Technical Publication

Boiler Slagging

by

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BOILER SLAGGING

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Mr. E. H. Holwick has offered us the opportunity to present a paper on the subject of "Boiler Slagging" with the contents of the paper completely at the speakers discretion. We appreciate this opportunity.

Free Hawley, whom most of you know, said all good ASME papers ended with the conclusions "yes a problem exists and more study is justified." I would like to start with that statement, yes slagging is a problem, even in some Riley units, but there are things that we collectively can do to minimize the problem. These are the subjects I will discuss with you today.

Slagging problems usually refer to coal-fired units, but problems with deposits from oil-firing can be just as severe and complicated and are worthy of a separate discussion.

Also, it is not unheard of to encounter problems with furnace deposits on gas-fired installations. These deposits are smaller, take longer to accumulate but can eventually require sandblasting. On the lighter side, one of our service engineers was convinced that the furnace wall deposits on a gas-fired job in Florida that raised boiler exit gas temperatures 100 F and raised steam temperature spray requirements beyond system capacity, were the result of mosquitos sucked into the forced draft fan.

I would like to concentrate the discussion today to pulverized coal-fired units. Many of the comments will apply to stoker-fired as well as pulverized coal-fired units. We have some 22 Riley pulverized coal-fired units in operation in REA plants, another on order, five (5) gas and oil-fired units with another on order and six (6) units fired by Riley Traveling Grate Spreader Stokers.

FUEL

Since the slag and its characteristics are the result of the ash in the coal, the analysis, ash fusion temperature, consistency, etc are very real factors in our slagging problem. Unfortunately we are not burning a synthetic fuel whose quality can be controlled to specified limits, but must expect some variations in fuel and ash quality even from a single mine. It therefore is necessary to make allowances for such variations in the design and operation of the equipment.

Blending of washed and unwashed coal by the mine to provide a customer with specified Btu content or ash content is now a common practice. As a rule, the fines in the unwashed coal are much higher in ash content than the larger sizes of washed coal. Thus a perfect blending of sizes is necessary to get a perfect blending of coal quality.

All of the spreader stoker operators here are familiar with the sensitivity of spreader stoker operation to coal sizing, having been impressed by the stoker service engineers on the need to eliminate segregation by care in handling coal, all the way from the mine to the bunker.

Pulverized coal operators, however, have only been interested in keeping the size small enough to get through the feeders and into the mills. With blended coals, the plant operators of pulverized coal-fired plants must now exercise care in loading onto storage piles, reclaiming, loading bunkers, etc to protect and maintain the blend of size and thus blend of quality.

With increased size of plants, it frequently becomes necessary to burn coal from several mines, often with quite different ash analysis and slagging characteristics. Mixing coal ash is like mixing metals in a solder. The melting point of solder is not the average of the melting points of the individual metals, but is always lower than any individual melting point. With coal ash this same phenomenon appears to exist.

It therefore may be advisable to segregate coal by supplier (mine) rather than attempt to mix and blend fuels at the plant. Good coal handling records could then provide the operator with information as to the coal he was burning so he could adjust his operation accordingly: excess air, soot blowing schedule, possibly fineness and even capacity. This also tends to isolate the one or two sources that are the real trouble makers and permits proper economic evaluation as well as operational analysis.

Large plants using coal from several sources may find it economically justified to make frequent analysis of coal as burned, proximate analysis and ash fusion temperature. This is helpful in evaluating coal quality received versus coal purchase specifications. It is also most helpful to analyze fuel samples collected when the slagging problem is being experienced.

DESIGN

The designer does not expect to keep a furnace or boiler clinically clean when burning coal with ash content from 5% to 25%. But it is necessary to prevent ash accumulations on waterwalls that cause physical damage when they fall off or plug ash hoppers and removal systems, to prevent accumulations in the screen tubes or superheater tubes that restrict gas flow, limit capacity and in some instances cause fly ash erosion and liquid ash corrosion. See Figure 1.

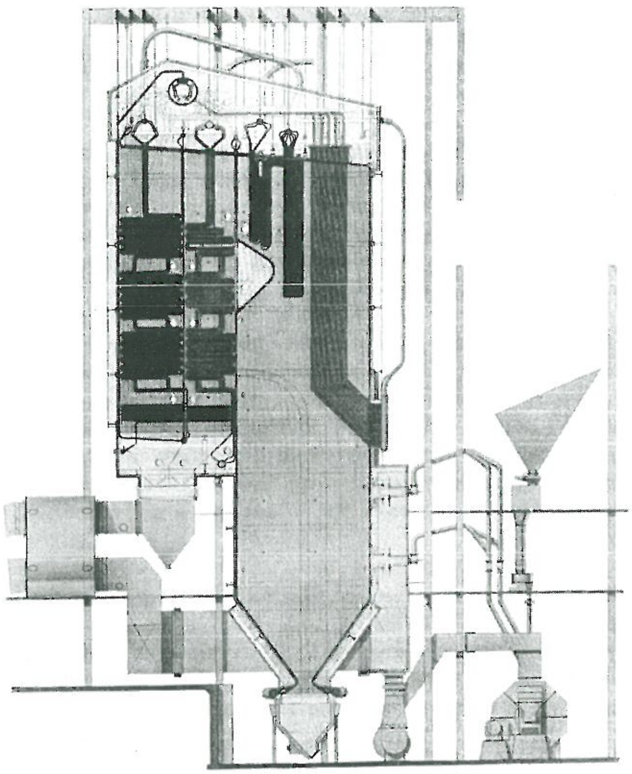

FIGURE 1
TYPICAL LARGE FURNACE WITH WATERWALL PLATENS

The furnace must be large enough to permit the fuel to burn completely without impingement on heating surfaces, both to prevent excessive heat input to the tubes and prevent chilling of combustion process with resultant incomplete combustion and carbon loss. The heating surfaces must be arranged so that the gases are cooled below the fusion temperature of the ash before the gas comes in contact with heating surface, especially the high metal temperatures of finishing superheaters.

The early REA specifications had a section entitled "Basis of Design of Standard Furnace and Other Parts" which specifies a standard furnace to be capable of burning coal with 1950 F ash softening temperature in a reducing atmosphere, but suitable for other fuels as specified, and a reduction in temperature of gases entering the superheater screen tubes in boiler circulating system to 1950 F as measured by high velocity thermocouple one-foot ahead of the screen. This specification also limits "area heat release" not to exceed 70,000 Btu/sq ft/hr.

These specifications have been revised to permit insertion of an ash softening temperature typical of coals to be burned and the heat release rate has been increased to 80,000 Btu/sq ft/hr. Conscientious fulfillment of this requirement has, we believe, assisted Riley in preventing "slagging problems" in Riley REA jobs. It has introduced problems in meeting superheat and reheat temperatures where coal with 2800 F ash fusion temperature is actually fired in a furnace designed to meet the 1950 F fusion coal requirement. See Figure 2.

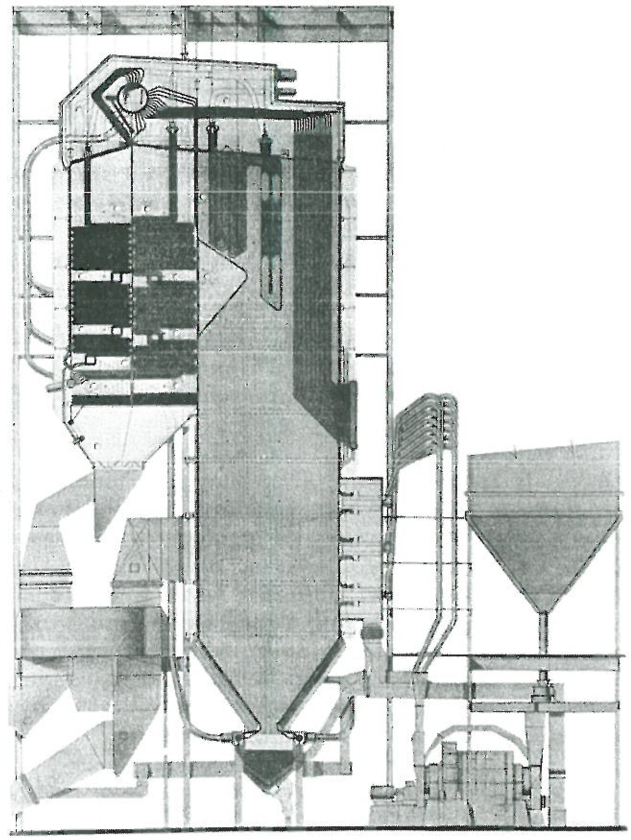

FIGURE 2

PULVERIZED COAL-FIRED UNIT FOR 1950 F FURNACE EXIT GAS TEMPERATURE

Although furnace volume and furnace heat absorption rates are figures frequently quoted as design criterion to prevent slagging, they are not the entire story. Furnace shape is a critical item only recently recognized. This involved particularly furnace depth to permit completion of combustion without impingement on rear walls, and furnace width to prevent flame impingement on side walls. You are all familiar with Riley's use of waterwall platens to maintain uniform gas temperature across the width of wide furnaces, liberal use of radiant superheater and reheater surface permits low furnace exit gas temperature and meeting of superheat and reheat steam temperatures and control range. Wide spacing of superheater tubes and low gas velocity through the superheater tube bank also reduce slag accumulations.

Burner size, number and location are important items that might also be considered part of furnace design. We have found that multiple burners arranged for either front firing or opposed firing fulfill these requirements and provide optimum turbulence and uniform heat input into the furnace.

We solicit as complete and accurate information as possible on the precise fuel to be burned, especially if it will be a long time source of fuel for the unit in question. This permits our designers to review with you the effects of these fuels on units designed to your general specifications. This will apply especially to the location and number of soot blowers. Although soot blower manufacturers suggest cleaning radius of blowers, (and make this maximum to reduce the number of blowers and get the order) it is up to the boiler manufacturer to guarantee performance and provide additional blowers when required. We therefore suggest your conservative evaluation of soot blower installations. A conservative number of soot blowers can give to the operator a real tool in preventing ash accumulations from reaching the point where slag problems occur. See Figure 3.

Proper evaluation of observation doors will also be helpful in permitting us to provide you with a "good unit." Soot blowing schedule and effectiveness can only be determined by observation which must be made through observation doors. Such doors contribute to cost of unit and may be omitted if selling price is the only criterion for purchase.

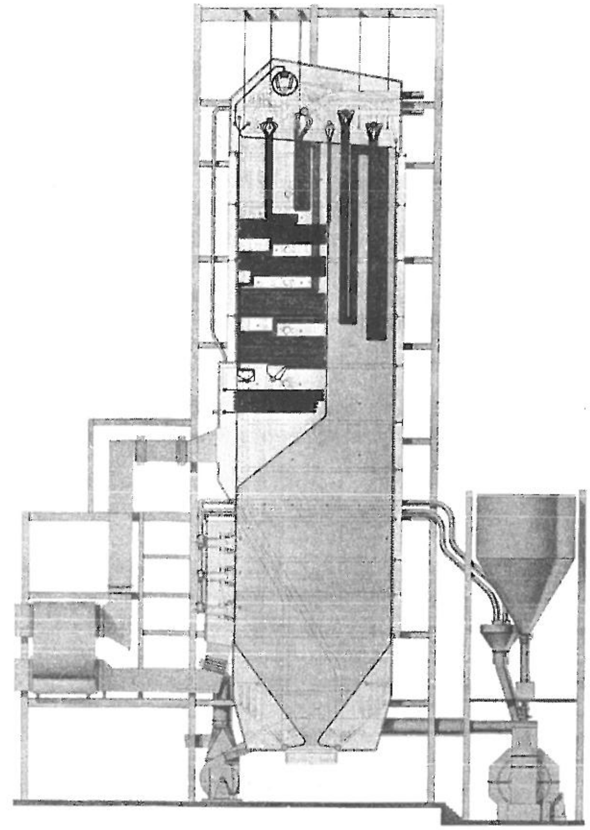

FIGURE 3
SOOT BLOWER LOCATIONS PREVENT SLAG ACCUMULATIONS

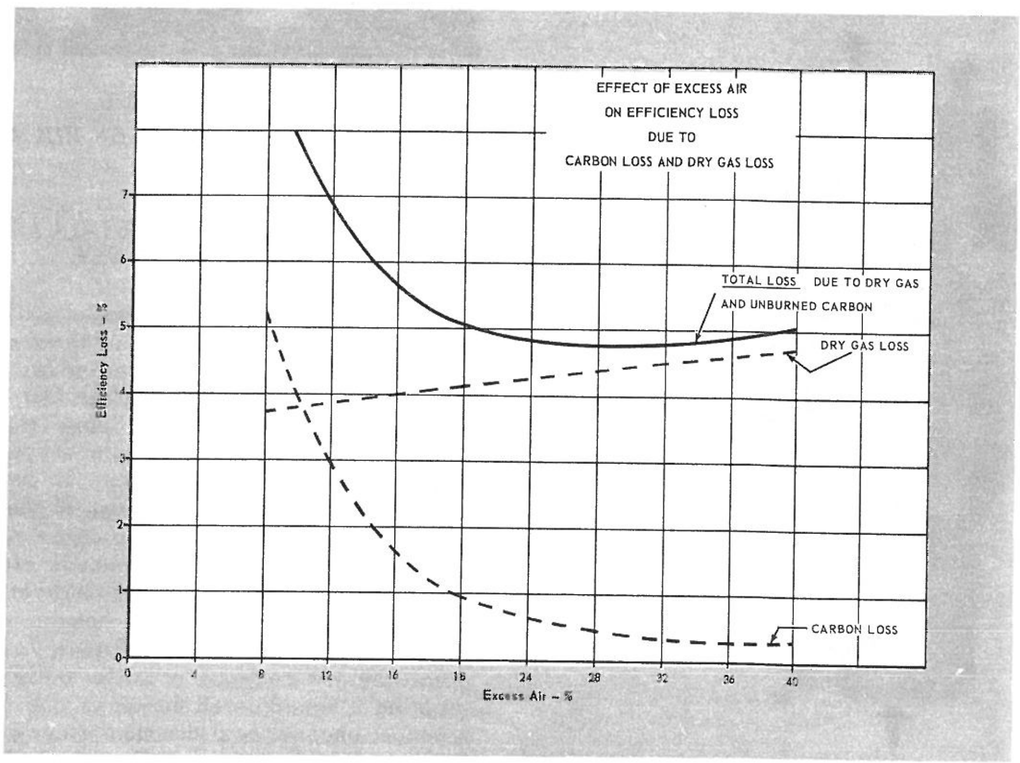

FIGURE 4
EXCESS AIR VS CARBON LOSS, DRY GAS LOSS AND EFFICIENCY

OPERATION

There are several steps that can be taken from an operational point of view to eliminate or reduce slagging problems.

First, the operating personnel should have a clear strong voice in the evaluation and selection of the design of the equipment as described above.

Secondly, the operating department should have a strong and continuing voice in the selection of the fuel.

Thirdly, there are operating techniques that are helpful in preventing slag and are well-known to all power plant operators:

EXCESS AIR

Increased excess air reduces the furnace temperature for any given Btu input (fuel feed rate or steam load). High excess air usually reduces carbon loss and shortens flame length. All of these are helpful in preventing slag problems, but increased excess air reduces efficiency by increasing the dry gas loss. There is an optimum excess air for maximum efficiency that results in a minimum total of carbon loss and dry gas loss. See Figure 4. However, slag problems may dictate higher excess air than required for maximum efficiency. Here, boiler availability must be evaluated against efficiency and the boiler operators made aware of such evaluations so they can prevent slagging problems at a slight loss in efficiency.

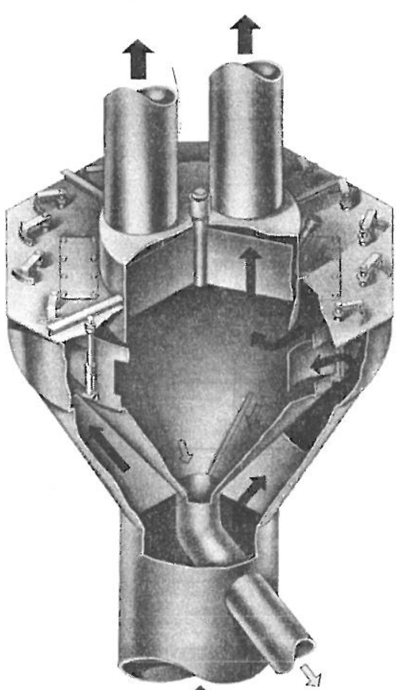

FIGURE 5
RILEY CENTRIFUGAL CLASSIFIER

FINENESS

It is generally conceded that high fineness of pulverization reduces slagging problems. This probably results from faster burning so combustion is completed before gases reach a location of possible pluggage. Hence, it appears that the % on 50 mesh screen is the critical item rather than % through 200 mesh. Although these two go along together, an increase in % through No 50 from 97% to 99% is much more significant than an increase in % through No 200 from 70% to 75%. Our mills equipped with classifiers, see Figure 5 can be adjusted to improve the cutoff point on 50 mesh size the critical item.

Careful maintenance of rejector arms, rejector rings and clearance between them on our Atrita Pulverizer, Figure 6, will provide this improved fineness.

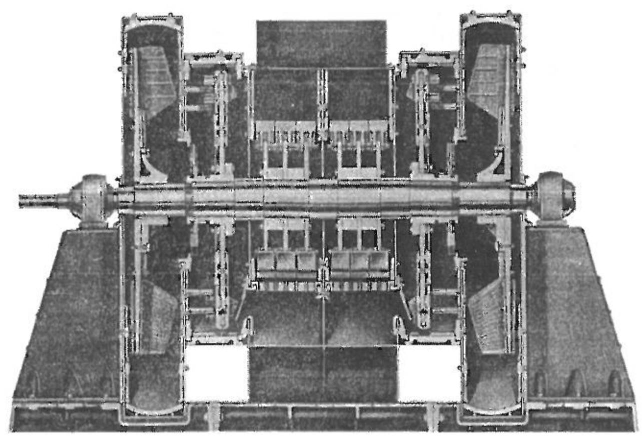

FIGURE 6
RILEY-ATRITA DUPLEX PULVERIZER

INSTRUMENTATION, INSTALLATION AND MAINTENANCE

In most installations the boiler exit gas temperature is an electrical average of three or four thermocouples and the O_2 recorder mixes three or four samples and reports the results. Our investigations of slagging problems have found that temperature and O_2 traverses with sample locations on about three-foot centers are necessary to determine actual conditions. It is not the average of the readings that indicates the source of the problem nearly as often as it is the individual low excess air or individual high temperature. There are indications that gas flows through large boilers remain stratified from burner to boiler outlet. See Figure 7. Hence temperature and gas analysis at boiler outlet can assist in locating a maladjusted burner or one requiring maintenance, unequal coal distribution or air distribution. Increased numbers of sampling points for gas temperature and analysis would be an effective tool for plant operators to use in normal operation.

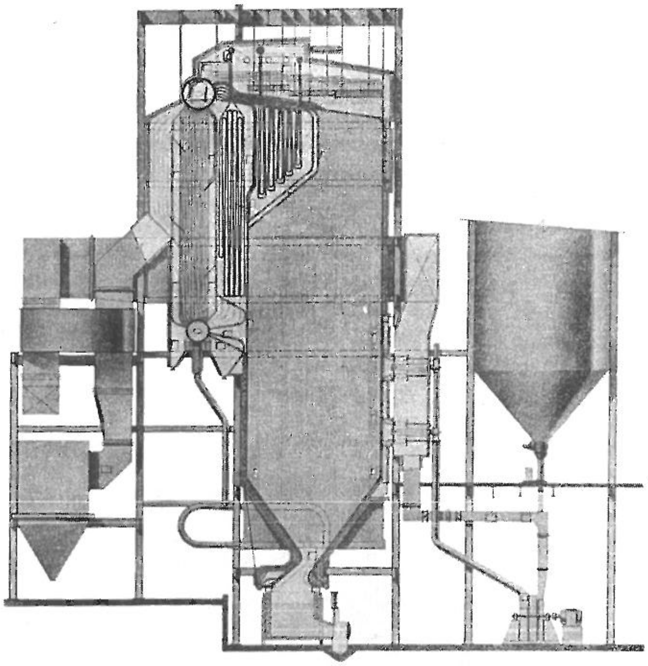

FIGURE 7
INSTRUMENTATION ASSURES OPTIMUM OPERATION

Any instrumentation is only as good as its calibration and maintenance. O_2 meters are one of the prime sources of information relative to slagging problems and so justifies all maintenance required to insure accurate readings.

Air flow measurements are usually made in venturi sections in the hot air duct and should be an accurate measure of air being introduced into the furnace. These are calibrated for normal operating air temperatures and errors from higher than expected air temperature can result from higher than expected gas temperatures as a result of the slagging. This error reduces air flow and aggravates slagging.

Older smaller units frequently used gas draft loss across the boiler as a measure of air flow. Slagging then would increase draft loss, indicate high air flow which would cause combustion control to reduce the air flow and aggravate the slagging. Here gas analysis at boiler outlet by Orsat, Heat Prover or O_2 meter is required for accurate determination of excess air.

COAL DISTRIBUTION

Every effort is made in the design of the pulverizing equipment to build in uniform distribution of coal to all burners. Riffles, equal lengths of coal pipes where possible or equalizing orifices and careful calibration during initial operation. This requires air flow tests in each line. Also a careful balancing of feeders is required, especially with the Atrita pulverizers where the coal is accurately metered to each pulverizer by positive displacement feeders. A check on these calibrations can be made by collecting timed weighted coal samples from coal pipes to each burner. These coal distribution checks can be combined with normal coal fineness check by the added effort of weighing the sample collected from each pipe before screening for fineness.

AIR DISTRIBUTION

Equal air distribution to each burner is just as important as equal coal distribution. Here again every effort is made in the original design to provide such distribution, good approach ducts with uniform flow through duct cross section, large plenum chamber type windboxes, sufficient pressure drop through burners etc. We conduct water table tests, see Figure 8, to arrive at optimum duct design. At the present

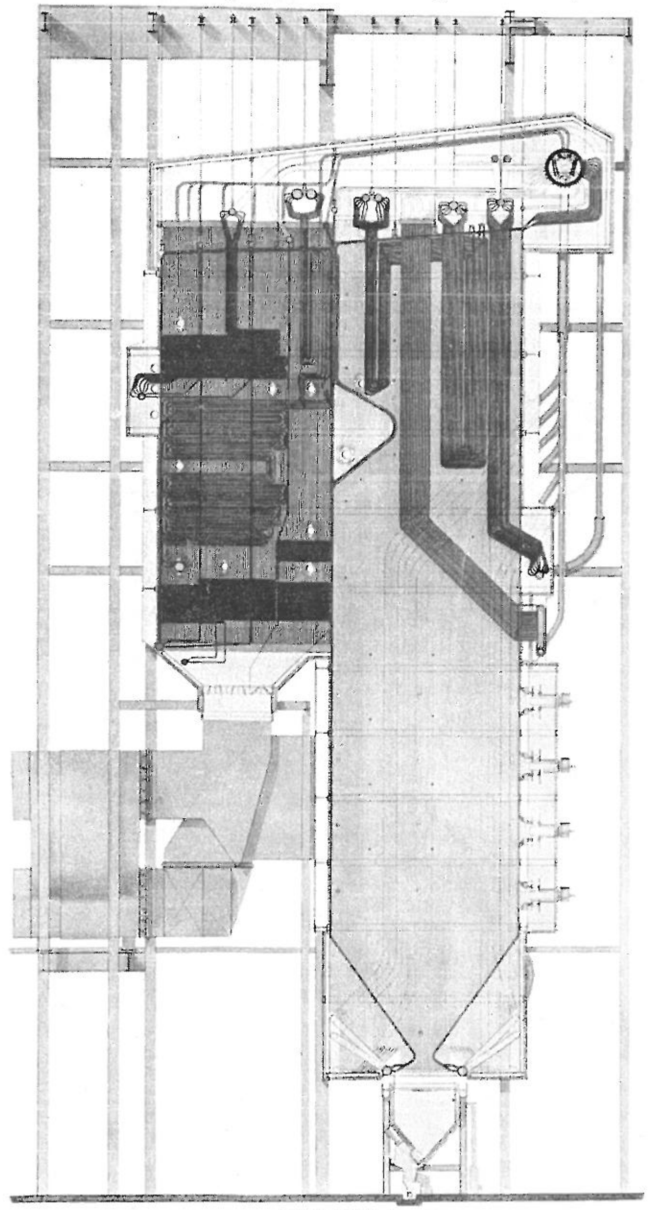

FIGURE 8
PROPER AIR DISTRIBUTION PREVENTS FURNACE SLAGGING PROBLEMS

time we are using a three-dimensional model to determine the optimum hot air duct and primary air duct windbox system to prevent occasional occurances of slag in the corners of a hopper bottom furnace. See Figure 9 and Figure 10.

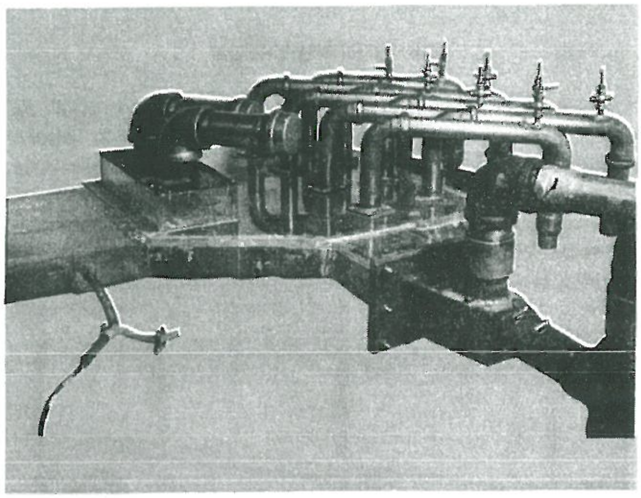

FIGURE 9
THREE-DIMENSIONAL WATER MODEL

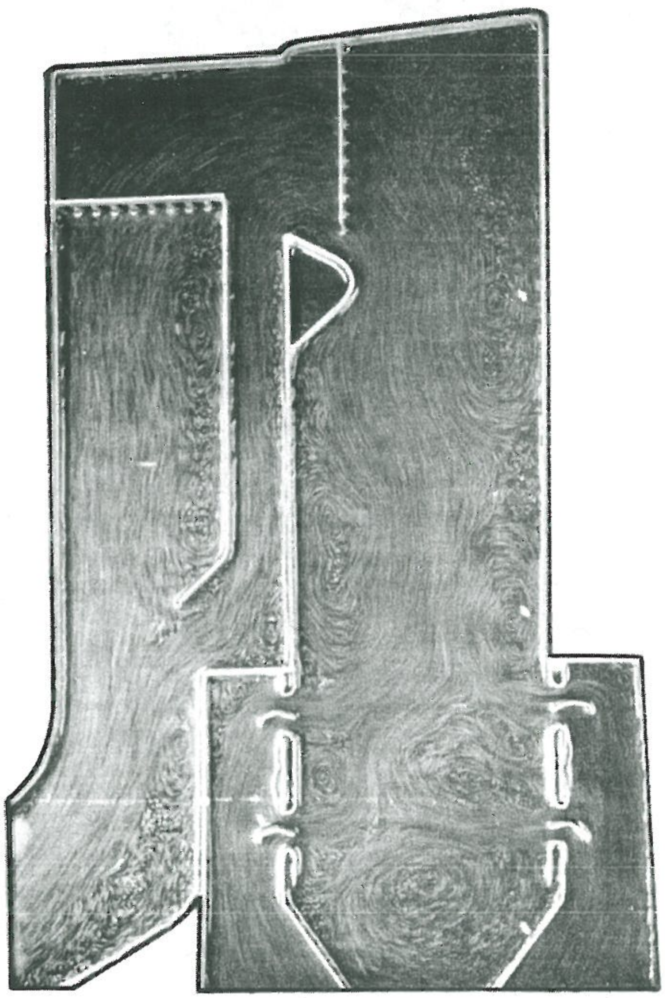

FIGURE 10
TWO-DIMENSIONAL TABLE MODEL

BURNER ADJUSTMENT AND MAINTENANCE

Our Flare Type Burners, Figure 11, have adjustable registers designed to permit adjustment of flame shape. Unfortunately they do influence air flow if there is a wide difference in vane opening. With stress on burner automation and remote operation, the burners are usually limited to three positions, "closed," "light off" and "operate," by the position of respective limit switches. If limit switches lose their setting, a burner can operate with deficiency of air and contribute to slagging. Frequent observation by the operator is suggested. This is also the best method of determining need for burner repairs which may affect flame shape and slagging problems.

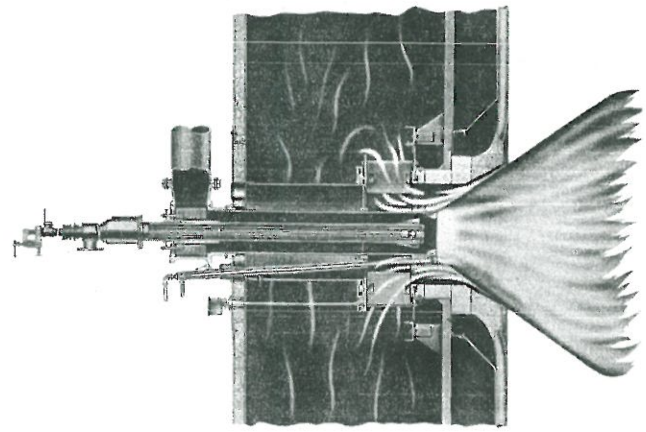

FIGURE 11
RILEY FLARE TYPE BURNER

RILEY CUSTOMER SERVICE DEPARTMENT

To assist you in any slagging problems, or any other problems with operation, performance or maintenance of Riley equipment we make our Customer Service Department and the entire Riley Stoker Corporation available to you. We have recently reorganized and strengthened our Customer Service Department, see Figure 12, by the creation of seven District Service Managers and a Results Engineering Section with engineering specialists. This is in addition to our normal force of 22 Field Service Engineers.

The District Service Managers, see Figure 13, are former Riley Service Engineers with long experience best qualified to serve you on any problems with Riley equipment. They will be calling on you in routine manner to discuss new designs in our equipment or repair parts, new operating techniques and to establish a closer and continuing relationship with you.

As Free Hawley said - "A problem does exist." We want to say "We are doing something about it" and offer you our assistance on a closer and continuing basis.

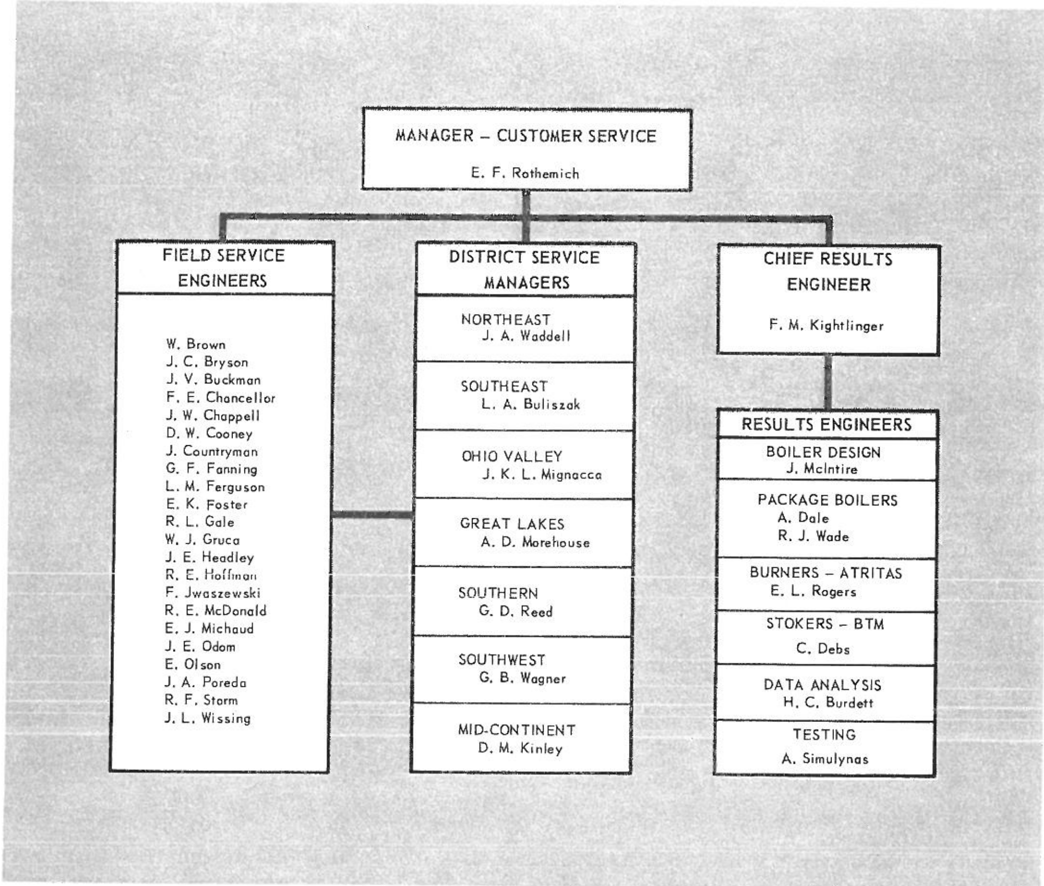

FIGURE 12 CUSTOMER SERVICE DEPARTMENT

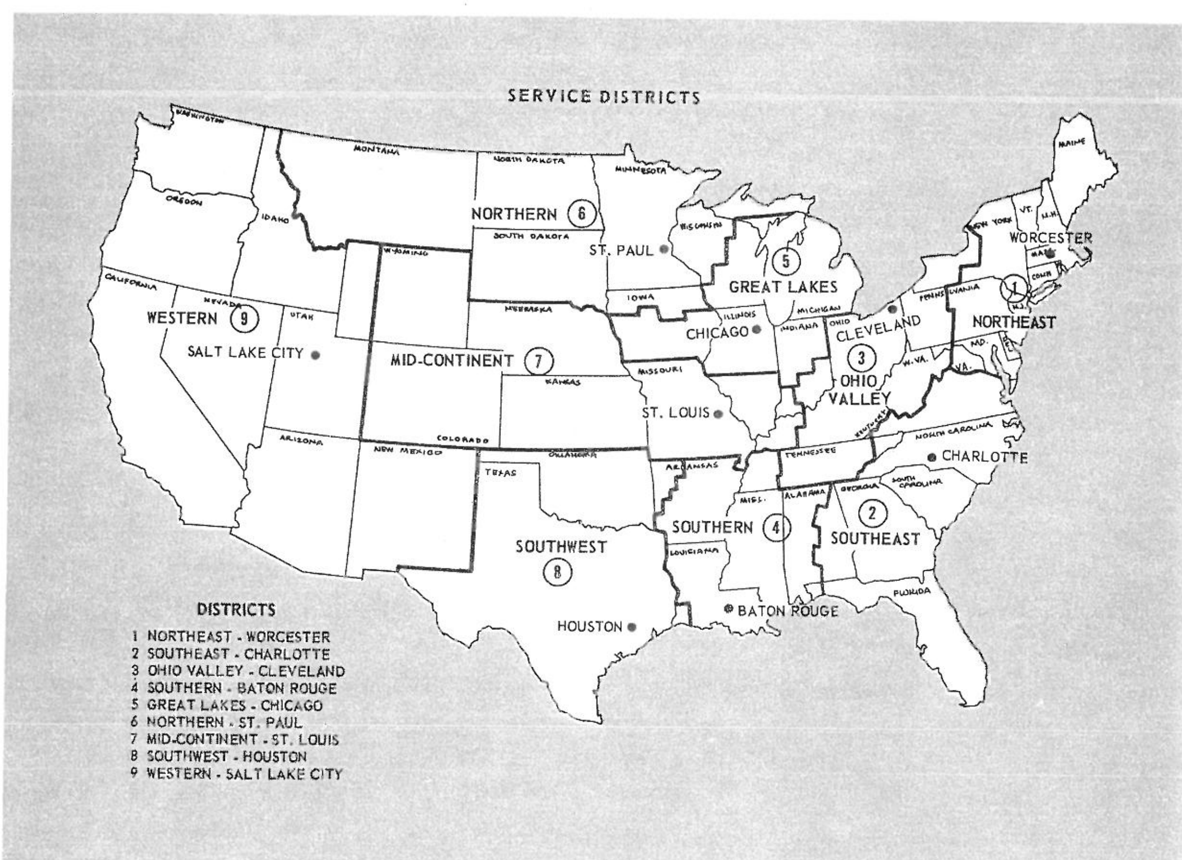

FIGURE 13 SERVICE DISTRICTS