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# Extension of Cogeneration Capability by Increasing Turndown of Pulverized Coal Fired Boiler

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# EXTENSION OF COGENERATION CAPABILITY BY INCREASING TURNDOWN OF PULVERIZED COAL FIRED BOILER

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## ABSTRACT

The typical cogeneration facility at a Miller Brewing Company plant involves a 180,000 pound per hour pulverized coal fired boiler with four burners and an originally specified turndown of 4 to 1. The boiler's generating capacity exceeds current load demands and significant fuel savings are available if oil firing can be avoided on weekends and holidays. Low load coal firing would also eliminate frequent shutdowns of the large boiler and startups on the package oil boiler, saving maintenance.

This paper describes the joint effort by Miller Brewing Company and Riley Stoker Corporation in modifying the controls and fuel system equipment. Operating techniques, mill conditions, coal fineness, combustion efficiency and other results are also described.

The modifications resulted in the ability to operate with a stable flame at 10,000 pph without ignitors in service and with sufficient scanner signal to allow burner safety controls to be on full automatic. Only one switch is required to go from normal to one burner operation.

## INTRODUCTION

Production of beer is a batch process requiring large amounts of heat in the form of steam at different pressures: 125, 45, and 25 psig. The demand for steam is highly variable, the load can swing by 40-50% in 1-3 minutes. On weekends and holidays, the process and packaging may not run which results in sharp reduction of steam demand, down to 20-25% during winter and even less than 10% during summer.

The typical cogeneration plant at a Miller Brewery consists of one or two Riley pulverized coal boilers rated at 180,000 pph of steam at 635 psig, 750°F with 259°F feedwater temperature and one GE backpressure turbine-generator, rated at 5480 kw, exhausting at 125 psig. These plants are located at Albany, Georgia, Fulton, New York, and Eden, North Carolina. See Figure 1.

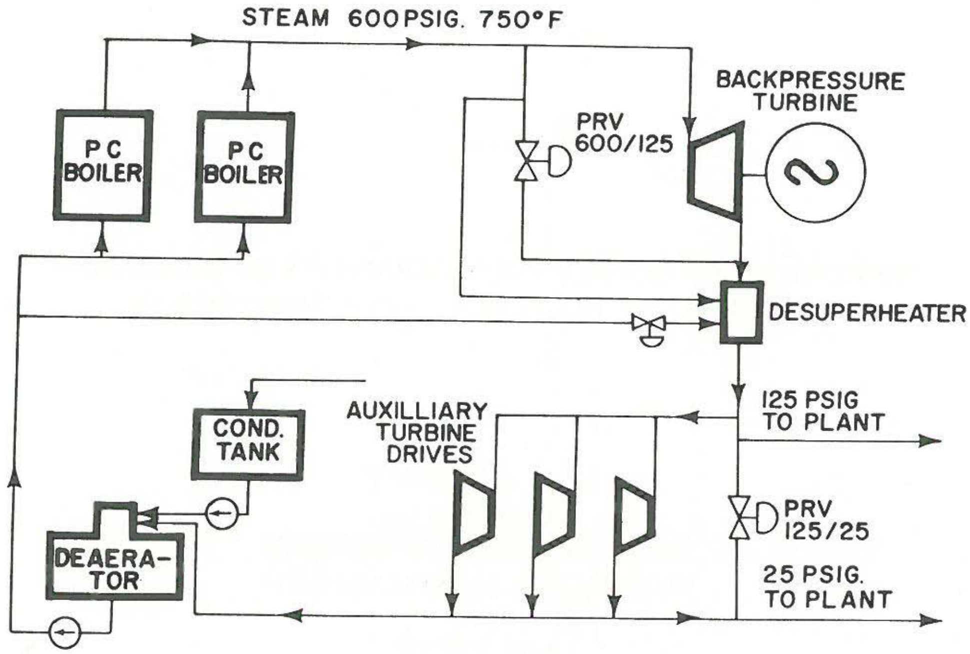


*Figure 1   Steam Flow Diagram*

Since on most weekends and holidays the lowest possible firing rate of the PC boiler exceeded the rate required by actual steam demand, the system was subject to frequent stops and starts. During the boiler and turbine downtime, steam to the plant was supplied by the gas or oil fired package boiler. This resulted in significant annual losses from higher operational costs, smaller electrical energy production, increased maintenance and required more attention from the plant supervisory personnel. Also, the equipment life expectancy could be affected. The estimated annual losses ranged from $300K to $500K, depending on the plant location.

Therefore, it was decided to modify the PC boiler fuel system in order to extend the turndown as much as possible.

## PC BOILER DESCRIPTION

The Riley steam generating unit is a type "RX" two drum vertical water tube boiler, having a dry ash recovery, membrane waterwall furnace and a vertical superheater. The unit is equipped with two Model No. 552S Atrita Pulverizers and two 18″ Riley drum type coal feeders arranged for pulverized coal firing through four Riley Model No. 3A flare burners. See Figure 2 and 3.

The combustion air is preheated in a steam coil air heater and in a regenerative Ljungstrom air preheater.

Each of two pulverizers is connected to a corresponding pair of burners: Mill "A" (right side) to the upper row, Mill "B" (left side) to the lower row. The coal pipe size was originally 12″, except for the horizontal run which was 10″ to prevent coal dust deposition. Each pipe had an individual coal plug valve with a manual drive. The primary air flow through the pulverizer is controlled by means of a tandem line damper, installed on each pair of coal pipes, downstream of the coal valves. Refer to Figure 4 and 5.

The boiler turndown was limited by design to 25%, or 45,000 pph steam flow. The limit was imposed by minimum primary air velocity in the coal pipe, which is 2500 fpm, and by the fact that the burners are arranged to always operate in pairs. Therefore, if the coal consumption is reduced below 25% of nominal with one mill running, the air/coal ratio in the coal pipes will be higher than 3:1, which is too lean for stable combustion.

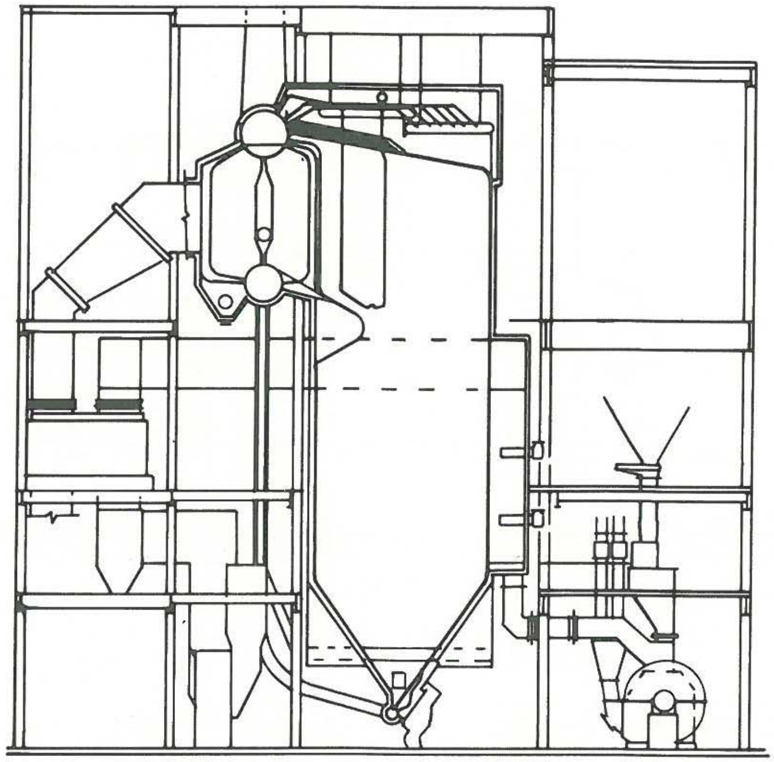

*Figure 2*

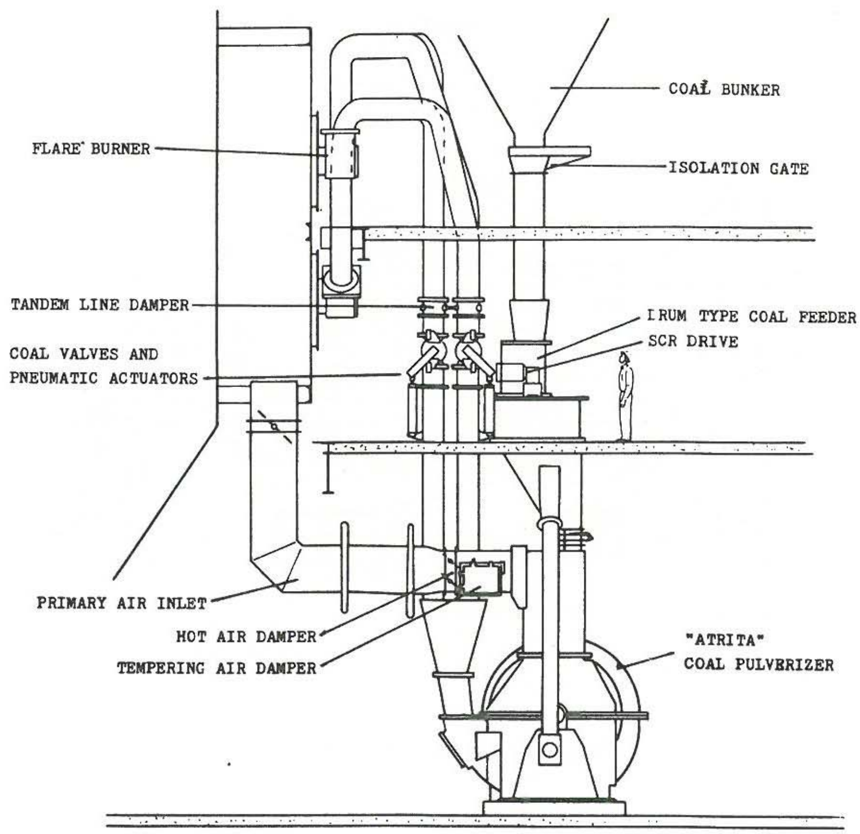


*Figure 3*

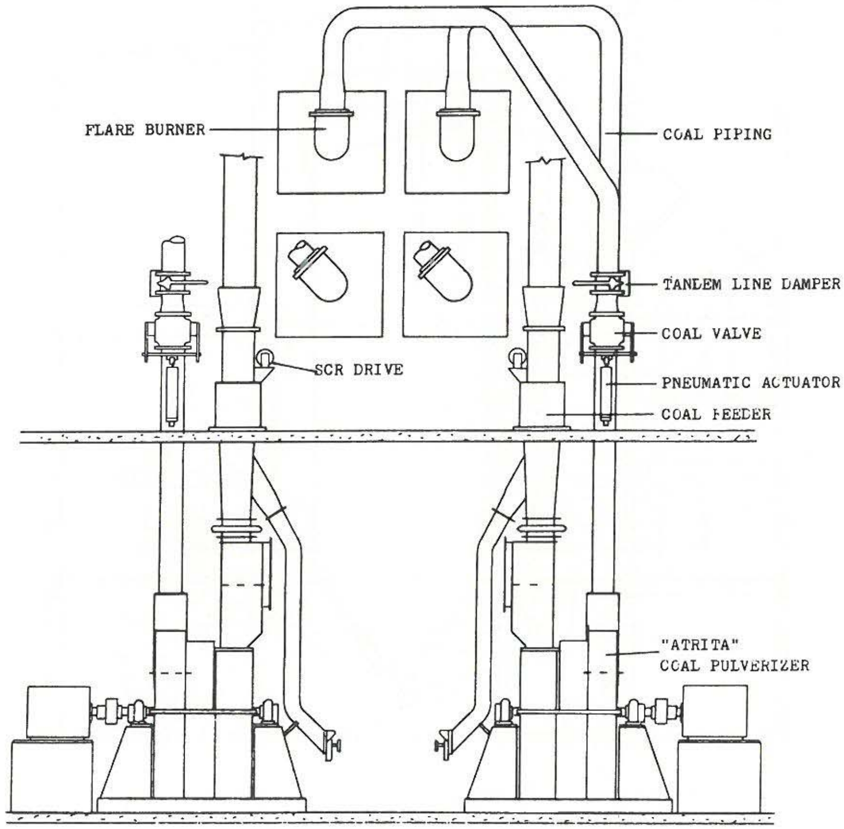


*Figure 4*

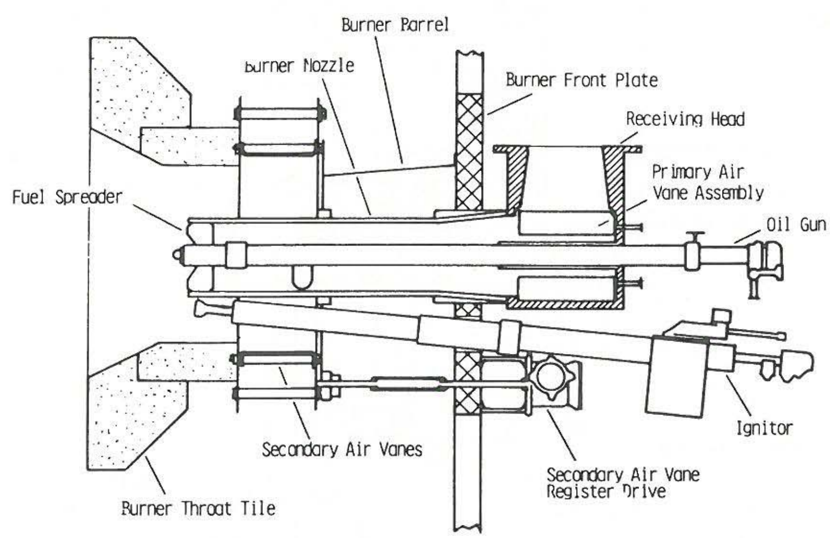


*Figure 5 Flare Type Burner*

All boilers are running on eastern bituminous coal with a volatile content of 34-36%. The flames are stable and combustion efficiency (completion) is 98-99% in a full range of loads. The flames are monitored by scanners at each individual burner, and the system logic requires that signals from both burners served by an individual pulverizer be present to keep the system in operation.

## BOILER FUEL BURNING MODIFICATIONS

According to General Electric Specifications, the lowest possible steam flow through the backpressure turbine is 18,000 pph. To achieve stable PC boiler operation at this small load, a concept requiring minimum modifications was developed through the teamwork of Miller Brewing Company and Riley Stoker Corporation engineers. The actual plant steam demand on a summer weekend or holiday can be much lower than required by the turbine design, down to 8,000-10,000 pph. It was assumed, however, that extra steam from the turbine exhaust will be vented after expansion in auxiliary turbine drives to 25 psig to keep the turbine on line or idle at reduced speed on weekends, until a way would be found to increase steam demand.

The concept was based on switching the boiler from two burners per mill to one burner per mill operation at low load. It included the following modifications.

1. Replacement of the existing mechanical V-belt variable speed drives on the coal feeders with variable speed SCR drives and DC motors to achieve higher turndown, (10:1 vs 3.3:1).
2. Installation of pneumatic actuators on every coal valve to enable remote or automatic cut-off of one burner of a pair.
3. Revision of the burner management controls to allow a single burner operation, with flame safety.
4. Modification of the combustion controls, primarily the installation of a halving relay to divide, by a factor of two, the fuel demand signal from the fuel master to feeder "A", then multiply the primary air damper demand by two to supply an adequate amount of primary air to the single remaining burner. See Figure 6.
5. Changing of the two upper burner coal pipes from 12″ to 10″ size. This would increase minimum primary air velocity above 2500 fpm with acceptable primary air/coal ratio. Prior to modification, the individual burner design range was 22,000 pph-64,000 pph steam flow. With the coal pipe size decreased to 10″, the predicted range will be 18,000-54,000 pph.
6. Installation of tandem air damper liners and blades, cast from a wear resistant material (Riloy #32). This would extend the life of the damper having smaller internal diameter, and maintain proper control of coal/air flow at various loads. See Figure 7.

   The modified controls logic was developed such that the operator may change the boiler operational mode, by turning a single selector switch. In other words, if the operator decides, for example to leave in service the #1 burner only, he turns the selector switch #2 to close. This will actuate the following events, provided both ignitors serving that mill are in service:

   a. closing of the #2 burner coal stop valve.

   b. decreasing the fuel master signal to the feeder "A" by 50%.

   c. by-passing the boiler trip relay from the #2 burner flame scanner.

   d. introducing a correction signal for the air/coal ratio in the #1 burner. At this point ignitors are removed from service. Refer to Figure 8.

Similar actions will take place if the #2 burner is selected for service. The second pulverizer may or may not be on line at that time, which allows for any combination of burners to be used: one, two, three, or four. By running three burners instead of four, another operational advantage can be realized: elimination of frequent stops and starts of a second pulverizer when the load fluctuates in wide range. The pulverizer motor,

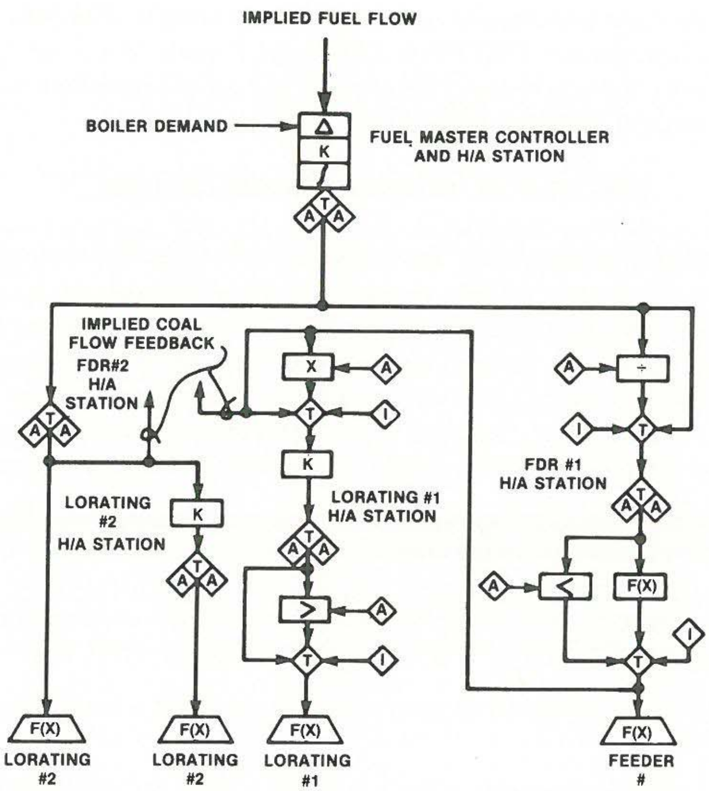


*Figure 6*

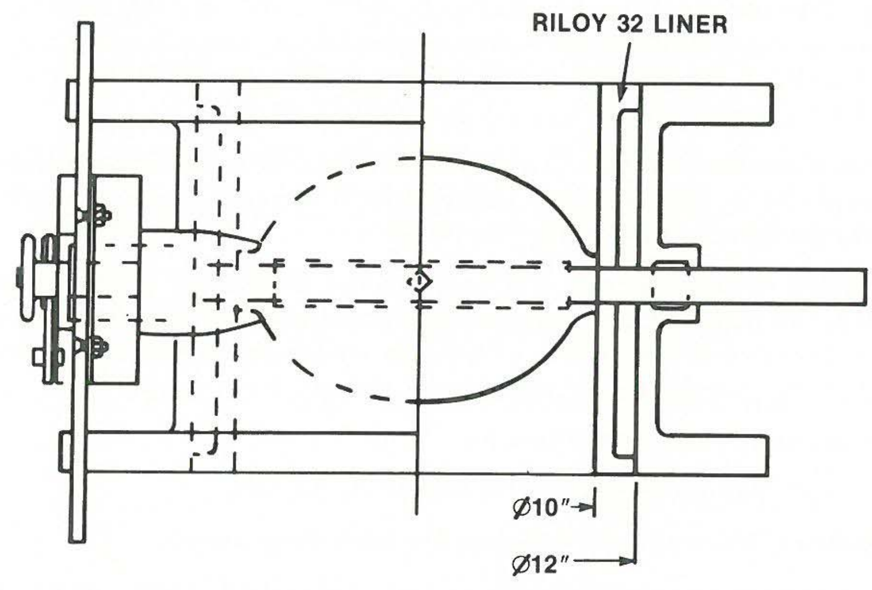


*Figure 7 Primary Air Line Damper*

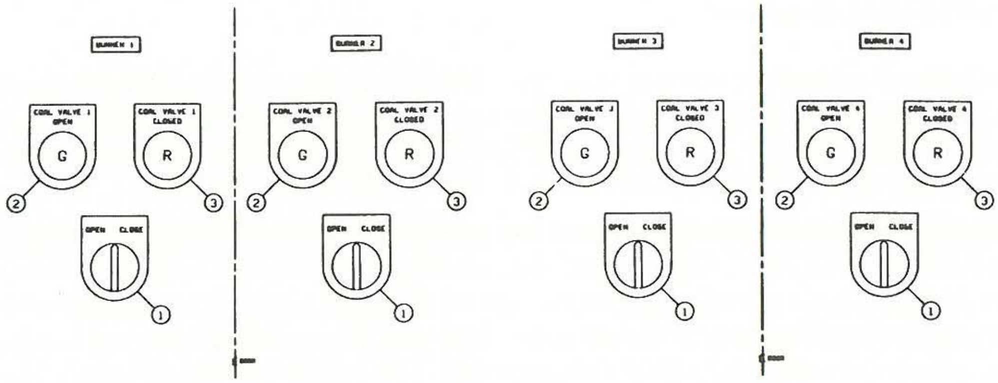

*Figure 8 ECA Control Panel - Boiler No. 2*

rated at 200 HP can be started only once in 90 minutes of down time or 30 minutes of running time. Therefore, to extend the motor life, plant personnel were often forced to vent the excess steam developed at intermediate loads when the pressure in the boiler increased.

From the above, the following table can be compiled, showing the intended increase in the boiler load flexibility:

| NO. BURNERS | BEFORE LOAD RANGE % | AFTER LOAD RANGE % |
|---|---|---|
| 1 | - | 10-30 |
| 2 upper deck | 25-70 | 20-60 |
| 2 lower deck | 25-70 | 25-70 |
| 3 | - | 35-100 |
| 4 | 50-100 | 45-100 |

*Table I*

One of the important conditions for the modification was that it would not affect the boiler performance at MCR (Maximum Continuous Rating). The above table shows that this condition was kept.

## OTHER ALTERNATIVES

A significant obstacle to achieving stable operation loads at lower that 25% was the requirement by the National Fire Protection Association 85E code to keep total air flow rate always above 25% of maximum continuous rating. In the modification described, the extra air not required by the burner in service, is passed through the idle burner secondary air registers. Of course, high excess air will deteriorate the boiler efficiency in a direct way by redistribution of the heat exchange in the boiler and increase in the flue gas losses as shown later. It was not clear if such a dumping would affect the active burner performance: combustion efficiency, ash formation, fireball shape, etc., since the burners are close to each other.

Another problem was maintaining primary air velocity above that at which pulverized coal can deposit in the coal pipe. Conversely, the flame stability can suffer, if the coal/air mixture becomes too lean. Two factors helped deal with these problems. One is finer coal pulverization, produced by the pulverizer at low primary air flow/coal throughput, and another was the relatively high volatiles content in the coal (34-36%).

Other options studied are as follows:

A. Installation of a centrifugal cyclone to separate coal from primary air and recirculate the air to maintain proper velocity in the coal pipe and pulverizer. Coal collected in the cyclone would be injected into the existing burner via a separate coal pipe. The reason for rejecting this option was that the system could be designed only for a relatively narrow load range. Figure 9.

B. Installation of a small auxiliary pulverized coal burner inside the main burner in place of the oil gun. This small burner would be supplied with concentrated coal/air mixture from a special concentrator, while the lean mixture is being disposed through the main coal nozzle. The advantage of this concept is the assured flame stability at extremely low loads and the possibility to set any required velocity of the primary air in the coal pipe and the pulverizer. This option was rejected because of the relative complexity and extensive study and modifications required for its implementation. See Figure 10.

C. Installation of a pulverized coal storage bin with an inerting system and pulverized coal feeder. This system is based on a proven technique which has been used for quite a long time particularly in Europe. Among the system advantages are extreme flexibility and the possibility of starting the boiler without using any oil or gas. However, in this particular case there was no space for its installation.

D. Installation of a special kind of refractory lined muffler burner capable of burning lean coal/air mixture. This option, though very attractive, also was abandoned because the required experimental study could not be performed in the existing time frame. It was reserved in case the basic option failed for any reason.

Also considered was the possibility of reducing furnace heat absorption for flame stabilization by installing refractory on the waterwalls in the burner area. This was not required even at extremely low load, because of the relatively high volatile content in the bituminous coal used and extremely fine pulverizer product.

## OPERATIONAL EXPERIENCE

The modifications, selective flame scan of the burners and the reduction of the upper burner coal pipe size was first implemented on boiler #2 in 1985 at the Albany, Georgia Brewery. After the first start up, it was found that a much lower load than initially expected can be easily achieved. The standard venturi flow nozzles in superheated steam and feed water lines in Albany could not provide reliable readings in this flow range. By using fuel input data, it was determined that the boiler operated somewhere in a load level below 6% of maximum continuous rating. At that time the turbine was not in service.

After adjusting the line damper for proper air/fuel ratio, a very stable flame was maintained without the ignitor and was easily scanned by the flame safety system. The flame was burning reasonably close to the coal nozzle and was approximately 3 to 4 feet long. The rest of the furnace volume was very clear with no smoke, sparks, or other adverse combustion indications.

As the load was increased on the single burner, the flame lengthened to the full furnace depth (17 feet) and remained very stable up to the full burner rating. The furnace condition remained satisfactory and there was no flame impingement on furnace walls or burner throat. The transition from one burner to another and to two, three, or four burner operation was smooth and simple.

Plant personnel have not required any additional training. The boiler operation both on manual and automatic control was basically the same as in the conventional mode.

Based on the almost year long experience, it is clear that the project goal was achieved. In addition, the boiler start up procedure was improved, since in one burner mode, the furnace heat release matches the required start up rate better than in the conventional two burner mode.

The system performance tests were delayed until the boiler was modified at the Fulton, New York Brewery, where the steam line has a high turndown turbine steam flow meter properly installed.

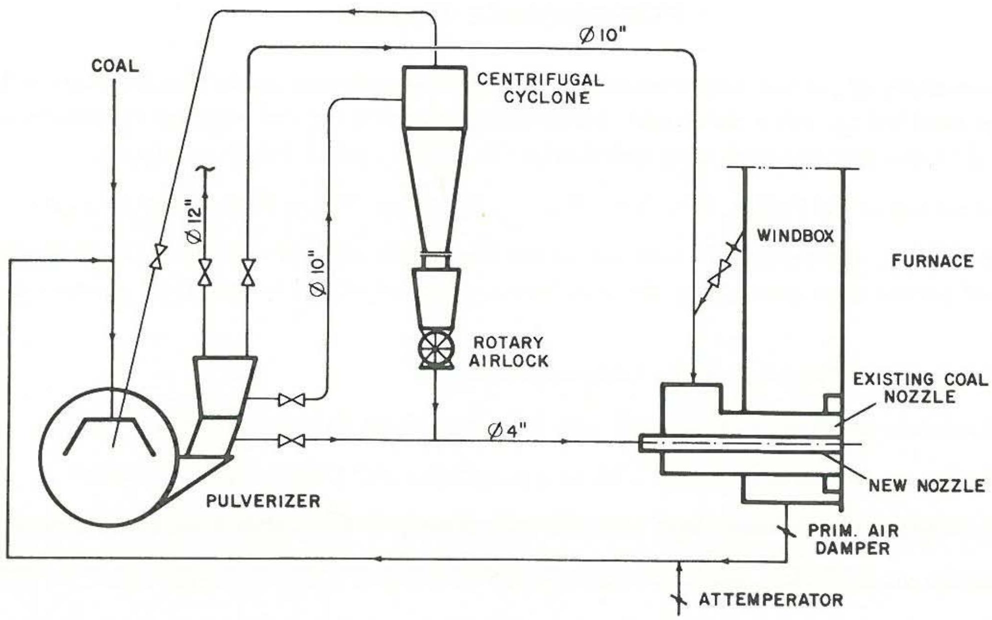


*Figure 9 Low Load Coal System with Centrifugal Cyclone*

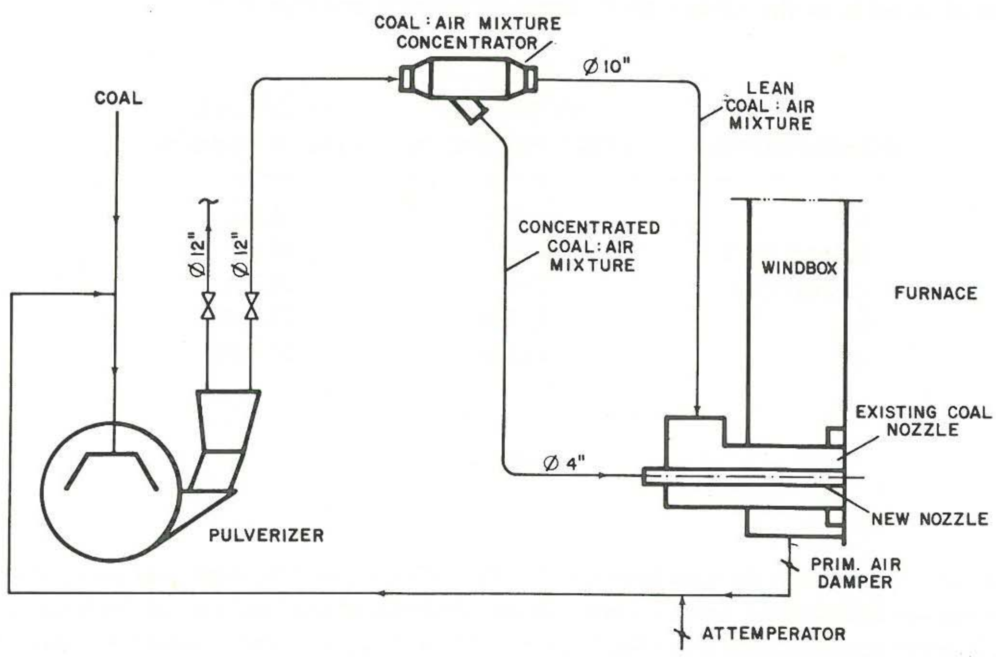


*Figure 10 Low Load Coal System with In-line Concentrator*

## PERFORMANCE TESTING

The main objective of the test was to establish the maximum safe and stable turndown of the boiler with a single upper deck burner firing pulverized coal without ignitors in service. Another objective was to determine the load ranges and corresponding efficiencies for 1, 2, 3, and 4 burner operation.

The tests were run at the Fulton, New York Brewery following the boiler modification in January, 1986.

Prior to the testing, the pulverizers were set up for the proper air/fuel ratio to the burners regardless of the number of burner lines open. Also, the coal feeders were calibrated to determine accurate coal flow to the burners.

The turndown testing consisted of the following runs:

Maximum continuous rating load with two pulverizers and four burners in service.

Maximum and minimum load with two pulverizers and three burners in service.

Maximum and minimum load with one pulverizer and two upper deck burners in service.

Maximum, minimum, and intermediate load with one pulverizer and a single upper burner in service.

A standard test procedure was used for the data collection and coal and ash sampling. The boiler master was placed in the manual mode for the test runs to assure a constant firing rate. Also, coal fineness samples were taken to determine coal pulverization at the lower loads.

## TEST RESULTS

The results of the test showed that the boiler is capable of operating continuously on one burner at approximately 6% of boiler load or 10,000 pph. This is approximately an 18 to 1 turndown ratio. The flame pattern was essentially as good as in the Albany plant. Refer to Table II and Figure 11.

| NO. BURNERS | PREDICTED LOAD RANGE % | ACHIEVED LOAD RANGE % |
|---|---|---|
| 1 | 10-30 | 6-30 |
| 2 upper deck | 20-60 | 12-46 |
| 2 lower deck | 25-70 | 25-70 |
| 3 | 35-100 | 31-100 |
| 4 | 45-100 | 37-100 |

*Table II*

The combustion efficiency at minimum load was 94.6% confirming that the flame was very stable and complete combustion was taking place, but the overall boiler efficiency at this load was 60.7% because of an extremely high flue gas heat loss since up to 600% excess air was being dumped through the three idle burner registers to meet the 25% minimum air flow requirement. As the unit load and number of burners were increased, the overall efficiency improved to 88.3%. See Figure 12.

Although the high excess air deteriorated the overall boiler efficiency, it did not have any adverse effect on the flame shape or combustion characteristics of the one burner left in service, with the rest of the air being dumped through the idle burner registers. Refer to Figure 13.

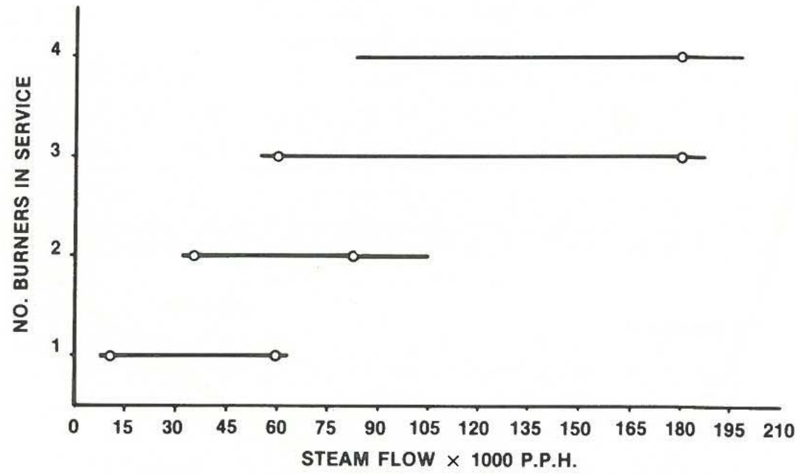


*Figure 11*

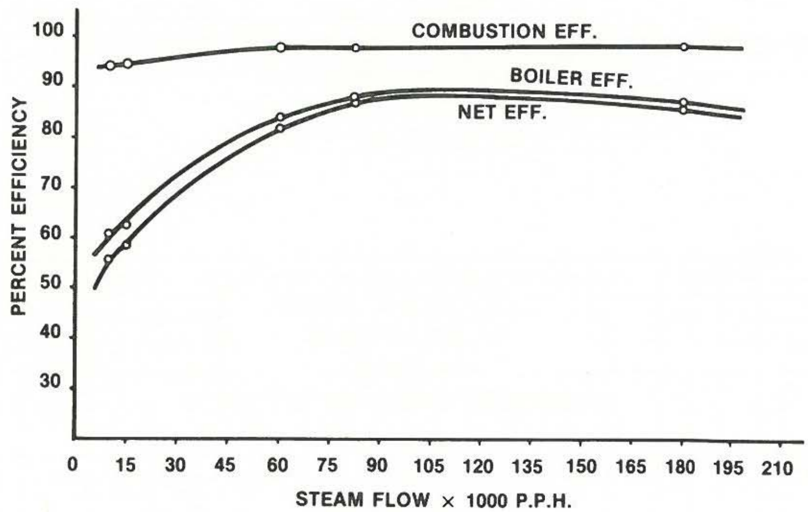


*Figure 12*

The coal fineness tests showed that the coal is being greatly over pulverized (up to 99.7% through a 200 mesh) at the low coal flows. For this application, the pulverizer is extremely oversized. A pulverizer sized strictly for these low loads, without regard to full load operation that would deliver at least 70% fineness through a 200 mesh should provide the same turndown and flame stability as obtained at Fulton and Albany, but actual testing should be done to verify this. Figure 14.

Loads lower than 10,000 pph were demonstrated on one burner but were unsatisfactory for continuous operation because of the following factors:

1. Steam, air and gas temperatures dropping off sharply with no indication of stabilizing due to such low heat input to the boiler.
2. Pulverizer temperature dropping below the minimum set point for the drying of coal, due to low hot air inlet temperature.

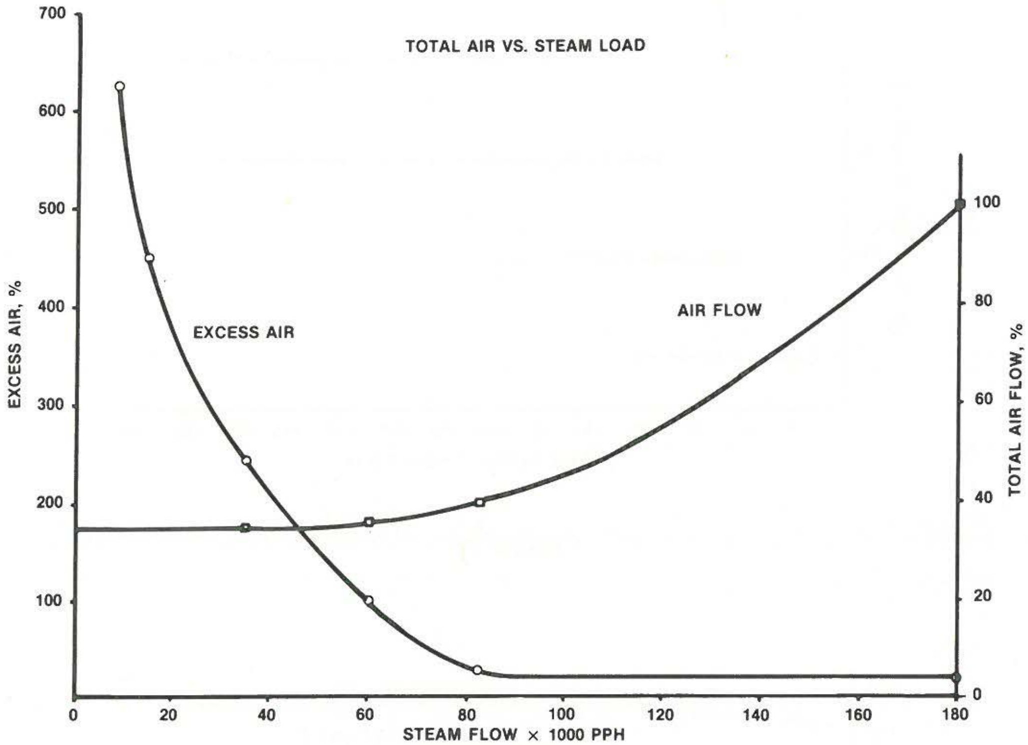


*Figure 13*

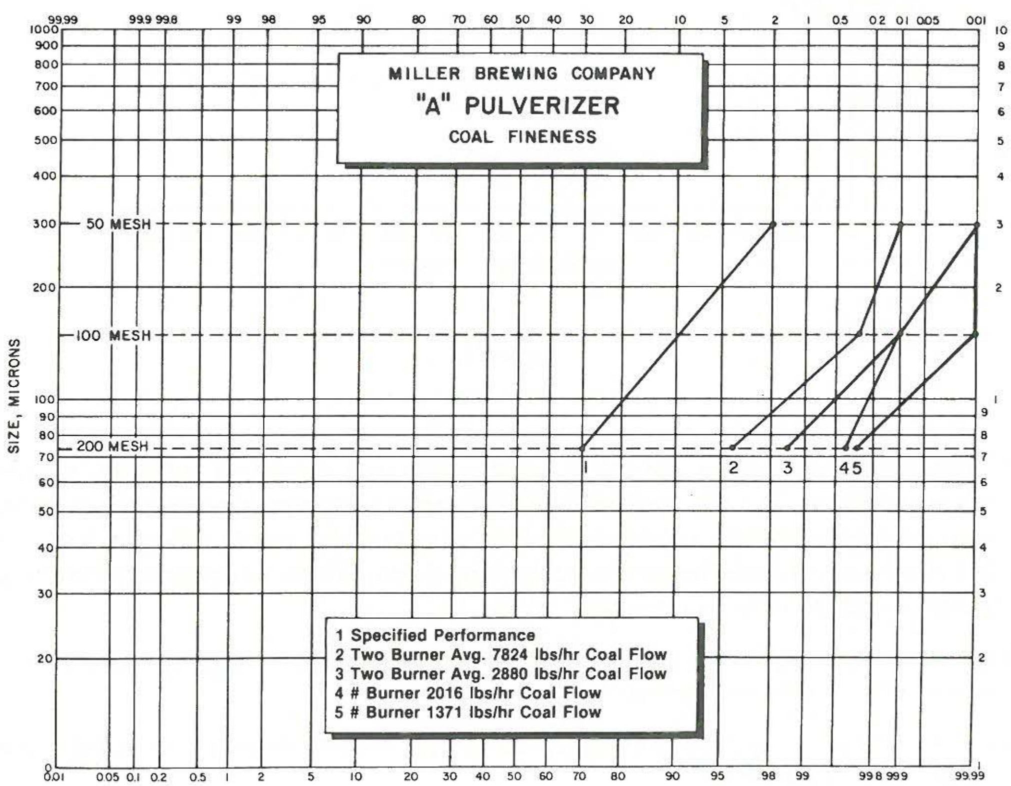


*Figure 14*

3. Increased CO gas detection in the exit flue gas.
4. Decreasing scan strength of the flame monitors and the possibility of a flame out.
5. Air preheater cold end temperature approaching flue gas dew point.
6. Appearance of moderate periodic pulsations in flame shape and brightness caused by uneven coal feed from the drum type coal feeder running at less then 0.5 RPM.

The concern of uneven heat distribution in the furnace when operating at high loads on three burners or a high load on one burner was evaluated on the Fulton boiler. The superheater tube metal temperature profile was found to be satisfactory while operating in this manner and no problems were encountered. Superheater tube life should not be effected. Figure 15.

Although final superheated steam temperature at the minimum load dropped off 90°F, this was 10°F less than predicted, remembering the upper row burner is in service during one burner operation. Refer to Figure 16.

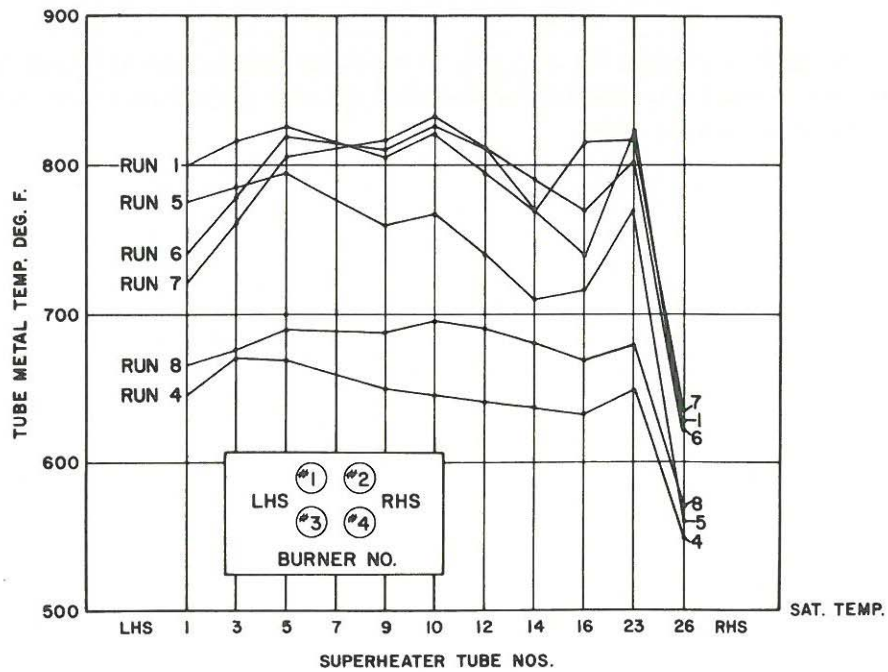


*Figure 15*

## SUMMARY

The new system has greatly increased the overall load range flexibility of the unit by being able to rapidly switch from any combination of 1, 2, 3, or 4 burners. This flexibility was chiefly due to the difference in coal pipe sizing from the upper to lower deck burners and the selective flame scanning system installed.

It is obvious that in this particular case, the extremely low load was easily achieved without flame stabilization with auxiliary fuels mostly because of the high volatile content of the coal used and the very fine pulverization. The study should be continued to establish correlation between coal quality and stable turndown.

For the Miller Brewing Company, the full implementation of the project may result in saving of more than one (1) million dollars a year from reduced oil usage, increased cogeneration capability and lower maintenance expenses. With the total capital cost of modifications at $660K the discounted pay back is six months.

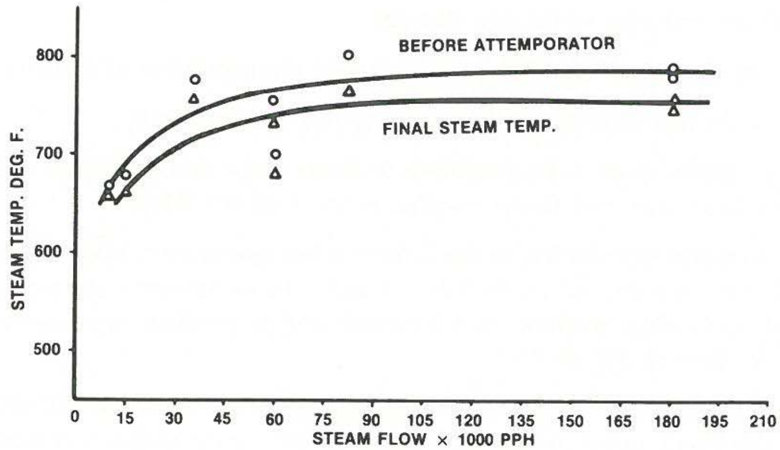


*Figure 16*

This situation is probably not unique for a number of industrial cogenerators with coal fired boilers and large variations in steam demand. The modification described can serve as alternative to the costly installation of a condensing turbine or package boilers.