REPORT ON DESIGN MODIFICATIONS TO SOUTH CAROLINA PUBLIC SERVICE AUTHORITY UNIT NO. 2 GEORGETOWN, SOUTH CAROLINA

by
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RILEY STOKER CORPORATION
WORCESTER, MASSACHUSETTS

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INTRODUCTION

One of the most critical areas in the design of any steam generator is furnace performance. In most cases when a unit is brought into service, furnace performance is reasonably close to design and small burner adjustments or changes in excess air are all that are necessary to correct small variations from predictions. However, if there is a significant change in fuel between original specification and what is ultimately fired there will most probably be a major change in furnace performance. This could, in turn, have an adverse effect on overall unit performance, generally in low superheat and/or reheat final steam temperatures, and could require major changes in order to correct the problem. This report describes a successful mechanical technique used to alter furnace performance and heat absorption characteristics on a 300 MW utility boiler.

BACKGROUND

South Carolina Public Service Authority - Unit No. 2 at Georgetown, South Carolina was the third dry bottom Riley Turbo utility boiler to see service. The unit was designed for a high slagging coal (2100 °F fusion temperature) and a maximum capacity of 2,100,000 lbs of steam per hour, a 2,600 psig operating pressure, and 1005/1005 °F superheat and reheat final steam temperatures. The unit is base loaded and has an intended steam temperature control range from 65% to 100% load. Steam temperatures are controlled by rear pass dampers which regulate the amount of flue gas flowing through the individual superheater and reheat cavities. (Figure 1 is a sectional elevation view of the unit.)

Early operation of the boiler, with very high fusion temperature coal (2750 °F), indicated low final steam temperatures. In order to obtain a strong data base from which corrective action could be determined, an extensive diagnostic test program was conducted in September 1977. The results of the program confirmed the unit to be deficient in superheat and reheat final steam temperatures at both control point and full load. Figure 2 compares design versus actual measured final steam temperature obtained during the September test program.

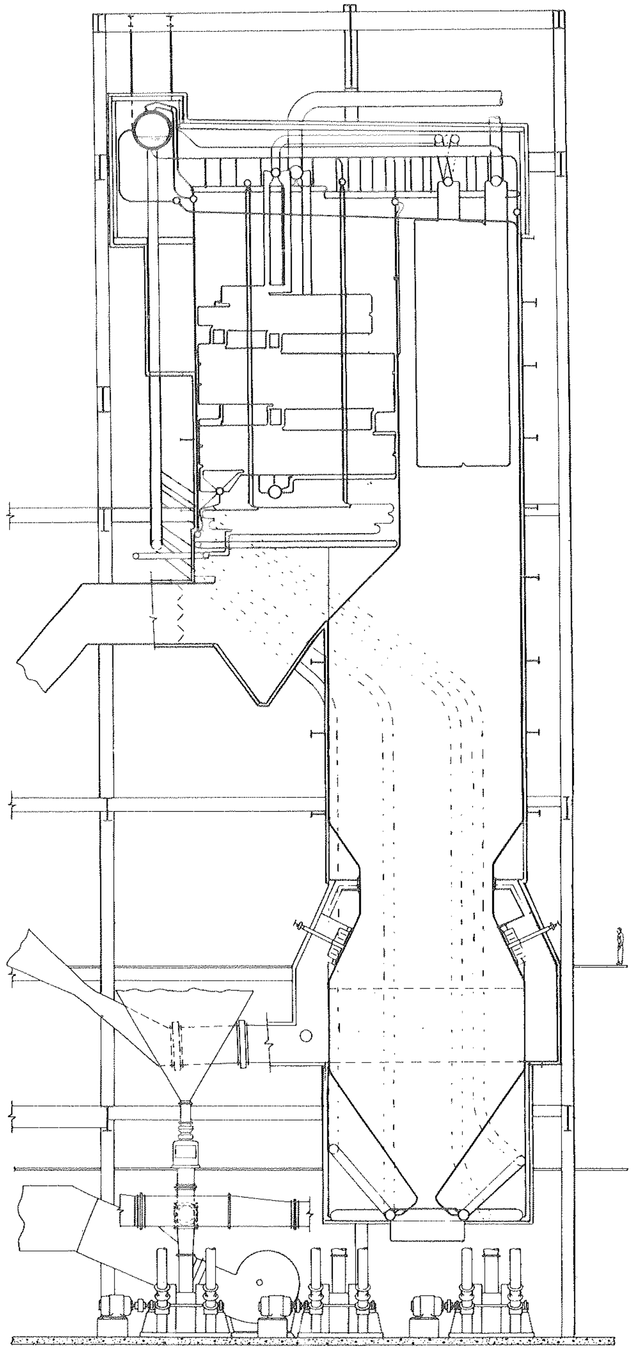


Figure 1 South Carolina Public Service Authority, Unit No. 2
Georgetown, South Carolina

	DESIGN		ACTUAL	
	CP	MCR	CP	MCR
FINAL S.H. TEMP., °F	1005	1005	875	870
FINAL R.H. TEMP., °F	1005	1005	800	835
% EXCESS AIR	20	20	20	20

Figure 2 Design versus Actual Steam Temperature Performance

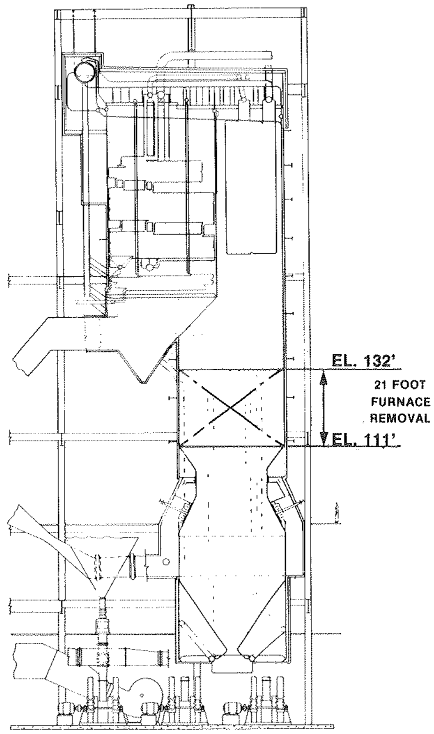


Figure 3 Proposed Furnace Removal Area

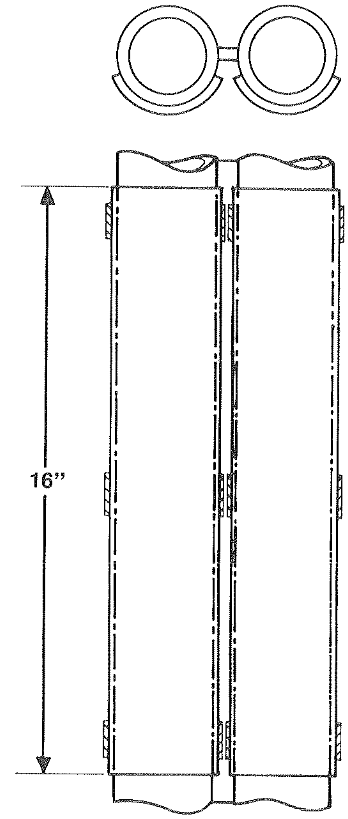


Figure 4 First Test Shields

An in-depth analysis of the performance test data revealed that the low final steam temperatures were caused by two principal factors:

1. A shortage of reheater surface as indicated by the superheater/reheater final steam temperature mismatch at control point.
2. A lack of furnace tube wall fouling or ash accumulations resulting in very high furnace efficiency and low furnace exit gas temperature.

In order to achieve design steam temperatures two simultaneous actions were necessary:

1. The addition of reheater surface.
2. The development and implementation of a means of reducing the furnace efficiency and/or raising the furnace exit gas temperature.

The addition of reheater surface posed no problem, as sufficient space existed in the unit. However, before the exact amount of additional surface could be determined, it was first necessary to select a means of changing the furnace performance and to direct that effect to the new reheater surface.

ALTERNATIVES FOR MODIFYING FURNACE PERFORMANCE

Several options were investigated for reducing the furnace efficiency. Those considered and/or tried were:

1. *Burner Adjustments* - Both air and fuel input direction can be controlled with the directional flame burner, used on the Turbo Furnace. Combustion zone or level will be determined by those adjustments. The higher the combustion zone in the furnace, the higher will be the radiant superheater absorption and the furnace exit gas temperature. Maximum utilization of burner adjustment resulted in a 50°F increase in furnace exit gas temperature and a 30-40°F increase in final superheat/reheat temperatures. Because of the magnitude of the deficiencies, burner adjustments by themselves were ruled out as a prime means of correction for this unit.

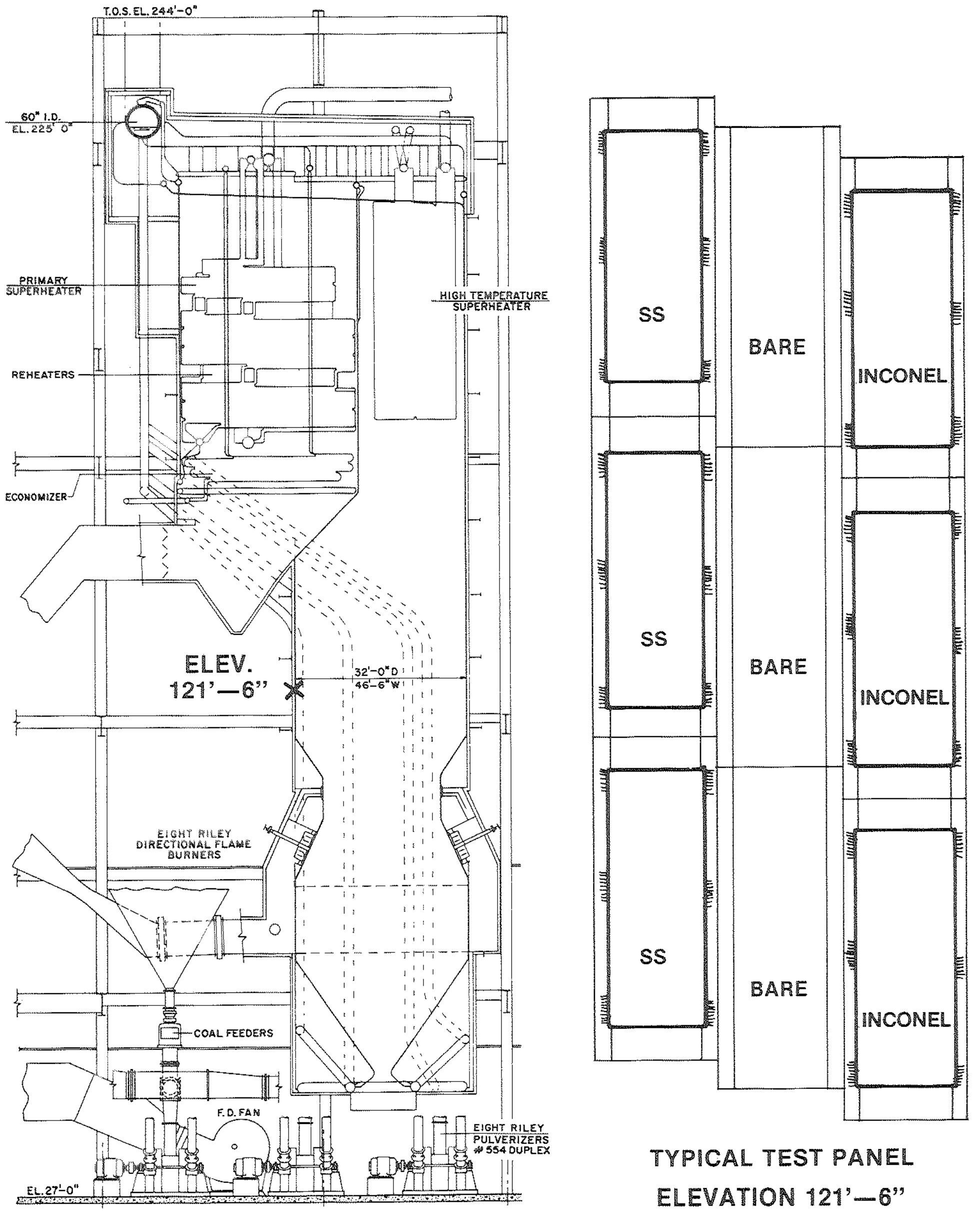


Figure 5 Typical Shield Test Panel Installation

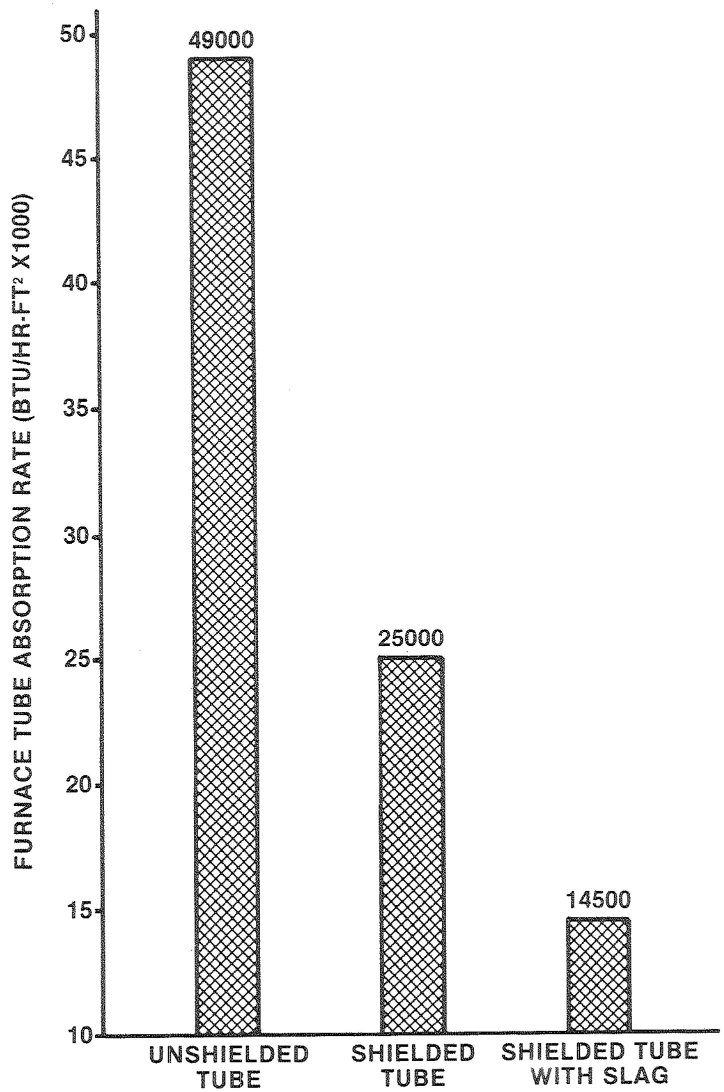


Figure 6 Heat Absorption Rate Comparison

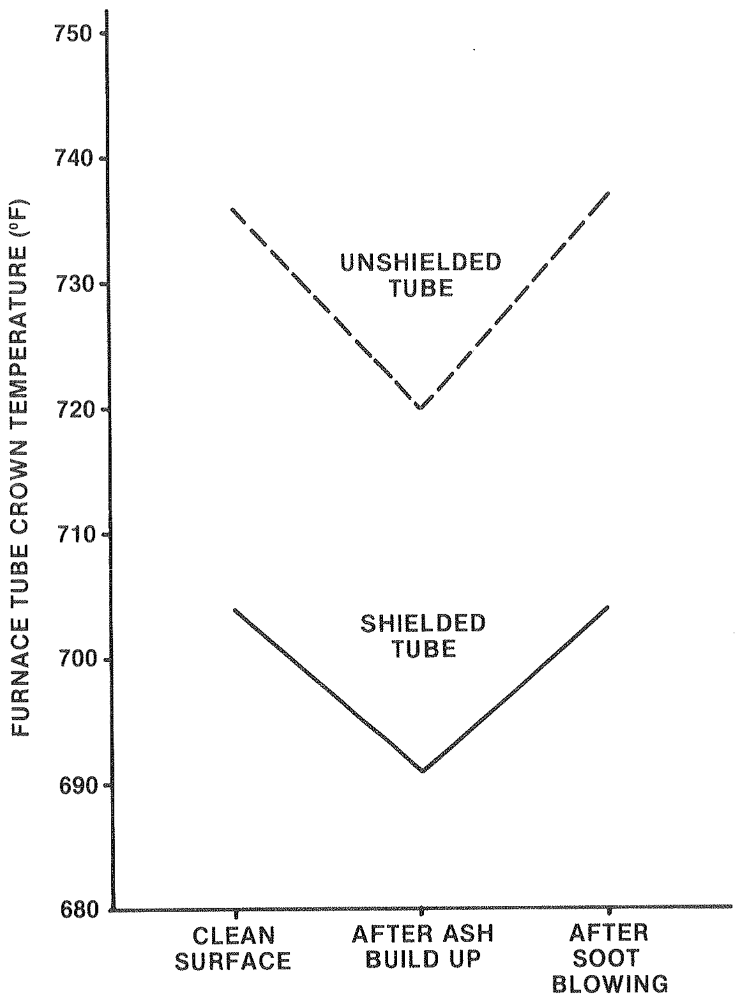
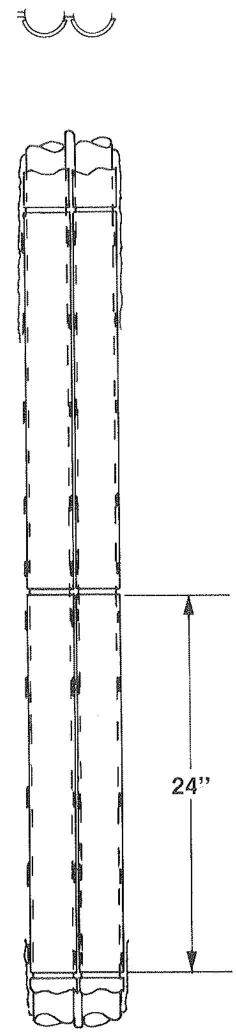


Figure 7 Furnace Tube Crown Temperatures



TYPICAL SECTION OF TUBE PANEL WITH SHIELDS ATTACHED

Figure 8 Shield Design Selected For Use On South Carolina Public Service Authority

2. *Furnace Surface Removal* - Since the furnace is too large for the fuel being fired, the Company studied the requirement and feasibility of removing a section of furnace surface.

   Analytically it was found that removal of 21 feet of furnace (as shown in Figure 3) would be necessary to achieve the gas temperatures desired. This approach was ruled impractical.

3. *Furnace Coatings*

   a. *Refractory*

   Riley's experience up to this time with furnace coatings on coal fired boilers has been limited usage of high temperature refractory. We have found refractory to be an effective insulator but a severe maintenance problem for boiler operator/owners. Our investigations into the newest refractories showed no significant upgrading in the state of the art which could provide trouble-free operation if applied.

   b. *Ceramic*

   Experiments were run with plasma flame sprayed ceramic material applied to various locations of the furnace. The ceramic was successful in reducing heat absorption by 25% where applied. After four months operation, however, the ceramic material became contaminated by combustion products which caused its heat transfer reduction characteristics to deteriorate.

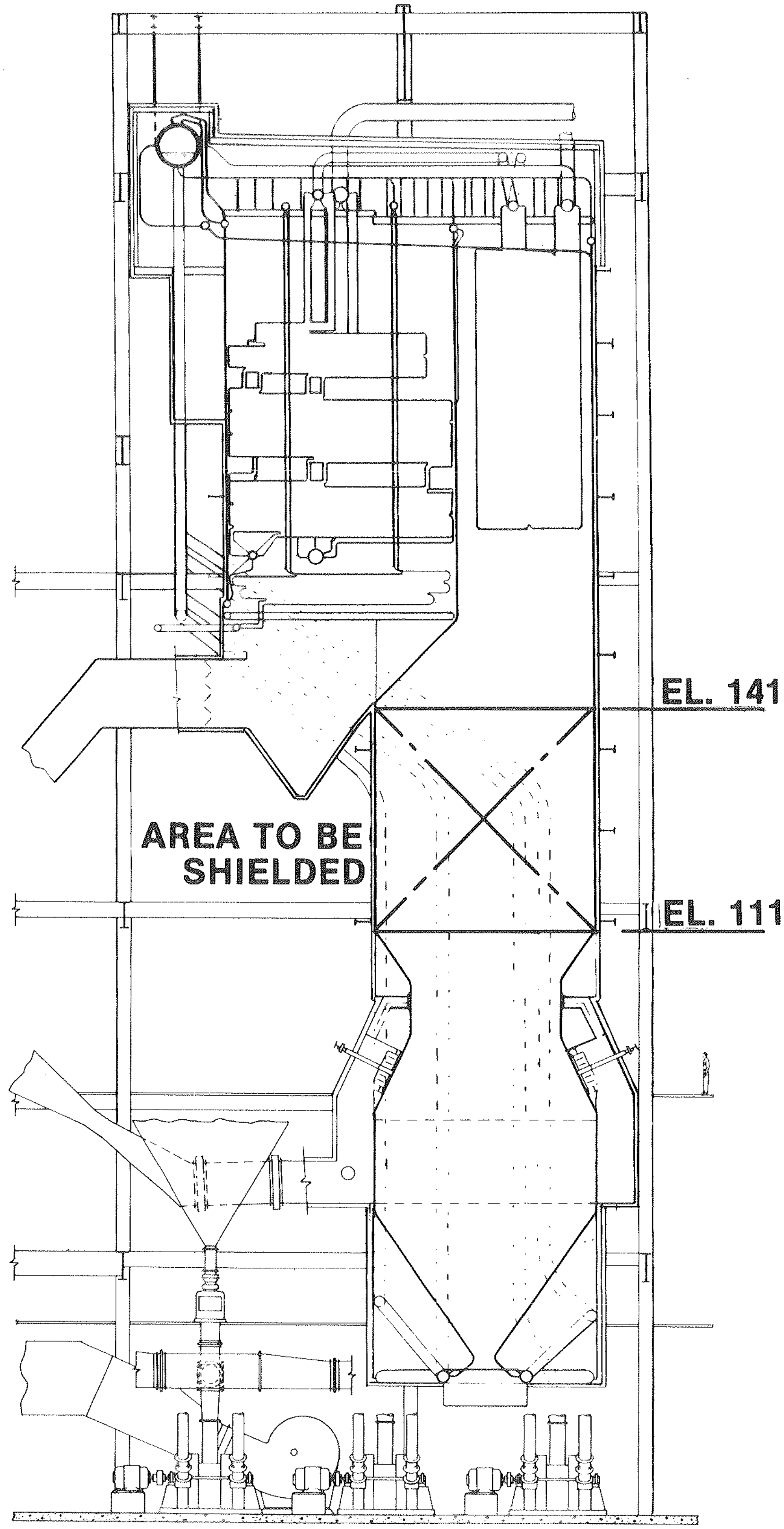


Figure 9 Area Of Furnace Where Shields Were Applied

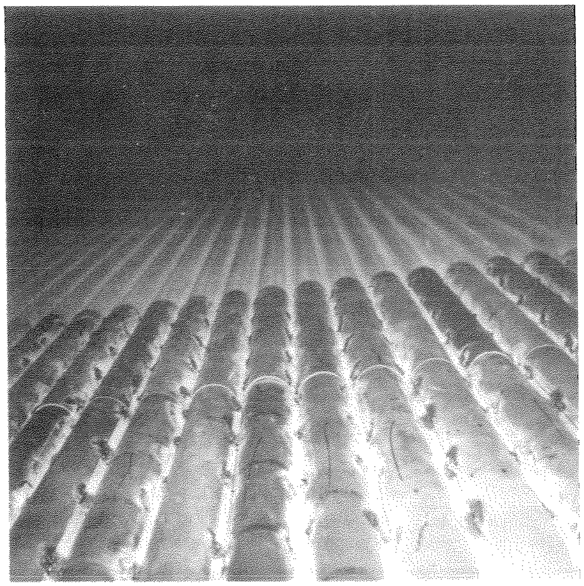


Figure 10 Shield Application

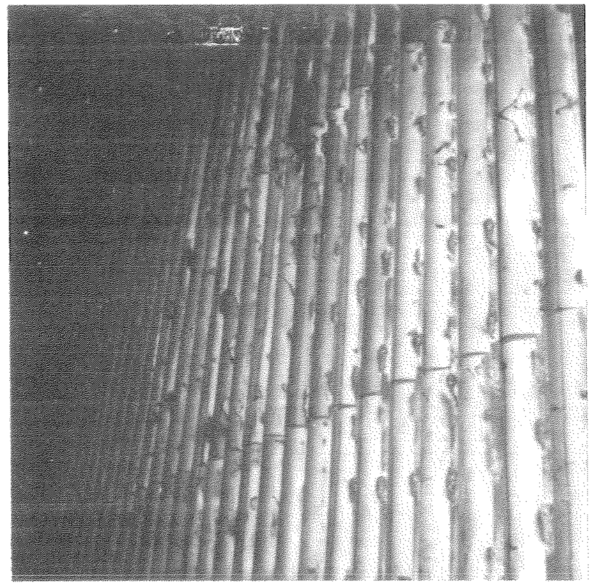


Figure 11 Shield Application

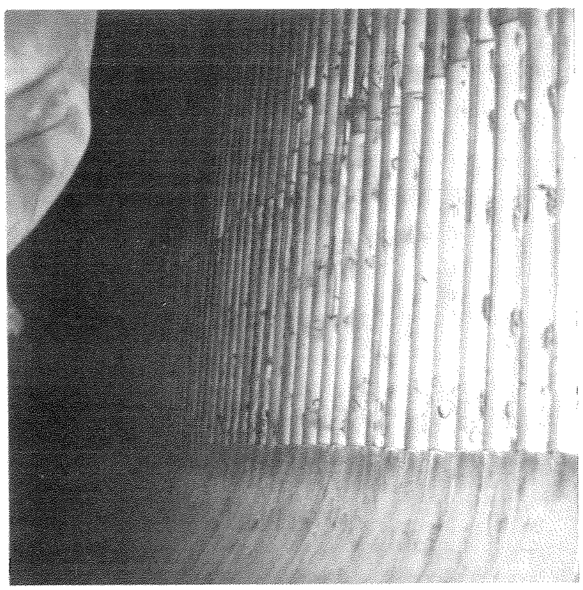


Figure 12 Shield Application

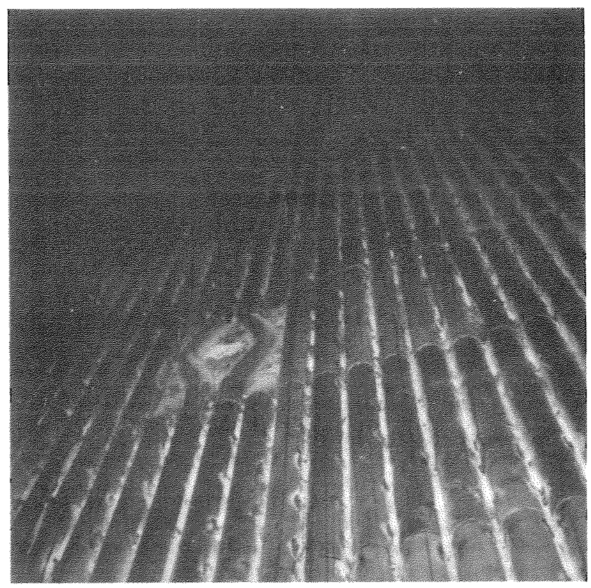


Figure 13 Shield Application

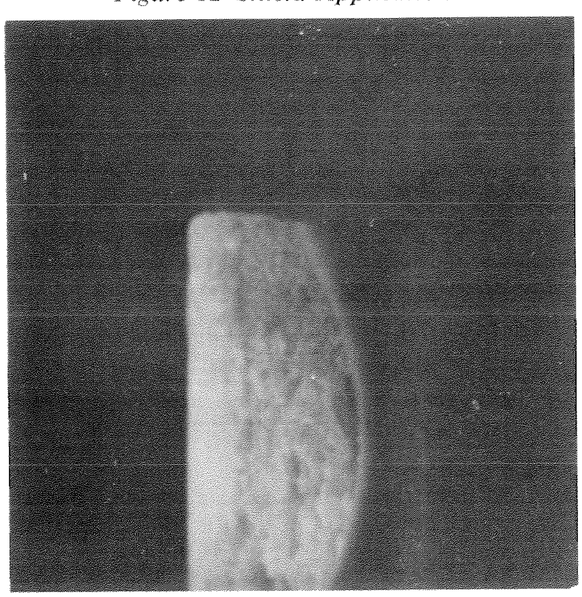


Figure 14 Ash Accumulation On Shields

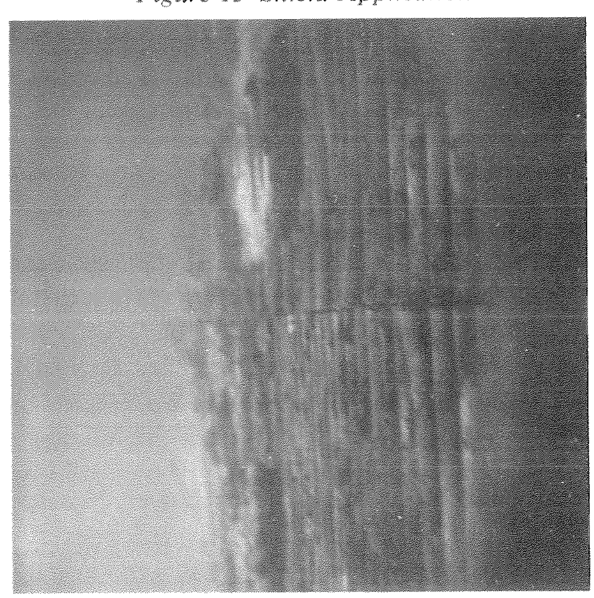


Figure 15 Ash Accumulation On Shields

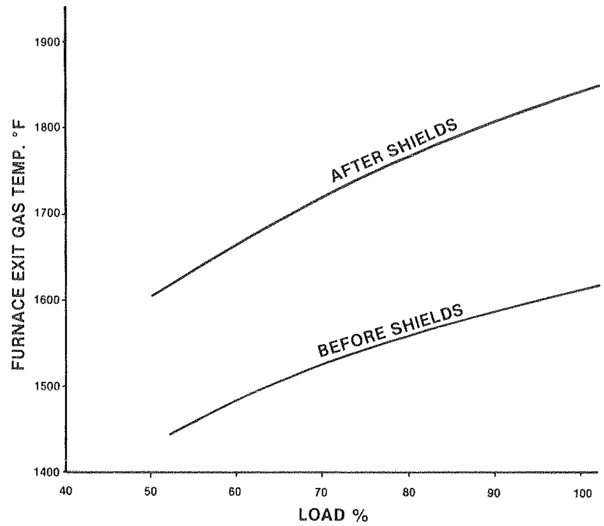


Figure 16 Furnace Exit Gas Temperature Change

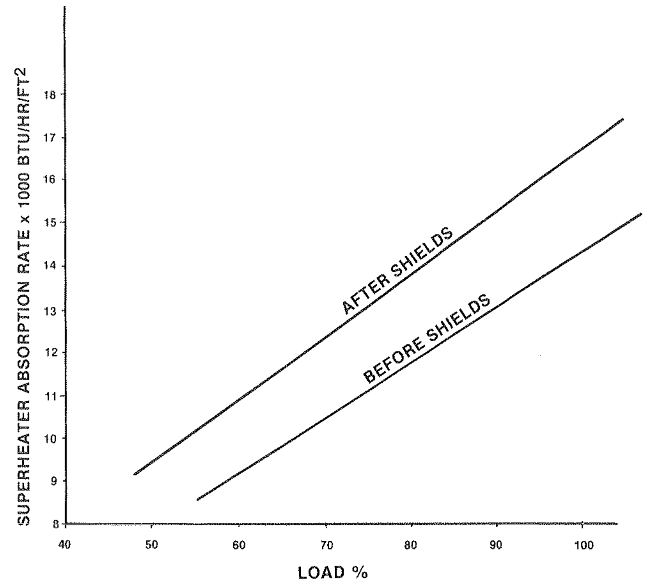


Figure 17 Radiant Superheater Absorption Change

4. *Metal Shields* - Very little information was available on the effect on heat absorption rate when a metal shield is applied to a furnace water wall tube. However, another boiler manufacturer has used metal shields in the furnace area to prevent corrosion of the tubing when firing black liquor. Riley has also utilized them in convection superheaters and reheaters to prevent tubing erosion damage.

   Theoretically, placing a shield against a tube which is absorbing heat will alter the rate of absorption. The degree of influence on the heat absorption rate is mainly a function of:

   a. Shield attachment area;

   b. The gap between the shield and the tube;

   c. The amount of fouling or ash deposits the shield will accumulate.

   Using the theoretical approach for shield design, test specimens of both stainless steel and Inconel 601 were made as shown in Figure 4. The test shields were 16 inches long, .095 inches thick and were designed for an air gap between the tube and shield of approximately 40 to 60 mils. The shields were designed to cover 140 degrees of the furnace tube face and would be attached to the furnace tubes in six (6) places with one inch stitch welds. In order to measure the effect on heat absorption rates of the shields, chordal thermocouples were installed in the furnace. Test shields were also located in areas where visual inspection via observation doors would be possible. In order to determine the temperatures of the shield metal itself "skin" thermocouples were attached to the outside surface of the test shields. Figure 5 shows a typical test shield application panel.

   Analysis of the test shield data showed that a bare shield reduces the heat absorption rate to a furnace tube to approximately 50%. Once ash deposition has been achieved the rates reduced further to approximately 30% of that of an unshielded furnace tube. Figure 6 is a bar graph comparison of heat absorption characteristics for unshielded tubes and shielded tubes with and without ash accumulations. Figure 7 shows the effect of soot blowing on furnace tube crown temperature. These comparisons were made at the full operating load of the unit.

RESULTS CORRELATION AND ACTIONS

From the data available after testing the various alternatives it was decided that the use of metal shields to cover a section of the furnace was the most viable solution to the problem of decreasing furnace efficiency

UNITS	CONTROL POINT 9/8/77 Before Shields	CONTROL POINT 12/5/78 After Shields	FULL LOAD 9/7/77 Before Shields	FULL LOAD 12/6/78 After Shields
Steam Flow (pph x 1000)	1300	1300	2000	2000
Steam Flow (% CAP.)	65	65	100	100
S.H. Temp. (°F)	870	1000	870	1005
R.H. Temp. (°F)	800	911	835	986
Excess Air (%)	20	20	20	20
F.E.G.T. (°F)	1511	1696	1606	1843
A.H Exit Gas Temp. (°F)	285	298	280	306
Avg. Carbon in Ash (%)	7.58	6.00	9.00	3.82
NO_X At Flue (Lbs/M. Btu)	—	—	0.643	0.645

Figure 18 Overall Performance Comparison Before And After Shield Addition

and increasing final steam temperature. It was still necessary, however, to make three significant decisions as to the design of the metal shields.

The first involved shield material. Even though both the stainless and Inconel shields exhibited similar operational results, it was decided that Inconel would be used in the final shield design because of its superior thermal, oxidation, and corrosion properties.

The second decision involved the physical size of the shield and the weld attachments. As previously noted the test shields were 16 inches long and had seven inches between the center and end welds. Even though no signs of weld failures were evident it was decided that for added design conservatism the shields would be 24 inches long with five (5) welds per side, with a maximum distance between welds of 4¼ inches. This design is shown in Figure 8.

The third, and final, decision was the amount of furnace area to cover. Integrating the furnace height heat absorption profile with the reduction effect from the shields it was determined that 30 feet in height of coverage was required. This amounted to approximately 20% of the total water wall surface.

Figure 9 describes the furnace area where shields were added.

SUBSEQUENT PERFORMANCE

Installation of the 30 foot band of furnace tube shields took four weeks. Figures 10, 11, 12 and 13 show various sections of the furnace after appliation of the shields. The unit returned to operation in early November 1978 and within seven days 70-80% of the shielded furnace tubes had dry ash accumulations of 2-4 inches. Figures 14 and 15 show these accumulations along the front wall and side walls. It was also noted at this time that some deformation was occurring in the shield at tops and/or bottoms. It was concluded however, that since the deformation was confined to only about 2% of the shields their loss would have a negligible effect on performance.

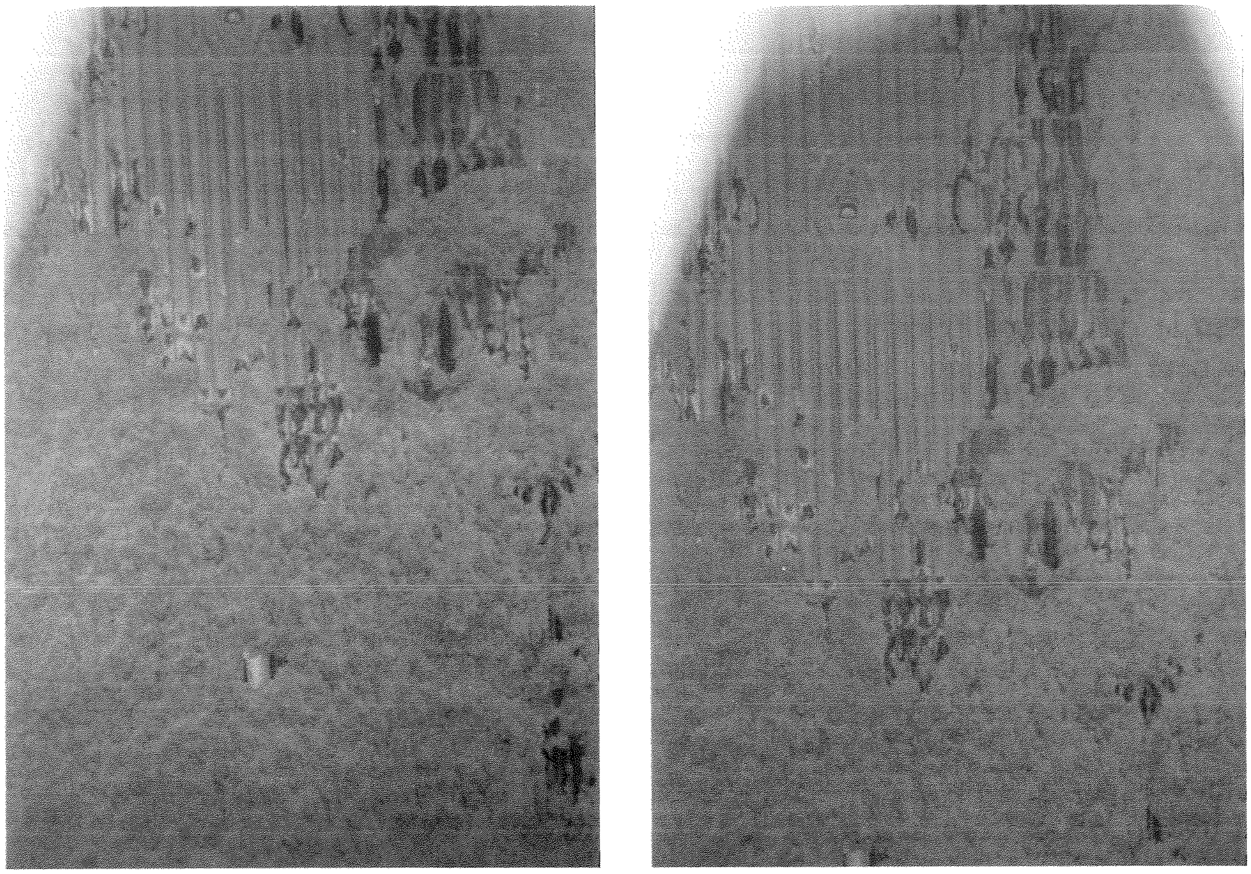


Figure 19 Shields Removed By Wall Blowers

Performance tests were run in January 1979. The results showed, as anticipated, a shift in furnace exit gas temperature and radiant superheater absorption rate in comparison to early tests. The results are plotted in Figures 16 and 17. A comparison of performance before and after the installation of metal tube shields is made in Figure 18 at both control point and full load. The significant items are:

1. FEGT has increased 237 °F at full load and 185 °F at control point.
2. Superheat temperatures have increased 135 °F at full load and 130 °F at control point.
3. Reheat temperature has increased 151 °F at full load and 111 °F at control point.
4. Airheater exit gas temperature has increased 26 °F at full load and 13 °F at control point.
5. NO_X emissions at full load have not significantly changed.
6. Average carbon in the ash has decreased from 9% to 3.8% at full load and 7.6% to 6.0% at control point.

As the unit continued to operate some problems with the shields began to appear. After approximately six weeks the unit experienced a slag fall which, after entering the ash hopper, pressurized the furnace due to the evaporation of water in the hopper, and caused a unit trip on high furnace pressure. Since that time a sequence of furnace wall soot blowing has been developed which has prevented other slag falls of that type. It is possible that an additional band of wall blowers may be required to provide better controllability of slag deposits.

Another problem which has developed is the deterioration of the shields. As previously mentioned some buckling and bowing had begun in a small percentage of the shields after approximately one week of operation. As the shields continued to become covered it was difficult to observe this condition. After further

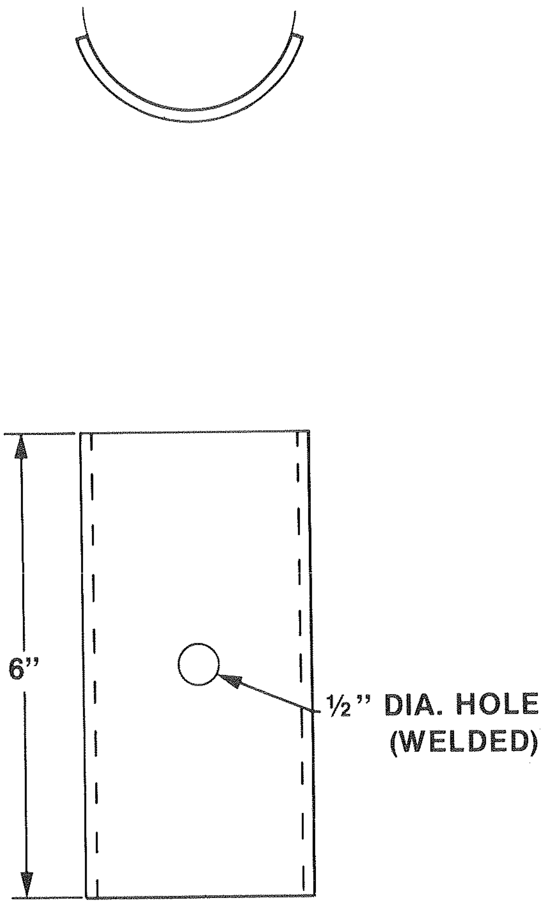


Figure 20 New Test Shield Design

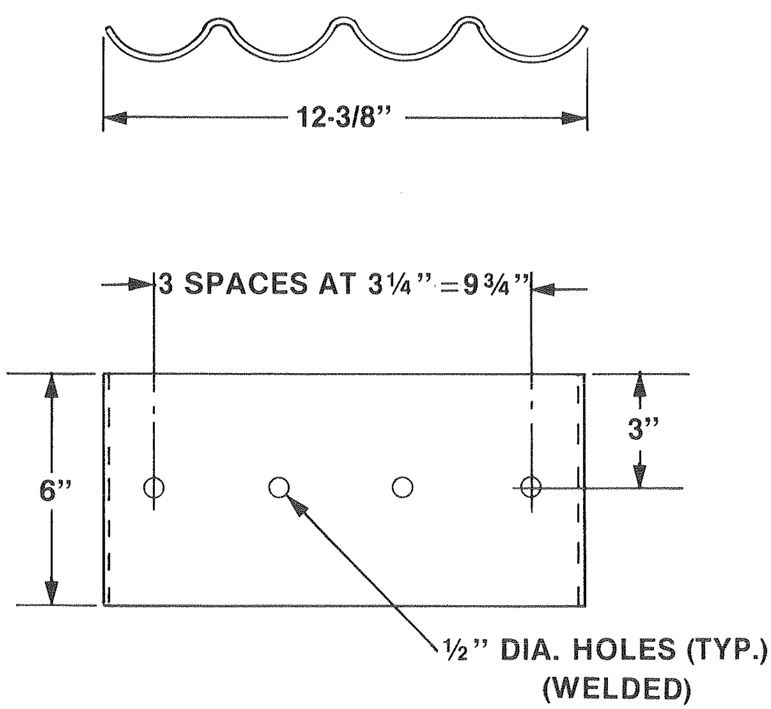


Figure 21 New Test Shield Design

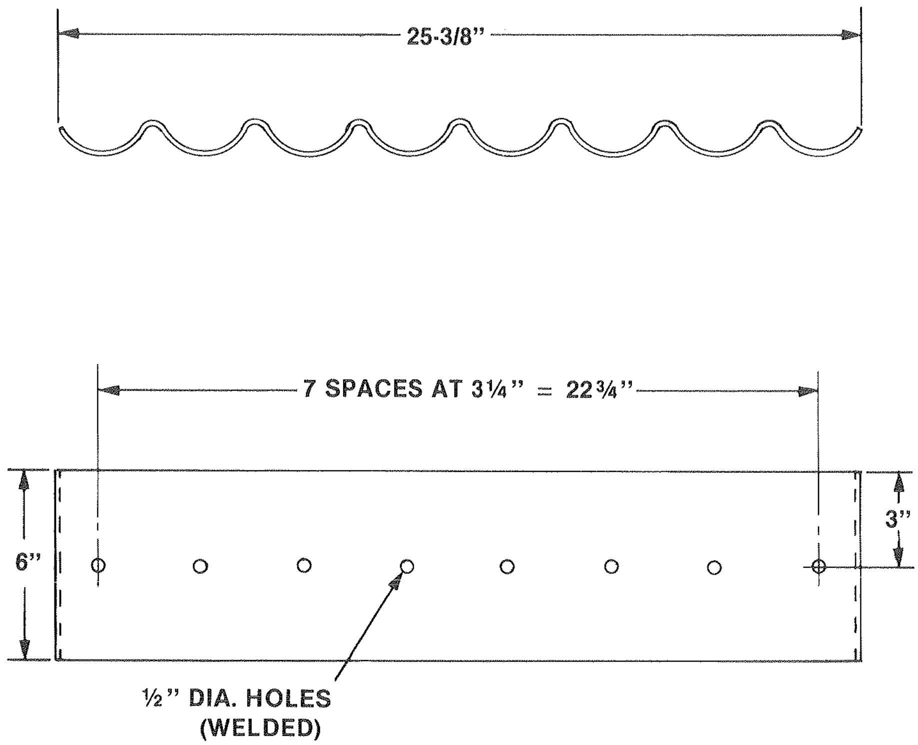


Figure 22 New Test Shield Design

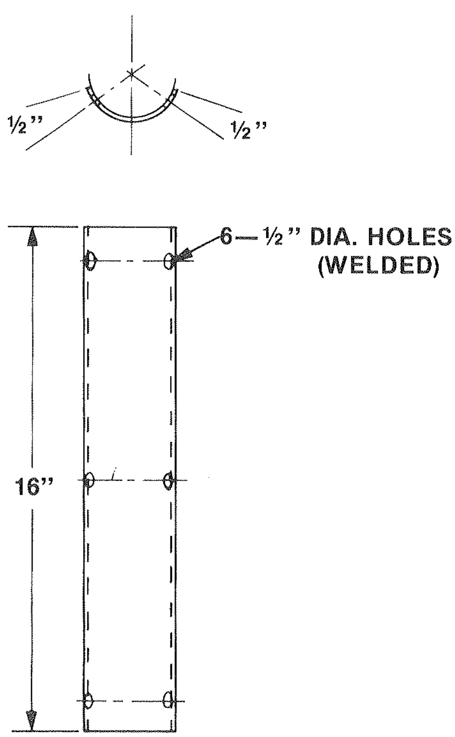


Figure 23 New Test Shield Design

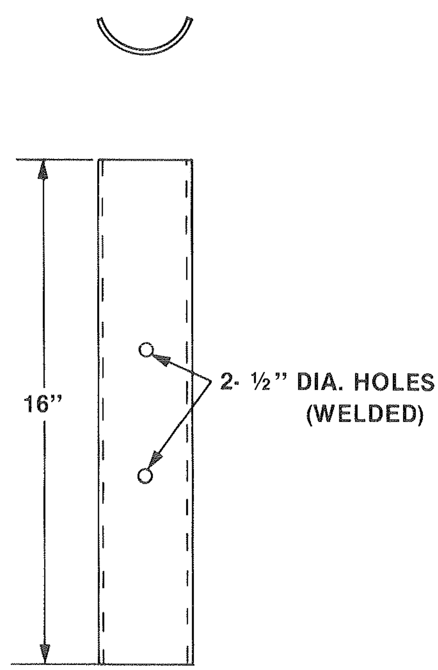


Figure 24 New Test Shield Design

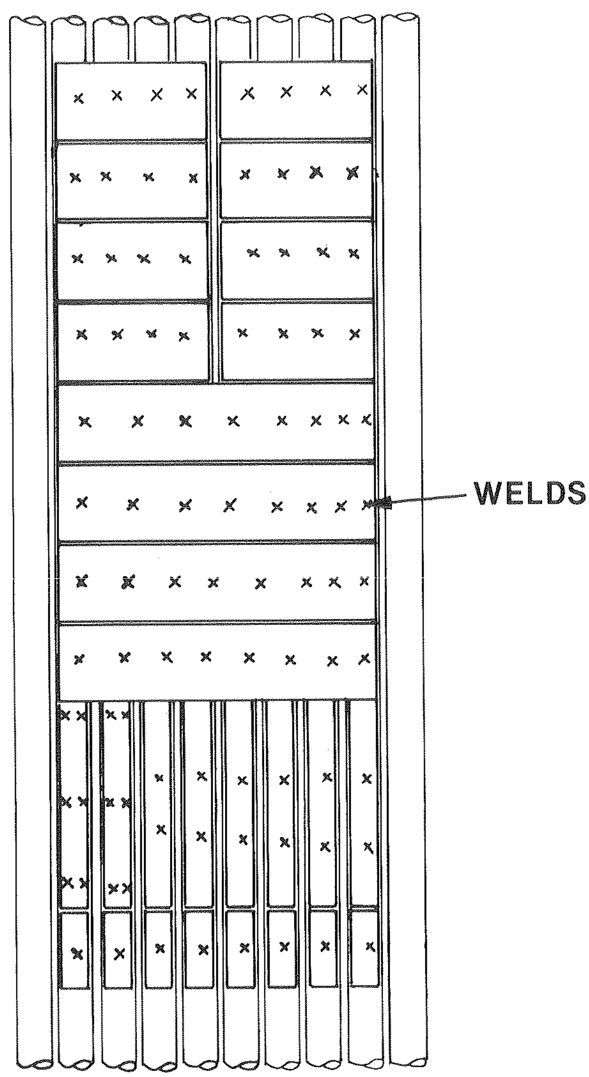


Figure 25 Test Panel Installation

operation it did become apparent that in the areas of wall blowers the shields were no longer in place. A shutdown of the unit was scheduled so that observations could be made. Due to the short duration of the outage all observations were made externally to the furnace through observation ports and doors.

During the inspection, it was seen that 80% of the shielded surface still had heavy ash accumulations making it impossible to pinpoint the condition of the shields in those areas. In other areas where accumulations were spotty or walls were clean it was evident the shields were in very poor condition. Figure 19 shows the rear furance wall in the vicinity of sootblowers. Note that the shields are missing from that area in approximately the effective blowing diameter of the wall blower. In other areas of shield visibility, bent, distorted and oxidized remnants were all that remained.

Several samples of the distorted shields were removed for metallurgical examination and determination of the possible cause of failure. It is apparent from viewing the samples that the weld attachment of the shields to the furnace wall tubes was inadequate to withstand the stress that was imposed. Adequate fusion between the shield material and the tube wall is difficult to achieve because of the difference in mass of the thin shield and the thick tube.

NEW SHIELD DESIGNS

Since the South Carolina experience new shield designs have been developed and are currently being tested. These designs emphasize minimal thermal differential expansion and ensure sound contact and attachment of the shield to the furnace wall tubes.

We understand the cause of failure of the first generation of furnace shields. The problem is simply mechanical attachment technique which should easily be solved with the superior non-stressed designs. Figures 20 through 24 show the new designs under consideration. Figure 25 shows a typical test panel utilizing those designs.

From a thermal performance standpoint the success of the shields is unquestionable. As attachment techniques are perfected the Company's design life criteria will be achieved.

SUMMARY/CONCLUSIONS

Test data and operating experience have shown that metal shields attached to the furnace tube wall are a viable means of reducing furnace efficiency and thereby increasing superheat and reheat final steam temperature.

A full scale application of the shields has shown excellent thermal performance results on a utility boiler designed for high slagging fuel while actually firing a very low slagging coal.

With the wide variation in fuel characteristics from the design stage to the operating unit and the expected gradual deterioration of available fuels in the future, a relatively inexpensive means of changing furnace performance is required. Future application of furnace tube metal shields may therefore become more common.