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Mill Steam Inerting System Review and Performance Validation

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ABSTRACT

NFPA 85, Chapter 9.5.4 states “A pulverizer that is tripped under load shall be inerted and maintained under an inert atmosphere until confirmation that no burning or smoldering fuel exists in the pulverizer or the fuel is removed.” Pulverizer systems with the potential for a resident inventory of combustible material upon trip must be designed and equipped with an inerting system that is capable of maintaining an inert atmosphere to meet this requirement. Proper design of the inerting system and operating procedure, integrated with the mill operation during start-up, shut down and emergency trip is critical for safe mill operation.

This paper presents a mill steam inerting system review and performance validation. The technology has been applied to ball tube mill systems at Hoosier Energy’s Merom Generating Station. A testing technique, used to validate performance of the steam inerting system at this generating plant, is described. It quantifies the compliance of the steam inerting system to meet NFPA requirements during start-up and shut down of the pulverizer. This type of operation is considered to be the most difficult for inerting as the primary air is flowing through the system. The developed testing approach can be applied to evaluate the performance of either existing or newly installed steam inerting systems. The validation technology, developed based on a ball tube mill system, can be readily applied on other types of mill systems, since the steam inerting principle is the same and inerting system requirements are similar, regardless of different mill types.

INTRODUCTION

In a coal-fired power plant, the coal pulverizer is critical for fuel processing. It is important to operate the pulverizer properly following the OEM specified procedure and NFPA code requirements. The increased use of highly volatile sub-bituminous coal such as Powder River Basin (PRB) coal has further emphasized the need to monitor and maintain appropriate mill operating procedures with inerting systems.

As part of the continuing effort to maintain proper mill system design and operation in coal-fired power plants, Riley Power Inc., a Babcock Power Inc. company has been actively developing technology to validate steam inerting system performance. The developed testing methodology to measure the actual oxygen concentration level in the mill, associated with the steam inerting system validation process per NFPA requirements, is a useful technique to evaluate the reliability of the steam inerting system design and effectiveness.

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COAL PULVERIZING SYSTEM

Figure 1 shows a typical mill system schematic including fuel bunker, feeder, mill, primary air system and relevant dampers. Raw coal is fed from the feeder at a controlled feed rate, to meet boiler steam demand. In the meantime, hot primary air of 300°F to 700°F, depending on coal moisture content, is introduced to the mill to dry the coal and transport it to the burners. The pulverized product from the mill is classified for specified particle size distribution requirements by an integrated or stand-alone classifier (not shown). The acceptable fine particles are delivered to the burners through coal pipes by pneumatic transportation, while coarse particles are re-circulated within the mill system for further particle size reduction.

There are three (3) types of coal pulverizer systems[1] designed for low, medium and high speed to process a variety of coals, from bituminous, sub-bituminous to lignite coals. These machines include Ball Tube Mills (BTM), vertical roller mills and Atrita® (high-speed attrition mills). During operation, ball tube mills and vertical roller mills have a substantial coal inventory and high recirculation rate within the mill system, which increases the importance of utilizing an inerting system on these mills to properly establish and maintain inert atmosphere during mill start-up, shut down and emergency trip. This is particularly important when processing sub-bituminous coal with relatively high volatility and high moisture content as compared to bituminous type coal.

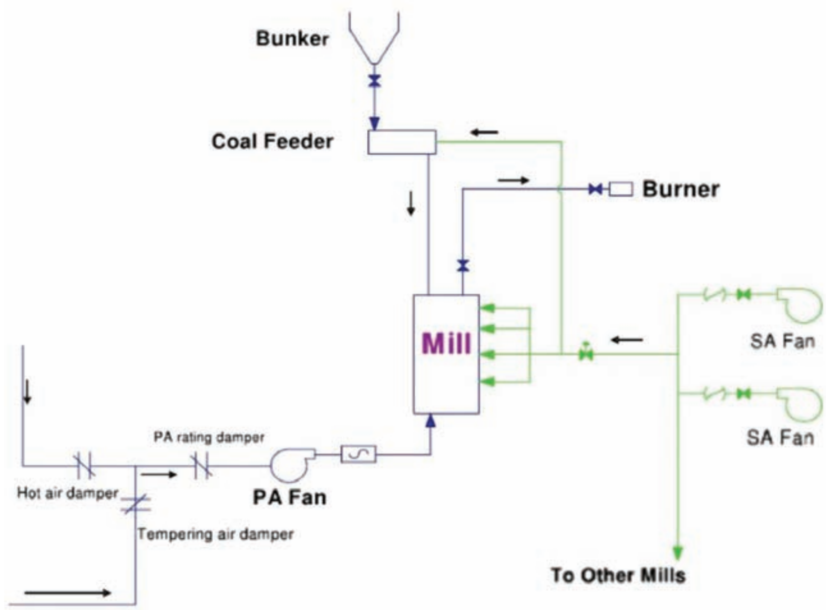

Figure 1 – Typical Mill System

MILL STEAM INERTING SYSTEM REQUIREMENTS

In addition to the requirement by NFPA 85 for inerting a tripped mill system, coal mill OEMs usually recommend that a mill system be inerted during both the normal mill start-up and shut down process. Steam is commonly employed in the power industry for coal pulverizer system inerting, due to its ready availability and cost effectiveness.

During a ball tube mill start-up, Riley Power Inc. recommends a specified steam flow rate to be introduced and mixed with the primary air entering the mill to establish an inert atmosphere in the mill. During mill shut down, the same inerting process starts when the coal feeder is stopped or mill coal inventory reaches a certain level. The inerting process is recommended to continue until the mill is fully stripped of coal. When tripped, a mill shall be inerted and maintained under an inert atmosphere until confirmation that no burning or smoldering fuel exists in the mill or the fuel is removed.

In order to properly design a steam inerting system, the following elements must be accounted for:

- Steam supply pressure and temperature
- Steam flow rate requirements for mill start-up, shut down and trip, depending on primary flow and mill system volume
- Steam System control, measurement and instrumentation
- Locations of steam admission ports for mill start-up, shut down and trip
- System mechanical design requirements
  - Steam piping size, material and design
  - For high pressure steam source, a steam pressure reduction system with a moisture separator is required
  - All piping should be insulated to minimize heat loss and maximize personnel protection
  - A steam trapping system for low lying piping areas
  - Steam piping system layout
  - Outdoor system installation requires heat tracing to prevent freezing

Figure 2 shows an example of a Process and Instrumentation Diagram (P&ID) for a steam inerting system. For a tripped double-end ball tube mill system, in order to inert the mill, multiple steam admission points are required, located at each classifier and mill inlet/outlet box. During mill start-up and shut down process, only one steam admission port is required, in the primary air inlet duct where the steam is introduced and split into the mill inlets. This is because the primary air will convey the steam into the mill.

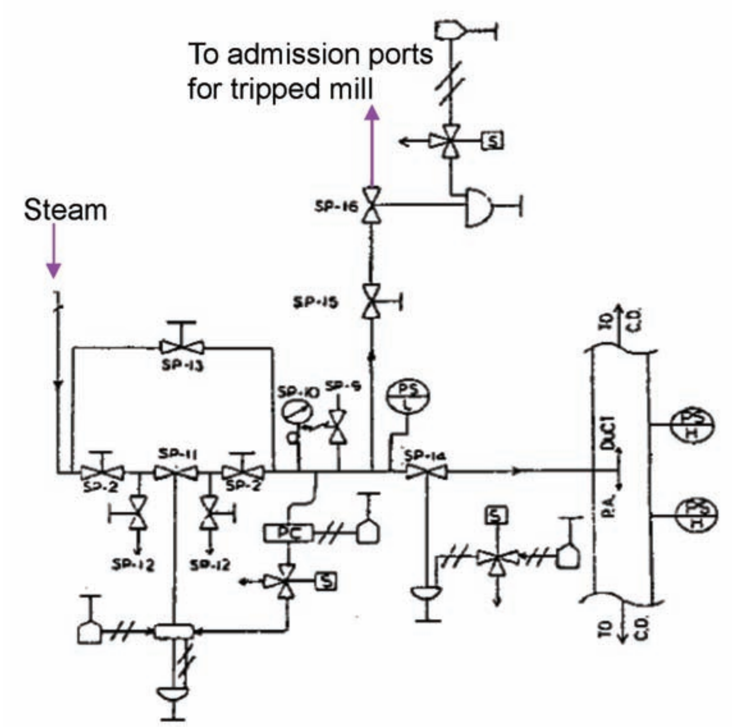

Figure 2 – P&ID for Steam Inerting System

STEAM INERTING SYSTEM VALIDATION SCOPE

As auxiliary equipment of a mill system, a steam inerting system must function properly and reliably in order to comply with NFPA requirements. To ensure proper operation, a comprehensive mechanical and instrumentation inspection and performance validation should be performed periodically for an existing steam inerting system. The inspection includes, but may not be limited to, the following areas:

- Steam supply source for inerting system (pressure and flow capacity)
- Mechanical components including all valves such as steam pressure reduction valve, steam isolation valves, control valves
- All instrumentation for both indication and control
- Control logic integrated with actual mill operation for start-up, shut down and trip operation
- All steam piping including steam admission ports, ensuring there is no plugging

After a thorough steam inerting system inspection is completed, oxygen concentration testing is recommended. This is performed to measure oxygen concentration reduction during the actual inerting process such as during start-up and shut down, which will ultimately validate the steam inerting system performance to achieve the required inert atmosphere in the mill system.

MILL SYSTEM OXYGEN TESTING

Distinct from other oxygen concentration testing, there is no industry consensus or common practice regarding a standard test or methodology for measuring mill system oxygen level during the inerting process. After a mill is inerted, significant steam typically in saturated phase is present in the mill. The air samples taken from the mill contain the same percent of steam. If the steam condenses in the samples, the testing could be inaccurate or invalid, since the condensation of steam changes the gas phase composition which in turn affects the oxygen concentration measurement. In addition, the condensed moisture can potentially plug the sampling line and damage the oxygen sensor in the analyzer. Previous field testing has demonstrated that the instrumentation can quickly become saturated with condensed liquid due to immediate steam condensation. The developed oxygen testing methodology provides a heated arrangement to maintain a sufficient temperature from the sampler to analyzer to prevent the steam from condensing. During the inerting process, air samples are taken every one (1) second to ensure adequate resolution for oxygen concentration variation. Data acquisition is real time and processed by a data acquisition processor.

1) Testing site

Oxygen concentration testing was performed at Hoosier Energy's Merom Generating Station, Unit 2, a 520MWg Riley Power Inc. Turbo® furnace, burning pulverized bituminous coal boiler rated at 3,900,000 lb/hr steam flow at 2630 psig and 1005°F superheat / 1005°F reheat. It is a balanced draft unit fired by twenty four (24) modified directional flame burners. Each unit is equipped with three (3) Riley double-ended Ball Tube Mills as shown in Figure 3. The mill system consists of coal feeders, crusher dryers, stand-alone centrifugal static classifiers and a ball tube mill. Raw coal from the feeders is mixed with hot primary air and then fed to crusher dryers. After primary crushing and initial drying with the crushers, the crushed coal is fed into the mill for pulverization. The pulverized coal from the mill is air conveyed to the classifiers. Acceptable particles are discharged from the classifier and transported to the furnace, while coarse particles are returned to the mill for further pulverization. The hot primary air from air heater (temperature up to 650°F) is tempered with cold tempering air to provide the required primary air temperature for coal drying required during the milling process. Typically, classifier exit temperature is controlled to 150-160°F for bituminous coal and 130-140°F for Sub Bituminous coal.

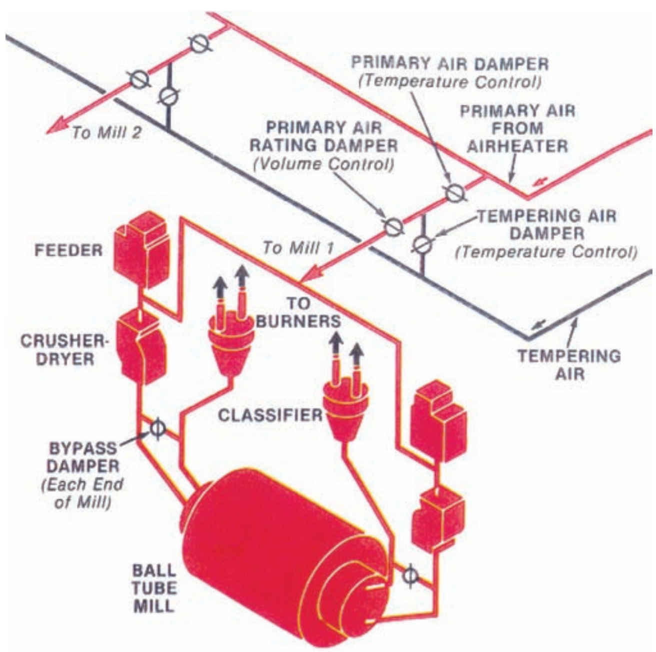

Figure 3 – BTM System at the Testing Plant

The existing mill steam inerting system at the plant was designed and installed after the initial boiler contract was completed in the mid 1970's. The steam source for inerting is from plant auxiliary steam supply at 172 psig and 400°F. A main pressure reducing valve (PRV) is used to reduce and regulate the steam pressure supplied to a steam header in the steam inerting system. For mill start-up and shut down, the inerting steam is supplied from the steam header and introduced to admission ports at primary air inlet duct through a 6" steam pipe. For mill emergency trip, the inerting steam is introduced into the mill system at multiple locations including classifiers and crusher dryers through 4" steam pipes. The steam inerting system validation was conducted under the "worst case" operation condition when primary air is flowing through the mill during start-up and shut down. This type of operation is the most difficult to inert as the primary air provides a continuous source of oxygen. The validation was to determine the system's reliability and capability of reducing the oxygen concentration to the required level.

2) Testing system configuration

The oxygen concentration measurement system consisted of a gas sampler with probe, an oxygen analyzer, a data acquisition processor, and heated hose to connect the sampler and analyzer, as shown in Figure 4. The heated hose was important to maintain gas sample temperature to prevent the steam from condensing when it was delivered to the analyzer from the sampler. An oxygen calibrator was also included in the system for the analyzer calibration.

Figure 4 – Oxygen Concentration Testing Instrumentation

Four (4) sets of testing equipment were employed for the testing to collect gas samples at four (4) different points located at mill inlets and classifiers at both mill ends, as shown in Figure 5. All four (4) testing equipment setups shared a common data acquisition processor.

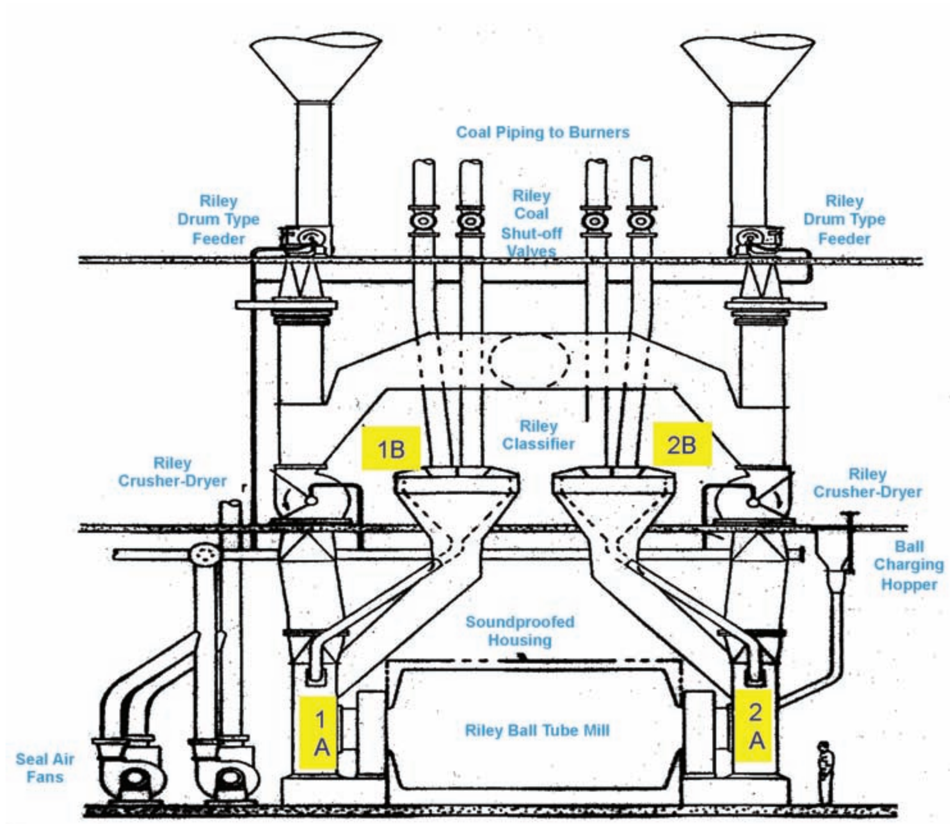

Figure 5 – Locations of Sampling Points

3) Testing and Results

The inerting testing was conducted under the simulated operation of mill start-up and shut down, while the mill was stripped of coal and the mill motor turned off. With selected coal pipe isolation valves open and a primary airflow set at the same as the mill start up and shutdown operation, the mill was inerted by the existing steam inerting system. During the testing, gas samples taken continuously from the four (4) locations were analyzed and oxygen concentration results were recorded.

Figures 6a - 6c show the trends of mill oxygen reduction during the testing with different inerting steam pressures. When inerting started or steam valve was opened, the oxygen concentration at four (4) sampling locations did not change immediately. After 25 seconds, the oxygen concentration level started to decrease dramatically. This high rate of oxygen reduction continued approximately another 25 seconds and then slowed down. The decrease of oxygen reduction rate depends on inerting steam pressure. The higher the steam pressure applied, the lower the reduction in the rate. Therefore, at the given mill system and duration of inerting, the achievable magnitude of oxygen reduction is the function of inerting steam pressure. For example, the mill achieved an oxygen concentration level of 14% -16.5% after being inerted with 4 psi steam for 250 seconds (Figure 6a), while inerted with 9 psi steam for the same duration, the oxygen concentration in the mill reached 12% or lower (Figure 6b). The test indicated 4 psi inert steam source pressure could not satisfy the steam inerting requirement to establish a sufficient inerted atmosphere within the mill at 12 -14% oxygen level.

Figure 6c shows the oxygen reduction trend during inerting process with multiple point steam injection. The steam at 9 psi pressure was introduced into the mill at primary air inlet duct, classifiers and crusher dryers through different sizes of steam pipes. The testing indicated that oxygen level of 14% or lower was achieved in 100 seconds. At 170 seconds, the oxygen concentration level below 12% was achievable. This test demonstrated the mill steam inerting system capacity to quickly reduce oxygen concentration to the desired level when increasing the steam pressure and inerting the mill through multiple injection points simultaneously.

During tests, the pressures in the primary air duct near steam injection location were monitored. The maximum pressure observed was 0.72 psi when the mill was inerted with the steam at 9 psi pressure.

There was an initial concern that condensation of steam during the inerting process might result in a "wetting" issue in the mill. A mill inspection was performed after four (4) inerting tests (total inerting time is 24 minutes). The inspection indicated that the mill internals were fairly dry and there was little cause for concern regarding the steam condensation during the inerting process. Also, there was no "condensation" or "wetting" issue reported when the test mills were returned to service.

If required, the testing could be conducted to evaluate inerting effectiveness for mill trip operation, in which, the required inerting duration to achieve a desired oxygen concentration level could be tested and evaluated with designed steam flow for an isolated mill system or at mill trip condition. Obviously, the time duration and/or steam flow required to effectively inert a tripped mill will be significantly less than that required for start-up and shut down modes of operation since all dampers and coal pipe valves are closed or no primary air passes through the mill system when a mill has emergency trip.

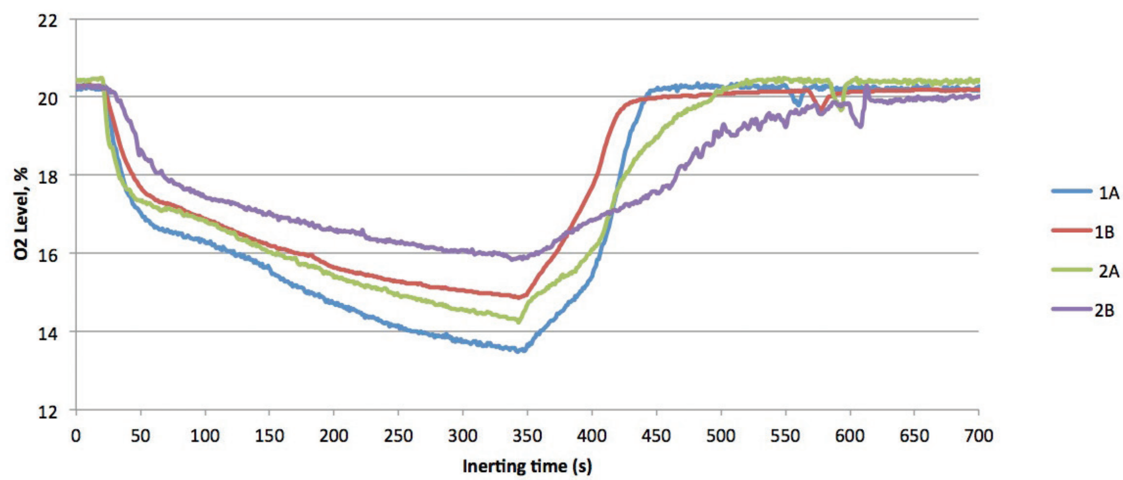

Figure 6a – Mill Inerted with 4 psi Steam for Start-Up/Shut Down Modes

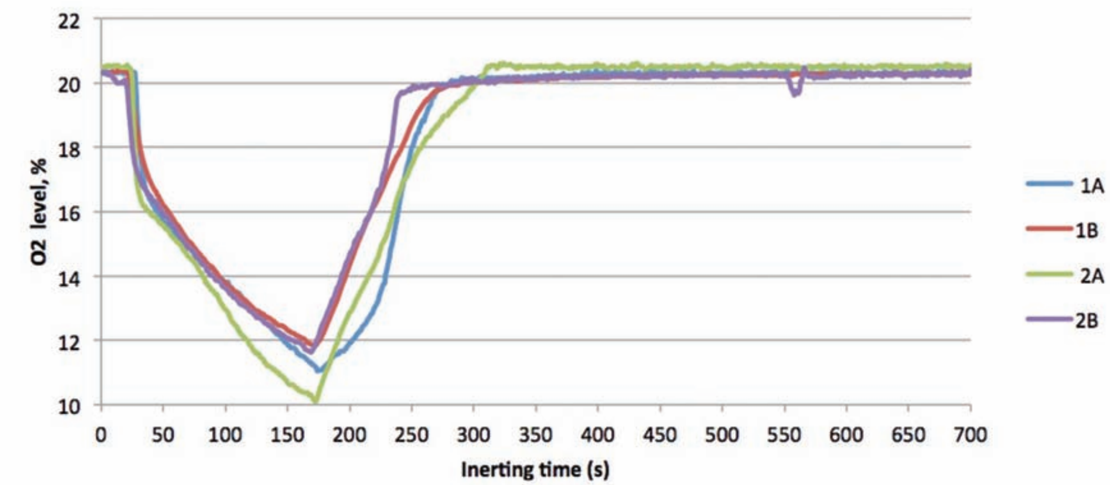

Figure 6b – Mill Inerted with 9 psi Steam for Start-Up/Shut Down Modes

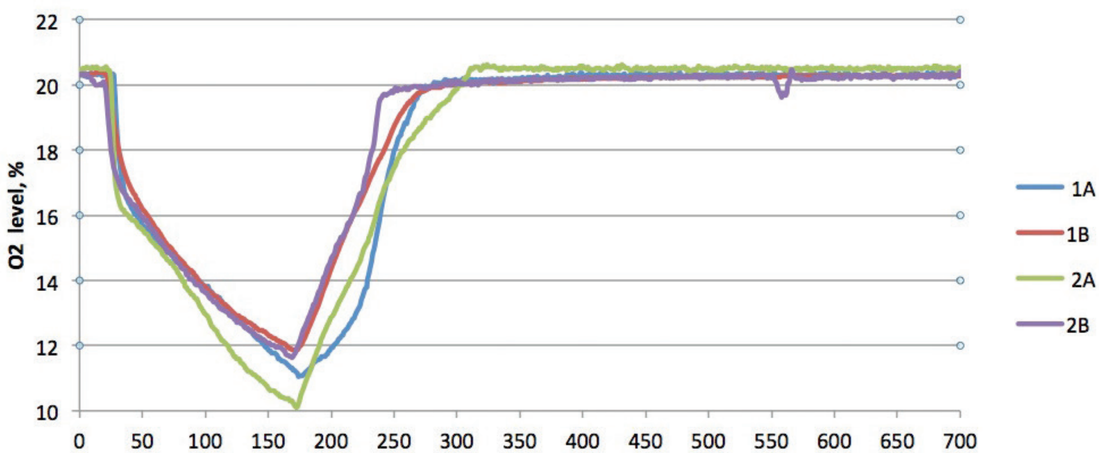

Figure 6c – Mill Inerted with 9 psi Steam at Multiple Points for Start-Up/Shut Down Modes

CONCLUSION

Effective design of a mill steam inerting system will help ensure for NFPA code compliance. The validation process developed and described in this paper, including oxygen concentration testing, provides an effective technique to evaluate an existing or newly installed steam inerting system. This evaluation will ensure that the inerting system is capable of establishing an adequate inert atmosphere within the mill system during mill start-up, shut down and emergency trip process. Riley Power Inc. uses this system validation as an integral part of its engineering approach to design new and retrofit steam inerting systems for both ball tube mill or vertical spindle mill systems to insure continued compliance with NFPA requirements. As demonstrated with the field oxygen testing, the increase of inerting steam pressure and multiple steam injection could improve the steam inerting system performance to quickly establish a desired inert environment. Although this validation technology was tested on a ball tube mill system, it can be readily applied to other types of mill systems, since the steam inerting principle is the same and inerting system requirements are similar, regardless of mill type.

The results set forth herein are specific to a single study; any effort incorporating the methods and techniques described above should include professional evaluation of the equipment in question.

ACKNOWLEDGEMENTS

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REFERENCE

1. L. M. Benson and C. Penterson, "A Comparison of Three Types of Coal Pulverizers", American Power Conference, Chicago, IL, April 22-24, 1985

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