

MATERIAL HANDLING SYSTEMS FOR THE
FLUIDIZED-BED COMBUSTION BOILER
AT RIVESVILLE, W. V.

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ABSTRACT

The 300,000 lbs/hr steam capacity multicell fluidized-bed boiler (MFB) utilizes complex material handling systems. The material handling systems can be divided into the following areas:

- Coal Preparation; Transfer and Delivery
- Limestone Handling System
- Fly-Ash Removal
- Bed Material Handling System

Each of the above systems will be described in detail and some of the potential problem areas will be discussed. A major potential problem that exists is the coal drying system. The coal dryer is designed to use 600°F preheated combustion air as drying medium and the dryer effluent is designed to enter a hot electrostatic precipitator (730°F) after passage through a cyclone.

Other problem areas to be discussed include the steam generator coal and limestone feed system which may have operating difficulties with wet coal and/or coal fines.

INTRODUCTION

The Monongahela Power Company's Power Station in Rivesville, West Virginia, provided the facility for the installation and operation of a fluidized-bed combustion (FBC) steam generator. The space for the FBC steam generator was available in the Rivesville Power Station's existing boiler room where four (4) older boilers had been removed. This plant not only had the space, but also had available concrete and steel plate bunkers for storage of coal and limestone. The existing coal handling facilities were also utilized by installing an interconnecting conveyor to deliver coal into the bunkers. The plant's facilities for boiler feed water makeup, treatment and storage were made available for use. The existing fly ash storage silo and ash disposal site were available and are used for this project.

The installation of connecting headers and valving allows 300,000 lbs/hr of 925°F steam @1250 psig from the fluidized-bed combustion steam generator to be delivered into an existing 1250 psig, 925°F steam header. The steam will be delivered to an operating turbine generator whose full load requirement is 450,000 lbs/hr of steam.

The agreement between Monongahela Power Company and Pope, Evans and Robbins was signed in June 1973 for the installation and the later operation of the fluidized-bed steam generator.

RIVESVILLE PLANT EXISTING EQUIPMENT

Existing steam and power generating equipment in the Monongahela Power Company's Rivesville Plant:

Existing Power Generating Units

<u>Unit No.</u>	<u>Capacity MW</u>		<u>Year Installed</u>	<u>Type</u>
	<u>Rated</u>	<u>Actual</u>		
5	35	50	1943	Condensing
6	65	94	1957	Condensing

Existing Steam Generating Units

<u>Unit No.</u>	<u>Capacity Lbs/hr.</u>	<u>Year Installed</u>	<u>Operating Conditions</u>
7	450,000	1943	1250 psig/925°F
8	900,000	1957	1275 psig/950°F

As of this date, the FBC steam generator has not feed steam into the plant header. Operations thus far have been conducted by venting steam to atmosphere.

COAL PREPARATION, TRANSFER AND DELIVERY

The fluidized-bed combustion steam generator coal preparation and storage system was designed to process 50 tons per hour. Dry coal is purchased at the present time due to potential problems with the coal drying system.

The dry coal is conveyed by Monongahela Power Company's coal handling equipment and deposited in one of the existing steel plate coal bunkers which were renovated for the FBC coal storage system. From the steel plate bunkers, the coal is carried by new Redler conveyors to a surge hopper. From the surge hopper coal can be routed directly to the dry coal bunker if drying, crushing and classifying are not required, or through the dryer, crusher and classifier if required. The dryer can be by-passed to permit the use of the crusher and classifier only if necessary.

The coal dryer is a parallel-flow rotary type which was designed to remove the moisture with 600°F air. The 60,000 lbs/hr drying air supply is provided from the preheated combustion air system.

The coal would normally be discharged from the dryer into a crusher where it would be reduced to 1/4 inch top size. Because the coal is purchased dry and double screened, the existing coal drying and sizing system is by-passed and the coal dryer is not used.

A schematic flow diagram describing this system is presented in Figure No. 1 titled "Coal and Limestone Schematic Flow Diagram."

Coal feeds from the dry coal bunker to the vibrating feeders then to weigh belt feeders. It is then conveyed by bucket elevators to the three coal storage bins. The three bins gravity feed coal at a rate regulated by rotary feeders located directly under the bins. The rotary valves feed into pipes which are designed to discharge 6,000 lbs/hr from the north and south bins serving Cells A, B and C and 3,600 lbs/hr from the east bin which is the Carbon Burnup Cell bin. The discharge rate will vary depending upon the turbine generator load.

The coal is then mixed in the fuel feed pipe with limestone and is fed to the vibrating table feeders by means of rotary valves. The vibrating table divides the coal and limestone into eight channels which feed the mixture into the 1 1/2" needles (fuel injection pipes). Cells A, B and C are equipped with vibrating feeders located on the north and south side. (See Figure 2). The Carbon Burnup Cell is equipped with

one vibrating table. Air from the auxiliary forced draft fan is introduced at the vibrating feeder to inject the coal into the bottom of the fluidized bed.

Flyash from Cells A, B and C is reinjected into the Carbon Burnup Cell to prevent excessive unburned carbon losses.

LIMESTONE PREPARATION AND STORAGE

Limestone from a nearby quarry is used to remove sulfur during the combustion process. It is delivered to the plant by truck and is unloaded pneumatically. The limestone is prescreened prior to delivery to insure its minus 1/8 inch particle size.

The blower system on the delivery truck pneumatically transfers the limestone through a pipe to a cyclone separator located above the limestone storage bunker. The rate of transfer is 6 to 7 tons per hours. The limestone, after separation from its transport air, is discharged by gravity into the limestone bunker.

The limestone storage bunker is part of an existing concrete coal bunker. It has a storage capacity of approximately 450 tons. The stored limestone is supplied by gravity to the vibrating feeders beneath the bunker as required by load demand. The limestone is fed from the storage bunker by the vibrating feeder to a weigh belt conveyor which transports it by bucket elevators and Redler conveyors to three bins. (See Figure 3).

The three bins are located to the north, south and to the east of the steam generator. The limestone from the north and south bins has three discharge connections with rotary feed valves located on the bottom. The east bin has only one rotary feed valve.

Limestone is mixed with coal after it leaves the rotary feed valves which control the feed rate to be mixed with coal in the coal-limestone feed pipe.

The mixture of coal and limestone is then fed to vibrating feeders. The mixture is divided into eight streams per feeder and is then fed into the 1 1/2" stainless steel injection needles which deliver the coal and stone to the fluidized bed.

FLUE GAS CLEANING AND ASH REINJECTION

The high carbon fly ash from Cells A, B and C is removed from the mechanical cyclones and/or the electrostatic precipitator and is injected into the Carbon Burnup Cell. The flue gas cleaning system was designed to reduce the exhaust gases particulate concentration to 15 pounds per hour at rated load. The exhaust gas cleaning system has

three mechanical dust collectors and an electrostatic precipitator.

Flue gas from the Carbon Burnup Cell is directed to the No. 1 fly ash collector. The 40,000 lbs/hr of flue gas contains 13,120 lbs/hr of solids of which the mechanical collector is designed to remove 12,460 lbs/hr of solids. The remaining 660 lbs/hr is carried over into the flue gas system and fly ash collector No. 2.

The flue gas from the steam generator mechanical collectors with small amounts of particulate matter from dust collectors serving other systems are combined and enter the electrostatic precipitator at a rate of 406,000 lbs/hr. The gases contain 1,440 lbs/hr of solids of which the precipitator collects 1,425 lbs/hr. The difference is 15 lbs/hr of entrained solids in the flue gas.

FLY ASH REMOVAL

The fly ash collector and storage system was designed to receive ash removed from the steam generator exhaust gases.

The fly ash from the No. 2 cyclone and from four (4) of the six (6) electrostatic precipitator hoppers is transferred by a pneumatic system to the plant ash silo. The existing silo is located outside of the plant and receives the fly ash at a rate of 13,885 lbs/hr. This includes the 1,300 lbs/hr of fly ash entering the system from the electrostatic precipitator. The electrostatic precipitator uses a disposal system similar to that of the fly ash No. 2 collector.

Air for ash transport is supplied from two (2) blowers to the pneumatic system at the rate of 530 SCFM at 14 psig.

The pneumatic system transfers fly ash at a rate of 12,460 lbs/hr from the No. 2 collector serving the carbon burnup cell. An air lock assembly discharges the ash to the pneumatic transport line which carries it to the plant ash silo.

The fly ash collected from the No. 1 collector serving cells A, B and C is transferred from the hoppers of this equipment by gravity fed rotary valves or by lock hoppers. The fly ash to be reinjected is pneumatically conveyed by 600°F air from the forced draft combustion air to the Carbon Burnup Cell where it is injected at a rate of 15,560 lbs/hr of high carbon fly ash. This feed system by-passes the CBC vibrating feeder. The fly ash to be transferred to the plant ash silo is fed to the transport line by the lock hoppers and carried to the silo by air from the blowers (See Figure 4).

BED MATERIAL HANDLING SYSTEM

The fluidized-bed boiler was designed so that 80,000 lbs/hr of bed material could be removed and separated into undesirable particles or desirable material on the basis of size. The undesirable bed material is discharged into the existing ash silo while the desirable material is lifted by steam jet ejectors and air from the blowers to the bed material storage tank from which it can be reinjected into the fluidized beds. Four (4) rotary feeder valves with an air slide located under the steam generator are used to discharge the bed material from the different cells and transport it to the bed material classifier.

The hot bed material is then separated by the classifier. Material $1/8$ inch or less passes through and is discharged by a rotary feeder from the classifier into a vacuum line which transfers the material to the bed material storage bin. The bed material in the storage bin can be returned to the boiler cells as required. The rate of material return is controlled by rotary feed valves and is assisted by air from the forced draft duct.

Material larger than $1/8$ of an inch is collected at the base of the screen and discharged by a rotary feeder into a pneumatic system which transfers the material to the ash cooler. After the bed material is cooled, it is transferred by a pneumatic system that discharges the material to an existing ash silo located outside the plant. (See Figure 5). The classifier can be by-passed and all bed material routed through the ash cooler to the silo.

OPERATING EXPERIENCE

Operating History

The initial coal fire was achieved December 7, 1976, in the carbon burnup cell. Since that time, the carbon burnup cell has operated on coal for approximately 343 hours and Cells D (carbon burnup cell) and C have operated in parallel for approximately 23 hours. The first parallel operation of D and C cells occurred on April 5, 1977. Parallel operation of cells D, C and B was attained on April 19 and three (3) cell operation has been repeated three (3) times since then. Four (4) cell operation has not yet been achieved. (June 1977).

The boiler reaches normal operating pressure (1250 psig) with Cells D and C in service, but not normal steam temperature since the primary and secondary superheaters are located on Cells A and B respectively. With Cells D, C and B operating at normal pressure with a shallow bed and near normal temperature, a steam flow of about one-half load (150,000 lbs/hr) can be reached.

The D or carbon burnup cell is the only cell equipped with oil burners. Start-up of adjacent cells is accomplished by opening a slide gate between cells, (Figure 6) then allowing hot bed material to flow into the next cell and igniting any residual carbon in the bed along with the coal being fed. This system has worked relatively well, although there have been some failures to achieve ignition when the slide gate was opened. Transfer of hot bed material has occurred rapidly (well under one minute) in every case except one, when a clinker blocked the slide gate opening.

Coal System Design

Both the original coal bunker and the new coal bins exhibit funnel flow because of their design and because in some cases fine moist coal has been used. As a result, severe problems of arching and ratholing above each outlet have occurred. Consequently, the live storage capacity of each unit is greatly reduced.

In addition to the above problems, flow problems occur in the bins because of their smaller outlets (4" for the CBC bins and 6" for the A, B and C cell bins vs. 2' in the bunker). The cause of this problem is the four (4) small ledges of each outlet where the square outlet interfaces with the round discharge pipe. Since the storage bins receive coal at fewer points as compared to the bunkers, fines accumulate below the bin feed point resulting in undesirable separation of fines and coarser material. Some operational problems occurring in the fluidized-bed boiler may be attributed to the material coming out of the central outlet having more fines than that coming out of the two end outlets. (Figure 7).

The coal dryer has not been operated as the mixture of 500°F drying air and coal dust is considered somewhat hazardous with the dryer located inside the plant. A further concern is that the coal fines-air mixture entering the electrostatic precipitator from the coal dryer might be ignited by a spark.

Some problems have been experienced with air leakage through the rotary valves above the vibrating feeders. These problems have not been as severe since vents were installed below the rotary valves at the upper end of the feed pipe; however, the vented air was not provided for in the auxiliary fan design. Plugged rotary valves may be caused by feeding material when flow has stopped in the vibrating feeder, and forcing material into the rotary feeders with a rod when attempting to restore coal flow as arching and ratholing occurs. Some material build-up on the rough carbon steel vanes of the rotary feeders has occurred.

Difficulty is experienced in obtaining equal distribution to the feed needles. The variation in flow rates through the several outlets of the vibrating feeders (Figure 8) is on the order of $\pm 30\%$. This appears to be inherent in the design.

Pluggage of the 1 1/2" stainless steel needles which connect the vibrating feeders to the fluid bed has been a frequent cause of shut-down. In some cases, this was caused by failure to establish or maintain sufficient air flow to the needles to prevent them from becoming overheated. When coal flow is initiated into an overheated needle, a coke plug can form and the needle may be rendered inoperative. Other potential causes of needle stoppage are failure to maintain adequate air pressure on the vibrating feeder as the bed height is increased.

The automatic sequencing of the coal and stone vibrating feeders under the bunker, the weigh belts, the bucket elevators and the Redler conveyors (Figure 9) has not yet worked as designed. The signals from the "Bindicators" in the surge bins often provide false information as the material assumes various configurations in the bins. It has been necessary to station personnel at the bins to initiate fill up and shut-down operations.

Oversize and foreign material has caused coal feed stoppages.

Bed Material System

This system (Figure 10) has operated successfully for short periods of time (total operating hours are estimated to be 100). Some difficulty has been encountered in attempting to feed from the bed material storage tank to the boiler cells despite the fact that an aerating ring is provided.

The vibrating air slide which handles bed material being removed, shook loose from its lead anchored bolts and had to be grouted and through bolted.

Some of the specially designed rotary feeders required resetting of clearances to prevent jamming, when handling hot bed material.

Fly Ash Collection, Disposal and Reinjection System

This system has performed relatively well although no reinjection has been attempted yet.

Some initial plugging of ash hoppers was caused by the operation speed of the lock hopper valves (too slow).

A potential problem exists which may become troublesome when larger quantities of calcines limestone dust begin to enter the ash silo and are quenched by water during removal from the silo.

The temperature of the ash to the power company ash silo must be monitored closely in order not to exceed their maximum allowable temperature of 150°F.

Stone Handling System

The limestone is delivered by truck and charged pneumatically into the concrete storage bunker. Before going into the bunker, the material goes through a separator and dust collector removing most of the fines.

The time required to unload a truck is about three (3) hours and this is two (2) times the intended unloading time; however, no availability problems have been experienced as yet. The required lift is 94 feet.

Discharge from the bunker is through two (2) 2' square outlets into vibrating conveyors and then by a bucket elevator and Redler conveyor to one of three limestone bins. Feed from these long rectangular bins is through a transition piece. The transitions have an outlet which is square and which feeds to a circular pipe whose inside diameter is, at most, 1/2" larger than the inside dimension of the square.

PRACTICAL APPLICATIONS OF OPERATING EXPERIENCE

Coal Systems

A temporary solution to the coal feeding problem has been to accept only properly sized (1/4" x 1/2"), dry (3% max. moisture) coal. This involves additional expense and since considerable breakage occurs in the plant coal handling system, a substantial percentage of fines must still be handled.

All welds on the new stainless steel sloping plates in the bins have been polished. These lessen the effects of the shallow corners in each pyramid. Low pressure pulse air supplied to the region between the pyramid and cone would probably promote better flow.

Smooth stainless steel liners were installed in the rotors of two of the rotary feeders, but this reduced the feed rate by 25% and could not be tolerated.

Vibrators have been installed on the bins.

Vents have been installed to avoid the air bubbles which form at the rotary feeder just under the bins. This is a temporary solution and may bleed off more air from the vibrating feeders than the auxiliary F.D. fan can supply, when all four (4) cells are in operation. If this proves to be the case, then a correct differential between vibrating feeder and fluidized bed cannot be maintained and needle pluggage may occur. This problem will be especially troublesome when a maximum bed depth is desired.

The ultimate disposition of the coal dryer problem is not clear at this time.

Some possible solutions are:

- o Move the dryer outside the plant.
- o Use the flue gas as the drying medium instead of heated air
- o Install explosion relief doors with ducts to the outside of the plant.

Limestone Systems

The limestone truck unloading time could be reduced by assisting truck mounted blower with conveying air from another source.

Coal and Limestone Systems

The control arrangement which starts and stops the vibrating feeders, weigh belts, bucket elevators and Redler conveyors fully loaded in response to bin levels could be modified to stop only the vibrating feeders first, then after a suitable time delay, to permit the other elements of the system to unload, the weigh belts, bucket elevators and Redler conveyors could be stopped. This would permit gradual loading and reduce the frequency of shearing pins in the bucket elevator and Redlers.

CONCLUSIONS

Rivesville has a plethora of material handling problems. Some of these problems are common to most material handling systems and can be corrected by available methods and equipment. Other problems which are peculiar to fluidized bed boilers are more difficult, but practical solutions must be found if the fluidized bed boiler is to achieve commercial success.

We believe that the most pressing problem facing this technology is the method of dividing the fuel into the required number of individual

streams. The second most obstinate design hurdle may be the method of conveying the individual streams into the fluidized bed, while avoiding such problems as feed stoppage, localized reducing conditions, poor distribution and excessive elutriation of fines.

We have not addressed the questions of combustion efficiency, automatic combustion control and sulfur removal since they are not directly related to materials handling and experience at Rivesville is not sufficient at this time to have conducted definitive evaluations. It appears that if the material handling and fuel feed systems can be made to function properly the boiler will be stable, efficient, reliable and will meet emission standards.

ACKNOWLEDGEMENT

We wish to thank the Pope, Evans and Robbins, Inc. personnel who have been extremely cooperative and open concerning the hardware performance at Rivesville.

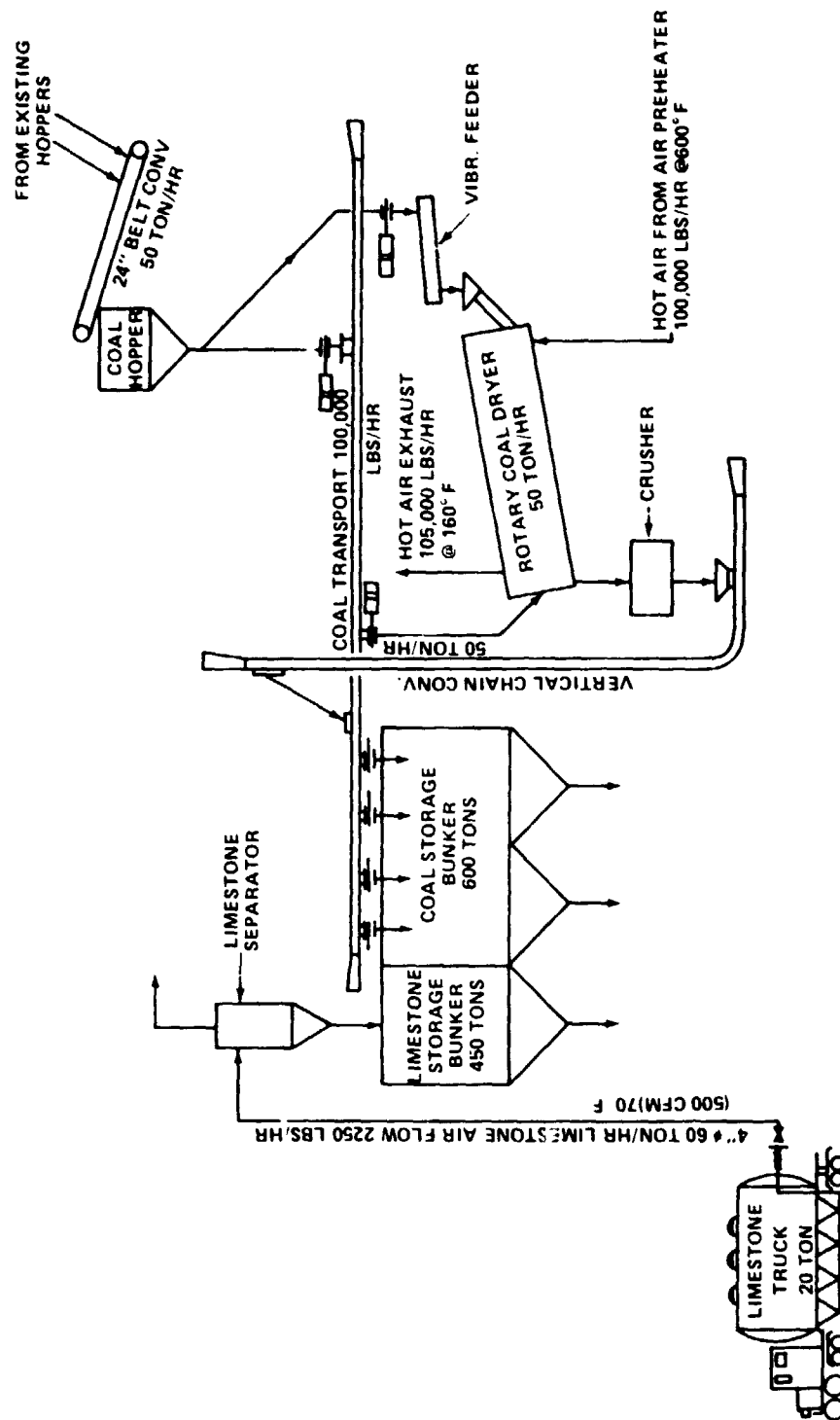
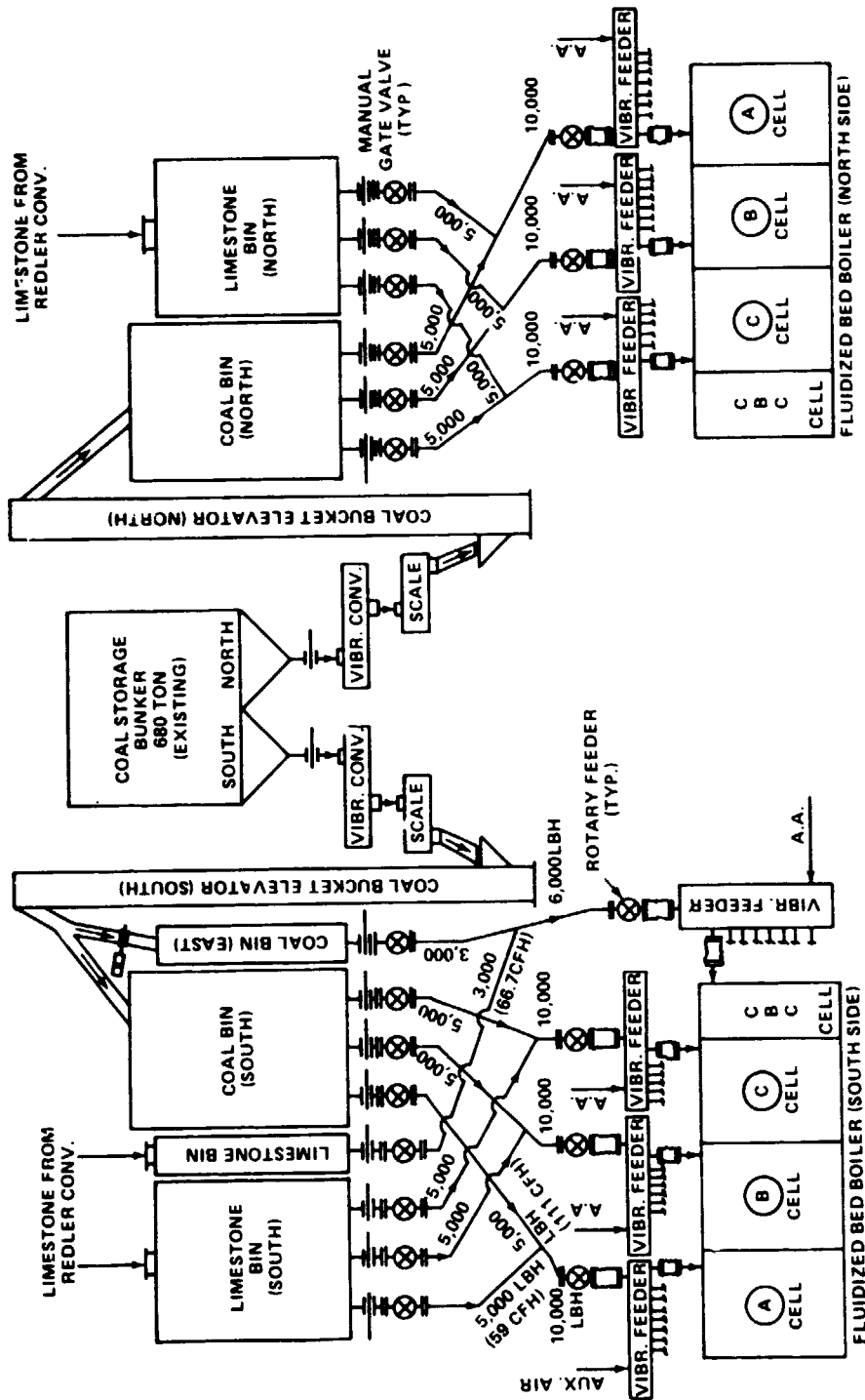


FIGURE 1
COAL & LIMESTONE
HANDLING SYSTEMS



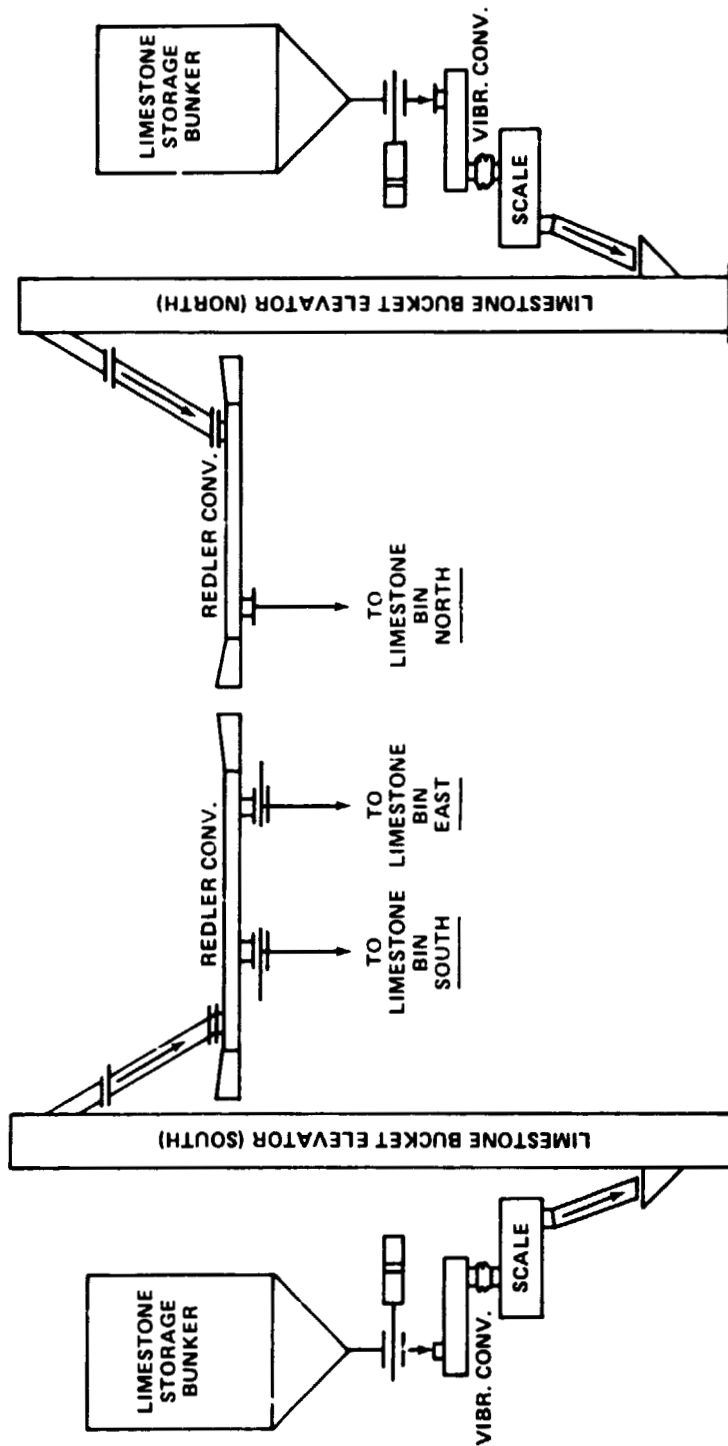


FIGURE 3
LIMESTONE HANDLING SYSTEM

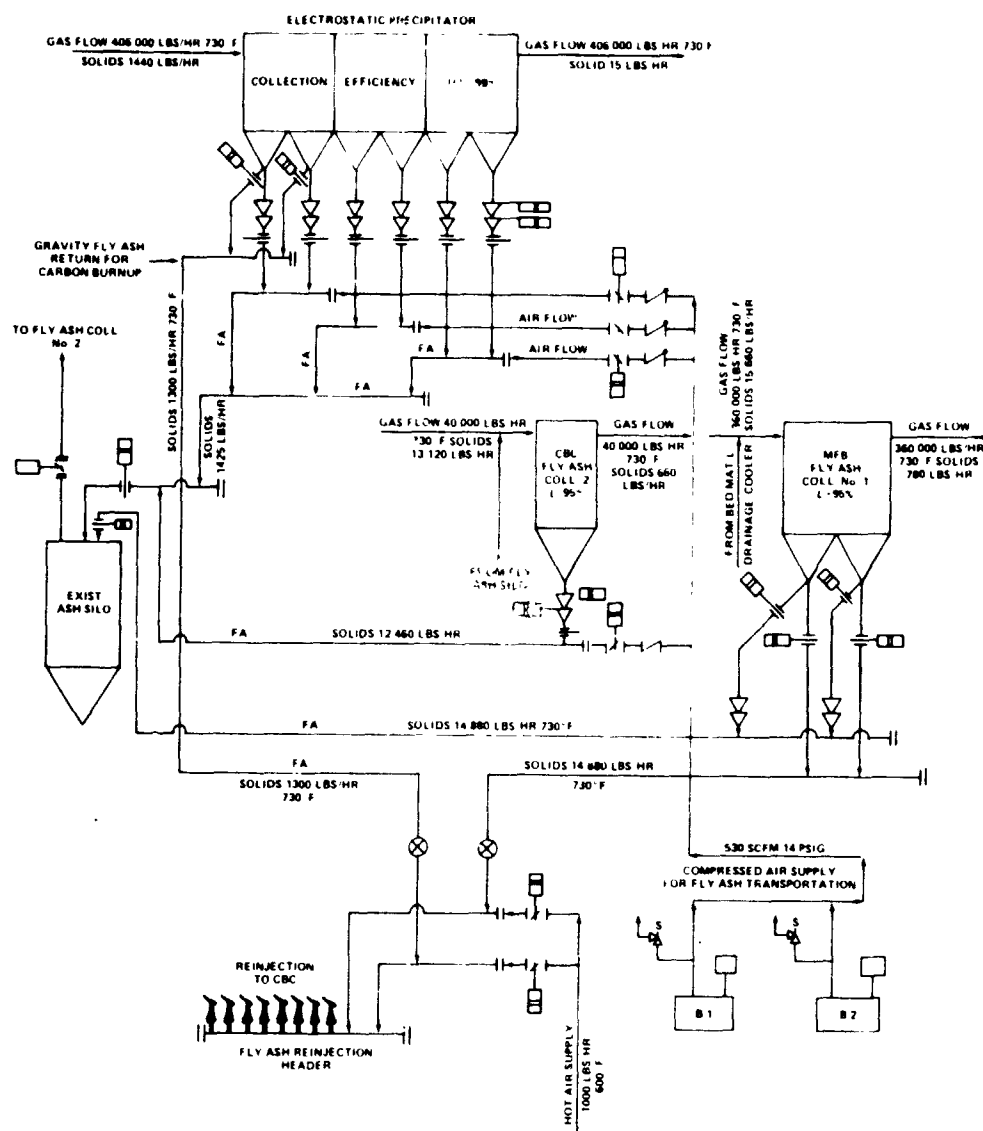


FIGURE 4
FLY-ASH COLLECTION AND
REINJECTION SYSTEMS

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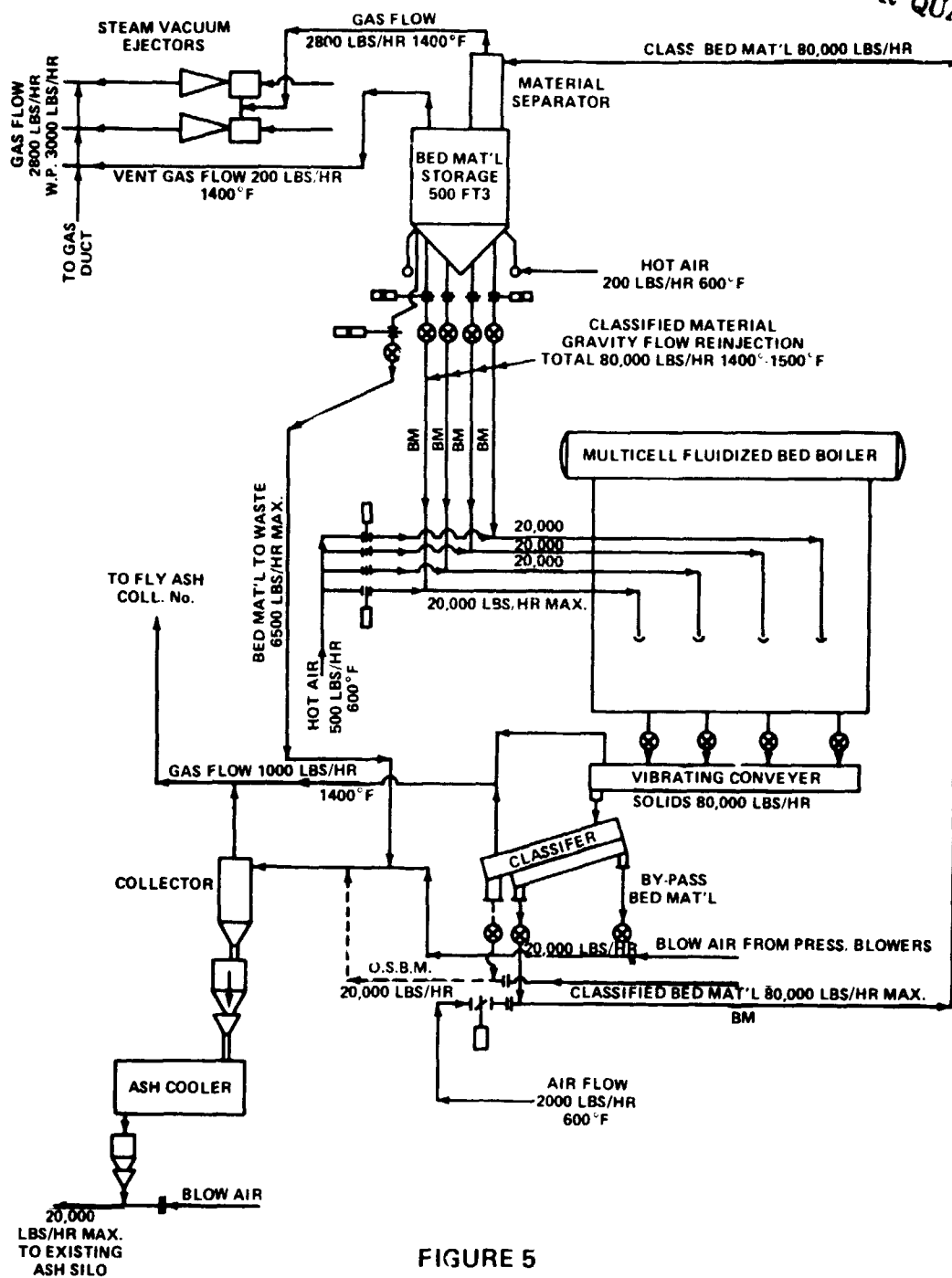


FIGURE 5
BED MAT'L HANDLING
SYSTEM



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FIGURE 6
CARBON BURNUP CELL SHOWING SLIDE GATE

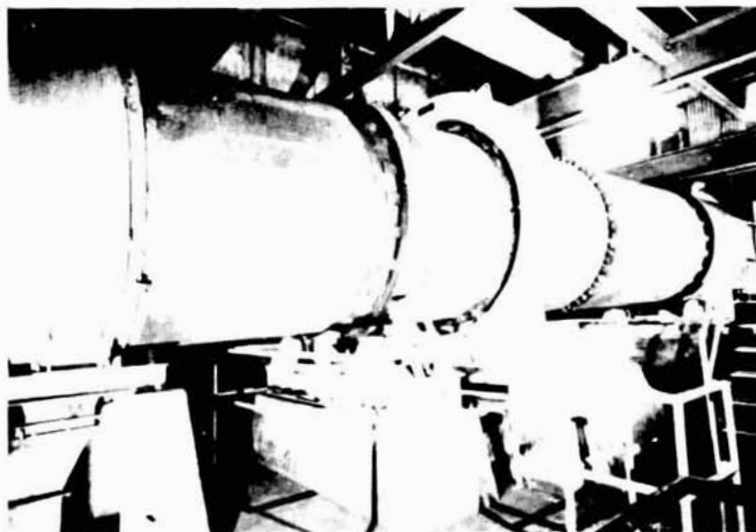


FIGURE 7
COAL DRYER

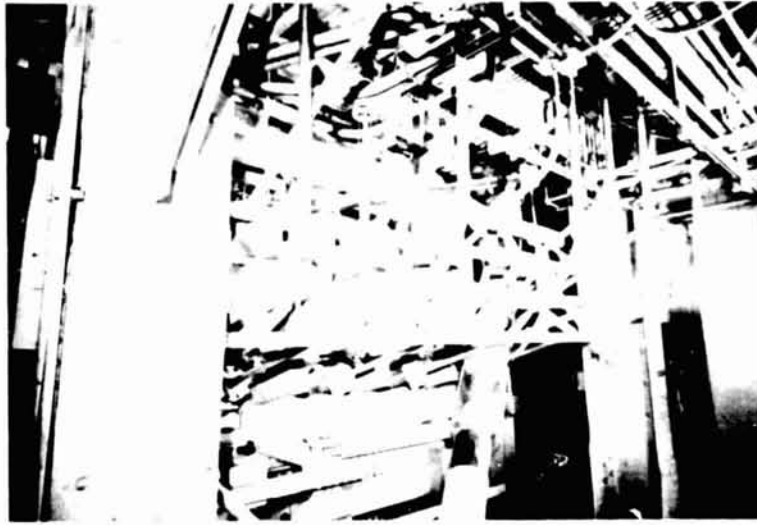


FIGURE 8
FEED NEEDLES

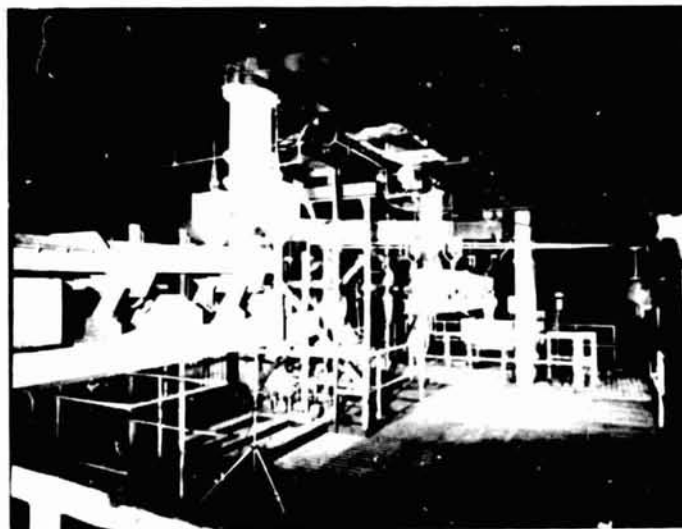


FIGURE 9
VIBRATING FEEDERS LIMESTONE

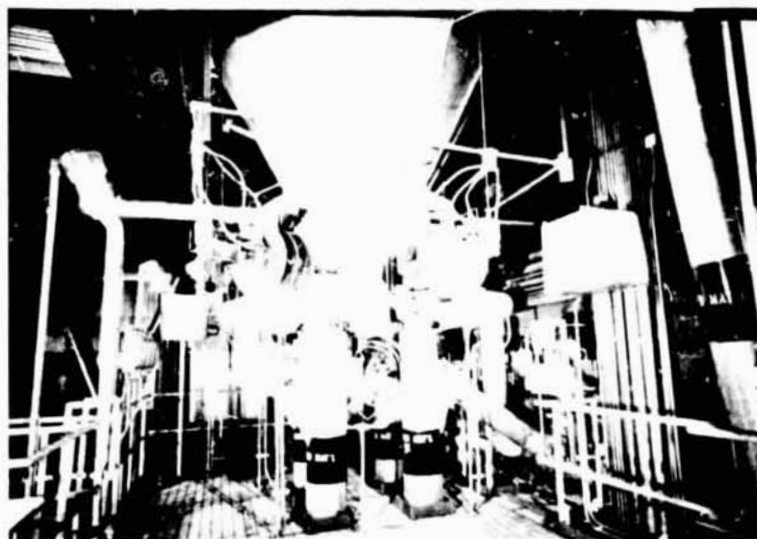


FIGURE 10
BED MATERIAL STORAGE

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FIGURE 11
FLY ASH REINJECTION AND/OR DISPOSAL