Babcock Power

Technical Publication

Fire and Explosion Prevention in Coal Pulverizing Systems

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RILEY POWER INC.
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Presented to
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FIRE AND EXPLOSION PREVENTION IN COAL PULVERIZING SYSTEMS

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INTRODUCTION

The safety record and availability history of coal pulverizing systems in the electric utility industry is commendable. The potential for fires and explosions inherent in air and pulverized coal mixtures has been studied for over 60 years. Design and operating practices have evolved to a state that allows the safe, practicable utilization of air-conveyed coal pulverizing systems for direct firing steam generators. Recent trends in the utility industry could increase the probability of fires and explosions. This paper focuses on the causes of fires and explosions and the preventive design and operating concepts available with Riley Stoker Corporation systems which, if employed, will maximize safety and availability in the future.

COAL DUST FIRES AND EXPLOSIONS

The pioneering effort to establish the relative ignition sensitivity and explosibility of air and various flammable dust mixtures was carried out by the U.S. Bureau of Mines over 60 years ago. Mine safety, and later, the safety of coal pulverizing systems, have received much detailed attention. Both field and laboratory testing programs have been conducted. In addition, the American Society of Mechanical Engineers in their Code Section VII, "Recommended Rules for Care of Power Boilers" and the National Fire Protection Association in their Codes 85E - 1974, "Prevention of Furnace Explosions in Pulverized Coal-Fired Multiple Burner Boiler-Furnaces" have provided good system design and operating guidelines. These documents should be studied and understood by all design and operating personnel.

The design and operation of fuel handling and burning equipment must provide for maximum personnel safety and minimal property damage in the event of a coal/air fire or explosion. In gas and oil fuel handling systems, explosive mixtures are minimized by keeping the air and fuel separate until they are combined at the point of combustion. In the air-conveyed direct-fired coal pulverizing system, used extensively in the industry today, there normally exists a combustible coal/air mixture in the burner lines and pulverizer equipment. Hence there is the continual danger of fires and, under certain conditions, explosions.

Proper design and operation of the pulverized coal burners protects the pulverizing system from ignition from the furnace fire. The coal/air mixture enters the furnace through a burner nozzle at velocities in excess of the flame speed. Thus, the flame front is held stable at a distance away from the end of the nozzle where the coal/air mixture velocity has slowed and is equal to the flame speed. From this we see the importance of maintaining burner operating velocities above the minimum specified by the manufacturer.

In practice, the more dangerous condition is an ignition source, i.e., a fire, within the coal pulverizing or conveying equipment. Fires are generally caused by accumulations of powdered coal brought to temperatures above their ignition temperature, either by hot air flowing over the deposit or by the deposit laying out on a hot surface. In addition, active fires are sometimes fed into the system from the bunker.

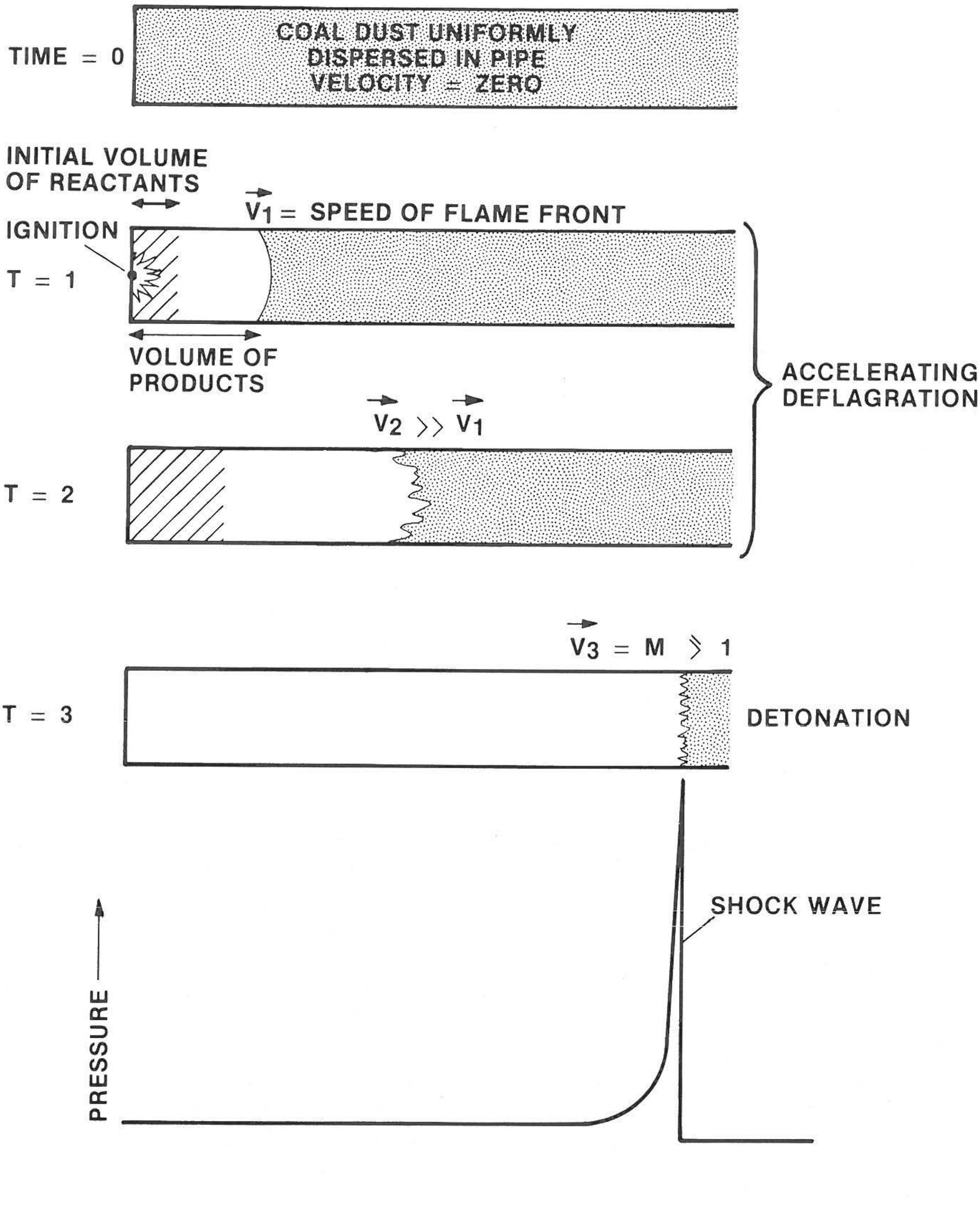
TIME = 0
COAL DUST UNIFORMLY
DISPERSED IN PIPE
VELOCITY = ZERO
INITIAL VOLUME
OF REACTANTS
$\vec{V}_1$ = SPEED OF FLAME FRONT
IGNITION
T = 1
VOLUME OF
PRODUCTS
ACCELERATING
DEFLAGRATION
$\vec{V}_2 \gg \vec{V}_1$
T = 2
$\vec{V}_3$ = M $\gg$ 1
T = 3
DETONATION
SHOCK WAVE
PRESSURE

Figure 1

In general, for a given system with coal dust dispersed in air throughout its volume (refer to Figure 1, Time = 0), the ignition source ignites adjacent suspended coal dust. Energy transfer from the burning coal to the next increment of unburned dust is by ordinary heat transfer, and if sufficient, will ignite the unburned dust. This ignition and combustion process continues as a propagating flame front through the air-coal mixture. The combustion products formed are high temperature gases which expand seeking equilibrium; and as they do (Time = 1), they push the flame front away from the point of ignition. As the flame front moves, it becomes more turbulent, further increasing the combustion rate, generating hot gases at an ever increasing rate, and accelerating the flame front (Time = 2).

When the flame front reaches the speed of sound, a sharp pressure discontinuity, or shock wave, develops. This propagating reactive shock wave is a detonation in which ingition energy is transferred to the next increment of unburned dust by pressure. The detonation propagates through the system with increasing pressure until it either is vented from the system, uses up all the oxygen or fuel within the system, or reaches a pressure which exceeds the local strength of the containment and bursts the containment. This bursting of the containment is defined as an explosion. Thus, an explosion can, and frequently has, occurred at a place in the system distant from the ignition source. While Figure 1 shows a one directional system, given the opportunity, the deflagration and/or detonation can propagate in different directions from the point of origin, causing more than one explosion in the system. Under proper conditions, the ignition, deflagration, detonation, and explosion can occur in about a tenth of a second.

The necessary conditions for such an event to occur are coal dust at the proper fineness, dryness, and chemical composition, suspended in air at the proper proportions, inside a containment with an ignition source of sufficient magnitude present.

There is experimental evidence that coal dust/air mixtures do have a lower explosive limit (i.e., that concentration of coal in air below which an explosion does not occur), but do not have an upper explosive limit as long as the coal/air mixture can be considered a cloud. In practice, a fire occurring during normal pulverizer operation does not result in an explosion. The rich coal/air mixture has been shown to absorb the heat of the ignition source without igniting, and therefore it often produces no deflagration. The fire can be extinguished and the system brought off the line safely. Explosions consistently occur when the coal air mixture is leaner than normal, either when initating coal feed on mill start-up, stopping coal feed on shutdown, or when equipment problems cause inadvertent loss of feed.

Upon loss of feed to a pulverizer, the coal/air mixture in the system becomes leaner and the coal dust will be ground to a more uniformly fine size and dried to a greater extent. All these factors make the coal/air mixture easier to ignite and, once ignited, more likely to detonate and cause an explosion.

RECENT INDUSTRY TRENDS

Industry trends which could increase the probability of fires and explosions in coal pulverizing systems are:

1. The increased use of coal by utilities which have no prior pulverized coal experience.
2. The increased use of lower rank, higher volatile content coals.
3. The increased use of control room electronic data gathering and retrieval systems which display only digital, rather than digital and analog, information.

The utility must recognize the fundamental differences between air-conveyed pulverized coal systems and gas or oil firing, as outlined in the previous section. An effective training program for operating personnel at start-up, as new personnel are added, and at regular intervals thereafter is necessary. The coal pulverizing system manufacturer must be a full and active participant in the training effort, with utility coordination of the various complimentary system manufacturers (i.e., combustion controls, etc.) to assure an integrated program. While there is no substitute for experience, training can improve the operating personnel's ability to diagnose conditions within the system, recognize fires, and react to assure a safe extinguishing procedure.

The lower rank, higher volatile content coals increase the probability of fires and explosions. There are experimental data[1] which clearly show decreasing ignition temperatures, decreasing ignition energy, and decreasing lower explosive limits with increasing volatile content. Refer to Figure 2. Furthermore, the relative

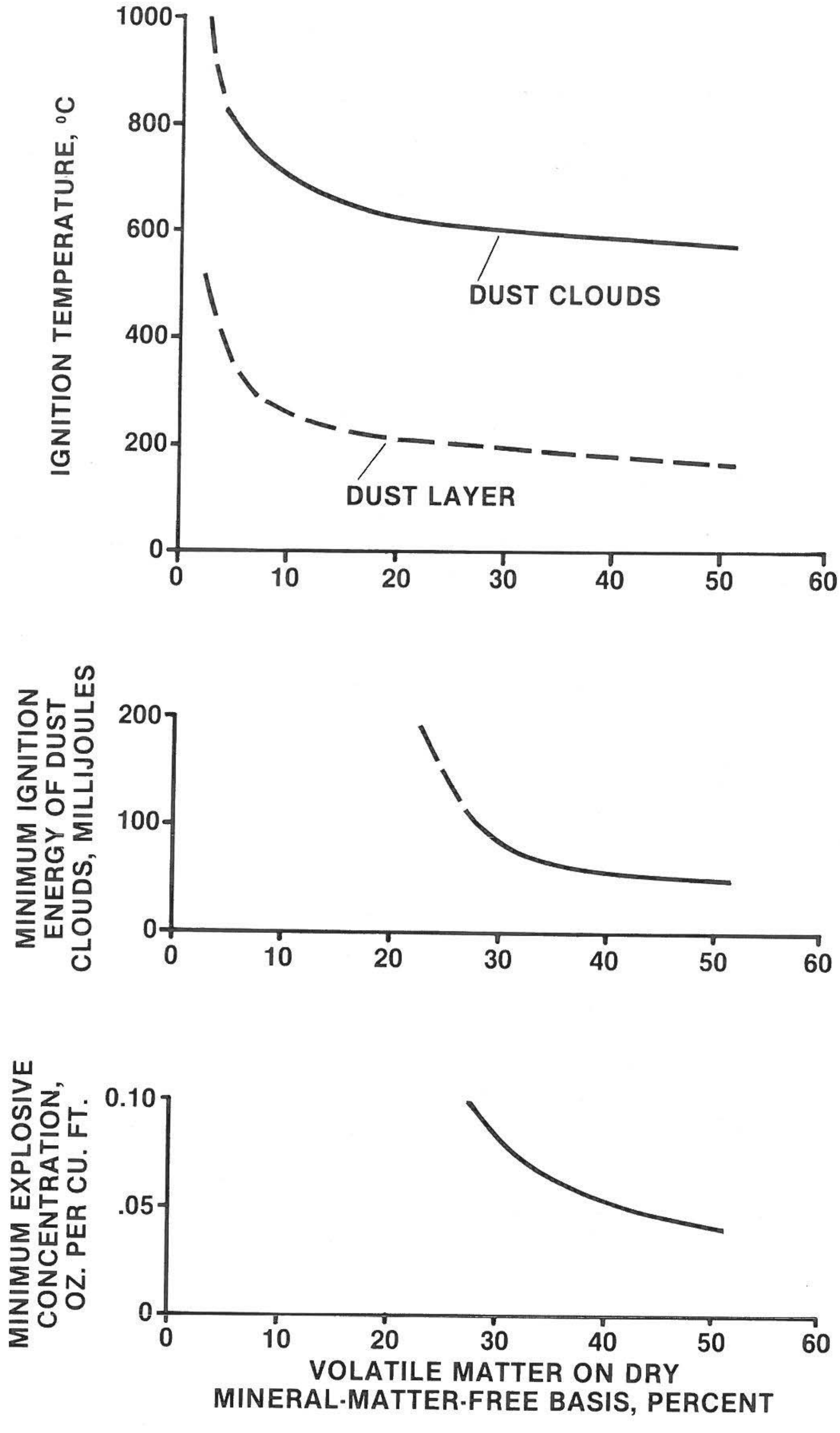
IGNITION TEMPERATURE, °C
1000
800
600
400
200
0
DUST CLOUDS
DUST LAYER
0
10
20
30
40
50
60
MINIMUM IGNITION ENERGY OF DUST CLOUDS, MILLIJOULES
200
100
0
0
10
20
30
40
50
60
MINIMUM EXPLOSIVE CONCENTRATION, OZ. PER CU. FT.
0.10
.05
0
0
10
20
30
40
50
60
VOLATILE MATTER ON DRY MINERAL-MATTER-FREE BASIS, PERCENT

Figure 2

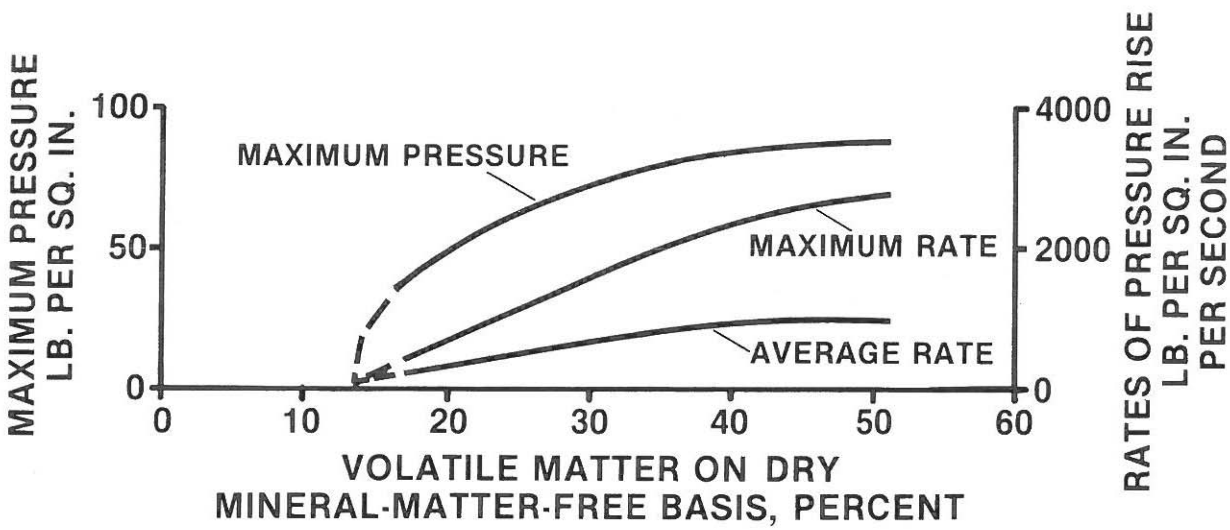

Figure 3

explosibility, as indicated by the rate of pressure rise and maximum pressure generated in a laboratory apparatus, is shown to increase with increasing volatility. Refer to Figure 3.

The increased use of electronic data gathering and retrieval systems can greatly benefit the operations personnel by making more information more readily available. However, it can also hinder the operators' ability to diagnose the condition of a pulverizer system if it does not display a time temperature history from which changes in the system can be discerned. Often only a digital readout displaying an instantaneous temperature is available when the operator is less concerned about the magnitude of the temperature than he is about the rate of change, what it was for the ten minutes earlier, or how it compares to a temperature in a similar location elsewhere in the same system.

RILEY PULVERIZER SYSTEM DESIGN FEATURES

The Riley Stoker Corporation coal pulverizing system utilizes the following design and operating principles to maximize safety and availability:

1. Design in accordance with the NFPA code recommendations where applicable for containment strength, combustion controls, and flame safety systems.
2. Recommend, and train for operation in accordance with the NFPA procedures.

Referring to Figure 4:

3. Utilize a crusher-dryer so the hot air contacts relatively coarse coal, simultaneously flash drying the coal and reducing the air temperature. This minimizes the amount of fine coal dust subjected to hot air or hot equipment surfaces. The potential for fires is greatly reduced.
4. Utilize a pulverizer air by-pass design to dry the coal with increased air mass flow rather than just air temperature. For a given degree of coal drying, the by-pass system design will operate with a significantly lower primary air temperature throughout the system than if no by-pass were available. This is especially important since the lower rank, high volatile coals are also generally higher in moisture and require more drying capability.The lower system temperatures reduce the probability of fires.
5. Utilize vertical stainless steel coal-air chutes to minimize the chance of accumulating coal.
6. Utilize accurate and fast responding thermocouples to assure early detection of a fire. Install these thermocouples in locations which take advantage of the basic symmetry of a double-ended ball tube mill. That is, fires can be detected by a lack of temperature symmetry from end-to-end. Require multiple pen recorders on a per mill basis for primary air (1 required), mill inlet (2 required), mill outlet (2 required), and classifier outlet (2 required) temperatures.
7. Provide for a permanently piped, remotely actuated water fire extinguishing system that assures rapid and thorough response to a fire.

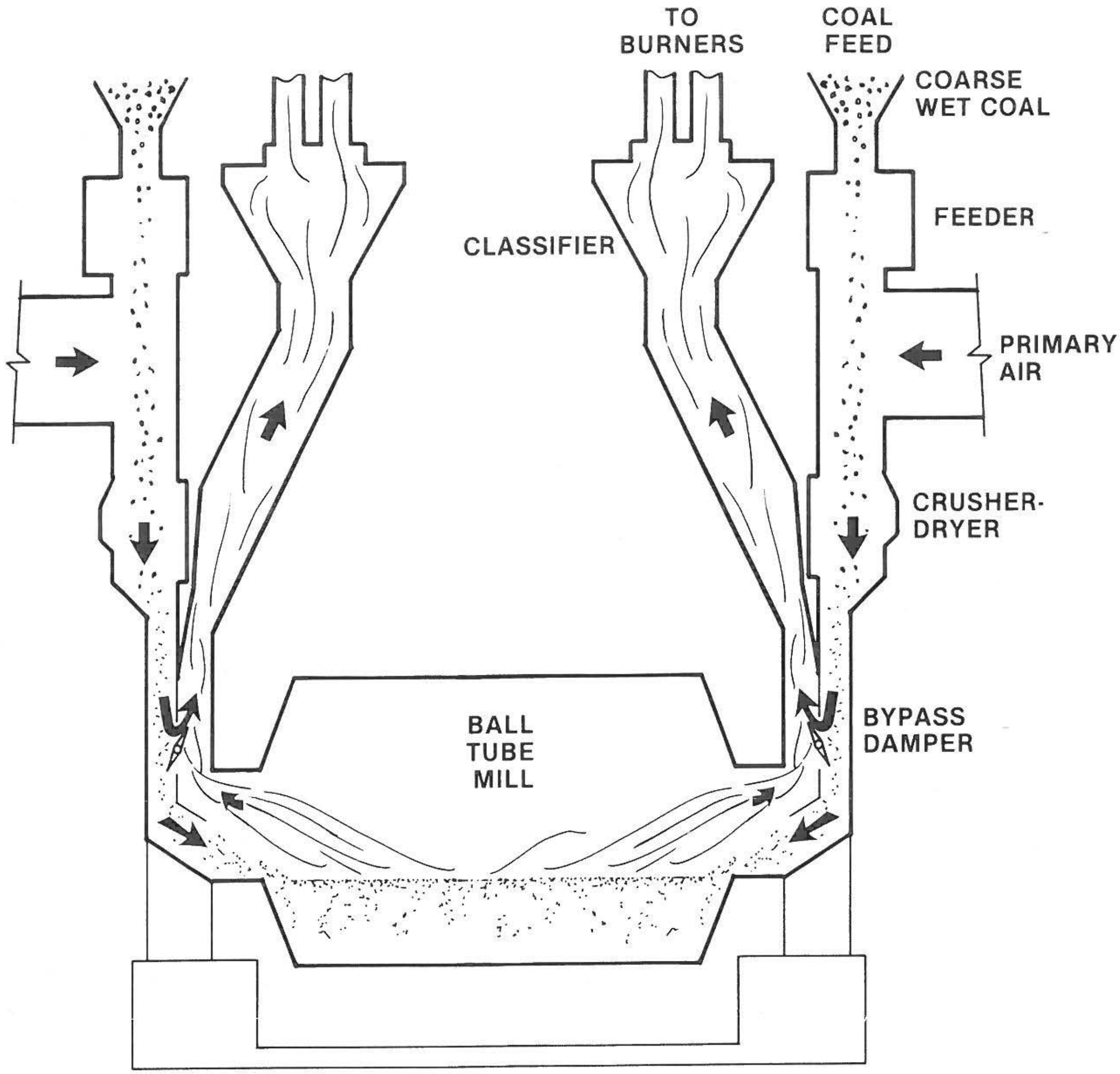

Figure 4 Ball Tube Mill Pulverizing System

8. Operate at system primary air temperatures below those historically used as normal. The trend is toward classifier outlet temperatures of 125°F away from 150 - 160°F.

In addition to the above, some utilities have utilized what has been termed "inerting systems". These systems are usually just one portion of the overall plant fire protection system, and for that reason usually fall within the scope of the Architectual Engineer.

Riley has become sufficiently knowledgeable about such systems to asure their effectiveness in our equipment and to minimize any adverse consequences associated with their installation and use. In general, inerting systems introduce sufficient inert medium into the coal dust/air mixture to prevent deflagration and/or detonation from occurring.

Returning to the example of dust suspended in air with an ignition source present, we found that the ignition-combustion process was able to propagate through the mixture when the energy transferred to the next increment of unburned dust was sufficient to ignite the dust. This energy is the activation of ignition energy as shown in Figure 5. If an inert medium is added to the coal dust/air mixture, such that a portion of the energy released is shared between both the coal dust and the inert medium, then the coal dust will receive less energy. With effective inerting, the energy available to the coal is less than required for ignition and the deflagration is suppressed.

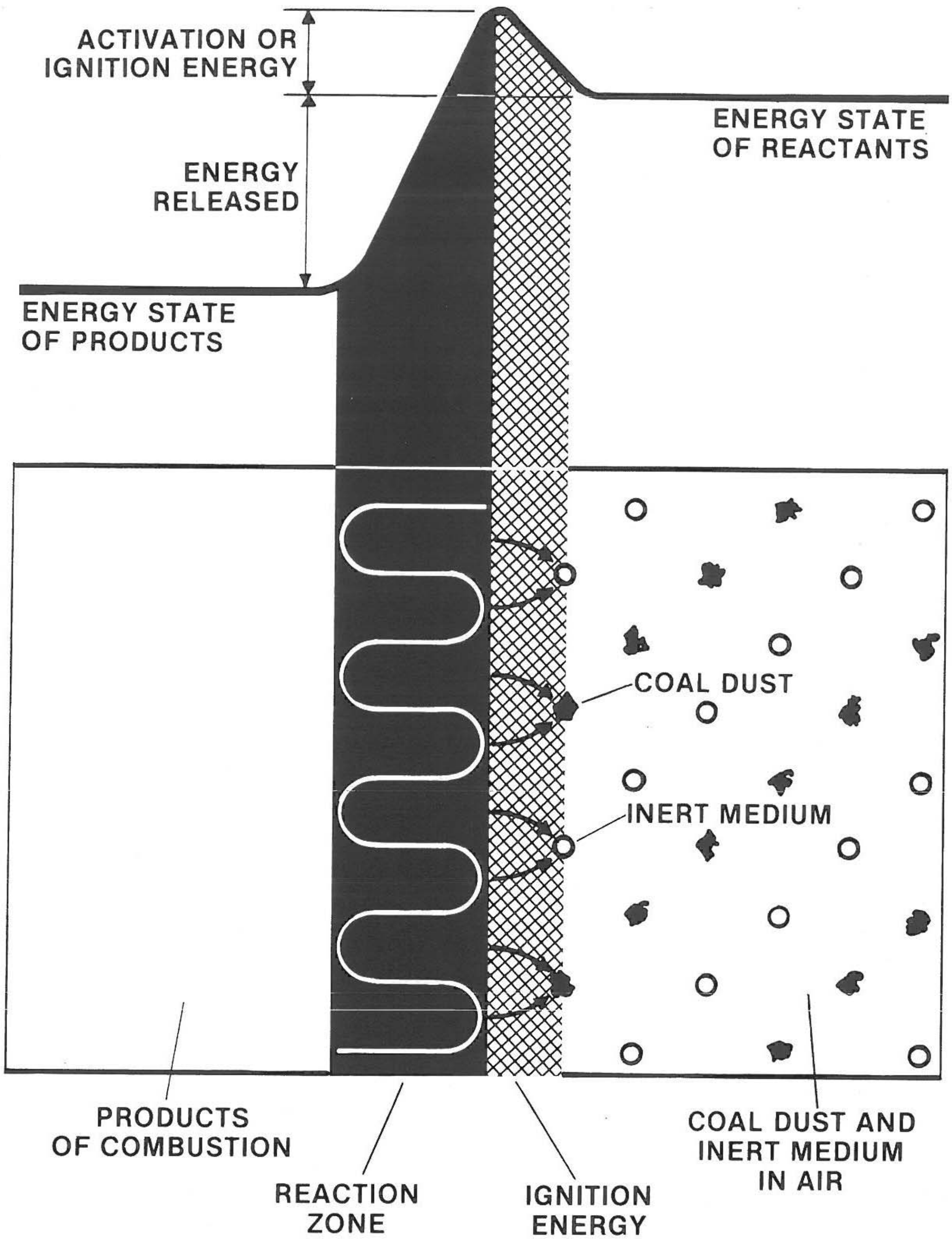
ACTIVATION OR IGNITION ENERGY
ENERGY RELEASED
ENERGY STATE OF REACTANTS
ENERGY STATE OF PRODUCTS
COAL DUST
INERT MEDIUM
PRODUCTS OF COMBUSTION
REACTION ZONE
IGNITION ENERGY
COAL DUST AND INERT MEDIUM IN AIR

Figure 5

The inerting medium can be any solid, gas, or liquid which absorbs energy without igniting. The effectiveness of the medium will be proportioned to the rate at which it absorbs energy (thermal conductivity), the amount of energy it absorbs (specific heat), and its concentration in the coal dust/air mixture.

Solid limestone has long been employed as a dusting over the inner surfaces of coal mines to suppress the fires and explosions potential in that environment. Solids have not found application in coal pulverizing systems.

The gases carbon dioxide and nitrogen are more commonly used and are reported to effectively prevent explosions when added to air such that the resulting oxygen concentration is reduced to between 15 and 6 percent, depending on the type and strength of the ignition source. Slightly lower oxygen concentration are required when nitrogen rather than carbon dioxide is used. These gases are used on coal pulverizing systems, but usually only introduced into the system upon a system trip due to evidence of a fire. Thus, they are being used as an extinguishing system. Riley Stoker recommends water sprays for extinguishing, and considers water to be the most effective medium for this purpose. We agree that the referenced gases, used as a diluent, can suppress deflagration and prevent explosions when an ignition source is present. However, their effectiveness as extinguishing systems is considered questionable.

Steam can be used as an inert medium. The gas/liquid combination which results when steam is injected into the coal dust/air mixture is effective by several mechanisms. The H_2O vapor reduces the oxygen concentration in proportion to the amount of steam injected and the resulting air saturation temperature. If the coal dust temperature is below the air saturation temperature, H_2O vapor will condense on the surface of the particle. Obviously, this is an effective location for it in preventing ignition. Furthermore, if the air temperature is below 212°F, and sufficient steam is injected, fog forms, suspending moisture droplets in the coal dust/air mixture.

One adverse consequence of using steam injection is wet coal deposits which may cause equipment pluggage. A balance among steam injection quantities, safety levels, and operations must be achieved. Riley Stoker Corporation is participating in a full scale development program of such a system, and is confident that it will arrive at the necessary balance.

The use of low oxygen content flue gas has also been employed to dry and transport pulverized coal and simultaneously to provide air inert coal pulverizing system. It is used on pulverized coal storage systems here in the U.S. and on direct fired high moisture, low rank coal pulverizing systems overseas. Riley Stoker Corporation is investigating this approach with the intent to conceptualize and, if practicable, commercialize such a system.

In general, all of these inerting systems can be used to provide insurance against deflagration or detonation while starting up or shutting down. They should only be used when there is no indication of a fire in the system. They are not recommended as fire extinguishing systems.

CONCLUSIONS

The Riley Stoker Corporation coal puvlerizing system capabilities can meet the needs of the future. The higher moisture, higher volatility, lower rank coals can be dried, pulverized and conveyed in a safe and reliable manner.

A continuing effort is being conducted to improve the coal pulverizing and fuel burning equipment. Active programs are aimed at studying the coals of the future and improving the equipment to meet the availability, reliability, and operating requirements imposed.

[1] Laboratory Explosibility Study of American Coals by I. Hartman, M. Jacobson, and R. P. Williams, U. S. Bureau of Mines Report of Investigations 5052.