DEMONSTRATION OF MICRONIZED COAL REBURNING FOR NO_x CONTROL ON A 175 MW UNIT

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ABSTRACT

The Tennessee Valley Authority (TVA) has been selected for the Department of Energy's (DOE's) Clean Coal Technology IV program to demonstrate micronized coal reburn technology for control of nitrogen oxide (NO_x) emissions on a 175 MWe wall-fired steam generator at its Shawnee Fossil Plant. As the technology of the MicroFuel Department of Fuller Power Corporation makes this demonstration feasible, TVA has selected them as the prime contractor for the project and partner in the commercialization of this technology. This retrofit demonstration is expected to decrease NO_x emissions by 50 to 60 percent. Up to 30 percent of the total fuel fired in the furnace will be micronized coal injected in the upper furnace creating a fuel-rich reburn zone. Overfire air will be injected at high velocity for good furnace gas mixing above the reburn zone to insure complete combustion. Shawnee Station is representative of a large portion of boilers in TVA's and the nation's utility operating base. Micronized coal reburn technology compares favorably with other NO_x control technologies and yet offers additional performance benefits. This paper will focus on micronized coal reburn technology and the plans for a full-scale demonstration at Shawnee.

INTRODUCTION

According to recent industry studies, 44 percent of the nation's coal-fired plants will have seen their 30th birthday by the turn of the century. Older fossil plants typically have the following operating characteristics, and many of these conditions lead to high NO_x production:

- high excess air,
- deteriorating coal fineness,
- poor control of secondary air,
- mill capacity limited from coal switching,
- poor turn-down ratio, and
- cyclic duty operation.

TVA has a high boiler population that falls into this category, yet demand upon this existing fossil generating capacity continues. Therefore, TVA has investigated methods of reducing NO_x while improving overall boiler performance.

A substantial database has been developed in the reduction of nitrogen oxides (NO_x) by various combustion modifications both here and abroad. Accurate control of coal particle fineness and air fuel ratios are essential ingredients in their success. The purpose of this project is to demonstrate the effectiveness of micronized coal (80 percent less than 325 mesh) combined with an advanced coal reburning technology.

Up to 30 percent of the total fuel fired in the furnace will be micronized coal. This fuel will be injected into the upper region of the furnace, creating a fuel-rich zone at a stoichiometry of 0.8 to 0.9. Overfire air will be injected at high velocity for good furnace gas mixing above the reburn zone, insuring an oxidizing zone for an overall furnace stoichiometry of 1.15 (excess air of 15 percent). Micronized coal reburn technology reduces NO_x emissions with minimal furnace modifications and enhances boiler performance with the improved burning characteristics of micronized coal (Figure 1).

The addition of the reburn fuel into the furnace solves several problems concurrently. Units that are mill limited now have sufficient fuel capacity to restore their lost capacity. Restoration of lost capacity, as a benefit to NO_x reduction, becomes a very economical source of power generation. Reburn burners can also serve as low-load burners, and units can achieve a turndown of 8:1 without consuming expensive auxiliary fuels. The combination of micronized coal reburn fuel and better pulverizer performance will increase unit performance by increasing carbon burnout.

Micronized coal reburn technology can be applied to cyclone-fired, wall-fired and tangentially-fired pulverized coal units. The overfire air system can also be easily adapted to incorporate in-furnace sorbent injection for SO_2 control.

A baseline test profile of the furnace, along with furnace flow and computer modeling, will be conducted prior to the design and installation of the MicroMill™ systems and micronized coal injector/burners. An extensive test program will document performance during a three-year operational period.

DOE CLEAN COAL TECHNOLOGY DEMONSTRATION PROGRAM

The Clean Coal Technology Demonstration (CCT) program is a multibillion-dollar national commitment, cost shared by the government and the private sector to demonstrate economic and environmentally sound methods for using our nation's most abundant energy resource, coal. The program will foster the energy-efficient use of the nation's vast coal resource base. The program will contribute significantly to the long-term energy security of the United States, further the nation's objectives for a cleaner environment and improve its competitive standing in the international energy market.

The objective of the CCT is to demonstrate a new generation of innovative coal utilization processes in a series of "showcase" facilities built across the country. The program takes the most promising of the advanced coal-based technologies and, over the next decade, moves them into the commercial marketplace through demonstration. These demonstrations are on a scale large enough to generate all the data for design, construction and operation that are necessary for the private sector to judge their commercial potential and make informed, confident decisions on commercial readiness.

DOE selected TVA's micronized coal reburning at Shawnee as one of the nine projects to be demonstrated under Round IV of CCT. Since NO_x and SO_2 have been designated by the 1990 Clean Air Act Amendments passed by the U.S. Congress as precursors of acid rain precipitation, controlling NO_x has presented challenging problems in achieving a low-cost retrofit control system. To date, there have been several methods used to reduce NO_x; however, each has some disadvantages. Low NO_x burners have been fairly successful but may not provide sufficient reduction by themselves. Gas reburning also has been successful, but it requires a steady supply of gas at a reasonable cost. Coal reburning shows promise in providing a NO_x control system which can be readily retrofitted and operated at low cost. Coal reburning does not require external modifications to the flue gas duct system nor does it require major modifications to the boiler or a separate type of reburn fuel. In fact, coal reburning may help some power producers who have had to derate their unit due to coal switching that was implemented to meet SO_2 reduction requirements.

Site

Site Description. The host site will be one of Units 1-9 at TVA's Shawnee Fossil Plant which was built to help meet the huge electric power requirements of a nearby DOE facility. Construction began in January 1951 and was completed in 1956.

Units 1-9 are 175 MWe (gross) front wall-fired, dry-bottom furnaces burning East Appalachian low-sulfur coal. The plant was originally designed to burn high-sulfur coal; but in the 1970s, the plant was modified to burn low-sulfur coal in order to meet an emission limit of 1.2 lbs. $SO_2/10^6$ Btu of heat input without the use of any sulfur dioxide control technology. Each unit has been equipped with a baghouse to control particulate emissions. Flue gas from each unit discharges to one of two 800-foot stacks, also constructed in the 1970s. The nine existing pulverized coal units are representative of a large number of wall-fired units in the industry which will be required to reduce NO_x emissions in response to the 1990 Clean Air Act Amendments.

Coal Acquisition

TVA has contracts in place to supply Shawnee with low-sulfur bituminous coals from Kentucky and West Virginia. These coals will be used as the primary fuels for the project. TVA has conducted test burns of western coals such as Powder River Basin (PRB) at a number of sites, including Shawnee, since the late 1970s. PRB coal will be obtained for testing during this demonstration.

REBURN CONCEPT

Concept Operation

Micronized coal reburning for NO_x control will operate in the same manner as natural gas reburning on coal-fired boilers. In effect, the entire furnace operates as a low NO_x burner. The existing burners shall be operated at a lower than normal stoichiometric ratio, with special attention being applied to fuel/air control. Microfine coal with a surface area of 31 m^2/gm is fired substoichiometrically in a reburn zone above the top row of the existing burners. Oxidation of high-surface-area micronized coal consumes oxygen very rapidly, converting NO_x to molecular nitrogen. NO_x conversion requires a residence time of 0.5 to 0.6 seconds. Above the reburn zone, high velocity overfire air will uniformly mix with the substoichiometric furnace gas to complete combustion, giving a total excess air ratio of 1.15. This concept should reduce NO_x emissions 50 to 60 percent from current levels of 0.82 to 0.95 $lbs/10^6$Btu to an emission level of 0.33 to 0.48 $lbs/10^6$Btu.

The proposed project will demonstrate the effectiveness of reducing nitrogen oxide emissions with an advanced coal reburning technology utilizing micronized coal. This technology can be applied in new as well as existing pulverized coal-fired furnaces. The coal used in reburning can be the same coal as used in the main fuel burners. A schematic of this system is shown in Figure 1. In addition, this reburn technology can be combined with various sulfur dioxide (SO_2) control technologies such as fuel switching, dry sorbent injection or other postcombustion technologies.

The addition of MicroMill systems will increase total heat input and will allow classifier settings on existing pulverizers to be adjusted for improved fineness, relating directly to combustion efficiency and lower Loss on Ignition (LOI). Stoichiometry in the lower furnace is maintained at 1.05 (5.0 percent excess air) to assure an oxidizing zone and minimize slagging and corrosion. The stoichiometry at burner level 5, the reburn level, is 0.8 to 0.9; and with the addition of overfire air at level 6, the furnace will have an existing stoichiometry of 1.15 (15 percent excess air), compared to the current operating condition of 1.21 (21 percent excess air). Thus, the micronized coal reburn system not only reduces NO_x emissions but also improves boiler efficiency and increases boiler capacity.

Process Advantages

Reburning is a recognized, effective technology for controlling NO_x emissions in a pulverized coal-fired boiler; however, most of the reburning activity to date has been with natural gas or oil as the reburn fuel. The following advantages of micronized coal reburning for NO_x control compare favorably with other NO_x control technologies.

- Disadvantages of natural gas and oil. Both natural gas and oil have been demonstrated to be effective reburning fuels; however, they are subject to one or more of the following disadvantages:

- availability, especially in winter,
- unstable/escalating fuel cost,
- operational problems firing dual fuels, and
- reduced boiler efficiency due to hydrogen in fuel.

- Micronized coal as reburn fuel, even with the additional coal handling and micronization cost, is a cost effective alternative to gas and oil due to the substantially lower fuel cost and elimination of problems associated with gas and oil.

- Flexibility: The technology is flexible enough to combine with other NO_x control technologies and reduce NO_x emissions to required lower levels.

- Site specific benefits:
  - reduced energy replacement costs due to improved ability to operate at a rated load, even with wet coals and/or equipment problems (mills, feeders),
  - reduced capacity costs due to increased power generation,
  - increased fuel flexibility allowing use of lower quality coals while mitigating deratings caused by fuel handling limitations,
  - the ability to operate existing pulverizers at reduced throughput without loss in unit capacity will improve coal fineness and possibly reduce unburned combustible in ash, thus increasing value of the ash as a marketable commodity,
  - improved turndown and stability at low loads without firing supplemental fuels and maintaining superheater outlet temperatures at low loads, and
  - knowledge gained from this demonstration can be used to scale up the micronized coal reburn technology for installation on TVA's Allen Fossil Plant (330 MWe cyclone fired).

NO_x Control Strategy

A majority of the 300,000 MWe generated by coal-fired utility units will be impacted by the 1990 Clean Air Act Amendments requiring reduction of NO_x emissions. It is unlikely that one NO_x control method will meet the needs of this diverse boiler population. NO_x control strategies fall into two major categories: combustion modification and postcombustion technologies.

Combustion modification includes low NO_x burners, reburning and fuel air staging. The postcombustion options are Selective Noncatalytic Reduction (SNCR) using reagents such as ammonia or urea and Selective Catalytic Reduction (SCR) using both reagent injections and catalysts.

In selecting a NO_x control strategy for a given unit, utility engineers must weigh many factors including the type of unit, operating requirements and unit design ratings versus current operating capabilities. Most utilities will probably select some form of combustion modification as their preferred NO_x control methods. Many utilities, already familiar with pulverized coal burners and burner management systems, will elect to install low NO_x burners as the method of controlling the combustion process.

There is, however, a large population of utility boilers for which reburning is an attractive option. Wet bottom furnaces such as cyclones and some wall-fired furnaces that operate in a slagging mode are obvious choices for reburning, and the addition of a micronized coal reburn system can be utilized in such diverse applications as start-up, low-load operation and restoring lost capacity. In addition, units that operate at very low loads for long periods of time, units that are relegated to cyclic duty and units that have pulverizer load limitations resulting from fuel switching are all very good candidates for micronized coal reburning as a primary NO_x control method.

SUPPORTING ACTIVITIES

While the micronized coal reburn system is in a state of technical readiness for full-scale demonstration, there will be several supporting activities to insure a high degree of success for the demonstration. Among these activities are furnace cold-flow and computer modeling. The modeling will be conducted in the first phase and will provide even further evidence of adequacy, availability, suitability and quality of the data and analysis to support the full-scale demonstration.

Diagnostic tests will be conducted to determine temperature and velocity patterns in the furnace, supplementing similar previous tests in another unit at the plant with different burner registers. Boiler performance tests will also be conducted providing flue gas flow rate, gas composition and unburned combustibles. These tests will be used to initiate preliminary design of the reburn injector/burners and overfire air nozzles. A cold-flow model will be built to simulate the existing burner windbox assembly, burners and air registers as well as the furnace flow regime, including the lower and upper furnace past the furnace nose and into the convection section. This flow model will permit determination of the number and location of both the reburn injector/burners and overfire air nozzles. With the cold-flow model existing windbox, burner and furnace flow patterns can be observed. In addition, the model will provide an easy, convenient method to vary the number and location of the reburn injector/burners, overfire air windbox and nozzles to assure dispersion and mixing of the micronized coal in the reburn zone and the overfire air in the burnout zone. The cold-flow model will also be available during Phase 3 of the test program in the event any fine tuning of the reburn system is required. The computer modeling of the furnace will provide not only screening for the cold-flow model but also predict reburn system performance on the furnace and boiler as well as the effect of heat release and mixing in the reburn zone.

Once the flow and mixing characteristics have been determined from the modeling activities, the reburn injector/reburner will be selected or designed. The design will accommodate the unit's flow characteristics while achieving local mixing of the micronized coal-air stream from the injector to achieve combustion at a prescribed fuel-rich condition (0.8 stoichiometry) for reburn operation and at normal fuel-lean conditions for start-up and low-load boiler operation.

MICRONIZED COAL TECHNOLOGY

Technology Description

The technology described in this paper is a combination of a technology that produces micro-fine coal reliably and economically with a known NO_x control technology (fuel reburning). When micronized coal is fired at a stoichiometry of 0.8 to 1.2, devolatilization and carbon conversion occur rapidly.

Micronized coal is defined as a coal ground so the 80 percent of the coal particles are 43 microns or smaller. The MicroFuel® system, consisting of the MicroMill and an external classifier, micronizes coal to a particle range of 10 to 20 microns.

The combined surface area of just one gram of micronized coal particles is 31 square meters, contrasted to a surface area of 2.5 square meters per gram for standard-grind pulverized coal.

The MicroMill system is a patented centrifugal-pneumatic mill with the replaceable rotating impeller as the only moving part. Size reduction is accomplished by the particles themselves striking against one another as they whirl in a tornado-like column of air inside the MicroMill. Centrifugal force retains material in the cone and Rotational Impact Zone (RIZ) as the particles reduce in size prior to being conveyed by the air stream entering the center of the rotating impeller. Figure 2 is a sectional view of the MicroMill, and Figure 3 is a cutaway view of the MF-3018 MicroMill.

Material entering the impeller is swept out of the MicroMill to the classifier, which separates particles by size. Micronized coal particles below 43 microns are discharged directly to the burners, and larger particles are returned to the MicroMill for further size reduction. Figure 4 is a dimensional elevation of a complete MicroMill system.

The net result of micronized coal as a reburn fuel is a uniform compact combustion envelope allowing for complete combustion of the coal/air mixture in a smaller volume than conventional pulverized coal. Heat rate, heat flux, carbon loss and NO_x formation are all impacted by coal fineness.

ENVIRONMENTAL ASPECTS

With the exception of significant reductions in NO_x emission, the environmental impact of the proposed project is inconsequential.

Shawnee currently burns low-sulfur Appalachian coal (1.195 lb. $SO_x/10^6$Btu). Lower-sulfur western coal (0.35 lb. $SO_x/10^6$Btu) will be burned briefly as part of the demonstration. During that period, SO_x emissions will be further reduced. The use of eastern low-sulfur coals with reduced grindability has made the existing pulverizers marginal. Equipment problems or wet coal will result in further derating of the unit. The introduction of micronized coal reburning as an additional fuel will allow Shawnee to overcome mill limitations and operate at somewhat higher capacity factors.

No significant changes in the emissions of greenhouse gases or air toxics are projected. A minor increase in emissions of CO and hydrocarbons may occur at times during the demonstration as parametric testing may occasionally result in slightly less than complete combustion. However, existing pollution control equipment should be able to maintain emission levels within regulatory limits. Emissions monitoring will be performed to insure continued compliance.

No new waste products will be generated by the micronized coal reburn process, as no reagents are utilized. Existing requirements for fly ash and bottom ash disposal are expected to remain constant. Current water usage by the unit averages 3.1 million gallons per day for ash sluicing, and no change is projected for the demonstration. Average fly ash particle size will decrease slightly, but existing baghouses will efficiently collect fly ash.

PREOPERATIONAL AND OPERATIONAL TESTING

Preoperational testing will be conducted to include baseline data acquisition and characterization of existing and newly designed components. Parametric testing will document the effect of the following reburn system variables:

- primary burner zone stoichiometry,
- reburn zone stoichiometry,
- final (burnout zone) stoichiometry,
- reburn zone momentum,
- micronized coal consumption in the reburn zone,
- reburn fuel particle size,
- load,
- coal composition reliability, and
- boiler load response.

All Continuous Emission Monitor (CEM) and boiler operation signals which can be efficiently monitored in real time will be directly stored on disk. The database will permit ready and efficient reduction and analysis of the data, both during execution of the program and during final analysis and evaluation. Information from the long-term test will permit evaluation of system efficiency and reliability under actual operating conditions. Also, the extended operating period will provide data for projecting economic impacts.

CONCLUSIONS

TVA has a strong history of leadership in the development of new and emerging technologies and the performance of successful R&D programs. TVA believes that this nitrogen oxide emission control technology shows promising benefit to its own system, as well as the utility industry in general, since it is taking a leadership position in sponsoring a micronized coal reburn demonstration.

The combination of micronized coal supplying up to 30 percent of the total furnace requirements and reburning for NO_x control will provide flexibility for significant environmental improvement without adding higher operating costs or furnace performance deratings normally associated with environmental controls.

By meeting the objectives of this important coal reburning project, coal will be shown to be its own best friend in controlling NO_x emissions and providing economical power to the public well into the future.

This report was prepared by Fuller Power Corporation pursuant to a cooperative agreement funded by the U.S. Department of Energy and TVA; and neither the Tennessee Valley Authority or any of its subcontractors or the U.S. Department of Energy, or any person acting on behalf of either:

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The American Society of Mechanical Engineers shall not be responsible for statements or opinions advanced in this paper. This paper, number 93-JPGC-FACT-10, was presented at the Joint ASME/IEEE Power Generation Conference in Kansas City, Kansas, October 17-22, 1993.

ATTACHMENT A

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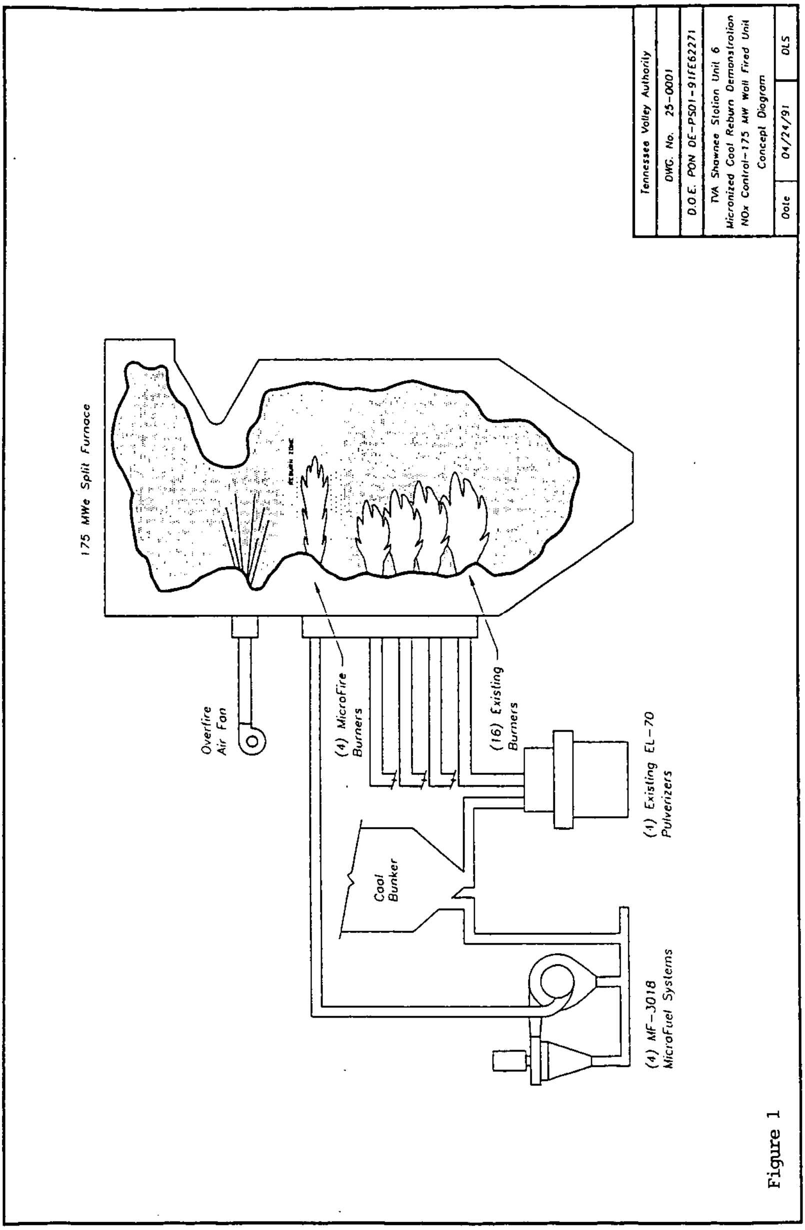

Tennessee Valley Authority
DWG. No. 25-0001
D.O.E. PON DE-PS01-91FE62271
TVA Shawnee Station Unit 6
Micronized Coal Reburn Demonstration
NOx Control-175 MW Wall Fired Unit
Concept Diagram
Date
04/24/91
DLS
175 MWe Split Furnace
Overfire
Air Fan
(4) MicroFire
Burners
(16) Existing
Burners
(4) Existing EL-70
Pulverizers
Coal
Bunker
(4) MF-3018
MicroFuel Systems

Figure 1

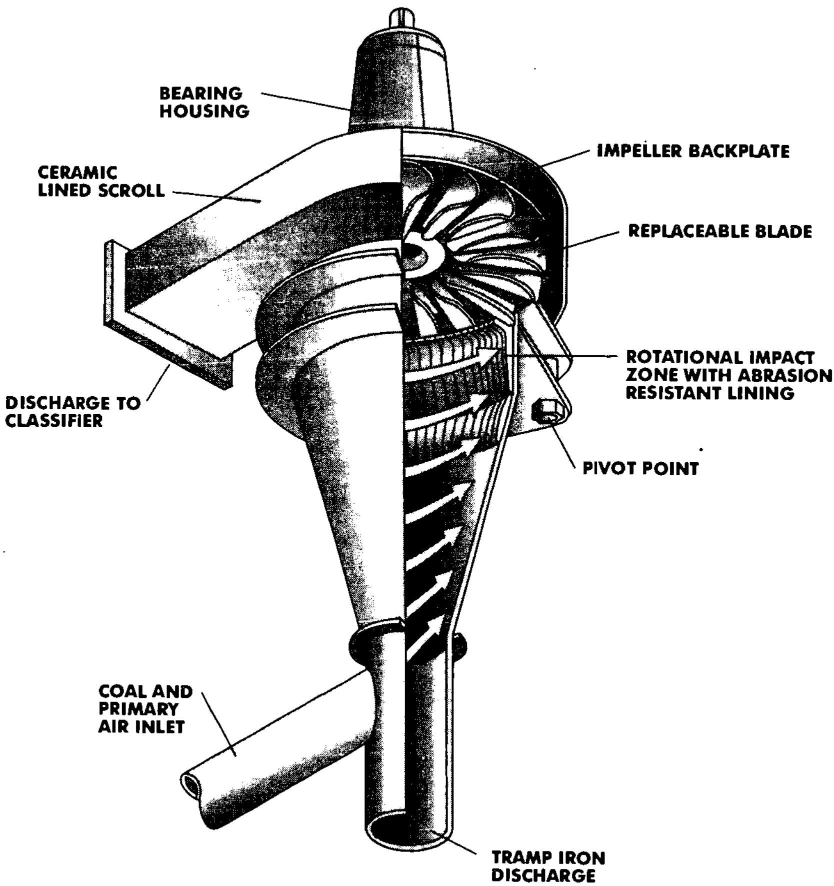
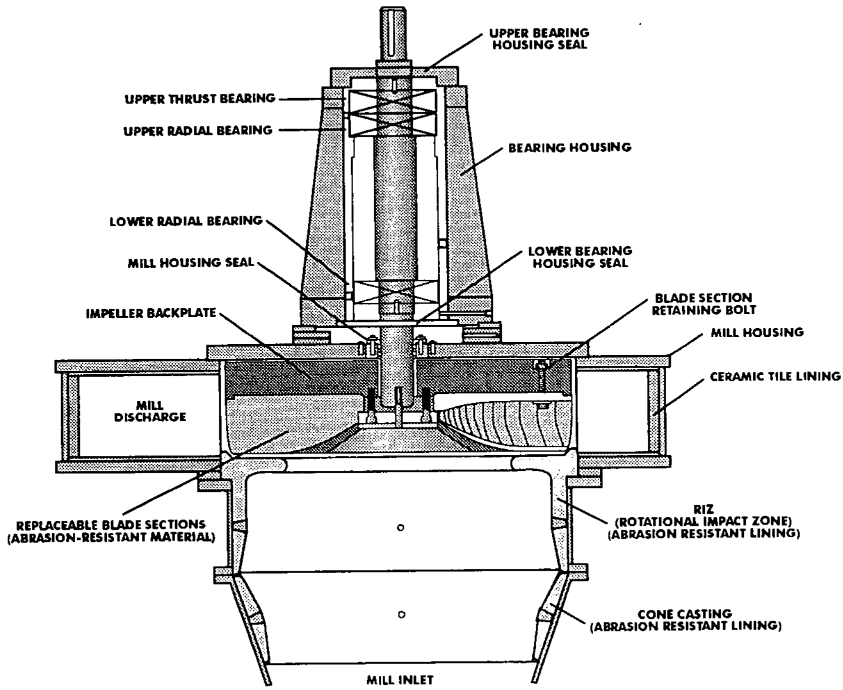

BEARING
HOUSING
IMPELLER BACKPLATE
CERAMIC
LINED SCROLL
REPLACEABLE BLADE
ROTATIONAL IMPACT
ZONE WITH ABRASION
RESISTANT LINING
DISCHARGE TO
CLASSIFIER
PIVOT POINT
COAL AND
PRIMARY
AIR INLET
TRAMP IRON
DISCHARGE

Figure 2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UPPER THRUST BEARING
UPPER RADIAL BEARING
BEARING HOUSING
LOWER RADIAL BEARING
MILL HOUSING SEAL
LOWER BEARING HOUSING SEAL
BLADE SECTION RETAINING BOLT
IMPELLER BACKPLATE
MILL HOUSING
CERAMIC TILE LINING
MILL DISCHARGE
REPLACEABLE BLADE SECTIONS (ABRASION-RESISTANT MATERIAL)
RIZ (ROTATIONAL IMPACT ZONE) (ABRASION RESISTANT LINING)
CONE CASTING (ABRASION RESISTANT LINING)
MILL INLET

Figure 3

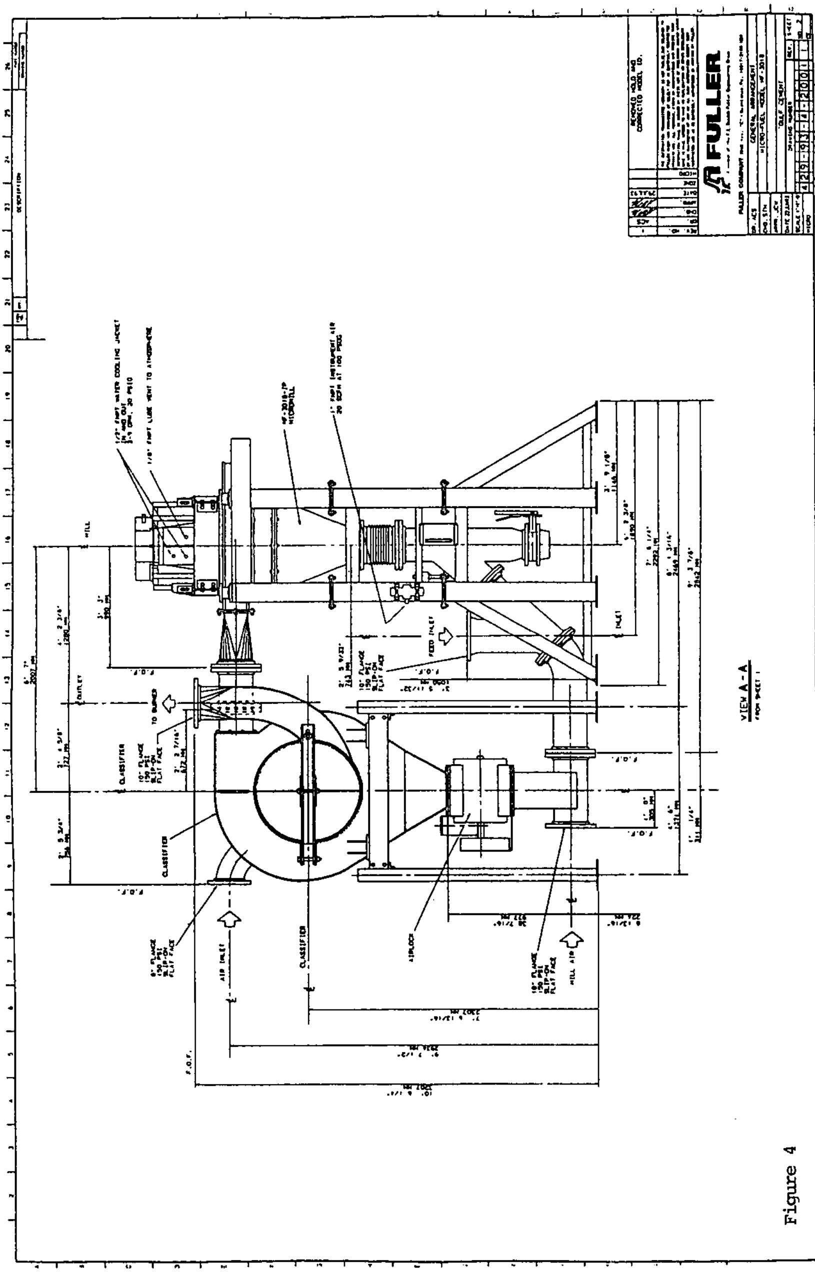
FULLER
VIEW A - A
AIR INLET
CLASSIFIER
AIRLOCK
MILL AIR
FEED INLET
TO BURNER
OUTLET

Figure 4