Babcock Power

Technical Publication

Firing Western Sub-Bituminous Coal at Interstate Power Company

by

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WORCESTER, MASSACHUSETTS

INTRODUCTION

During the period beginning on August 1, 1977 and extending through October 25, 1977, numerous tests were carried out on unit No. 4 of Interstate Power Company located in Lansing, Iowa. Included in these were the A. S. M. E. Boiler Performance Acceptance tests which were conducted on October 19, 1977. The intent of this paper is to summarize the results of these tests and to comment on the versatility of the dry bottom Riley Turbo® Unit.

DESCRIPTION OF THE BOILER AND FIRING EQUIPMENT

The boiler being discussed in this paper is a Riley reheat steam generating unit of the dry bottom Turbo Furnace design, and is in operation at the Interstate Power Company Station in Lansing, Iowa. It is a high pressure (2875 PSIG design) natural circulation, balanced draft unit and is rated at 1,920,000 lbs. steam/hr.; operating pressure is 2620 PSIG and final steam temperature is 1005/1005°F. Western sub-bituminous coal is fired through 18 Riley Directional Flame Burners supplied by 3 Riley Ball Tube Mill pulverizers. The convection section is single pass. Steam temperature control through the load range is by excess air. A sectional side elevation of the unit is shown in Figure 1.

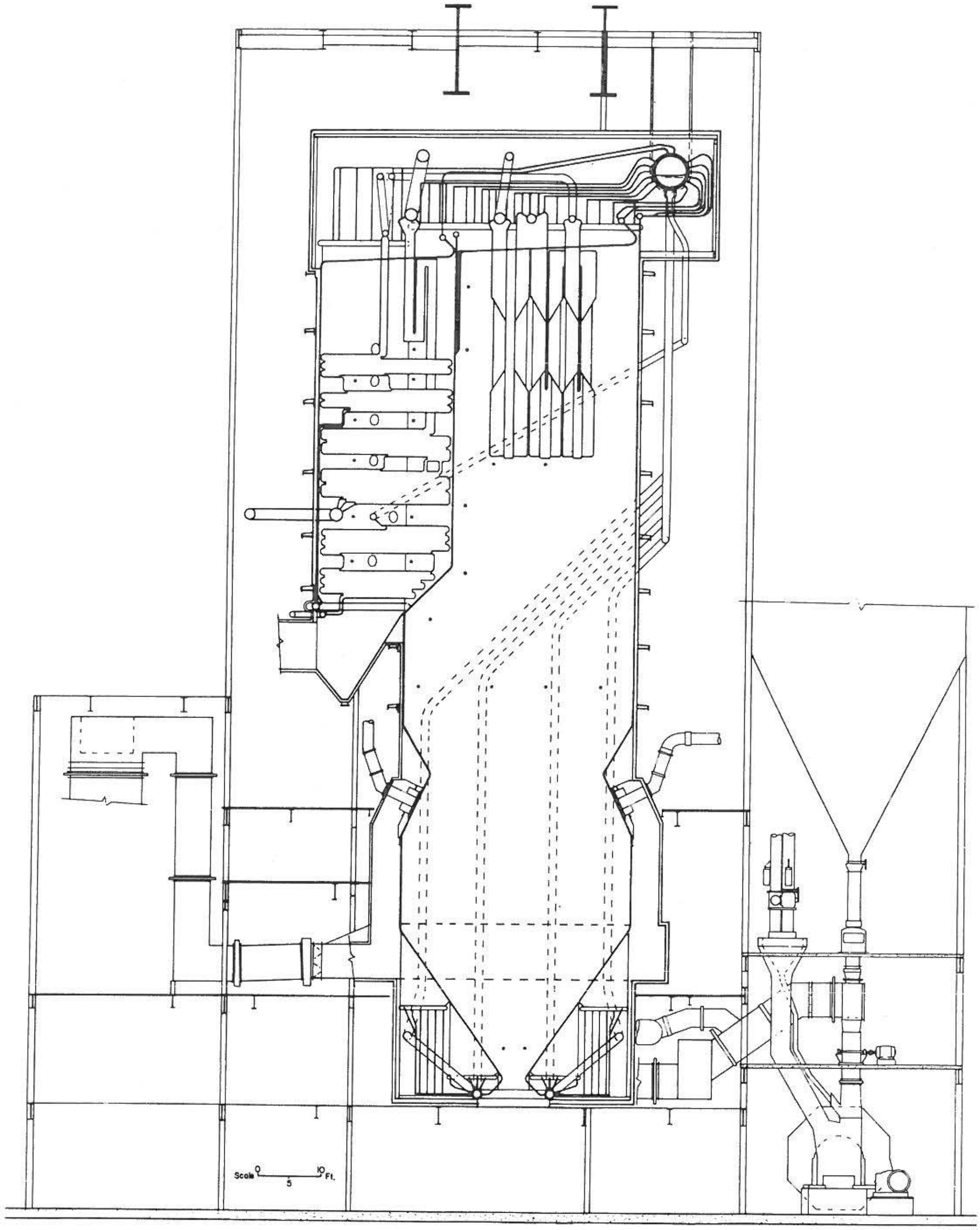


Figure 1. Interstate Power Company, Lansing, Iowa

The unique feature about the dry bottom Riley Turbo Furnace is its venturi-like cross section in the lower furnace with the burners firing downward into the lower furnace. An illustration of the venturi shape and flame pattern is shown in Figure 2.

Because combustion is gradually completed in the lower furnace area with flame temperatures in a range desirable for minimum fixation of atmospheric nitrogen, EPA limits on No_x emissions can be met. Figure 3 is a closeup of the Directional Flame Burner. The directional air vanes that are shown above and below the burner nozzle can be tilted up or down in a number of different positions. These positions are shown in Figure 4.

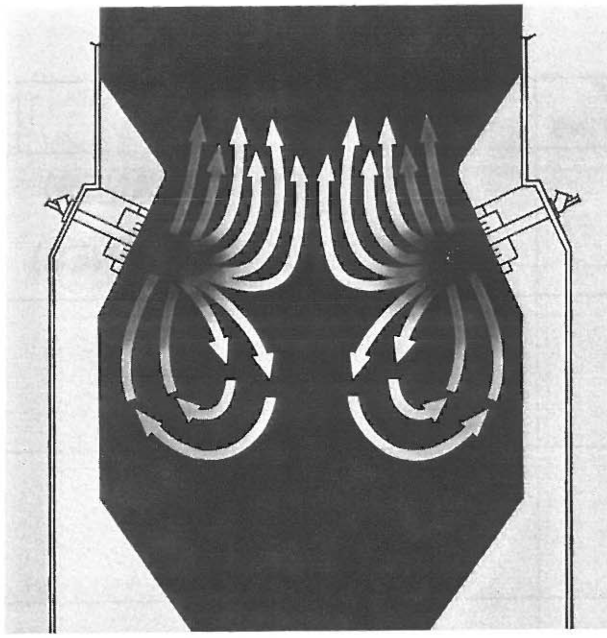


Figure 2. Turbo Furnace Venturi Shape
and Flame Pattern Diagram

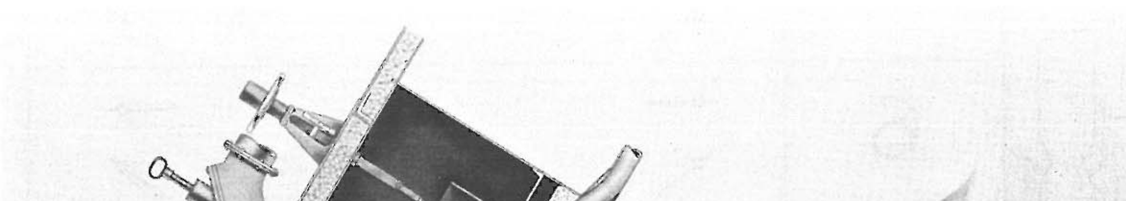


Figure 3. Riley Directional Flame Burner

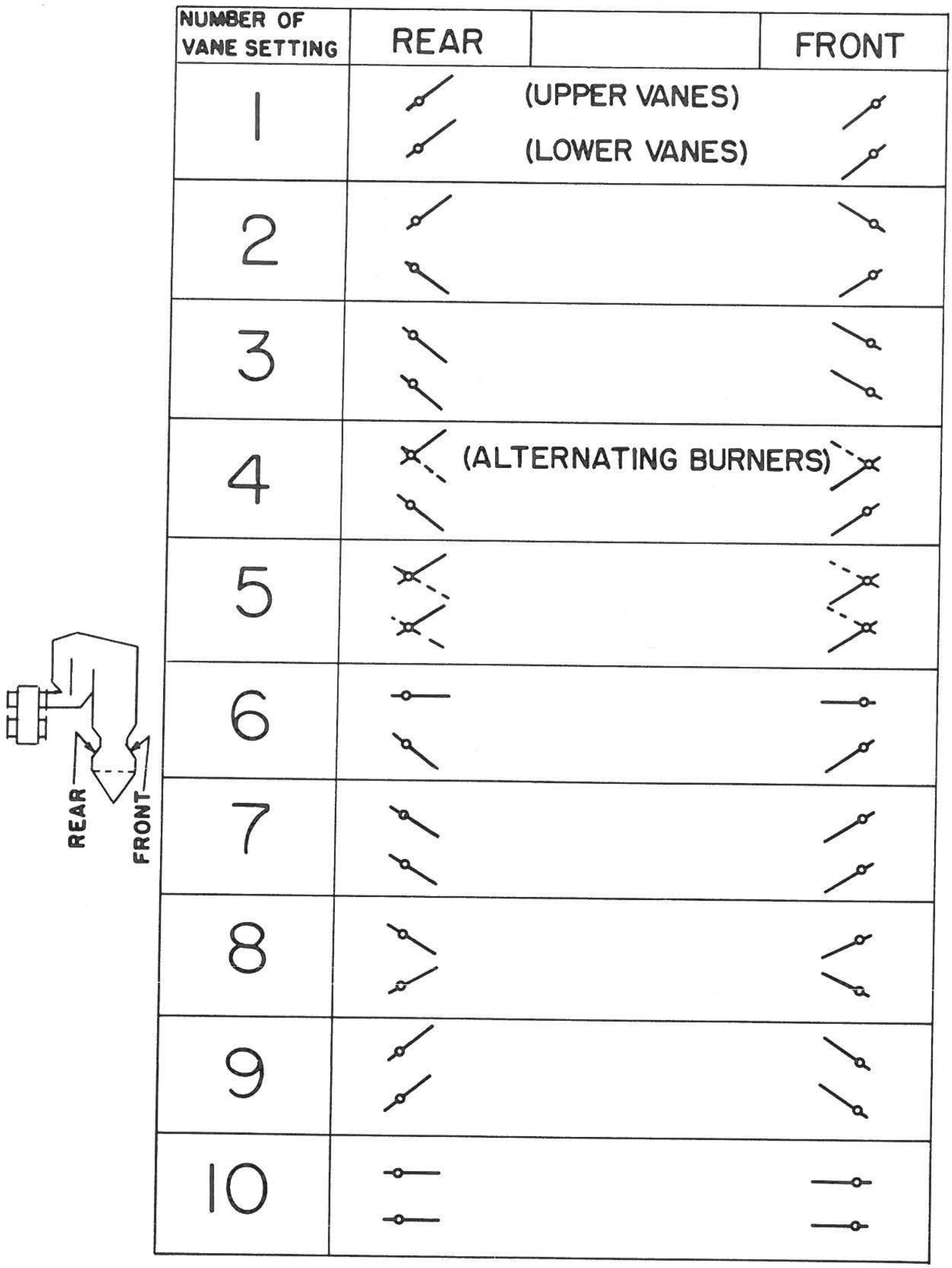


Figure 4. Burner Air Vane Settings

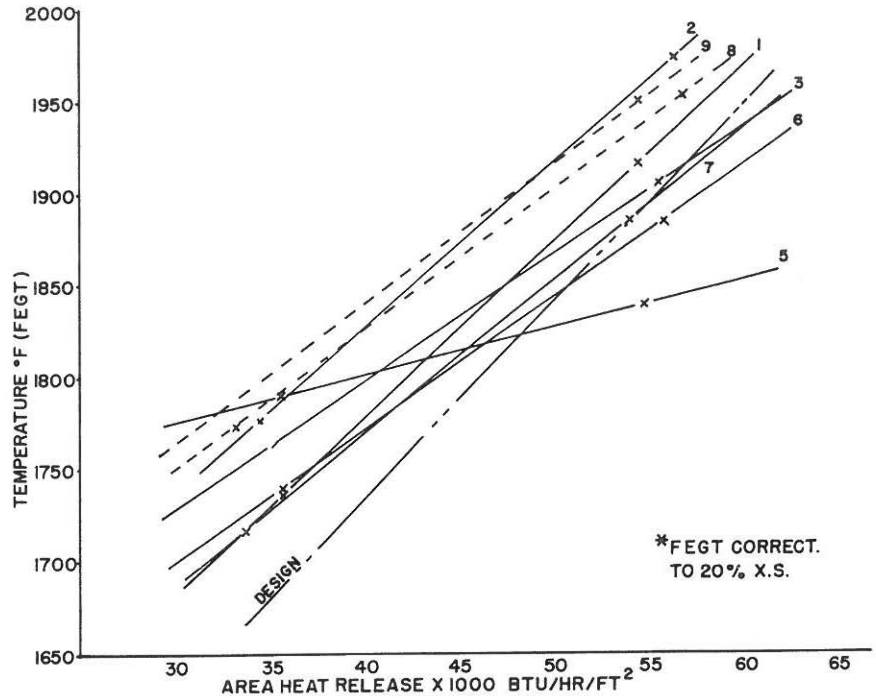


Figure 5. Effect of Directional Vane Position on FEGT

A test program was undertaken at the Interstate Power Plant to determine the effects of manipulating the directional air vanes, and Figure 5 shows the results on furnace exit gas temperature.

At a heat release of 60,000 BTU/HR-Ft² the variation in furnace exit gas temperature is approximately 160°F. The effects of this on steam temperature is shown in Figure 6; the variation in superheat temperature is 72°F and in reheat temperature is 58°F.

Some of the superheater temperature increase is caused by the change in radiant superheater absorbtion rates, due to the manipulation of the directional air vanes, as shown in Figure 7.

The above information shows how furnace performance can be changed to comply with the changes in coals without costly furnace modifications.

FUEL COMPARISON

The unit was designed to fire a western sub-bituminous coal. The ash chemistry indicated that the fuel would have a high slagging and fouling index. The constituents of the design fuel and actual fuel fired are shown in Table 1.

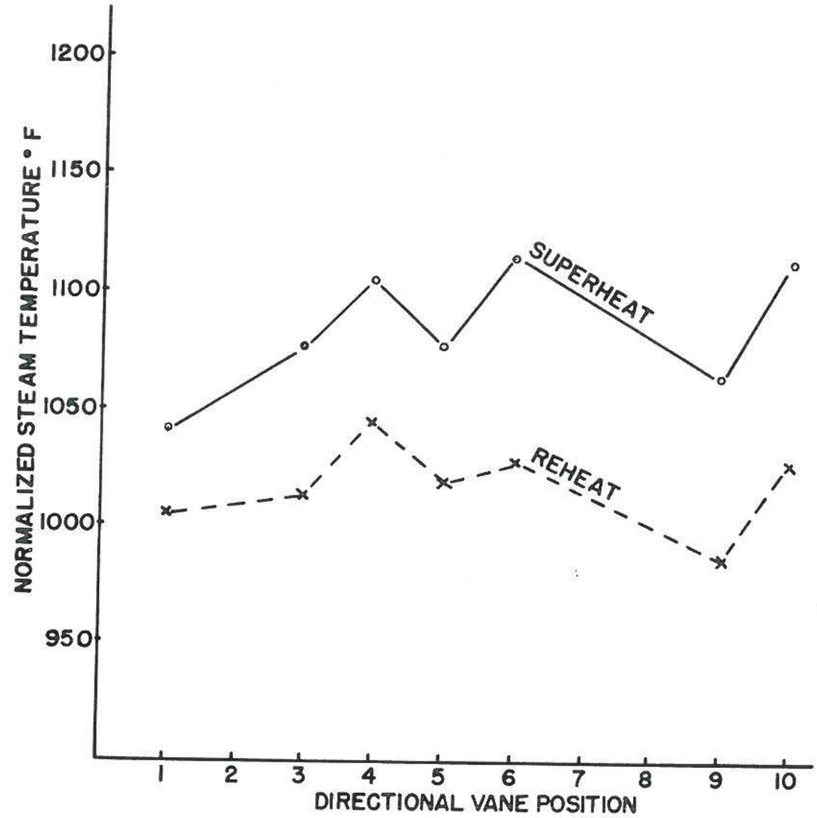


Figure 6. Effect on Final Steam Temperature of Directional Vane Position at 100% Load

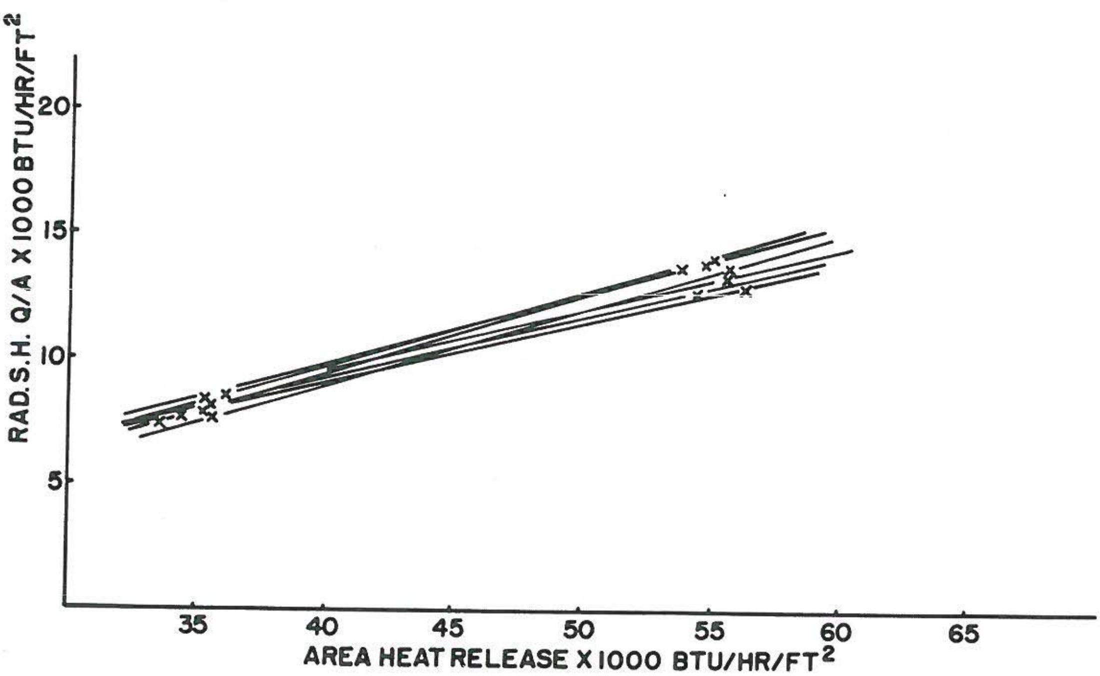


Figure 7. Radiant Superheater Absorption vs. Heat Release, Various Directional Vane Settings

"DESIGN" COAL

PROXIMATE ANALYSIS AS REC'D		ULTIMATE ANALYSIS AS REC'D	
Moisture	30.4%	Moisture	30.4 %
Volatile	31.2	Carbon	49.61
Ash	6.4	Hydrogen	3.55
Fixed Carbon	32.0	Nitrogen	0.63
		Oxygen	8.88
		Sulfur	0.48
		Ash	6.40
		Chlorine	0.05
	100.00%		100.00%

HHV = 8020 BTU/#

Grindability 63.

Initial Deformation
H = W (Reducing) = 2212°F

LABORATORY ANALYSIS "ACTUAL" COAL

PROXIMATE ANALYSIS AS REC'D		ULTIMATE ANALYSIS AS REC'D	
Moisture	31.2%	Moisture	31.2 %
Volatile	32.1	Carbon	47.4
Ash	5.2	Hydrogen	3.51
Fixed Carbon	31.5	Nitrogen	1.03
		Oxygen	10.94
		Sulfur	0.69
		Ash	5.23
	100.00%		100.00%

HHV = 8228 BTU/#

Grindability 72.5

Initial Deformation
H = W (Reducing) = 2110°F

ASH ANALYSIS

Constituents	"Actual" Coal	"Design" Coal
SiO_2	35.8%	28.87%
Al_2O_3	{ 18.7	18.57
TiO_2	}	0.40
Fe_2O_3	5.0	8.32
CaO	{ 25.3	26.49
MgO	}	2.96
Na_2O	1.2	0.82
K_2O	0.3	1.17
SO_3	12.5	11.31
Undetermined	0.2	

TABLE 1

Figure 8.

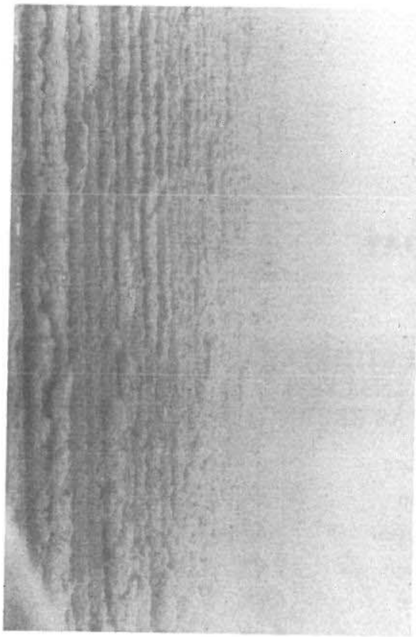


Figure 9.

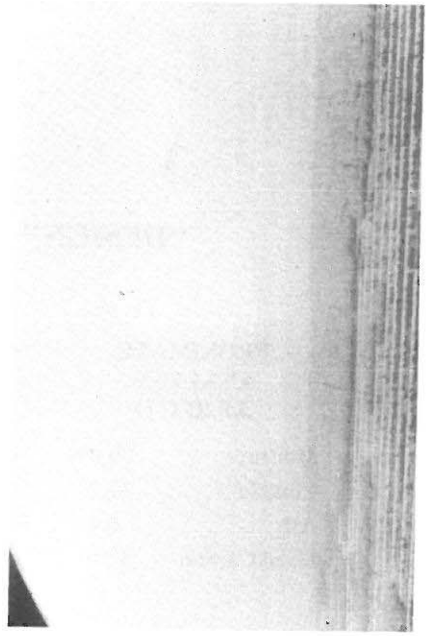


Figure 10.

Slag Accumulations, Radiant Superheater Tips and Furnace Walls

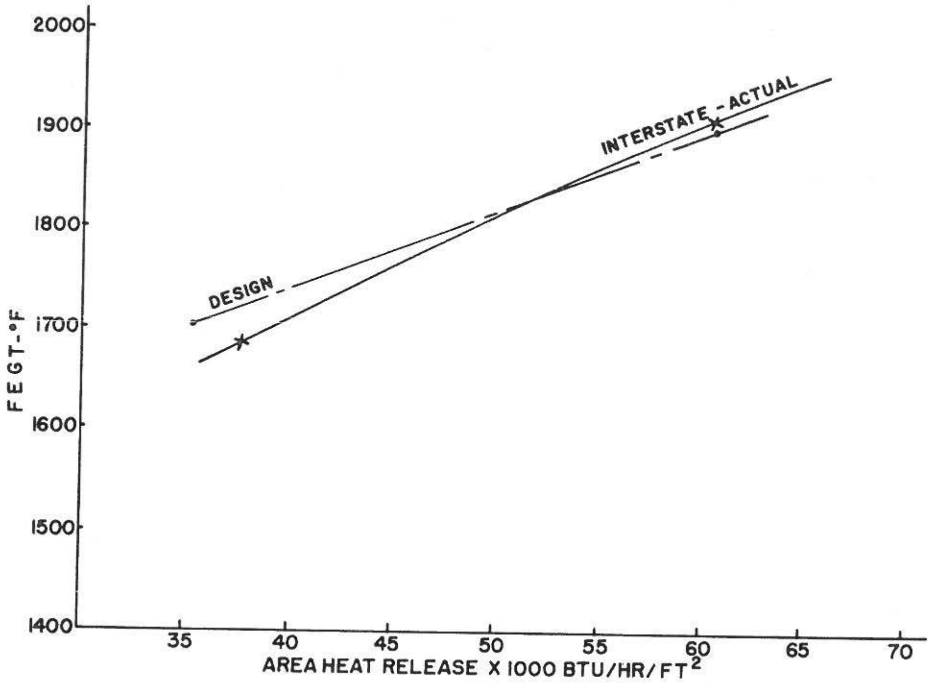


Figure 11. Actual Data FEGT vs. Heat Release
Coal Fired Dry Bottom Turbos

Slag accumulations on the radiant superheater tips and the furnace walls are shown in Figures 8, 9, and 10.

These accumulations proved to be dry and friable and easily removed with the design complement of soot-blowers. Ash fouling has occurred in the primary superheater and reheater tube bundles in the front section of the convection pass, up close to the rear furnace wall. The amount of fouling is not causing performance problems. Adherence to soot-blowing schedules and sequences prevents uncontrolled back pass plugging and maintains high availability operation.

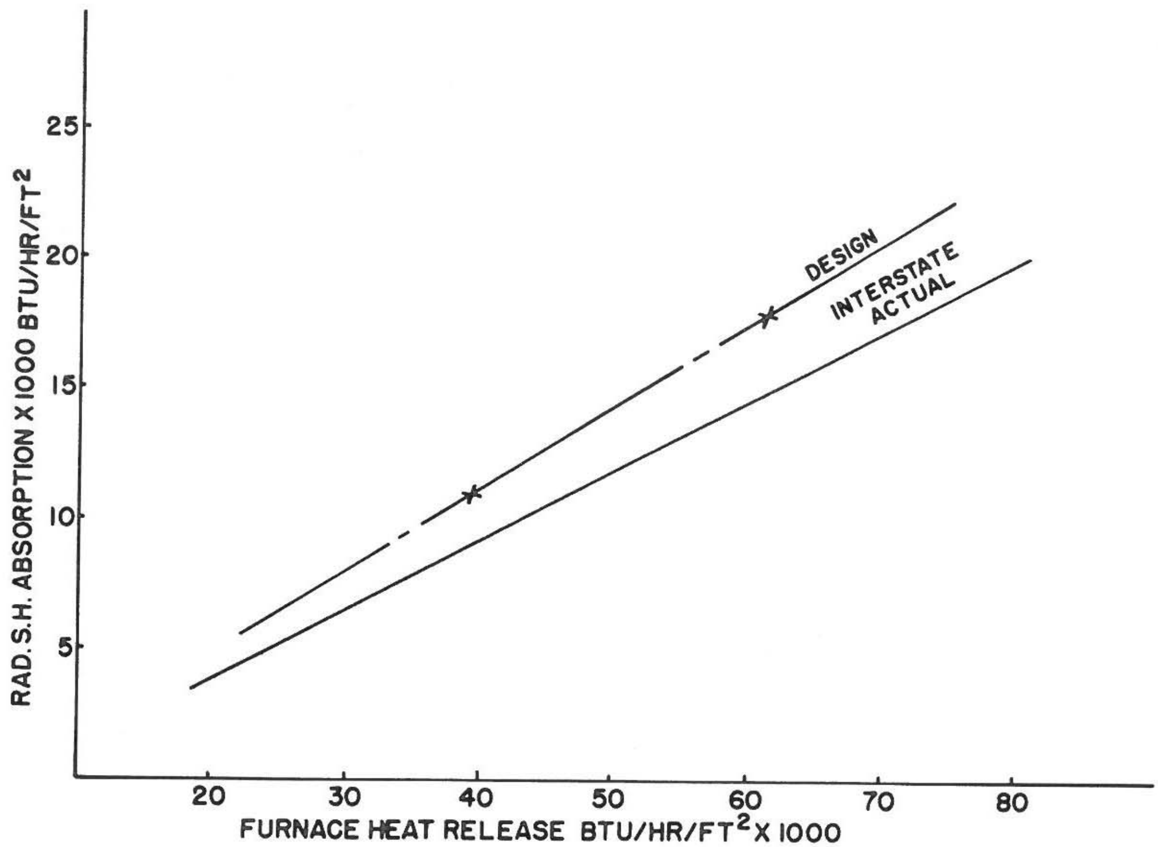


Figure 12. Radiant Superheater Absorption vs. Heat Release From Actual Data

COMPARISON OF PREDICTED VERSUS ACTUAL PERFORMANCE AS RECORDED FROM ASME TEST

Furnace exit gas temperatures (FEGT) were measured with high velocity thermocouple probes traversing at the furnace exit. These temperatures compared very closely to those calculated by a heat balance from the economizer outlet to the furnace exit. A comparison of measured FEGT versus predicted are shown in Figure 11.

Radiant superheater absorption rates are predicted during design. The abilitity to predict these rates accurately is very important because superheater steam temperature rates are predicated on these predictions. Actual versus predicted absorption rates are shown in Figure 12.

The unit performance during the ASME tests met with all guarantees with the exception of uncorrected gas temperature leaving the air heater (318°F. actual versus 300°F. guaranteed) and steam purity (0.41% moisture carryover actual versus 0.2% guaranteed).

Air heater performance did not meet guarantees due to pluggage in one air heater and slightly higher than predicted excess air. If the air heater was clean and excess air normal, uncorrected gas temperatures leaving the air heater would be 5 to 10°F. above guarantee. Performance curves, actual versus predicted, are shown in Figures 13, 14, 15, and 16.

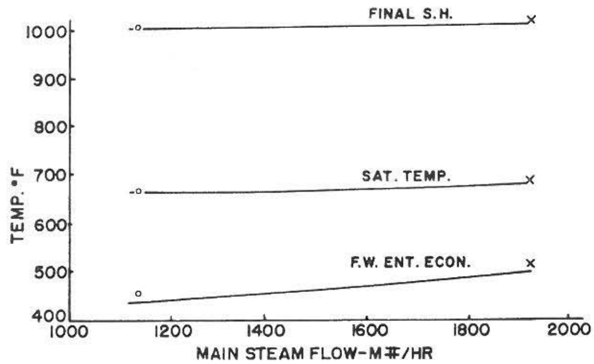


Figure 13.

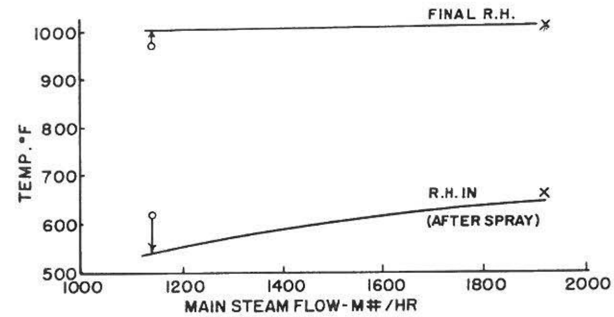


Figure 14.

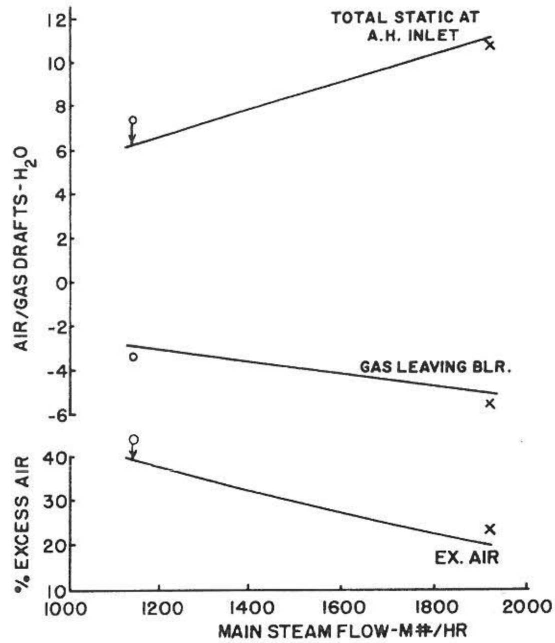


Figure 15.

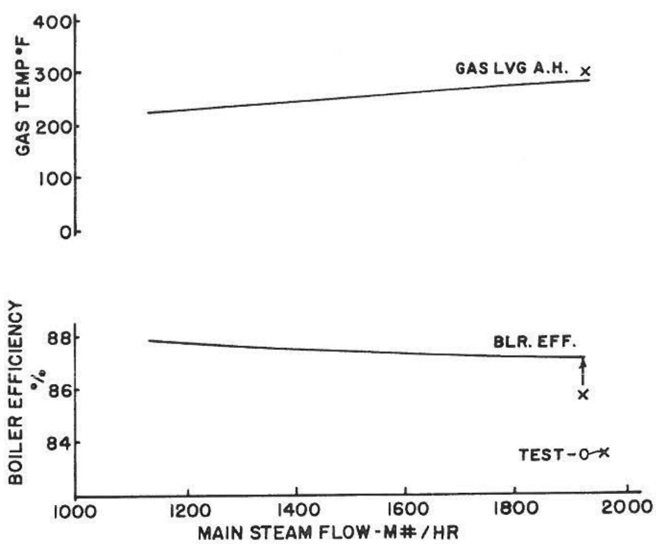


Figure 16.

STEAM PURITY

Riley uses centrifugal type primary separators and channel type secondary separators in the main steam drum to control steam purity. The guarantee for steam purity was 1 PPM total dissolved solids with maximum boiler water concentrations of 500 PPM which equates to 0.2% moisture carryover. After the unit started up and ran for several months, steam purity measurements showed moisture carryover exceeding 2%.

The unit was brought off the line and an inspection showed:

a) errors in the installations of the drum internals.

b) substantial leakage around the primary separators.

After the above areas were repaired, an intermediate separator was installed, and the unit was retested. The moisture carryover level was reduced to 0.18%.

Initial and final drum internal configurations are shown in Figures 17 and 18.

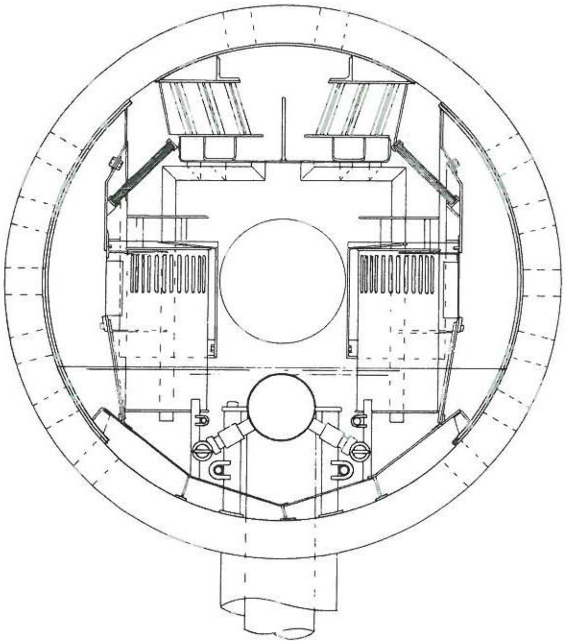


Figure 17.

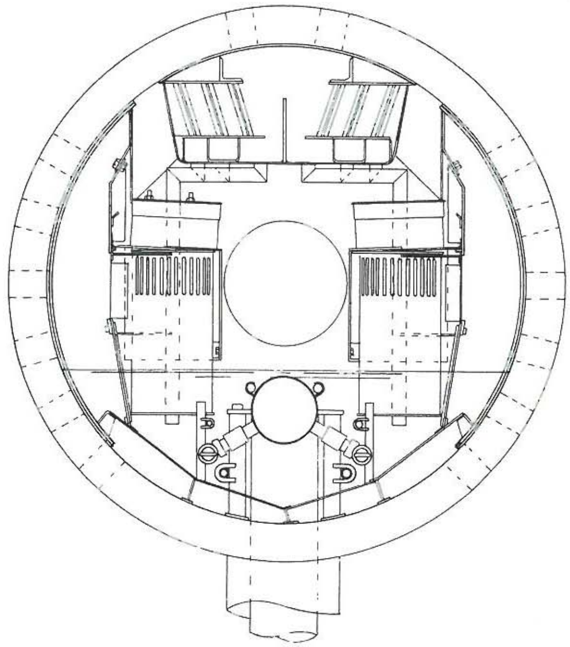


Figure 18.

HEAT DISTRIBUTION

In order to determine tube metal temperature profiles shown in Figure 19, thermocouples were attached to selected tubes in the superheater and reheater across the width of the unit. The plot shows outlet tube temperature profiles of the high temperature superheater, the low temperature superheater and the high temperature reheater.

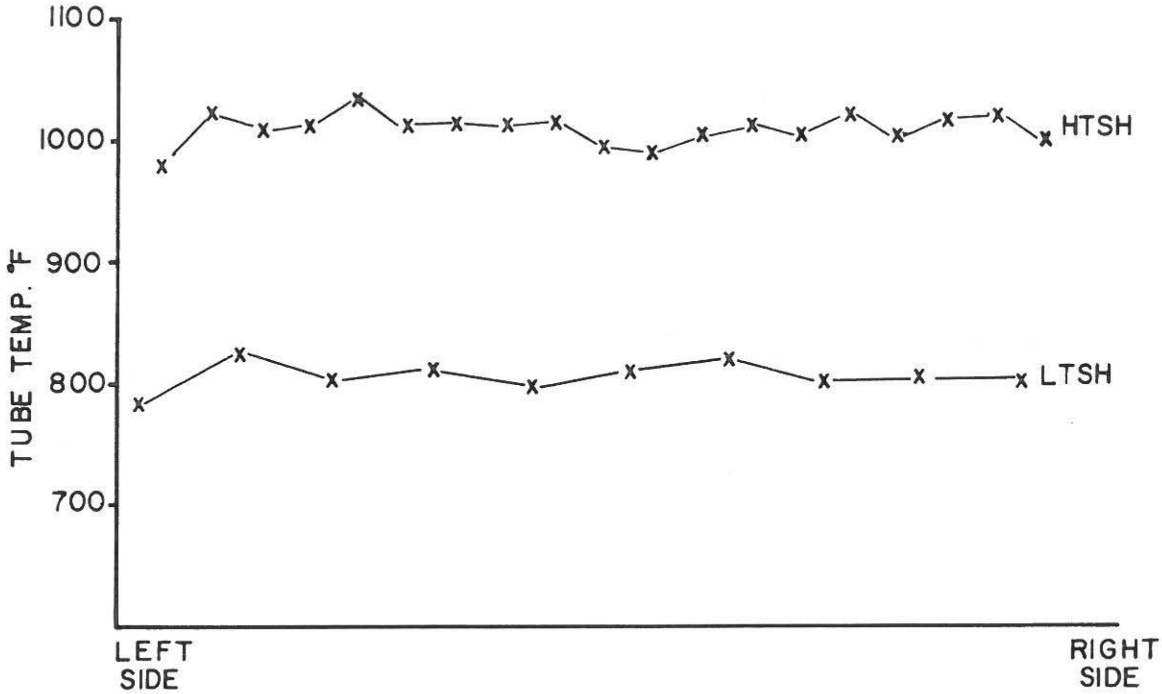
The flat profiles are indicative of a uniform heat distribution across the unit width.

Because of the uniform lateral distribution of fuel and air into the Turbo Furnace, gas temperatures and flows entering superheater, reheater and economizer heating surfaces produce very level and balanced tube metal temperature patterns. This will result in longer trouble-free life of the tubing material.

DESCRIPTION OF PRIMARY AIR SYSTEM

The primary air system is comprised of two primary air fans (driven by two 1500 hp, 1780 rpm motors), each located on the cold side of a corresponding trisector air heater, plus three double ended Ball Tube Mill Systems. The Ball Tube Mill Systems which provide pulverized coal for firing are located on the hot side of the trisector air heaters. Each Ball Tube Mill is 11½ ft. dia. x 16 ft. long, and each is driven at 17.16 rpm by a 1250 hp motor through appropriate reduction gearing. Raw coal flows vertically downward from the coal silos to gravimetric feeders located above both ends of each Ball Tube Mill. Hot air from the hot side of the primary air system is delivered via inter-connecting ductwork to both ends of the mill system for coal drying and transport. Approximately 2/3 of the coal drying within each mill system is carried out in Riley 506 Crusher Dryers, one of which is located above each mill inlet.

The 506 Crusher Dryer is a constant speed, swing hammer type coal crusher driven by a 75 hp, 880 rpm motor. It simultaneously crushes and dries all of the surface moisture in the coal and some of the inherent moisture before discharging the coal/air mixture to the Ball Tube Mill for final pulverization. The Ball Tube Mill System schematic (Figure 20) shows components found in each ball tube mill system including feeders, Crusher Dryers, the Ball Tube Mill, classifiers, coal plug valves, and burners.



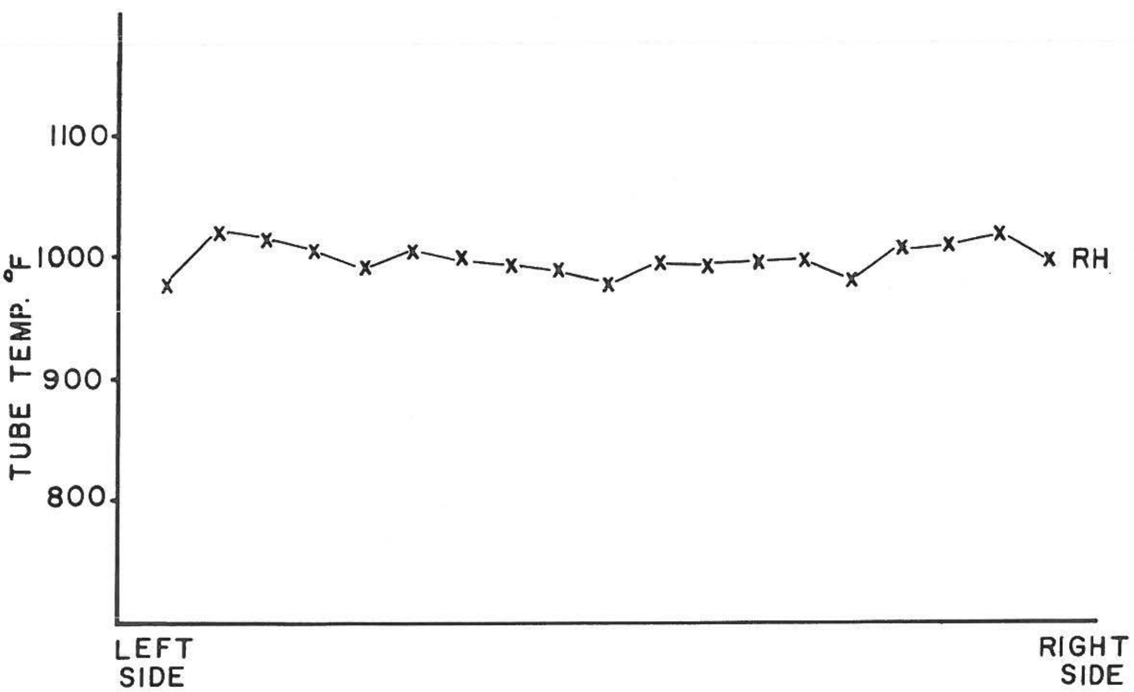


Figure 19. Tube Metal Temperature Profile
High Temperature Superheater, Low Temperature Superheater
and Reheater

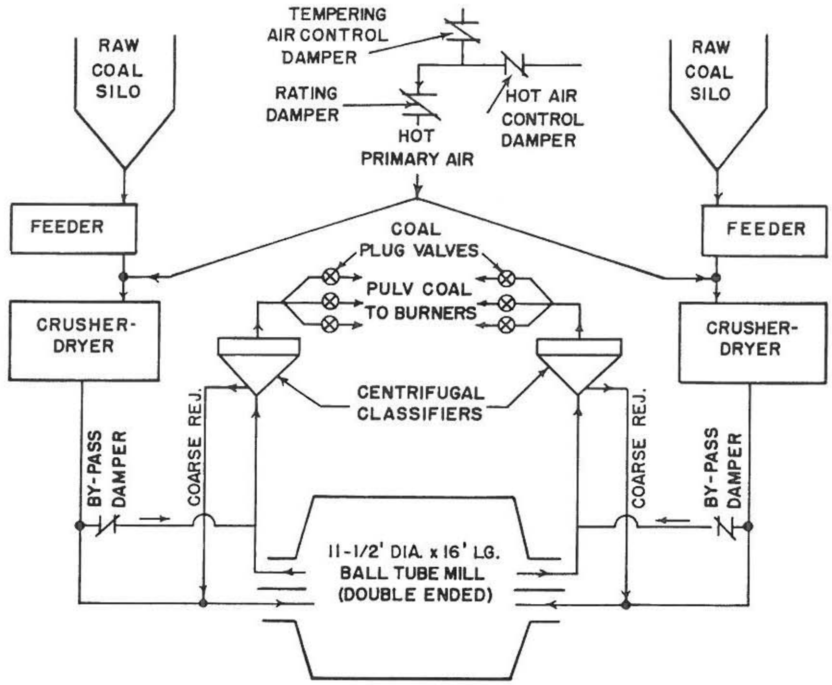


Figure 20. Mill System Schematic

MILL SYSTEM PERFORMANCE

GRINDING:

Coal Source	Bel Air Wyoming
Unit Output, lbs Steam/hr	1,910,000
Raw Coal to System, lbs/hr	105,534
Primary + Seal Air Flow, lbs/hr	251,334
Air-Fuel Ratio (Input) lbs/lb	2.38
Power Input to Mill, kW-hr/ton	12.52
P.A. Fan Discharge Pressure Ins. H_2O	45.5″
Pulv. Coal Fineness, %/#200	72.24
Hot P.A. Header Pressure Ins. H_2O	32.0

DRYING:

Primary Air Temp. to Crusher	593.3°F
Classifier Outlet Temp.	149°F
Moisture in Raw Coal	31.2%
Total Moisture Input, lbs/hr	32,927
Total Moisture Evaporated, lbs/hr	18,680
Moisture in Pulv. Coal	16.4%
Initial Moisture Removed	56.7%

TABLE 2

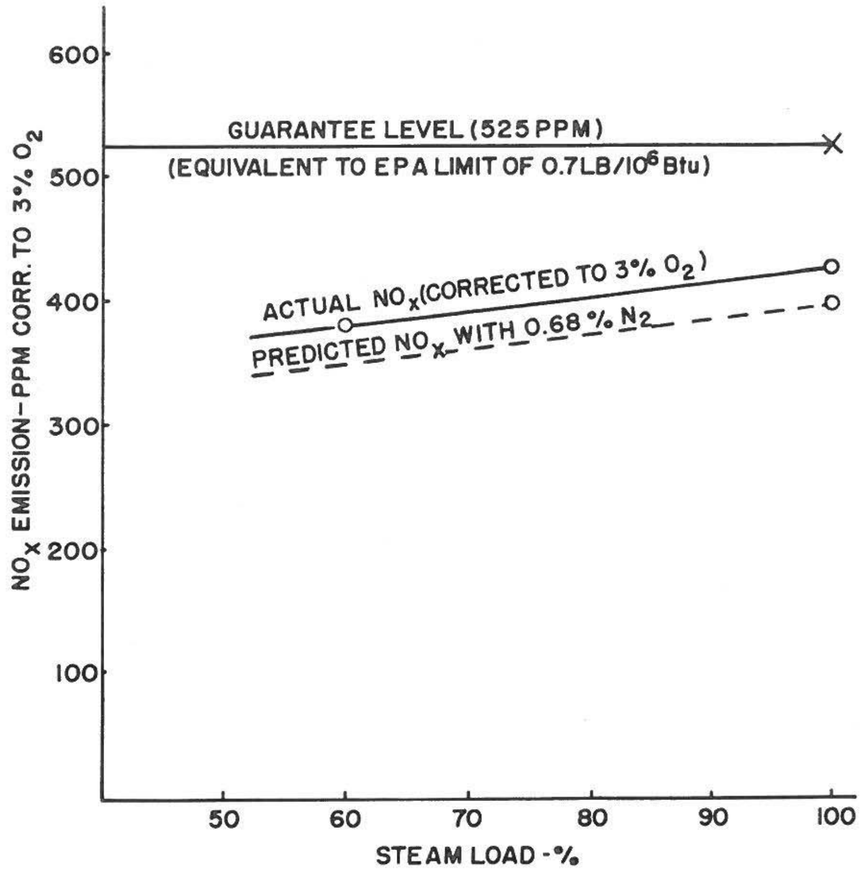


Figure 21. Actual and Guarantee NO_x Emissions vs. Steam Load (Normalized to 20% Excess Air)

MILL SYSTEM PERFORMANCE

A summary of test results for a typical mill system using the Bel Air, Wyoming coal is listed on Table 2. It gives a breakdown of the data for both the drying and pulverizing functions of the system.

UNIT NO_x EMISSIONS

Figure 21 shows how well the unit performed with regard to NO_x emissions. The "Actual" NO_x values measured on this unit are shown in relation to the NO_x limit which Riley guaranteed to the customer (525 ppm dry and adjusted to 3% O_2 at 100% of boiler output when firing the "design" coal having an as-fired Nitrogen content not to exceed 0.6% with 20% excess air. Also shown are the NO_x values that Riley predicted would occur based on a 0.68% as-fired Nitrogen content in the coal. It is important to note that the "Actual" NO_x values correspond to the "actual" coal with an as-fired Nitrogen content of 1.03% as shown in the "Coal Analysis" (Table 2).

UNIT CARBON LOSS

The total carbon loss for the unit was calculated to be 0.34%.

SUMMARY

As other dry bottom Turbo Furnace units go into operation, extensive tests will be performed to increase our knowledge as to their flexibility when firing different coals. The data that we have to date confirms the following:

1. Present Turbo Furnaces can conform to lower NO_x emission standards without costly modifications.
2. The Directional Flame Burner allows flexibility in operation if significant fuel changes occur.
3. Turbo Furnace combustion efficiency is at least equal to that of straight walled furnaces, and appears to be significantly better.
4. Furnace slag deposits have been shown to be dry and self-limiting when firing severely slagging coal.
5. The balance tube metal temperature profiles demonstrated in the Turbo Furnace will give longer tube life.
6. Better efficiency of a Riley Turbo Furnace will permit furnace exit gas temperatures from smaller furnaces equal to those from larger straight walled furnaces. This results in lower costs for foundations, steel, piping, insulation, and lagging.

This is the first Riley unit to go on line which utilizes trisector air heaters (i.e., cold-side primary air fans) and which burns Western sub-bituminous coal. Referring to Table 2, it is important to note that the classifier outlet temperature of 149°F. is lower than the 160°F. temperature originally anticipated. This lower temperature value is desirable both from a fire-prevention standpoint and a coal-drying standpoint. More specifically, it indicates that the system is evaporating more moisture from the coal than originally predicted. Also, the lower classifier discharge temperature gives added assurance that the coal/air mixture is staying below the auto-ignition temperature of the coal. The 16.4% inherent moisture content remaining in the coal at the classifier discharge is low enough to ensure stable ignition at the burners.