air to fuel ratios are higher during:

- Start-up.
- Shutdown.
- Interruptions in raw coal feed.
- Lower feeder speeds.
- This occurs because a minimum airflow through the coal mill must be maintained to insure that burner line velocities are not too low to allow settling of coal in the fuel lines or burner components.
- Not uncommon to achieve air to fuel ratios of 3 to 5 pounds of air per pound of coal.



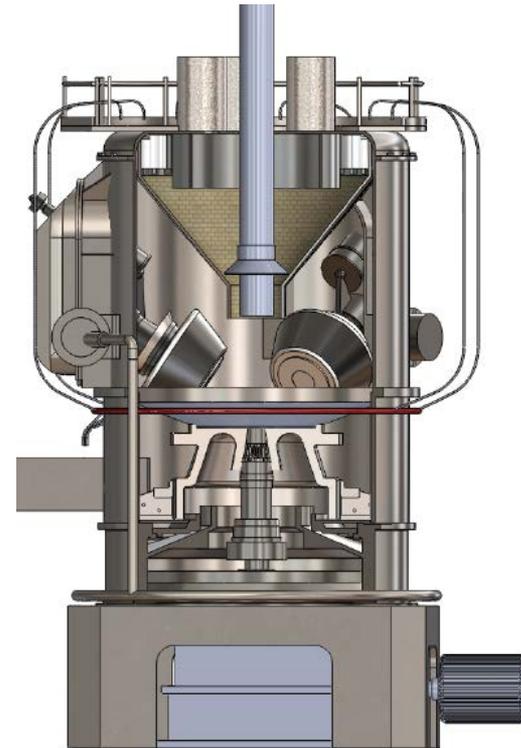
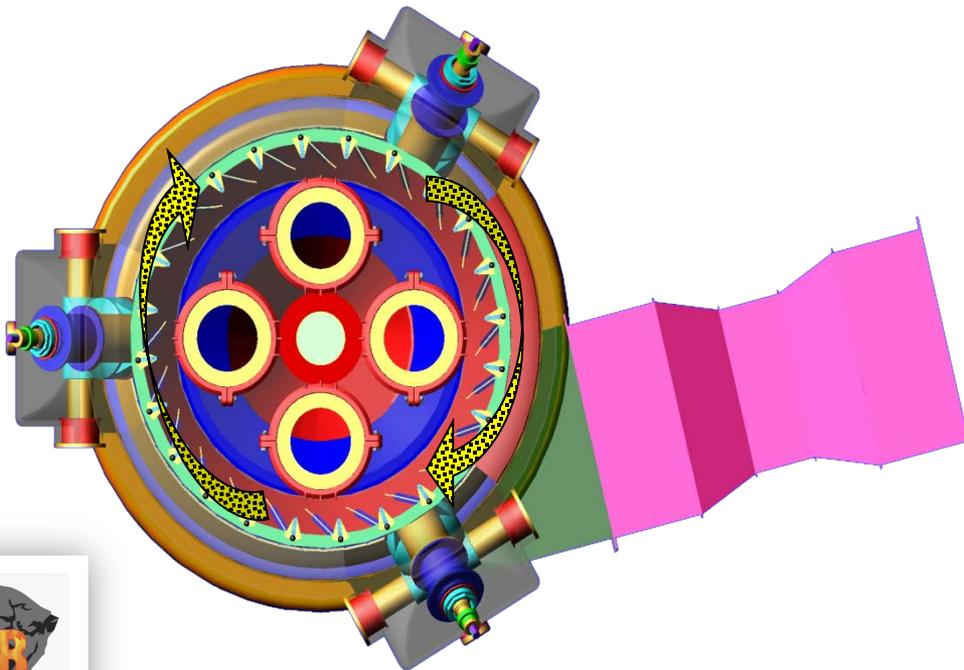
In the example below, which is typical, Mill air flow is held constant at 140,000 Lbs./Hr. at coal flows <78,000 Lbs./Hr. to maintain minimum burner line of 3,500 Fpm.

### Typical Ideal Pulverizer Primary Air to Coal Relationship



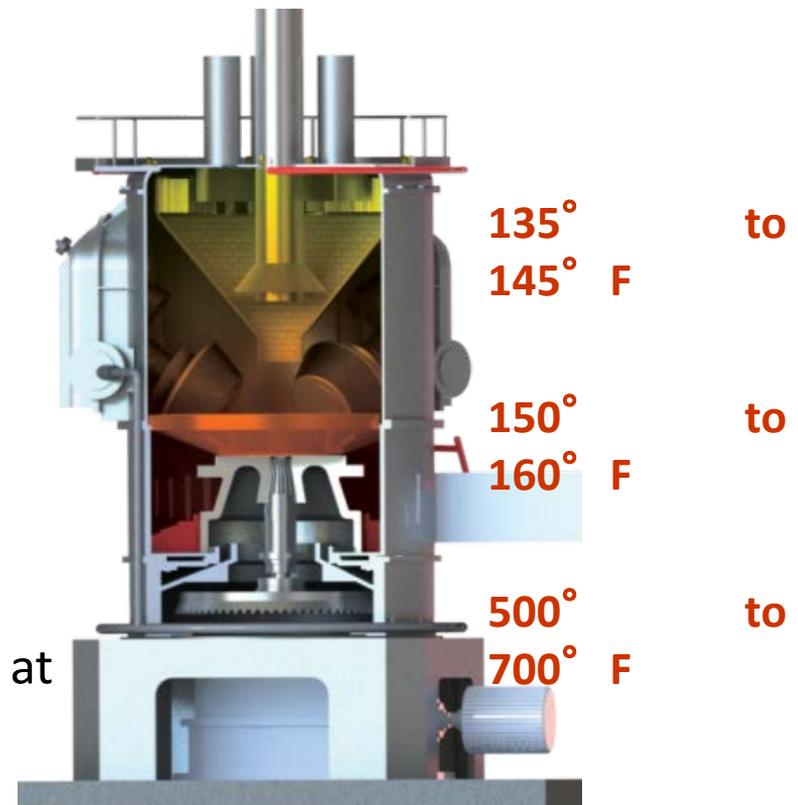
A common assumption is that at full load coal flows, air to fuel ratio is too low for pre-ignition of coal or below the explosive or combustible range inside the coal mill.

- Coal and air is being actively mixed inside the mill and localized areas of high air to fuel ratio.
- Air to fuel ratio can suddenly increase to explosive levels with an interruption in raw coal feed.



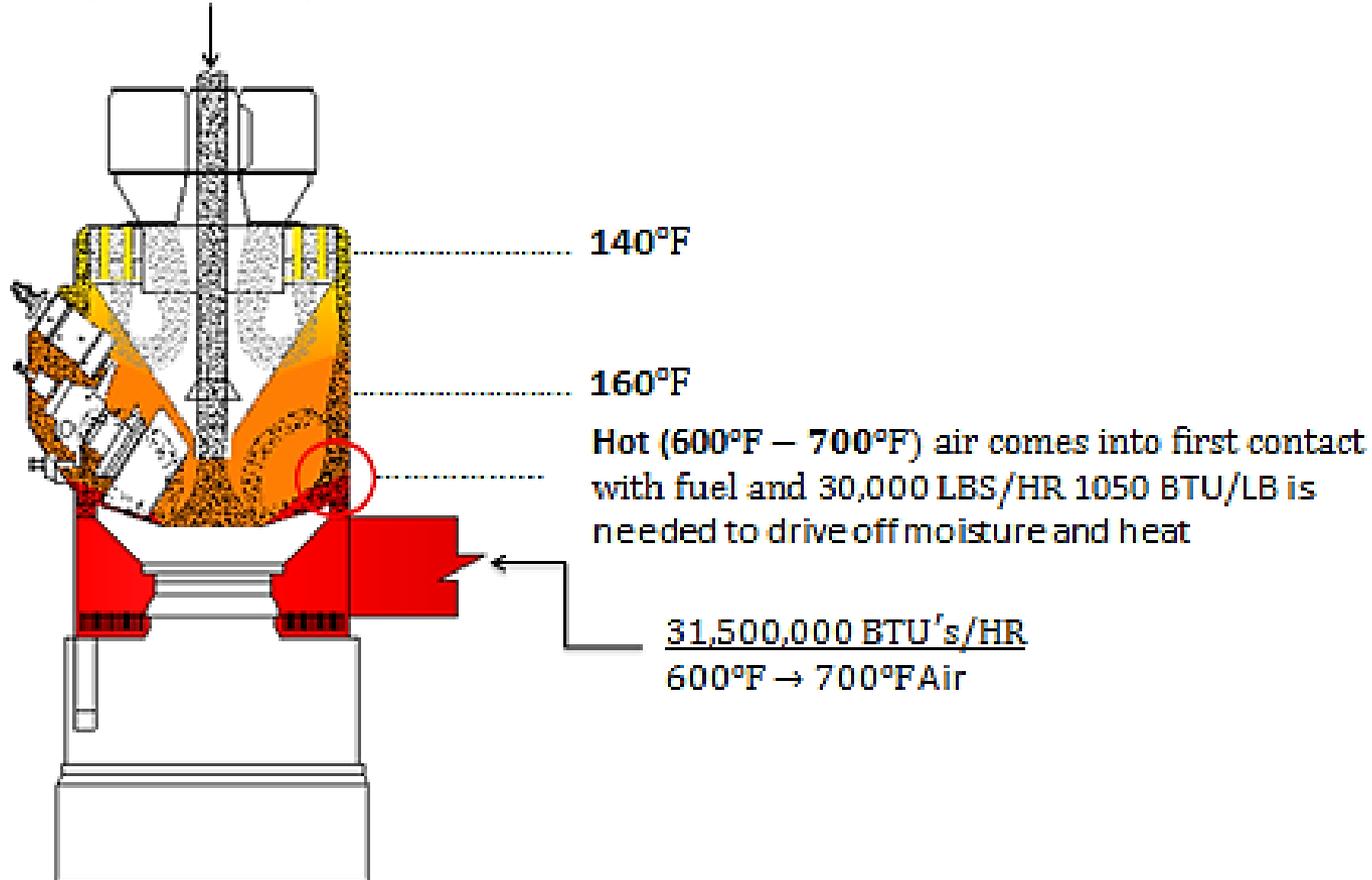
# Hot Temperatures always exist inside the coal mill while firing PRB Coal

- Sub-bituminous Coal is 15-30% moisture. PRB usually 25% to 30% moisture.
- Very hot mill inlet temperatures are required to:
  - Dry coal
  - Achieve mill outlet temperatures.
  - Heat required is determined by coal moisture.
  - Heat supplied is product of the temperature and quantity of airflow at mill inlet.

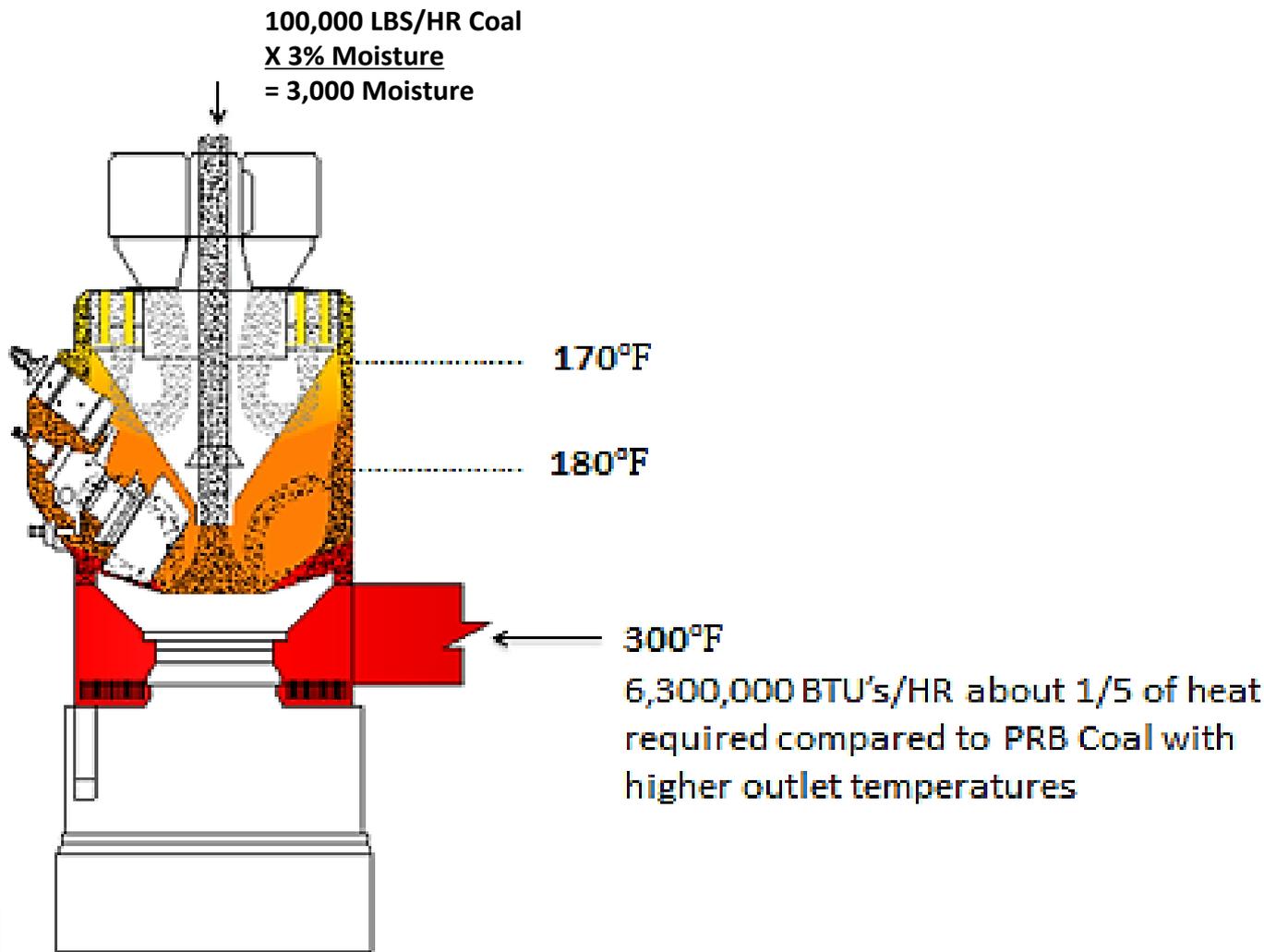


# Typical temperature inside the mill with Coal Moisture of 30% Higher Moisture = Higher temperatures and higher risk of mill fire

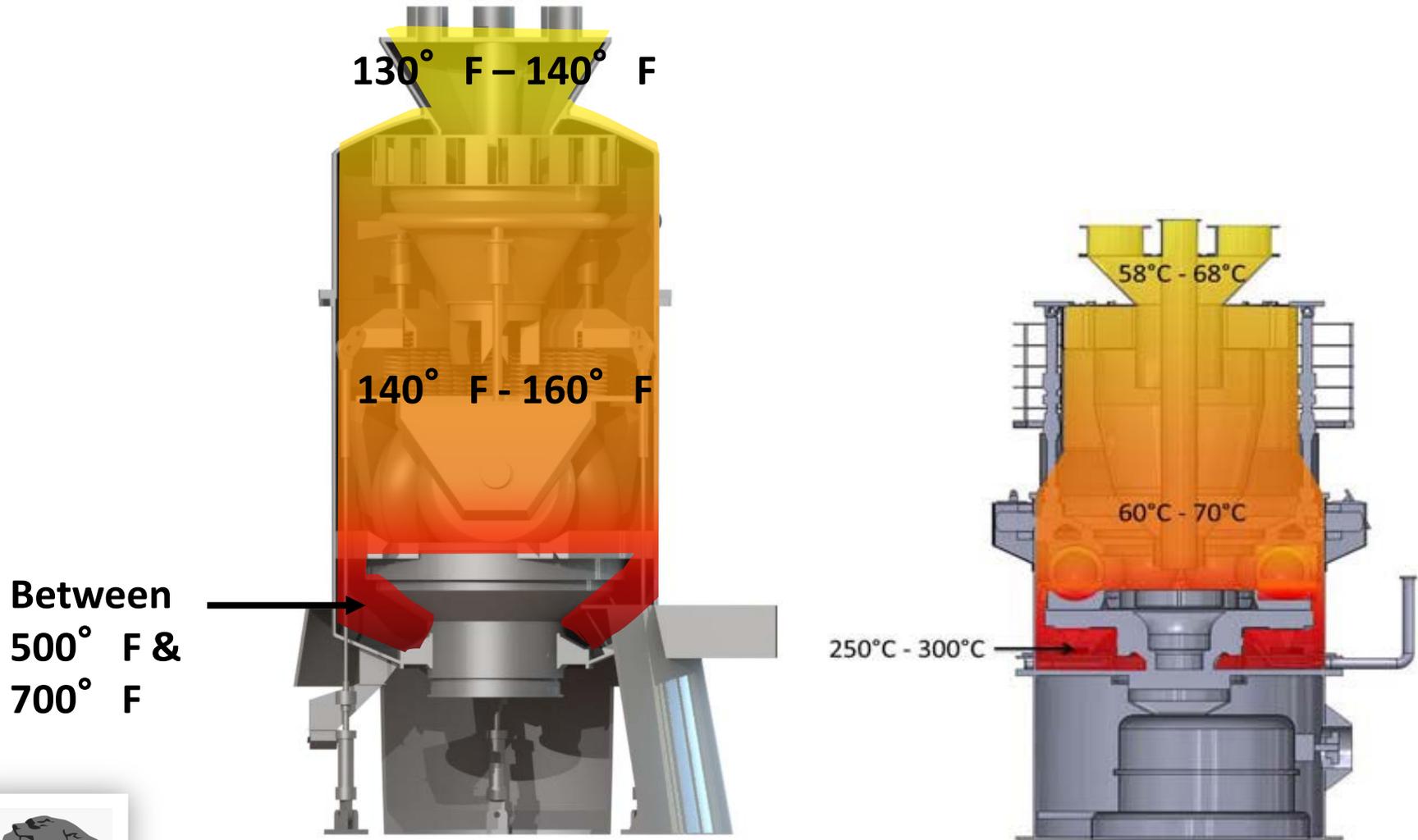
100,000 LBS/HR Coal  
x 30,000 LBS/HR Moisture (Water)  
or 3,600 Gallons/HR



# Typical temperature inside the mill with Coal Moisture of 3% Less Moisture = Lower Mill Inlet Temperatures - despite the Higher Outlet Temperature



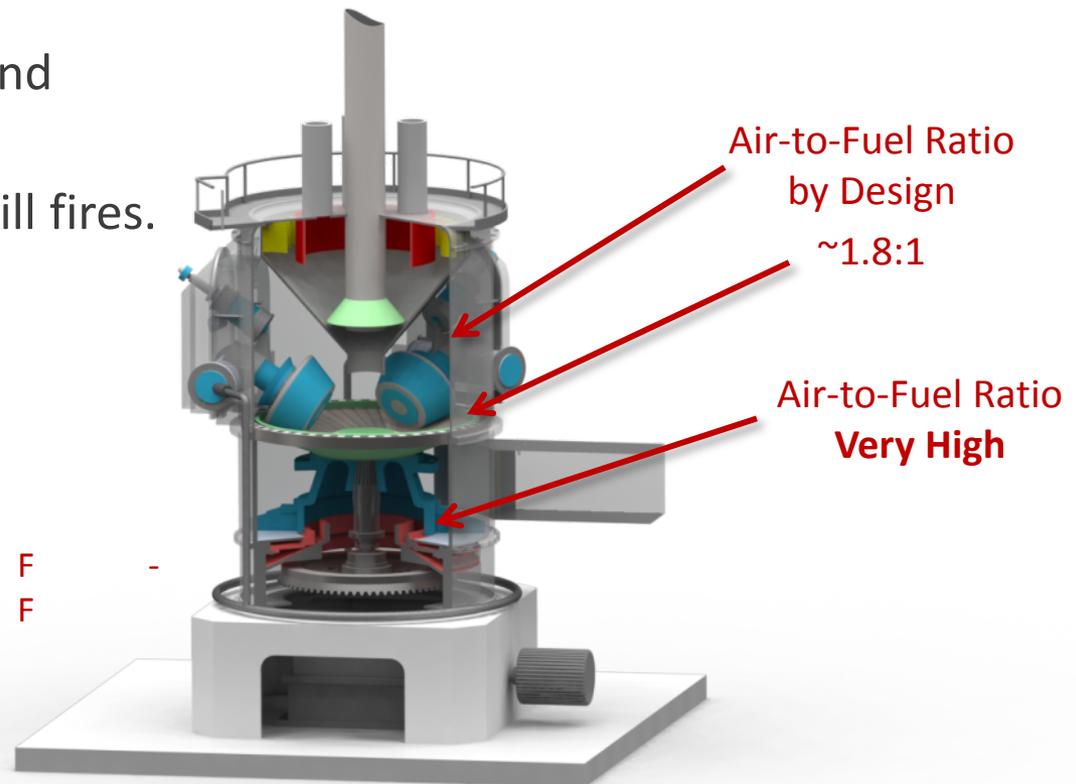
# Typical Temperature of a Pulverizer – Inlet Temperatures will high regardless of pulverizer manufacturer with high moisture coal.



# COMMON CAUSE OF MILL FIRES: COAL SPILLAGE UNDER THE BOWL

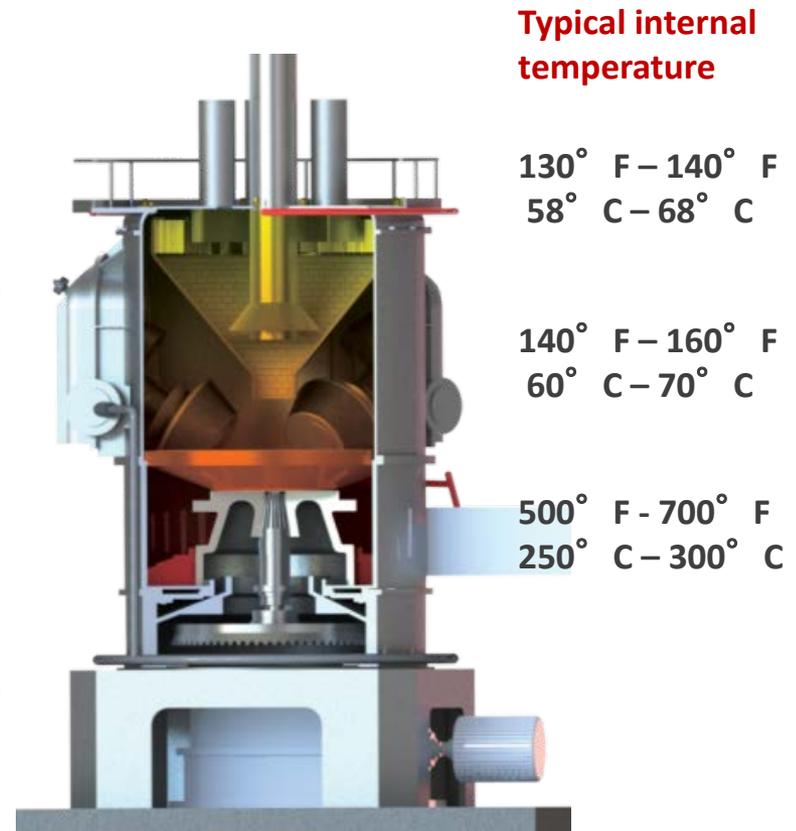
- Temperature and air-to-fuel ratio is very high under the bowl.
- Rejected coal quickly dries and ignites.
- Most common location of mill fires.

500° F -  
700° F

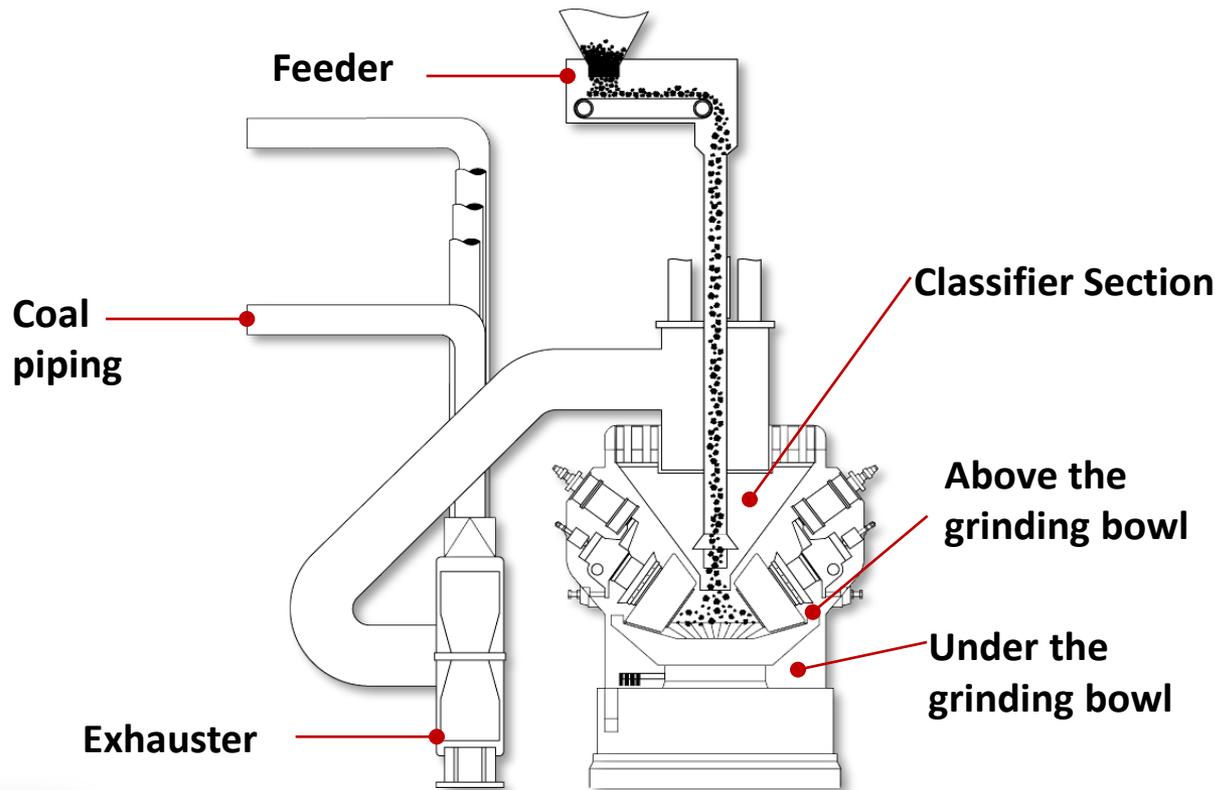


# TYPICAL PROGRESSION OF A MILL FIRE

- 1) Coal feed is interrupted either intentionally or unintentionally during start-up and shutdown of the mill or due to clogging or equipment failure
- 2) Because there is no longer a flow of coal - which normally absorbs heat through the evaporation of the coal's moisture content - the high temperatures typical of the under bowl/under table area migrate upward into the grinding zone
- 3) The decreased quantity of coal also means there is an increase in the air-to-fuel ratio
- 4) The combination of high temperatures and a high air-to-fuel ratio causes the coal remaining in the grinding zone to ignite



# Mill Fires: Potential Areas



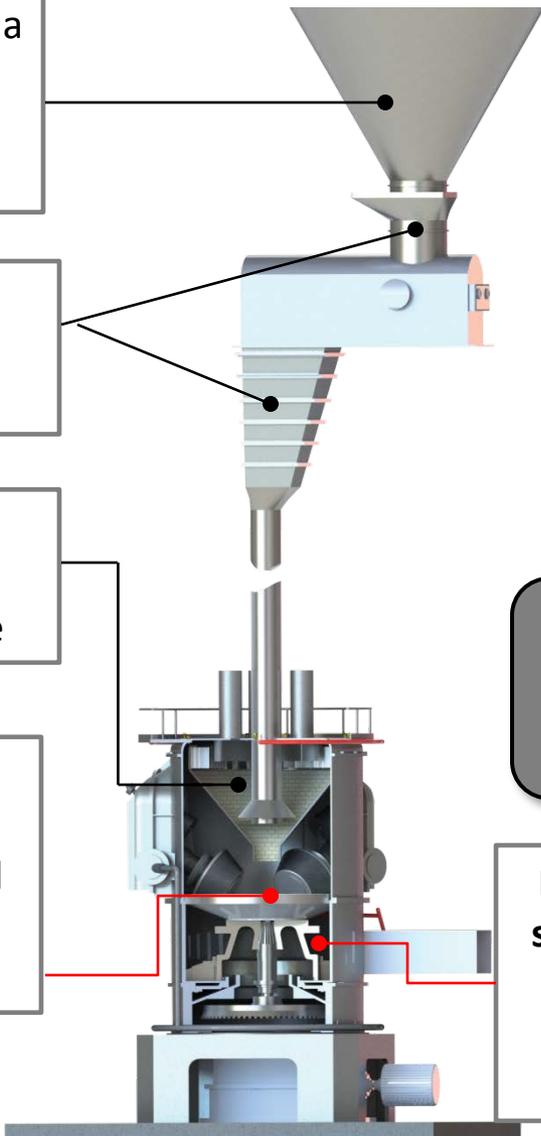
# COMMON CAUSES OF FIRES, PUFFS & EXPLOSIONS

Smoldering coal from the bunker reaches a point of deflagration (bursts into flames) as it travels through the feeder down to the mill

Raw coal supply is interrupted due to imprecise feeder control and stoppages above and below the feeder

Accumulation and settling in pulverizer components allow coal to dry – such accumulations can spontaneously ignite

Excessive pulverizer airflow provides an abundant source of air for combustion of ignition sources including smoldering coal in the classifier, pulverizer or raw coal in the high temperature under bowl



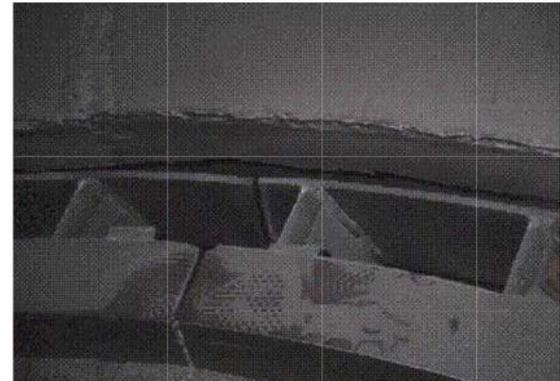
*Most pulverizer fires and/or puffs are caused by coal spilling into the high temperature area where primary air enters the mill.*

**Raw coal which is allowed to spill over into the under bowl section accumulate and are exposed to temperatures >500°F**



# Worn or Improper (oversized) Components can allow coal spillage into the high temperature zone below the grinding zone

- Generally, velocities less than 7,000 fpm allow raw coal to fall into the high temperature zone below the grinding zone.
- Some throats are oversized, low velocity is the result and primary air must be biased up to increase velocity.
- If pulverizer throat openings increase in size due to wear, velocities through the openings will drop.
- If there is excessive clearance between the vane wheel and the deflector/liner, air can by pass the throat opening and air velocities will drop below that needed to suspend coal.



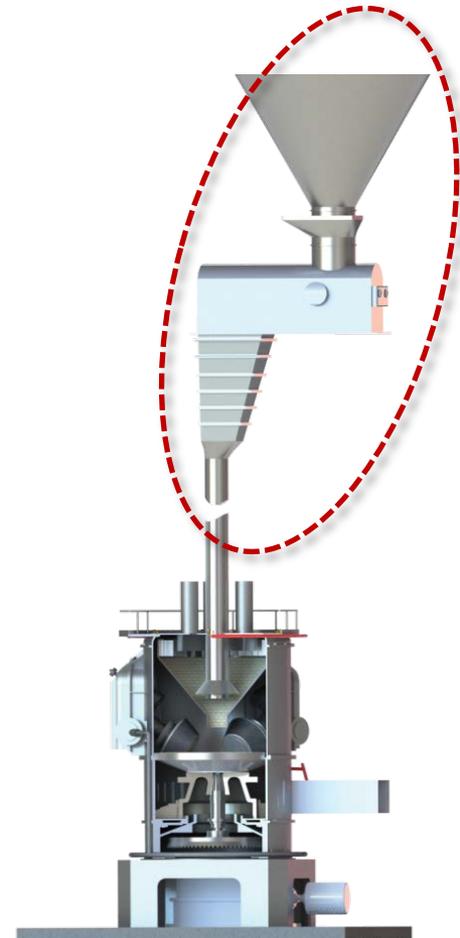
# Smoldering Coal from above

## Smoldering coal from the bunker

- Reaches a point of deflagration as it travels through the feeder, and into the mill

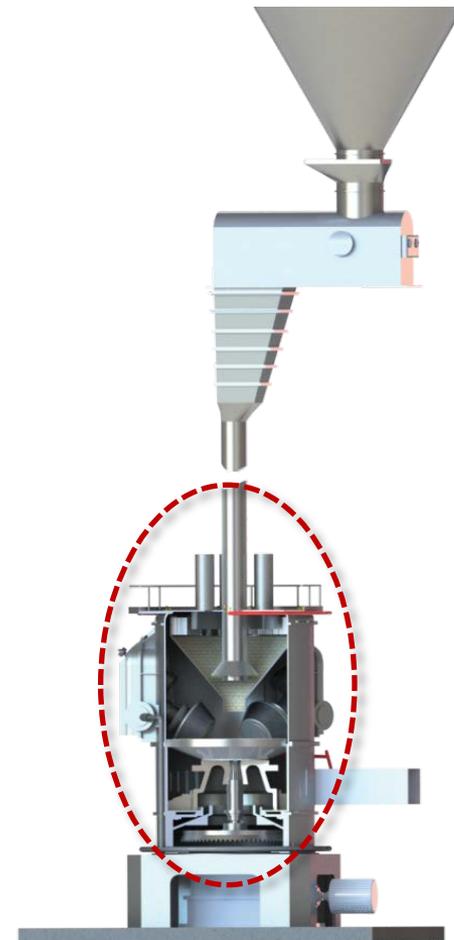
## Smoldering coal that has no access to oxygen in the tightly packed bunker

- Will suddenly be exposed to oxygen as it breaks apart in transit
- There is also a decrease in particle size



# Common Causes of Mill Fires Accumulation

- Accumulations of debris or coal *anywhere* in the pulverizer will increase the chance of a mill fire
- Accumulation and settling in pulverizer components allow coal to dry
  - Such accumulations can spontaneously ignite
  - Stoppage of pyrite chute flow can cause debris and-or coal to back-up into the primary air ducting



# Common Causes of Mill Fires

## Poor Airflow Control

- Excessive airflow to the pulverizer
  - Provides an abundant source of air for combustion of ignition sources including smouldering coal in the classifier, pulverizer or raw coal under the bowl
- Sufficient air velocity should be maintained at all loads to prevent the settling of coal from the air stream

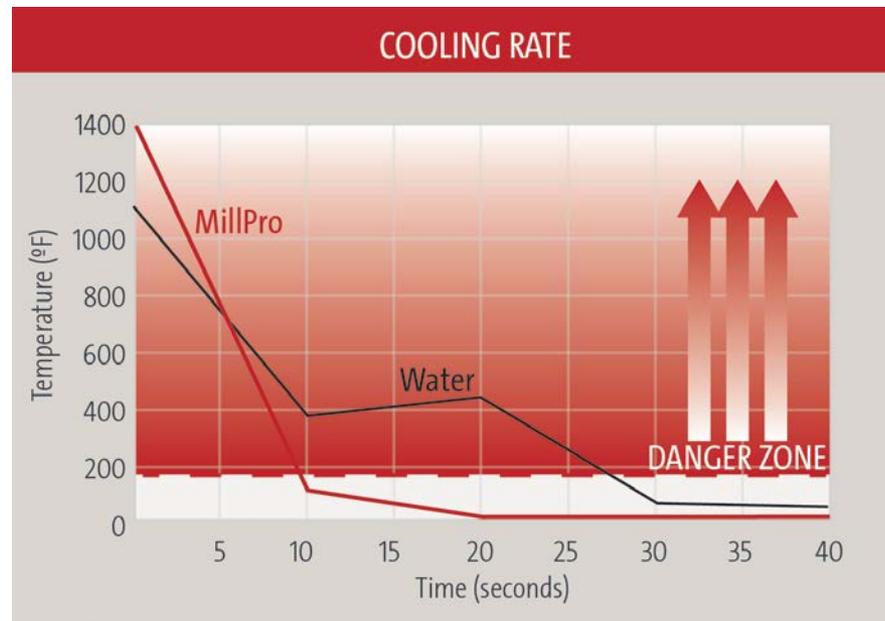


# MillPro Mill Protection System

- *A Proactive* Mill Protection System for Coal Fired Power Plants
- Incorporates
  - Mill outlet temperature management
  - Faster cooling with less water.
  - Mill fogging, internal combustible dust suppression
  - Fire suppression
- Operates continuously while mill is in service



- **Hazard Control Technologies (HCT)** are experts on chemistries that rapidly reduce the temperature of hot coal, as proven through F-500. MillPro TS-EA builds on this technology to reduce high internal mill temperatures faster.
- At the same application density of 0.30 gpm/ft<sup>2</sup>, the temperature of the MillPro TS-EA drops to 118°F in 10 seconds, **3 times faster** than plain water

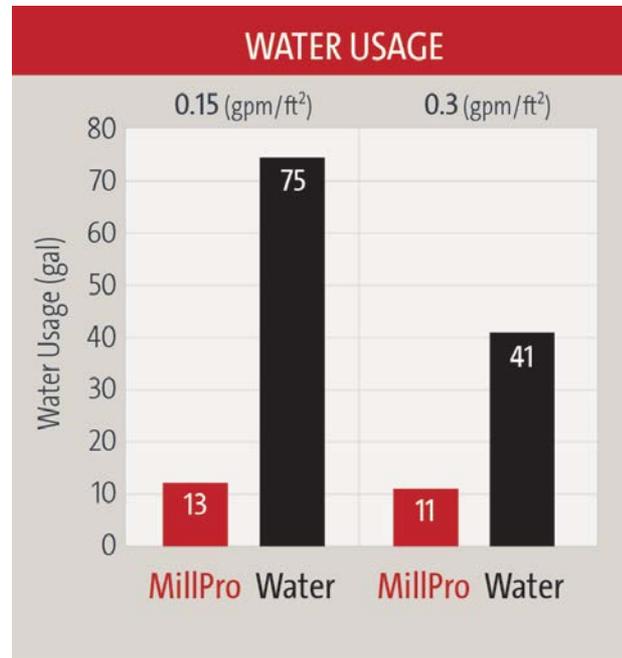


# Rapid Suppression/Extinguishment

- Key to the MillPro System – the MillPro TS-EA
  - Controls the temperature inside the mill environment
    - More effective than traditional solutions or water alone
  - Unique molecular design
    - allows for specific alignment within a water droplet to accomplish significantly higher heat reduction
  - Once injected into the pulverizer as a fine mist, cooling begins immediately
    - reducing damage to your equipment and returning your mill to standard operating conditions within seconds



- Building on the same **HCT** technology and experience:
  - Significantly Less Water Usage is Required.
- At the same application density, MillPro utilizes as much as 83% less water to extinguish the same fire.



# MillPro vs. Traditional Systems

	MillPro	Steam	Water /Fog
Inhibits mill excursions during start-up & shut-down	■	■	■
Inhibits mill excursions due to coal feed interruptions	■		
Internal fire suppression/extinguishing system	■		
External fire suppression/combustible dust management	■		
Rapid cooling of mill internals leading to decreased maintenance intervals	■		
Helps manage mill outlet temperature excursions before they evolve into fires	■		
Operates while the mill is in service	■		
Low water requirements	■		
Uniform cooling of mill internals	■		
Functions as mill internal wash down	■		■
Can be integrated to protect the entire fuel burning system	■		
In case a fire does occur, accelerated fire suppression and heat removal results in minimizing damage to mill internals	■		

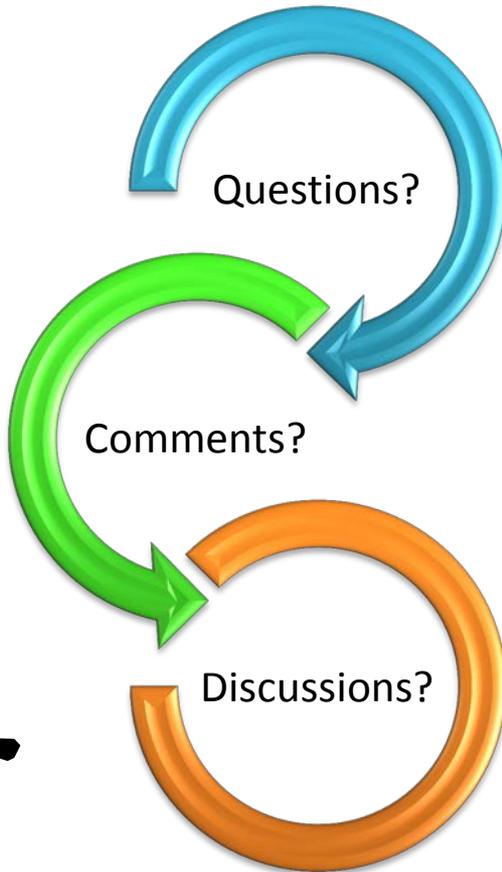




**ALWAYS  
ON  
GUARD**



# Questions? / Discussions?



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