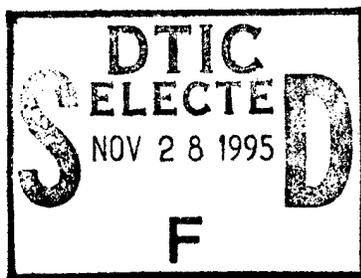




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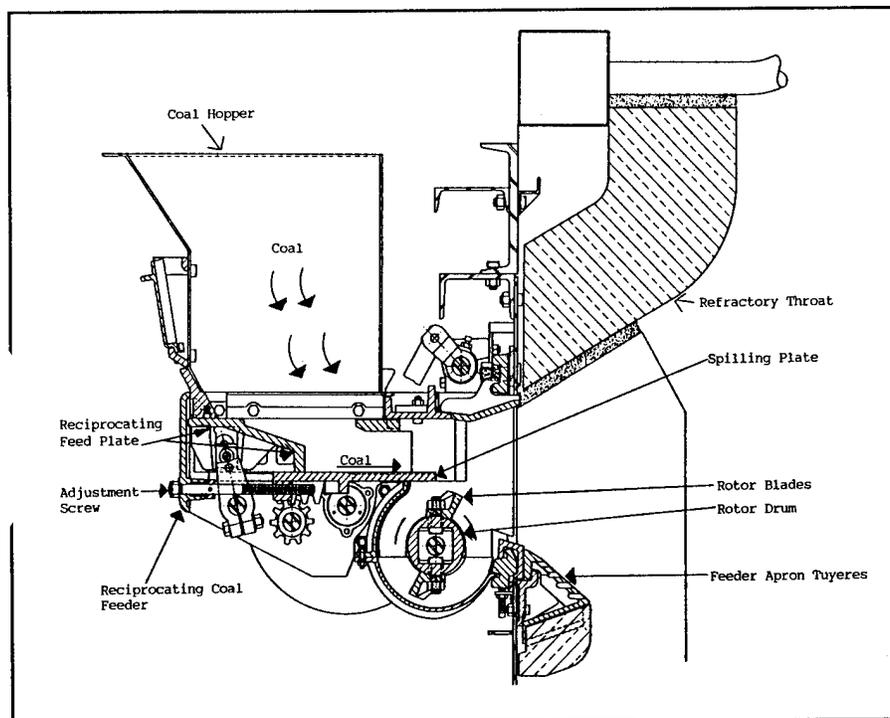


USACERL Technical Report 95/29  
August 1995

# Evaluation of the Boiler Plant at Malmstrom Air Force Base, MT

## An Air Quality Permit Review

by  
Jearldine I. Northrup, Charles Schmidt, and Robert Brinkley



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An evaluation of the Malmstrom Air Force Base (MAFB) coal-fired Central Heat Plant (CHP) was begun in January 1995. The system was evaluated and tested, on-site improvements were made, and recommendations were made to continue improved system performance.

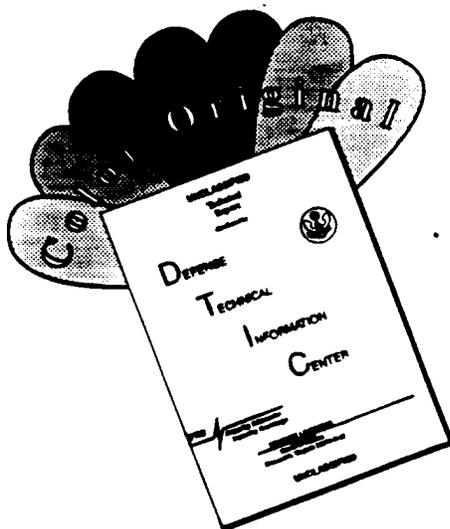
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Operation of the spray dryer equipment may also be improved by correcting problems involving low exit temperatures by raising the temperature at the inlet to the spray dryer. Tests proved conclusively that the existing SO<sub>2</sub> removal system can be operated to achieve removal rates higher than 85 percent. However, investigation revealed a significant equipment problem; the baghouse flue gas outlet emission monitor gives unacceptable, operationally unreliable readings. If MAFB continues to use this inadequate equipment, such incorrect readings will likely cause further regulatory problems.

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## Executive Summary

An evaluation of the Malmstrom Air Force Base (MAFB) Central Heat Plant (CHP) was requested in 1994 and the work commenced in January 1995. A team of experts from Schmidt and Associates, Joy Technology, and the U.S. Army Construction Engineering Research Laboratories (USACERL) was assembled at MAFB. Corrections were made on-site by the team. Additional work was contracted to another group to run tests to verify the need for the recommended work and to detect the effects on the system. This report presents the results from the site visits and testing.

It was found that the control equipment, as it was installed, will perform at the level required to meet environmental regulatory standards. The spray dryer equipment was at the time of installation, and still is, the Best Available Control Technology (BACT). Operation of that spray dryer equipment has changed significantly in the last 10 years. It is now known that the effectiveness of the equipment depends on the change in temperature of flue gas as it passes through the reaction chamber. This means that problems involving low exit temperatures (condensation in the baghouse) can be controlled by raising the temperature at the inlet to the spray dryer (above 300 °F is recommended). It is recommended that this be achieved by reducing the speed of the Ljungstrom Air Heater during conditions of low loads.

Continuing to use coal technology offers a fuel resource advantage because, in Great Falls, the competing fuel (natural gas) is imported from Canada. One way to decrease the tons per hour of sulfur output is to modify the controls to allow co-firing of gas and coal. Since the control equipment at MAFB is 10 years old, the installation may do better by replacing present equipment with new controls.

If regulatory officials desire to have flue gas SO<sub>2</sub> concentrations indicated as a relationship to heat output, then the metering equipment must be changed. The current BTU output meter is in error by more than 30 percent under the best operating conditions. The most accurate devices that the team found at the plant in terms of heat input were the coal scales. These scales have maintained their accuracy because the plant personnel accurately calibrate and maintained them in excellent condition. The lack of accurate information about the BTU output is, in fact, a result

of the inaccuracy of the device, which reflects on the original construction, not on equipment maintenance or operation .

Current equipment operation shows that the existing SO<sub>2</sub> removal system can be operated to achieve removal rates of 85 percent only when the plant is operating at peak condition. Several minor changes are recommended to improve the operation and reliability of the SO<sub>2</sub> removal system. It is recommended that the federal limitation of 0.32 lb/MBTU be adopted as a more realistic SO<sub>2</sub> removal rate limitation.

This study revealed a significant equipment problem; readings from the existing baghouse flue gas outlet emission monitor were in error by a factor of 300 percent—a marked contrast with the required on-line reliability of this equipment, which must approach 98 percent and be in the +10 percent range for reading accuracy. It cannot be overemphasized; the flue gas outlet emission monitor simply gives incorrect readings. This is an unacceptable, operationally unreliable condition that must be fixed. If MAFB continues to use this inadequate equipment, such incorrect readings will likely cause further regulatory problems.

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## Foreword

This study was conducted for the Malmstrom Air Force Base Environmental Office under Military Interdepartmental Purchase Request (MIPR) No. N95000010, dated 10 March 1995. The technical monitor was David Heckler, 341 CES/CEVC.

The work was performed by the Industrial Operations Division (UL-I) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). The USACERL principal investigator was Jearldine I. Northrup. Ralph E. Moshage is Acting Chief, CECER-UL-I; John T. Bandy is Operations Chief, CECER-UL; and Gary W. Schanche is Chief, CECER-UL. The USACERL technical editor was William J. Wolfe, Technical Resources.

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# 1 Introduction

## Background

On 31 October 1986, construction of a new coal-fired central heating plant (CHP) was completed at Malmstrom Air Force Base, MT (MAFB) to replace the existing, poorly operating system and to increase the facility's heating capacity. The new system was designed to burn coal and (as a back-up fuel) natural gas. During initial start-up, the construction contractor experienced problems in operating the system while firing coal. The U.S. Army Construction Engineering Research Laboratories (USACERL) helped the Army Corps of Engineers, Seattle District and MAFB isolate problems, identify their causes, and develop solutions.

Despite the resolution of initial operating problems, the CHP continued to experience limitations in equipment operation. Although a complete equipment analysis by skilled engineers was never performed, it was postulated that the low sulfur content of the local coal rendered the spray drying equipment unusable at low loads of less than 35 percent.

The Malmstrom Air Force Base (MAFB) Environmental Office requested USACERL's assistance in remediating a Montana Department of Health and Environmental Science (MDHES) and an Environmental Protection Agency (EPA) Notice of Violation involving the installation's CHP. Specific tasks included evaluating the equipment and operation of High-Temperature Water Generators (HTWGs) No. 1 and 3 to determine why the plant was unable to meet the existing construction permit requirements. Operational assistance was to be provided by the contractors if that was discovered to be the problem. Additionally, the Air Emissions Construction Permit was to be revised and a Title V permit developed for the HTWG house.

## Objectives

The objectives of this study were to investigate and identify combustion and air pollution compliance problems at the Malmstrom AFB, and to provide guidance on maintaining efficient and compliant HTWG plant operation.

## Approach

1. In October 1994, the Malmstrom Air Force Base (MAFB) Environmental Office requested USACERL's assistance in remediating a Notice of Violation involving the installation's CHP.
2. USACERL researchers assembled an investigative team of experts in December 1994.
3. The team made its first site visit in January 1995, in which it inspected, tested, and set up operational procedures for HTWG Nos. 1 and 3 and associated equipment.
4. The team concluded its visit with operational and maintenance workshops.
5. In March 1995, a return visit was made to test HTWGs No. 1 and 3, specifically to evaluate their performance against MDHES and EPA requirements.
6. The results of the inspections and tests were analyzed, conclusions were drawn, and specific operational and maintenance recommendations were made to continue efficient and compliant HTWG operation.

## Terminology

Throughout this report, the terms "left" and "right" sides of the equipment refer to the user's perspective while standing in the firing aisle looking directly at the unit. From this standpoint, the user's left hand is the left side of the unit and the right hand is the right side of the unit. Figure 1 gives unit numbers including "right" and "left" designations.\*

## Metric Conversion Factors

Metric conversions for standard units of measure used in this report are:

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 lb	=	0.453 kg
°F	=	(°C × 1.8) + 32

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\* All figures follow their corresponding chapters.

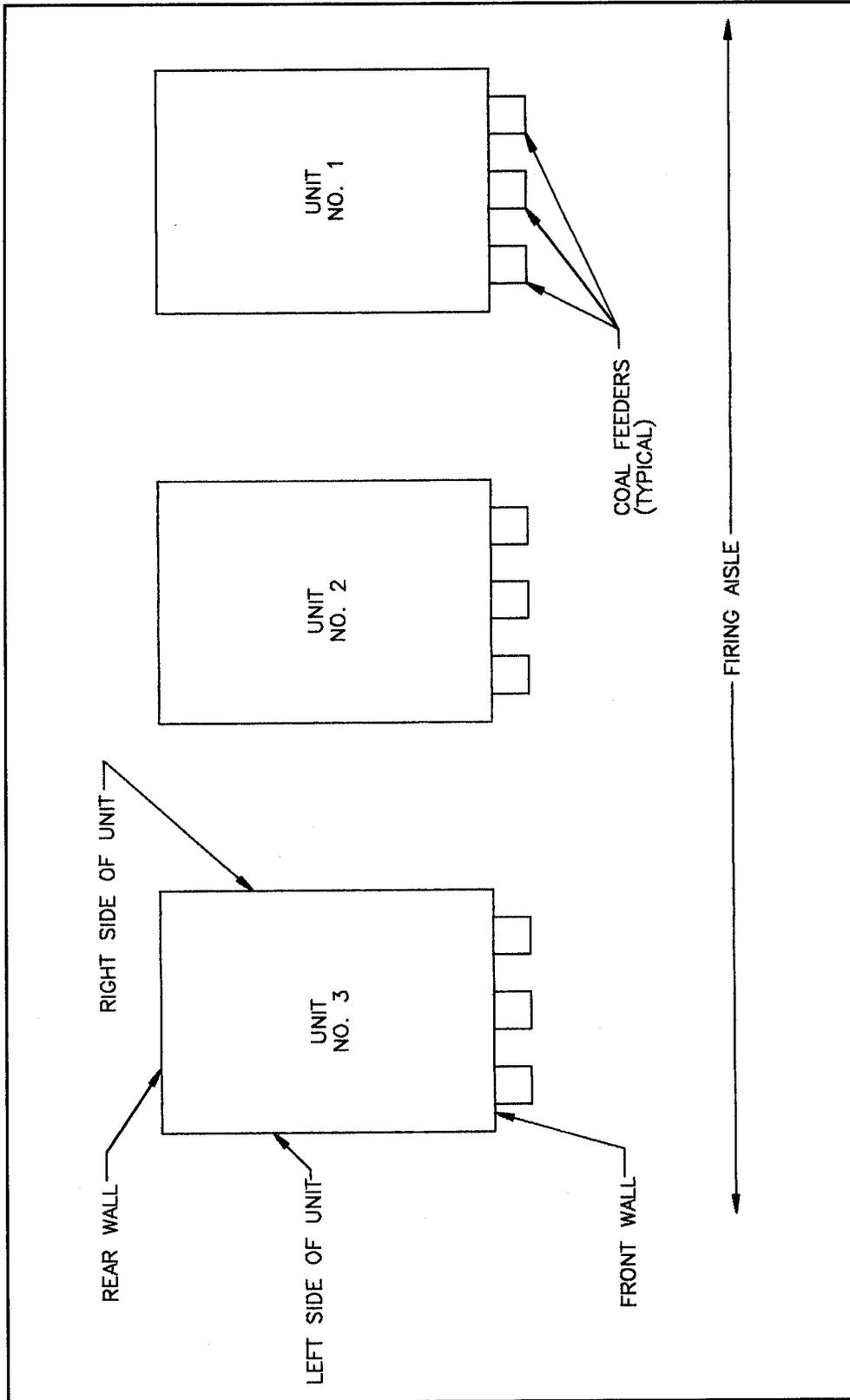


Figure 1. MAFB coal-fired high temperature hot water generator configuration.

## 2 High Temperature Hot Water Units 1 and 2

### Unit 1, Coal Feeder

#### *Description and Assessment*

Unit No. 1 is a 85,000,000 BTU heat output, High Temperature Hot Water Generator. The fuel firing equipment is a Detroit Spreader Stoker Traveling Grate unit (Figure 2). Coal sizing has been a recurrent problem for the equipment operators, who often have difficulty correcting the wide variation in coal size. The coal feeder distributes the coal from the back to the front of the HTWG by using rotor blades that operate at a constant speed (revolutions per minute, or RPM), and at a constant force. Depending on the mass size of the coal, large pieces of coal will be thrown to the rear of the grate and fine pieces of coal will remain in front.

Figures 3 and 4 shows the right coal feeder; Figure 5 shows a section view of the coal feeder. The coal enters the coal hopper and falls by gravity into the reciprocating coal feeder. The reciprocating feed plate pushes the coal over the edge of the spilling plate. The coal falls on to the rotor blades and is thrown into the furnace. The speed actually sets the coal flow rate that spills off the spill plate. The spill plate is the first manual adjustment of how the fuel will be distributed on the grate. The coal falls off the spill plate and hits the rotating blades running about 800 RPM and then throws the coal back on the grate. A uniform product size is needed from 1-1/4 in. to zero size (or a maximum of 25 percent 1/4 in. by zero). Fewer fines at 1/4-in. by zero is always a preferred fuel condition.

The large pieces of coal are thrown to the back of the grate because of size and the smaller coals are distributed from the back to the front; the 1/4 in. by zero coal falls no more than 3 ft from the feeder. A large amount of 1/4-in. by zero coal will accumulate in a very thick pile of fuel on the front grate and a thinner layer of coarser coal in the rear fuel bed. Air will flow more freely through the thinner fuel bed, making it physically impossible to burn the fine coal in the front of the grate. The air comes up through the grate air holes and through the ash/fuel bed. The plant does an excellent job of air control and is running 7 percent O<sub>2</sub> or 50 percent excess air (50 percent more air than theoretically required). A uniform fuel bed on the grate is absolutely required and that fuel bed depends on coal size and the manual manipulation of the operators.

The fuel is rapidly consumed by this combination of suspension and thin fuel bed burning, making the Stoker highly responsive to load variations. Response to automatic control is immediate on either an increase or decrease in load demand. Synchronized connections to the combustion control system provide automatic regulation of the fuel feed rate, air supply, and grate travel speed, to conform to variations in load.

Beneath the burning fuel, the ash bed serves to protect the grate surface from the heat of the burning fuel and combustion chamber. The ash bed also serves to cause uniform air flow through the fuel bed. The forced draft undergrate air cools this ash bed and the grates, helping to prevent fusing (clinkering) of the ash. The forward rate of motion of the traveling grate is adjustable and designed to allow the formation of an ash bed thickness (preferably 3 to 8 in. deep at the front) to maintain this protection (depending on load).

Strictly speaking, there is practically no fuel bed with the Stoker. The depth of the burning coal on the grates, or on top of the ashes, will vary from practically nothing to about 1 or 1½ in. depending on the size and characteristics of the fuel. It is important to prevent the burning coal from reaching a greater thickness because of the tendency of deep coal beds to smoke and form clinkers from lack of sufficient air supply.

Optimally, the flame should be from 4 to 6 in. off the back wall of the furnace. If the flame is located too far from the wall, 1 to 1-1/2 ft for instance, the coal will be thrown short on the grate and will cause air leakage through the rear of the grate. Furnace operators should be able to see across the furnace to the back wall to correctly adjust for conditions of coal size, spill plate adjustment, and rotor speed.

### ***Problem***

The system cannot tolerate coal containing 40 percent by weight less than 1/4-in. size. The system can accept coal sizing from 1-1/4 in. to zero, but large quantities of fines cannot be tolerated. These coal feeders also cannot tolerate an inconsistent mix of coal sizes, a problem commonly produced by poor handling and storage of the coal. Typically, the coal is discharged down a drag conveyer and dropped into the bunker through three openings, which alternate every 2 minutes. When coal is piled in one spot, the large coal rolls to the perimeter and the small (1/4-in. x zero-in.) coal is

concentrated in the center—a process that inadvertently sizes the coal into a product unsuitable for the feeders.

### ***Solution***

The solution to this problem lies in creating more, smaller piles of coal, e.g., six smaller piles instead of three large ones. The more small piles made, the less segregation or the separation of big coal and fine coal will occur (Figures 6 and 7).

The fuel purchaser should ensure that the incoming coal does not have more than 10 percent 1/4-in. by zero coal because the process of handling coal creates fines; any higher percent of fines will eventually result in an unacceptable fuel. For example, unloading the coal from the railroad car and placing it in the stock pile generates 5 percent more fines; i.e., a purchase of 10 percent immediately results in 15 percent fines in the stock pile. Moving the stock pile into the bunker generates another 5 percent, i.e., up to 20 percent 1/4-in. by zero fines.

When coal segregation does occur, the coal handler must ensure that the stockpile is re-mixed to a uniform state. Since it is undesirable to have 25 percent 1/4 by zero at these coal feeders, the coal handler person must receive help from the person that's reclaiming the stock pile. The stock pile front end loader operator must mix some of coal on the perimeter with some of the fines in the center. A rubber tire front end loader is the correct type of vehicle to move coal without creating yet more fines. The front end loader operator should lay the coal in layers while building the coal pile so the coal is segregated no more than necessary. Once the pile is reclaimed, it should be correctly placed in the bunker right, separated by three wedges to get six drop points (rather than three). The wedges will cut the minimize coal sizing problems down at a slight cost (about \$500 each to build).

## **Stock Conical Distributer**

### ***Description and Assessment***

The Stock Conical Distributer is the mechanism that feeds coal from the coal scale to coal feeders; it takes a slice of a perimeter of the pile of the cone. The Conical Distributer has a warped shape that allows it to distribute the fuel equally by fines and coarse to all feeders.

### ***Problem***

During this study, plant personnel calibrated the coal scale. An hour test showed that, when checked against a measure of coal input and HTWG efficiency, a coal-scale output measure of 40,000,000 BTU/HR was actually putting out 51,000,000 BTU/HR. This indicates that the HTWG heat output indication on the Net 90 Computer is in error, and has apparently been operating under these conditions since the last testing of the unit (1986). Even if one allows a large margin of error (500,000 BTU), for an output of only 50,500,000 BTU/HR, the difference between the instrument-measured and calculated values is so great that it indicates a significant problem. The water orifice plate is greatly suspect to be in error or the computer calculation.

### ***Solution***

The coal scales can be used to measure the heat input to the plant.\* To get a sample of what is truly coming through the feeder, take a 2-lb composite sample every 10 minutes, e.g., if the stack test run takes 60 minutes, take six coal samples, 2 samples on one feeder, 2 samples on the second feeder, and 2 samples on the third feeder. Average numbers will suffice, but it is imperative to use current readings.

The Base Engineering Group at Malmstrom AFB is planning a long-term project to install an opacity monitor after the mechanical collector to allow the operator to better see what is going on in the furnace.

It is also important to keep current maintenance and operator logs. Annual inspection forms will help keep a historical record of maintenance and inspections.

## **Rotor Blades**

### ***Description and Assessment***

There are two types of rotor blades—"straight" and "curved." The straight blade type is typically located along the side of the feeder closest to the wall. Detroit Stoker has two designs of rotor blades, "stepped" and "nonstepped"; these should always be alternated. In other words, in the right side of this right feeder starting from the center of the HTWG working to the sidewall, there should be a curved stepped, a curved nonstepped, and a straight stepped. Figure 8 shows the correct rotor blade location.

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\* The plant should calibrate coal scales before every stack test.

## Coal Feeders

### *Description and Assessment*

The Center Coal Feeder (Figures 9 and 10) shows no throat refractory wear on the right hand side of the coal feeder. The left hand side of the throat refractory shows some coal wear.

Left Coal Feeder (Figure 11) shows the lower front overfire air nozzles, which are in very good condition. The refractory surrounding the nozzles is properly flared or coned.

### *Problems*

If the coal hits the coal feeder throat refractory, it will drop in the front of the grate.

Figure 9 shows where coal has been striking the refractory surfaces, limiting the ability of the fuel to evenly distribute itself to the rear of the grate.

### *Solutions*

The broken refractory brick above the coal feeder should be repaired.

On the left feeder, refractory problems require attention, but should not be torn out; instead, the excessive refractory should be ground down. The left hand side of the throat refractory also shows coal wear and should be ground down by  $\frac{1}{2}$  in. in the area of wear. It is important to note that, even though a conscientious maintenance man may prefer to rebuild the refractory, the best course is *not* to replace or rebuild the refractory in the throat opening because the coal will simply hit the refractory and improperly distribute itself on the bed—duplicating the problem that occurred on No. 3 HTWG on two of three of the feeders.

The coal feeder refractory and the refractory above the feeders meet at a “joint” with the side wall tubes (Figure 12), which must be packed with mineral fiber or other fibrous refractory. The mineral fiber or other fibrous refractory will expand and contract as the front wall refractory expands. The front wall refractory must not push against the sidewall tubes.

## Overfire Air & Flyash Reinjection Air

### ***Description and Assessment***

Each HTWG has five ductwork headers that supply 15 to 17 percent of total combustion air from the overfire air fan:

1. Front upper overfire air
2. Front lower overfire air
3. Rear upper overfire air
4. Rear lower overfire air
5. Flyash reinjection air.

Each header has a manual damper to distribute the quantity of total overfire air fan flow. The overfire air fan has an automatic damper to proportion the overfire total air flow to HTWG total heat output load.

### ***Problem***

The overfire air causes a "rolling of the fire" from the upper front overfire air traveling into the furnace and down near the grate, then rolling, turning, and coming back up towards the coal feeders. This "rolling of the fire" directs the flame back up into the coal feeder throat, causing the cast iron coal feeder to become hot, possibly causing major damage to the feeders, which are worth about \$25,000 each.

### ***Solution***

The plant maintenance personnel need to install pressure gages between the manual damper and each header. These pressure gages should be in the range of zero to 40 in. of water column.

As the coal size changes, the individual static air pressure in the various overfire air headers require adjustment. General criteria for individual static air pressure at 38 million BTU/HR heat output on the panel screen are:

- *flyash reinjection air*: this should be as low as possible to just keep flyash moving into the furnace through the reinjection pipe; 10 in. static pressure
- *front upper*: 2 in. static pressure
- *front lower*: 5.3 in. static pressure
- *rear upper*: 20.0 in. static pressure
- *rear lower*: 17.5 in. static pressure

There are also two rows of overfire air in the rear. The upper rear overfire air header static pressure will also have to be decreased when the percentage of fine coal increases, or coal feeders will overheat.

As the coal sizing changes, the overfire air must be adjusted to hold down the opacity. Especially if there are fines, it becomes important to increase the lower front set of overfire air and decrease the upper front overfire air. Be careful when firing a spreader stoker with these upper front overfire air. If static pressure in the header reaches 20 in. in the upper front overfire air header, it will actually cause that air to come out and down to the grate, roll back up front, and bring flame up into the coal feeder, causing the cast iron coal feeder parts will get red hot. This generally occurs as a result of two conditions: (1) a high percentage of fines in the coal and (2) a thick fuel bed of fine coal on the grates in front of the feeder.

## **Furnace Tube Alignment**

### ***Description and Assessment***

The front wall tubes are in nearly perfect alignment. The convection tubes are also in very good alignment (Figures 13 to 16). However, some tubes are out of alignment on both sidewalls. The upper sidewalls are very good condition; the maximum tube misalignment is ½ in. The lower side wall shows poor workmanship either in the original fabrication or repair work.

### ***Problem***

In the rear of the furnace wall, the tubes will wear from flyash in about 10 to 15 years. The rear of the furnace wall has severe tube movement, most likely due to the difficulty of positioning the tubes during the original construction of the unit.

The thin plate at the burner hole is warping and allows a lot of air infiltration, but the burner location is correct.

### ***Solution***

When the tubes are replaced, they should be rolled out of the furnace to the outside casing. This will increase their useful life to as long as 50 years. The tubes that hang out where the flue gas stream and the fly ash particles pass over them will have 10 to 15 years of life.

The maintenance personnel should sketch the furnace, noting how far out into the furnace these tubes are protruding. Tube movement should be monitored yearly to ensure that the tubes do not continue to move out into the furnace. If checks show that the tubes are continuing to move out, the tubes will have to be replaced to prevent problems.

There is always concern that the front, rear, and sidewall pressure part tubes may become misaligned or move over time (Figure 13 to 16)—conditions that will reveal themselves in an annual check. A "light test" can be done to quickly check these conditions in the field. All lights should be off except one strong bright flashlight. Shining the flashlight perpendicular to the tubes will show which tubes are protruding (bending) into the furnace space. Shining a flashlight over the wall tubes will show tube alignment and misalignment.

The burner hole in the burner throat (Figure 16), should be plugged with a lightweight refractory plug, cut in half so it can be handled, but tapered so the refractory wedges together on the circumference and drives together at the centerline.

The nozzles on the upper and lower rear row of overfire air should always be kept clean—as they were at the time of this study. Any slag on the nozzles should be removed (Figures 14 and 15). This slag shown in Figures 10 and 11 on the rear wall comes from the flyash reinjection system. (Flyash is being reinjected in the middle of the slag.)

## **Grates**

### ***Description and Assessment***

The grates are in excellent condition because of a excellent ash fusion temperature of coal. The grate holes are not plugged or cracked. Several gates show minor imperfections in the casting, which is acceptable.

These grates appear relatively newly installed, and have probably been in operation less than 12 months. Successful grate maintenance is a result of proper ash fusion temperature coal; in this case, the plant operators have distributed the fuel on the grates properly and had sufficient ash on the grates to provide the grates insulation. The coal bed in combustion actually protects the grates from the radiant heat of the furnace. If the fuel bed at the rear of the grate becomes too thin, the radiant heat from the coal combustion radiates back down on those grates, overheating them.

### **Problem**

With time, these grates will crack, generally from the back edge, the thinnest part of the casting, into an air hole.

Where the under grate air seals down between the grates in the windbox area on the front grate seals, the combustion air must be controlled—in front of the big structural member that crosses the width of the unit, where the front shaft carries the grate. The bearings are supported off the structural member. The structural member seals the air from going out towards the grate when it turns around the front. Of the three upper air seals; one is dropped down and leaking (Figure 17). That air seal should be as tight as possible against the grates. By the time the coal and ash gets this far forward on the grate, it should be completely burned out.

Maintenance personnel should be aware that a certain amount—about 10 percent—of new products from manufacturers may be unsuitable for a given application. Figure 18, for example, shows grates riding on the top support rail. The support rails are beveled so that, as the grate moves forward, it cannot catch on the edge of the support rails. If a replacement rail is not beveled when it arrives at the plant, it should be beveled at the plant. A “marriage” exists between the HTWG manufacturer and the stoker manufacturer at the L-type side support rail that the grate rides on. In this unit, the packing between the L-type support rail and the tubes is almost entirely burned out.

### **Solution**

When an HTWG is shut down for maintenance, the opportunity should be taken to enter the furnace with a hammer to punch every air hole out. If a grate is cracked, replace the grate bar.

Many areas require insulating cement to control air (Figure 19). The grates must be removed annually to drop the air seal down and install the insulating cement.

Another annual maintenance item that was missed in the past and these are rear grate tuyeres (Figure 20). They must be loose enough to move and are hung from a frame. This tuyere is loose. Clean out this ash back to the mineral fiber or other fibrous refractory insulation, about 9 in.. Every year, put “insulating cement” (not hard castable refractory) in the cavity. Insulating cement is more suitable than other refractory material because it will take a dent, and because it allows the tuyeres to move up and down so they will not wear the grates and overload the grate drive. The insulating cement also stops the cold air infiltration rolling up the rear wall tubes,

carrying flyash and wearing out the wear blocks. Such "tramp air" causes wear blocks to wear out. This rear wall should be protected. HTWG tubes should not be left exposed or the flyash will erode them. The tubes can be protected by either replacing the steel or cast iron block, or by adding some refractory to protect the tubes.

The packing between the L-type support rail must be pulled out and replaced annually even if the HTWG has been on-line only 2 months.

## High Temperature Hot Water Generator No. 2

### *Description*

Unit No. 2 is equipped with a Coen natural-gas burner that will carry approximately 35 million BTU/HR heat output. Note that this equipment has not been used for coal firing for some time. This year, the coal feeders were removed, and a new operations permit is currently being processed. This unit is used for:

1. Small spring seasonal load
2. Small fall seasonal load
3. Additional load capacity on the coldest winter days.

The unit has grate protection insulation already in place along with a short refractory wall for coal feeder protection. The coal feeders can be removed as spare maintenance reserve units for the other two HTWGs.

### *Recommendations*

A 3/8-in. thick stainless steel plate with insulation protection should be installed over the feeder openings. All bolt holes should be oversized to allow expansion of the stainless steel plate.

Installation of soft-block refractory on the furnace floor would reduce tramp air.

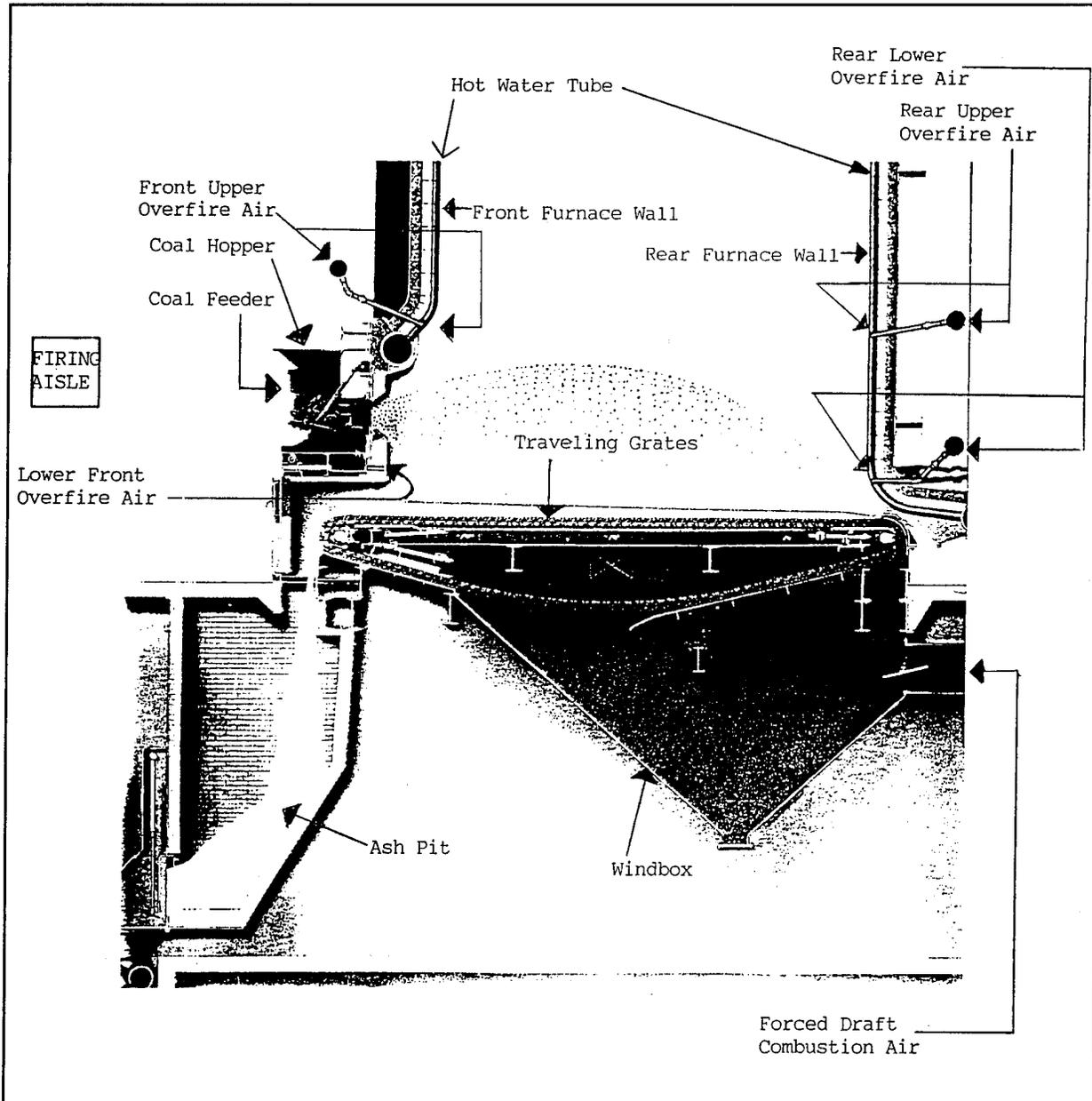


Figure 2. Detroit Spreader Stoker Traveling Grate unit.

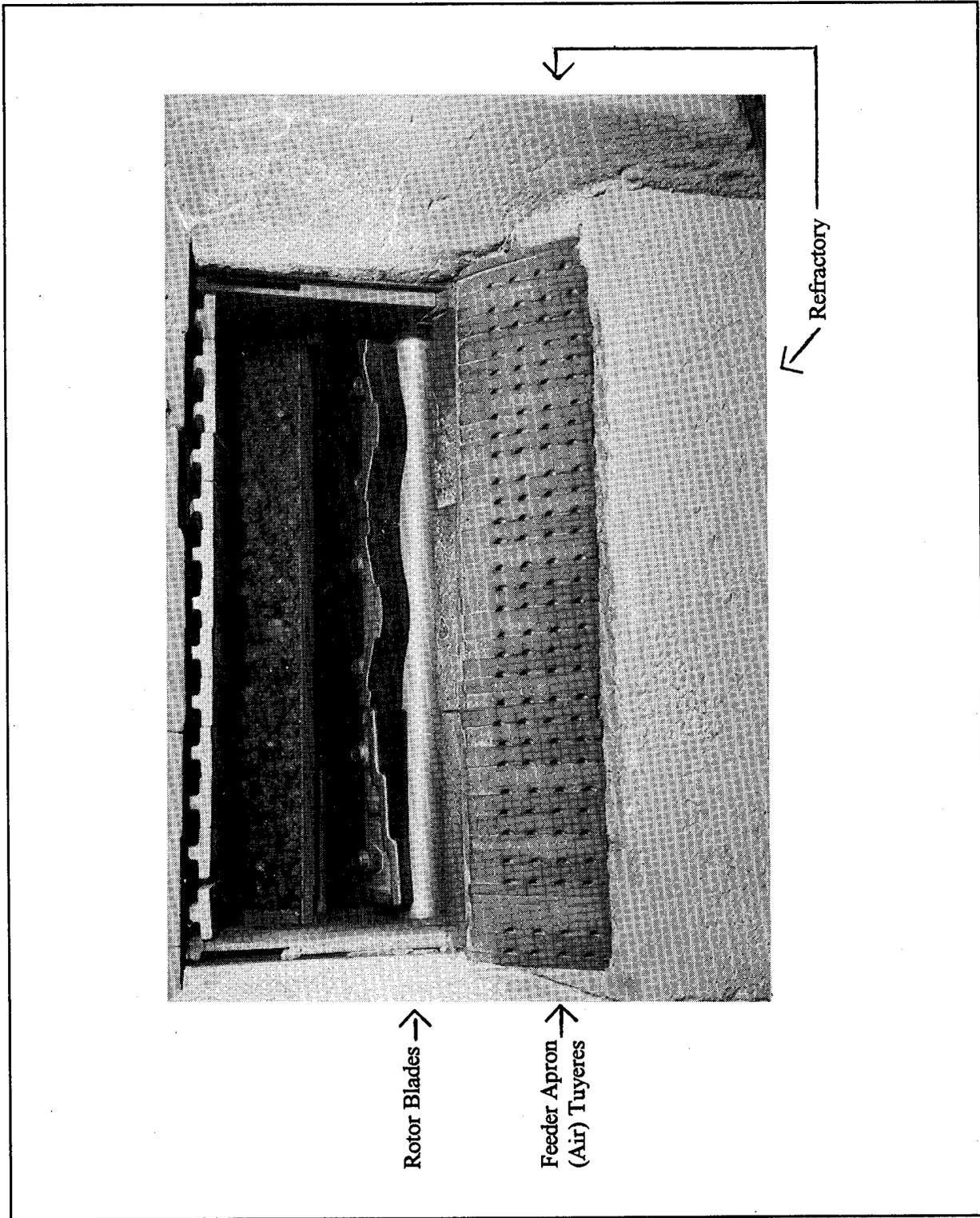


Figure 3. View of right-hand coal feeder from inside generator.

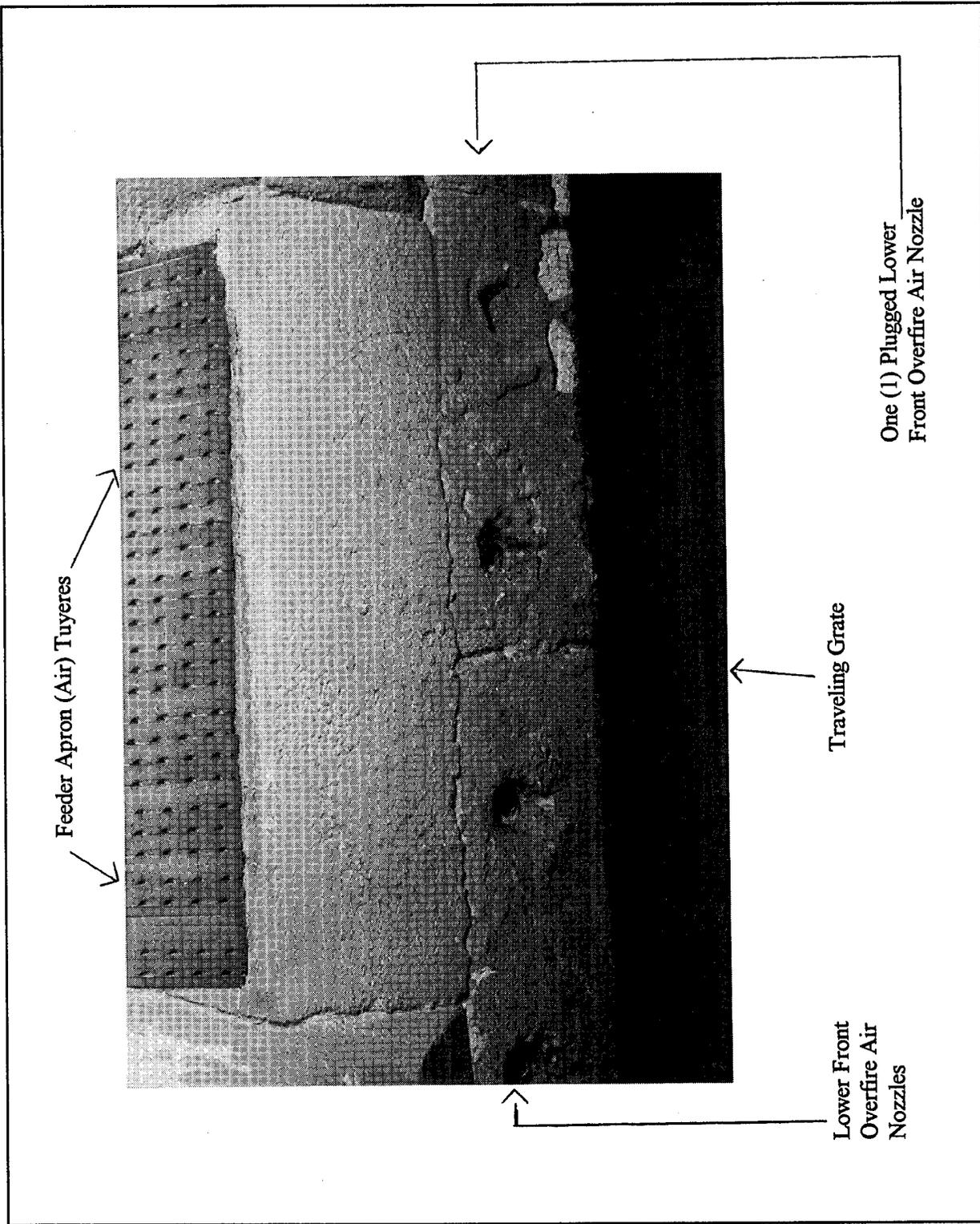


Figure 4. View of right-hand coal feeder from inside generator showing plugged overfire air nozzles.

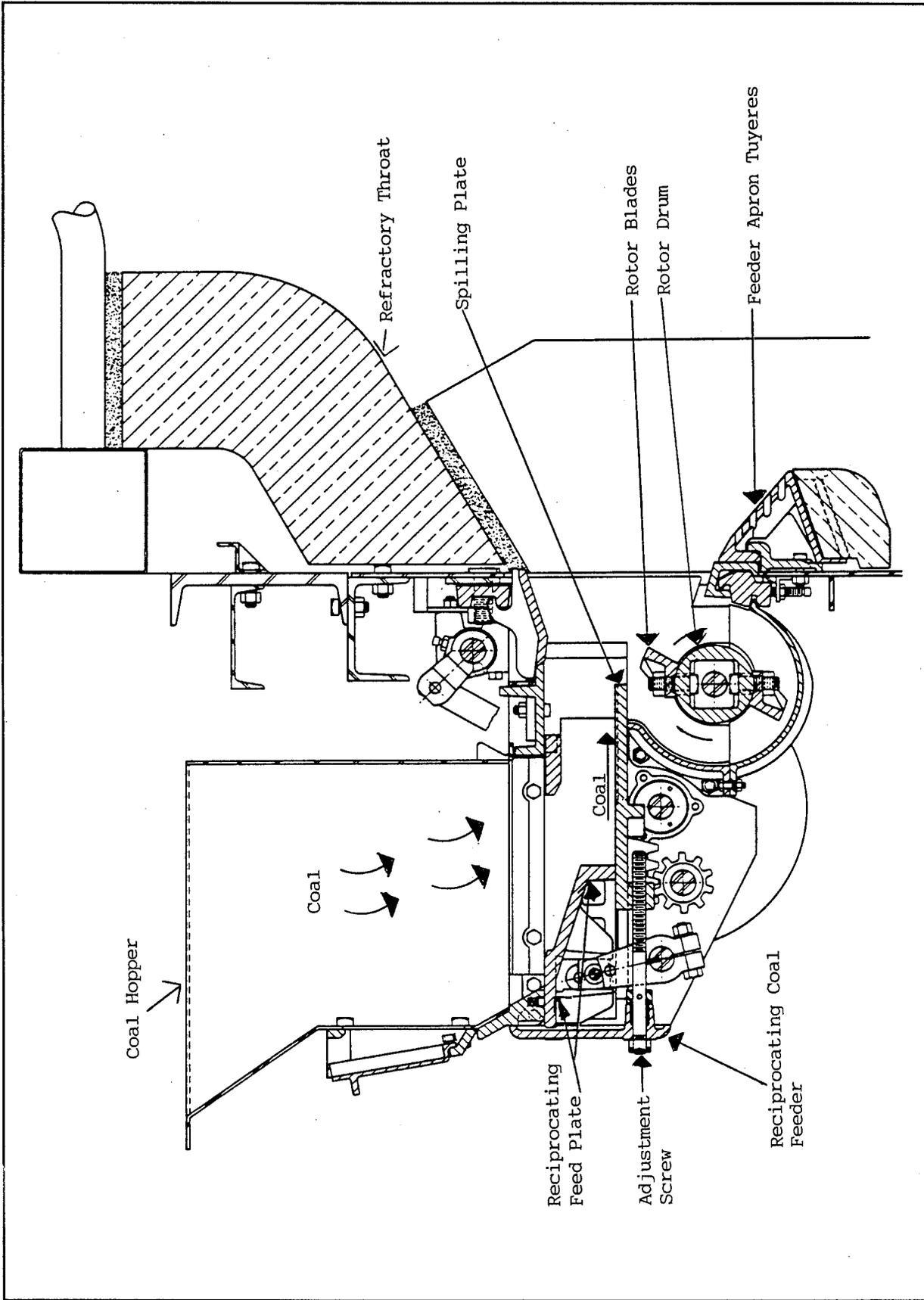


Figure 5. A section view of the coal feeder.

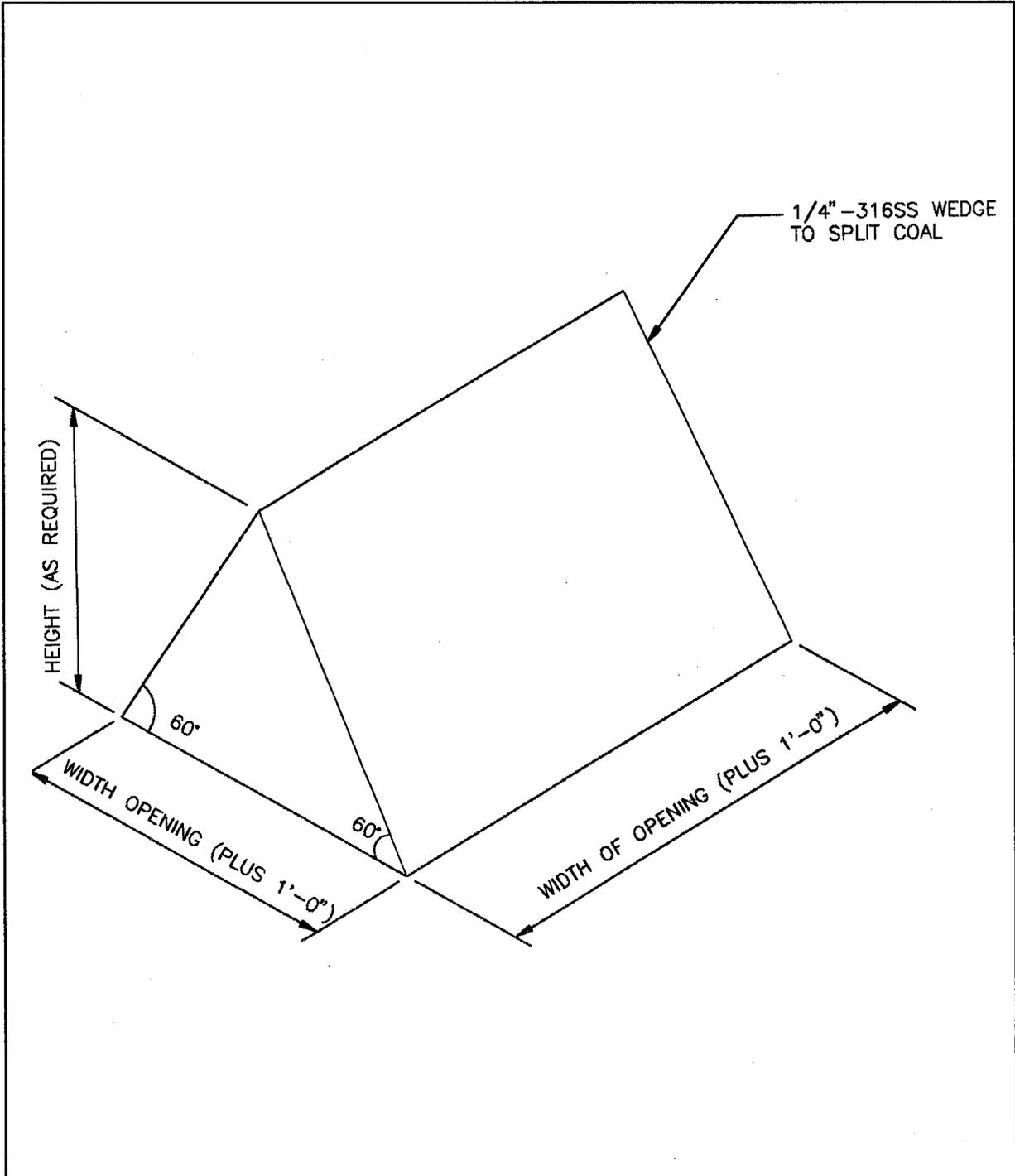


Figure 6. Wedge to split coal.

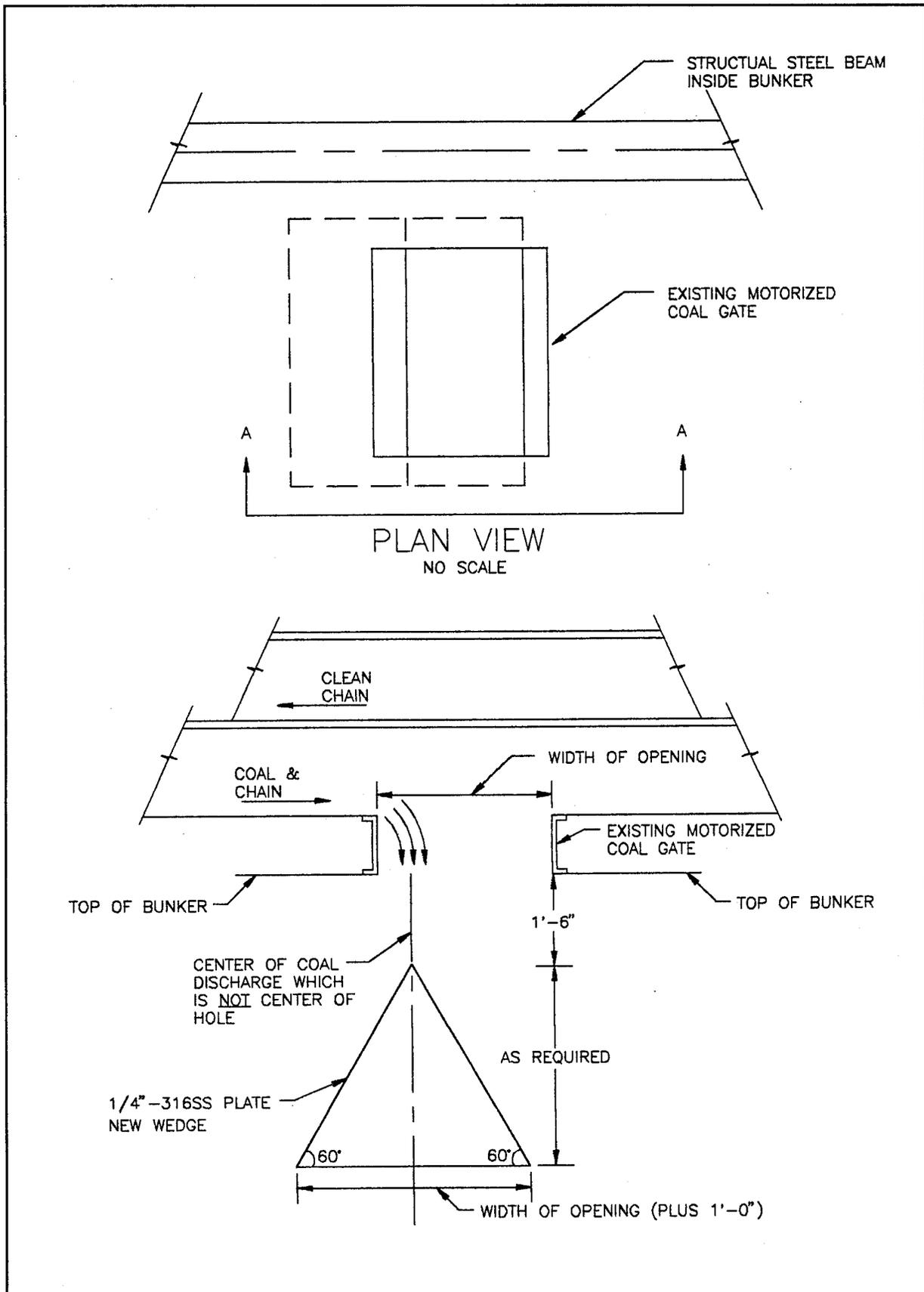


Figure 7. Plan for coal bunker using wedge.

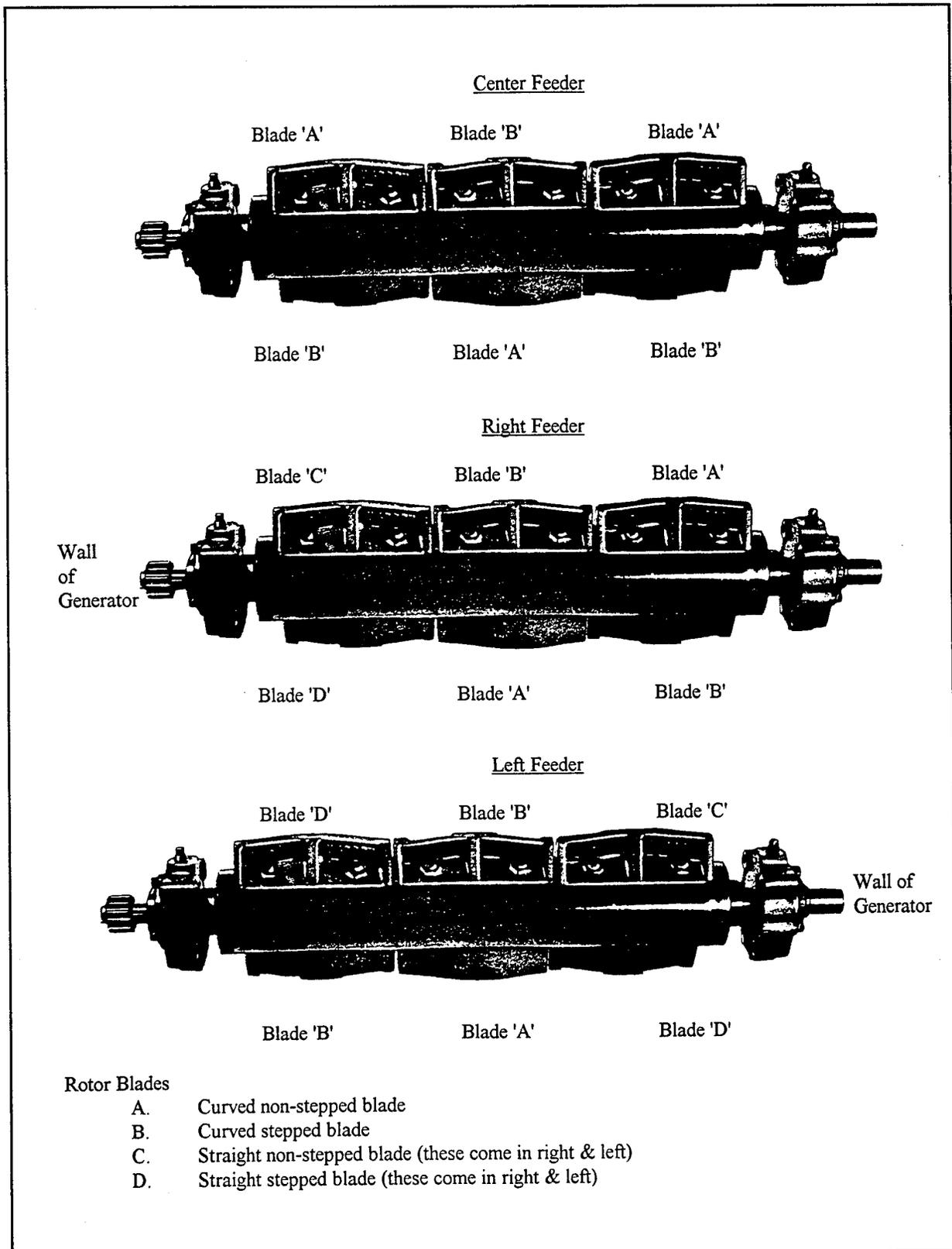


Figure 8. Correct rotor blade locations.

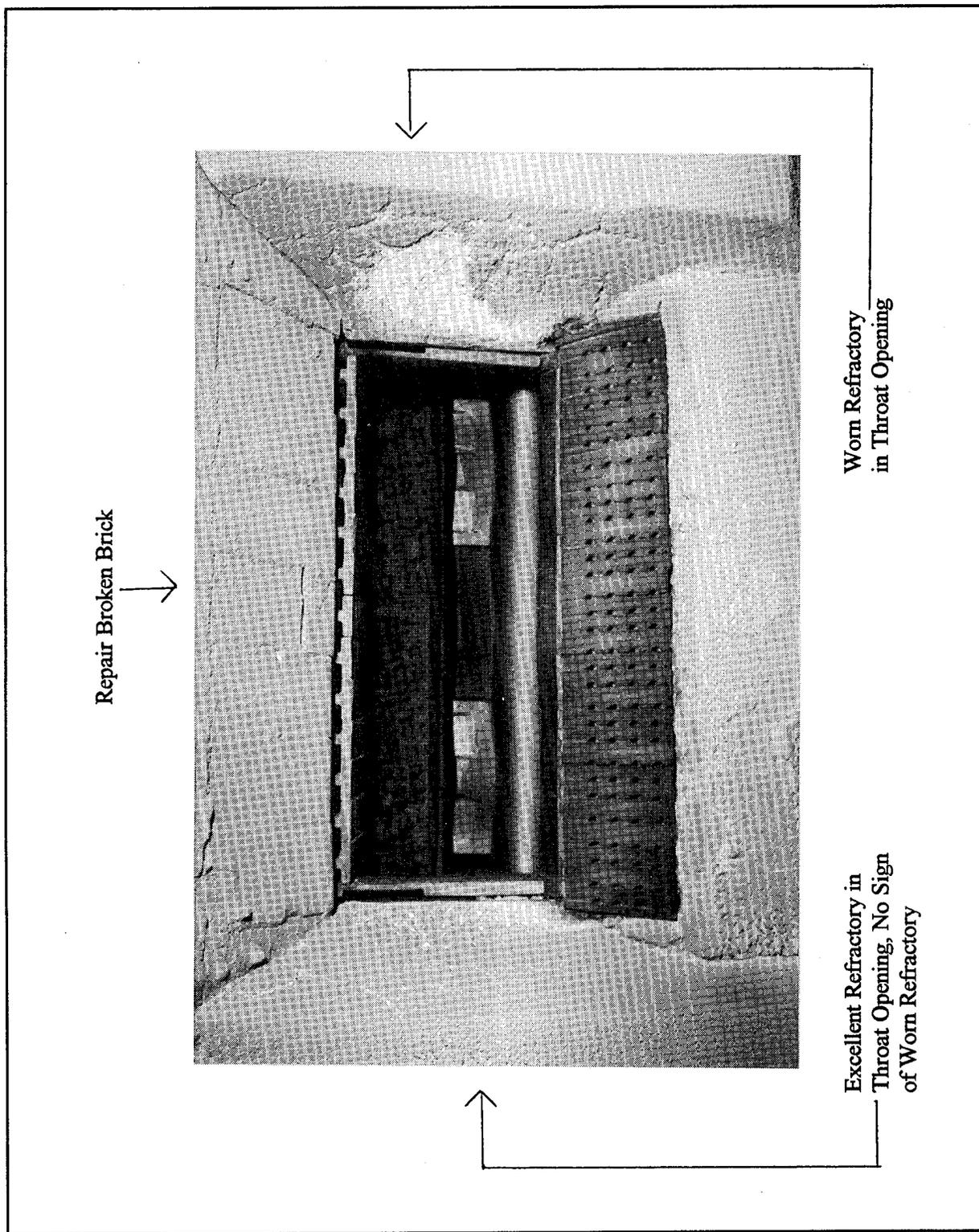


Figure 9. Malmstrom generator No. 1, center coal feeder from inside generator.

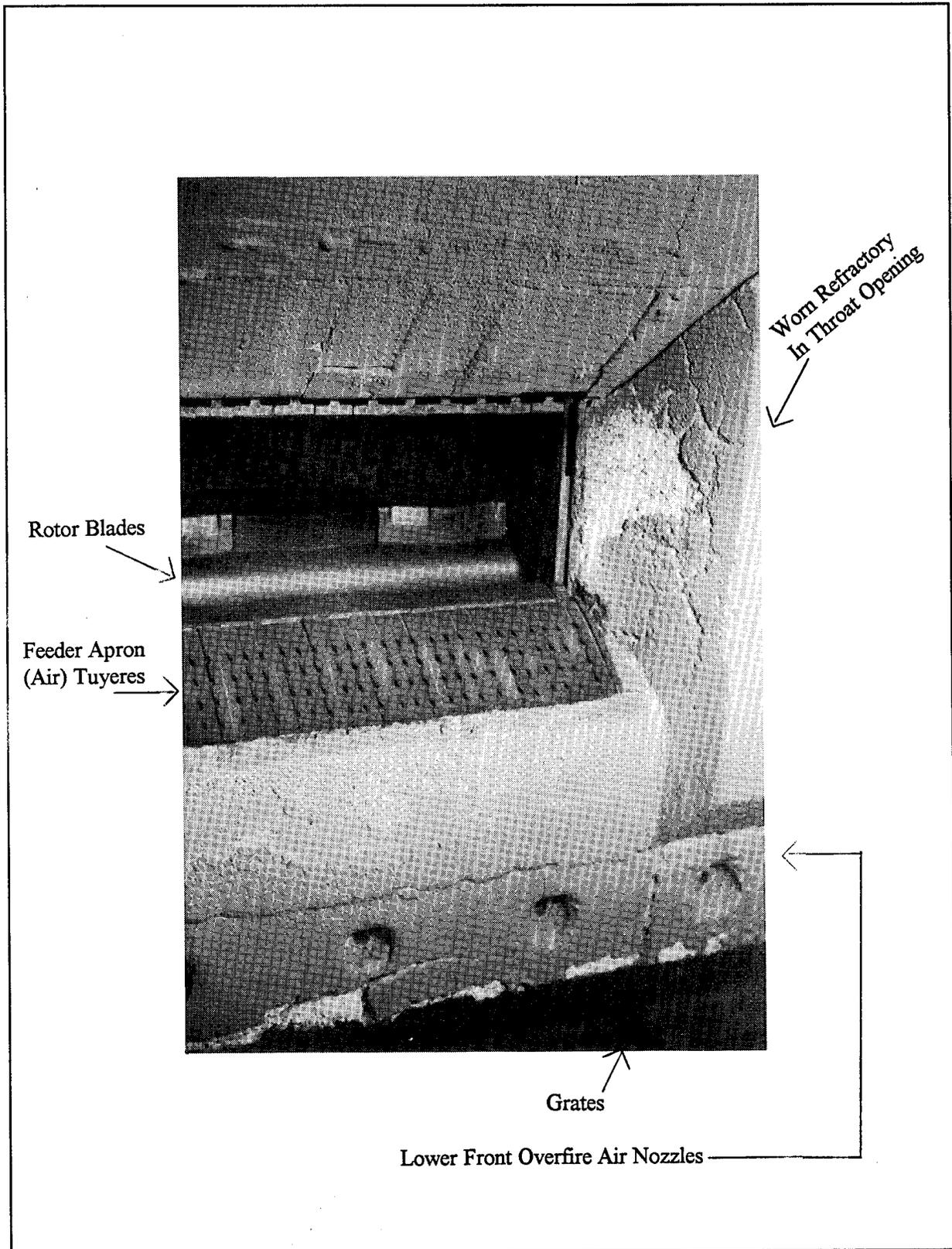
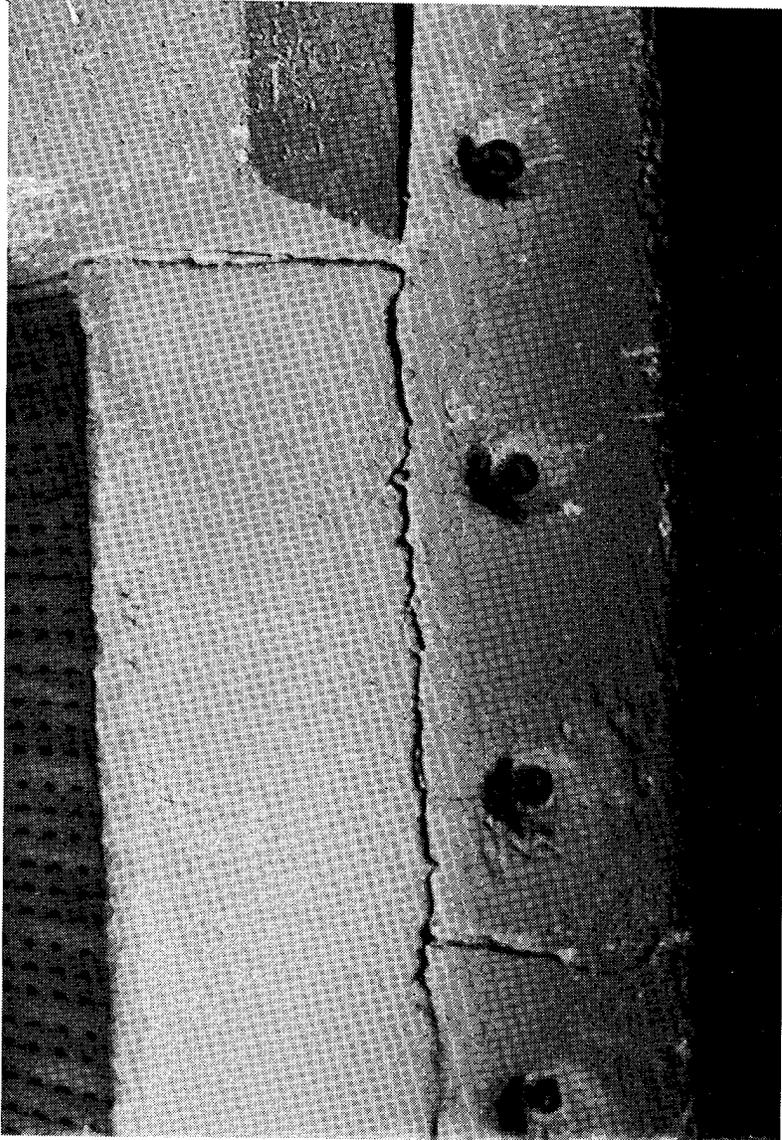


Figure 10. Malmstrom generator No. 1, center coal feeder from inside generator, highlighting lower front overfire air nozzles.



Excellent Lower Front Overfire  
Air Nozzles

Note: DO NOT fill refractory cracks because they are needed for expansion.

Figure 11. Malmstrom generator No. 1, left coal feeder from inside generator, highlighting overfire air nozzles in excellent condition.

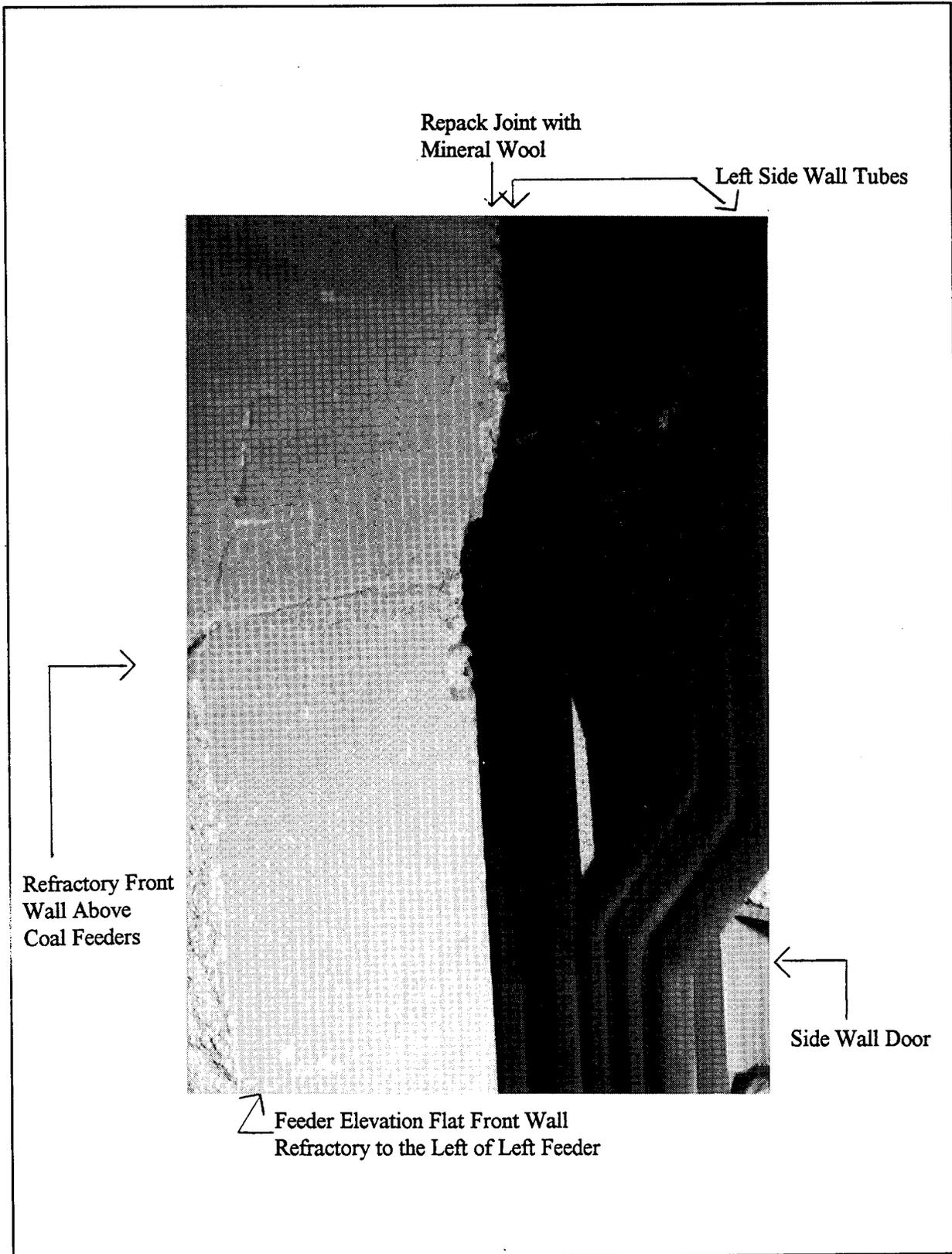


Figure 12. Malmstrom generator No. 1, front wall and left side wall intersection, from inside generator.

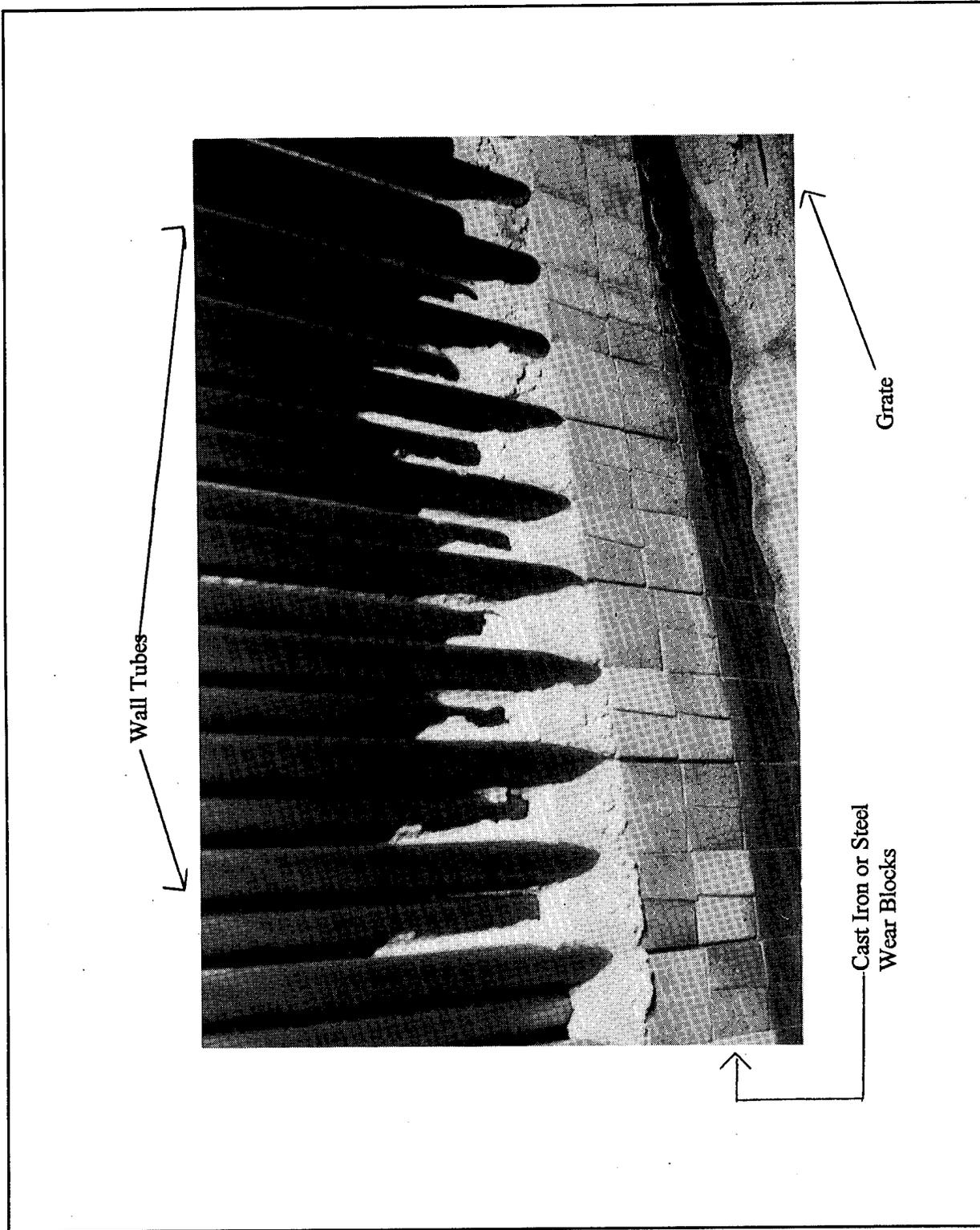


Figure 13. Malmstrom generator No. 1, right side wall from grates up, 3 ft, from inside generator.

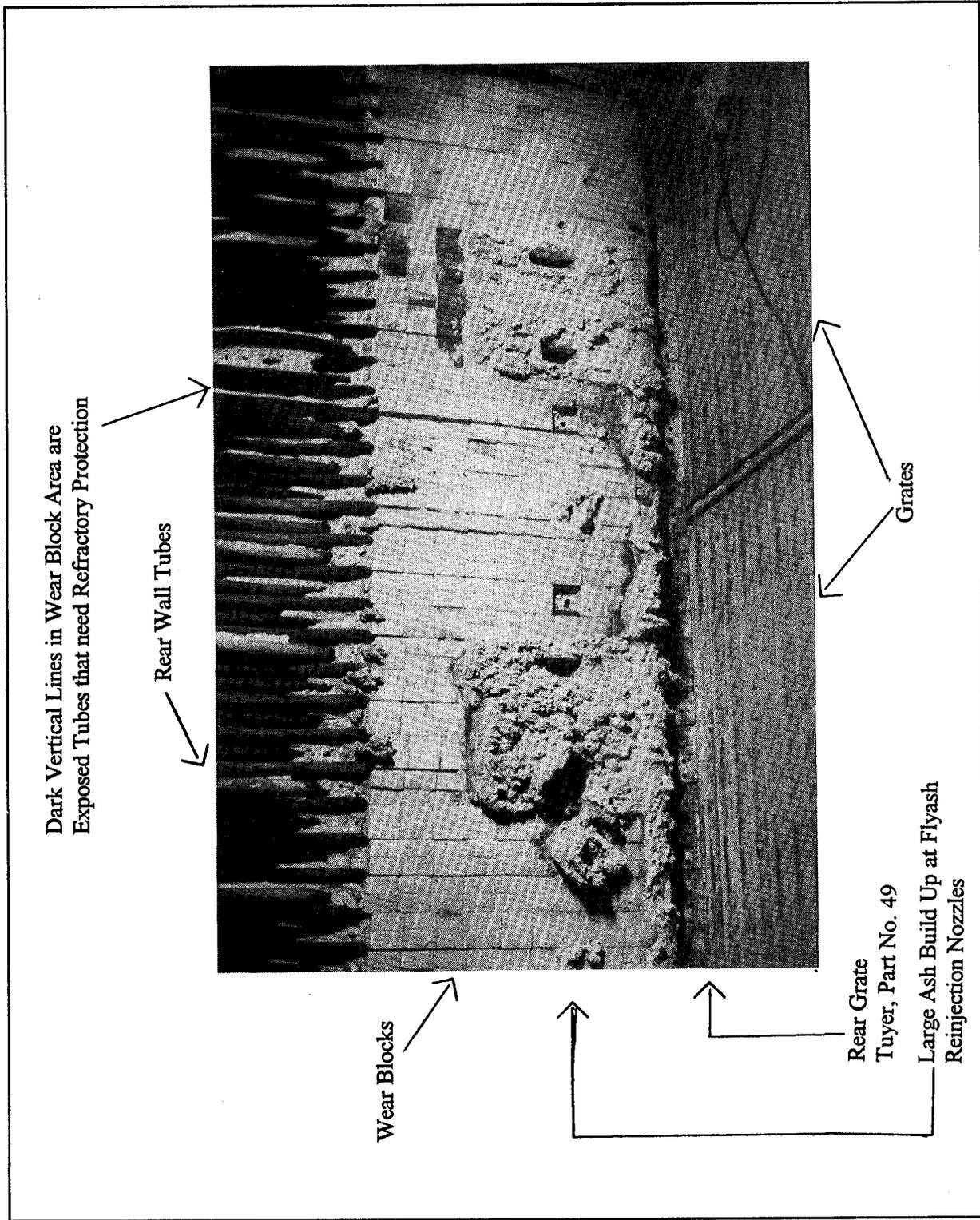


Figure 14. Malmstrom generator No. 1, rear furnace wall from grates up, vertically to 3 ft, from inside generator.

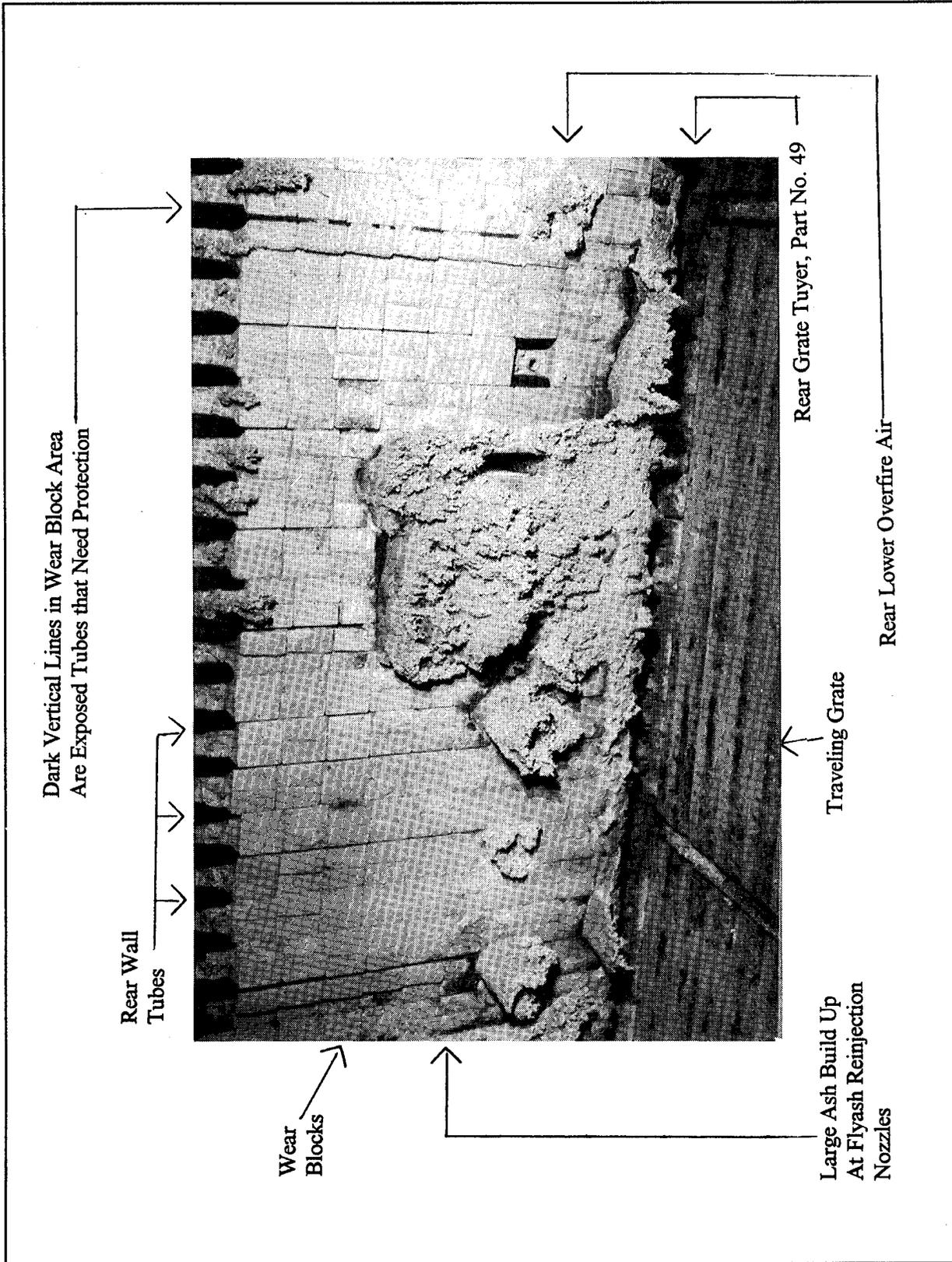


Figure 15. Malmstrom generator No. 1, rear furnace wall from grates up, vertically to 3 ft, from inside generator, clear view of ash buildup.

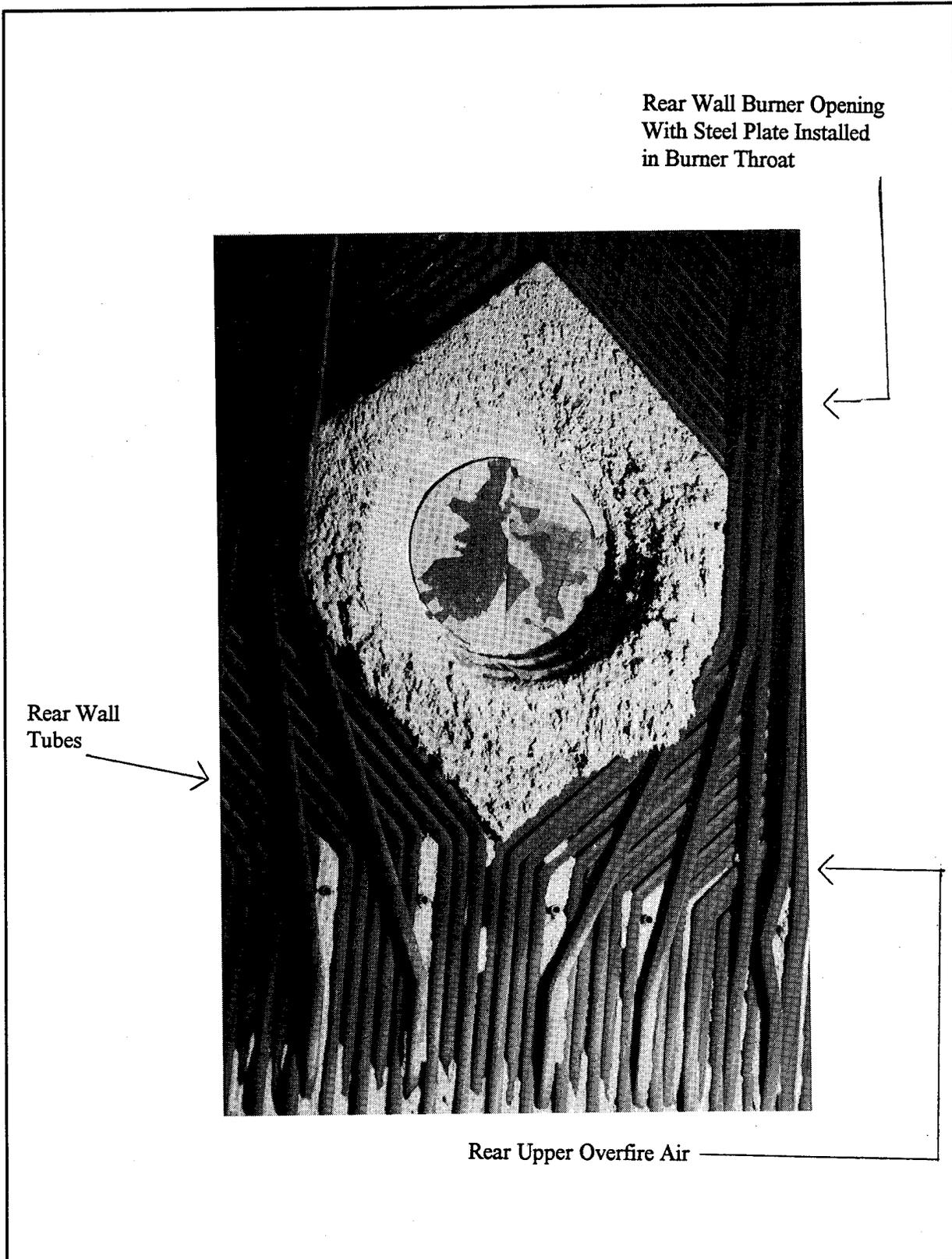


Figure 16. Malmstrom generator No. 1, rear furnace wall from grates up, vertically 8 ft.

Note: This is an example of correct "front upper air seal" and "front lower air seal".

Grate Bar Above



Front Upper Air Seal  
Part No. 26

Figure 17. Malmstrom generator No. 1, grate seals in area below furnace, an example of correct front upper and lower air seals.

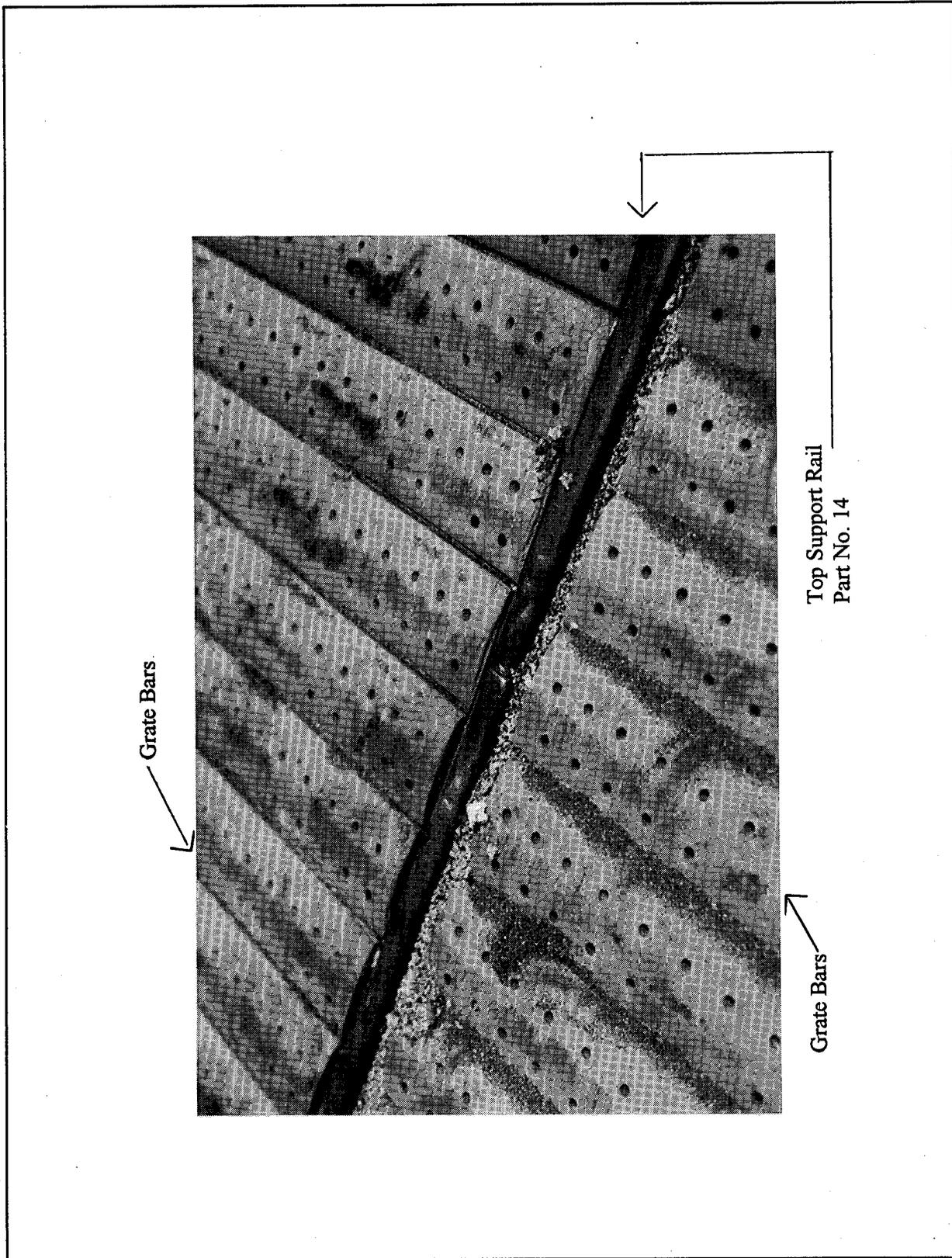


Figure 18. Malmstrom generator No. 1, grates, from inside generator.

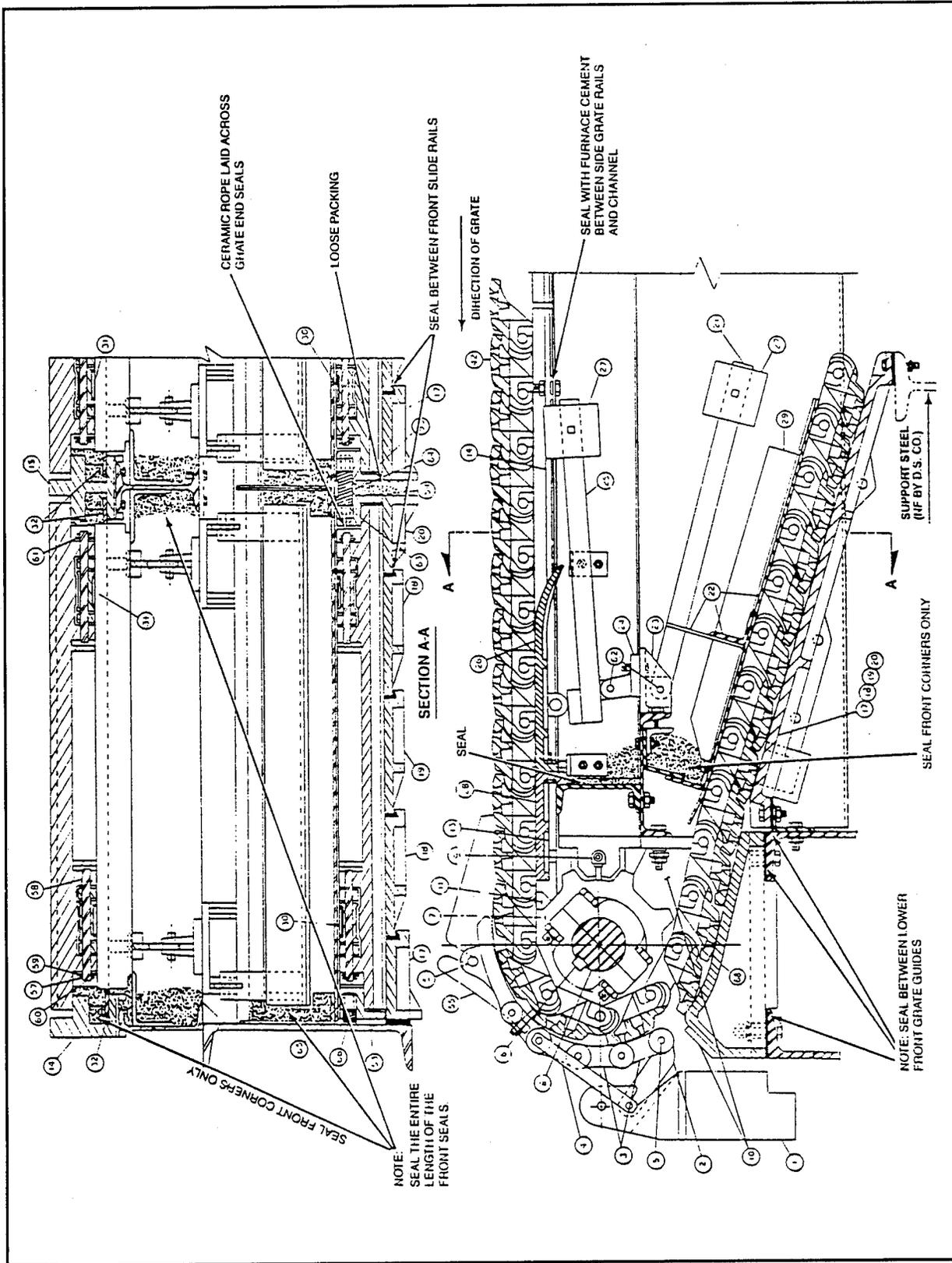


Figure 19. Areas requiring insulating cement to control air.

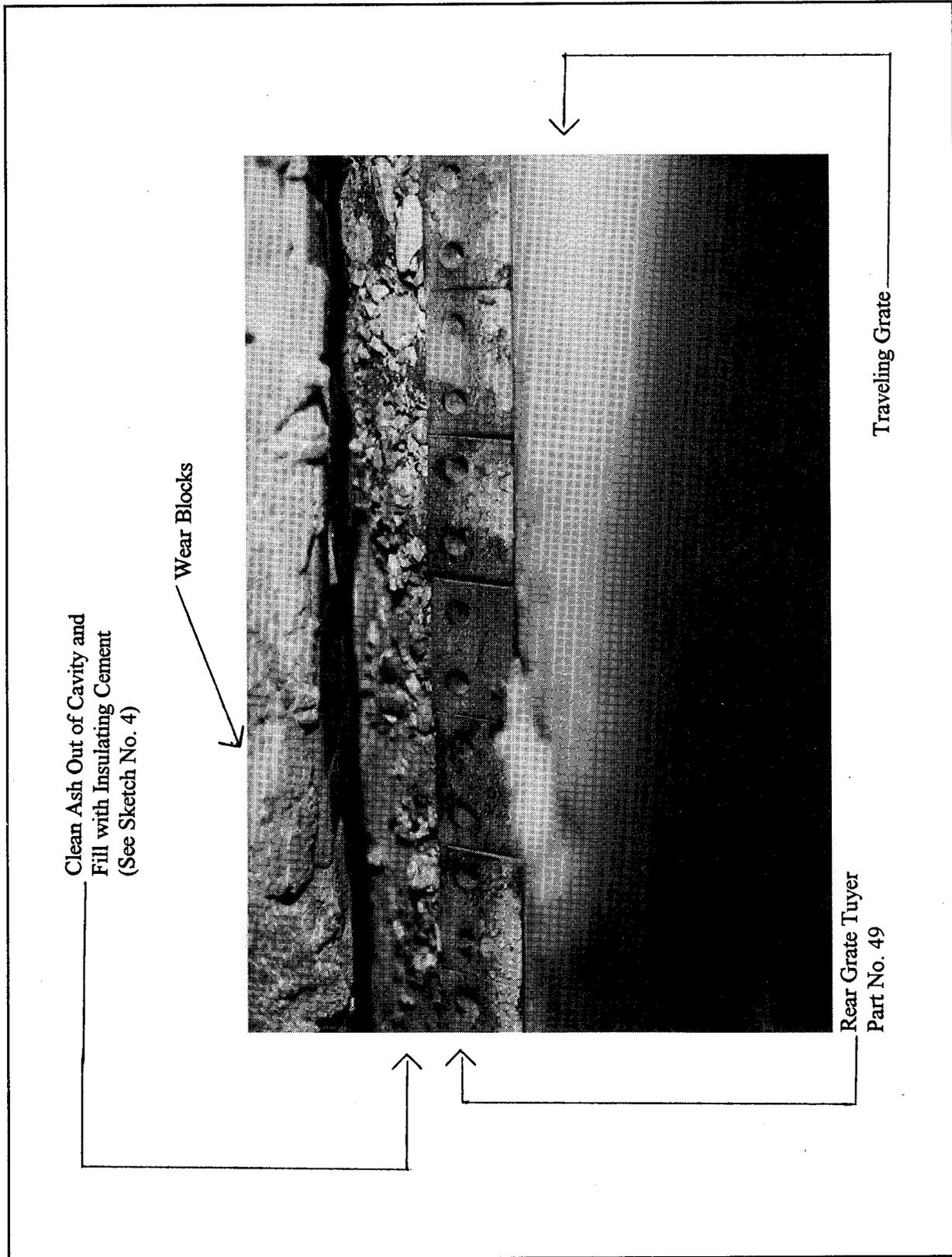


Figure 20. Malmstrom generator No. 1, rear wall at grate, from inside generator.

### 3 High Temperature Hot Water Generator No. 3

#### Description

Figure 21 shows an exterior view from the firing aisle of HTWG No. 3. The entire stoker system consists of three (3) coal feeders, traveling grates for ash removal, overfire air for turbulence, seals, supporting steel, and was manufactured by the Detroit Stoker Company. Figure 2 shows a section side view of a typical spreader stoker, including a definition of various parts of the furnace and stoker system related to later photographs and sketches.

The Detroit RotoGrate Stoker is a continuous ash discharge spreader stoker having forward traveling grates. The Stoker is reliable under both steady and variable load conditions and responds relatively quickly to load changes.

The fuel is continuously and automatically fed from the fuel receiving hoppers (coal hopper), picked up by revolving rotors and uniformly distributed into the furnace. The fine particles of fuel entering the furnace are burned rapidly in suspension (approximately 35 percent). The coarser, heavier particles of fuel are spread evenly on the grates, forming a thin (up to 12-in.), flat burning fuel bed (approximately 65 percent).

The Overfire Air System with air jets in the front and rear walls of the combustion chamber (furnace) are strategically located to create the necessary furnace turbulence and to supply the secondary air required to burn the fine fuel particles in suspension and volatile gases driven off from the solid fuels during the combustion process. As the combustion of the fuel is completed, the remaining ash is continuously discharged over the front end of the traveling grate into the ash pit.

## Coal Feeder

### *Description*

Figure 22 shows the three coal feeders at the front wall. Figure 5 shows a side section of one coal feeder. The coal enters the coal hopper and falls by gravity into the reciprocating coal feeder, and the reciprocating feed plate pushes the coal over the edge of the spilling plate. The coal falls on to the rotor blades and is thrown into the furnace.

Figure 23 shows the left coal feeder from inside the furnace and the rotor blades. The reciprocating feed plates are made of stainless steel (not carbon steel) to prevent wet coal fines sticking to the feed plate. Secondly, the spilling plate has a 1/4-inch of stainless plate on top of the standard cast iron, which lowers the coefficient of friction, and reduces the amount of wet, fine, sticky coal that will adhere to it. The feeder is 27 in. wide and has six rotor blades per feeder.

The refractory over the top of the feeder is perfect for this feeder; coal has not worn the top refractory. In normal coal feeder operation, coal hits the rotor blade and is thrown to the back of the furnace. Coal that hits the refractory will drop right in front of the feeder, and will not reach the grate. To control the  $O_2$  to a minimum and control the nitric oxides down to 0.4 lb per million BTU, the fuel must be distributed on the grate as evenly as possible.

### *Problem*

Figure 23 shows a white area where coal has rubbed against the refractory in the throat opening of the feeder. No refractory in the throat should interfere with the coal thrown out of the feeder by rotor blades. If the coal hits the refractory, it will not travel sufficiently back towards the rear furnace wall (Figure 2). Figure 24 shows where, on the inside of this left feeder toward the center of the HTWG, the coal has been striking and wearing the refractory. In fact, this refractory is a repair made on top of the original refractory. When this HTWG was built originally, this refractory was protruding too far into the throat opening. The original Detroit Stoker drawings will show the correct refractory throat dimensions.

### *Solution*

All coal feeders need a clean open throat to feed coal into the furnace. The throat should not be narrowed by patching or building the refractory into the throat or any

open area of coal movement into the furnace; the refractory should be ground back to the proper spacial dimensions.

In Unit 3, this refractory should be ground down ½ in.

## **Center Coal Feeder**

### ***Description and Assessment***

In the center feeder, there are all curved rotor blades (Figures 5 and 25). Curved on the outside, curved stepped in the center, and curved. The feeder rotor blades are correct in this feeder (compare with Figure 8). The under feeder and over feeder tuyeres are perfect. Patching was done on the refractory, most likely because the outer two feeders probably received coarse coal and the center feeder received finer coal, thus overheating the center lower refractory (Figure 25).

### ***Problems***

On the throat opening on the center feeder, in both the right- and left-hand throat opening, the refractory patch protrudes too far into the throat area.

### ***Solution***

The minor patching on the sides of the throat opening must be removed. It may be expedient to let the coal define the shape of the throat; when the coal starts to wear on the throat, take the opportunity to grind the refractory off. The refractory repairs on the center feeder, lower overfire air nozzle, has refractory over the air nozzles and must be removed.

The extensive refractory repair below the feeder most likely was caused by fine coal piling on the grate in front of this feeder, caused by improper coal handling. The coal handler must ensure a consistent fuel mix.

## **Right Coal Feeder**

### ***Description and Assessment***

The rotor blades in the right feeder next to the wall (Figure 26) should be as shown in Figure 8. The underfeeder and overfeeder tuyeres are perfect.

### **Problems**

1. The existing rotor blades are not properly installed, a condition that has most likely existed since the HTWG was built. As a result, the operators must compensate by adjusting the spill plates.
2. The fallen bricks making up the center of the upper throat opening obstruct the flow of coal out of the coal feeder.
3. A small amount of refractory is left on the underfire air nozzles.
4. Where the front refractory wall comes up to the sidewall tubes (Figure 27), the mineral fiber or other fibrous refractory needs replacement.

### **Solutions**

1. The rotor blades should be replaced as shown in Figure 8.
2. The four refractory bricks in the upper throat area that have broken and fallen down must be replaced or repaired.
3. The diameter of the overfire air nozzle refractory should be coned out another 4-½ to 5 in. Another inch diameter is needed to let the overfire air flow from the lower overfire.
4. Replace the expansion material. (Mineral or other fibrous refractory fiber is required. Do not take refractory right to the tubes or fill it in with a solid-setting refractory material.)

## **Rotor Blades**

### **Description**

There are two types of rotor blades, straight and curved. The straight blade type is along the side of the feeder closest to the left wall. Detroit Stoker has two designs of rotor blades, stepped and nonstepped. These two types should always be alternated around the rotor drum. In other words, in the right side of this left feeder starting from the center of the HTWG working to the sidewall, the sequence should be: a curved stepped, straight stepped, curved stepped, etc.

### **Problem**

At the outside of the feeder (sidewall of HTWG), there is a problem: a curved blade is used that requires a straight blade. (A curved blade in this location will throw the coal into the sidewall.)

### ***Solution***

Replace the rotor blade with the correct type. Figure 8 shows correct rotor blade locations.

## **Underfeeder and Overfeeder Tuyeres**

The underfeeder and overfeeder tuyeres are in excellent condition (Figure 5 and Figure 23).

## **Overfire Air Nozzles**

### ***Description and Assessment***

This is a very clean furnace; there is no slag to speak of on this front wall. This condition can probably be attributed to the fact that high ash fusion temperature coal is being delivered from Utah. The overfire air nozzles are all relatively clean.

### ***Problems***

1. Old mortar from the original construction is still visible in a few nozzles.
2. The upper overfire air nozzles are relatively clean, but are not correctly adjusted for direction. The upper overfire air nozzles should hit the rear of the grate at the rear furnace wall, but they are misdirected by about 3 ft, into the middle of the grate.
3. The refractory cone diameter is too narrow.

### ***Solutions***

1. The overfire air nozzles refractory should be coned out more (Figure 24). As air discharges out the nozzle, it should penetrate to the center of the furnace. The cone at the refractory face should be 4-1/2 in. in diameter and then coned back to the nozzle.
2. The upper front overfire air nozzles should be correctly adjusted for direction. Note that this change is not imminent; it should be made when there a major refractory change to the HTWG. (This can be considered a long-term correction.) The upper front overfire air is actually aimed at center of the grate and it should be aimed at the rear of the grate, at the rear tuyeres, where the grate starts to come into the furnace.

3. The refractory cone diameter should be increased by 50 percent and to allow the air to exit freely. Note that attaching thin plastic strips to the tops of these nozzles will let maintenance personnel see (and adjust) air direction when the fan is on.

## **Furnace Tubes**

### ***Testing for Broken Tube Ties and Misalignment***

A back-light test can be done to check for broken tube ties. Roll the light across the wall to see the maximum tube misalignment. No tubes should stick out more than half a tube-width. Roll the light to the bottom very slowly. It is likely that several tubes will be out of alignment (Figure 28). (Some tubes were probably originally installed this way.) Lay a straight edge across the tubes to determine tube misalignment and monitor tube movement. If a tube keeps moving with time, stop and replace that tube.

An HTWG is held together by "tube ties." The HTWG consists of an outside casing, and the water wall tubes separated by the insulation and refractory. The tube material may reach a heat up to 650 °F while the steel casing will reach only 120 °F. The tube ties can be found by looking at the detailed drawings by International Boiler Works.

On the outside structural steel, there is a round ring with a hole in it (a donut) welded to the steel. A round bar that is bent at a 90-degree angle and that runs through the donut, is welded to the backside of the tubes, allowing the metal inside of the furnace tube to expand to 600 °F and the outside structural steel to reach only 100 °F, and still not move. However, when the tubes start moving from their original location, tube ties may be broken. It is not a serious matter if one tube tie breaks as long as the tube does not move too far into the furnace. The tube must not move much further than the existing right wall has already moved because:

1. Pushing out the cast iron wear blocks keeps fly ash from wearing out the tubes.
2. If a tube moves out far enough that hot flue gases move in behind it, it will start burning out the tube ties around it, soon allowing the whole wall to move into the furnace.

### ***Description and Assessment***

The front wall is in excellent condition.

The rear furnace wall has some bent tubes for the future location of a natural gas burner (Figure 29). Hanging ash slag from the refractory is normal because the refractory is at an elevated temperature.

The cast iron or cast steel protection blocks of the lower rear furnace tubes (Figure 29) are between 1-1/2-in. tubes; this is a standard International Boiler Works design for protection of tubes from fly ash erosion on the back wall. The furnace sidewalls have approximately 1 ft of these blocks above the traveling grate to protect the water tubes (Figure 28). The furnace rear wall has approximately 3 ft of these blocks above the traveling grate to protect the water tubes.

### **Problems**

1. On the right wall, two tubes were out of alignment, probably since the original construction.
2. On the left wall, another tube movement was seen.
3. Tube alignment at the top on the left wall is approximately two-thirds of the way back into the furnace.
4. The tube from half way up the furnace to the roof and is in good condition. From half way down the furnace to the header, the tubes are out of alignment.
5. The header was nearly in alignment. Slight misalignment may have been caused by a broken tube tie or a poor repair job.
6. Both sidewall and rearwall water tubes have been moved (Figures 28 and 29) by expansion or contraction, caused most likely by too fast start-up and shut down of the unit.
7. The rear furnace wall water tubes have been pushed into the furnace. This movement of water wall tubes is large and some of the blocks do not fill the area between the water wall tubes (Figure 30). Some of the tubes are now exposed to the fly ash erosion.
8. There is an additional problem on the rear wall water tubes where they bend 90 degrees to exit the rear of the furnace just above the traveling grate. The cast iron or cast steel (wear blocks) blocks have been worn away by the fly ash erosion and the tubes are now being worn away.

### **Solutions**

- 1-5. Start counting tubes back from the front wall and locate these misaligned tubes, and sketch their positions. Keep a record of these tubes.
- 6, 7. Locate the current position of the sidewall and rearwall water wall tubes and monitor them over time to detect any additional movement.

8. The wear blocks must be repaired soon (within the next 180 days) or tube failure will begin (Figure 31).

## **Rear Tuyeres**

On top of the traveling grate at the rear furnace water tubes, the "rear tuyeres" (Item 49, Figures 31 and 32) must float on top of the grates to form an air seal. The cavity above the tuyere must be filled with material (insulating cement\*) to allow some movement of the tuyeres yet not restrain the movement of the rear wall tubes. (This material cannot be a hard refractory as it will force the tuyere down on the grate and break the grate, tuyere, or water tube.) This material must be replaced annually. The cavity should be cleaned of all ash and fly ash and packed with insulating cement. Massive tramp air entering the cavity, that should be filled with insulating cement, will increase nitrogen oxides from the unit.

All tuyere air holes on the face need to be cleaned annually with a punch, gently, to remove all ash particles. All tuyeres should "float" on the grates. The motion can be checked by inserting a screwdriver blade in the air hole and moving the tuyere gently up and down. If there is no movement, remove the tuyere and clean the tuyere hanger and the cavity above the tuyere.

Any grooves on the top of the grate could be caused by the tuyeres being pushed down hard on the grate. This pushing action could be from ash build-up in the cavity above the tuyere.

## **Reinjection Nozzles for Fly Ash**

### ***Assessment***

The reinjection nozzles (Figure 33) and the pipe that feeds the reinjection line must be cleaned whenever the unit is removed from operation. Fly ash should not be reinjected because it causes slagging around the reinjection nozzles and the backwalls.

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\* Insulating Cement No. 207011730 or Plisulate No. 1900 can be obtained from: Frank W. Schaefer, Inc., tel: 513/253-3342. Note that this is the original material and supplier to the Detroit Stoker Company.

### ***Problem and Solution***

The reinjection lines, the one on the left hand side of the furnace is partially plugged and should be cleaned.

## **Rear Overfire Air Nozzles**

### ***Assessment***

This unit must be cleaned off every time the unit is removed from operation. The large amount of slag is caused by all the reinjection of fly ash from the mechanical dust collectors. All slag must be removed from the nozzle and air pipe.

### ***Problem and Solution***

The low rear overfire air nozzles (Figures 2 and 33) are partially covered over with slag and should be cleaned.

## **Grates and Rails Top**

### ***Description and Assessment***

Typical grate bars will last 7.5 years to 12.0 years depending on operation. The existing grate bars show less than 1 year of operation. The existing grate bars are in excellent condition. As long as the ash bed depth is maintained to protect the grates from the heat of combustion and coal is fired to the rear furnace wall of the grates, the grates will have a long life.

The combustion air holes in the grate bars (Item 42, Figure 34) are clean; they show no slag buildup. Utah coal apparently has a high ash fusion temperature, which forms a minimum amount of slag.

The coal and ash insulate the grate from the 2800 °F combustion flame overheating the cast iron grate. The grate is not pure cast iron, but—like the rotor blades and other cast iron parts of the HTWG—contains nickel and chrome to raise its temperature limitation.

Between the stoker and the HTWG (between the grate "top support rail sides," Item 14, Figure 35), there is a mineral fiber or other fibrous refractory type material

packing that wears from the cycles of heating and cooling, and should be removed and replaced annually (Figure 36). The existing packing is in very good condition.

The grate bars are supported by Item 13, 14 and 15 as the grate travels in the furnace as shown Figures 34 and 35. The ends of these rails are tapered. Always check after replacement or inspection that the grate bar cannot catch on these rails. Check the bolts on these rails from between grates.

The counter weights in the front of the grates are in good condition.

### **Problems**

Grate failures will begin at the rear combustion air hole on the grate bar and crack to the rear of the bar when standing in the furnace looking down on the grate. The cast iron grate that has a crack will eventually fail and wedge in a rotating or stationary part shown in Figure 34:

- sprocket for grate shaft, item 45
- rear tuyere support air seal, item 69
- rear coking section, item 16
- rear coking section extension, item 52
- rear tuyere, item 49.

The broken grate could also wedge in the rotating or stationary part of the front grate drive shown in Figure 35:

- front upper air seal, item 26
- front upper air seal extension, item 28
- top support rail sides, item 14
- grate guide weight, item 1
- grate guide toggle link, item 2
- grate guide link, item 3
- 8-tooth sprocket for grate chain, item 7
- grate shaft, 4-in. diameter, item 8
- front end support rail side, item 13
- lower front air seal section, item 22.

### **Solutions**

1. The grate should be checked at every shutdown of the unit.

2. Any slag accumulation in the air holes should be cleaned out. The simplest way to punch out all the air holes is to sit on the grate or box, slowly moving the grate, and with a small "drift pin" and with a hammer, pound out all slag and ash from the top of the grate, and taper the air holes (Figure 34).
3. The mineral fiber or other fibrous refractory type material packing between the stoker and the HTWG should be removed and replaced annually.

## Grates and Air Seals

### *Description and Assessment*

For a stoker to operate correctly, the combustion air must be controlled to flow up through the active grate area. Close attention must be paid to the air seals and counterweights regardless of the length of time the HTWG has been in operation (Figures 34 and 35). Air should not go to the ash pit as the grate operates. A large structural channel member is located in front between the grates where air cannot go forward into the ash pit. If air goes into the ash pit, it will return to the furnace and produce high oxygen. The lower piece of structural steel flat plate is the lower seal (Item 22). The lower seal is held into position by these counterweights and the lower counterweight (Item 21). These counterweights must be free to push that plate as tight as it can against the grate. The lower seal must be vacuum cleaned.

The same is true of the upper front seal (Item 26). At the point when combustion air gets underneath the refractory duct oven (the refractory below the feeders that one passes under to enter the furnace), combustion is no longer desired and combustion air coming through the grates is useless. If there is coal, the refractory will be destroyed.

Any inspection of the grate system must include the area between the grates that is entered from the side access door. This area, which has apparently been ignored by the plant, is critical for:

- NO<sub>x</sub>
- VOC Control
- baghouse operation and cake release characteristics.

Figure 35 (Item 28) shows the front grate air seals. The correct operation of the Upper Air Seal is shown in Figure 37. The rear grate air seals are in good working order (Figures 34 and 38.) The upper rear seal's counterweights are free on all three seals. The counterweight pins appear sufficiently clean. The weights should move easily to

hold that seal up tight against grate so excess air does not pass through the rear of the grate.

The first 6 in. of grate (the "coking section") exposed in the furnace is where the seal stops air flow. This allows large pieces of coal a required fraction of time on the grate without air to get warm enough to ignite. It is not a problem if the coal smolders at this point; the rear overfire air will take care of opacity. The coal must start to burn and these rear air seals are required.

### **Problems**

1. The weight (Item 27) at one end of each of the three "front upper air seals" (Item 26) is not engaged and therefore cannot seal combustion air (Figure 39). The counterweight hangs on a pin and should rub against a half circle to hold the seal plate in position. That plate is coming down because of the position of the counterweight and combustion air is sneaking up underneath that dead ash on top of the grate where air is not needed for combustion. These counterweights must be free to allow for the movement of the grates. In their present condition, the counterweights interfere with each other.
2. The three lower air seals are correct, but much ash has accumulated on top of the "lower front air seal section" (Item 22).
3. To reduce NO<sub>x</sub> problems, the furnace must operate with the lowest possible excess air in the fuel bed. Air should not be allowed to leak into the furnace through these air seals. As these grates go across the top seal and come around these bottom seals, the seals have to be able to freely move up and down slightly. All three upper seals are faulty, which contributes to higher excess air because combustion air is leaking up underneath where the ash is already dead, up in front of the traveling grate. The more air that passes into that furnace area, the greater the chance for high excess air and NO<sub>x</sub> problems.

### **Solutions**

1. The maintenance personnel will have to move the one counterweight further up on the lower bar. It should be possible to get underneath those counterweights to lift them up. The counterweights should be relatively free. Presently, one can be moved and the other cannot. Maintenance personnel will have to clean the ash out completely of the mechanisms. Maintenance personnel should check this every time the HTWG comes down.
2. This ash must be cleaned from the lower front air seals. Get the ash out of these mechanisms and then get up in there and determine what is wrong. Remove four or five grate bars to get the seal back in position. The bolt may have seized

(stuck) because of the high temperature. There may be some little imperfection or difference in thickness between each grate because they are cast iron and never have been machined.

3. The three upper air seals should be repaired or replaced.

## **Insulating Cement and Tramp Air**

“Tramp air” is uncontrolled and undesired air that enters the furnace or flue gas stream as excess air that accomplishes nothing. Figure 19 shows where insulating cement and ceramic rope that should be installed to minimize combustion air from becoming tramp air and leaking through the ash pit near the front shaft.

## **Convection Section**

The water tubes in the convection section of the HTWG (the close spaced water tubes after the furnace) are in excellent alignment and appear to be in excellent condition. The soot blower is in the proper location to keeping the flue gas flow lanes clean.

## **Mechanical Dust Collector, Inlet Breeching and Outlet Breeching**

### ***Description and Assessment***

Overall, the mechanical dust collector is in excellent condition and is operating as designed (Figure 40). The breeching between the HTWG outlet and mechanical dust collector inlet was inspected through the side access door. A large amount of fly ash was seen on the bottom of the breeching and somewhat less on the turning vanes at the HTWG outlet end. The fly ash thickness was approximately 24 in. across the breeching on the bottom and 3 to 12 in. on the turning vanes. The fly ash was light gray, indicating very good carbon burnout in the HTWG combustion. This is typical for a HTWG operating at lower loads due to the reduced mass flue gas flow and lower velocities resulting in the heavier fly ash settling out in the breeching and not being carried into the mechanical dust collector (Figures 41, 42, and 43). The ash should be cleaned out during the annual inspection.

Inspection of the inlet to the mechanical dust collector (top of dirty gas tube sheet and inlet ramps) revealed like-new condition of the tube sheet and inlet ramps. The absence of a hard concrete-like scale on the inlet ramps indicates very good operation of the HTWG over the past 8 years. The scale will form when the HTWG goes through

many on-line and off-line cycles and the sulfur trioxide in the flue gas condenses on the tube sheet and ramps when the HTWG is taken off-line and the deposit then being baked to a hard scale when the HTWG is put on-line. See Figure 44.

The hopper area of the mechanical dust collector is also in excellent condition with very clean hopper walls and the typical small amount of fly ash on the outside of the collecting tubes. Erection of the mechanical collector was made per the manufacturer's instructions as evidenced by the seal welding of the hopper to the main collector shell. See Figure 45.

The access door to the horizontal breeching between the mechanical dust collector and the vertical breeching to the air heater was incorrectly gasketed with a 1/4-in. round rope material instead of a flat 2-in. wide material on the mating surfaces. There was also a large amount of fly ash on the bottom of the breeching and collector outlet turning vanes due to reduced load velocities. The ash should be cleaned out during the annual inspection.

#### ***Recommendation***

The accumulated ash across the breeching and on the turning vanes should be cleaned out during the annual inspection.

## **Air Heater**

### ***Description and Assessment***

The existing C-E air preheater-Ljungstrom air heater (Figure 46) is an excellent unit in heating the combustion air from the forced draft fan and cooling the flue gas from the HTWG.

As the flue gas temperature is cooled and the combustion air is heated, the efficiency of the fuel usage is improved. The improvement in efficiency is approximate, following the original predicted data (Table 1)

Table 1. Approximate fuel usage efficiency improvement.

Generator Load In 106 BTU/HR	Generator Outlet Flue Gas Temp.	Air Heater Outlet Flue Gas Temp.	Temperature Drop °F Flue Gas Through Air Heater	Improvement °F Efficiency %
85	545 °F	350 °F	195 °F	4.87%
70	520 °F	345 °F	175 °F	4.37%
55	500 °F	340 °F	160 °F	4.00%
40	475 °F	335 °F	140 °F	3.50%
30	460 °F	330 °F	130 °F	3.25%
An actual test on 27 January 1995 was:				
37.5	407 °F	296 °F	111 °F	

Slurry flow was measured at 1.94 GPM and the spray dryer outlet temperature was 180.3 °F (panel reading), 180 °F (field instrument measurement). The original HTWG manufacturer oversized the convection section of the unit which, provides lower generator outlet flue gas temperature. This means that Malmstrom Air Force Base received a larger unit than was required, but, since these units are less efficient at low loads, other parameters must be changed.

### Problems

There is a problem with the cooler flue gas temperature to the air heater—flue gas leaving the air heater is also cooler by approximately 40 °F. The slurry flow to the spray dryer is proportional to:

- flue gas flow
- temperature of flue gas at inlet to spray dryer less temperature at outlet of spray dryer (a constant 180 °F).

The flue gas temperature exiting the air heater must be greater than 320 °F. The problem starts at approximately 50 million BTU/HR load and less.

### Solution

Bypass a small amount of combustion air around the air heater to increase the flue gas temperature at the outlet of the air heater (Figure 46). Note that air heater rotation *should not* be stopped. The temperature of the seals (between air and flue gas) will not withstand the elevated temperatures. (Figure 47 shows the seals.)

Sizing and data gathering is beyond the scope of this work. However, the following data gathering is required at every 10 million BTU/HR of heat output of the HTWG:

- data at air heater
- flue gas flow, #/HR (mass flow)
- flue gas inlet temperature, °F
- flue gas inlet static pressure, inches of water
- flue gas outlet temperature, °F
- flue gas outlet static pressure, inches of water
- forced draft fan flow, #/HR (mass flow)
- forced draft fan inlet temperature, °F
- forced draft fan inlet static pressure, inches of water
- forced draft fan outlet temperature, °F
- forced draft fan outlet static pressure, inches of water.

Take the above data back to the base-design engineer and have him determine the exact amount of forced draft fan air to be bypassed. The bypass damper will *always* leak a small amount of air, even when closed. Be careful of the pressure drop across the air damper. Note the following warnings:

1. Do not preheat the forced draft fan combustion air. There are enough stoker maintenance problems with the preheated air that is currently going into the windbox (under grate air).
2. Do not preheat the forced draft fan combustion air. This increases the ash fusion temperature requirements of the coal and can cause increased slagging and clinkering.
3. Do not bypass the flue gas because the air heater baskets will be in the acid dew point temperature range.

## Coal Handling System

### *Description and Assessment*

The remainder of the system from the hopper vibrating feeders, belts, chutes and transfer points are very clean and well maintained. At transfer points are exhaust ventilation system that carries the fugitive dust to a baghouse at the transfer house. This ventilation system performs excellently for the large quantity of fugitive dust due to the 3-year-old dry and fine coal.

### ***Problems***

1. The rail car unloading hopper was not used during field site visit. It is likely that fugitive dust is generated during the unloading of rail cars.
2. When the coal is dropped into this reclaim hopper, the coal dust boils to the extent that it is impossible to view through the boil to the front end loader.
3. The only operating problem in the system is the coal belts do not stay in the trough of the rollers. When the belt is unloaded (no coal), it moves to one side of the rollers. When the belt is loaded (with coal), it still moves to one side of the rollers.
4. The over bunker conveyor drops coal at three locations over each HTWG. As the coal drops on these three piles, it segregates coarse coal to the outside of the pile and fine coal in the center of the pile.

### ***Solutions***

1. It is strongly suggested that the rail car unloading hopper area be covered, heated, and that fugitive dust be captured in a baghouse similar to the type used at transfer points in the conveyor.
2. A roofed and three-sided enclosure plus a baghouse to contain the fugitive dust is required in the reclaim hopper area.
3. Adjust the head and tail pulleys, either one or both need to be turned slightly with the adjustment stud bolts. This adjustment must be done slowly and carefully. Select several exact locations of belt and dimension to a structural member. Make a small adjustment, then check the change in dimensions.
4. The more drop points in a bunker, the less segregation is generated. A wedge should be located below each existing drop location to split the coal stream and decrease segregation. The three existing drop locations would be increased to six drops, which would decrease segregation by 50 percent (Figures 6 and 7).

## **Ash Handling System**

### ***Description and Assessment***

The ash handling system is a negative pressure (vacuum) pneumatic conveyor with a mechanical exhaustor for both bottom ash (grate ash) and flyash (mechanical dust collector and baghouse) (Figure 48). The system is an excellent design and installation that requires only slight improvements.

### **Problems**

1. The isolating gates are air-piston driven and do not open or close fully. Either the air pistons are too small, the air pressure is insufficient, and/or the isolating gates need maintenance.
2. The top of ash bin is exposed to weather and elements.
3. The ash pit for the bottom ash requires the operating personnel to open the ash hopper door to remove grate ash. The existing system then grinds the ash in a crusher.
4. The existing ash conditioner design is for very fine flyash and very large bottom ash (grate ash), each of which requires very different amounts of water and mixing. This causes fugitive dust as the ash discharges the ash conditioner.

### **Solutions**

1. The isolating gates require either service or maintenance. Appropriately-sized air pistons should be installed, the air pressure should be increased, and/or the isolating gates should be repaired.
2. Enclose the ash bin area from weather to improve operation of air operated valves and gates. This will also improve operation of bag filter, which uses compressed air for cleaning. Install a stairway from the plant roof to the enclosure. Include structural steel beams over these items that require replacement with the steel beam protruding through side wall of enclosure. Heat this area to hold the temperature above freezing for the compressed air and ventilation for spring and fall (Figure 48). This enclosure must be designed by the original ash handling manufacturer to ensure proper clearance information, structural load on ash bin, and structural columns and foundations.
3. The crusher should be below the ash pit (Figure 49), a design which is safer for personnel, saves labor, and stops upsetting the furnace draft and spray dryer operation. The design effort for this item should be done by the original ash handling manufacturer.
4. A more common design in current use are "pug mills," which improve the mixture of water and ash.

Left Feeder                      Center Feeder                      Right Feeder

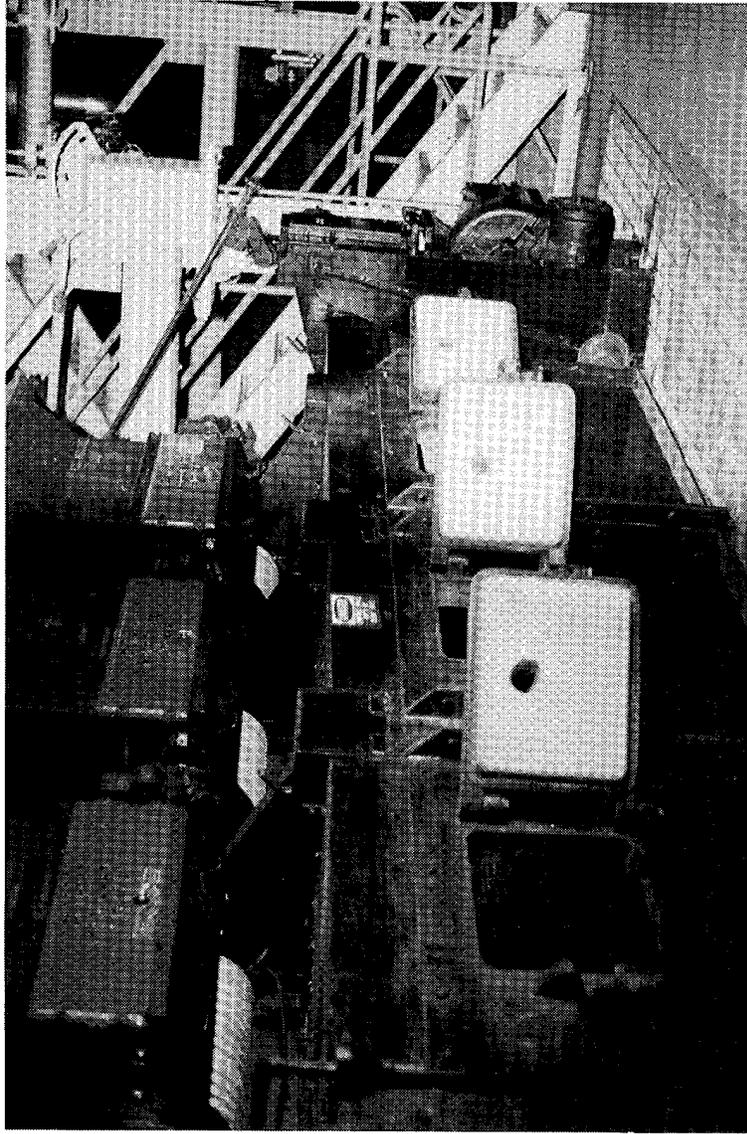


Figure 21. Malmstrom generator No. 3, front of spreader stoker feeders.

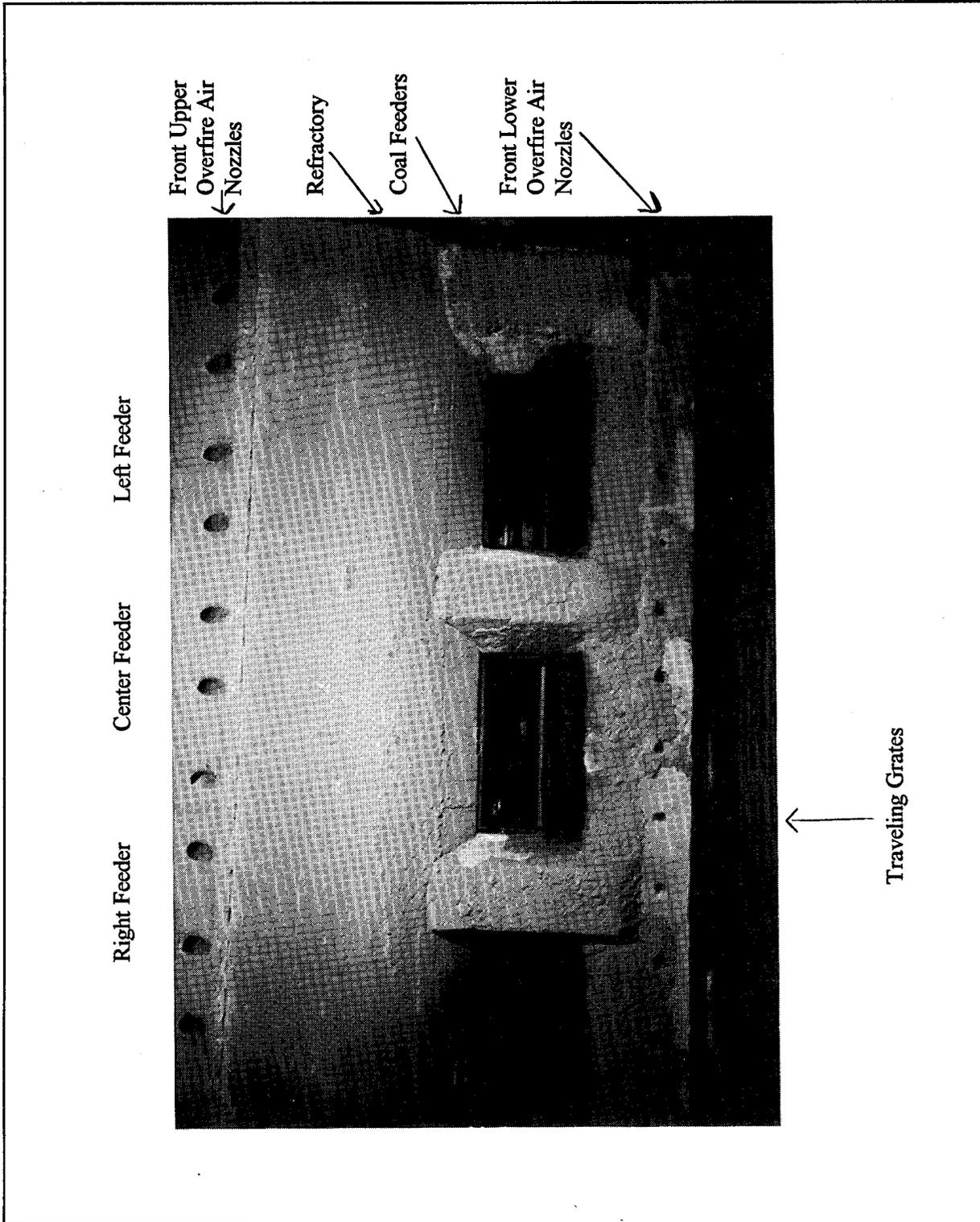


Figure 22. Malmstrom generator No. 3, coal feeders from inside generator.

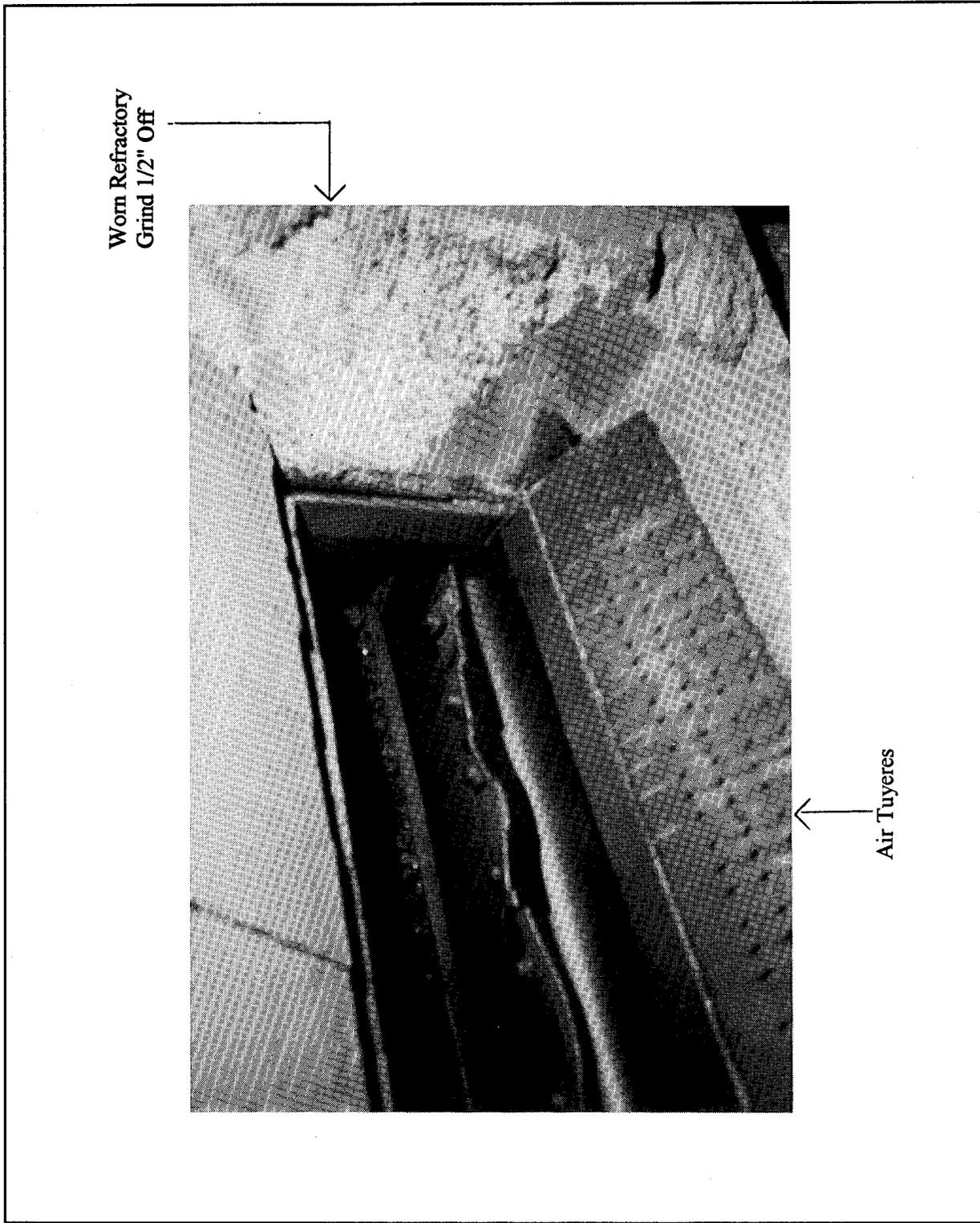


Figure 23. Malmstrom generator No. 3, left coal feeder from inside generator.

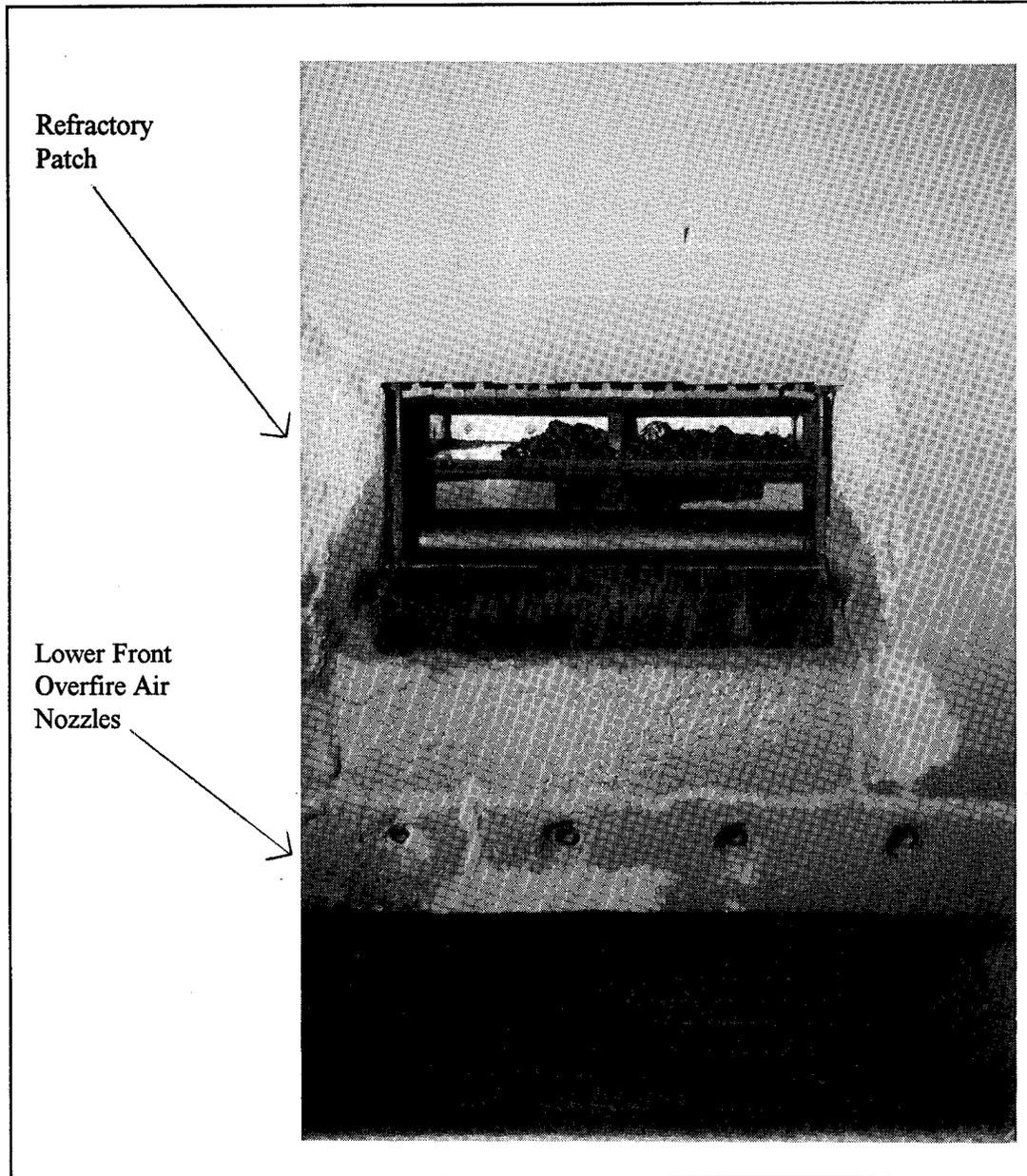


Figure 24. Malmstrom generator No. 3, left coal feeder from inside generator, highlighting lower front overfire air nozzles.

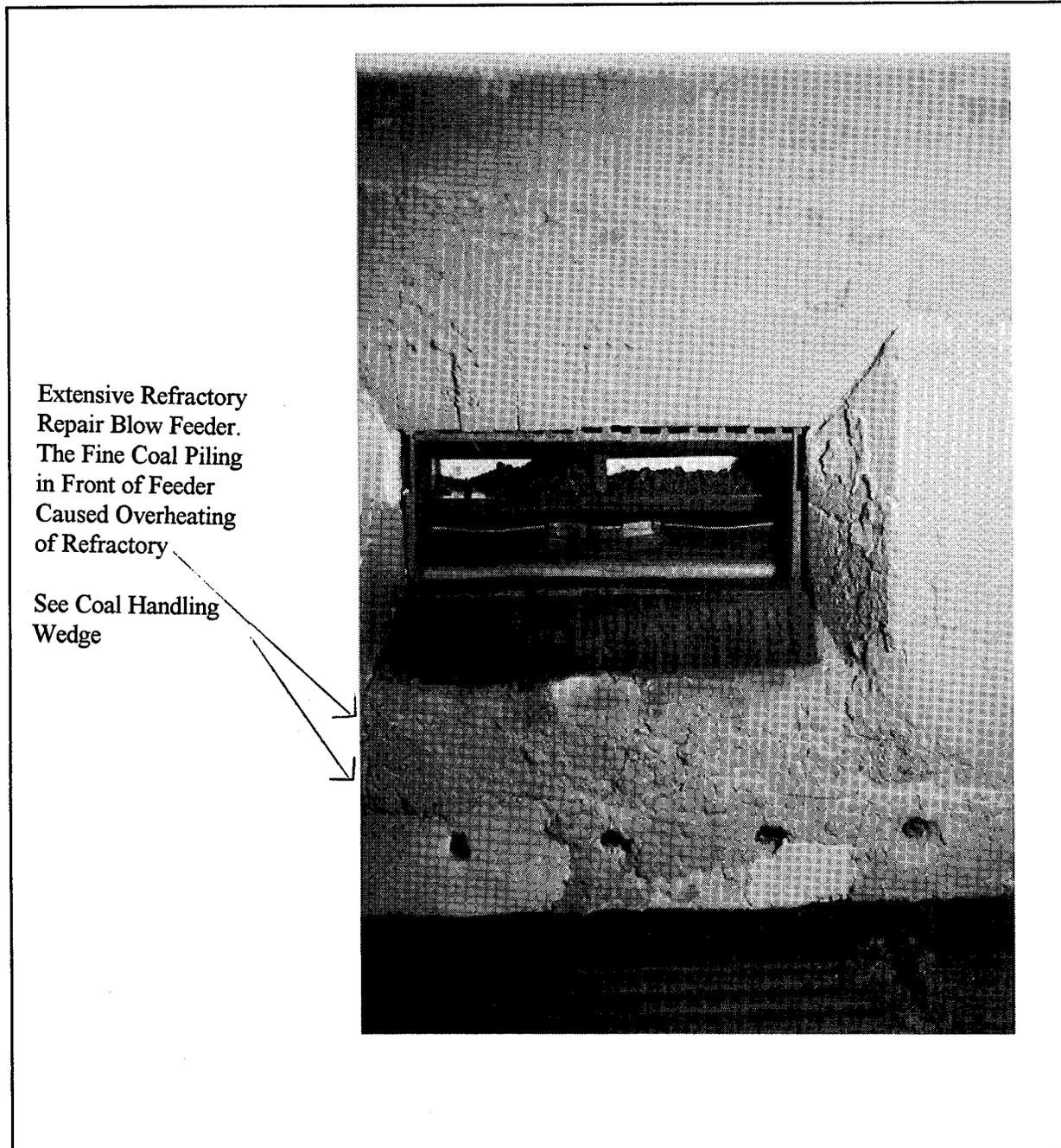


Figure 25. Malmstrom generator No. 3, center coal feeder from inside generator.

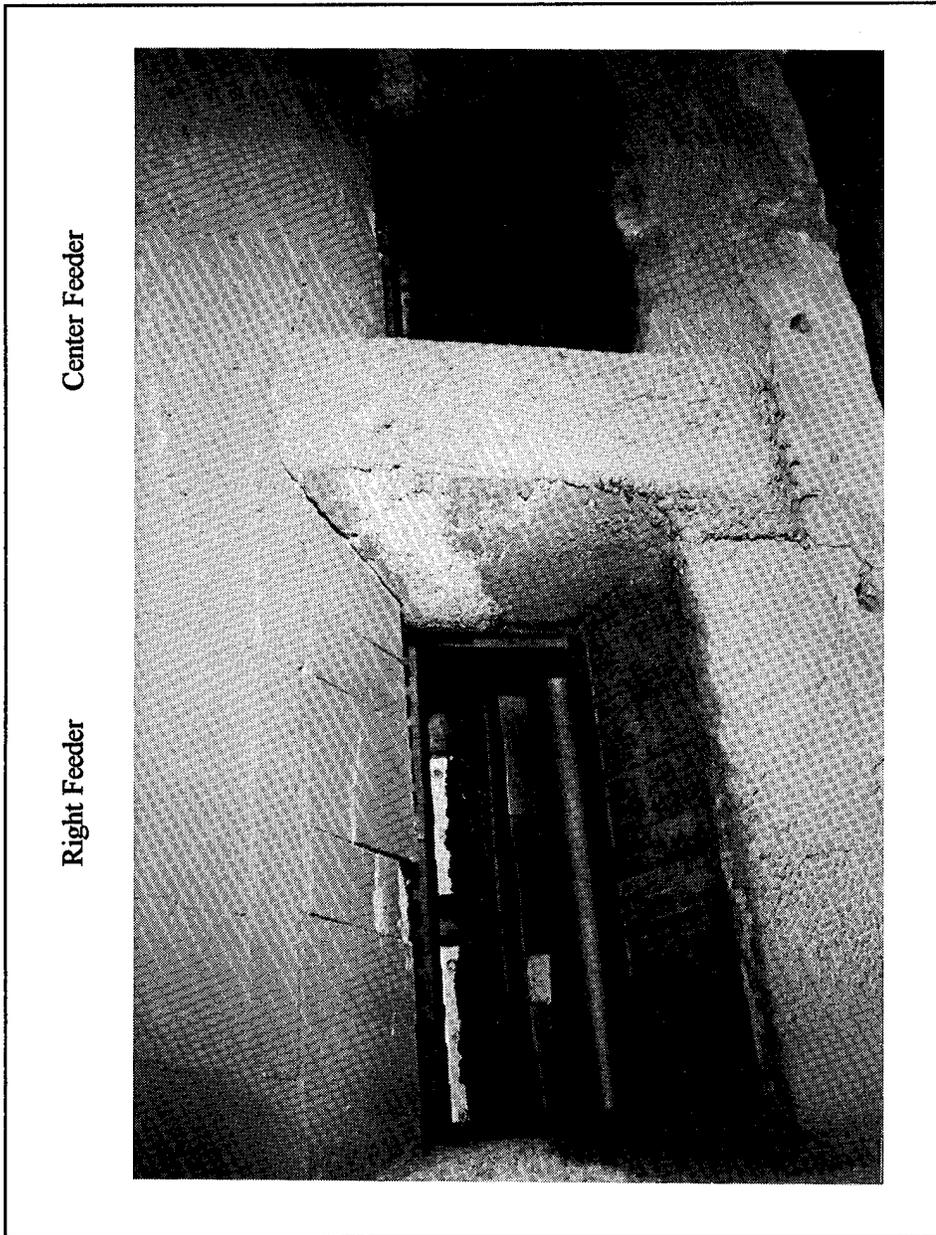


Figure 26. Malmstrom generator No. 3, right coal feeder from inside generator.

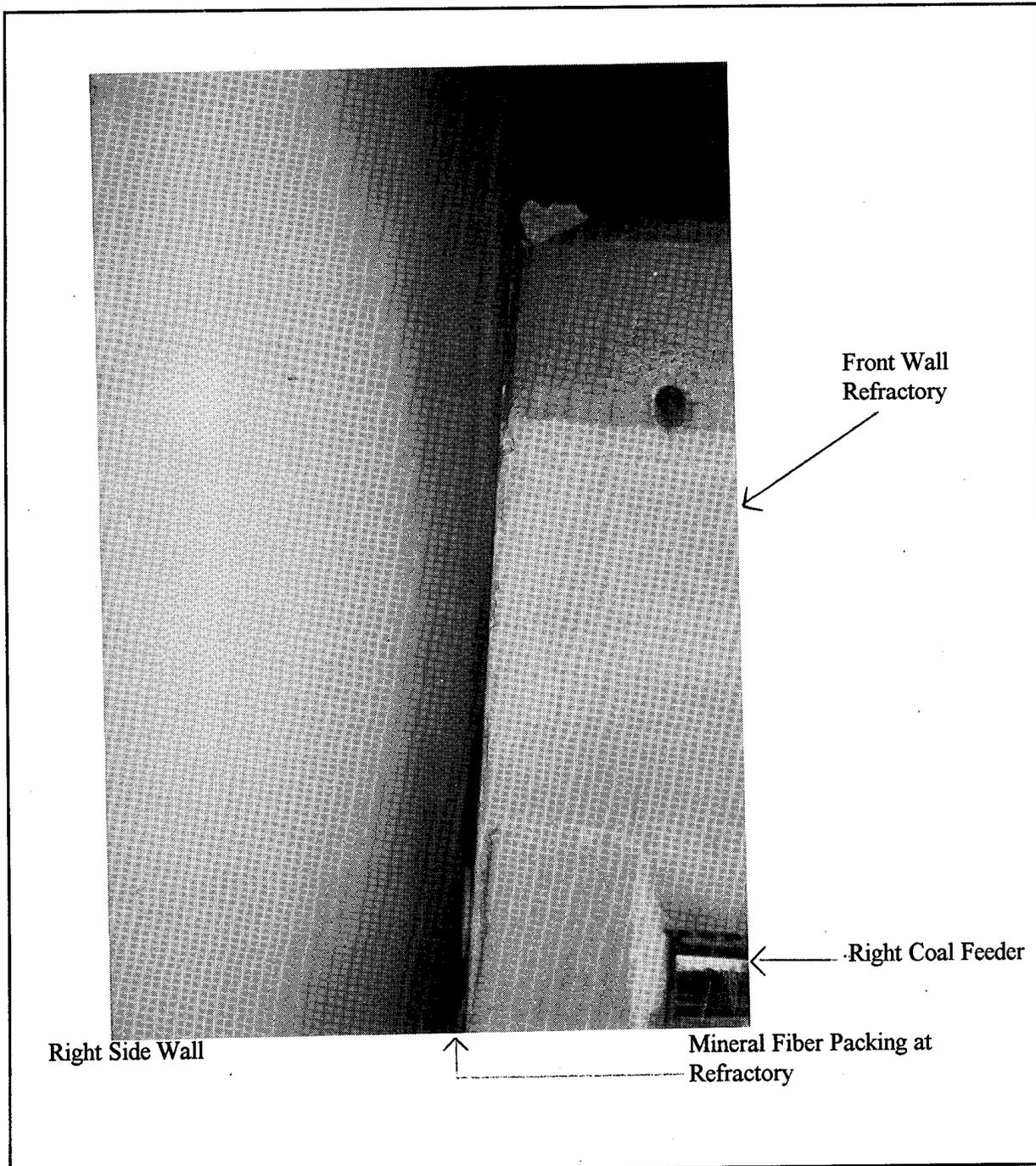


Figure 27. Malmstrom generator No. 3, right wall to front wall refractory.

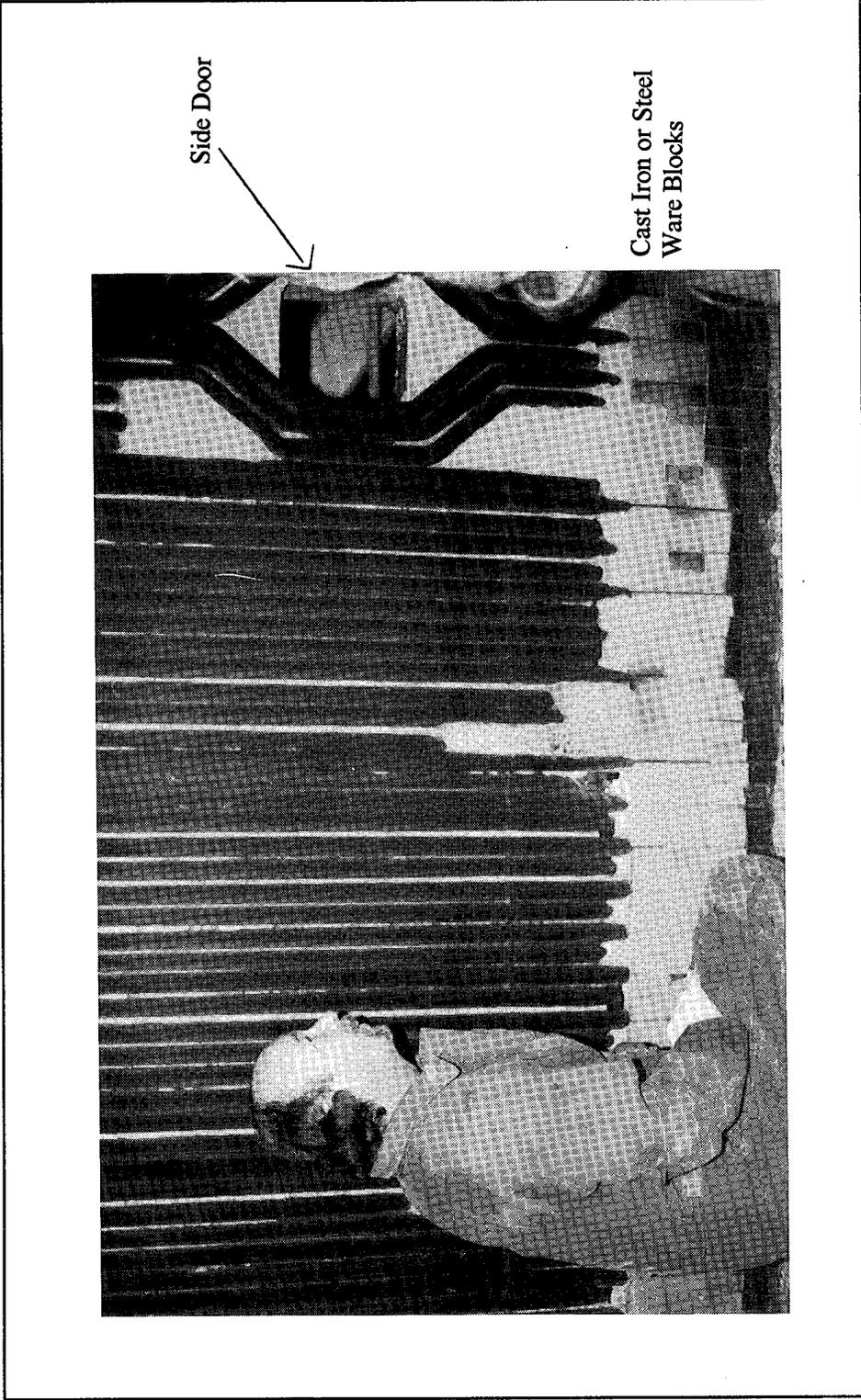


Figure 28. Malmstrom generator No. 3, right side wall tubes.

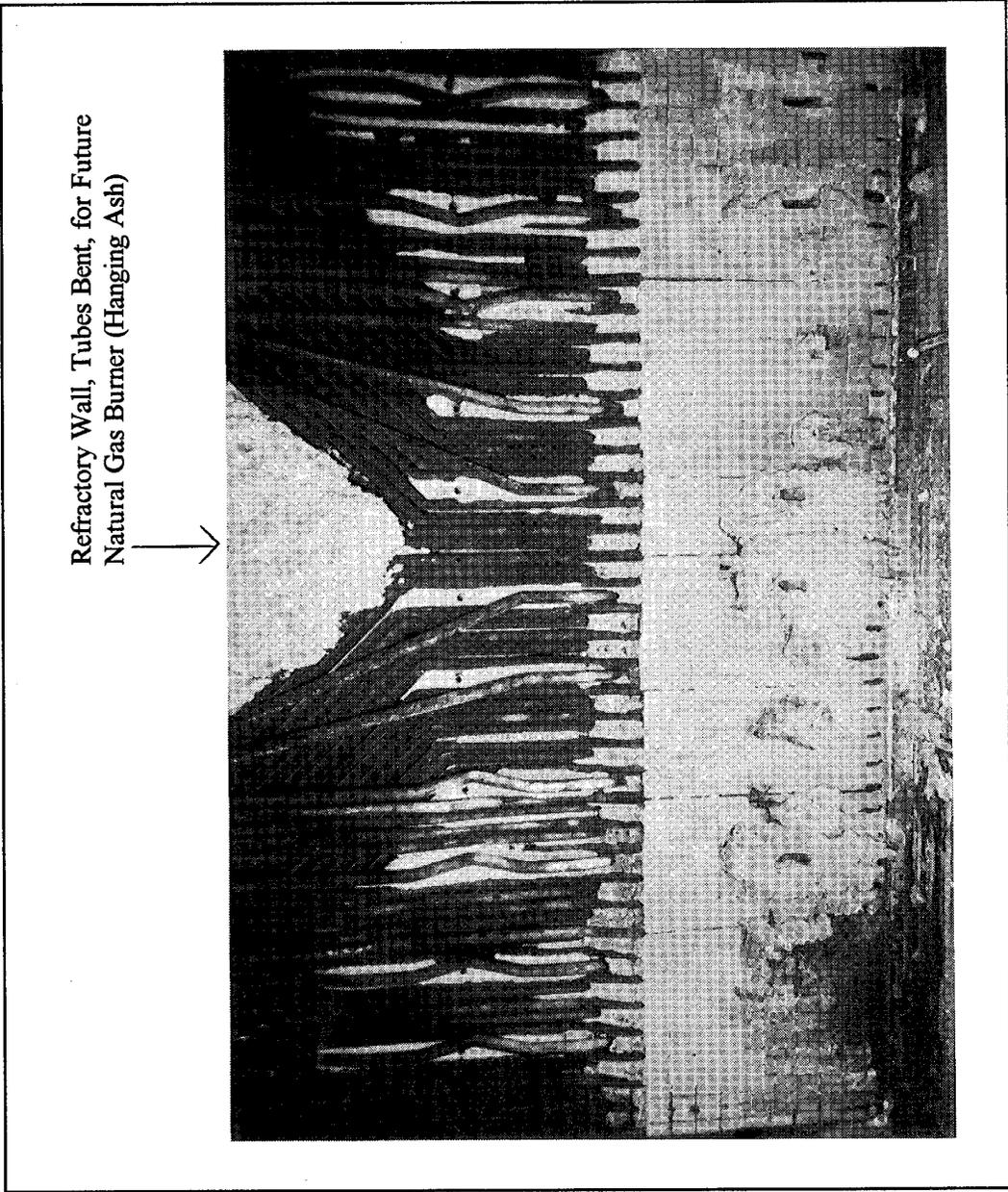


Figure 29. Malmstrom generator No. 3, rear furnace wall view.

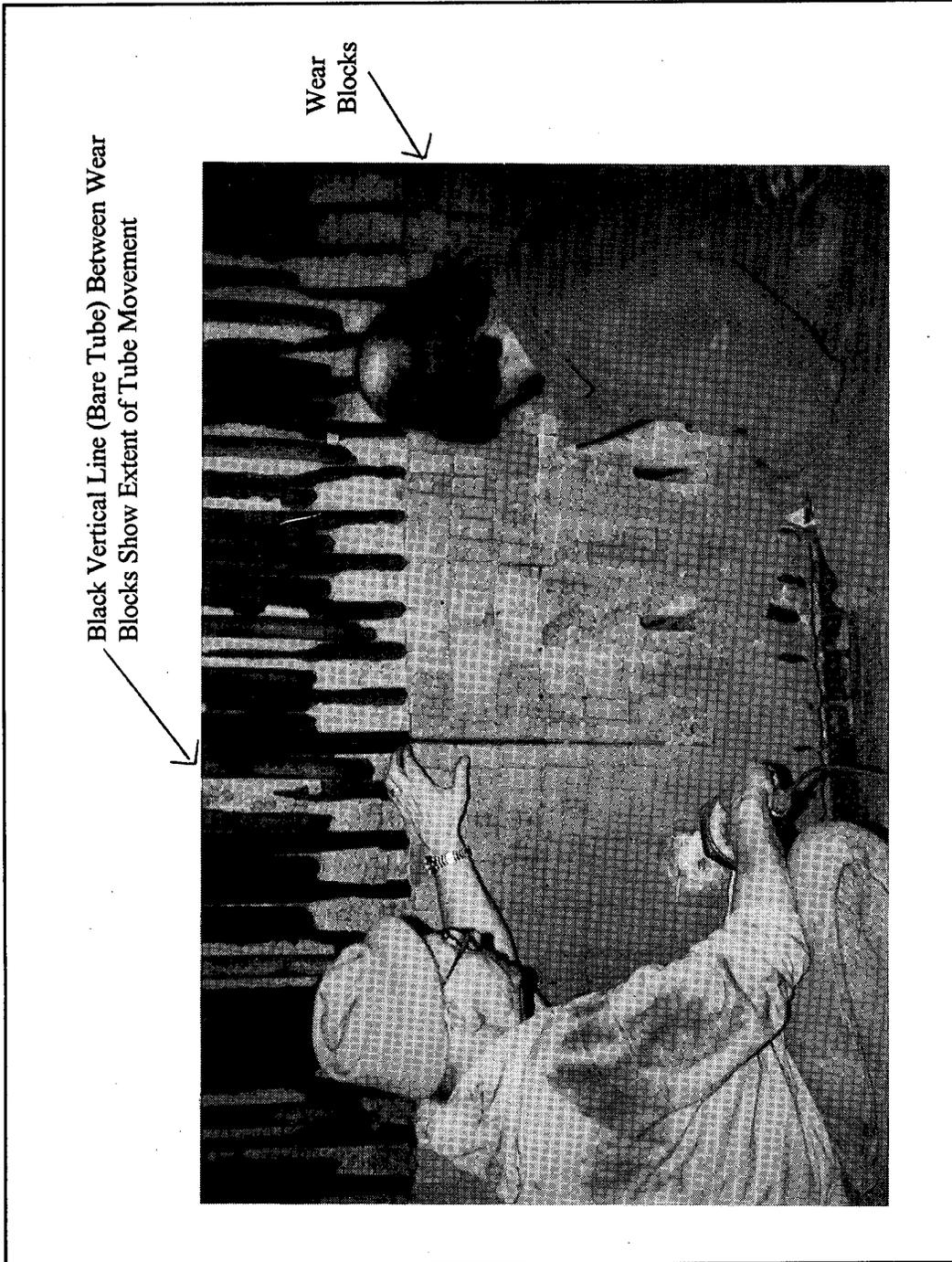


Figure 30. Malmstrom generator No. 3, view of rear wall showing extent of tube movement.

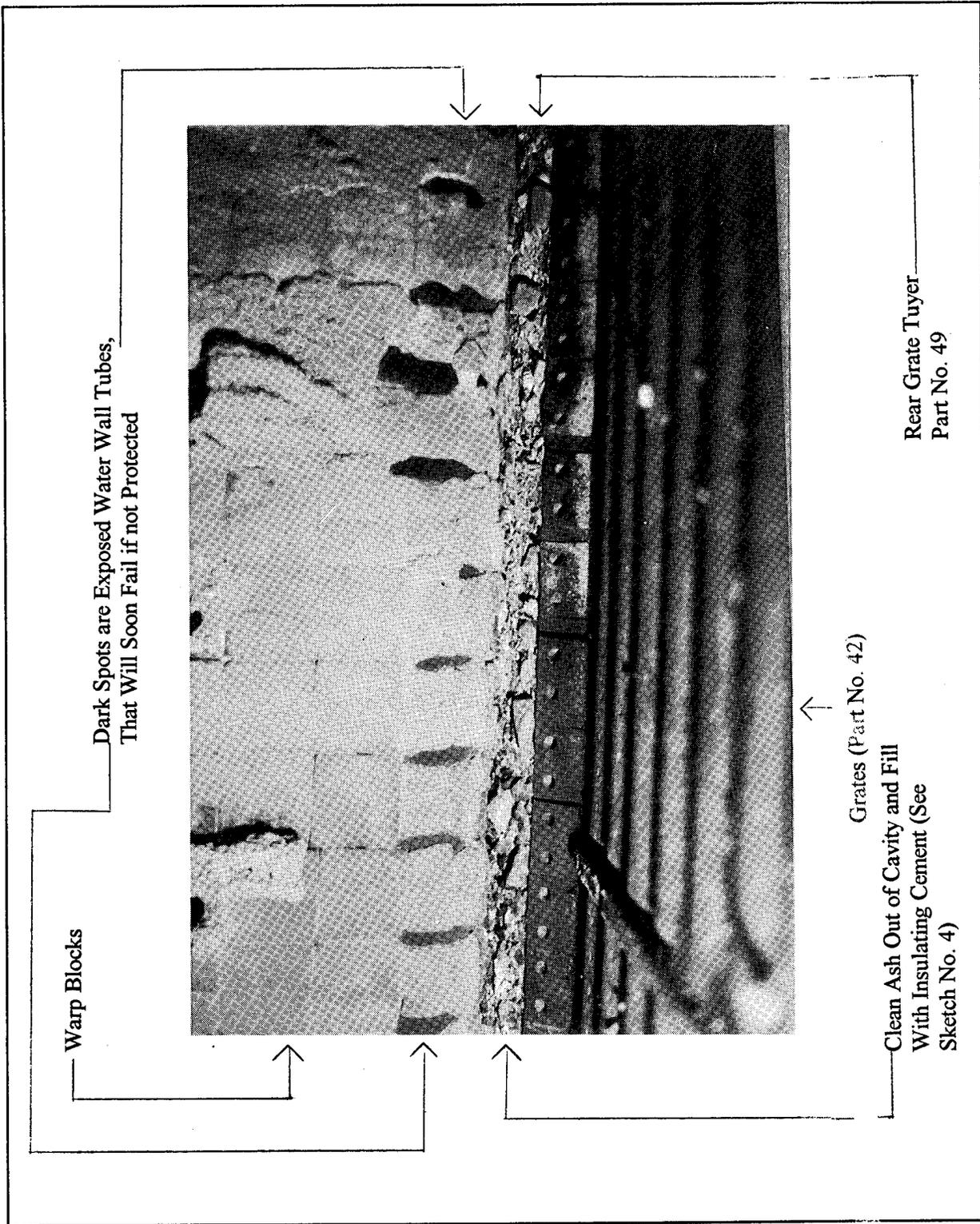
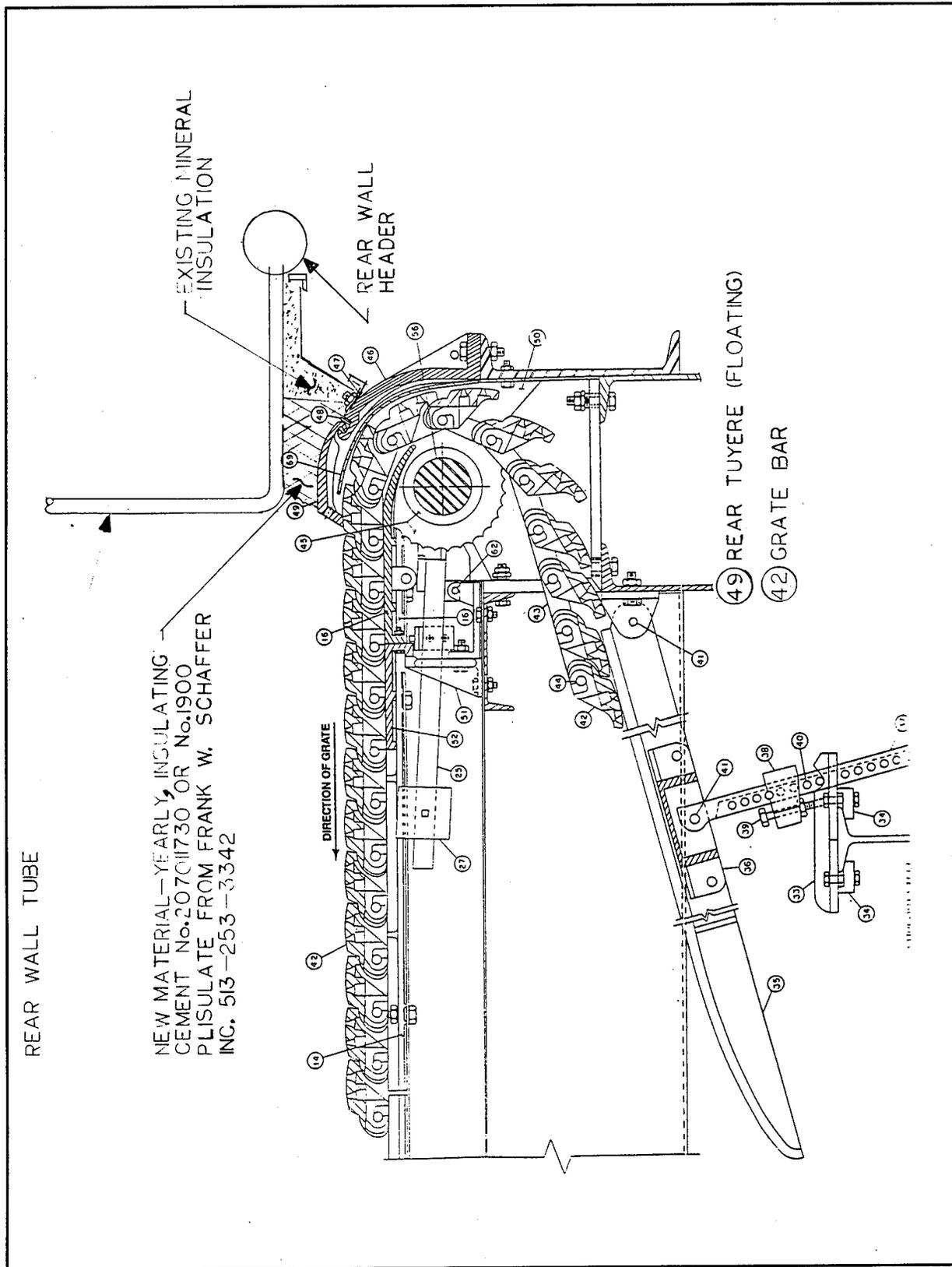


Figure 31. Malmstrom generator No. 3, rear wall at grates.



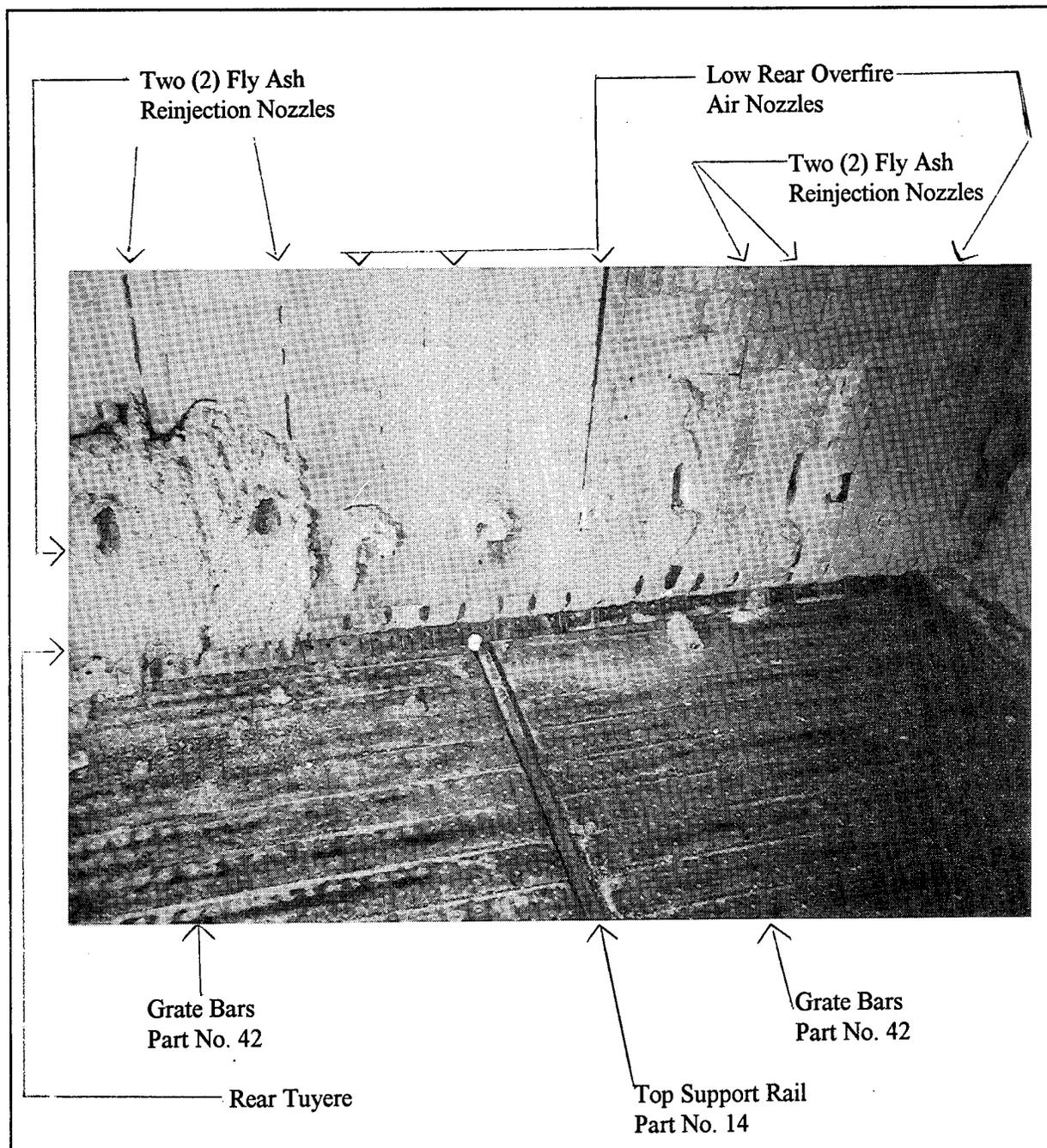


Figure 33. Malmstrom generator No. 3, reinjection nozzles.

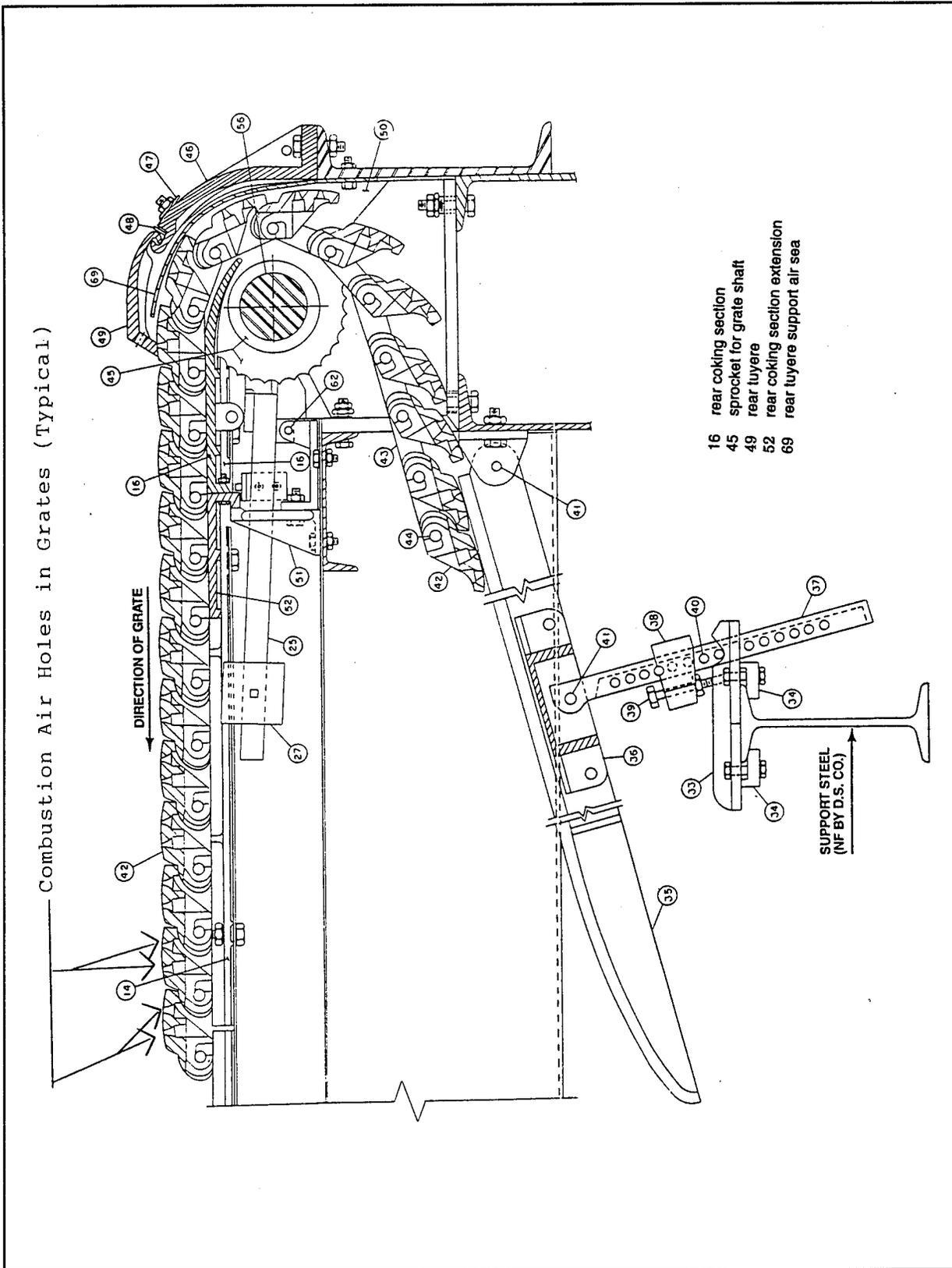


Figure 34. Sectional side view of typical combustion air holes in grates.

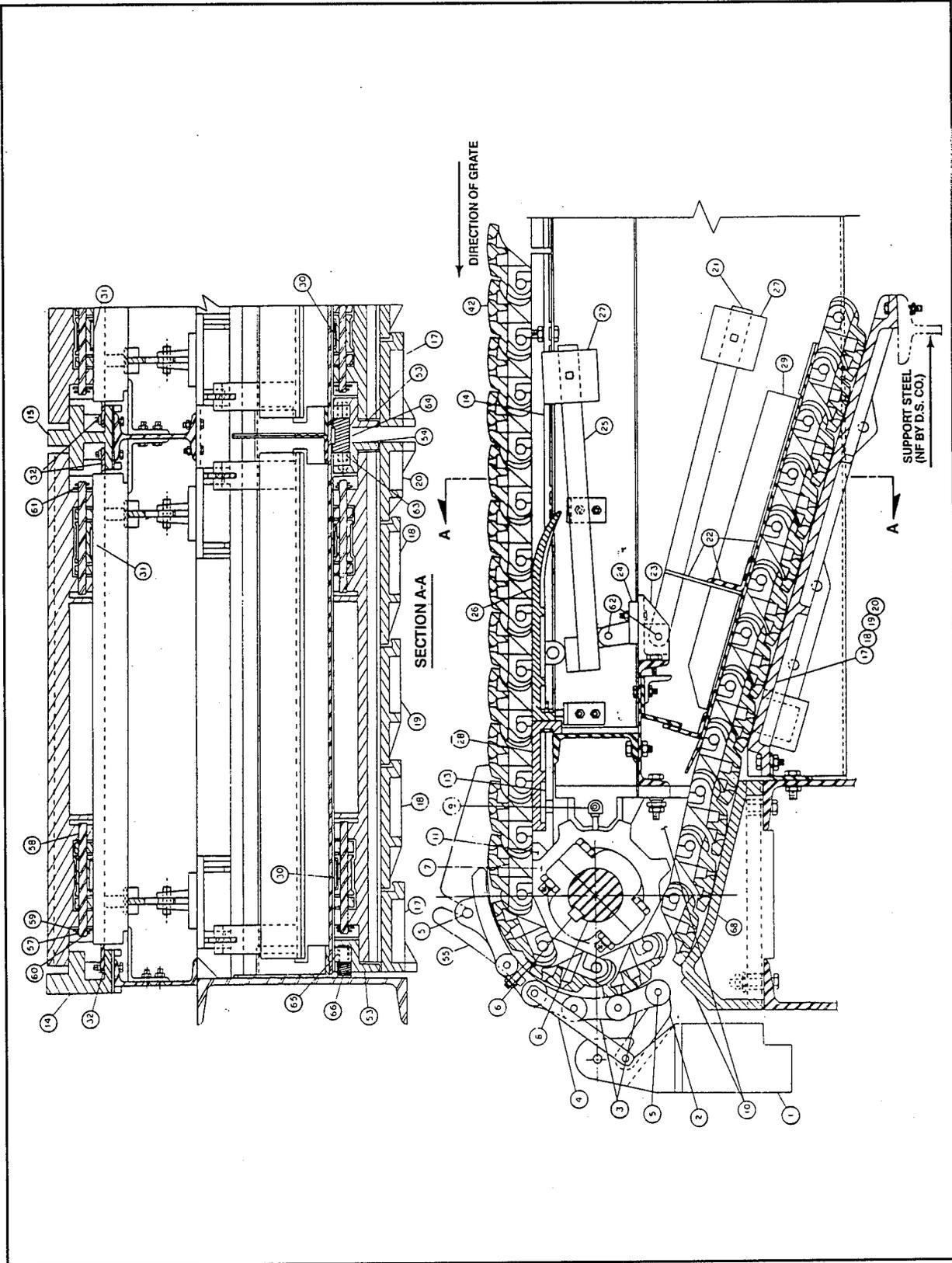


Figure 35. Sectional side view of top support rail sides.

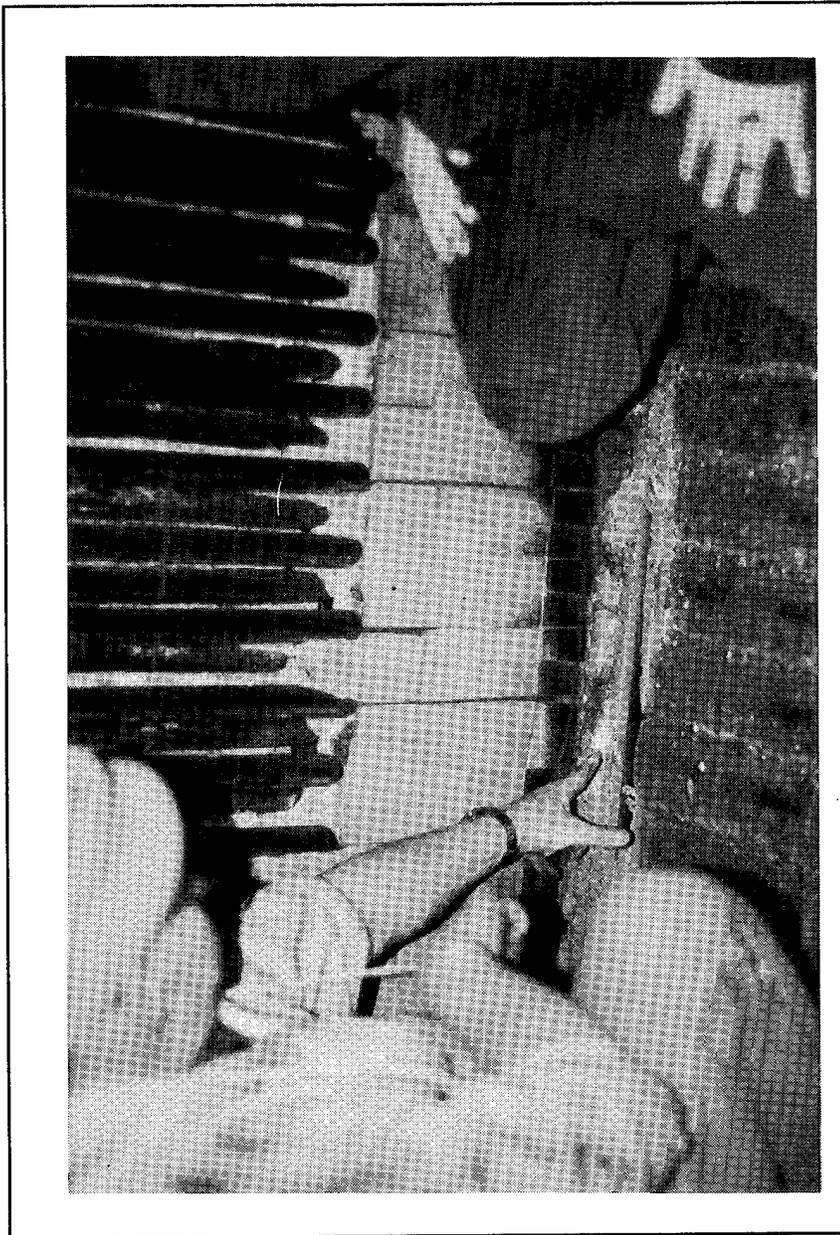
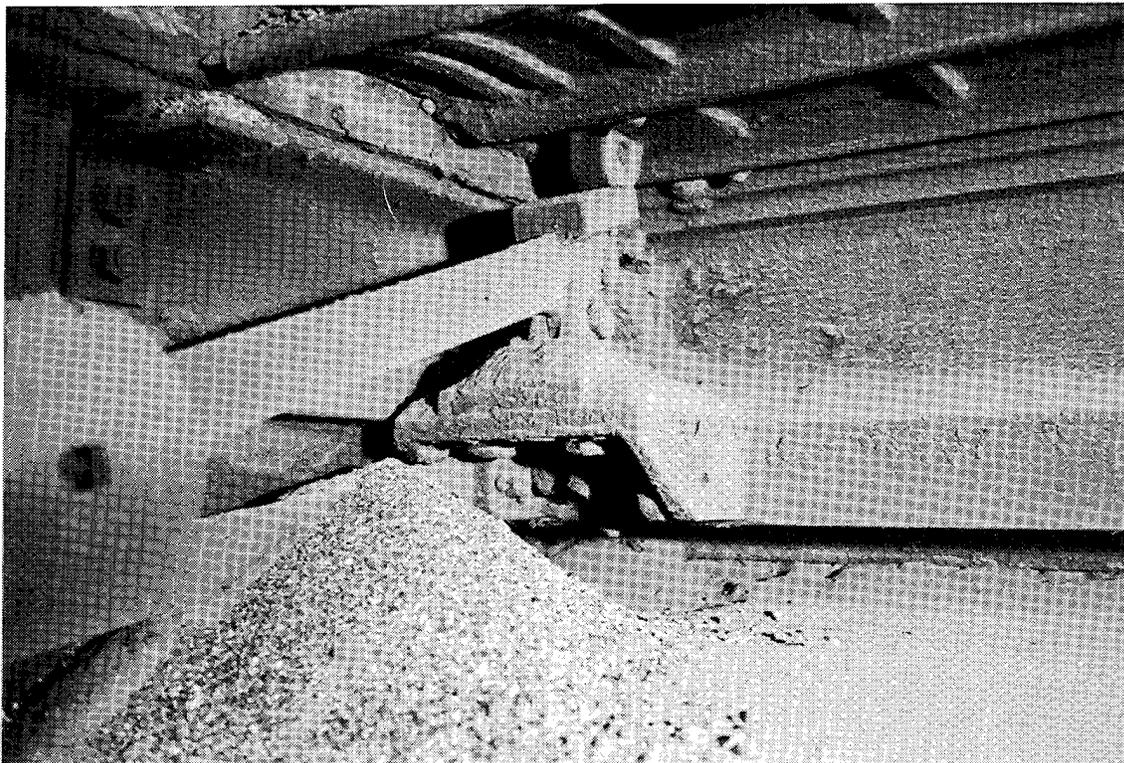


Figure 36. Malmstrom generator No. 3, packing at top support side rails that requires replacement.

Correct Front Upper Air Seal

The Weight (Item 27) is Free and Pushing Upward on Front Upper Air Seal (Item 28)

↙ Front Upper Air Seal



Weight, Item 27 & Upper Air Seal Arm, Item 25

Figure 37. Malmstrom generator No. 3, correct front upper air seal.

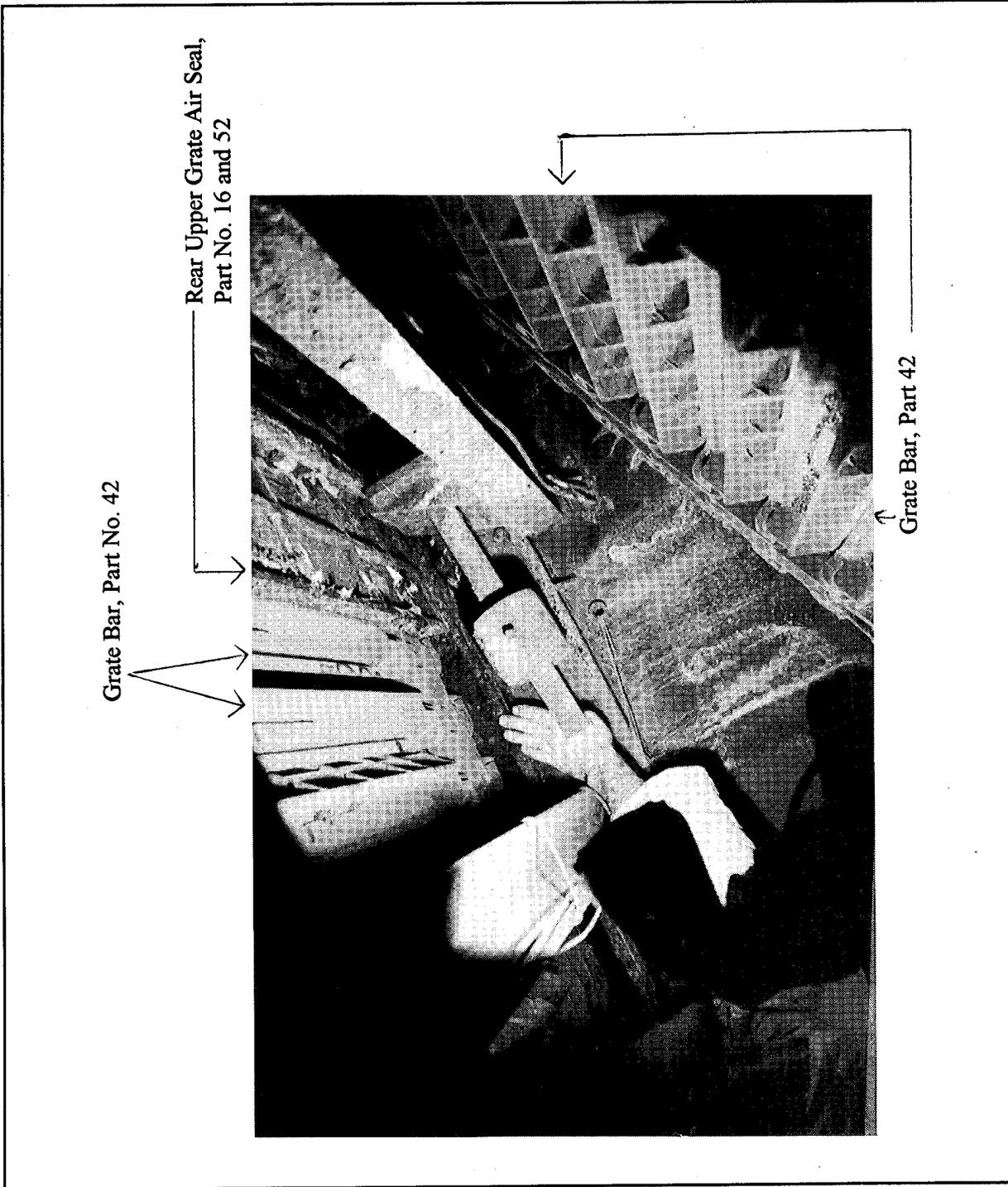
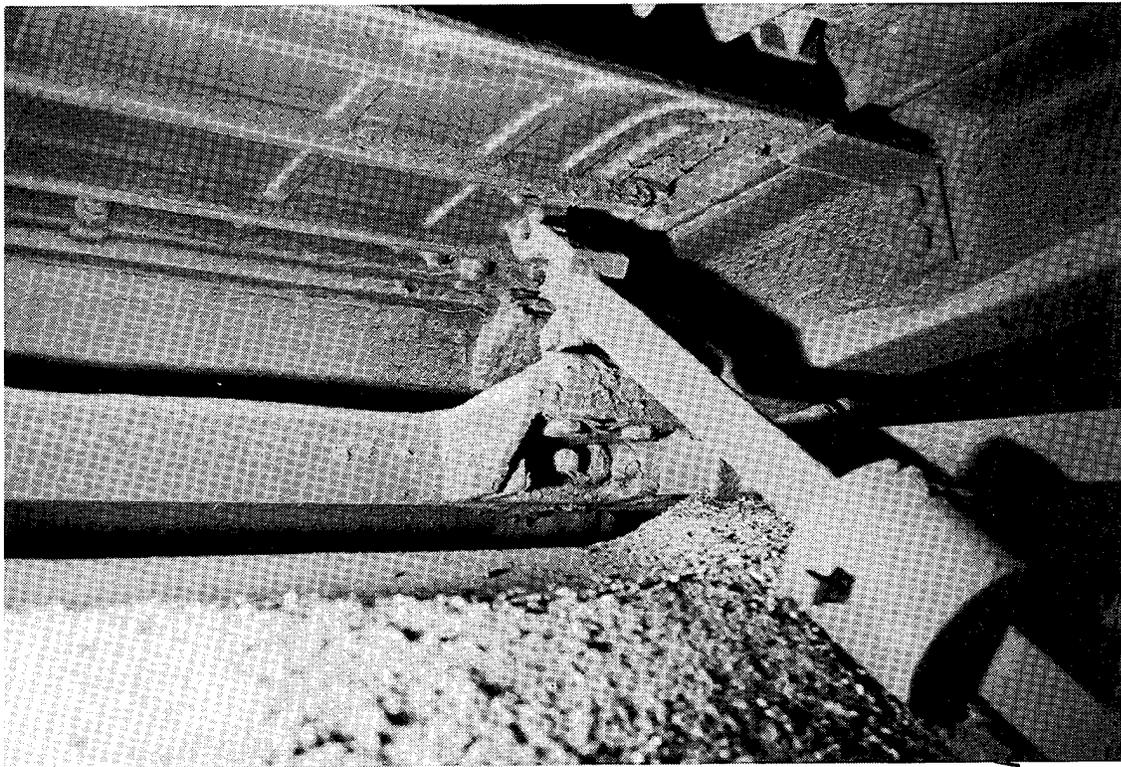


Figure 38. Malmstrom generator No. 3, rear upper grate seal.

Weight (Item 27) laying in Ash (should be removed) and not Forming Front Upper Air Seal. The Seal is not Tight up Against Grate

Item 26  
Front Upper  
Air Seal

Grate Bar



Item 25  
Upper Air Seal  
Weighted Arm

Item 27  
Weight That Acts as  
Counterweight

Figure 39. Malmstrom generator No. 3, incorrect front upper air seal.



Figure 40. Collector end of mechanical dust collector to air heater breeching.

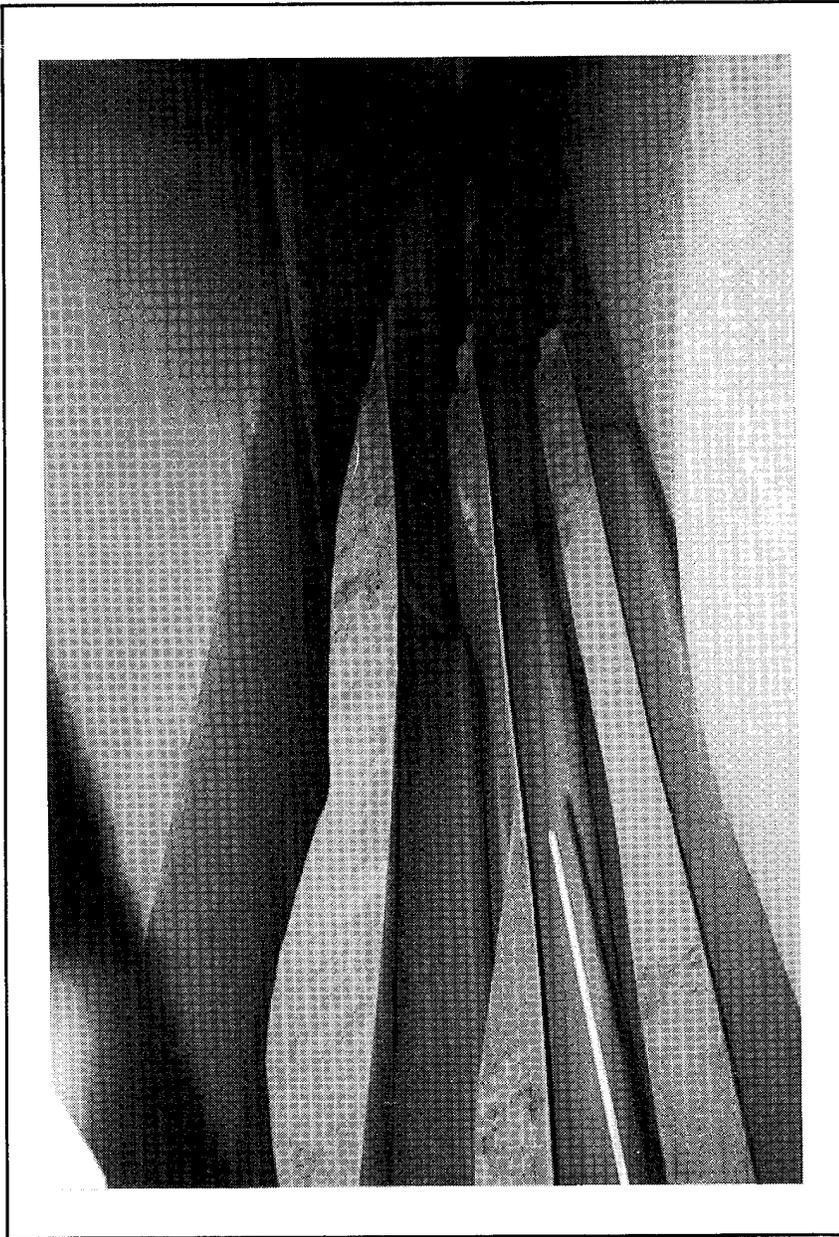


Figure 41. Generator end of generator to mechanical dust collector breaching.

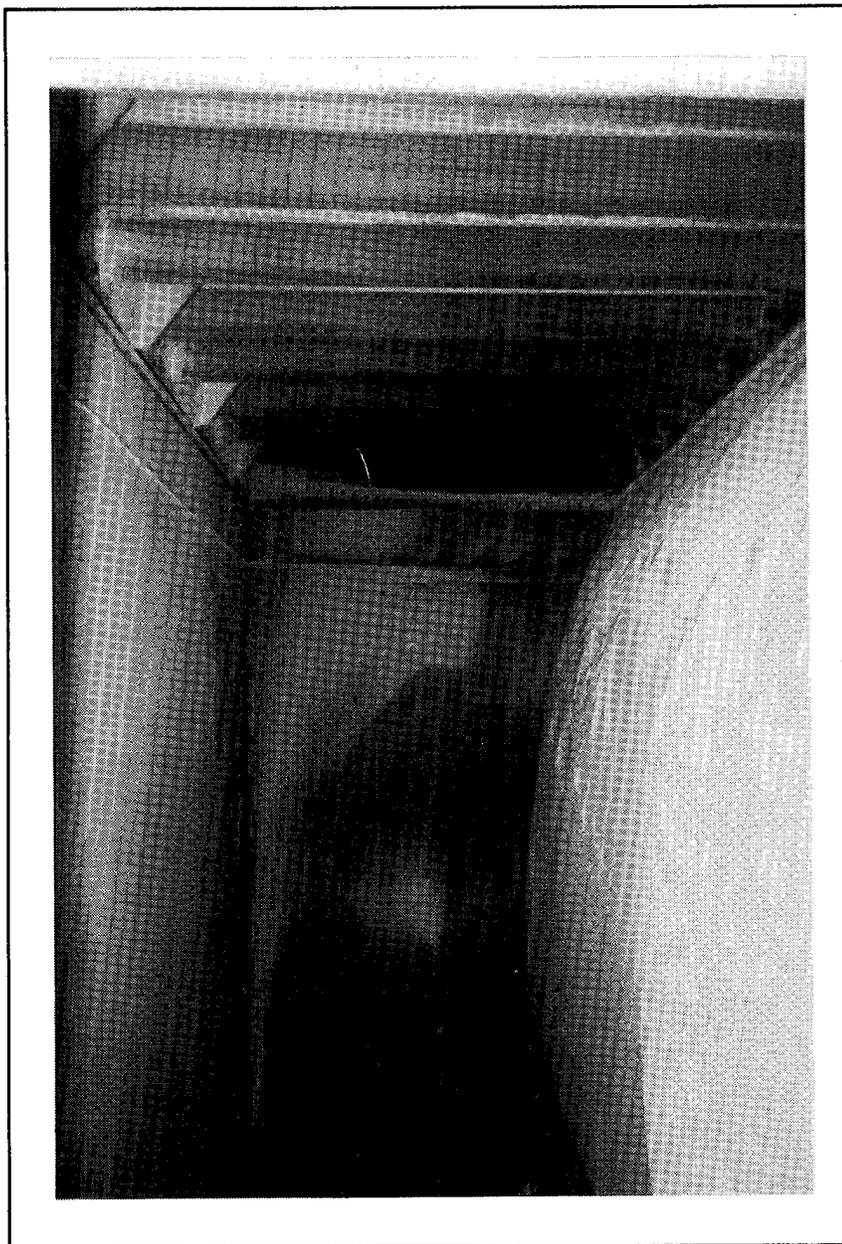


Figure 42. Collector end of generator to mechanical dust collector breaching.

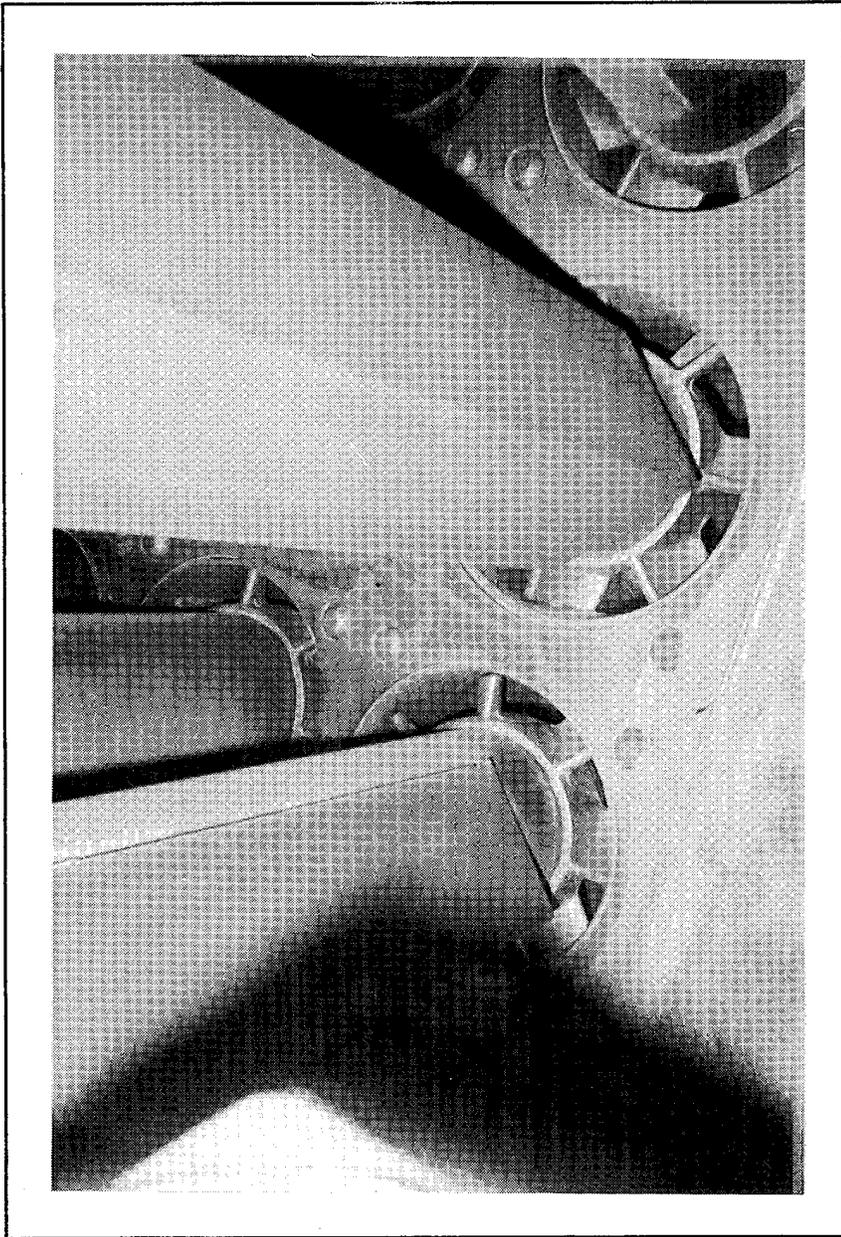


Figure 43. Mechanical dust collector top of dirty gas tube sheet.

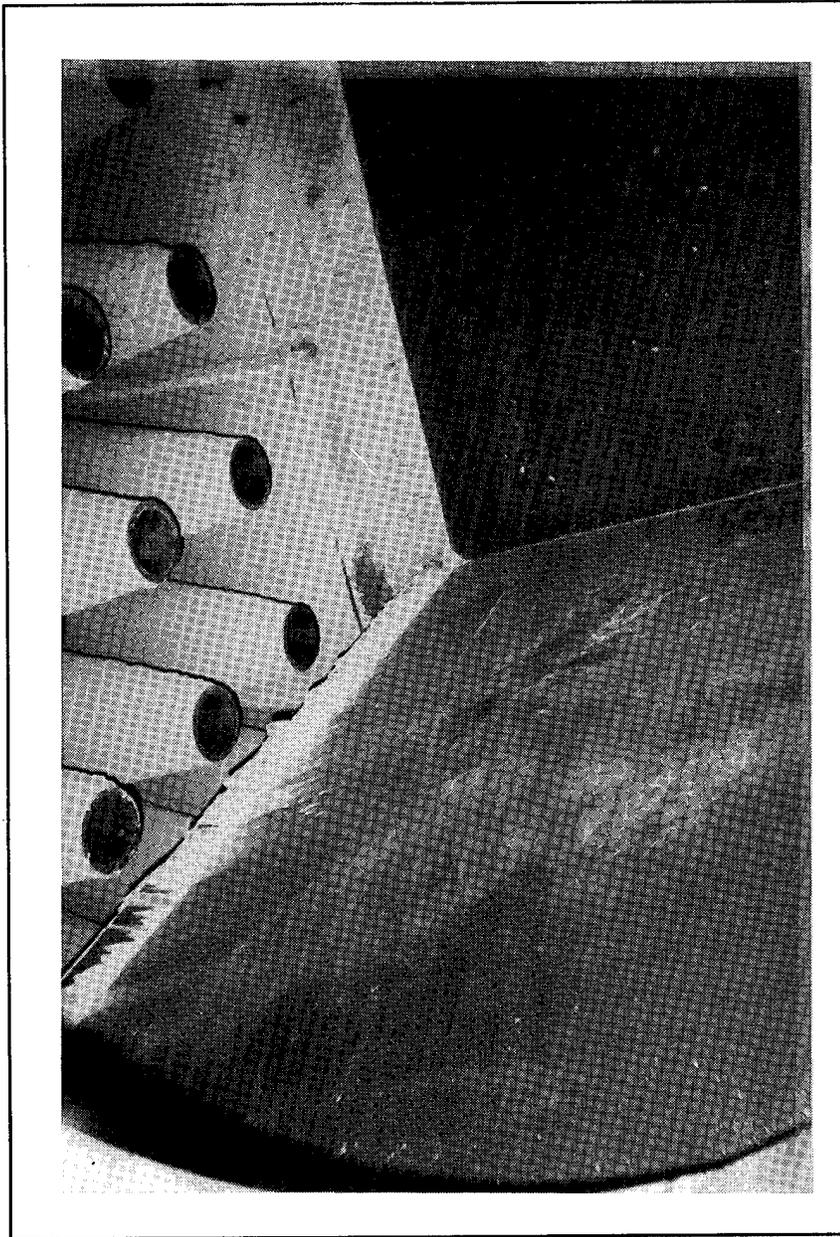


Figure 44. Mechanical dust collector hopper.

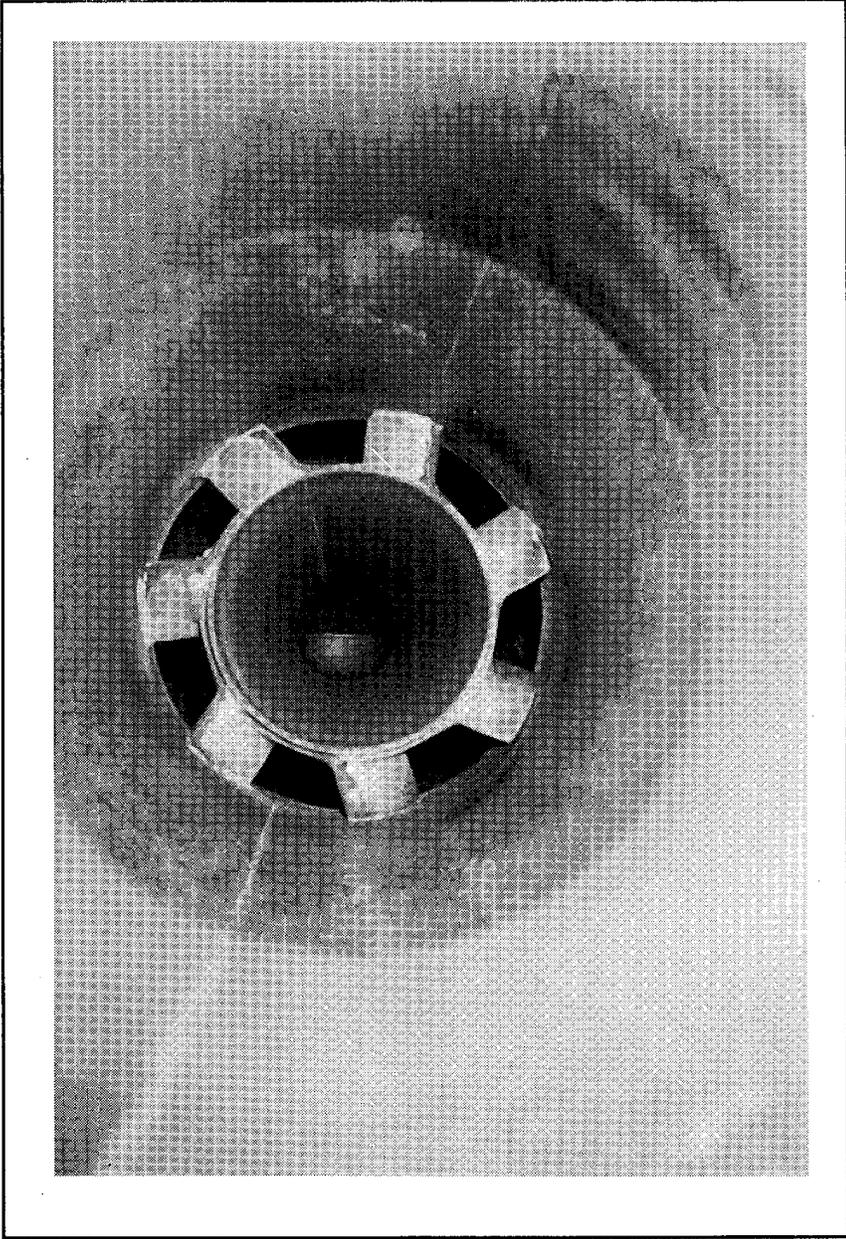


Figure 45. Inside of collecting tube, up from bottom of tube, showing bottom of inlet ramps and clean gas tube in center

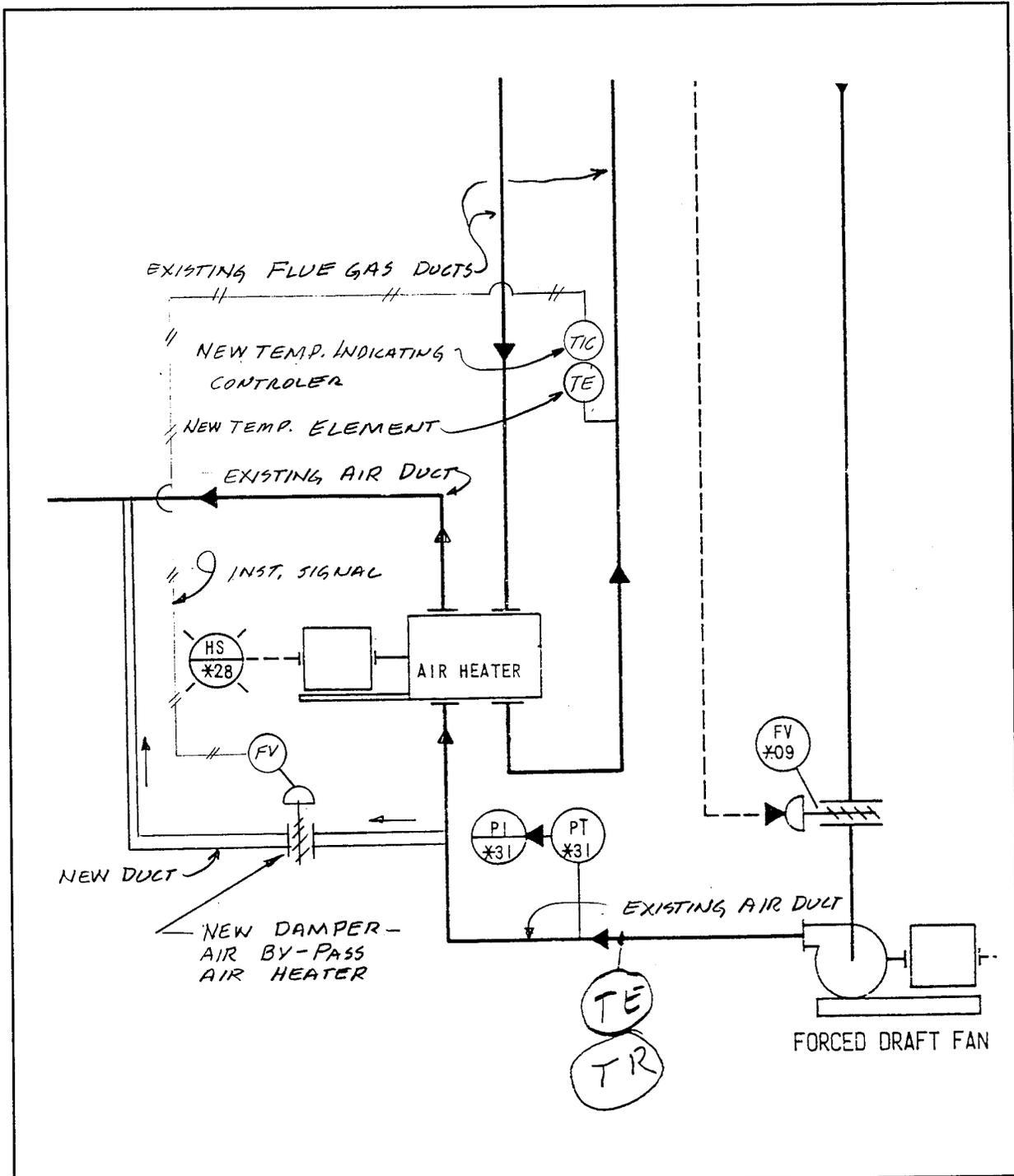


Figure 46. C-E air preheater-Ljungstrom air heater.

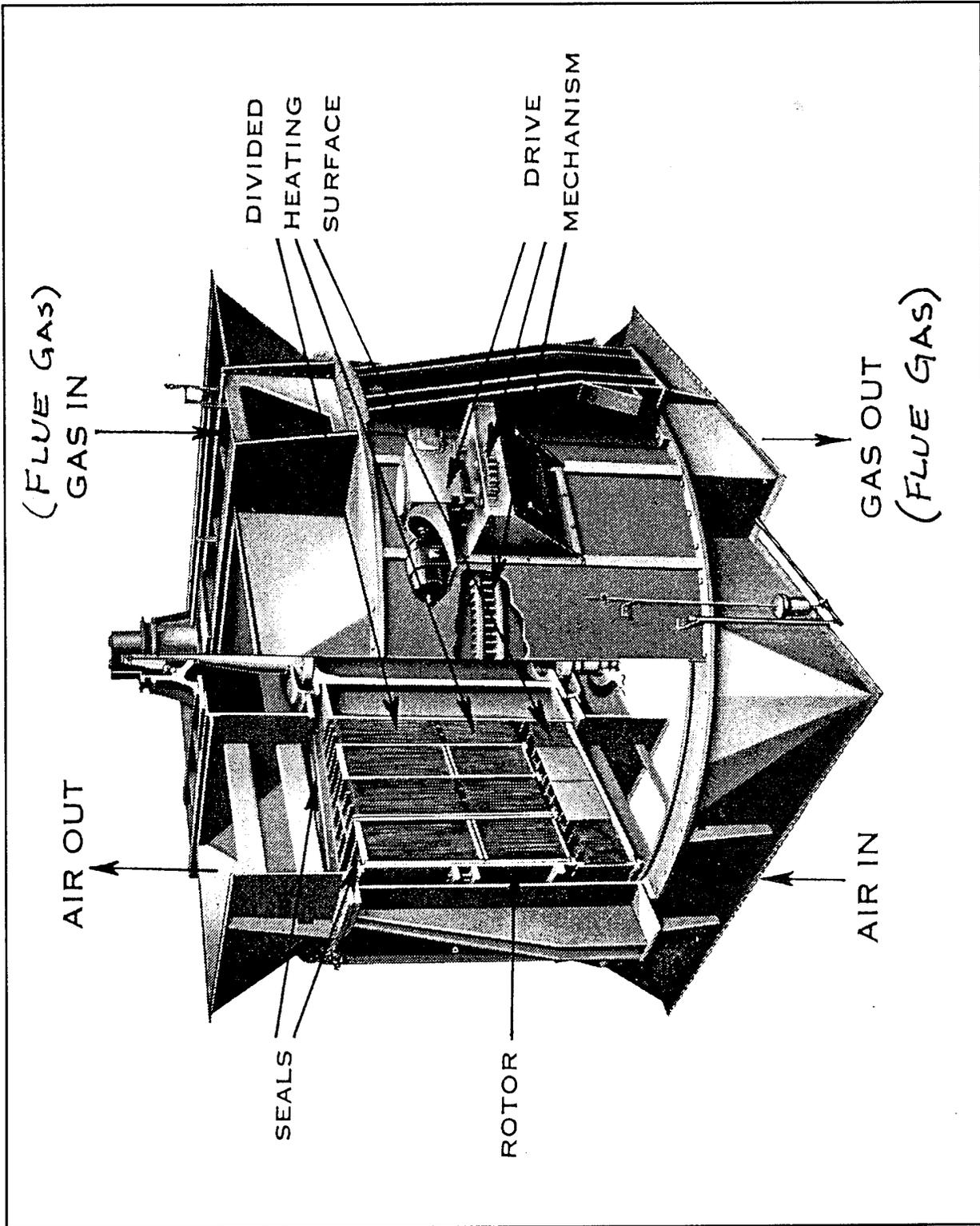


Figure 47. Air heater seals.

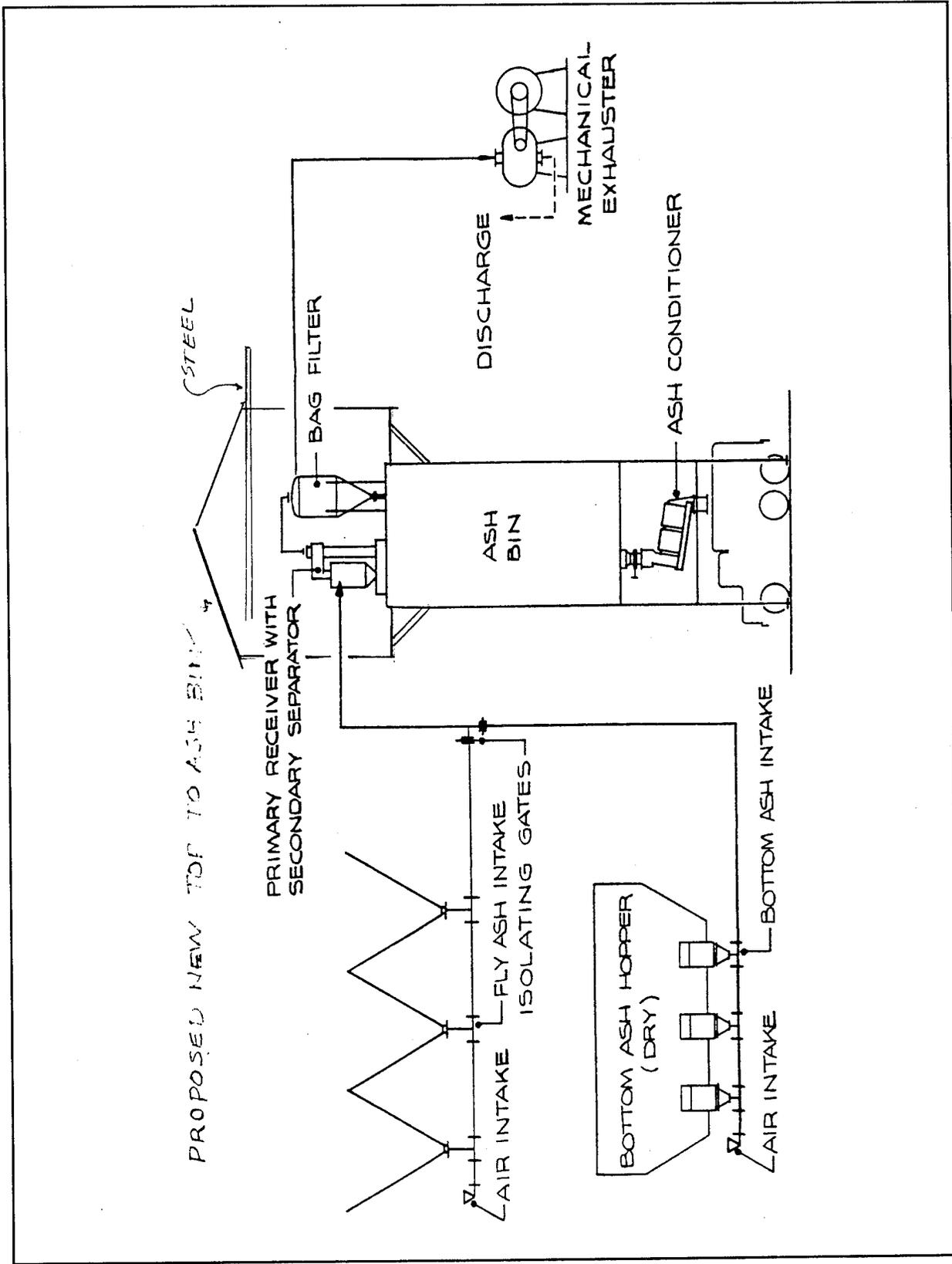


Figure 48. Negative pressure pneumatic conveyor.

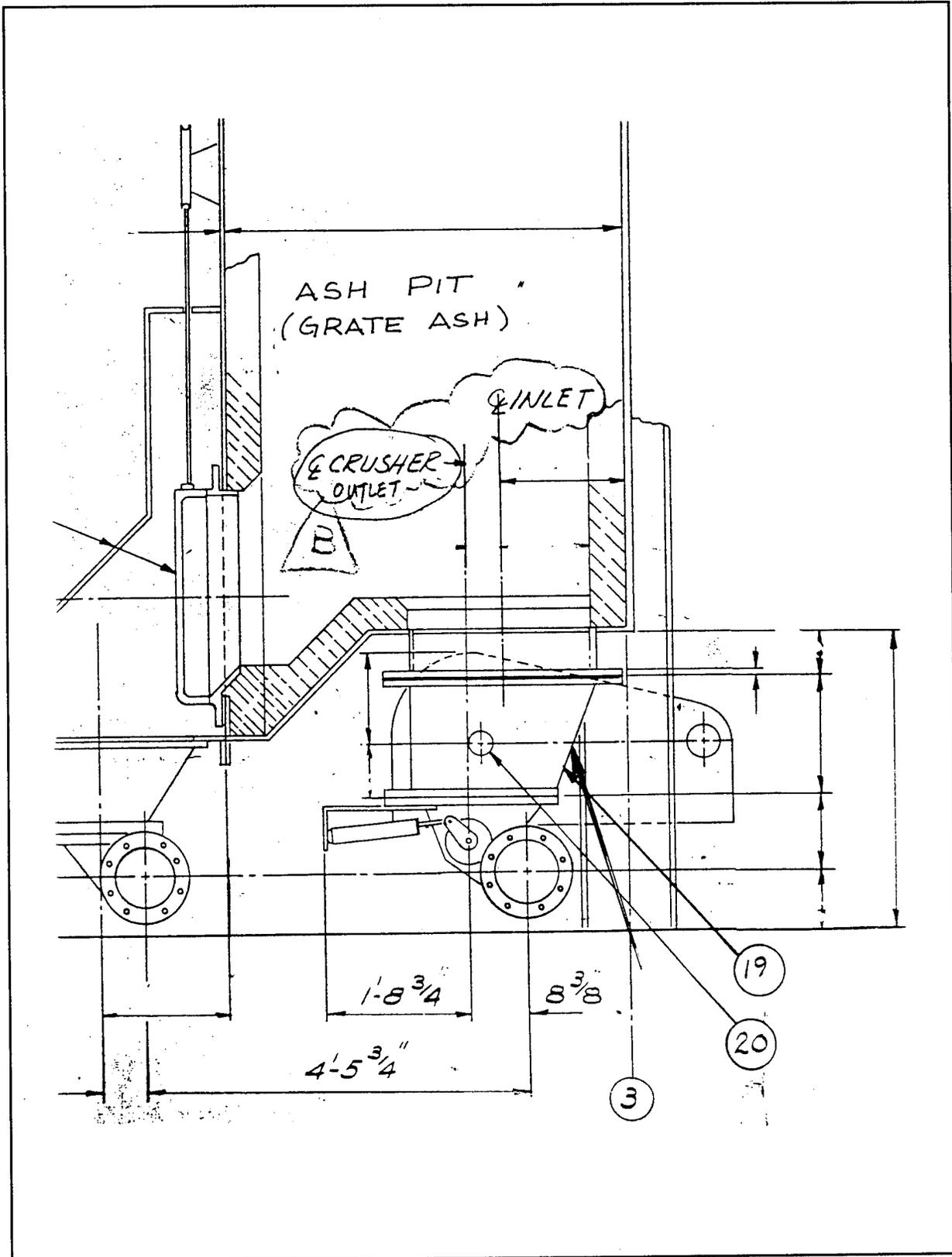


Figure 49. Proposed crusher location in the ash pit.

## 4 Air Pollution Control Equipment

### Preliminary Findings

#### *Operational Problems*

1. Several problems combined to reduce the system's ability to achieve an 85 percent removal of SO<sub>2</sub>. The plant had stopped using the recycle system of mixing flyash with lime slurry last year because of associated problems, including pluggage in the piping, pluggage in the atomizer, chamber wall deposits, etc. The plant currently uses a single pass operation (lime slurry only).

The first problem limiting the removal of SO<sub>2</sub> was the spray dryer atomizer (SDA) flue gas discharge temperature. High SDA outlet temperature setpoints, along with low SDA inlet temperatures resulted in poor removal. At times, this was also combined with weak lime slurry solids. During the visit, the plant personnel closely monitored the lime slurry concentrations, increased the inlet temperature to about 300 °F, and decreased the SDA outlet temperature setpoint to 180 °F. At these conditions, the system operated with SO<sub>2</sub> removals of 90 percent or greater.

The removal rate numbers are based on a wet chemical test by EEMC. Figure D1 shows a recommended curve showing SDA outlet temperature vs. percent (percent) solids of lime slurry based on the measured adiabatic saturation temperature of 133 °F (the curve also shows °F from adsat vs. percent (percent) solids). Operating the system above the curve should be in the safe area, however, operating below the curve may result in drying problems in the SDA vessel. This should serve as a guide for proper spraydown temperatures at different lime slurry concentrations.

2. Recently, the plant had two atomizer failures, both in Unit No. 3. An investigation revealed that the failure was caused by incorrect rotation of the atomizer motor. Since the oil pump is driven directly through the gearbox, it also was rotating backwards. Failure occurred because of lack of lubrication to the gearbox or spindle. Failure of a number of spindles from last year's operation may also be attributed to this problem.

3. Problems were also experienced with the atomizer feed control valve on Unit No. 3. The valve was finally replaced with the control valve on Unit No. 2. When the valve was removed, it was discovered that the boot insert was not the correct size. The original valve had a 1.5 x 0.75-in. boot insert, which had been replaced with a 1.5 x 1.5-in. insert. The replacement boot was simply too large for the feed rates, which resulted in erratic control. The control valve on Unit No. 3 should be inspected.
4. Several problems interfered with the slaking process. The weigh belt feeder has been removed and the slaker is now operated in manual mode. The operators must set the ratio of lime to water by manually setting the screw feeder speed and then controlling the slaking water and dilution water from setpoints in the Bailey Network 90.

During the visit, the heat exchanger on the slaking water failed and could no longer be used. Proper slaking can still be achieved without the heater, however, the slaking temperature is reduced. The important criteria in slaking is to achieve a 100 to 110 °F temperature rise from the starting temperature of the water. This generally indicates that lime is being properly slaked. With the heater, the final temperature reached 180 °F; without the heater, the final temperature was 160 °F. These slaking temperatures appeared to be reasonable guidelines for operating this slaker.

The screw feeder speed should be set and then left alone. The slaking water flow rate should then be adjusted to maintain the slaking temperature. The dilution water should then be adjusted to maintain the proper solids. These values of water flow can then be used each time the slaking process is in operation. This should result in a fairly consistent batch mode of operation. The slurry concentration for the slaking and the atomizer feed should be measured at least once per shift.

5. The CEM system failed a couple of times during the visit. This system is critical since it is the only means of determining the performance of the spray dryer.

### ***Recommendations***

The following list of recommendations concerns items critical to maintaining emission requirements:

1. Proper slaking procedures that result in consistent lime slurry densities must be followed. The slurry exiting the slaker and entering the classifier trough should

be about 20 to 22 percent solids. Because of the occasional flushing, the lime slurry will tend to dilute over time. Under normal conditions, the lime slurry feed should be about 15 to 20 percent solids. The atomizer feed should be measured once per shift and a sample of the slaking product should be measured during each batch of slaking. This close monitoring will help alleviate upset conditions. If lime slurry concentrations become low, then actions need to be taken. One possibility in emergency conditions is to use calcium hydroxide in powder form, either added directly to the lime storage tank or to the feed tank. Manual mixing and testing will be required.

2. The SDA outlet temperature or the spraydown temperature is critical in achieving the removal of  $\text{SO}_2$ . The attached curve should be used as a guideline to determine safe operating spraydown temperatures. The density of the atomizer feed is an important parameter in the drying characteristics. During the visit, successful operation at 180 °F produced acceptable  $\text{SO}_2$  removal results with no apparent drying problems.
3. During the visit, a modification to the baghouse cleaning cycle was suggested to plant personnel. Currently, the cleaning initiates on the pressure drop and cleans all five compartments. The controls should be changed to initiate on the overall baghouse pressure drop and clean one compartment only. This change would help maximize the removal of  $\text{SO}_2$  in the baghouse, minimize the swings on the ID fans, and spread out the ash removal cycle. This was discussed with the instrument technician, who reviewed the drawings with the pressure drop input moved in the logic to interrupt and initiate the sequencer stepping. In this way, the baghouse cleaning would follow the same cleaning sequence as in pressure drop cleaning, with the exception that only one compartment would be cleaned at a time.
4. Due to the atomizer troubles, the rotation of the motors needs to be verified. It is recommended that quick-disconnect connectors be installed on the power cable to atomizer motor. This change was discussed with the instrument technician, including different suppliers that have been used in the past. If the recommended units are installed, care must be taken to ensure that both the motors and disconnects are identically wired so atomizers can be interchanged between units and still rotate properly.
5. If CEM equipment is required at some point in the future, certain modifications will need to be made. The outlet monitor for  $\text{SO}_2$  is currently calibrated using the same span gas as the inlet. Using a lower value span gas for  $\text{SO}_2$  on the

outlet monitors is recommended. This would allow more accurate calibration of the monitor in the normal operating range.

## Proposed Modifications and System Operation

### *Recommendations*

1. If problems with pluggage of the atomizer feed persist, a new designed "volute-type" liquid distributor should be installed. Figures D2 and D3 show a drawing and cost estimate for the conversion. The volute section is fabricated from Teflon/plastic, which is less likely to have build-up problems.
2. If the plant is operated in lime-only mode with no use of recycle, the current lime storage tank can be converted to serve as the feed tank. This conversion can be easily accomplished by relocating the head tank return lines to the lime storage tank. The feed pumps could then be connected to the lime storage tank by use of hoses and quick disconnects. Figure D4 through D7 show the process flow eliminating the classifier on the head tank return. In a number of similar facilities, the head tank return is no longer routed through the classifier (vibrating screen). By making this conversion, the current collecting trough, classifier, feed tank, transfer pumps and associated piping could be eliminated. This would be the easiest and simplest modification to improve the system.
3. If the plant was not comfortable in eliminating the classifier from the system, the collection trough and vibrating screen could be relocated to the lime storage tank. Figure D8 shows the system modification leaving the vibrating screen in service.
4. The feed pumps could all be connected using quick disconnects and hoses. Appendix E contains a recommended layout for pump connections on the suction and discharge using hoses and quick disconnects. Flush water can also be connected using hoses and quick disconnects. This allows simple operation with maximum flexibility.
5. Another operation improvement could be made in the transfer of lime slurry from the classifier collection trough to the lime storage tank. Currently, the flow must be balanced by regulating the amount of lime slurry to the storage tank and the amount of return back to the collection trough. It is recommended that the centrifugal slurry pump be replaced with a pneumatic style slurry pump. The pumping rate can then be adjusted by using a pressure regulator for the air supply, thus eliminating the return pipe. The pump speed could then be adjusted

- to match the slaking rate. Appendix E contains vendor literature for a pneumatic pump. It is recommended that hose connections be used when installing this pump. Refer to Figure D8.
6. Another useful modification would be to eliminate the screen in the head tank and use a duplex strainer. Recently designed units incorporate duplex strainers to allow swapping of a plugged screen without interrupting the flow. Appendix E contains a copy of the duplex strainer taken from the McMaster-Carr catalog.
  7. Appendix E includes copies of two operating condition run-outs from the absorb program. The first is based on the HTWG operating at full load conditions and the second is based on about 40 percent load. These are both calculated with the unit operating on lime only mode with the sulfur content of the coal at approximately 0.5 percent. Both of these are calculated with a removal of about 95 percent SO<sub>2</sub>. Also in both instances, the lime slurry density to the atomizer was selected at a 10 percent solids. The spraydown curve contained in Appendix E shows that this is about a 50 °F approach temperature. This should still be in the safe spraydown operating range of the curve.

The original design of the units were based on the SO<sub>2</sub> level of the coal at about 1.5 to 2.0 percent. The pebble lime consumption rate for original design with the use of recycle was about 297 lb/hr for one HTWG at full load. From the run-out estimates on lime only at full load with the SO<sub>2</sub> at 0.5 percent, the pebble lime consumption rate is about 336 lb/hr (this is at a slightly higher removal rate of 95 percent instead of the design of 85 percent). The pebble lime consumption at the 40 percent load condition is about 97 lb/hr. From these results, it is evident that the lime consumption increases substantially when the unit is operating in lime-only mode. Observation confirms that operating in this manner results in a much smoother and easier operation. This appears to be a viable means of operation when one looks at the typical operation of the HTWGs over a season. If this alternative is not acceptable, the plant could also consider modifying the recycle system to make this portion more reliable. At this point, there is no apparent economical advantage in considering using the recycle system.

## Summary

These recommendations should serve as a guideline for successful operation of the units. The removal of SO<sub>2</sub> can be adjusted by regulating the actual spraydown temperature and the density of the lime slurry. The plant can determine, through operating experience, the parameters at which the units operate smoothly with the

desired performance. In so doing, the object would be to minimize the amount of pebble lime needed to achieve the desired SO<sub>2</sub> removal. The slurry density and the curve that was submitted should be used as a guideline to determine the actual spraydown temperature at which the unit should be able to operate without potential buildup on the chamber walls.

## 5 Conclusions and Recommendations

### Conclusions

If regulatory officials desire to have flue gas SO<sub>2</sub> concentrations indicated as a relationship to heat output, then the metering equipment must be changed. This study showed that the current BTU output meter is in error by more than 30 percent under the best operating conditions. The most accurate devices that the team found at the plant in terms of heat input were the coal scales, which have maintained their accuracy because the plant personnel have accurately calibrated and maintained them in excellent condition. The lack of accurate information about the BTU output is, in fact, a result of the inaccuracy of the device, which reflects on the original construction, not on its maintenance or operation.

Current equipment operation shows that the existing SO<sub>2</sub> removal system can be operated to achieve removal rates of 85 percent only when the plant is operating at peak condition. Several minor changes are recommended to improve the operation and reliability of the SO<sub>2</sub> removal system. It is also recommended that the federal limitation of 0.32 lb/MBTU be adopted as a more realistic SO<sub>2</sub> removal rate limitation.

This study revealed a significant equipment problem; readings from the existing baghouse flue gas outlet emission monitor were in error by a factor of 300 percent—a marked contrast with the required on-line reliability of this equipment, which must approach 98 percent and be in the +10 percent range for reading accuracy. It cannot be overemphasized; the flue gas outlet emission monitor simply gives incorrect readings. This is an unacceptable, operationally unreliable condition that must be fixed. If MAFB continues to use this inadequate equipment, such incorrect readings will likely cause further regulatory problems.

The coal combustion and the operation of the spreader stoker by the plant personnel is very good. A number of small operating problems were identified and detailed maintenance recommendations were made.

This study concludes that the MAFB plant can be well operated within the extremely tight limitations of the permit to operate conditions as set forth by the State of Montana and the Federal Environmental Protection Agency.

## Recommendations

The following list of problems and recommendations outlines high priority issues to maintain the continued operation on coal:

1. Continuous Emission Monitor (CEM). The baghouse flue gas outlet emission rate of sulfur oxides absolutely must be known by the plant operating personnel, to within 10 percent accuracy of reading at all times.

It would be of great help to know the flue gas sulfur oxide content at the spray dryer atomizer vessel inlet, normally from 290 PPM to 330 PPM by volume with an average of 310 PPM by volume, with 0.50 percent sulfur coal and 12,200 BTU/# heating value as received.

The existing baghouse flue gas outlet emission monitor was in error by a factor of 300 percent. It cannot be over-emphasized; this an unacceptable, operationally unreliable condition that must be fixed. This study has found the source of the error to be in the instrumentation; the flue gas outlet SO<sub>2</sub> emission monitor simply gives incorrect readings.

It must be noted that the plant's instrumentation technician has done an excellent job trying to keep the sulfur oxide emission monitors in operation and calibrated. The typical expenditure in technical effort has been 20 work-hours per week for one inlet and one outlet sulfur oxide monitor.

If the plant is going to rely on the programmable controller to determine SO<sub>2</sub> emissions in relationship to heat outputs, then the heat output analyzer portion of this programmable controller must be corrected. This study determined from coal input that the heat output measurement is incorrect by as much as 30 percent (low readings). The instrumentation that goes into the heat output of each HTWG is the thermocouples, the temperature of the water into the HTWG, the temperature of the hot water out of the HTWG, and the flow rate of the water. Whether it is the flow element, the flow transmitter, or the flow recorder, apparently something in the flow quantity causes this piece of instrumentation to give unacceptably erroneous readings.

2. Slaked lime.
  - a. Lime slurry - requires a consistent slurry to trough at approximately 20 percent solids, test per batch. The temperature rise of 100 to 110 °F in the slaked lime water will consistently produce a slurry of approximately 20 percent solids. If the starting water temperature is 55 °F, the final slurry

- temperature should be 160 °F. If the starting water temperature is 75 °F, the final slurry temperature should be 180 °F.
- b. Lime slurry feed to spray dryer atomizer requires a consistent slurry at approximately 15 to 20 percent solids, test per shift.
  - c. Atomizer correct size of the feed control valve is 1.50 by 0.75 in. The insert boot must be tapered from 1.50 to 0.75 in.. The failure rate of these insert boots cannot be predicted and an adequate number of spares (three) should be kept in stock.
3. Spray Dryer Atomizer (SDA) vessel.
- a. The outlet flue gas temperature should be approximately 180 °F. This temperature is controlled by the atomizer feed control valve (listed in Item 2.C. above).
  - b. The inlet flue gas temperature to the SDA must be greater than 300 °F even at low high temperature hot water generator heat output. The existing air heater must be modified, preferably with the approval of the original manufacturer.
4. Baghouse. Clean only one module at a time on pressure drop. After one module is cleaned, put all modules back into operation. On increased pressure drop, clean the next (one) module and then put all modules back into operation. This method of operation will keep the maximum amount of slaked lime on the bags for sulfur oxide removal.
5. Coal and handling.
- a. A coal analysis shall ensure the following:
    - 1) percentage of ash
    - 2) heat value as received
    - 3) ash fusion temperature under reducing condition
    - 4) quantity of fine coal in delivered material
    - 5) the existing coal is of good quality.
  - b. Add splitter wedges in coal drop points in bunker.
  - c. When heat output loads are light (less than 45 million BTU/HR heat output), remove fine coal that accumulates in bunker over HTWG No. 3 through the underbunker conveyor to HTWG No. 1 or fire in HTWG No. 3.
  - d. The existing coal belts need alignment under both load (with coal) and unloaded (without coal) conditions.
6. Coal feeders.
- a. Install correct rotor blades in each of the three coal feeders.

- b. Correct refractory problems at throat openings of all coal feeders so that the refractory does not interfere with the distribution of coal.
7. Overfire air.
  - a. Install pressure gauges downstream of the manual dampers in each overfire air line and reinjection fly ash line.
  - b. Increase the diameter of the refractory opening at the front lower overfire air nozzles to approximately 4½ to 5 in. so that the refractory does not interfere with the lower front overfire air.
  - c. Clean all old refractory out of the nozzles.
  - d. Every time a unit is taken offline, clean out the fly ash reinjection nozzles at the rear of the furnace. Clean all rear wall overfire air nozzles of slag that builds up on the rear wall every time the unit is removed from operation.
8. Front wall refractory to side wall joint. Pack the vertical joint with mineral fiber or other fibrous refractory expansion joint type material.
9. Startup time. Increase the time of startup of these units to reduce refractory maintenance and movement of ASME pressure parts.
10. Cast iron/cast steel wear blocks for tube protection in lower portion of furnace. At the rear wall, replace these blocks at the tube bend near the grate as the tubes themselves are currently exposed to fly ash erosion and failure will occur within 1 to 2 years.
11. The rear top grate tuyeres should be thoroughly cleaned and insulating cement installed above these tuyeres.
12. All grate bar air holes must be thoroughly cleaned each and every time the unit is removed from operation.
13. The side wall of HTWG to grate expansion joint must be repacked annually with all old material removed and repacked with a high temperature mineral fiber or other fibrous refractory.
14. Under grate air seals
  - a. The three front upper, three front lower, and three rear upper air seals must be checked every time the unit is removed from operation and thoroughly cleaned at least annually.

15. Flue gas breeching
  - a. From HTWG outlet to mechanical collector, the horizontal duct must be completely cleaned annually.
  - b. From the mechanical collector to the air heater, the horizontal duct must be cleaned annually.
  - c. From air heater to spray dryer, the horizontal duct must be cleaned annually.
  - d. From the spray dryer to the baghouse inlet, the horizontal duct must be cleaned annually.
  - e. From the baghouse to the ID fan, the horizontal duct must be cleaned annually.
  - f. From the ID fan to the stack, the horizontal duct must be cleaned annually.
  - g. Always install new gaskets when excess doors are removed for cleaning as gaskets only maintain their tightness for one usage.

## Appendix A: Test Results

### 1. Summary

A. Particulate - one (1) test consisting of three (3) runs at each HTWG load was performed.

1) HTWG No. 1

	High Load	Medium Load	Low Load
Emission in #/HR (Mont. Limit 4 #/HR)	1.79	1.22	0.94
Heat Output (106 BTU/ HR) Inaccurate	61.73	41.98	26.58
Heat Output (106 BTU/ HR) Accurate	77.91	51.66	32.77
Heat Input (106 BTU/ HR) Accurate	90.80	61.09	40.57
Emission #/106 BTU Heat Input	0.020	0.020	0.023
Opacity; Certified Visual Observer, Average Accurate (Limit 20%)	0	0	0
Opacity by CEM Monitor, Inaccurate	3.6	3.3	4.2

\* This unit is in compliance with particulate.

2) HTWG No. 3

	High Load	Medium Load	Low Load
Emission in #/HR (Mont. Limit 4 #/HR)	1.36	1.00	1.07
Heat Output (106 BTU/ HR) Inaccurate	56.94	41.02	16.40
Heat Output (106 BTU/ HR) Accurate	78.24	53.79	23.06
Heat Input (106 BTU/ HR) Accurate	91.30	63.89	28.10
Emission #/106 BTU Heat Input	0.015	0.016	0.038

Opacity; Certified Visual Observer, Average Accurate (Limit 20%)	0	0	0
	High Load	Medium Load	Low Load
Opacity by CEM Monitor, Inaccurate	16.5	22.8	22.4

Heat input by accurate coal scale.  
 Heat output by control panel, INACCURATE  
 Heat output by accurate coal scale and ASME PTC 4.1  
 efficiency, maximum rated continuous heat output is  
 85 x 106 BTU/HR.  
 More standard method of expressing emission.

\* This unit is in compliance with particulate.

B. Sulfur Oxides - Three (3) analysis at each of the HTWG loads was performed.

1) HTWG No. 1 (3 Run Average)	High Load	Medium Load	Low Load
Inlet SO2 in #/HR	52.19		2828
Outlet SO2 in #/HR	2.27		0.71
% Removal (Mont. Req. 85% Removal)	96.16		97.49
Outlet SO2 in #/HR (Mont. Req. 37 #/HR or less) (Federal EPA Limit 67.8 #/HR for two (2) units or 33.9 #/HR per unit)	2.27	---	0.71
Heat Input (Coal scale) 106 BTU HR	90.80	61.09	4057
Outlet SO2 in # of SO2/ 106 BTU (Federal EPA Limit Outlet SO2 in #SO2/106 BTU is 0.32)	0.025		0.018

\* This unit is in compliance

2) HTWG No. 3 (3 Run Average)	High	Medium	Low
	Load	Load	Load
Inlet SO2 in #/HR	61.07	44.27	35.36
Outlet SO2 in #/HR	9.77	2.27	0.59
% Removal (Mont. Req. 85% Removal)	84.00	94.87	98.33
Outlet SO2 in #/HR (Mont. Req. 37 #/HR or less) (Federal EPA Limit 67.8 #/HR for two (2) units or 33.9 #/HR per unit)	9.77	2.27	0.59
Heat Input (Coal scale) 106 BTU HR	91.30	63.89	28.10
Outlet SO2 in # of SO2/ 106 BTU (Federal EPA Limit Outlet SO2 in #SO2/106 BTU is 0.32)	0.107	0.036	0.021

Removal efficiency for the high load test was not met due to plugging of the slurry feed control valve.

\* This unit is in compliance except for the high load removal efficiency caused by the plugging control valve.

C. Nitrogen Oxide - Three (3) analysis at each of the HTWG loads for Unit No. 3 only.

1) HTWG No. 3	High	Medium	Low
	Load	Load	Load
NOx Emission in #/HR (3 Run Average)	36.36	24.04	10.76
Heat Input (Coal Scale) 106 BTU/HR	91.30	63.89	28.10
NOx Emission in # NOx/ 106 BTU (Federal EPA is 0.50 #/ 106 BTU or 53 #/HR)	0.398	0.376	0.383

\* At 08:00 a.m., some cast iron parts of the coal feeders were cherry red due to excessive coal fines in the coal bunker. This condition had been occurring since 06:00 a.m. and had created an excessive formation of NOx emissions. The overfire air was adjusted to cool the front of the stoker and save the stoker parts. The overfire air system was recorrected back to normal operation by 11:30 a.m. but the affect of better coal and correct distribution of fuel on the grate was not attained until 13:00.

2. Coal Scale vs. Control Panel Screen Heat Output

A. Coal scale

- 1) Coal scale
- 2) Coal analysis
- 3) O<sub>2</sub>
- 4) Flue gas temperature
- 5) Results
  - Wet flue gas flow (ACFM)
- 6) Tested wet flue gas flow by stack testing (EEMC) at spray dryer atomizer inlet vessel (ACFM)

B. HTWG No. 1 Flue Gas Flow at SDA Inlet

	High Load	Medium Load	Low Load
ACFM (EEMC)	34,001		16,297
Temperature (EEMC), °F	298		325
ACFM (SAI) Coal Scale	35,109	24,964	21,608
Temperature (SAI), °F	300	309	346
Adjusted ACFM for temperature	35,017		21,046
% Deviation	3.0%		29%

C. HTWG No. 3 Flue Gas Flow at SDA Inlet

	High Load	Medium Load	Low Load
ACFM (EEMC)	32,805	25,313	19,176
Temperature (EEMC), °F	289	346	338
ACFM (SAI) Coal Scale	34,027	26,052	13,327
Temperature (SAI), °F	286	344	330
Adjusted ACFM for temperature	34,164	26,117	13,462
% Deviation	4.1%	3.2%	28%

D. The velocity head reading taken by EEMC at less the high load becomes inaccurate caused by the very small V<sup>2</sup>/2g reading and inability to accurately read the monitor. This is not unusual!

E. Heat Output Comparison

- 1) HTWG No. 1

	High Load	Medium Load	Low Load
Heat Output from Coal Scale, O <sub>2</sub> & Flue Gas Temperature x 106 BTU/HR	77.91	51.66	32.77
Control Panel Screen x 106 BTU/HR	61.73	41.98	26.58
% Deviation	21%	19%	19%

	High Load	Medium Load	Low Load
2) HTWG No. 3			
Heat Output from Coal Scale, O2 & Flue Gas Temperature x 106 BTU/HR	78.24	53.79	23.06
Control Panel Screen x 106 BTU/HR	56.94	41.02	16.4
% Deviation	27%	24%	29%
3) The statement is the control panel screen heat output in 106 BTU/HR is NOT accurate.			

MALMSTROM AFB  
HTWG NO. 1  
Detail of 3/2/95 Testing

	Run 1	Run 2	Run 3
1. Heat Output MBTU/Hr. based on			
BTU Meter	61.73	41.98	26.58
Water Flow Meter	60.89	41.42	26.24
Coal Scale & ASME Efficiency	77.91	51.66	32.77
2. Heat Input MBTU/Hr. based on			
BTU Meter & ASME Efficiency	72.32	49.60	32.99
Water Flow Meter & ASME Efficiency	71.33	48.94	32.57
Coal Scale	90.80	61.09	40.57
3. ASME Thermal Efficiency %			
BTU or Water Flow Meters	85.36	84.63	80.56
Coal Scale	85.01	84.56	80.77
4. Spray Dryer Inlet Flow ACFM based on			
BTU Meter, ASME Efficiency Air Infiltration & EEMC Temperature	27,888		17,115
Coal Scale, Infiltration and EEMC Temperature	35,017		21,045
EEMC	34,001		16,297
BTU to EEMC % Error	-18		+5
Coal Scale to EEMC % Error	+3		+29
5. Stack Flow ACFM based on			
BTU Meter, ASME Efficiency and Air Infiltration	29,149	21,062	17,211
Coal Scale, ASME Efficiency and Air Infiltration	36,601	25,939	21,163
EEMC - Particulate	37,310	30,735	26,058
EEMC - SO2	38,032		27,106

	BTU to EEMC Particulate % Error	-22	-31	-34
	Coal Scale to EEMC Particulate % Error	-2	-16	-19
6.	Flue Gas Temperature °F			
	HTWG Outlet			
	Control Room	421.3	405.2	371.0
	SAI	450.6	410.0	375.5
	Air Heater Inlet			
	SAI	440	411.8	377.5

MALMSTROM AFB  
HTWG NO. 1  
Detail of 3/2/95 Testing

	Run 1	Run 2	Run 3
Air Heater Outlet			
SAI	196.4	284.6	239.7
SDA Inlet			
Control Room	300.4	308.8	346.3
SAI	309.4	240.9	325.3
EEMC	298		325
Baghouse Inlet			
Control Room	173.3	176.5	175.1
SAI	178.0	173.6	175.3
Baghouse Outlet			
Control Room	178.1	178.2	181.3
SAI	173.6	172.6	174.5
Stack - EEMC	192	192	194

Data is suspect, possible equipment malfunction.

7.	SO2 Emissions			
	SDA Inlet - Dry			
	EEMC Measured PPM	283.7		291.1
	SAI Calculated PPM	344.5	324.9	257.9
	100% S to SO2			
	EEMC Measured lb./hr.	59.2		28.3
	SAI Calculated lb./hr.	77.8	51.7	34.2
	100% S to SO2			

MALMSTROM AFB  
HTWG NO. 3  
Detail of 3/5/95 Testing

	Run 1	Run 2	Run 3
1. Heat Output MBTU/Hr. based on			
BTU Meter	56.94	41.02	16.4
Water Flow Meter	55.61	40.78	17.19
Coal Scale & ASME Efficiency	78.24	53.79	23.06
2. Heat Input MBTU/Hr. based on			
BTU Meter & ASME Efficiency	66.00	48.71	20.18
Water Flow Meter & ASME Efficiency	64.46	48.43	21.15
Coal Scale	91.30	63.89	28.10
3. ASME Thermal Efficiency %			
BTU or Water Flow Meters	86.27	84.22	81.25
Coal Scale	85.69	84.20	82.05
4. Spray Dryer Inlet Flow ACFM based on			
BTU Meter, ASME Efficiency Air			
Infiltration and EEMC Temperature 24,697	19,911		9,670
Coal Scale, ASME Efficiency Air			
Infiltration and EEMC Temperature 34,027	26,052		13,327
EEMC	32,805	25,313	19,176
BTU to EEMC % Error	-25	-21	-50
Coal Scale to EEMC % Error	+4	+3	-31
5. Stack Flow ACFM based on			
BTU Meter, ASME Efficiency and			
Air Infiltration	25,417	17,167	7,187
Coal Scale, ASME Efficiency and			
Air Infiltration	35,159	22,517	10,006
EEMC - Particulate	37,596	26,323	18,144
EEMC - SO2	37,501	29,046	19,108
BTU to EEMC Particulate % Error	-32	-35	-60
Coal Scale to EEMC Particulate			
% Error	-6	-14	-45
6. Flue Gas Temperature °F			
HTWG Outlet			
Control Room	424.0	363.0	340.75
SAI	417.0	363.0	338.8
Air Heater Inlet			
SAI	424.7	367.8	343.5

MALMSTROM AFB  
 HTWG NO. 3  
 Detail of 3/5/95 Testing

	Run 1	Run 2	Run 3
Air Heater Outlet			
SAI	289.8	343.3	340.9
SDA Inlet			
Control Room	289.2	333.0	326.5
SAI	285.7	344.0	329.5
EEMC	289	346	338
Baghouse Inlet			
Control Room	177.3	178.4	176.4
SAI	178.7	180.5	176.5
Baghouse Outlet			
Control Room	186.4	182.0	179.73
SAI	186.7	187.5	183.0
Stack - EEMC	200	200	198
7. SO2 Emissions			
SDA Inlet - Dry			
EEMC Measured PPM	301.2	302.2	315.3
SAI Calculated PPM	348.6	362.5	289.8
100% S to SO2			
EEMC Measured lb./hr.	61.1	44.3	35.4
SAI Calculated lb./hr.	79.0	58.3	24.5
100% S to SO2			

## Appendix B: Process Description

### PROCESS DESCRIPTION

#### MALMSTROM AIR FORCE BASE

#### COAL FIRED HIGH TEMPERATURE HOT WATER GENERATOR

##### 1. Fuel

A. The following coal is used as fuel for HTWG No. 1 and HTWG No. 3. This analysis is only one sample of coal taken December 31, 1994. Hopefully, future coal deliveries will be of similar analysis.

	Proximate		Fusion Temperatures of Ash	
	As Received Basis	Dry Basis		Reducing Atmosphere
% Moisture	5.86	----	Initial Def.	2285 Degrees F.
% Ash	9.54	10.13	H = W	2345 Degrees F.
% Volatile	41.05	43.60	H = 1/2 W	2410 Degrees F.
% Fixed Carbon	<u>43.55</u>	<u>46.27</u>	Fluid	2495 Degrees F.
	100.00%	100.00%		
% Sulfur	0.51	0.54		
BTU/Lb..	12171	12928	Moisture Ash Free BTU/Lb..	
14385				

#### Screen Analysis

Retained On	Passing	Percent	Acc. Percent
1 3/4" Rd.	-----	0.0	0.0
1/2" Rd.	1 1/4" Rd.	92.2	92.2
-----	1/2 Rd.	7.8	100.0

B. There are coal scales for each HTWG as manufactured by Stock Equipment. This is the most accurate measurement of heat input to the HTWG. The scale will be calibrated with a 200 pound test load to insure accuracy of scale.

##### 2. Fuel burning equipment - spreader stoker traveling grate is manufactured by Detroit Stoker Company, Model RotoGrate, RG-1048.

###### A. Feeders

- (1) Coal is fed into each HTWG by three (3) coal feeders. Each feeder is 27 inches wide. The coal feeders distribute the coal from side to side and back to front on the traveling grate. Approximately 35% of coal is

burned in suspension and 65% of coal is burned on the grate.

- (2) See Exhibit "A" of coal feeder
- B. Traveling Grate
  - (1) The traveling grate moves continuously from the rear of the furnace (away from feeder) to the front. The ash is dropped into the ash pit at the front (below feeders) of the HTWG.
  - (2) Effective grate area - 157.6 sq. ft.
  - (3) See Exhibit "B", a side section through the feeder and traveling grate.

3. High Temperature Hot Water Generator

- A. Water is circulated through tubes in the HTWG to heat water.
- B. The HTWG was manufactured by International Boiler Works, Model No. TJW-VC-85.
- C. The maximum heat input of coal to the units is 106 million BTU/Hour.
- D. The maximum heat output of the HTWG is 85 million BTU/Hour.
- E. The flue gas discharge from the high temperature hot water generator is dependent on heat output and was predicted by manufacturer to be:

<u>Generator Heat Output</u> Million BTU/Hour	<u>Flue Gas at</u> <u>Generator Exit</u>	<u>% O<sub>2</sub> Oxygen</u> <u>By Volume</u>
85	545 °F	3.8
70	520 °F	5.4
55	500 °F	7.0
40	475 °F	8.6
28	460 °F	9.9

- F. The plant is currently limiting the heat output to 70 million BTU/Hour.
- G. See Exhibit "C" for flue gas flow sheet. The data of temperatures and oxygen are at 40 million BTU/Hour, average operating conditions.

4. Mechanical Dust Collector

- A. The mechanical dust collector is designed for approximately 2 inches pressure drop at full HTWG load. This means for a spreader stoker traveling grate unit, the collector efficiency is approximately 85% of the fly ash inlet loading to the collector.
- B. Thirty% of the collected fly ash is reinjected back into the furnace of the high temperature hot water generator.
- C. Seventy% of the collected fly ash is removed to the ash silo.
- D. The manufacturer is Enviro Systems and Research, Inc., Unit 1085 No. 6 x 11-2
- E. See Exhibit "C" for flue gas flow sheet.

5. Air Heater

- A. The flue gas flows through the air heater, cooling the flue gas.
- B. The combustion air flow through the air heater, preheating the air.
- C. The air heater manufacturer is Ljungstrom by ABB/CE Air Preheater Unit No. 13-VIK-30.
- D. See Exhibit "C" for flue gas flow sheet.

6. Spray Dryer
  - A. Flue gas flow at inlet is approximately 119,100 #/Hour at full load.
  - B. Sprays slaked lime [ $\text{Ca}(\text{OH})_2$ ] and water into the flue gas without hitting the walls of the spray dryer.
  - C. Cools the flue gas from approximately 300 to 180 °F with water.
  - D. The slaked lime is made in the plant by the operating personnel. See Exhibit "D".
  - E. The chemical reaction for removal of the sulfur dioxide is shown on Exhibit "E".
  - F. See Exhibit "C" for flue gas and spray dryer flow sheet.
  - G. The spray dryer manufacturer is Niro, Model No. F-100. The atomizer is a rotary type (14,150 RPM).
  
7. Baghouse
  - A. Reverse air baghouse with 5 compartments.
  - B. Flue gas flow at inlet to baghouse is 125,700 #/Hour at full load.
  - C. Each compartment has 120 bags, 8-inch diameter by 21 to -9 ft long.
  - D. Reverse air cleaning fan 8,911 ACFM.
  - E. The baghouse manufacturer is Joy Manufacturing (now Joy Environmental).
  - F. See Exhibit "C" for flue gas flow sheet.
  
8. Induced Draft Fan
  - A. Induced draft (I.D.) fan pulls the flue gas from the furnace of the high temperature hot water generator through the following:
    - Mechanical dust collector
    - Air heater, flue gas side
    - Spray dryer
    - Baghouse
    - Ducts and dampers and discharges the flue gas to the stack.
  - B. The induced draft fan was manufactured by Robinson, Model No. RB-1216, 400 horsepower.
  - C. See Exhibit "C" for flue gas flow sheet.
  
9. Forced Draft Fan
  - A. Supplies hot combustion air to under side of stoker grates for coal combustion on the grates. The air flow is through the grates. The combustion air is preheated through the air preheater.
  - B. The forced draft (F.D.) fan was manufactured by Robinson, Model No. AF-0925, 100 horsepower.
  - C. See Exhibit "C" for air flow sheet.
  
10. Overfire Air
  - A. Supplies 17% of the combustion air over the grates through high pressure air nozzles.
  - B. The overfire (O.F.A.) fan was manufactured by Twin City, Model No. 923 HP, 50 horsepower.
  - C. See Exhibit "C" for air flow sheet.

## Appendix B: Test Protocol

1. Check calibration of coal scale. Make sure a properly sized coal is evenly distributed in coal bunker.
2. The first HTWG should be on-line for 5 days at the testing load desired by the facility. This load should be 70 MBTUH as indicated by the BTU meter and selected by the facility for the derated load.
  - A. The HTWG internals, refractory, casing and pollution control equipment need five days to stabilize temperature and expansion of the material to prevent small particles from flaking off and ending up in the EPA train as particulate.
  - B. Two days are needed to get correct lime milk solids content and flow rates to head tank and nozzles of the spray dryer SO<sub>2</sub> removal system.
  - C. Two days are needed to get the correct filter cake material on the baghouse bags to collect as much of the particulate and SO<sub>2</sub> as possible and establish a good baghouse cleaning cycle.
3. EPA compliance test sampling should consist of three test runs minimum. If there are equipment operating problems during the first test run, then a fourth test run should be made to get a good three-run average.
  - A. Testing at stack should consist of particulate, SO<sub>2</sub> and NO<sub>x</sub>.
  - B. Testing at the spray dryer inlet for SO<sub>2</sub> should be performed simultaneously with the stack test runs to calculate SO<sub>2</sub> removal efficiency.
4. HTWG operation should be monitored during the compliance testing to calculate heat input per the ASME Power Test Code PTC 4.1.
  - A. HTWG outlet flue gas oxygen.
  - B. Air heater outlet flue gas temperature.
  - C. Coal scale coal flow.
  - D. HTWG heat output.
  - E. Air heater air inlet temperature.
  - F. Coal samples taken from stoker feeders during each test run for proximate and ultimate analysis.

- 
- G. Printouts from Network 90 system every 10 minutes for the test unit.
    - HTWG
    - Spray dryer
    - Baghouse
  
  - 5. Entire HTWG system should be fingerprinted for temperatures, oxygen and static pressures for repeatability during future tests.
    - A. HTWG outlet.
    - B. Mechanical dust collector outlet.
    - C. Air heater outlet.
    - D. Spray dryer outlet.
    - E. Baghouse outlet.
    - F. Coal sizing for each stoker feeder.
  
  - 6. First HTWG should be taken off-line and second HTWG put on-line and repeat steps 1 through 5.

## **Appendix C: Stack Test Protocol**

**STACK TEST PROTOCOL  
HIGH TEMPERATURE HOT WATER GENERATORS  
MALMSTROM AIR FORCE BASE  
GREAT FALLS, MONTANA**

Date: February 16, 1995

By: Jeri Northrup  
US Army Corps of Engineers  
Construction Engineering Research Laboratory (CERL)

1. Pretest Information Gathering & Calculations

A. Coal

1) Analysis

- a) Proximate, Exhibit "A"
- b) Ultimate, Exhibit "B" from coal supplier
- c) Fuel curve or computer program

B. Generator

1) Heat output by Btu/Hour meter

- a) Inputs to Btu/Hour meter
  - (1) Water temperature into generator
  - (2) Water temperature out of generator
  - (3) Mass flow; orifice flow element at inlet water temperature and water density

2) Heat output by coal feed

- a) Pounds per hour coal feed from coal scale
- b) Heat input  
= (Heat value coal as received Btu/#) x (Coal scale #/Hour)  
= Btu/Hour
- c) Generator efficiency
  - (1) Flue gas oxygen at generator outlet
  - (2) Flue gas temperature at air heater outlet
  - (3) Combustion efficiency from fuel curve, Exhibit "C"
  - (4) Carbon loss - ABMA curve, Exhibit "D"
  - (5) Radiation loss - ASME curve, Exhibit "E"
  - (6) Net efficiency = combustion efficiency - carbon loss - radiation loss
- d) Heat output = [(Heat input, Item b.)] [Net efficiency, Item c.)]

This is the most accurate heat output for the generator.

C. Wet Flue Gas Flow

End of first year = (12,1721 Btu/#) (1.00 - .10) = 10,954 Btu/#  
 End of second year = (10,954 Btu/#) (1.00 - 0.5) = 10,406 Btu/#  
 End of third year = (10,406 Btu/#) (1.00 - .05) = 9,885 Btu/#  
 The January 25, 1995 test burn was with 1992 Utah coal per plant personnel.

Heat Input = (5,000 #/Hour Coal Usage) (9,885 Btu/#)  
 Heat Input =  $49.425 \times 10^6$  Btu/Hour

D. Generator Field Test  
 Generator No. 1  
 1/25/95  
 15:20 TO 16:00

Generator Outlet O<sub>2</sub> Wet            7.24%    58% Excess Air  
 Air Heater Flue Gas Outlet        311°F

Efficiency            87.6  
 Carbon loss        - 1.755  
 Radiation loss     - 1.2  
                           84.645%

Heat Input by Generator Efficiency

Panel Board Heat Output             $37.05 \times 10^6$  Btu/Hour

Heat Input = Heat Output/Efficiency =  $37.05 \times 10^6$  Btu/Hour / .84645

Heat Input =  $43.771 \times 10^6$  Btu/Hour

Coal Input

Coal Heat Value =  $\frac{\text{Heat Input}}{\text{Coal Usage}} = \frac{43.771 \times 10^6 \text{ Btu/Hour}}{5,000 \text{ #/Hour (Coal Usage)}}$

Coal Heat Value = 8,754 Btu/#

Water Flow Meter Comments

The flow rate (GPM) looks LOW on water flow meter to generator. Generator is most likely producing more heat output than the meter indicates.

## 2. Test Information

### A. Coal

- 1) Coal feed rate - record integrator readings at beginning and end of each test run
- 2) Coal sample during each run of stack test run, 3# sample removed from coal feeder every 10 minutes to make one (1) composite sample per stack test run
- 3) Coal analysis - Commercial testing and engineering company or equal
  - (a) Proximate
  - (b) Ultimate
  - (c) Mineral analysis of ash in coal plus lead
  - (d) Ash fusion temperatures, reducing condition
  - (e) Free swell index
- 4) Coal sizing to each feeder for sample from feeder pokehole plate, check before each test run

### B. HTHW Generator System

- 1) Grate speed - Record at beginning and end of each test run
- 2) Ash bed thickness at front of grate - record at beginning and end of each test run
- 3) Temperatures
  - (a) Water in - print (Screen A) every 5 minutes
  - (b) Water out - print (Screen A) every 5 minutes
  - (c) Combustion air to air heater - portable instrumentation every 10 minutes
  - (d) Flue gas from generator - print (Screen C) every 5 minutes and portable instrumentation every 10 minutes
  - (e) Flue gas at air heater outlet - portable instrumentation every 10 minutes
  - (f) Flue gas at SDA inlet - print (Screen C) every 5 minutes and portable instrumentation every 10 minutes
  - (g) Flue gas to baghouse - print (Screen C) every 5 minutes and portable instrumentation every 10 minutes
  - (h) Flue gas from baghouse - print (Screen C) every 5 minutes and portable instrumentation every 10 minutes
- 4) Oxygen
  - (a) Generator outlet - print (Screen A) every 5 minutes and portable instrumentation every 10 minutes
  - (b) Mechanical dust collector outlet - portable instrumentation every 10 minutes

- (c) Air heater flue gas outlet - portable instrumentation every 10 minutes
- (d) SDA inlet - portable instrumentation every 10 minutes
- (e) Baghouse inlet - portable instrumentation every 10 minutes
- (f) Baghouse outlet - portable instrumentation every 10 minutes

5) Static Pressures

- (a) Forced draft fan
  - (1) Fan discharge - print (Screen C) every 5 minutes
  - (2) Combustion air - print (Screen C) every 5 minutes
  - (3) Undergrate air - print (Screen C) every 5 minutes
- (b) Overfire air
  - (1) Main header - print (Screen A) every 5 minutes and portable instrumentation at beginning and end of each test run
  - (2) Front upper header - portable instrumentation at beginning and end of each test run
  - (3) Front lower header - portable instrumentation at beginning and end of each test run
  - (4) Rear upper header - portable instrumentation at beginning and end of each test run
  - (5) Rear lower header - portable instrumentation at beginning and end of each test run
  - (6) Rear reinjection header - portable instrumentation at beginning and end of each test run
- (c) Furnace pressure - print (Screen A) every 5 minutes
- (d) Generator outlet - print (Screen C) every 5 minutes and portable instrumentation every 10 minutes
- (e) Mechanical collector outlet - print (Screen C) every 5 minutes and portable instrumentation every 10 minutes
- (f) Air heater flue gas outlet - portable instrumentation every 10 minutes
- (g) SDA outlet - portable instrumentation every 10 minutes
- (h) Baghouse outlet - portable instrumentation every 10 minutes
- (i) Baghouse  $\Delta P$  - print (Screen C) every 5 minutes

- 6) Btu Output - print (Screen A) every 5 minutes and record Integrator at the beginning and end of each test run

- 7) Opacity - print (Screen C) every 5 minutes

- 8) HTHW Flow - print (Screen A) every 5 minutes and record Integrator at the beginning and end of each test run

C. SDA System

- 1) Analysis of lime - at beginning of testing
- 2) Slurry percent solids - at beginning of each test run

- 3) Slurry flow - print (Screen F) every 5 minutes
  - 4) Atomizer current, amps - print (Screen F) every 5 minutes
  - 5) SO<sub>2</sub> at inlet, ppm (CEM) - record every 5 minutes
  - 6) SO<sub>2</sub> at outlet, ppm (CEM) - record every 5 minutes
  - 7) SO<sub>2</sub> removal efficiency - print (Screen F) every 5 minutes
3. Informational or Compliance Testing
1. Prior to starting test, calculate flue gas flow based upon boiler operating efficiency and compare to stack flow. Prior to any stack test, this will be completed. Estimated time - 7:30 a.m. to 8:30 a.m.
  2. Sample for SO<sub>2</sub> at SDA inlet.
  3. Sample for SO<sub>2</sub>, particulate and NO<sub>x</sub> at stack.
4. All stack testing and data gathering shall be started and stopped at the same exact (within one minute) time. There will be one (1) designated person in charge of testing in the Control Room with respect to starting and ending times of each run.

	<u>Time</u>	
Run No. 1	Start _____	End _____
Run No. 2	Start _____	End _____
Run No. 3	Start _____	End _____

# Appendix D: Lime Slurry Pump Specifications

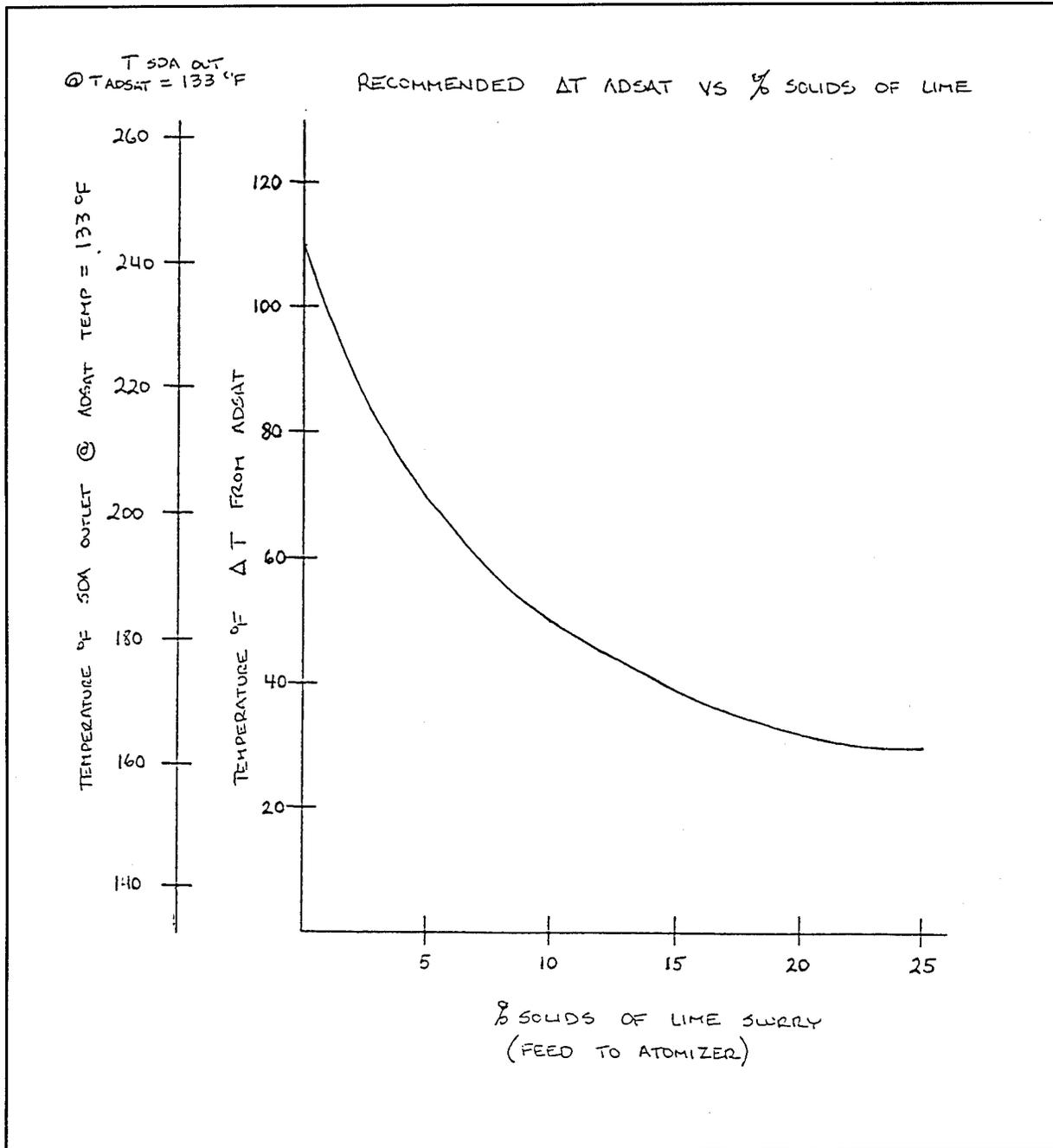


Figure D1. Recommended change in temperature vs. percent solids of lime slurry.

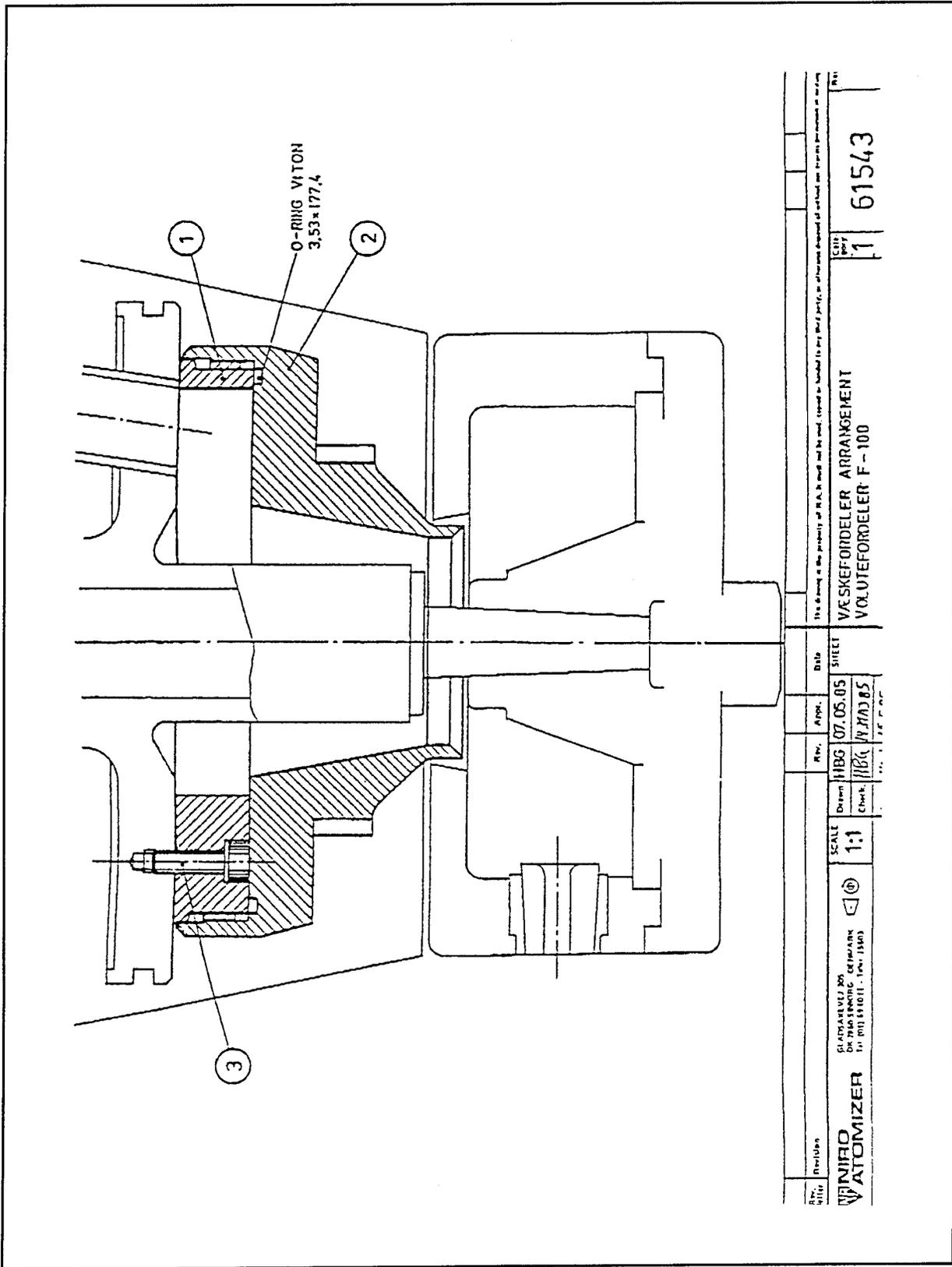


Figure D2. Newly designed "volute-type" liquid distributor.



GLADSAXEVEJ 305  
 DK-2860 SØBORG  
 COPENHAGEN  
 TEL 01 69 10 11 Telex 1 56 03

PARTS LIST

PART NO.	DESCRIPTION	APP. DATE		
61543-0001	VESKEFORD. ARR. VOLUTE 316 F100 DISTRIBUTOR ARR. VOL. 316 F100 VERTEILER AUFST. VOL. 316 F100	21.05.85	01	01

POS. NO.	PART NO.	DESCRIPTION	QTY.	UNIT
0001	61544-0001	VOLUTE INSERT AISI316 F100	2,330.28	1.0000 EA
0002	60585-0003	VORTEX PIPE AISI316 F35/100	3,027.20	1.0000 EA S
0003	14101-0825	ALLEN SCREW MC 8*25 DIN912-A2	.43	8.0000 EA

*All items are in stock.*

Figure D3. Cost estimate for "volute type" liquid distributor.

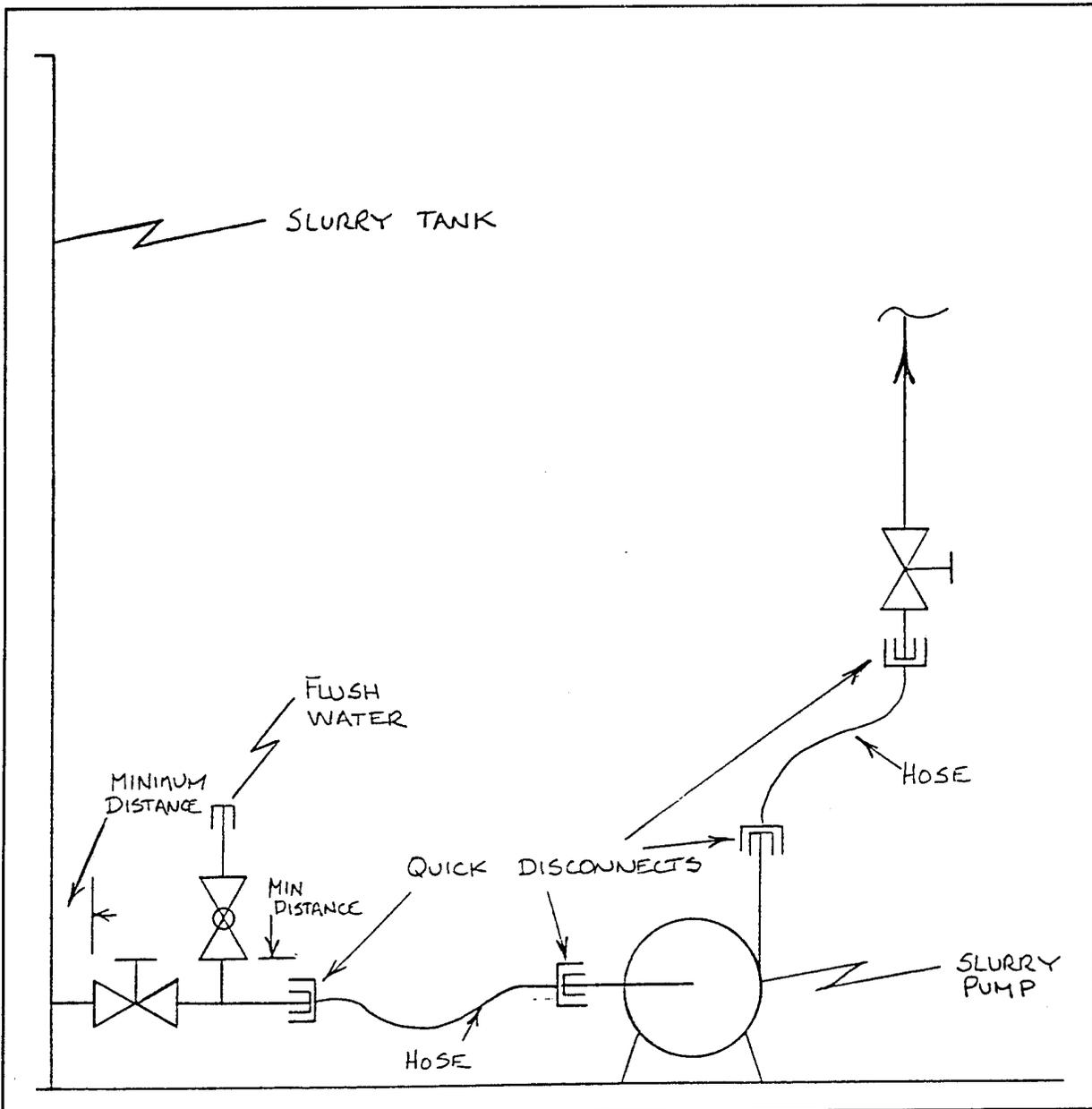


Figure D4. Recommended layout for slurry pump connections.

(1)

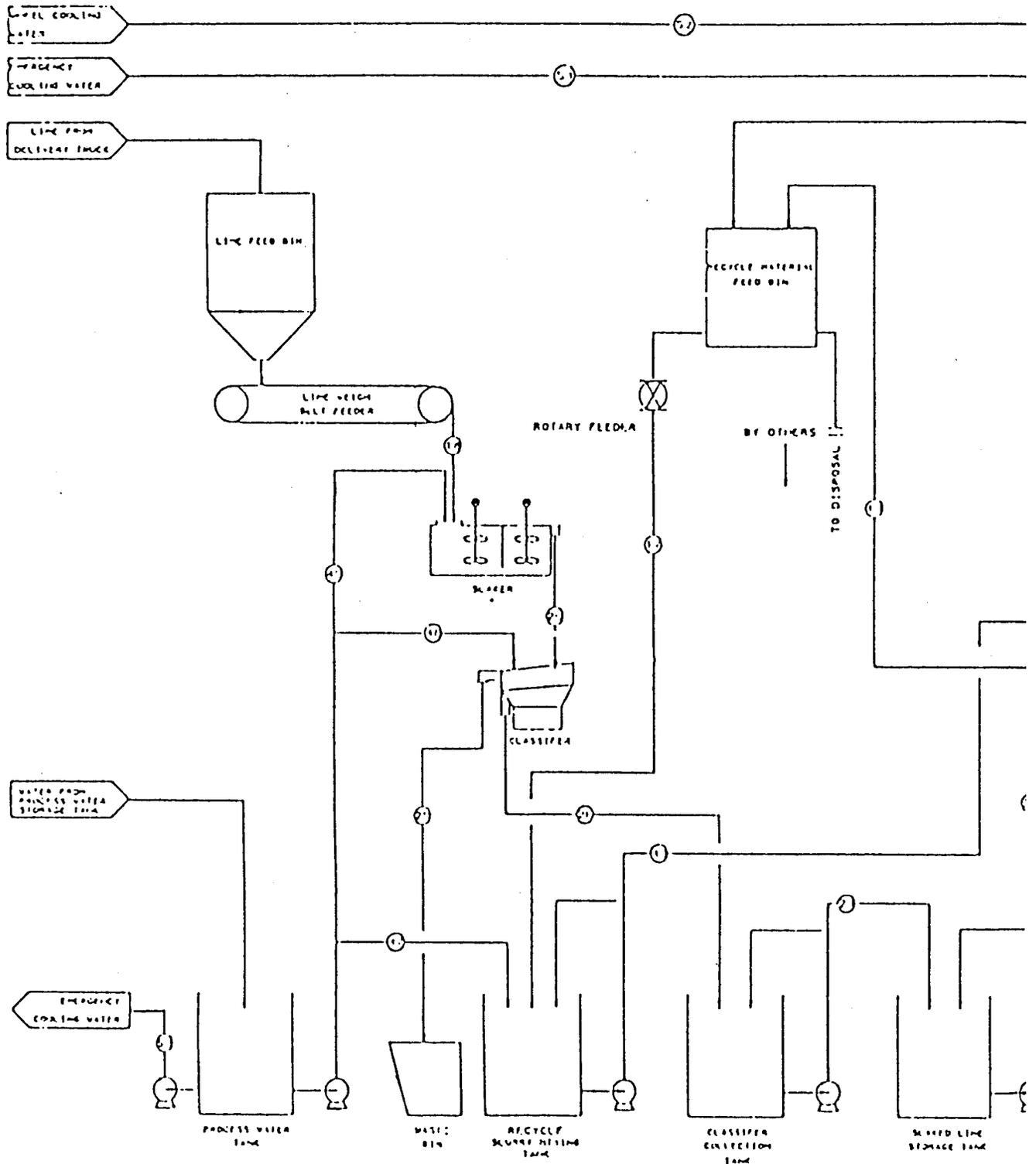
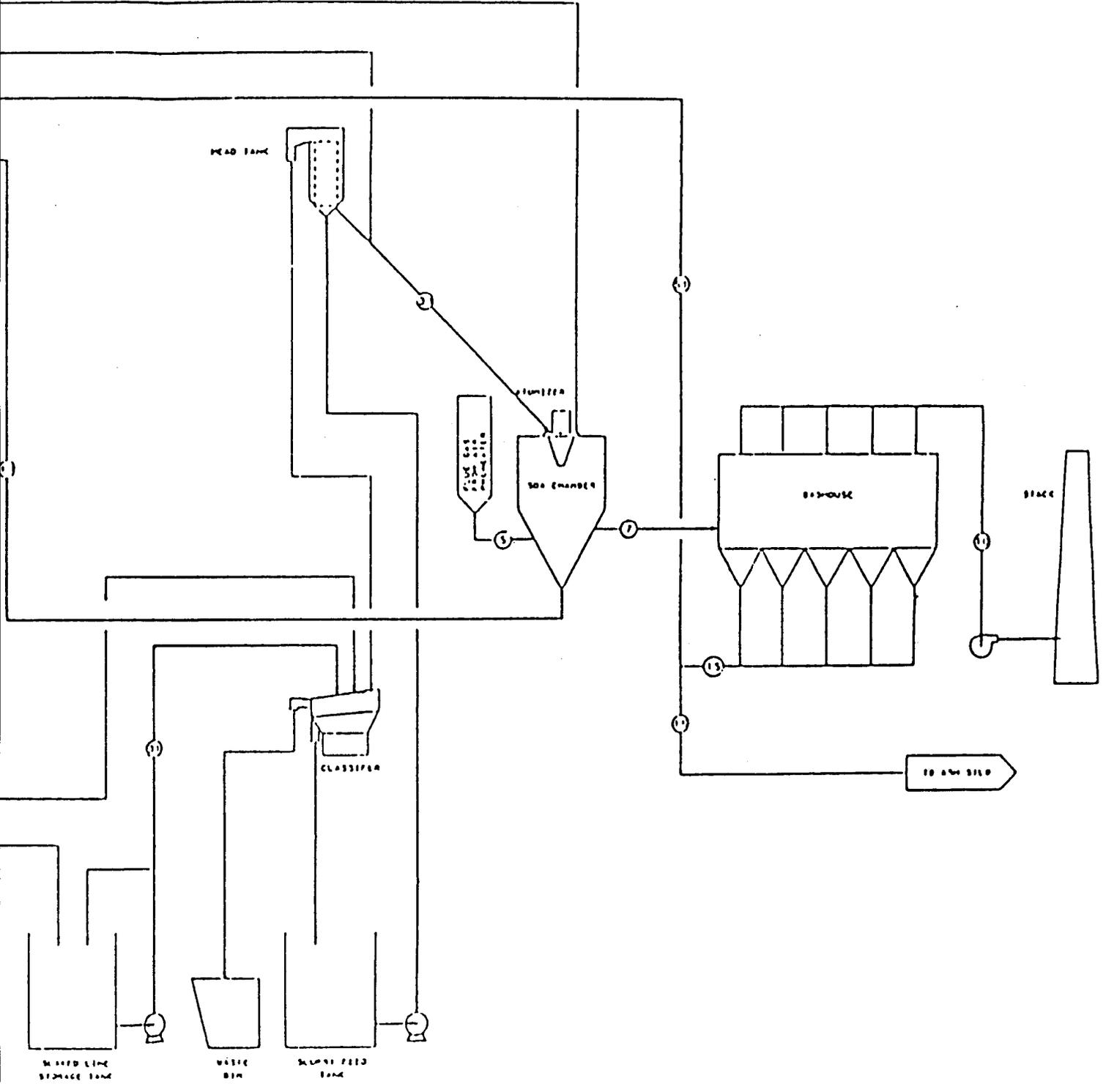


Figure D5. Original process flow sheet.

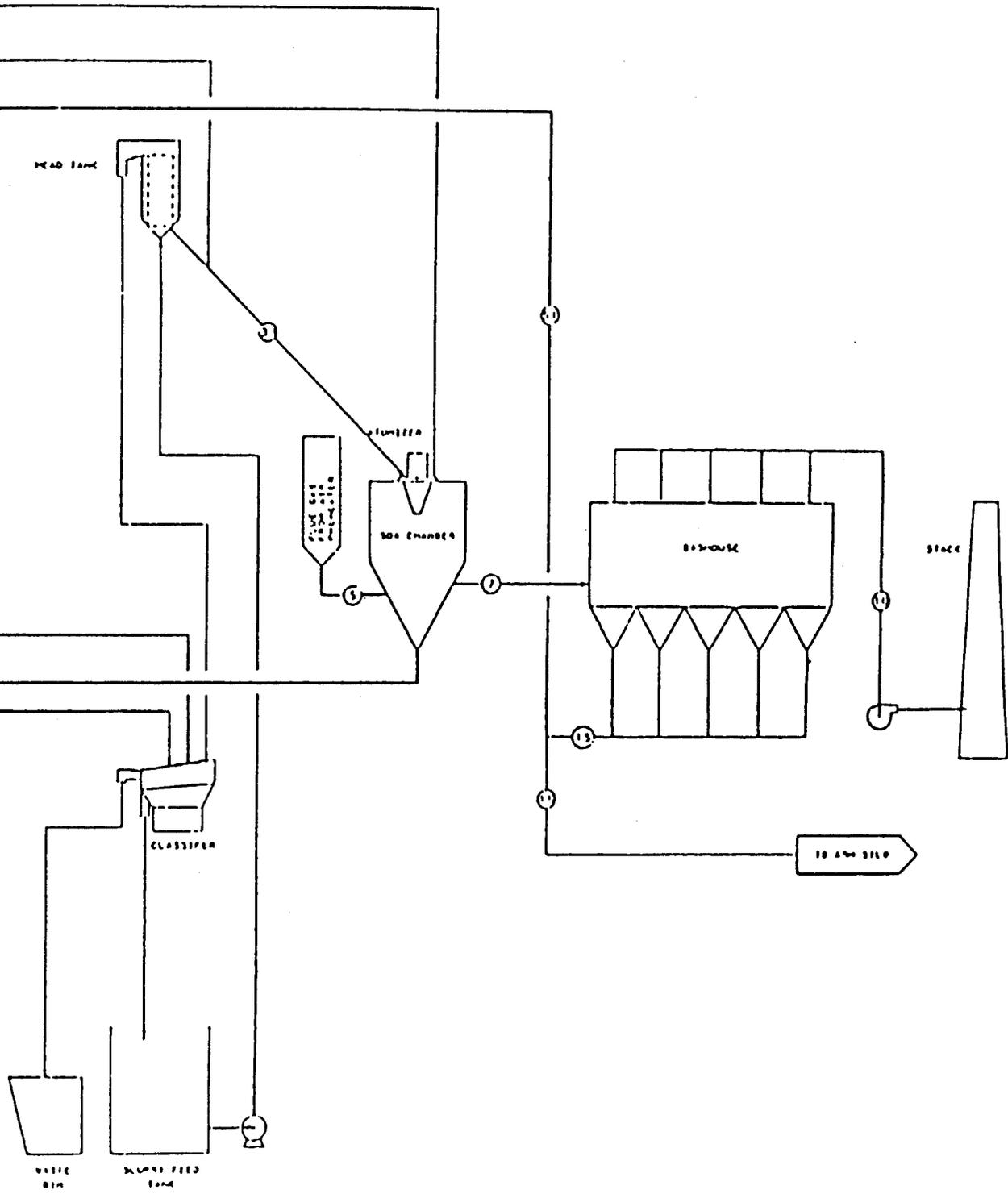
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3



2

3



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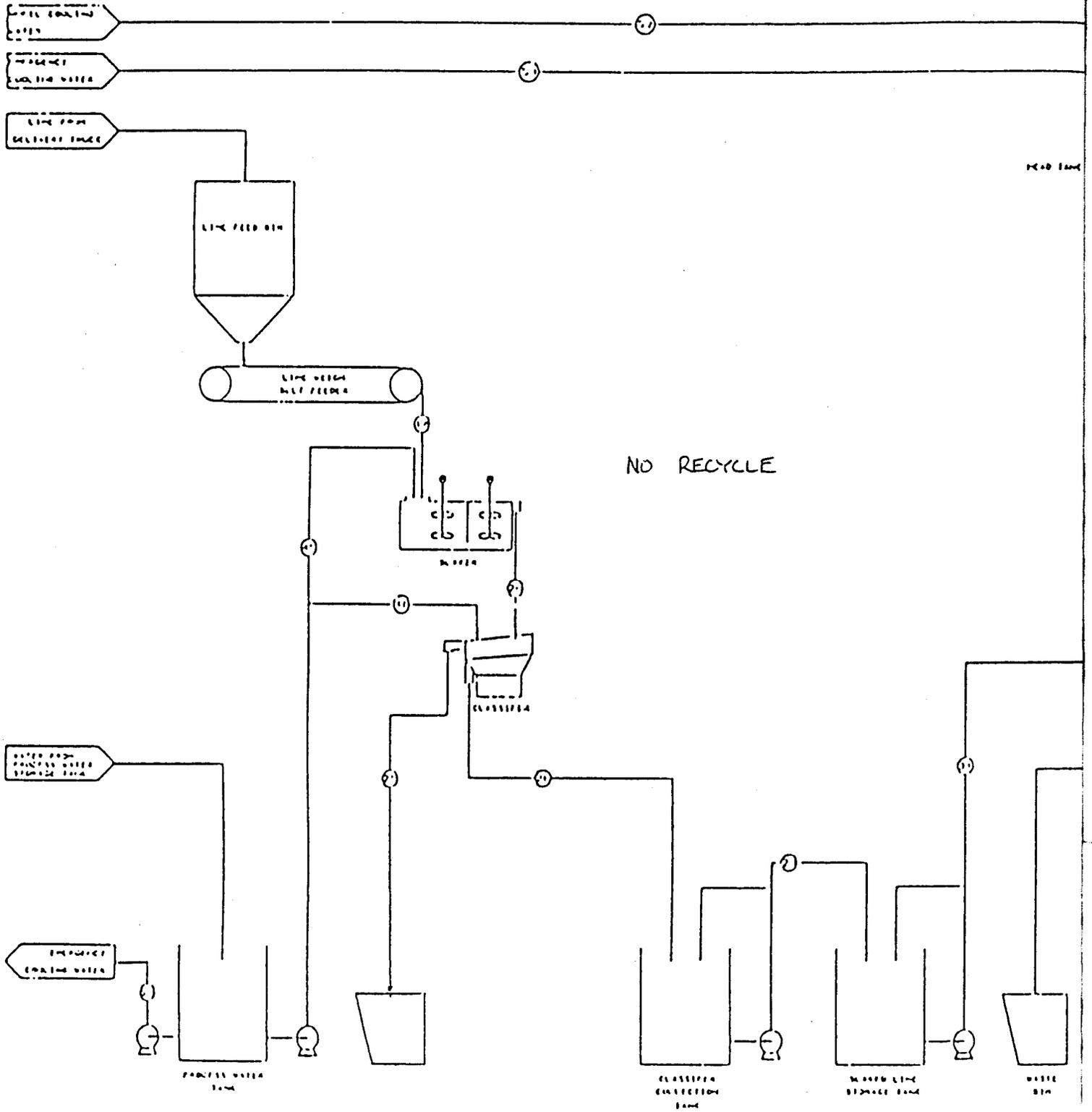
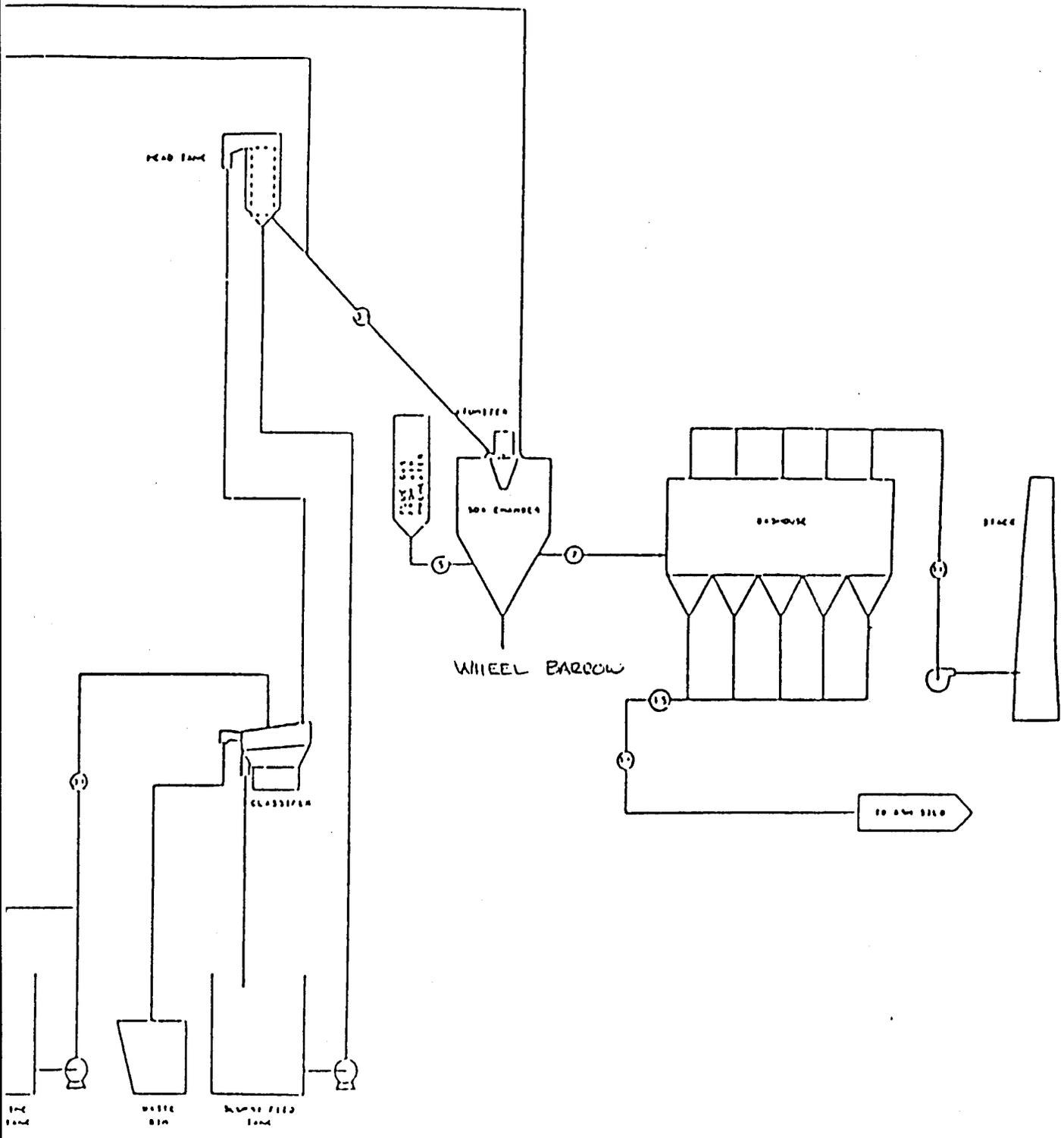


Figure D6. Current operating process flow (lime only).

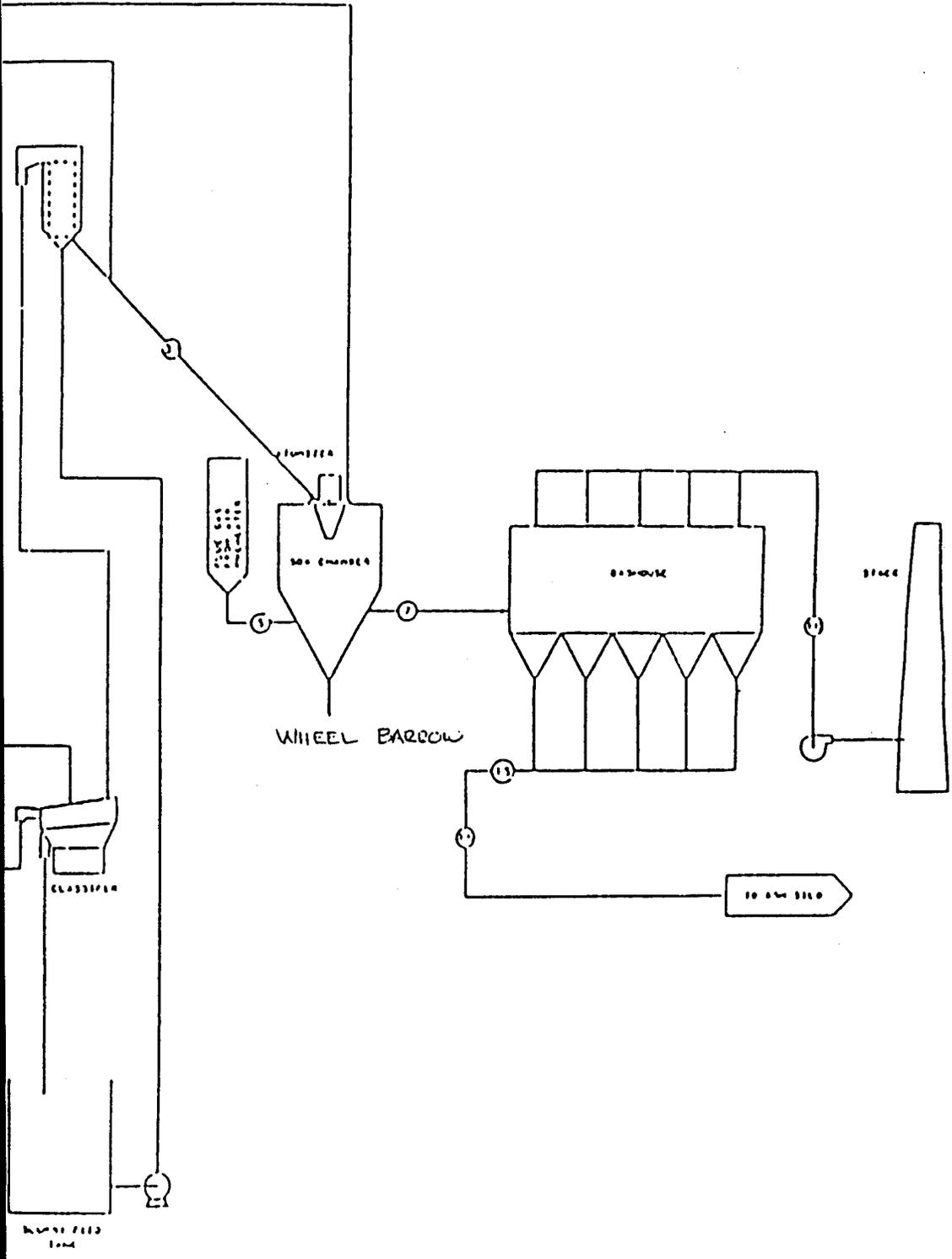
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5



(2)

3



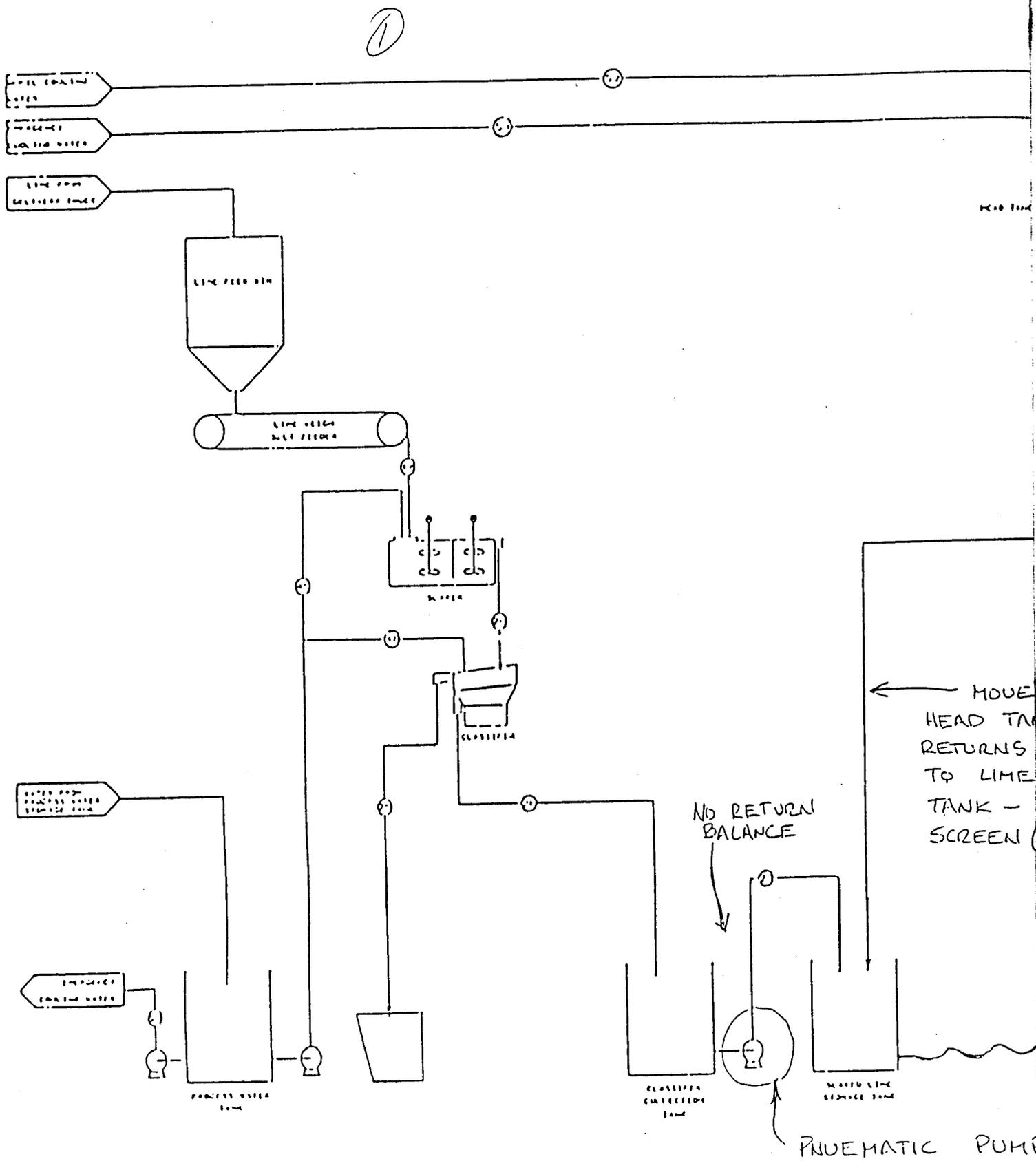
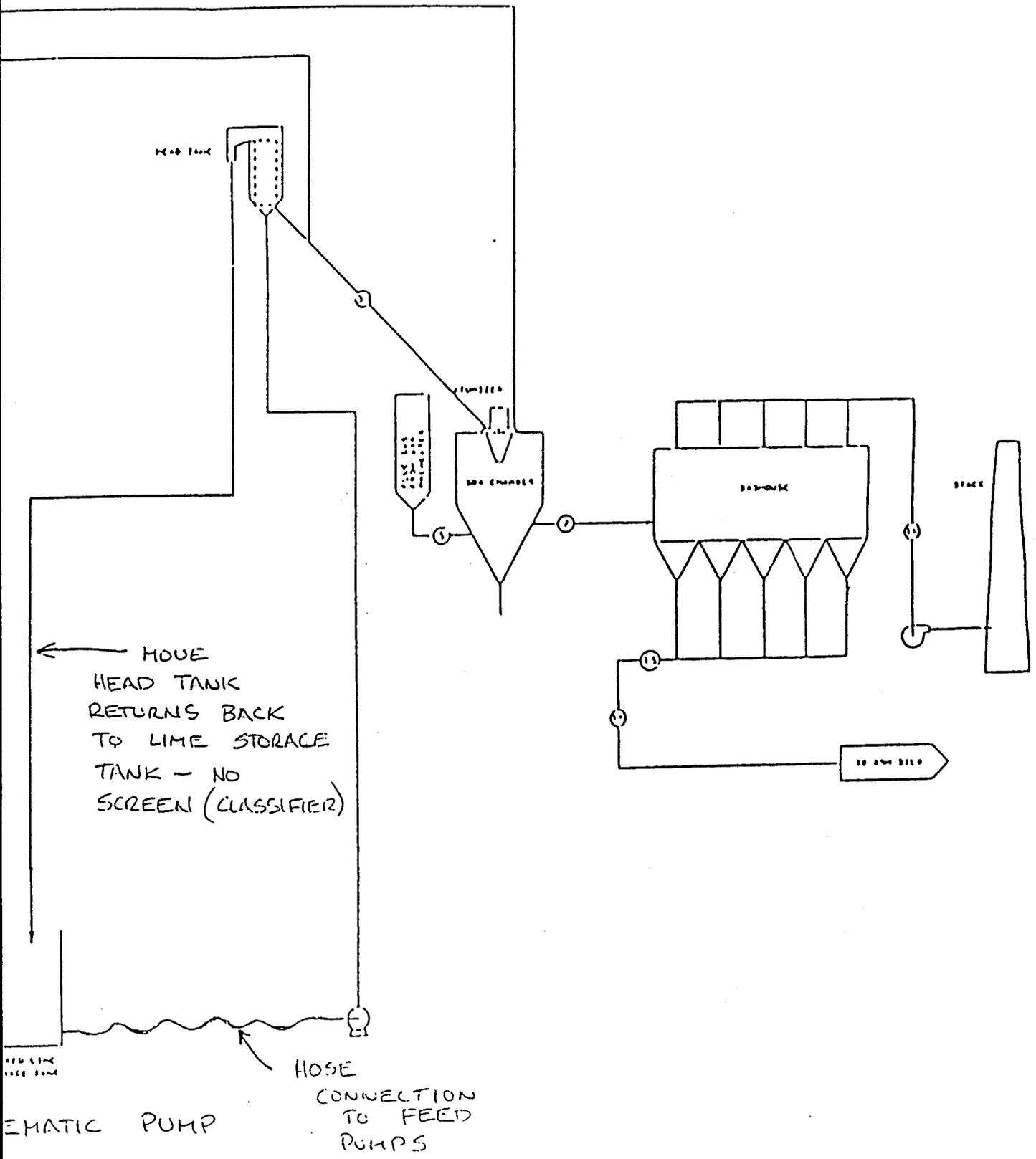


Figure D7. Recommended process flow sheet (eliminate head tank return classifier).

2

3





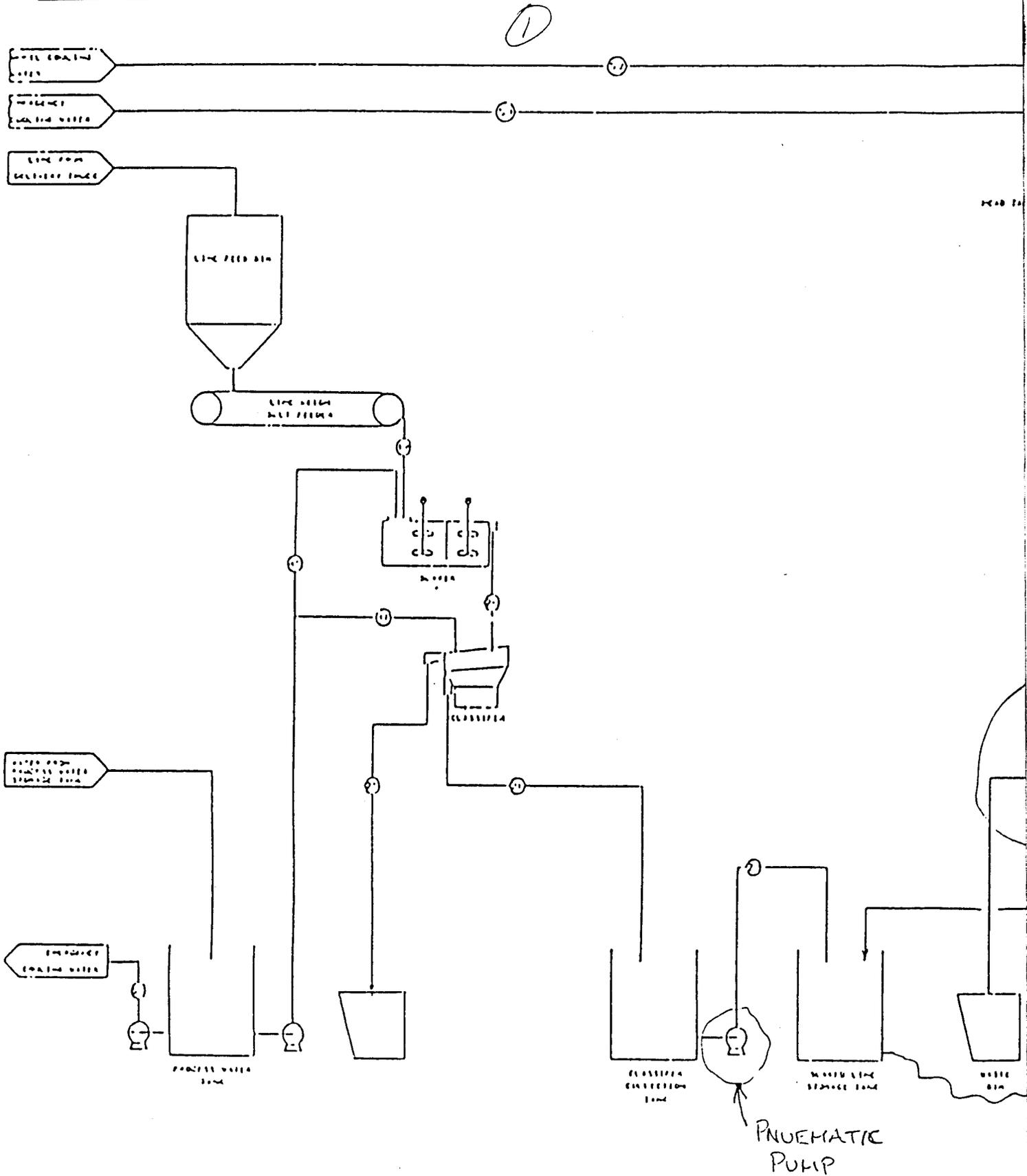
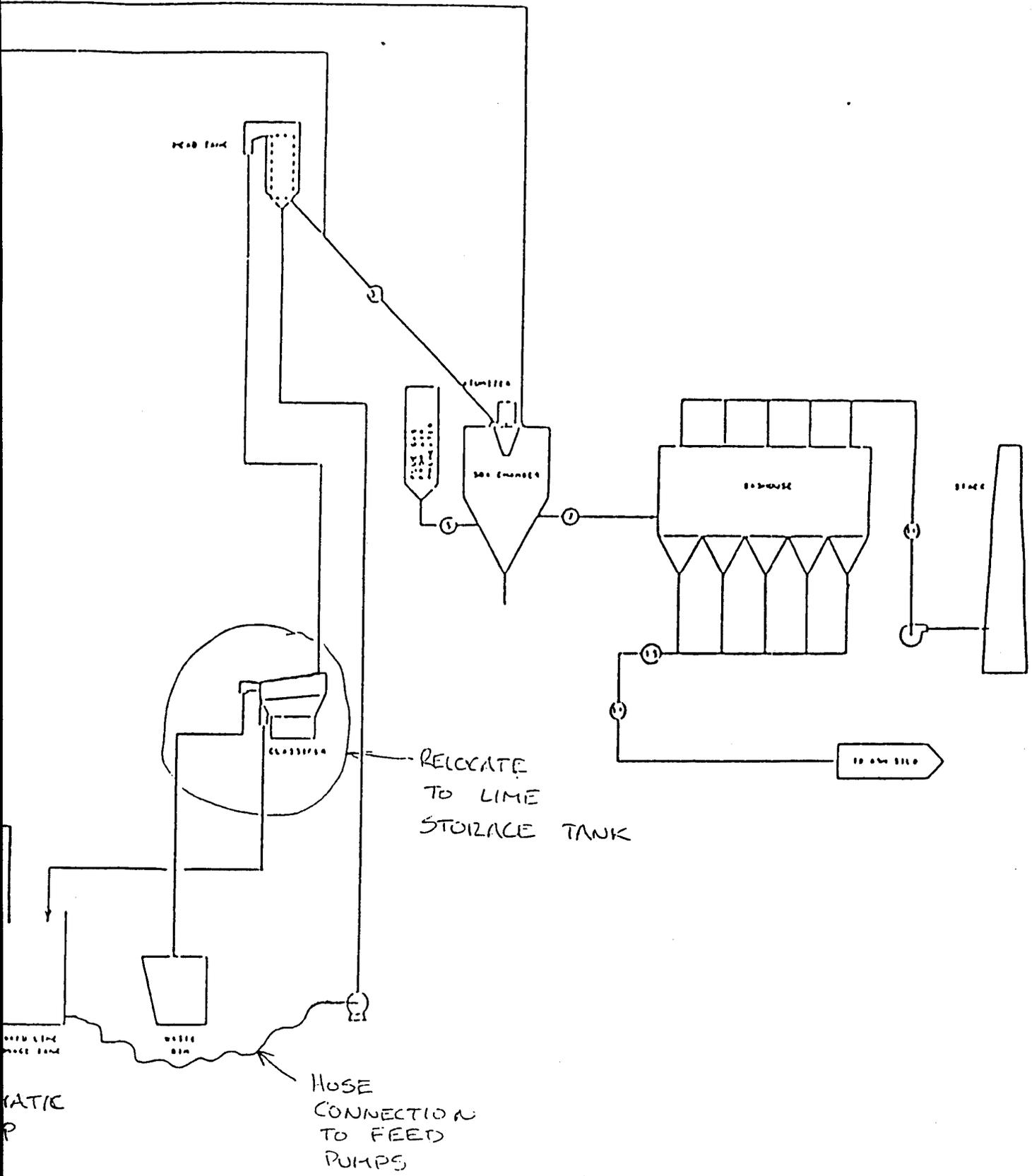
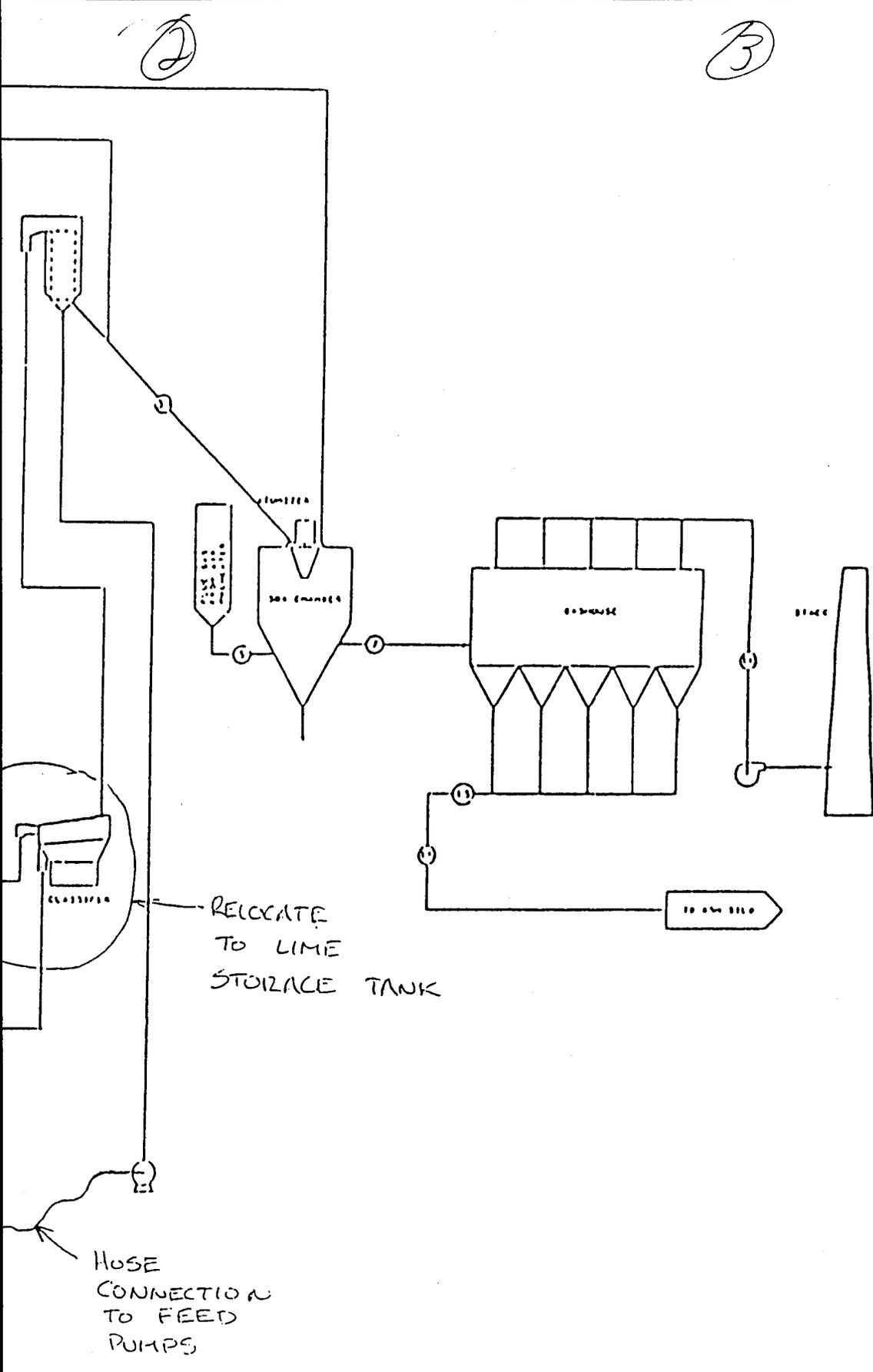


Figure D8. Recommended process flow sheet (with head tank return classifier).

②

③





## **Appendix E: Wilden® Diaphragm Pump Manufacturer Brochure**

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\* Reprinted courtesy of Wilden Pump & Engineering Co., Grand Terrace, CA 92313, tel: 909/422-1730; FAX: 909/783-3440.

# INTRODUCING THE M20

Through our research we have found that the waste treatment and mining industries in particular, as well as industries involved in processing heavy, solids-laden slurries are requesting a high-volume, easily serviceable, self-priming pump capable of passing large solids. The Wilden Model M20 has been engineered in response to these needs.

The M20 has the same basic characteristics as other Wilden models: no seals or motors, runs dry, variable speed, no bypass needed, submersible, explosion resistant, maximum rating of 125 psi and clamp band design for easy assembly.

Additionally, the M20 is engineered with features not found in our standard pumps. The housing enclosing the valve ball and seat was specifically designed to allow the passage of solids up to 1 3/8" in diameter. The housing also incorporates a wing nut design allowing easy access to the ball and seat where clogs are most likely to occur.

Also, each inlet and discharge elbow is designed with a flush port allowing access to the area beneath the ball seat. The ports allow fluidization of the elbow and ball seat area, keeping solids or fibrous debris from gathering. For pumping non-compressible or quick-settling solids the M20 can be inverted to prevent material accumulation in the liquid chambers.

The M20, as is the case with all Wilden pumps, is a self-priming unit. Under normal operating conditions the pump is capable of full prime in seconds. The M20 has suction lift capability of 14' dry and 28' wet.

We understand that eliminating downtime as well as cost-effective maintenance and operation is the goal of any plant manager. We feel that we have designed a pump to assist in achieving these goals. We proudly present the M20, a pump we build with care and pride to handle your most difficult assignments.

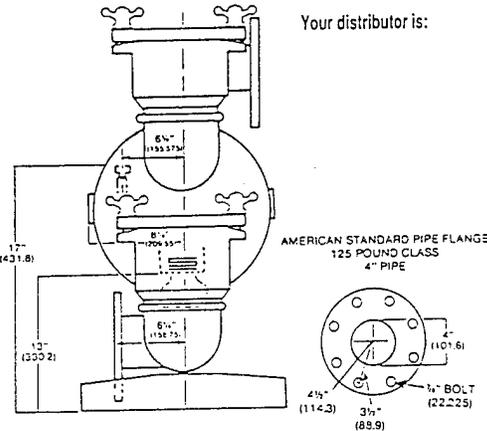
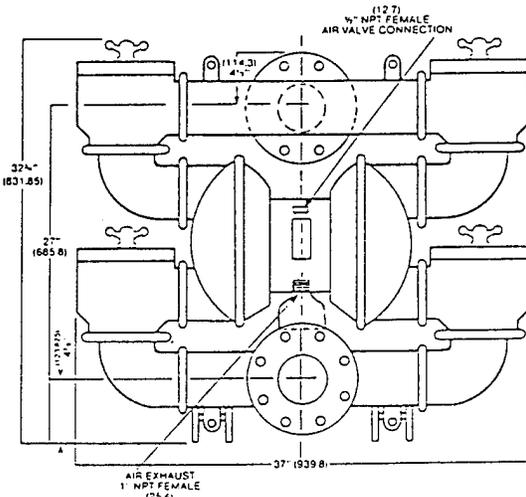
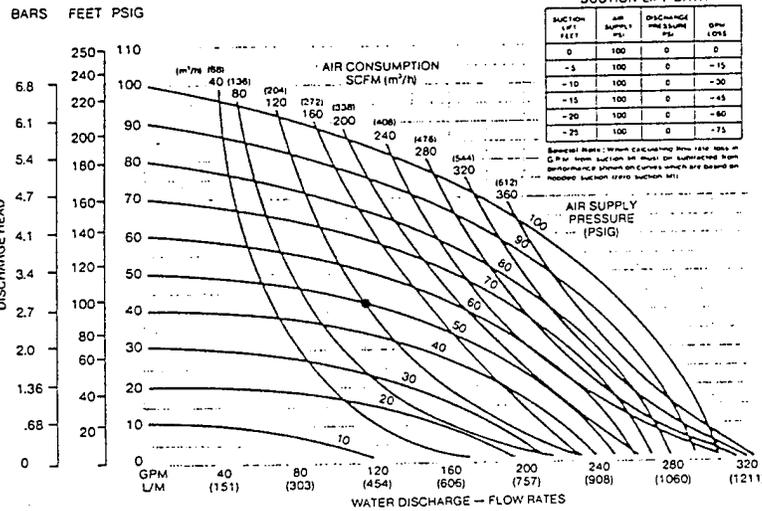
## SPECIFICATIONS AND PERFORMANCE

## M20

### WILDEN® MODEL M20

- Height ..... 32 3/4"
- Width ..... 37"
- Depth ..... 6.1"
- Weight ..... 509 lbs.
- Air Inlet ..... 1/2" NPT
- Inlet ... Std ANSI Flange 4"
- Outlet ..... 4"
- Suction Lift ..... Dry 14'
- Wet 28'
- Max. Size Solids ... 1 3/8"

Example: To pump 112 gpm against a discharge pressure of 42 psig requires 50 psig and 120 scfm air consumption. (See dot on chart.)



Your distributor is:

© Copyright: 1992, Wilden Pump & Engineering, Canton, CA

1394

# Basket Strainers

## Single Basket Strainers



Threaded

When temporary shutdown for cleaning is possible, these are the strainers to use. Swinging top yoke lets you remove the baskets in seconds for cleaning. Use the threaded drain plug as a backwash connection. Baskets are 40-mesh 316 stainless steel. Working pressure: Water, oil, and gas—200 psi at 100° F. Flanges on flanged strainers are ANSI rated—125 psi for cast iron; 150 psi for bronze. Flanged strainers have legs for bolting to the floor.

Pipe Size	Ht.	Wd.	Cast Iron		Bronze		Repl. Basket	
			No.	NET EACH	No.	NET EACH	No.	NET EA
<b>FEMALE THREADED STRAINERS</b>								
3/4"	6 3/4"	4"	4454K41	\$86.90	4454K51	\$132.69	4454K125	\$52
1"	6 3/4"	4"	4454K42	86.90	4454K52	132.69	4454K125	52
1 1/2"	8 3/4"	5 1/2"	4454K43	111.90	4454K53	187.38	4454K126	63
2"	8 3/4"	5 1/2"	4454K44	111.90	4454K54	187.38	4454K126	63
2 1/2"	9 7/8"	6 3/4"	4454K45	148.81	4454K55	278.85	4454K127	83
3"	11"	7 1/2"	4454K46	176.95	4454K56	278.85	4454K128	91
3 1/2"	13 1/4"	8 3/4"	4454K47	213.46	4454K57	410.48	4454K129	101
4"	14 1/2"	10 1/2"	4454K48	289.62	4454K58	575.74	4454K131	122
4 1/2"	17"	11 1/2"	4454K49	343.18	4454K59	874.39	4454K132	142
<b>FLANGED STRAINERS</b>								
2"	13 3/4"	10 1/2"	4454K61	291.07	4454K66	597.52	4454K129	101
3"	18"	13 1/2"	4454K63	399.82	4454K68	1087.50	4454K132	142

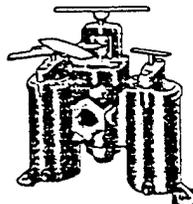
## Dual Basket Strainers

Basket seats are precision machined for a tight, positive seal. Strainer baskets are stainless steel. Sizes 3/4" and 1" have 1/2" perforations. Size 1 1/2" has 3/4" perforations. Sizes 2" and 2 1/2" have 1/2" perforations. Size 3" has 3/4" perforations.

Working pressure: Water, oil, and gas—200 psi at 100° F. Flanges on flanged strainers are ANSI rated—125 psi for cast iron; 150 psi for bronze.

Pipe Size	Ht.	Wd.	Cast Iron		Bronze		Repl. Basket	
			No.	NET EACH	No.	NET EACH	No.	NET EA
<b>FEMALE THREADED STRAINERS</b>								
3/4"	12 1/2"	11"	4416K51	\$337.67	4416K11	\$620.72	4416K112	\$40
1"	12 1/2"	11"	4416K52	337.67	4416K12	620.72	4416K113	40
1 1/2"	15"	15"	4416K53	605.82	4416K13	1226.54	4416K114	50
2"	20"	18 1/2"	4416K54	968.32	4416K14	1877.05	4416K115	60
2 1/2"	20"	18 1/2"	4416K56	968.32	4416K34	1877.05	4416K115	60
<b>FLANGED STRAINERS</b>								
2"	20 1/2"	18 1/2"	4416K62	1037.84	4416K65	2090.58	4416K115	60
3"	21 3/4"	22"	4416K63	1365.58	4416K66	3093.66	4416K116	70

• Allow additional 9" (maximum) clearance for basket removal.

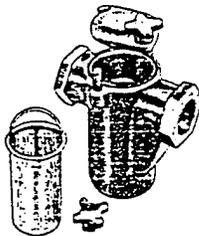


Threaded

Switch flow from one basket to the other in less than 30 seconds—simply turn the valve handle. Ideal for applications that require continuous operation.

When one basket gets clogged, transfer the flow. The first basket can then be removed, cleaned, and replaced. No tools are needed to remove the baskets. All strainers have legs for bolting to the floor.

## Stainless Steel Single Basket Strainers



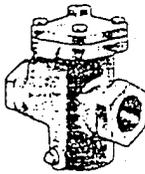
Large-capacity strainers are ideal for use in liquid pipelines where infrequent cleaning is desired. The baskets can handle up to six times the amount of liquid coming in the inlet with very low pressure drop. The body is made of 316 stainless steel and the baskets are made of 304 stainless steel.

Baskets have .057" perforations. A machined, gasketed seat ensures foreign objects won't bypass the basket. Simple hand pressure will loosen the quick-opening knob for easy basket removal.

Maximum working pressure: 200 psi at 400° F. Female threaded connections. NOTE: Not recommended for steam service.

Pipe Size	Ht.	Wd.	Strainers		Replacement Baskets	
			No.	NET EACH	No.	NET EACH
3/4"	6 1/2"	4 1/2"	9874K31	\$231.81	9874K41	\$71.35
1"	7 1/16"	5 1/4"	9874K33	305.45	9874K43	71.35
1 1/2"	9 1/2"	6 1/4"	9874K35	474.49	9874K45	95.81
2"	11 1/2"	8 1/4"	9874K37	705.46	9874K47	95.81

## Cast Iron Single Basket Strainers



Flanged

Ideal for large pipes, these strainers have a stainless steel basket that can be removed by opening the bolted top cover. Basket for threaded strainers has 1/2" perforations. Basket for flanged strainers has 1/4" perforations, except 6" size which has 3/8" perforations. Working pressure: Threaded: Steam—250 psi at 406° F. Water, oil, and gas—200 psi at 150° F. Flanged: Steam—125 psi at 450° F. Water, oil, and gas—200 psi at 150° F.

Pipe Size	Ht.	Wd.	Strainers		Replacement Baskets	
			No.	NET EACH	No.	NET EACH
<b>250-LB. FEMALE THREADED STRAINERS</b>						

## PVC Single Basket Strainers



All you need to remove, clean, and place the basket is your hands in a few seconds. All plastic construction compatible with fresh and salt water, dustrial, and agricultural chemicals, acids, oils, and other liquids. Ideal for removing unwanted material from pipelines to protect pumps, filters, and nozzles.

Strainers have a Viton O-ring seal. Sizes 1/2" to 1" have baskets with 1/2" perforations. Sizes 1 1/2" and 2" have baskets with 3/4" perforations. Working pressure: 150 psi at 75° F with low pressure drop to ensure high flow rate. Female threaded connections.

Pipe Size	Ht.	Wd.	Strainers		Repl. Basket	
			No.	NET EACH	No.	NET EA
1/2"	6 3/4"	7"	9885K61	\$143.85	9885K68	\$60
3/4"	6 3/4"	7"	9885K62	143.85	9885K68	60
1"	8 3/4"	7"	9885K63	143.85	9885K68	60
1 1/2"	12"	10 1/2"	9885K64	267.46	9885K69	60
2"	12"	10 1/2"	9885K65	267.46	9885K69	60

## PVC Dual Basket Strainers



Two-basket design assures uninterrupted flow—when the strainer basket becomes clogged, simply switch to the second by turning the valve handle. Strainers feature all plastic construction—they won't corrode and contaminate fluids. Use with plastic and metal pipelines carrying fresh and salt water, chemicals, acids, oils, and other liquids to protect pumps, filters, nozzles, and instruments.

Strainers have Viton O-ring seals. Sizes 1/2" to 1" have baskets with 1/2" perforations. Sizes 1 1/2" and 2" have baskets with 3/4" perforations.

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