MILLPRO

ALWAYS ON GUARD

Mill Protection System

Agenda

- MillPro Overview
- Risks Associated with Pulverizers Firing PRB
- Causes of Mill Fires, Puffs, and Explosions
- Progression of a Mill Fire
- Comparison with Existing Technologies
- MillPro Protection System – Modes of Operation
- MillPro Protection System – Major Subsystems

MillPro Overview

- Combining industry leading technology and experience
  - **Innovative Combustion Technologies** (ICT)
    - Industry leading consultants on mill modification, maintenance and performance
  - **Hazard Control Technologies** (HCT)
    - Experts on chemistries that rapidly reduce the temperature of hot coal
  - **Benetech**
    - Industry leader for liquid injection systems, installation and execution

MillPro Overview

- Over 80 years of combined experience in all aspects of coal fired power plants
- These leading experts recognized the need for improving the mill inerting/protection process
  - Proactive vs. reactive
  - Improve safety and reduce downtime
- ICT, HCT and Benetech joined forces to build a better mousetrap
- MillPro is formed

INDUSTRY LEADERS JOIN FORCES TO CREATE REVOLUTIONARY SYSTEM

- Control temperature w/minimal water & chemical usage
  - Nozzle quantity, placement (zones), design, spray geometry and flow rates.
  - PLC based control system for precise control of fluid in multiple zones that are driven by mill internal temperature and-or carbon monoxide.
  - Enhanced and more uniform cooling with water using Micelle encapsulation built on technology of F500. (less quenching of hot parts)
  - Reduced to zero chance of plugging mill internals, burner lines and burners.
- Designed for Reliability
  - Nozzles selected field proven to have >5 year life
  - Precise control and metering of fluid flow to each individual nozzle. Worn or plugged nozzles do not go undetected.
- Designed for Coal Mill Availability
  - Resolve temperature excursions and fires without tripping the coal mills.
  - Reduced coal mill downtime. Conventional systems require mills to be tripped and often 1-2 hours before mill can be restarted.
  - Prevent mill trips on high outlet temperature without relying on operator intervention by increasing fuel flow and reducing inlet air temperature.
  - Mill can be cooled if equipment fails or malfunctions (isolation gates, feeder, coal plugging above the mill)

POTENTIAL RISKS ASSOCIATED WITH PULVERIZERS

The Heart of your Plant

- Max capacity and performance of your operation rely on the critical roles that your mills perform:
  - Conditioning coal for proper combustion
  - Delivering 100% of fuel to the boiler
  - Profoundly influencing ability to generate power economically.

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PULVERIZERS-
THE HEART OF YOUR PLANT
PROFOUNDLY INFLUENCE YOUR ABILITY TO GENERATE POWER ECONOMICALLY

The Heart of your Plant

- *But 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.

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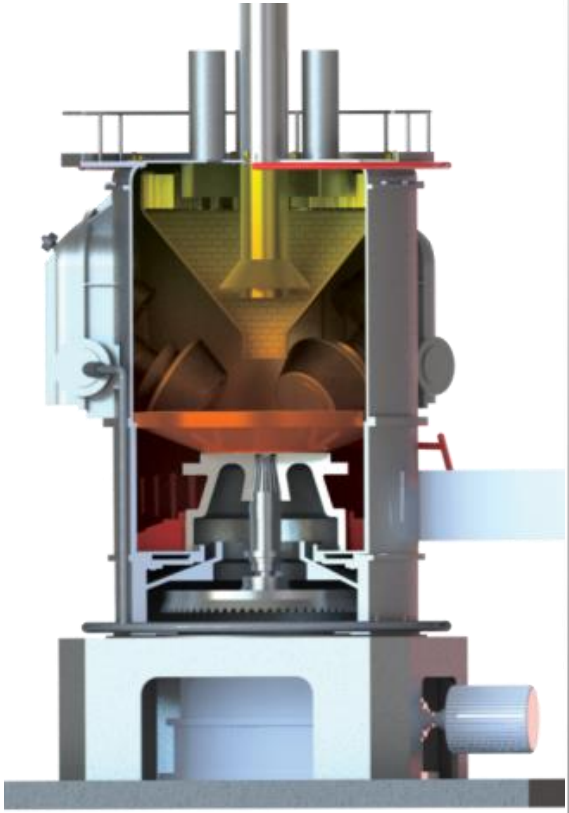
PULVERIZERS-
THE HEART OF YOUR PLANT
PROFOUNDLY INFLUENCE YOUR ABILITY TO GENERATE POWER ECONOMICALLY

Increased Mill Temperature

- PRB Coal is 25-30% moisture
- Very high mill inlet temperatures are required
  - to dry coal
  - achieve optimum mill outlet temperatures

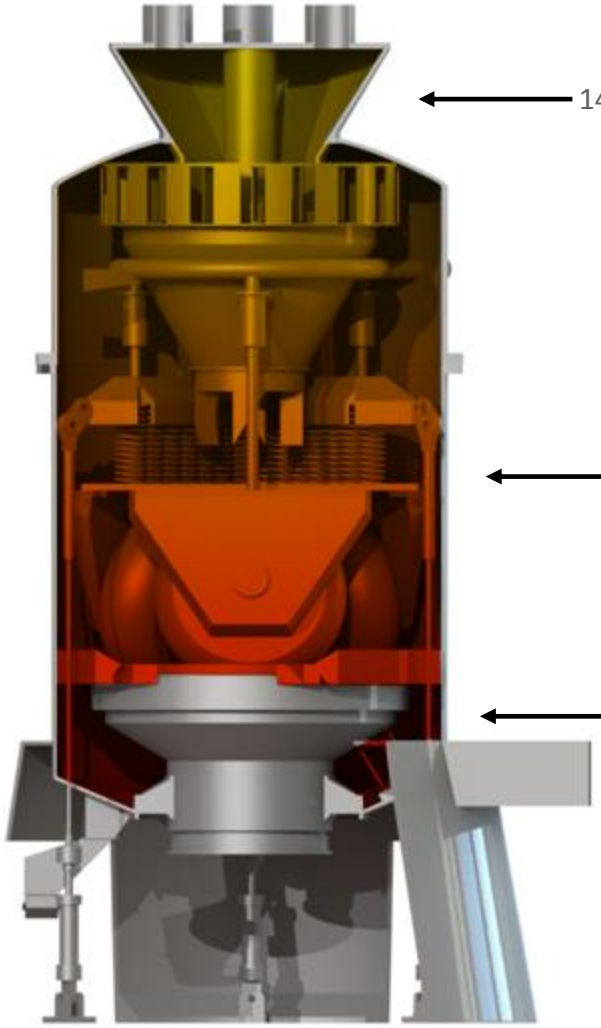


130°F - 140°F

140°F - 160°F

600°F - 700°F

Risk of Mill Fires



100,000 LBS/HR Coal
= 30,000 LBS/HR Moisture
Or 3,600 Gallons/HR

Hot 600°F – 700°F air comes into first contact with fuel and 30,000 LBS/HR 1050 BTU/LB is needed to drive off moisture and heat

31,500,000 BTU's/ HR
600°F- 700°F Air

HIGH MOISTURE PRB COALS:

- MORE PRONE TO MILL FIRES

Due to higher inlet temperatures required to dry coal

Risk of Puffs

- 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 Kst (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$_1$	200 bar-m/sec
Bituminous$_{1,2,3}$	55-154 bar-m/sec
Lignite$_3$	123 bar-m/sec

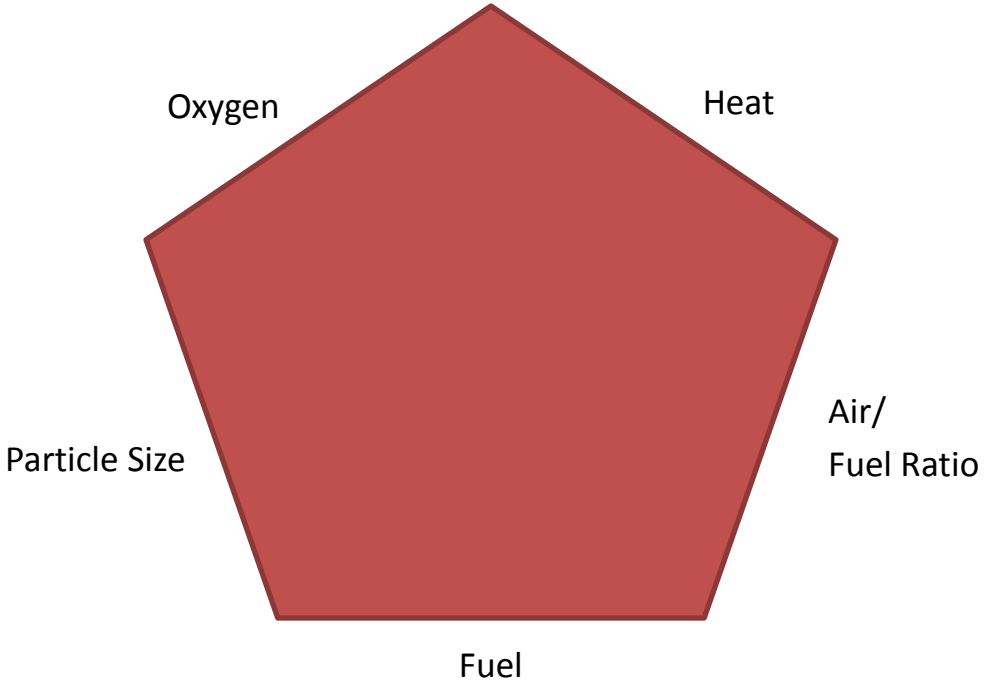
1 Options for Biomass Fuels Utilization in Power Plants, 2011, Don Koza
2 NFPA 68 Guide for Venting of Deflagration, 1998
3 Dust Explosions in the Process Industries, 1991, R.K. Eckhoff

HIGH MOISTURE PRB COALS:

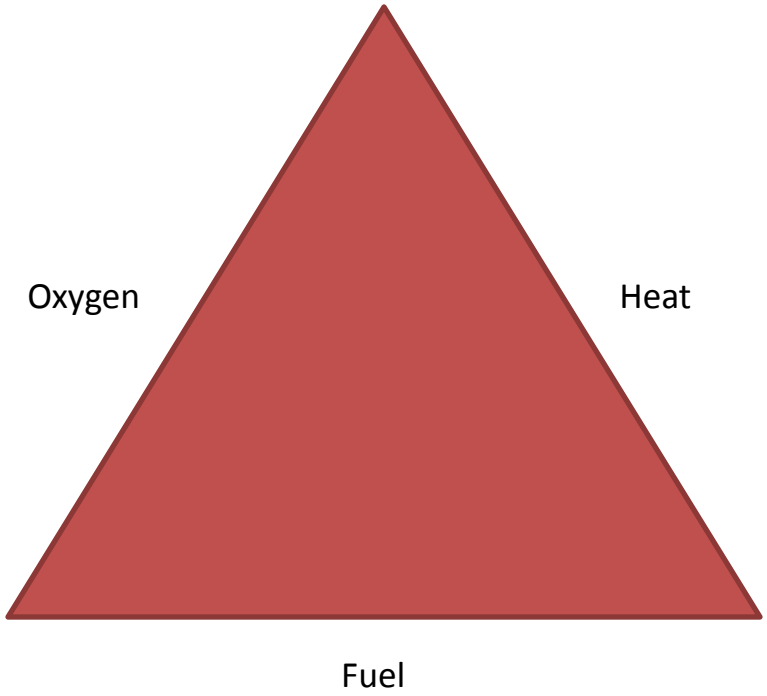
- GREATER CHANCE OF EXPLOSION
- MORE DESTRUCTIVE EXPLOSIONS

Risk of Puffs

The Deflagration Pentagon



The Fire Triangle



Potential Risks

- Threats to worker safety
- Significant financial losses
  - Repair Costs
    - Air Inlet Ducts
    - Primary Air Fans
    - Mill Internals
- Downtime may lead to forced outages extending to weeks or months resulting in great expenses related to replacement power and startup costs

THE ABSENCE OF SOUND OPERATIONAL PRACTICES AND PROTECTION MAY RESULT IN GREAT COST

COMMON CAUSES OF FIRES, PUFFS & EXPLOSIONS

COMMON CAUSES OF MILL FIRES

- Smoldering Coal From Silo
- Coal Feed Interruptions
- Accumulation and Settling
- Poor Airflow Control
- Coal Spillage Under the Bowl
- High Air/Fuel Ratio During Start-Up and Shutdown
- Residual or captive coal in the mill following mill trip under load.

COMMON CAUSES OF FIRES, PUFFS & EXPLOSIONS

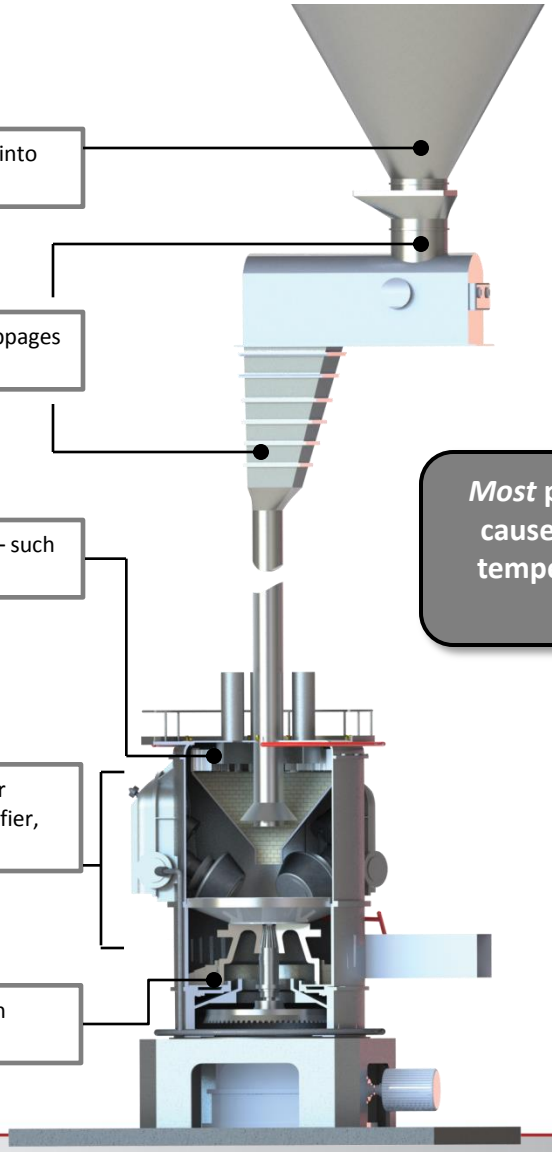
Smoldering coal from the silo reaches a point of deflagration (bursts into flames) as it travels through the feeder down to the mill

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

Raw coal which is allowed to spill over into the under bowl section accumulate and are exposed to temperatures of 500˚F or higher

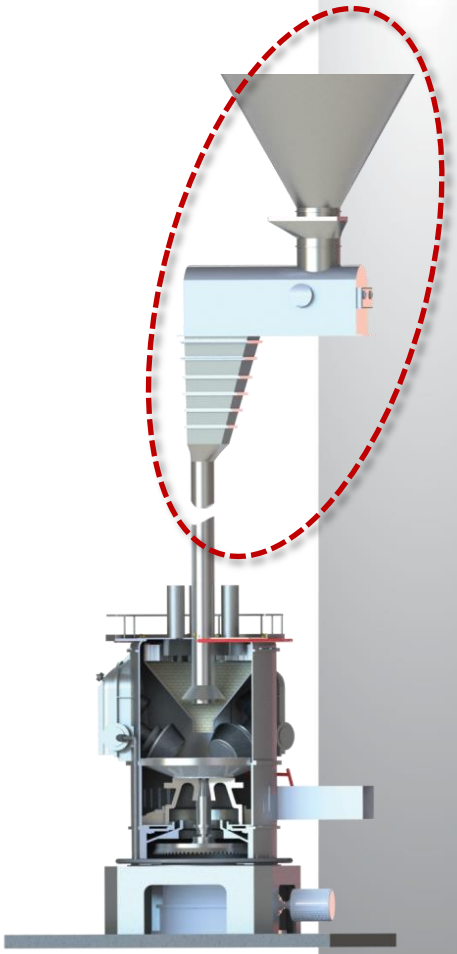


Most **pulverizer fires and/or puffs are caused by coal spilling into the high temperature area where primary air enters the mill.**

Common Causes of Mill Fires

Smoldering Coal in Coal Delivery

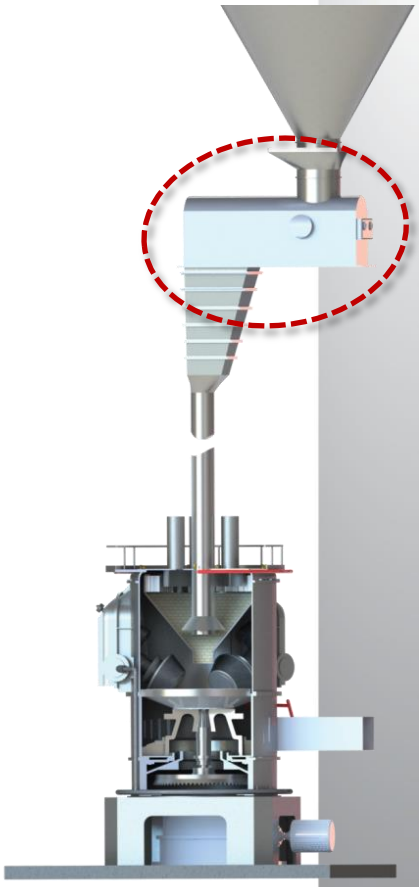
- Smoldering coal from the silo
  - Reaches a point of deflagration as it travels through the feeder, and into the mill
- Smoldering coal that has no access to oxygen in the tightly packed silo
  - Will suddenly be exposed to oxygen as it breaks apart in transit
  - There is also a decrease in particle size



Common Causes of Mill Fires

Coal Feed Interruptions

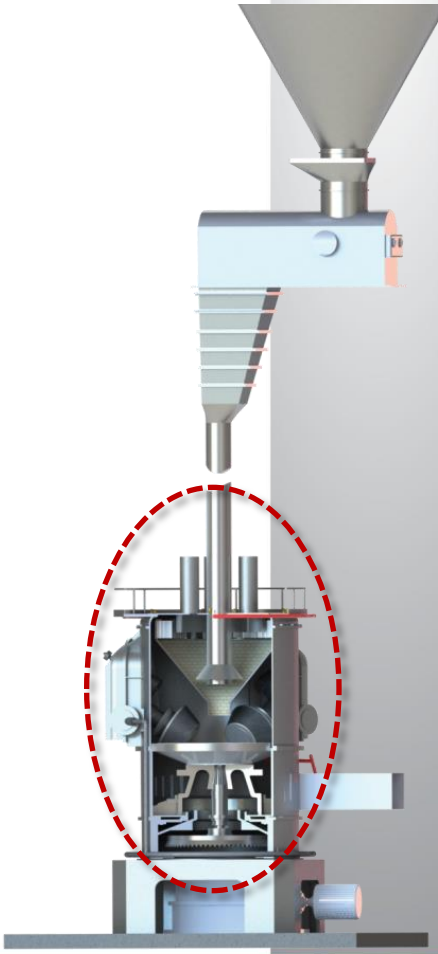
- Raw coal supply is interrupted due to imprecise feeder control and stoppages above and below the feeder.
  - With no supply of moist coal, the higher temperatures and air-to-fuel ratios present under the bowl migrate upwards into the grinding zone.
  - This is also a risk in the case of mill trips or shut-down.



Common Causes of Mill Fires

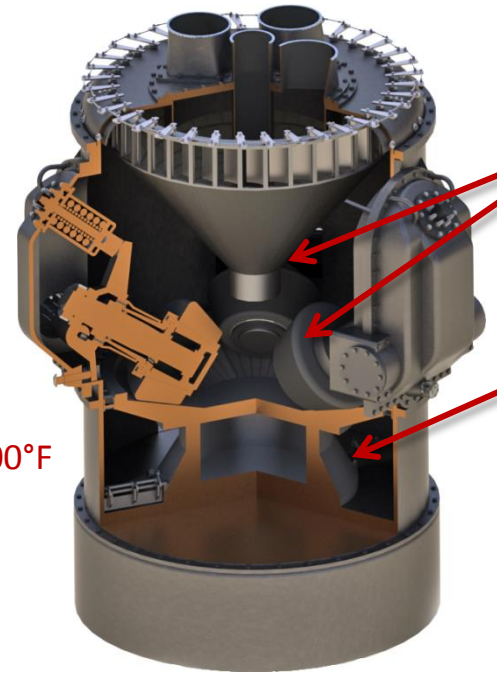
Accumulation

- 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



Coal Spillage Under the Bowl

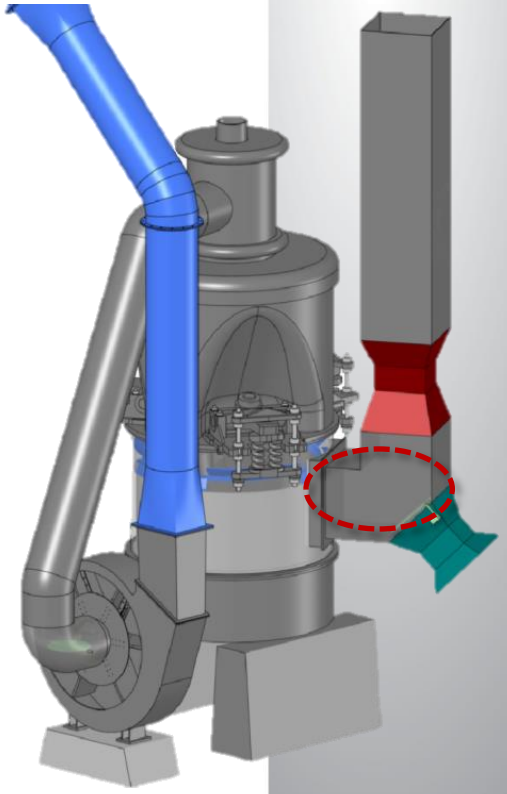
- Temperature and air-to-fuel ratio is very high under the bowl
- Rejected coal quickly dries and ignites
- Most common location of mill fires



Common Causes of Mill Fires

Poor Airflow Control

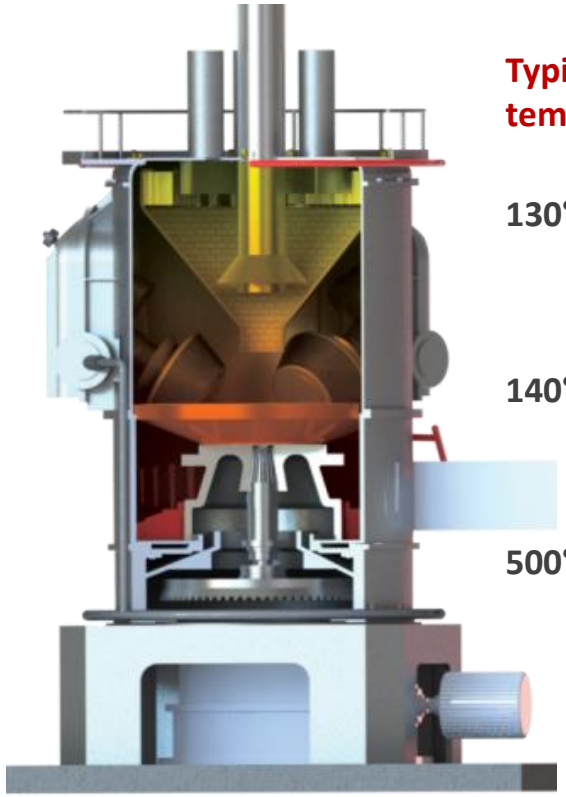
- Excessive airflow to the pulverizer
  - Provides an abundant source of air for combustion of ignition sources including smoldering coal in the classifier, pulverizer or raw coal under the bowl
- Insufficient airflow to the pulverizer
  - Sufficient air velocity should be maintained at all loads to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



PROGRESSION OF A MILL FIRE

PROGRESSION OF A MILL FIRE

- Coal Feed is Interrupted
- High temperatures migrate upward into the grinding zone
- Air-to-Fuel Ratio Increases
- Ignition ---Fire Occurs



MILLPRO -

THE **REVOLUTIONARY**, **PROACTIVE** PROTECTION SYSTEM FOR COAL FIRED POWER PLANTS

MillPro vs. Traditional Systems

	MillPro	Steam/ CO_2	Water /Fog
Inhibits mill excursions during start-up & shut-down	■	■	■
Inhibits mill excursions due to coal feed interruptions	■		
Internal fire suppression/extinguishing system	■		
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	■		■
In case a fire does occur, accelerated fire suppression and heat removal results in minimizing damage to mill internals	■		

LESS RISK

MORE EFFICIENT

MORE EFFECTIVE

LOWER COST

MillPro vs. Traditional Systems

Steam, CO_2 and N_2 Inerting Systems

- Achieving an “inert” environment inside a coal mill, the O_2 level should fall below 14% O_2.
- Only Steam, CO_2 and N_2 (Rare) systems are true inerting systems.
- To know with confidence that an inerting environment is achieved, an O_2 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.
- No Fuel flow while inerting; long cycle time before mill is returned to service.
- Reliance on “bottling up” the mill – closed inlet and outlet gates
- Not effective at washing away coal residues, fines and dust that can be combustible or explosive.
- Inerting systems are expensive

LESS RISK

MORE EFFICIENT

MORE EFFECTIVE

LOWER COST

MillPro vs. Traditional Systems

Water Fog Systems

- 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. 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.
- Internal plugging of mill internals and burner lines as a result of coal-water slurry.
- Potential for damage from quenching hot mill internal parts.
- Feeder must be tripped – fuel flow interruption.

LESS RISK

MORE EFFICIENT

MORE EFFECTIVE

LOWER COST

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ALWAYS ON GUARD

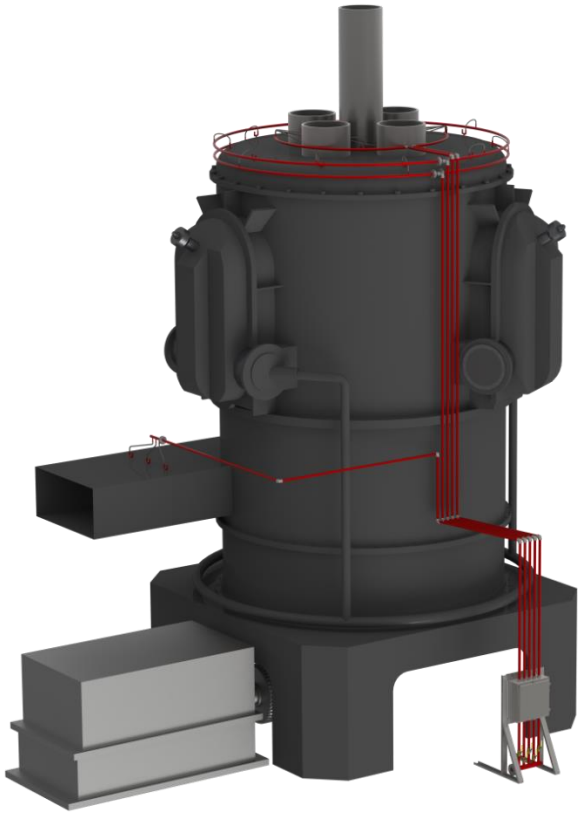
MillPro Mill Protection System

- Incorporates
  - Mill outlet temperature management
  - Continuous encapsulation of combustibles
  - Fire suppression
- Operates continuously while mill is in service
- Pro-actively manages temperature in mill to reduce chance of mill trips due to major event

PROACTIVE VS. REACTIVE

DESIGNED FOR ALL MAJOR MILL TYPES

B&W MPS



CE Raymond Bowl Mills

Doosan Babcock
E-Type

Rapid Suppression/Extinguishment

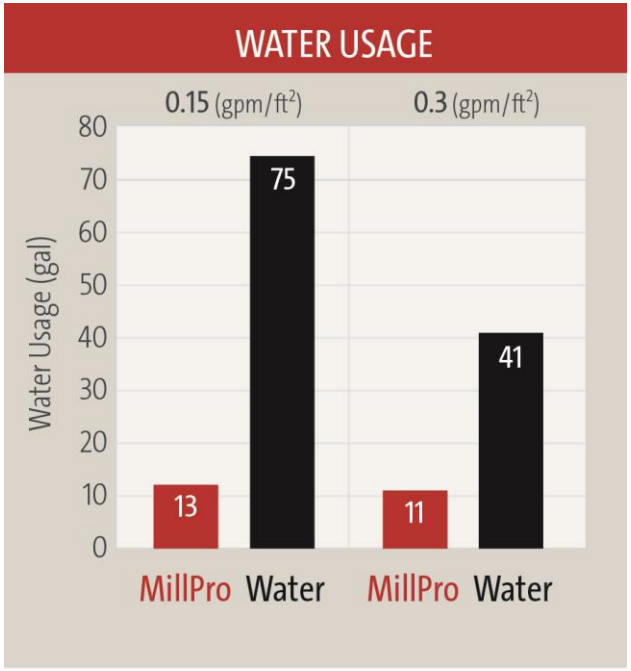
- Key to the MillPro System – the MillPro TS-EA
  - Controls the temperature inside the mill environment
    - More effective than traditional solutions or water alone
  - Unique molecular design
    - allows for specific alignment within a water droplet to accomplish significantly higher heat reduction
  - 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

MillPro Temperature Suppressant Encapsulating Agent (MillPro TS-EA)

Advantage

Significantly Less Water Usage

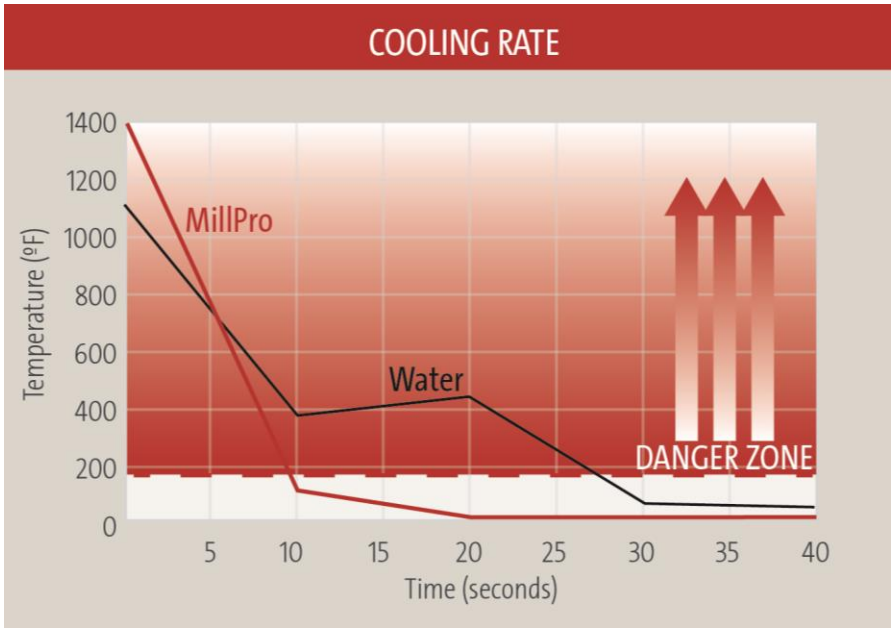
- At the same application density, MillPro utilizes as much as 83% less water to extinguish the same fire



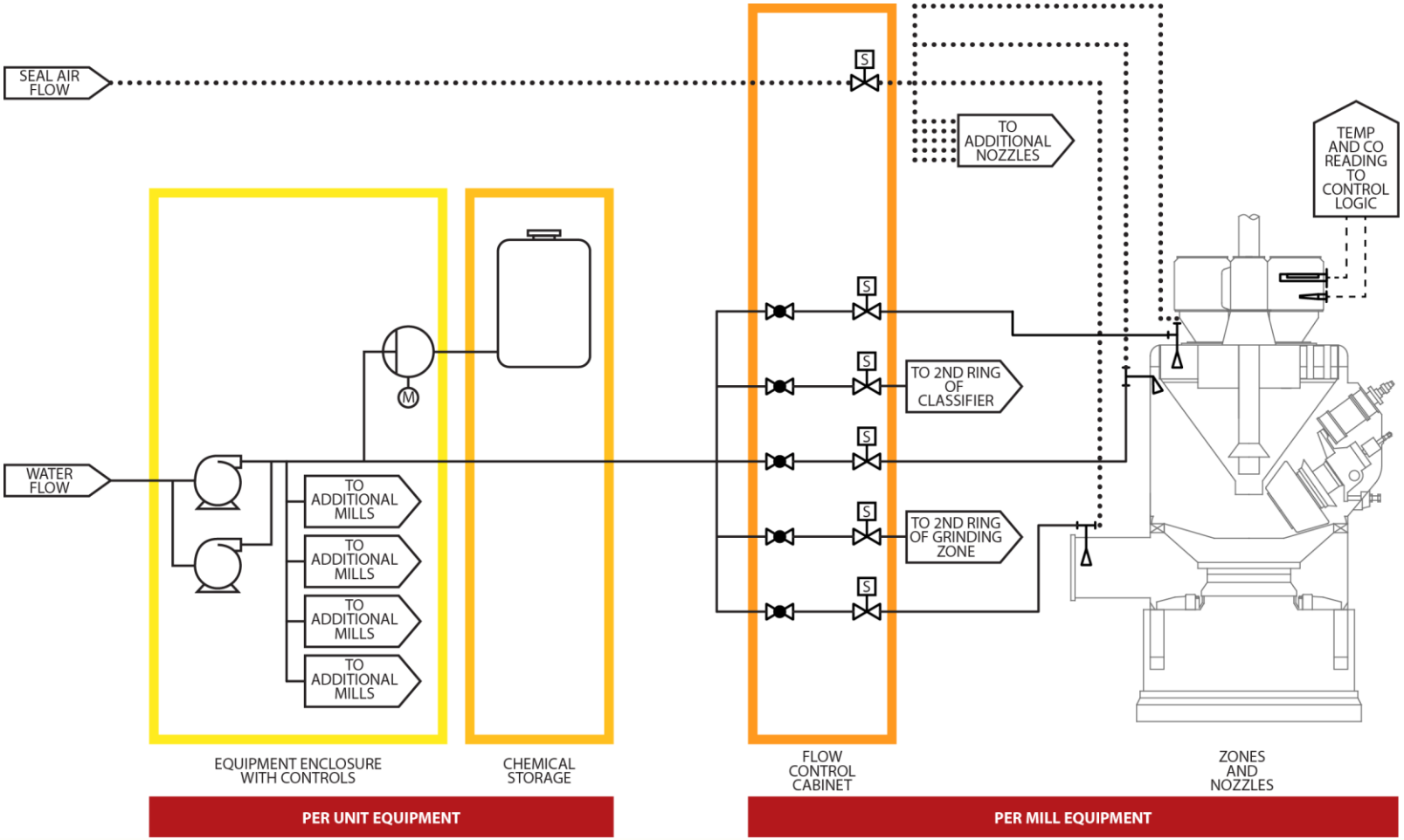
Advantage

Remarkably Faster Cooling

- At the same application density of 0.30 gpm/ft2, the temperature of the MillPro TS-EA drops to 118˚F in 10 seconds, 3 times faster than plain water

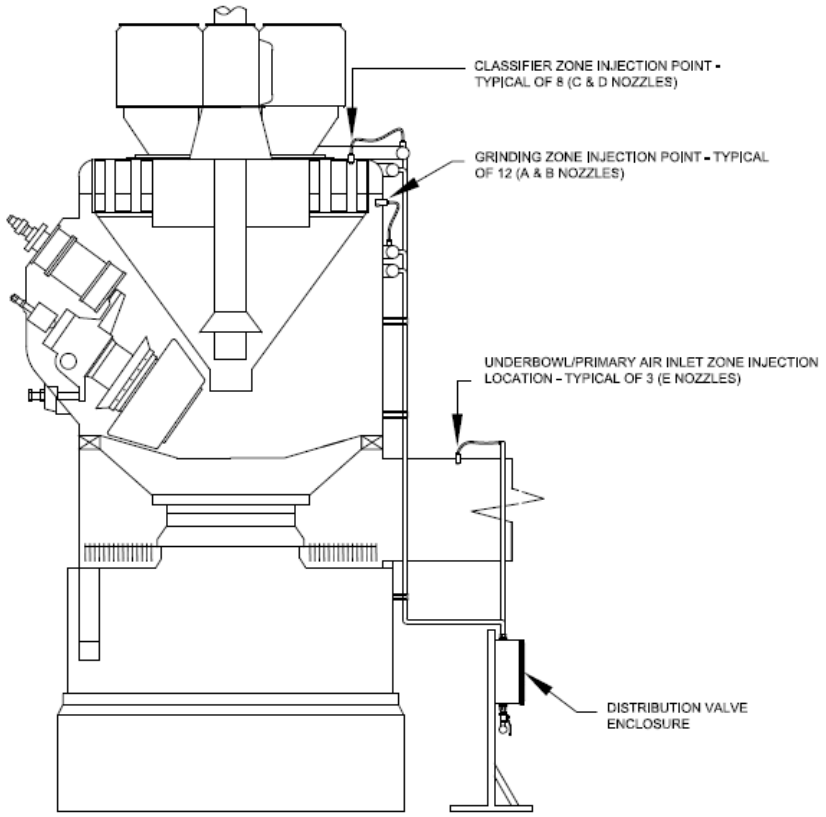


Major Subsystems

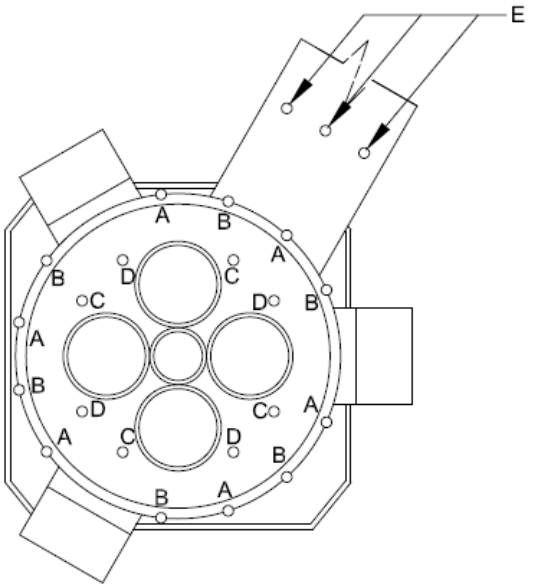


Nozzles

TYPICAL PIPING AND PANEL LAYOUT

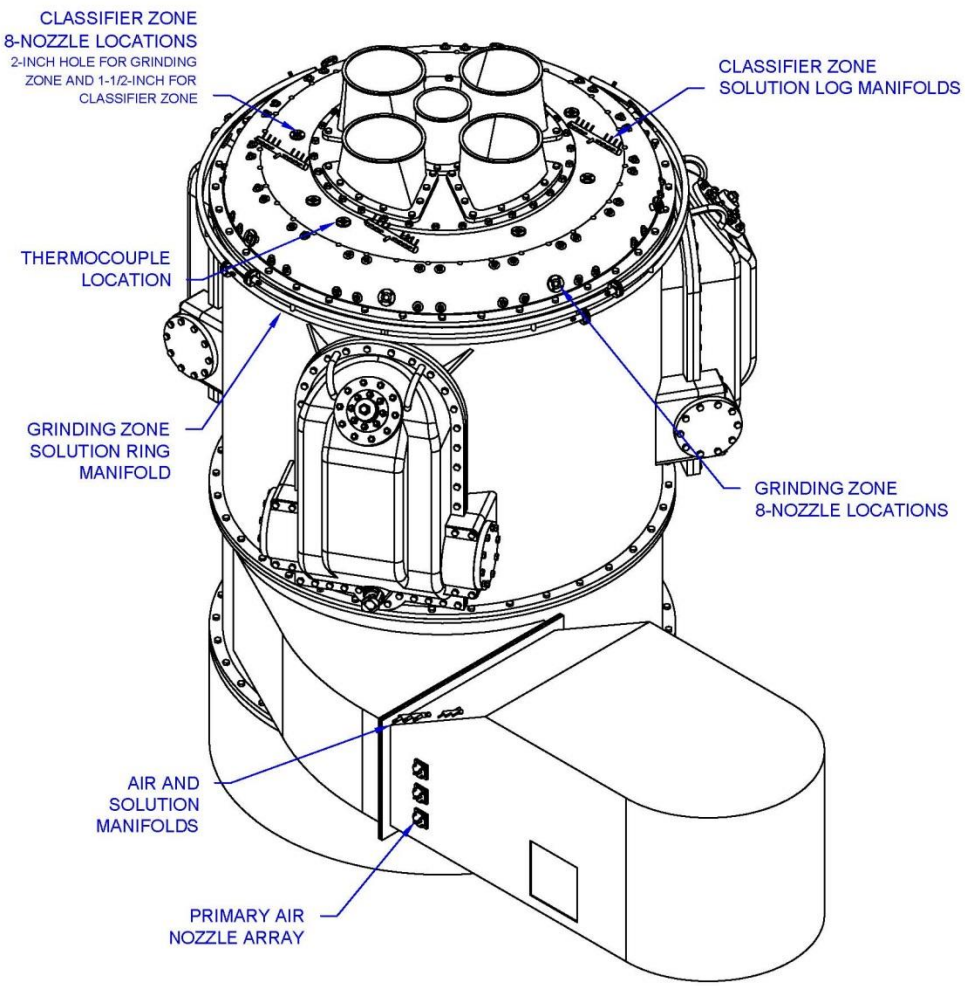


NOZZLE INSERTION POINTS

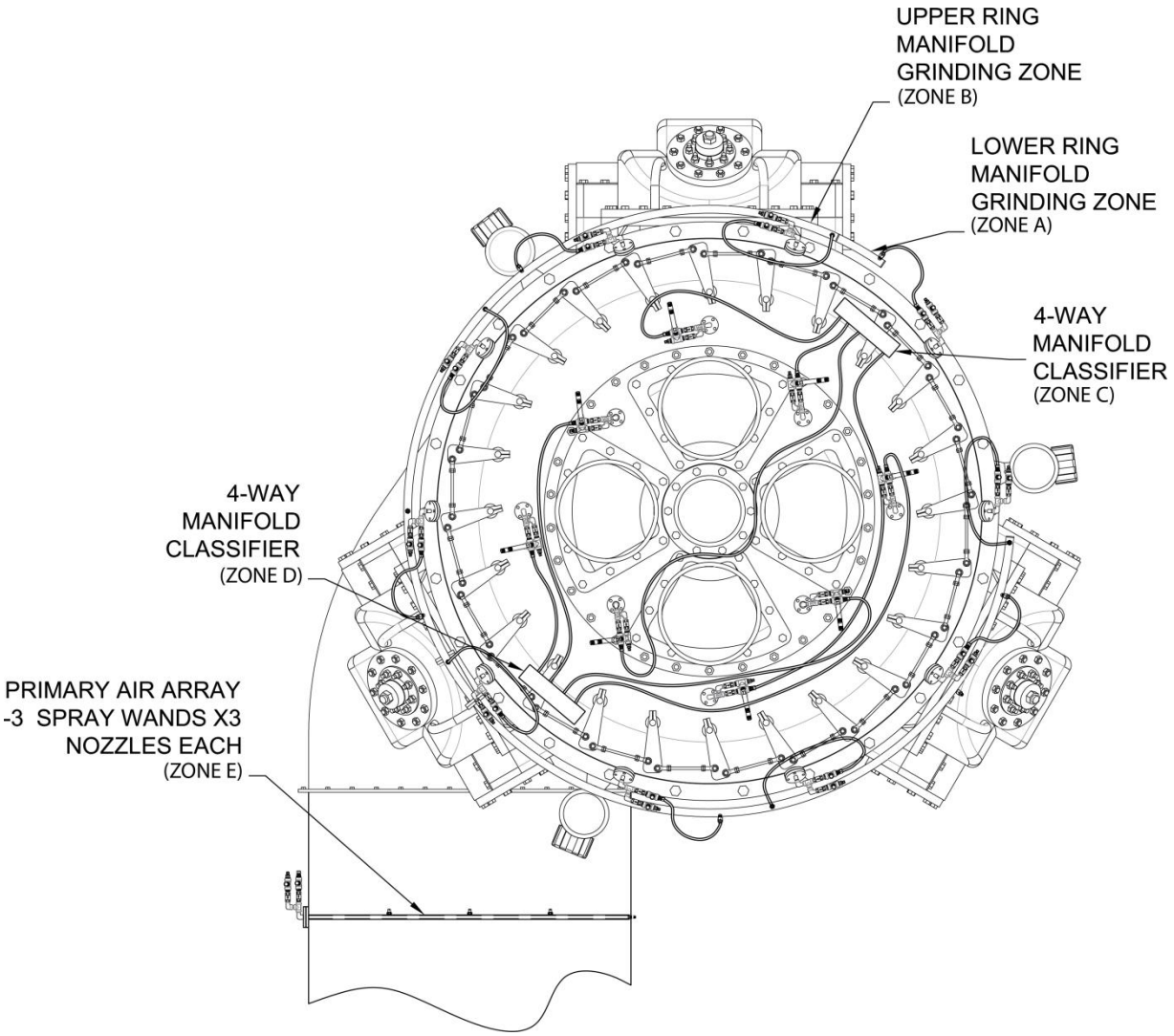


NOZZLE/INSERTION POINT KEY	
DESIGNATION	SPRAY CHARACTERISTICS
A	30° FULL CONE SPRAY NOZZLES
B	30° FULL CONE SPRAY NOZZLES
C	60° FULL CONE SPRAY NOZZLES
D	60° FULL CONE SPRAY NOZZLES
E	90° FINE MIST NOZZLES

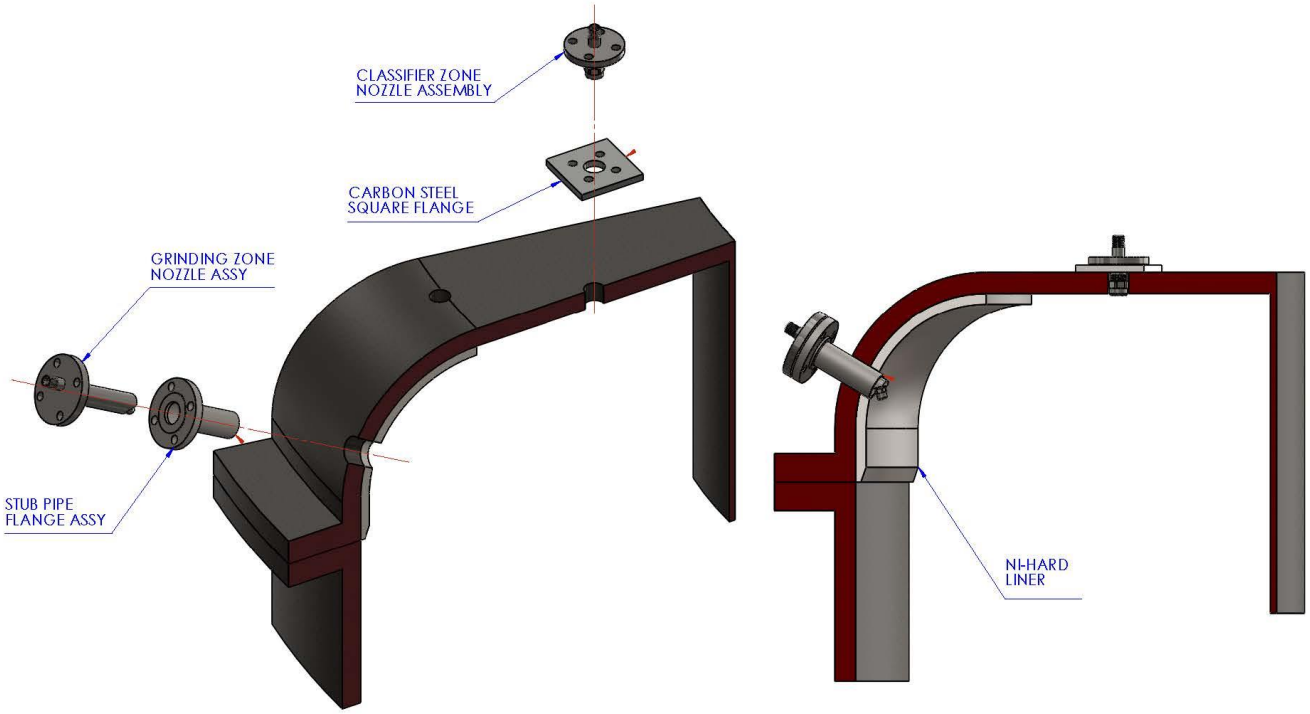
Nozzles


CLASSIFIER ZONE
8-NOZZLE LOCATIONS
2-INCH HOLE FOR GRINDING ZONE AND 1-1/2-INCH FOR CLASSIFIER ZONE
CLASSIFIER ZONE
SOLUTION LOG MANIFOLDS
THERMOCOUPLE LOCATION
GRINDING ZONE
SOLUTION RING
MANIFOLD
GRINDING ZONE
8-NOZZLE LOCATIONS
AIR AND
SOLUTION
MANIFOLDS
PRIMARY AIR
NOZZLE ARRAY

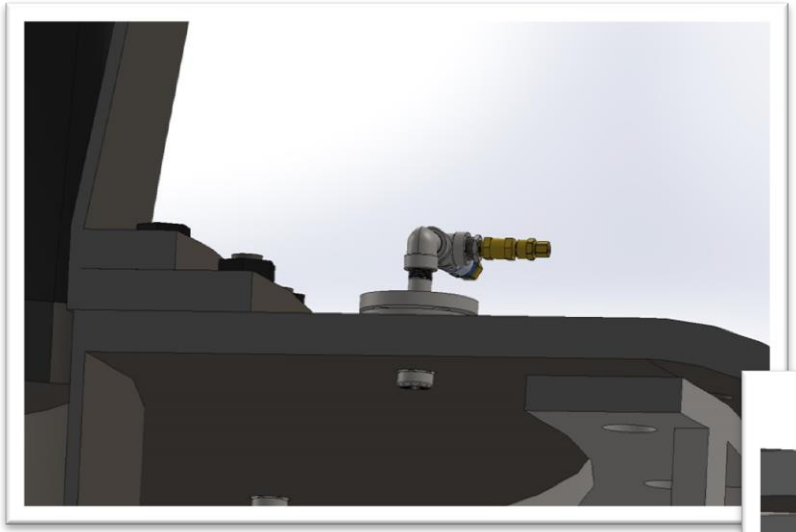
Nozzles

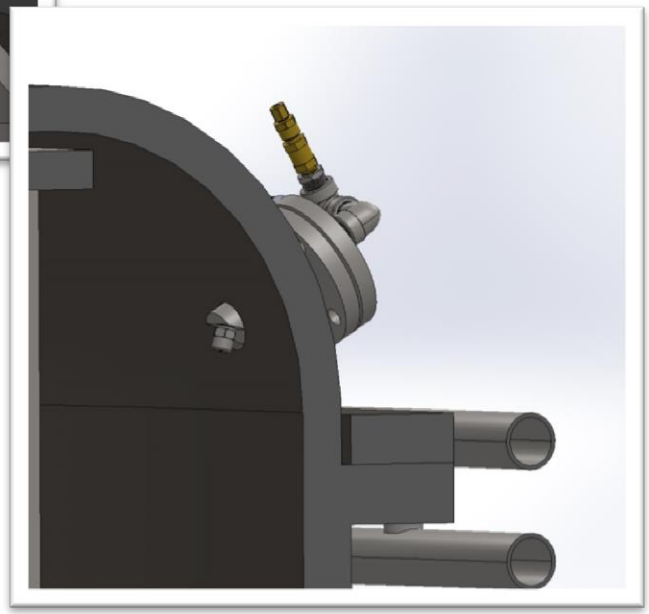

UPPER RING
MANIFOLD
GRINDING ZONE
(ZONE B)
LOWER RING
MANIFOLD
GRINDING ZONE
(ZONE A)
4-WAY
MANIFOLD
CLASSIFIER
(ZONE C)
4-WAY
MANIFOLD
CLASSIFIER
(ZONE D)
PRIMARY AIR ARRAY
-3 SPRAY WANDS X3
NOZZLES EACH
(ZONE E)

Nozzles

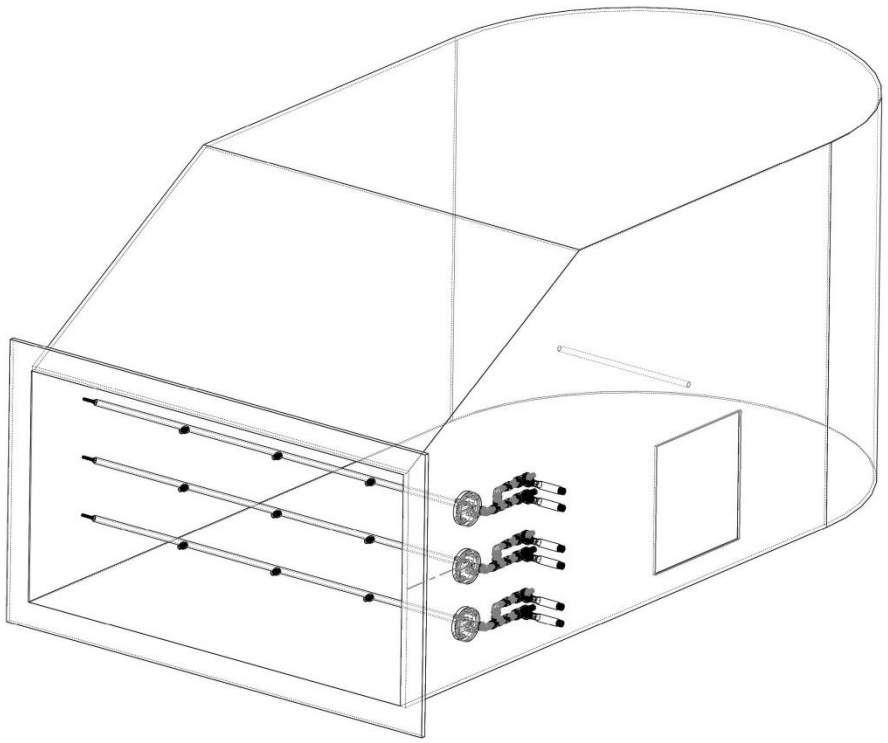

CLASSIFIER ZONE
NOZZLE ASSEMBLY
CARBON STEEL
SQUARE FLANGE
GRINDING ZONE
NOZZLE ASSY
STUB PIPE
FLANGE ASSY
NI-HARD
LINER

Nozzles

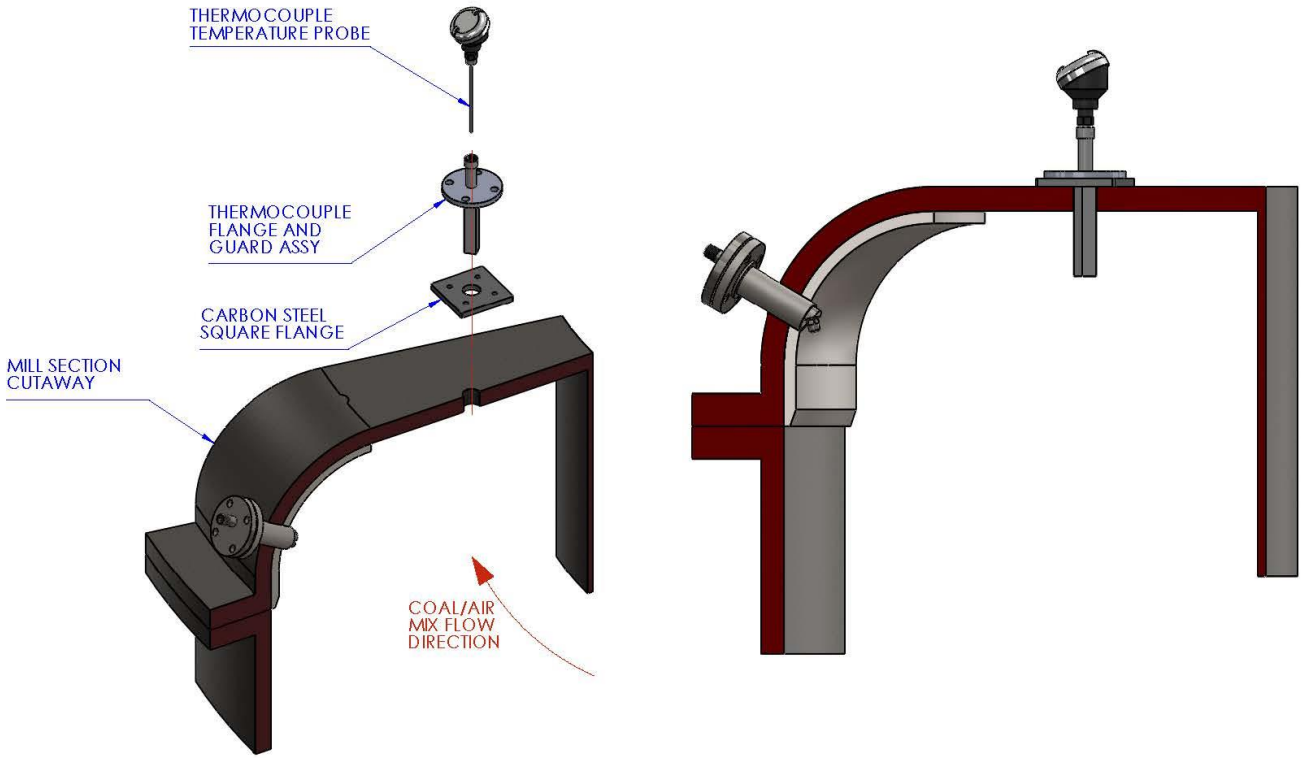




Nozzles



Thermocouple



CO Sensors

MILLPRO -
MODES OF OPERATION

Modes of Operation

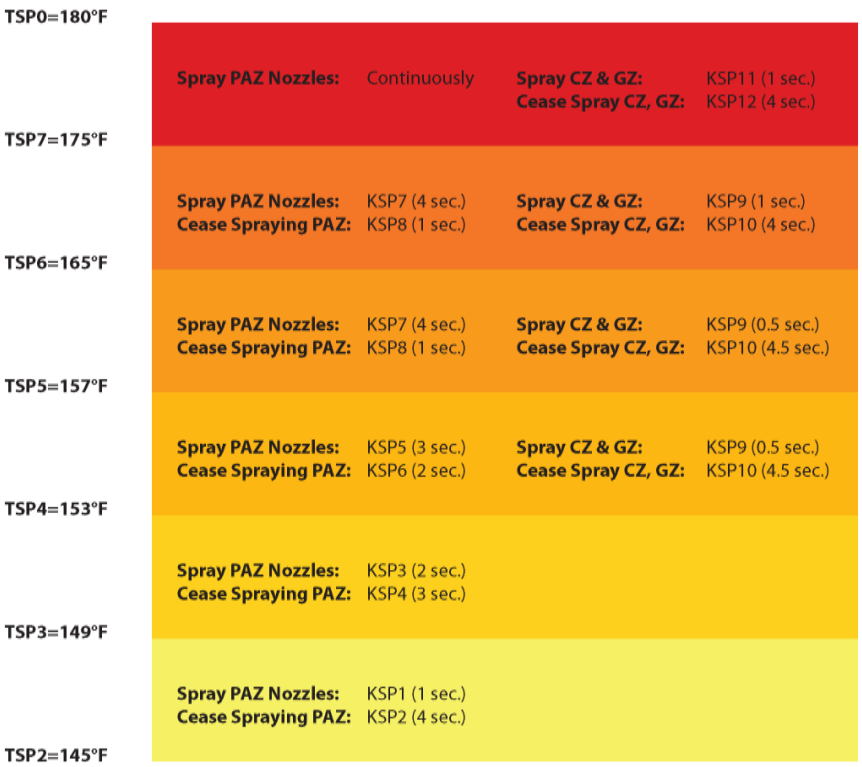
- Temperature
- Coal Feed Interruptions
- Start-Up & Shutdown
- Manual (Hand) Modes

Temperature Excursions

- While mill is in service
- Initially
  - A few short bursts of spray in the underbowl (PA duct) occurs well below the blast gate temperature setpoint.
- If Temperature or CO continue to rise
  - Longer bursts of spray in the underbowl (PA)
  - As temperature rises towards blast gate set point, classifier (single zone), grinding zone (single zone) and underbowl spray in increasingly longer bursts
- At a temperature just below the blast gate set point
  - All spray zones fire continuously
- After the blast gate closes
  - Continuous spray in all zones persists in order to completely cool the mill internals and encapsulate combustibles

Modes of Operation

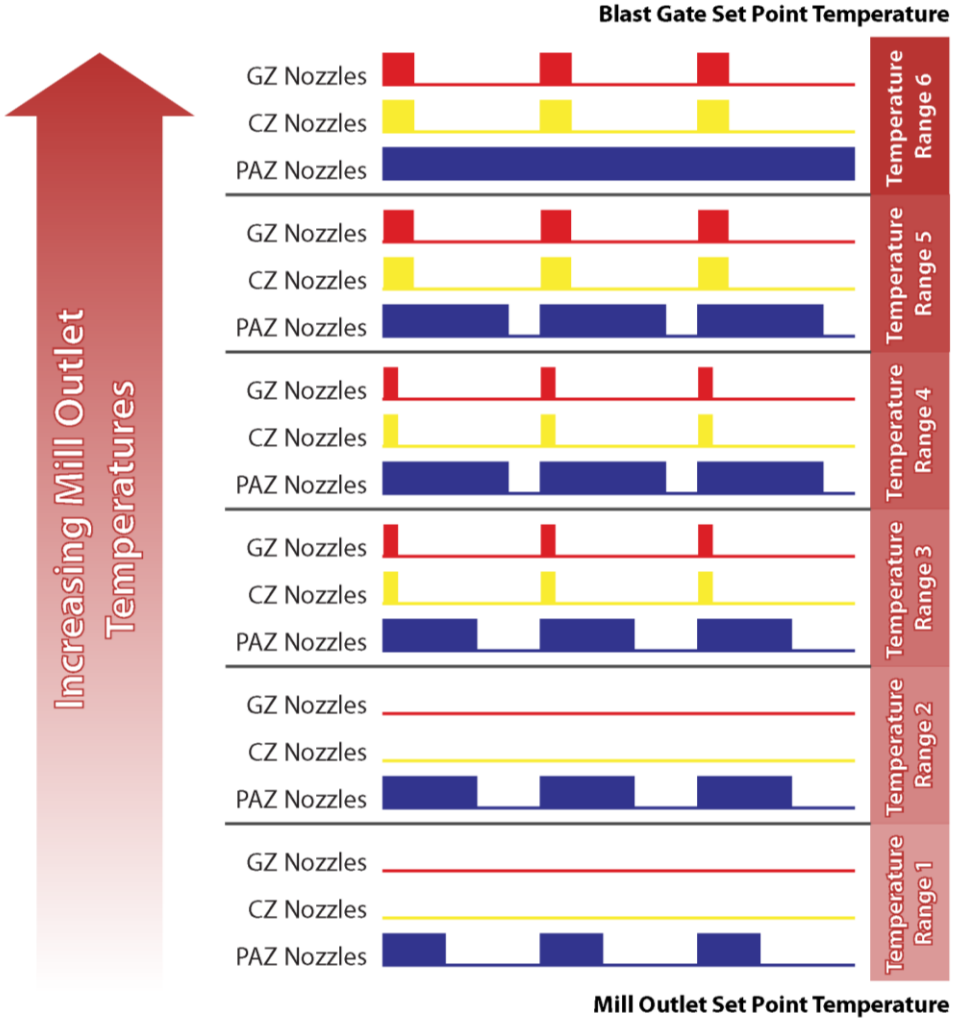
Temperature Excursions



AS TEMPERATURES IN THE MILL RISE, THE SPRAY INTENSITY INCREASES.

Modes of Operation

Temperature Excursions



AS TEMPERATURES IN THE MILL RISE, THE SPRAY INTENSITY INCREASES.

Coal Feed Interruptions

- In instances of the feeder trips or other indication of interrupted coal feed into the mill
  - Intermittent bursts of solution flow keep the mill temperature under control until the blockage is cleared
  - Spraying occurs in the underbowl region, classifier and grinding zone

Modes of Operation

Dirty Mill Trip

- If the mill trips while loaded with coal
  - All nozzles spray continuously for 1 minute to wash down the mill
  - Combustibles exit through the pyrite hopper
  - Spraying occurs in the underbowl region, classifier and grinding zone

Modes of Operation

Start-up & Shutdown

- During start-up
  - System sprays in the classifier (single zone), grinding zone (single zone) and underbowl in frequent bursts that taper off as temperatures in the mill stabilize
  - The mill is sniffed for CO (ignition source) before startup
- During shutdown
  - System sprays in the classifier (single zone), grinding zone (single zone) and under bowl first in short, infrequent bursts that become more and more frequent
- If the mill is taken offline long term
  - Continuous spray may be optionally used to completely cool the mill and encapsulate combustibles for maintenance purposes

Manual (Hand) Modes

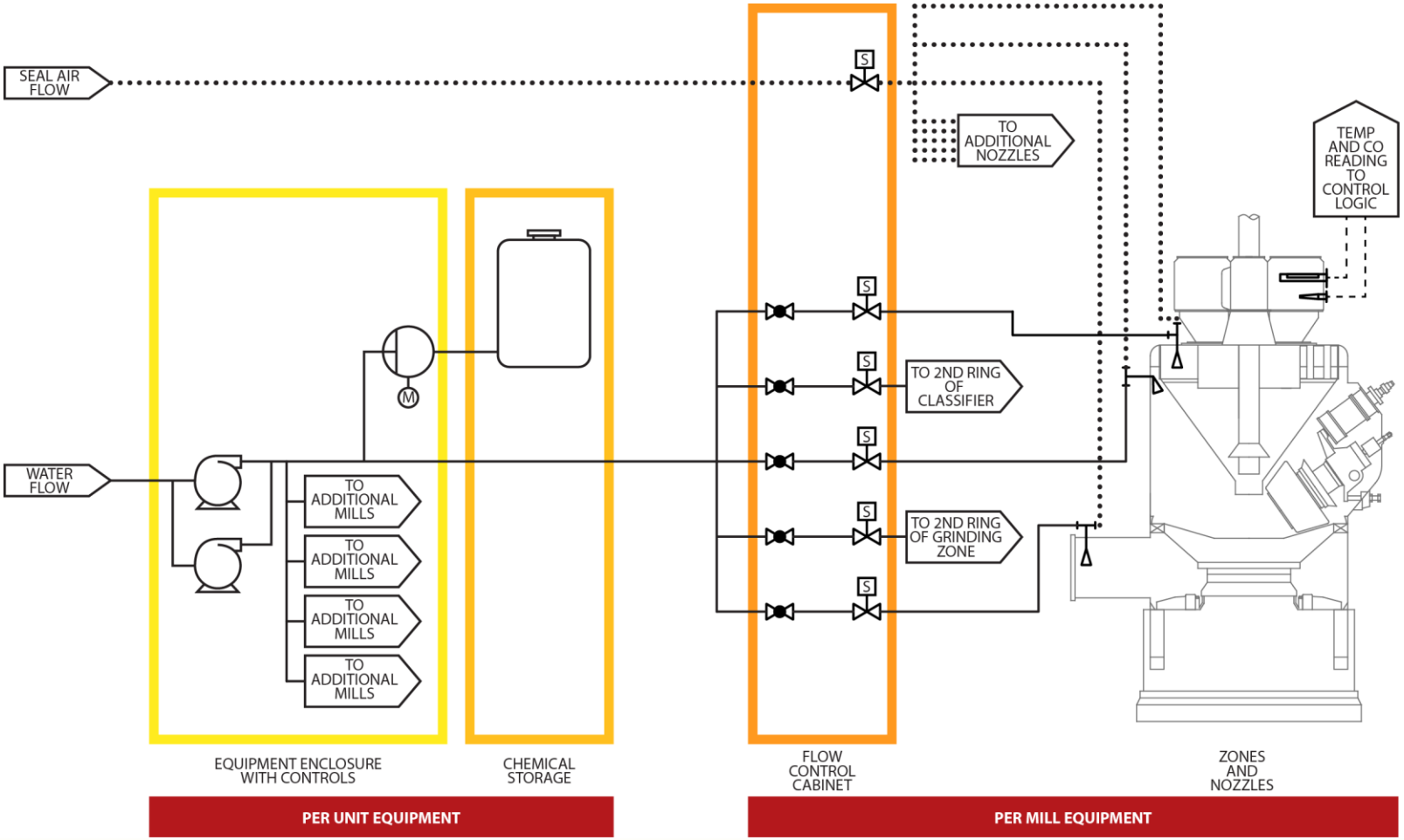
- The system may be set into hand mode and individual spray zones or entire mills may be activated
- Some reasons for manually triggering spray zones include
  - Observation of burning coal in pyrite reject area
  - Cooling the mill prior to entering the confined space
  - Encapsulating combustibles (effectively inerting) in the confined space of the mill prior to maintenance
  - Internal wash down either with solution or clean water by opening the solution bypass valve

MILLPRO -
MAJOR SUBSYSTEMS

Major Subsystems

- Equipment Enclosure with Controls
- Chemical Storage
- Flow Control Cabinet (FCC)
- Zones and Nozzles
- Purge Air
- CO & Temperature Excursion Sensing

Major Subsystems



Major Subsystems

Equipment Enclosure with Controls

- Will accommodate all mill types/models
- Multi point application
- Houses multiple water pumps and multiple chemical pumps
- Isolation and/or bypass valves for:
  - Water pump isolation/bypass
  - Chemical metering pump bypass (to allow clean water to be used for housekeeping)
- Houses PLC and control equipment
- Heated/ventilated
- Accommodate any voltage configuration

Major Subsystems

Chemical Storage

- Standard size 330 gal, self contained storage tote
- Heated tote option
- Larger sizes available as required

Major Subsystems

Flow Control Cabinet (FCC)

- Standard design for application
- Single cabinet assigned to each mill
- Electronically actuated solenoid valves
- Individually controlled, multi point outlet zones within each cabinet:
  - 2 for the 2 sets of classifier zone nozzles
  - 2 for the 2 sets of grinding zone nozzles
  - 1 for the primary air inlet zone
- Fully controlled, demand based operation to suit the needs of mill.
- Proven performance and reliability

Zones and Nozzles

- Three typical areas of coverage
  - Classifier injection point (typ. 8x)
  - Grinding injection point (typ. 8x)
  - Under bowl / primary air inlet injection point (typ. 3x)
- Multi-orifice fine mist, high flow nozzles at classifier provides a high cooling rate in classifier and fuel lines
- Full cone, medium droplet type nozzle at grinding zone provides full coverage
- Fine mist type nozzles at PA duct/underbowl zone provides superior cooling
- Nozzles secured to mill with welded flanges
- Hydraulically balanced fluid flow to promote efficient delivery of protection at each zone

Purge Air

- To keep nozzles from plugging, a continuous stream of air (usually from seal air systems) is supplied to every nozzle
- When solution is supplied to the mill, a single air valve (solenoid type) is closed halting air supply to all nozzles
- Check valve on the air side keeps solution from running up into the air lines when air supply is shut off
- Flow switch on the water supply side indicates when a nozzle is plugged or eroded

CO &Temperature Excursion Sensing

- Thermowells and CO monitoring equipment are installed in the mill outlet
- Not all fires and puffs are preceded by a measureable CO spike
  - Likewise, not all are preceded by a measurable temperature excursion
- By installing both CO and Temperature monitoring equipment, the likelihood of the onset of a fire going undetected is greatly reduced

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Mill Protection System

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