FURNACE PERFORMANCE OF RILEY DRY BOTTOM TURBO® FURNACE UNITS

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WORCESTER, MASSACHUSETTS

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"Riley has been blessed with the most effective furnace in the Utility Boiler Industry." This comment was overheard at a recent meeting and while many heads swelled with pride and good feeling, the same people realized that too much of a good thing has its drawbacks as well as advantages. The paper will present both sides of the picture based on actual performance of coal fired Riley dry bottom Turbo® Furnaces.

The story starts many years ago with the conception of the Turbo Furnace's unique configuration. The problem at the time was the burning of a petroleum by-product called fluidized coke. The fuel, while high in calorific value, was slow burning and required a longer residence time in the furnace. The simple expedient of bending the front and rear water-walls in towards the center of the furnace provided a means of aiming the burners downward. Fuel and air admitted through the burners on both walls mixed in the center of the unit, curled down and up and followed a longer path of travel compared to a straight walled unit whether front, rear or opposed fired. See Figure One.

The inward bending of the front and rear waterwalls form a venturi shape, called a "Mae West" by Riley engineers. This configuration produces a diffused flame pattern with a long path for combustion when used with the Directional Flame Burner. The result is an even distribution of heat across the unit with lower and upper furnace walls relatively clean and free of ash or slag deposits.

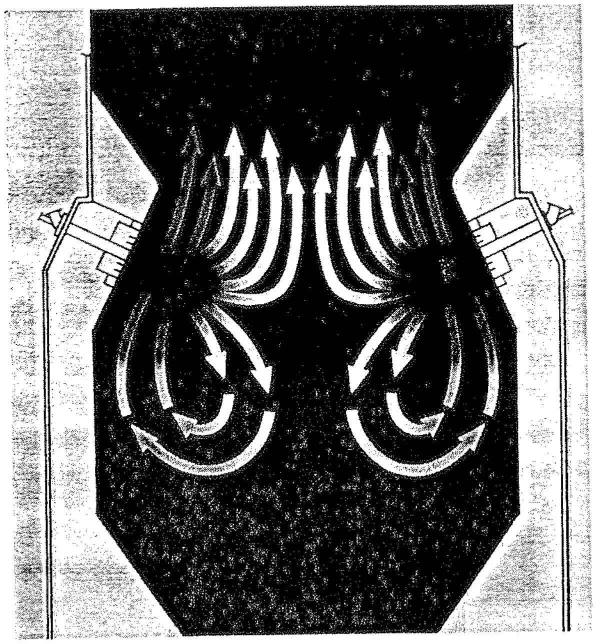

Figure 1. Showing Configuration and Flow Patterns of the Turbo® Furnace.

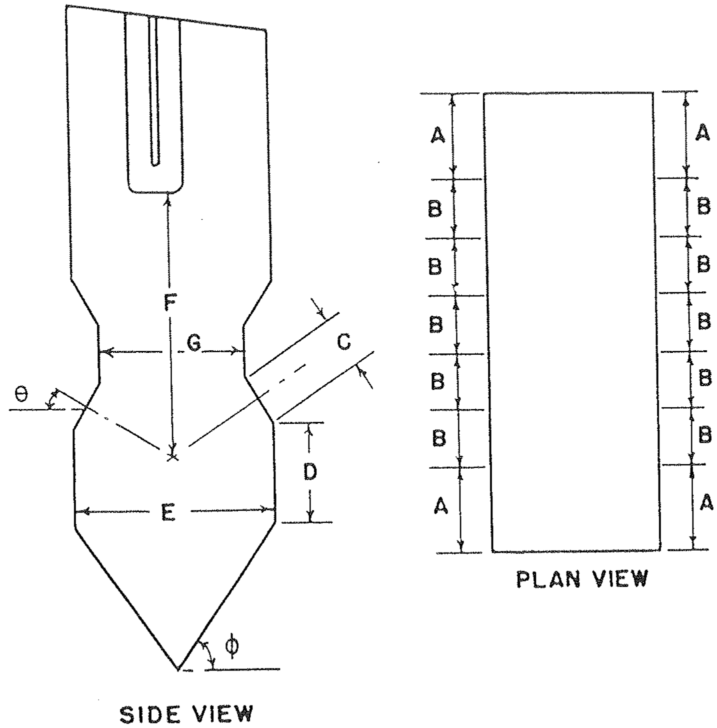

Figure 2. Dry Bottom Turbo Furnace Minimum Furnace Spacing - Utility Units

A second generation of Turbo Furnaces evolved with a relatively flat floor formed by the waterwall tubes and covered with refractory rubble. The furnace was able to bring the performance of widely varying fuels such as natural gas and residual oil closer together. The design of the burner, with the ability to move the air flow in comparison to the fuel flow, allowed more or less absorption to take place in the furnace with the various fuels producing furnace exit gas temperatures more closely aligned than straight wall firing.

With the change back to coal firing due to the energy crunch and the desire of the United States to reduce its dependency on foreign oil imports, Riley introduced a third generation of Turbo Fired Furnaces. Coal had been burned successfully with a "flat" or slag-tap type furnace but the fuel was limited to relatively high slagging characteristic coals and a market was needed for the type of ash produced in a slag tap unit. The modern concept of the Turbo Furnace embraces a dry hopper bottom with a water impounded ash hopper beneath the hopper throat. Critical dimensions are shown in Figure Two.

Riley has sold some 28 units of this type. A list of these boilers is found in Appendix I. Of these units, eight are presently in operation. The utility boiler hopper bottom Turbo Furnaces which have started up are:

1. City Utilities of Springfield
2. Interstate Power Company
3. Santee-Cooper Public Service Authority
4. South Mississippi Electric Power Association
5. Alabama Electric Co-op., Inc.
6. Arizona Electric Power Corp., Inc.

Sectional side elevations and performance data for the above units are in Appendix II. The boiler designer is faced with many problems in the design of the furnace. The primary function of the boiler is to provide steam at a certain rate and temperature. To do this the designer must ensure a proper division of the evaporative and heat recovery surface. While the furnace, superheater, reheater and economizer are all heat recovery per se, the furnace waterwalls and the economizer primarily perform evaporative duty while the superheater and reheater are primarily for heat recovery. (Some evaporative duty may be accomplished in the superheater, i.e. spray water injection for steam temperature control).

An imbalance between evaporative and heat recovery surface can result in steam temperatures too high for effective spray down or low steam temperatures. Natural circulation units are fired for generation and pressure (although the latter is principally controlled by the turbine throttle valves). When a furnace absorbs too much heat, the amount of steam produced meets the demand more readily at a lower firing rate with less heat thus being available for superheating and reheating. Figure 3 shows the approximate distribution of heat recovery in a utility boiler.

In addition to the balance between evaporative and heat recovery surface the boiler designer faces the following problems in designing the furnace:

1. Geometry for proper flame development and completion of combustion.
2. Judicious placement of burners and radiant heat recovery areas.
3. Adequate water paths for good circulation.
4. Minimization of ash deposits and provision for easy removal of ash.
5. Structural strength and integrity for normal operation, puffs and implosions.

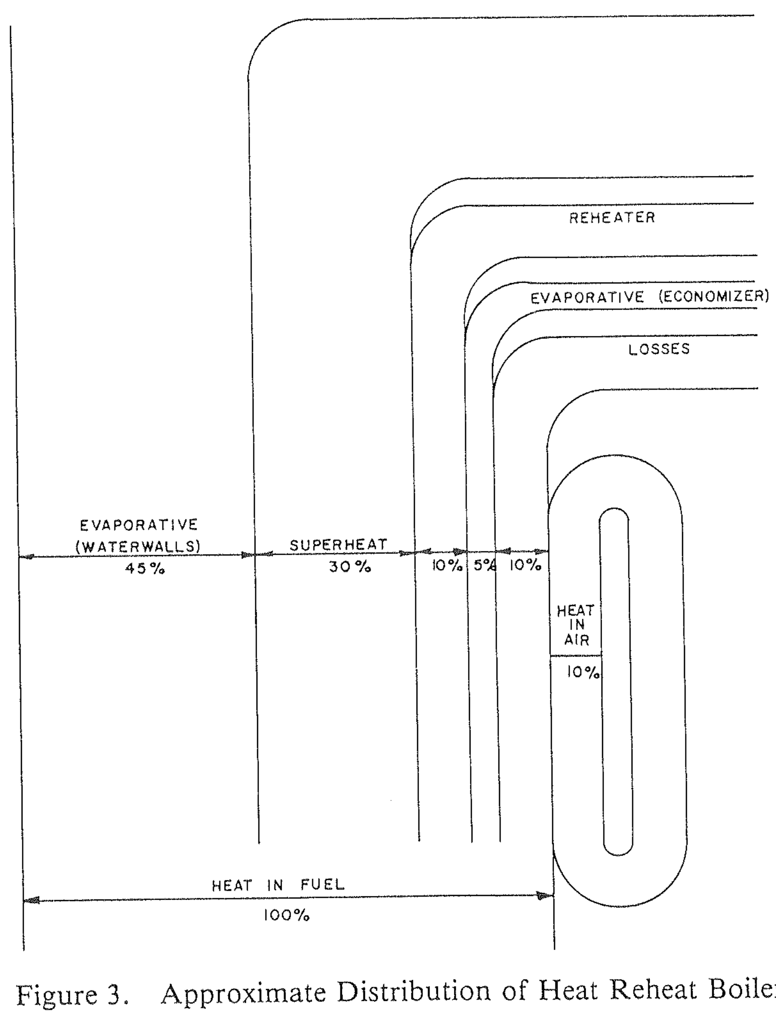

Figure 3. Approximate Distribution of Heat Reheat Boiler

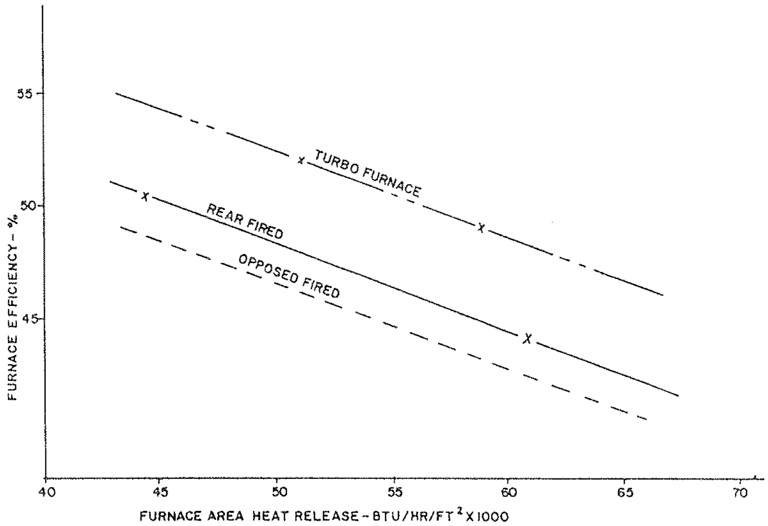

Figure 4. Furnace Efficiency Vs. Heat Release Rear Fired Furnace Vs. Dry Bottom Turbo Furnace

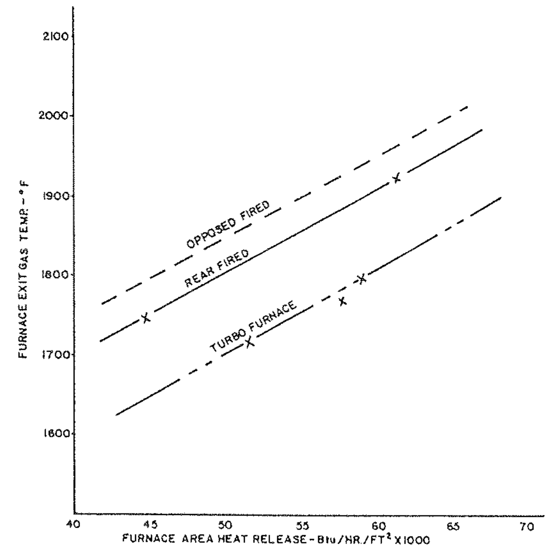

Figure 5. Furnace Exit Gas Temperature Vs. Heat Release Rear Fired Furnace Vs. Dry Bottom Turbo Furnace

Furnace efficiency, which is defined as the amount of heat recovered in the furnace up to and including the furnace exit plane divided by the total heat input, can be affected by the fuel being fired, slag or ash buildups, burners in service and numerous other factors. Figures 4 and 5 show the effect of type of firing on furnace efficiency and furnace exit gas temperature based on actual data of two similar units except for their mode of firing.

Two of the Riley dry bottom Turbo Furnace units in operation have furnace efficiencies which are significantly greater than design values. Furnace efficiency is a measure of furnace effectiveness. A high furnace efficiency means that a higher proportion of the heat released in the furnace by the fuel and air is consumed in the evaporative process. While this is good from a NO_x point of view and promotes good circulation, it can bring about low steam temperatures as described previously. In fact, that is exactly what has happened in the Santee Cooper Public Service Authority (SCPSA) and South Mississippi Electric Power Association units.

While all dry bottom Turbo Furnaces exhibit a greater furnace effectiveness than their straight wall fired counterparts, the problem of low steam temperature is not universally present. Dry ash buildups on the other units tend to negate the higher effectiveness and bring the performance more in line with predictions. See Figures 6 and 7.

Mr. P. J. Hunt reported last year to this group that the units in operation at that time "experienced some ash deposits which never reached thickness of more than two inches. . . were self-limiting. . . and were easily removed".

Interstate Power and the City of Springfield units fire coals with high to severe slagging tendencies and both meet their steam temperature requirements. SCPSA and South Mississippi have low to medium slagging tendency fuels and both fall short of meeting their steam temperature requirements. Because the furnaces of both units stay so exceptionally clean, heat transfer is increased to the waterwalls and furnace efficiency climbs above predictions. The resulting lower furnace exit gas temperatures provide insufficient thermal head for superheating and reheating the steam to design levels.

At SCPSA, additives were introduced with the coal fuel in an attempt to lay down deposits on the waterwalls and reduce the heat input on the evaporative size. These tests

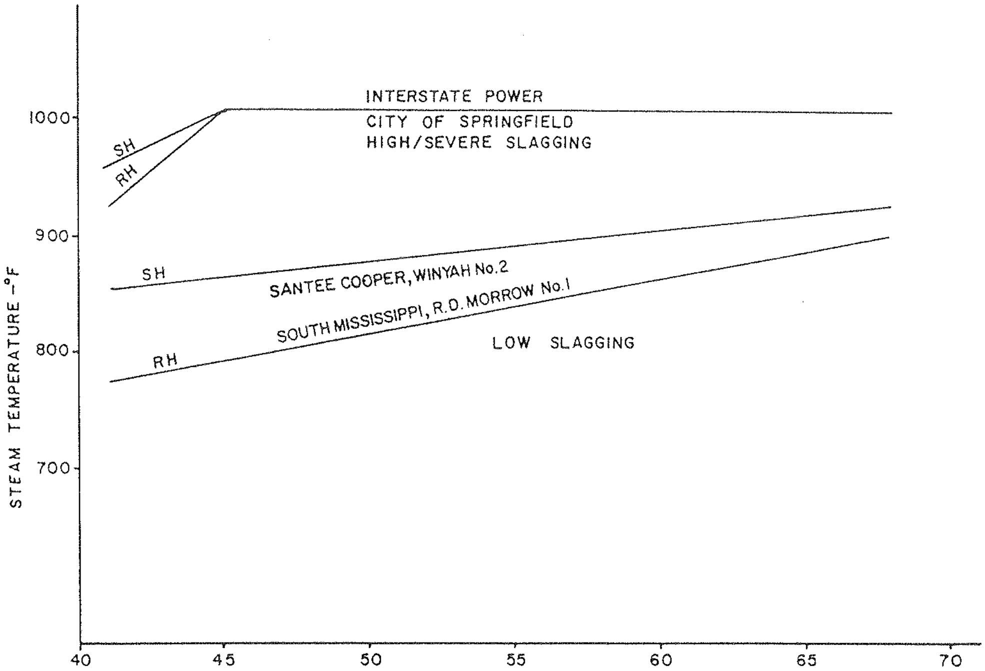

Figure 6. Final Steam Temperature Showing Affect of Fuel Slagging Tendency

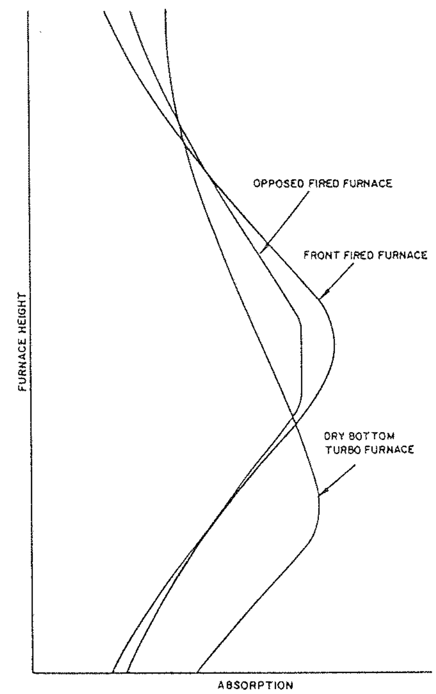

Figure 7. Furnace Absorption Profiles Showing Increased Dry Bottom Turbo Furnace Effectiveness

were very successful and steam temperatures reached predicted levels in a short time. The problem returned, however, when the walls shed their buildup as load was dropped during the evening hours. Further additives were not a practical solution due to the cost of the quantities needed to maintain a coating on the walls.

One corrective program is the removal of evaporative surface. New units on order for SCPSA are designed with lesser furnace surface. In the case of other units in the design stages which have low slagging fuel, waterwall platens have been removed.

To eliminate the need for waterwall surface removal on existing units, Riley is evaluating schemes to cover portions of the waterwalls by physical means to reduce their heat transfer effectiveness of the surface. These include refractory, tile, stainless steel sheets or plasma spray coatings. Buildup of ash deposits and maintenance of the covering are two adverse factors which must be considered. Modified firing techniques are also being evaluated to be used separately or in combination with furnace surface coating.

In summary, the words "Riley has been blessed with the most effective furnace in the utility boiler Industry" need not be a detriment. Quite the contrary, now that more is known about the performance characteristics of the dry hopper bottom Turbo Furnace, new units having smaller furnaces can be designed requiring less space and providing initial cost savings in less furnace steel, piping, insulation and lagging. The performance of the smaller furnace will be equal to its straight walled counterpart and still maintain the inherent advantages which go along with the Turbo Furnace. These include:

1. Low NO_x formation
2. Uniform Heat Input
3. Good Circulation
4. Uniform metal temperatures
5. Dry, self-limiting ash deposits

Appendix I

RILEY DRY BOTTOM TURBO FURNACE UNITS

73020	Emery Industries
74003	Interstate Power Company
74017	West Texas Utilities Company
74024	Cleveland Cliffs Iron Company
74030	South Mississippi Electric Power Association (2 Units)
74041	Santee Cooper Public Service Authority
74046	Delmarva Power and Light Company
74054	Dairyland Power Cooperative
74058	Salt River Project
75004	Arizona Electric Power Cooperative, Inc.
75005	City of Kansas City
75006	Alabama Electric Cooperative, Inc.
75007	Wisconsin Electric Power Company
75013	Wisconsin Electric Power Company
75015	Arizona Electric Cooperative, Inc.
75016	Alabama Electric Cooperative, Inc.
75017	Salt River Project
75018	Salt River Project
75033	Cleveland Cliffs Iron Co.
75034	Cajun Electric Power Cooperative, Inc.
75038	Cajun Electric Power Cooperative, Inc.
76002	Upper Peninsula Generating Company
76008	Upper Peninsula Generating Company
76012	Hoosier Energy Division
76013	Hoosier Energy Division
77014	Santee Cooper Public Service Authority
78001	Santee Cooper Public Service Authority
78005	Central Illinois Light Company

Appendix II

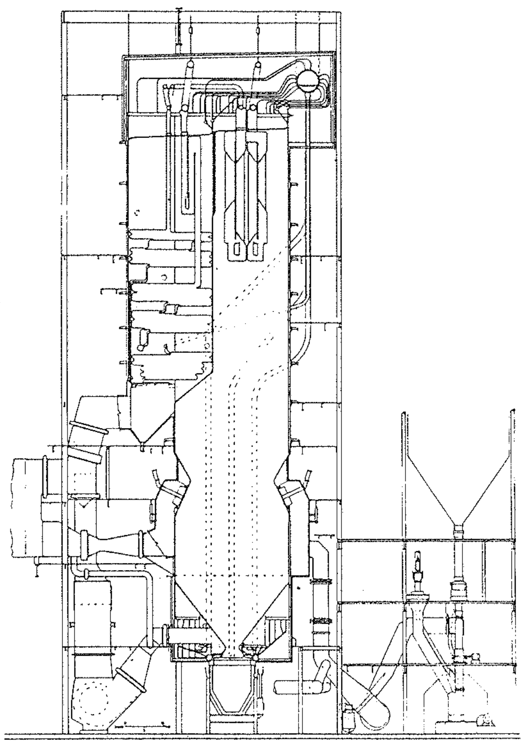

Figure 8. Southwest Power Station
City Utilities of Springfield
Springfield, Missouri

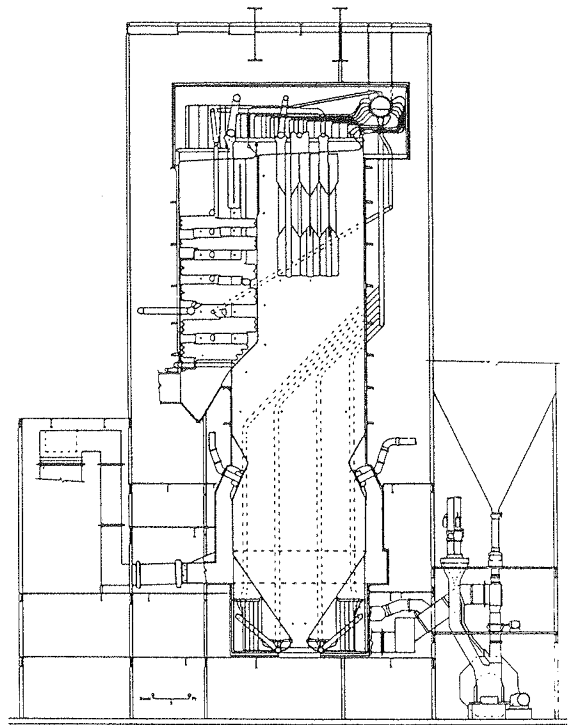

Figure 9. Interstate Power Company
Lansing Power Station
Lansing, Iowa

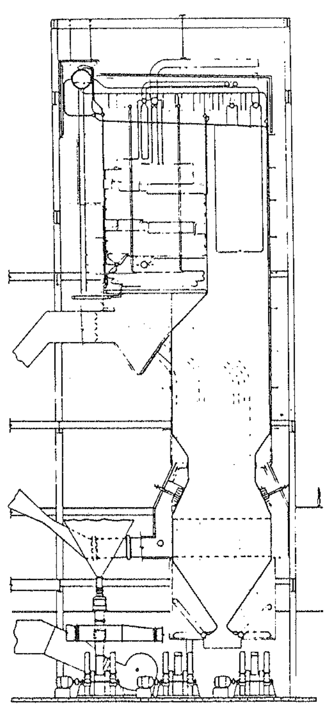

Figure 10. Santee Cooper
South Carolina Public Service Authority
Georgetown Steam Electric Station, Unit No. 2
Georgetown, South Carolina

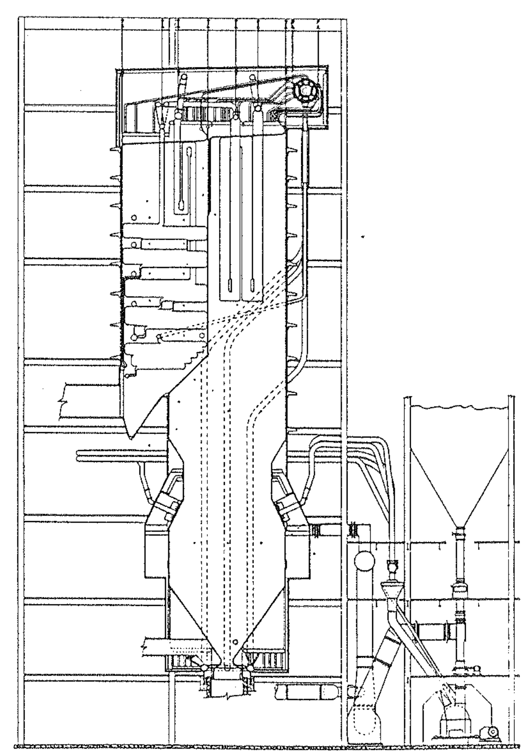

Figure 11. South Mississippi Electric Power Association
Purvis Plant, Units No. 1 and 2
Hattiesburg, Mississippi

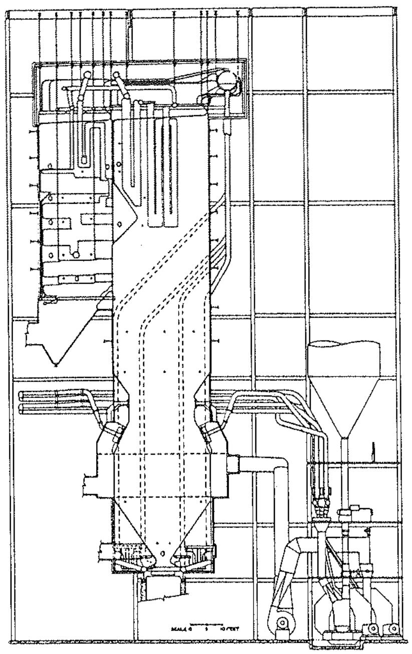

Figure 12. Alabama Electric Cooperative Inc.
Tombigbee Plant, Units No. 2 and 3
(near) Jackson, Alabama

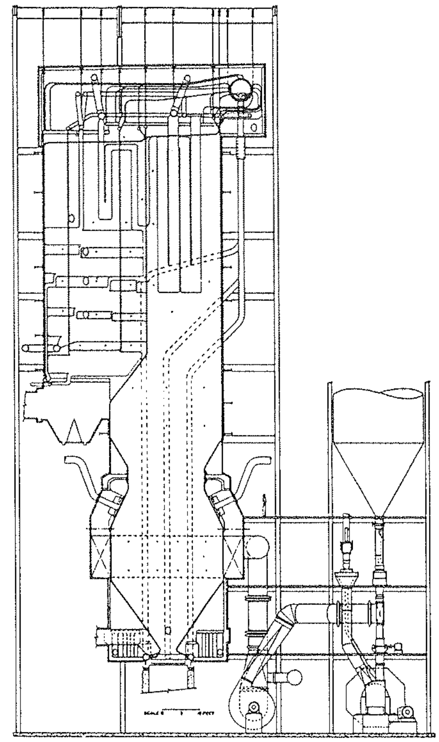

Figure 13. Arizona Electric Power Co-operative, Inc.
Apache Station, Units No. 2 and 3
(near) Cochise, Arizona