Inerting System Design for Medium Speed Vertical Spindle Coal Pulverizers

The PRB Coal Users' Group plans to develop a Design Guide for Mill Inerting as an aid to users when designing a mill inerting system. This is a first draft document by the The Group on the subject of mill inerting. Feedback is encouraged.

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PREFACE

This design guide has been prepared in cooperation with the PRB Coal Users' Group Subcommittee on Mill Inerting, and as many of the applicable pulverizer manufacturers as would participate. The development model for this design guide was to:

1. Understand the problems and concerns related to coal pulverizer fires and explosions,
2. Review and understand each pulverizer manufacturer's guide specifications for inerting, clearing and fire mitigation,
3. Develop a resulting composite design guide that addresses all of the above, noting and explaining exceptions and intentional omissions, and
4. Add technical improvements for consideration where applicable.
5. Encourage the user to apply both the manufacturer's guide specifications and this design guide with sound professional engineering judgment, including results testing.

SCOPE AND APPLICATION

This design guide has been prepared to address pulverizer inerting for vertical spindle, medium speed coal pulverizers. Examples of this type of coal pulverizer are the Alstom HP, B&W MPS, Babcock Power MPS, and the Foster Wheeler MB and MBF. The application of this design guide may be subject to modification as required by the particular equipment manufacturer. Other coal pulverizers also exist which may be included, but were not studied here. This design guide does not address fogging, fire detection or fire fighting.

This design guide addresses pulverizer explosions and mitigating the risk for those explosions. Pulverizer explosions may occur when all of the following conditions are met:

- Either combustible gasses or pulverized coal (fuel), or both, is in suspension within the pulverizer internal environment,
- The oxygen volumetric concentration within the pulverizer internal environment is above the explosive limit appropriate for the material and internal pressure,
- The pulverizer internal environment air/fuel ratio is within appropriate explosion limits, and
- An adequate ignition source is available.

The fuel and air conditions may be achieved when the coal feed rate is either 1) Just increasing from zero (startup) while air flow is maintained, or 2) interrupted while air flow is maintained (shutdown). An explosion is then possible if an adequate ignition source exists once the mixture transitions into an explosive air/fuel ratio.

Coal pulverizers normally operate in a safe mode, with the air-to-fuel ratio outside of explosive limits, and without the presence of a suitable ignition source. However, transitional operations such as pulverizer startup, pulverizer shutdown and emergency shutdown places coal pulverizing equipment, along with associated equipment and personnel, at risk via passing the coal pulverizer's internal environment into the range on explosive limits.

PRECAUTIONS

This design guide is intended to be a component of the design; Not a specification for the complete design. The designer, plant operations personnel and plant maintenance personnel should all review this design guide, integrate it into the design with the manufacturer's recommendations and local plant installation considerations. A designer capable of applying more complete and rigorous analysis to special or unusual situations should exercise that ability is the design. There is a wide variety of fuels, primary air parameters, coal pulverizers, pulverizer equipment, inerting media and other application parameters to consider in the inerting system design and implementation as this design guide is being applied. The objective is always complete safety of the plant personnel and plant equipment.

DEFINITIONS

Coal Burner Safety Shutoff Valves: The automatic open/close valve included in each coal conduit for the purpose of toggling the admission of pulverized coal and primary air into the furnace. The Coal Burner Safety Shutoff Valves are usually located on top of the coal pulverizer.

Design Isolation Inert Flow Rate: The mass quantity of inerting media required to achieve Inert Status within the target time period.

Inert Status: A condition of the pulverizer internal environment in which the volumetric O_2 concentration is low enough to be considered inert, usually below 14% O_2 on a wet basis.

Maintenance Inert Flow Rate: The reduced amount of inerting media required to maintain Inert Status once Inert Status has been achieved. Maintenance Inert Flow Rate must overcome losses cause by leakages and steam condensation.

Transport Steam Flow: The mass quantity of inerting steam required to achieve and maintain Inert Status with the pulverizer inlet dampers and Coal Burner Safety Shutoff Valves open and primary flow at minimum. Application and use of Transport Steam is not addressed in this design guide.

INERTING SYSTEM DESIGN CONSIDERATIONS

Ierting Media Selection

The user must select an inerting media before designing the inerting system. Below is a discussion of the three most common inerting media: Steam, CO_2 and N_2. Flue gas recirculation is also used, but not discussed here. This design guide addresses only steam as an inerting media because steam is the most commonly used inerting media, and usually is most plentiful and least expensive. This design guide can still be used for other inerting media, with consideration given for using the alternative inerting media.

Steam:

Steam is a cost effective method of inerting, and is the inerting media of choice by many users. It works well for both inerting and fire suppression. Steam is significantly less dense that air. One pound of steam will inert approximately 20 cubic feet of pulverizer volume.

The problems with steam are:

- That the steam condenses in the pulverizer, which allows the pulverizer internal environment oxygen content on a volumetric basis to be increase. Thus, it does require a rather significant flow to maintain an Inert Status, even after Inert Status has been achieved. For that reason, a significant amount of superheat is recommended.
- Inerting steam piping must be maintained warm when in service but not flowing.
- Possible unavailability of steam during initial startup or restart.

CO_2

The molecular weight of CO_2 is 44, so it is heavier than air. One pound of CO_2 will inert approximately 7 cubic feet of pulverizer volume. Required flow rate is approximately three times that of steam. However, maintenance flow only has to overcome leakage, and not condensation.

The problems with CO_2 are:

- The primary purpose of the CO_2 storage tank may be for other equipment on site.
- The CO_2 system is prone to freezing with extended use.
- Care must be taken to protect personnel and equipment from the extreme cold of this media.
- CO_2 cannot be “manufactured” on site, so it must be purchased and stored on site.
- Confined space entry procedures must be followed with this media, since it is heavier than air and will settle in the low areas of the pulverizer.

N_2

The molecular weight of N_2 is 28, so it is slightly lighter than air. One pound of N_2 will inert approximately 11 cubic feet of pulverizer volume. Required flow rate is approximately one and one-half times that of steam. However, maintenance flow only has to overcome leakage, and not condensation.

The problems with N_2 are:

- Nitrogen is not commonly used in power plants except for boiler caps, so the infrastructure to support an inerting system usually does not exist.
- The N_2 system is prone to freezing with extended use.
- Care must be taken to protect personnel and equipment from the extreme cold of this media.
- N_2 cannot be "manufactured" on site, so it must be purchased and stored on site.
- Confined space entry procedures must be followed with this media, since it very closely approximates the weight of air and not easily displaced by dispersion.

Steam Source Considerations

Steam pressure, temperature, and available quantity are all critical for proper design.

Steam Quantity:

The system designer must carefully consider the quantity of steam required per pulverizer for inerting, the amount of time allowed for reaching Inert Status, the quantity of pulverizers, the quantity of pulverizers to be inerted simultaneously, and the steam pressure and temperature which determine steam volume. All of these parameters combined will determine steam flow and pipe size in the supply header and each pulverizer header. One additional consideration: Some manufacturers specify "transport steam" in addition to inerting steam. Transport steam is enough steam to achieve and maintain Inert Status at minimum primary air flow rate. The amount of transport steam can easily exceed ten times the Design Isolation Inert Flow Rate. This can be a major consideration.

Steam Pressure:

Manufacturers recommend a steam supply between 50 psig and 150 psig, usually around 60 psig.

Steam Temperature:

Steam temperature is not as important as the amount of steam superheat. An increase in the amount of superheat will result in a lower tendency for condensation, which in turn reduces Maintenance Inert Flow Rate. If transport steam is to be used, then high superheat is a necessity. Condensation in the long coal conduits will result in a "fines soup" instead of clearing fines from the conduits.

Steam piping Considerations:

The inerting steam piping must be kept warm when not in use. A warming steam flow system should be incorporated into the design.

Inerting system piping is kept as small as possible because it wraps around the pulverizer and inhibits access to other components. However, sound should be a design consideration. Small piping causes high velocity and in turn high noise.

Nozzle Consideration:

Each manufacturer provides recommendations for locating nozzles. Following manufacturer's recommendations, each nozzle should also consider:

- The molecular weight of the chosen inerting media. Steam for example, will rise from the nozzle, while CO_2 will drop.
- Nozzle exit velocity should be kept as low as possible, preferable below 15 fps. High velocity nozzles may raise dust and actually increase the risk of explosion.
- Do not aim nozzles directly at horizontal surfaces which may collect settled fines.
- Do not aim nozzles directly towards any pulverizer component. This is especially true for CO_2 or N_2 nozzles which will deliver very cold fluid.
- Certain nozzles are located for a specific purpose rather than general coverage. Nozzles beneath the grinding table are required for example, because 1) Of the large amount of fines in this area after a trip, and 2) This is the primary air inlet area, with flow from this point into the pulverizer. Nozzles should also be located inside captive areas such as the inner classifier cone.
- This design guide includes the addition of a full time air purge to keep nozzles clean when not flowing steam. This system is interrupted during inerting to minimize inert media dilution.

PULVERIZER NORMAL STARTUP

Application – This design guide applies to an empty and cleared pulverizer on a normal startup.

> *NOTE: If this is the first pulverizer to be started in a "black plant", then steam inerting may not be available. All precautions must be made to mitigate risk of fire and explosion during startup.*

1. All pre-pulverizer start tasks must be completed, including inspections, lubrication system status, hydraulic system status, purge status, adequate furnace air flow, igniters in service, etc. See manufacturer's guide specifications for start-up procedure.
2. Confirm that there is no fire present in any portion of the pulverizing system.

3. If a fire is detected, go to manufacturer's Firefighting Mode and do not proceed until evidence of fire is not present.
4. Confirm that inerting steam line is warm (See Inerting System Design).
5. Confirm that inerting steam supply pressure is within design operating range.
6. Confirm that Coal Burner Safety Shutoff Valves are all closed.
7. Close hot primary air damper and confirm.
8. Close primary air capacity damper and confirm.
9. Open tempering air damper to 100% and confirm.
10. Place seal air system in service and confirm adequate d/p.
11. Prove igniters in service.
12. Start PA fans, or confirm that primary air system is in service and primary air is available to the hot and tempering air dampers.
13. If this is the first pulverizer to be placed in service, open inerting steam block valve, thus charging inerting steam header to all pulverizers (Otherwise already open).
14. Remove fogging and inerting nozzle air purge from service. This action should occur automatically.
15. Initiate inerting steam flow to this pulverizer at the Design Isolation Inert Flow Rate as determined by testing (See Inert Status Confirmation).
16. Wait for confirmation that the pulverizer internal environment has reached Inert Status, if equipped with closed loop feedback via wet basis O_2 analyzer. If not equipped, then wait for a time out as determined by testing (See Inert Status Confirmation).
17. Once Inert Status is confirmed, reduce inerting steam flow to Maintenance Inert Flow Rate as determined either by closed loop feedback or by testing (See Inert Status Confirmation). This reduction should be programmed to occur automatically.
18. Maintain Inert Status until ready to complete pulverizer startup.
19. When ready to complete pulverizer startup:
    a. Start pulverizer.
    b. Open coal feeder inlet shutoff gate.
    c. Start coal feeder at minimum feeder speed.
    d. Two minutes after initial coal (consult with pulverizer manufacturer on time), open primary air capacity damper to a minimum setting, open Coal Burner Safety Shutoff Valves, and adjust primary air flow to minimum.
    e. If not NFPA 85 Class 1 igniters, prove main flame per NFPA 85.
    f. Place pulverizer exit temperature control in automatic.
20. Five minutes after initial coal (consult with pulverizer manufacturer on time), stop all inerting steam.
21. Place fogging and inerting nozzle air purge system back into service.
22. Start-up complete.

PULVERIZER NORMAL SHUTDOWN

Application – This design guide applies to a coal pulverizer embarking upon a normal, controlled shutdown.

1. Place igniters in service.
2. Run coal feeder to minimum and place feeder in manual.
3. Set primary air flow to minimum. If capacity damper is still in automatic, this should occur automatically.
4. Reduce pulverizer exit temperature setpoint to minimum.
5. Set burner air registers to Light-off position.
6. Remove fogging and inerting nozzle air purge from service. This action should occur automatically.
7. Initiate inerting steam flow at the Design Isolation Inert Flow Rate as determined by testing (See Inert Status Confirmation).
8. Close feeder inlet shutoff gate and run all coal off the feeder belt.
9. Stop the coal feeder.
10. Close hot air damper.
11. Open tempering air damper & increase primary air flow to maximum to clear fines).
12. Five minutes after opening tempering air damper (consult with pulverizer manufacturer on time), reduce primary air flow to minimum and close Coal Burner Safety Shutoff Valves.
13. Close primary air capacity damper.
14. Stop coal pulverizer.
15. Remove seal air system from service.
16. Wait for confirmation that the pulverizer internal environment has reached Inert Status, if equipped with closed loop feedback via wet basis O_2 analyzer. If not equipped, then wait for a time out as determined by testing (See Inert Status Confirmation).
17. Once Inert Status is confirmed, reduce inerting steam flow to Maintenance Inert Flow Rate as determined either by closed loop feedback or by testing (See Inert Status Confirmation). This reduction should be programmed to occur automatically.
18. Confirm that there is no fire present in any portion of the pulverizing system.
19. Once it is confirmed that no fire is present, stop all inerting steam flow.
20. If a fire is detected, go to manufacturer's Firefighting Mode.

PULVERIZER RESTART AFTER EMERGENCY TRIP (ie, with coal inventory present)

Application – This design guide applies to a coal pulverizer that has been tripped with fuel in the pulverizer, and will be restarted.

> *NOTE: If this is the first pulverizer to be started in a "black plant", then steam inerting may not be available. All precautions must be made to mitigate risk of fire and explosion during startup.*

1. All pre-pulverizer start tasks must be completed, including inspections, lubrication system status, hydraulic system status, purge status, adequate furnace air flow, igniters in service, etc. See manufacturer's guide specifications for start-up procedure.
2. Confirm that there is no fire present in any portion of the pulverizing system.
3. If a fire is detected, go to manufacturer's Firefighting Mode and do not proceed until evidence of fire is not present.
4. Confirm that inerting steam line is warm (See Fogging and Inerting System Design).
5. Confirm that inerting steam supply pressure is within design operating range.
6. Confirm that Coal Burner Safety Shutoff Valves are all closed.
7. Close hot primary air damper and confirm.
8. Close primary air capacity damper and confirm.
9. Open tempering air damper to 100% and confirm.
10. Place seal air system in service and confirm adequate d/p.
11. Prove igniters in service.
12. Start PA fans, or confirm that primary air system is in service and primary air is available to the hot and tempering air dampers.
13. If this is the first pulverizer to be placed in service, open inerting steam block valve, thus charging inerting steam header to all pulverizers (Otherwise already open).
14. Remove fogging and inerting nozzle air purge from service. This action should occur automatically.
15. Initiate inerting steam flow to this pulverizer at the Design Isolation Inert Flow Rate as determined by testing (See Inert Status Confirmation).
16. Wait for confirmation that the pulverizer internal environment has reached Inert Status, if equipped with closed loop feedback via wet basis O_2 analyzer. If not equipped, then wait for a time out as determined by testing (See Inert Status Confirmation).
17. Once Inert Status is confirmed, reduce inerting steam flow to Maintenance Inert Flow Rate as determined either by closed loop feedback or by testing (See Inert Status Confirmation). This reduction should be programmed to occur automatically.
18. Maintain Inert Status until ready to complete pulverizer startup.
19. When ready to complete pulverizer startup:
    a. Open primary air capacity damper to a minimum setting, open Coal Burner Safety Shutoff Valves, and adjust primary air flow to minimum.
    b. Start pulverizer.

c. Open coal feeder inlet shutoff gate.
d. Start coal feeder at minimum feeder speed.
e. If not NFPA 85 Class 1 igniters, prove main flame per NFPA 85.
f. Place pulverizer exit temperature control in automatic.

20. Five minutes after initial coal (consult with pulverizer manufacturer on time), stop all inerting steam.
21. Place fogging and inerting nozzle air purge system back into service.
22. Start-up complete.

PULVERIZER SYSTEM CLEAN-OUT AFTER EMERGENCY TRIP

NOTE – Following a pulverizer trip, the coal pulverizer contains feed coal, pulverized fines, and all particle sizes in between. The coal conduits and burners also contain fines that dropped out of suspension once primary air flow ceased. If the pulverizer will not be restarted for an extended period of time, all coal must be removed to avoid subsequent fires.

If the furnace is inoperative and fuel/air cannot be transported to the furnace for cleanout, then the coal conduits and burners may have to be dormant for an extended period of time with fines inside. In that case, plant staff must diligently monitor all conduits and burners for evidence of fire until the risk has passed. If the furnace is still in service but this pulverizer cannot be restarted, then the following procedure will apply.

1. Confirm that there is no fire present in any portion of the pulverizing system.
2. If a fire is detected, go to manufacturer's Firefighting Mode and do not proceed until evidence of fire is not present.
3. Confirm that inerting steam line is warm (See Inerting System Design).
4. Confirm that inerting steam supply pressure is within design operating range.
5. Place igniters in service.
6. Confirm that Coal Burner Safety Shutoff Valves are all closed.
7. Confirm that coal feeder inlet gate is closed.
8. Close hot primary air damper and confirm.
9. Open tempering air damper to 100% and confirm.
10. Place seal air system in service and confirm adequate d/p.
11. Start PA fans, or confirm that primary air system is in service and primary air is available to the hot and tempering air dampers.

12. Remove fogging and inerting nozzle air purge from service. This action should occur automatically.
13. Initiate inerting steam flow to this pulverizer at the Design Isolation Inert Flow Rate as determined by testing (See Inert Status Confirmation).
14. Wait for confirmation that the pulverizer internal environment has reached Inert Status, if equipped with closed loop feedback via wet basis O_2 analyzer. If not equipped, then wait for a time out as determined by testing (See Inert Status Confirmation).
15. Once Inert Status is confirmed, open primary air capacity damper, open Coal Burner Safety Shutoff Valves, and adjust primary air flow to maximum to clear fines.
16. Five minutes after establishing minimum primary air flow (consult with pulverizer manufacturer on time), stop all inerting steam.
17. Place fogging and inerting nozzle air purge system back into service.
18. Close all primary air dampers (hot, tempering and capacity dampers) and close Coal Burner Safety Shutoff Valves.
19. Commence with pulverizer manufacturer's pulverizer clean-out procedure to wash pulverizer contents into pyrites hopper.

INERT STATUS CONFIRMATION

The objective of an inerting system is to achieve Inert Status, and maintain Inert Status as long as necessary. Pulverizer manufacturers recommend a specific inerting medium flow rate for each coal pulverizer. One question the system designer may ask is, does the system actually achieve and maintain inert status? This is somewhat of an open-loop control as recommended by the pulverizer manufacturers. This design guide recommends that one of two methods be employed to confirm Inert Status:

- Closed Loop Method: The objective of the inerting steam system is to lower the volumetric O_2 content of the pulverizer internal environment to 14% or less. The closed loop method includes a wet-basis O_2 analyzer installed at each coal pulverizer to continuously sample the volumetric oxygen content of the coal pulverizer internal environment. When pulverizer inerting is initiated, this analyzer output signal becomes a control system feedback. The system setpoint should be at 14% O_2 or less, and the system should modulate the inerting steam valve as required to maintain the setpoint. If steam is the inerting media, then the analyzers must be wet-basis analyzers.
- Open Loop Method: The objective of the inerting steam system is to lower the volumetric O_2 content of the pulverizer internal environment to 14% or less. The open loop method includes testing to determine the necessary inerting steam flow rate and duration required to 1) Achieve Inert Status in the target amount of time, and 2) Maintain Inert Status. Since pulverizer seals and damper seals can wear, and other variables can change the results of these tests, the tests should be repeated periodically and timers

and/or flow rates adjusted accordingly. If steam is the inerting media, then the analyzers used in the testing must be wet-basis analyzers.