BOILER MAINTENANCE AND OPERATING COST REDUCTION

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ABSTRACT

This paper discusses equipment retrofits and services for reducing boiler maintenance and operating costs. Specific examples of actual retrofit projects and their economic justifications are discussed.

INTRODUCTION

To reduce maintenance and operating costs associated with their boilers, utility and industrial owners are concentrating their efforts on upgrading their existing power plant equipment. Significant cost reductions result from increasing boiler reliability, improving boiler efficiency and enhancing the ability to fire less expensive fuels.

Riley Stoker Corporation designs new utility and industrial boilers and serves the aftermarket through its Plant Improvement Division. In addition to emergency repairs and parts replacement services Riley Stoker supplies carefully engineered equipment retrofits to reduce maintenance and operating costs of boilers. This paper discusses recent retrofit projects, services and their economic benefits.

IMPROVING BOILER AVAILABILITY

Boiler operating availability is defined as the fraction of time that a boiler is available for operation. Since the boiler and its immediate auxiliaries account for approximately half of the forced outages of electric generating units, it is obvious that these items should command immediate attention for maintenance and upgrading.

In many cases, good operating practice and maintenance procedures are not enough to produce an increase in availability.(1) There is the need to identify the real causes of problems and eliminate them, rather than applying temporary, repeated fixes. Riley Stoker has developed the Boiler Availability Improvement Program (BAIP) based on this need.

The BAIP consists of three major sections: performance analysis, equipment inspection, and operation and maintenance review. In the performance analysis, current operating data is obtained and compared with the original design. Recommendations are then made for optimizing unit performance and improving efficiency. During the equipment inspection all applicable equipment is inspected and findings documented. Material samples and non-destructive test data are collected. The maintenance review consists of reviewing the manufacturer's recommended operating procedures and implementing operator training seminars.

The BAIP is a continuing program which enhances boiler availability by identifying and eliminating the root causes of a problem, optimizing boiler performance, providing a data base for diagnosis of future problems, and providing for cost control and reduced downtime.

For stations where a full BAIP is not practical because of timing or economic considerations, the minimum suggested program is a physical inspection. For this, Riley Stoker offers the Team Inspection Service (TIS) in which a team of experts perform a customized mechanical inspection and analysis. The team typically consists of Boiler Design, Stress Analysis, and Fuel System Engineers, a Service Engineer, a Metallurgist and a Construction Specialist. Over fifty (50) Team Inspections have been successfully performed in recent years for utility and industrial customers.

Gains in availability can be realized by updating equipment to the current design. Examples of recent retrofit work are as follows:

a. *Balanced draft conversion:* By conversion of a pressurized furnace operation to balanced draft operation, boiler maintenance is reduced. Pressurized operation puts severe stress on the boiler setting. Fixing casing leaks and cleaning flyash that has leaked through the casing are maintenance costs associated with pressurized operation. Major equipment changes required for a balanced draft conversion are the addition of an induced draft fan, addition of structural steel, and control system modifications.
b. *Superheater upgrade:* Improvements in metallurgy and support mechanisms can minimize tube failures and element misalignment. Many older units are now used for duties for which they were not originally designed, such as peaking and cycling, making fatigue stress a significant factor in the superheater (and reheater) life. A change to a fuel which produces more corrosive flue gas can affect support system reliability. Improvements in the support design such as stringer tube supports, removal of cantilevered loads, and support material upgrade are features used on new designs which have been retrofitted to older boilers to improve reliability.
c. *Fuel systems upgrading:* The addition of crusher dryers to ball tube mill systems improves pulverizing capacity when wet coal is fired. Addition of Power-Sonic ball tube mill controls increase the accuracy and reliability of mill control systems. The use of mill level probes, a constant maintenance item, is eliminated in the Power-Sonic mill control system.
d. *Burners:* The retrofit of low NO_X producing burners allow coal burning with minimal emission of oxides of nitrogen. Recently, two central station units were retrofitted with Riley Controlled Combustion Venturi Burners (Patent applied for) and are now operating below Federal NO_X emission limits. On units where coal firing load capability is limited by emission output, retrofit of these burners may allow regaining of lost capacity.

Riley supports improvement in the availability and reliability of new and existing products through the Riley Research Center. Major areas of involvement are in coal processing and combustion technology, flow modeling and analytical laboratories.

Subjects relative to improved availability which can be addressed at the test facility are:

a. fire side corrosion
b. combustion efficiency
c. tube erosion
d. slagging and fouling
e. combustion control systems
f. flame stability and scannability
g. process data for development of design standards
h. component failure analysis
i. boiler safety code compliance
j. mechanical and thermal testing of structural components
k. field test services

For instance, if a customer is contemplating changes in fuels or operating parameters, such as changing to cycling duty from base load operation, the Research Center can provide insight into burner development, flow modeling and fuel characterization. If recommended or desired, full scale burner development tests could be run to demonstrate fuel conversion possibilities or emission reduction capabilities.

The burner test facility is supported by analytical laboratories which determine the physical and chemical properties of fuels, water, residues and minerals, and a flow modeling laboratory with both two and three dimensional model capabilities.

IMPROVING BOILER EFFICIENCY

Boiler efficiency is defined as the ratio of net heat output to heat input. Maintaining the highest boiler efficiency insures minimum fuel expenditure.

Savings can be realized with little or no expenditure by reviewing operations, maintenance and equipment, and taking appropriate action. Two specific items affecting boiler efficiency that should be investigated are minimizing excess air and reducing exit gas temperature.

As *excess air* is reduced, heat losses due to dry gas and moisture formed by combustion of hydrogen in the fuel are reduced. Figure 1 shows the percent of efficiency improvement for every one percent reduction in excess air.

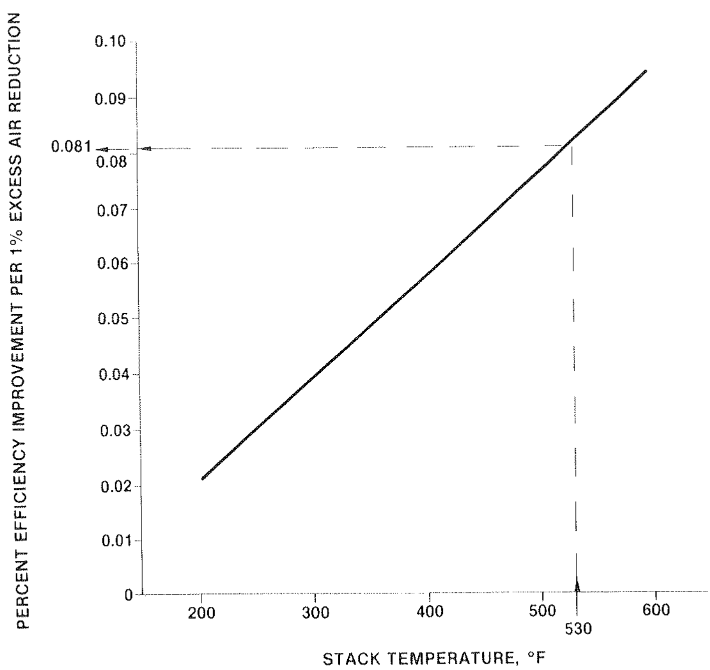

Figure 1 Curve showing percent efficiency improvement per every one percent reduction in excess air. Valid for estimating efficiency improvements on typical natural gas, #2 through #6 oils and coal fuels.

Operationally, excess air can be minimized through burner adjustments, conditioning of the fuel, and air flow trimming. Excess air must not be lowered to a point where flame stability, smoking, or steam temperature are adversely affected.(2) On coal fired units, care must be taken not to create a reducing atmosphere near the waterwalls because of the danger of corrosion.

An inspection by the burner manufacturer will point out areas where maintenance is required in order to achieve design excess air. Manufacturers are continually improving the performance and reliability of their designs. For example, updating of the burner register controls to current designs has shown marked increases in controllability and reliability on several recent retrofit contracts. Also, total replacement low excess air burners for oil and gas firing have been available for some time. Combustion control system upgrading to include O_2 trim is a viable alternative for reducing excess air.

Reducing the *flue gas temperature* means that more heat is taken from the fuel fired before it is exhausted to the atmosphere. Figure 2 shows the percent efficiency improvement per 10 °F stack temperature reduction.

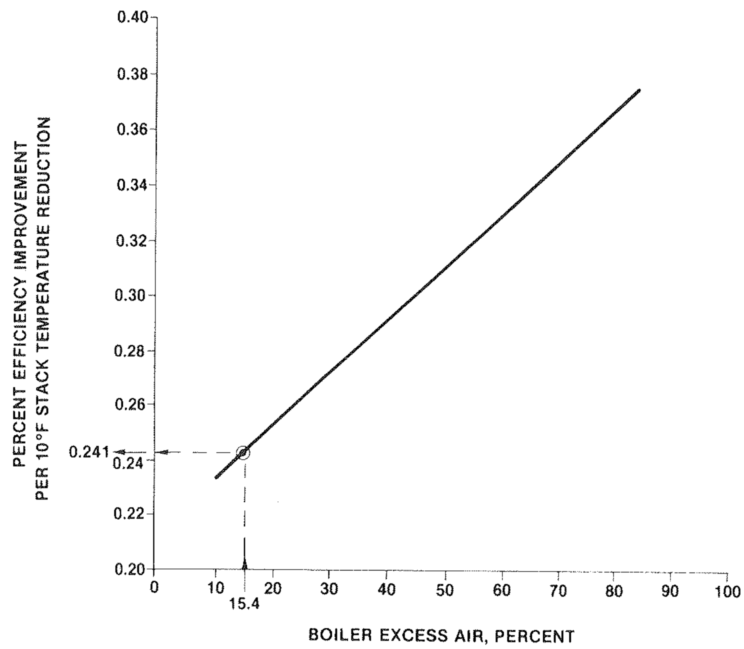

Figure 2 Curve showing percent efficiency improvement per every 10 °F drop in stack temperature. Valid for estimating efficiency improvements on typical natural gas, #2 through #6 oils and coal fuels.

Boiler heating surfaces must be kept clean of ash. Ash will act as an insulator and reduce heat transfer effectiveness. Inspection of heating surfaces should be routinely scheduled to confirm that sootblower cleaning is effective.

A boiler diagnostic test performed by the original manufacturer will be a basis of comparison of original design performance with current operation. The test may reveal that the performance of some heat transfer bundles has diminished in effectiveness over time. Areas requiring closer inspection and attention will be identified. Instrumentation may require refurbishment and calibration. Additional instrumentation may be required to provide the necessary data for the test.

Once the operating and maintenance avenues of reducing flue gas temperature have been exhausted, equipment retrofit for reducing flue gas temperature should be considered. Equipment retrofit usually takes the form of recovering heat from the outgoing flue gases to heat incoming feedwater or combustion air. In a recent industrial boiler economizer retrofit at a refinery, a fin tube economizer was added to a unit which fired oil and gas. The boiler is rated at 325,000 lbs/hr (147,417 Kg/hr), 825 psig (5.67 M Pa) and 790 °F (421 °C) superheat temperature. The boiler efficiency improvement is approximately 2.5%. The plant owners estimate the payback for this project to be 1.1 years.

The flue gas temperature reduction is primarily limited by cold end metal temperature in the heat trap compared to water and sulfur dewpoint temperatures (see Figure 3). In the case of an economizer, the water temperature leaving the economizer must be sufficiently below the saturation temperature to insure that steaming does not result. A steaming economizer would adversely affect boiler circulation and steam drum level. For an airheater, the air temperature leaving the airheater must not exceed the fuel burning equipment design limitations.

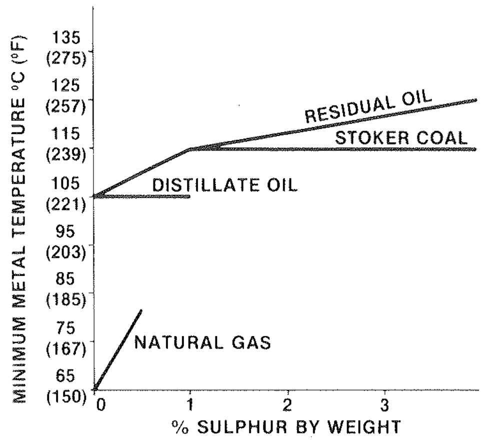

Figure 3 Curve showing minimum metal temperature for various fuels.

A three valve bypass around the economizer is always recommended. The bypass insures that the boiler will not be shut down if an economizer tube fails. The three valve bypass consists of the items in Figure 4.

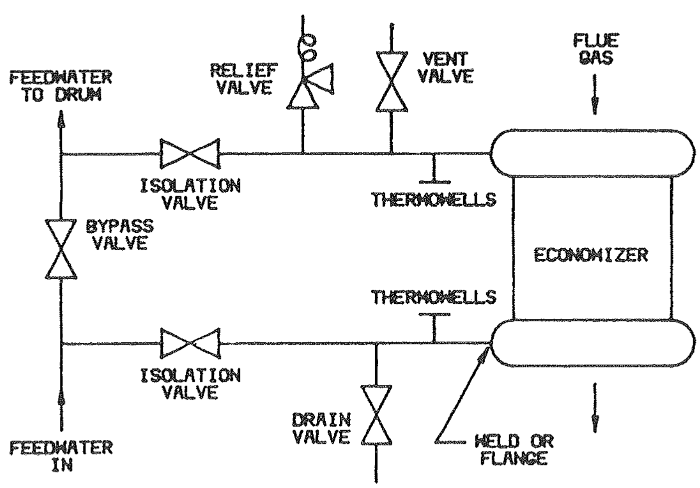

Figure 4 Economizer Three Valve Bypass

FIRING LESS EXPENSIVE FUELS

Fuel costs are a significant portion of boiler operating costs. Recent retrofit projects for fuel conversion have produced cost reduction results, and have also reduced the dependence on unreliable fuel sources.

A northern utility has recently completed a coal conversion of one unit and has been successfully operating for over a year. The boiler fired coal until the early 1970's, when it was converted to oil firing. The unit is rated at 1,000,000 lbs/hr (453,592 Kg/hr) at 1950 psig (13.44 M Pa), with 1000°F (538°C) superheat and reheat (see Figure 5). Coal conversion requirements for this unit consisted of boiler upgrading, fuel system upgrading and the addition of emission controls.

The utility estimates that this conversion has saved its customers 1.2 million barrels of oil in one year. The utility was able to establish, with the cooperation of state government, an innovative method of sharing fuel cost savings with customers while recovering the cost of conversion.

The conversion of a utility boiler originally designed for oil firing to coal has been recently proposed. The boiler is rated at approximately 700,000 lbs/hr (317,514 Kg/hr) at 1980 psig (13.65 M Pa), with 1005°F (540°C) superheat and reheat. The proposed modifications to enable coal firing are:

a. an increased slope on furnace hopper to improve ash removal
b. the replacement of superheater and reheater surface to reduce gas velocities, preclude ash fouling, and upgrade metal material
c. the replacement of a finned economizer with less tightly spaced surface to preclude fouling
d. the addition of an ash removal hopper at economizer outlet
e. the addition of a new fuel system including pulverizers, feeders, and low NOx burners
f. support steel modifications for the new equipment and for balanced draft operation
g. the addition of an induced draft fan and gas cleaning equipment

With the proposed modifications, 75% of boiler maximum continuous rating can be achieved when firing the design coal. The benefits of conversion (lower fuel costs and a reliable fuel source) will be compared to capital and operating costs of the conversion and projected electricity demand.

The recent conversion of a 200,000 lbs/hr (90,718 Kg/s) oil fired industrial boiler to wood firing has been completed and is now successfully operating. Conversion work included addition of the following major equipment:

a. water cooled grate stoker and pneumatic wood distributors
b. furnace heating surface
c. overfire air system
d. superheater
e. boiler bank replacement
f. dust collector
g. forced and induced draft fans
h. air heater
i. flue gas scrubber

The boiler runs at 180,000 lbs/hr (81,646 Kg/hr) of steam 24 hours per day, 345 days per year. The plant will eventually run the boiler at 200,000 lbs/hr (90,718 Kg/hr). The boiler is normally fired on 100% wood and can run on automatic control on all wood, all oil, or any combination of the two. Much of the wood is waste, including oversize chips and fines from the pulp mill and waste bark, sawdust and shavings from sawmills. The majority of the wood is chipped specifically for boiler fuel.

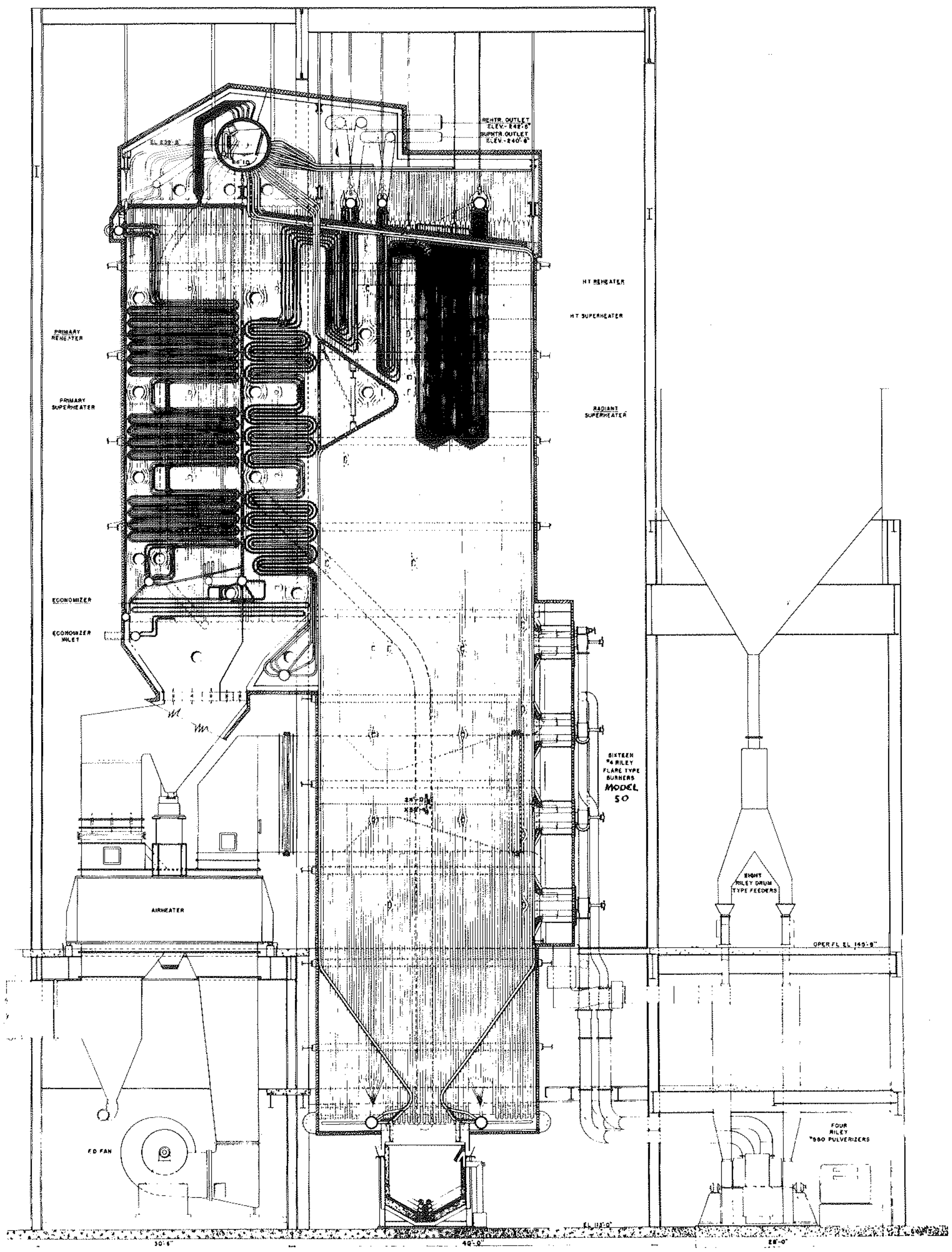

Figure 5 Sectional Side Elevation of Recently Converted Central Station Unit

A significant feature of this retrofit project is the high percentage overfire air system. The overfire air system is made up of the fan, ductwork, header, and air nozzles. Five rows of nozzles, three front and two rear, are staggered at different furnace elevations and introduce 50 percent of the combustion air above the grate. The system improves the wood combustion process by increasing furnace residence time. Particulate carryover is reduced and carbon burnout increased, thus increasing boiler efficiency. A schematic of the system is shown in Figure 6.

The owners of this installation estimate that the fuel savings from firing wood are approximately $13,000 per day. The payback period for the project is three years.

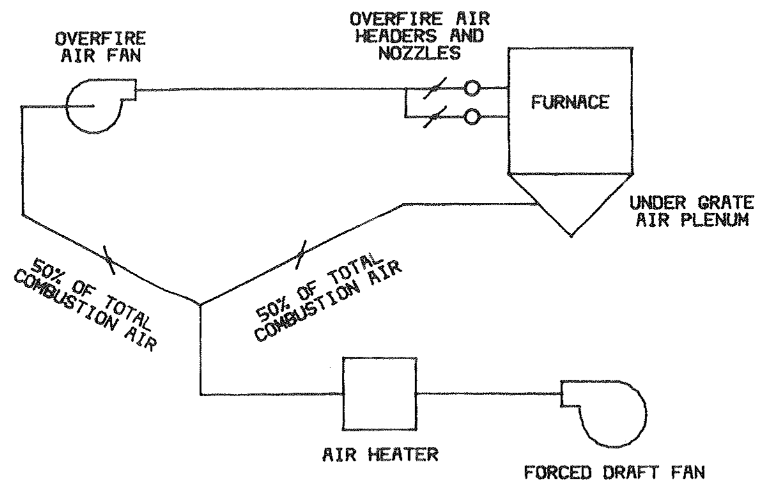

Figure 6 Overfire Air System Schematic

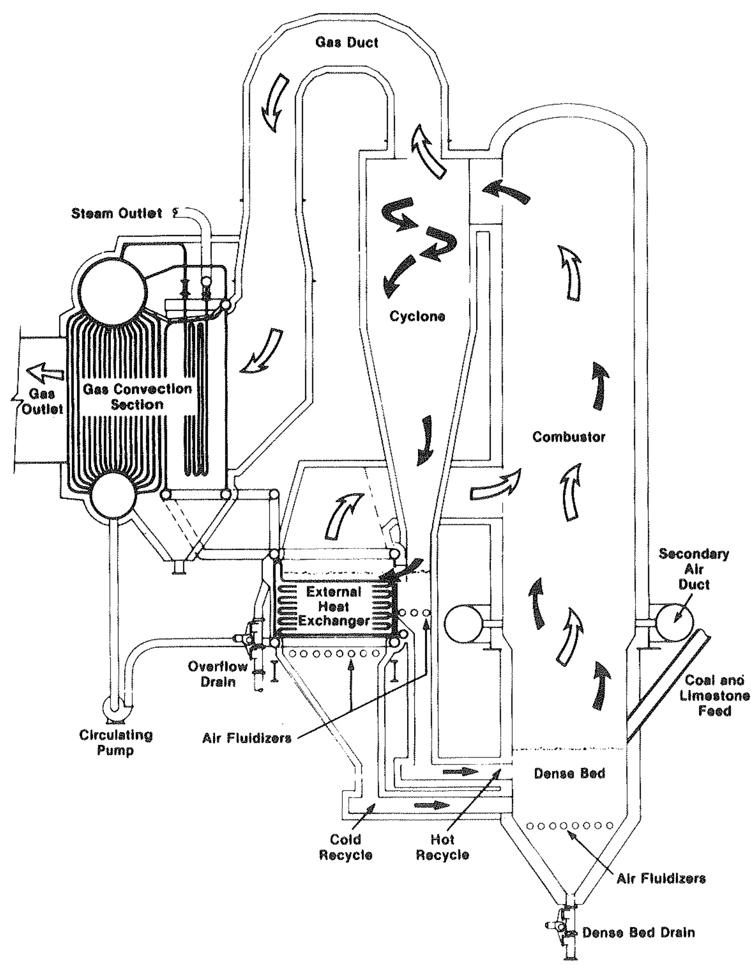

Figure 7 Riley Advanced Fluidized Bed Steam Generator

The application of an existing coal pulverizer for peat pulverization has shown encouraging results. In recent tests performed on an industrial size boiler using the Riley ATRITA® pulverizer, various grades of peat were pulverized and burned with a stable flame. Peat grades ranging from unmilled to pelletized were burned. Further operational testing is scheduled for a larger unit in the fall.

A new development for firing less expensive fuels in an environmentally acceptable manner is the Multisolid Fluidized Bed Combustion (MSFBC) process. Compared to conventional fluidized bed designs this system offers the advantages of rapid load response, fuel flexibility with regard to type and size, low operating costs, and minimal boiler tube erosion and corrosion. The system separates the combustion and heat transfer process into two distinct sections, maximizing controllability and efficiency (see Figure 7).

In the MSFBC process, a recirculating bed of fine particles is superimposed on a fluidized dense bed of large particles. The entrained bed controls the combustion temperature. The heat contained in the entrained bed particles is captured in a low velocity external heat exchanger. The heat from the flue gases is captured in a conventional steam generator arrangement.

The MSFBC process has been developed by Battelle and is licensed to Riley Stoker. After 7000 hours of pilot plant operation, the system has entered the commercial stage with 5 million Btu/hr and 50 million Btu/hr units currently operating.

For retrofit applications, an existing oil or gas fired boiler could be used as a waste heat boiler to capture the heat in the flue gas.

SUMMARY

The current economic conditions have forced boiler owners to maintain and upgrade their existing boilers rather than buying new boilers. In order to keep the costs of operating these older units reasonable, they must be made reliable and efficient. The foregoing discusses equipment retrofits and services designed to assist boiler owners in reducing maintenance and operating costs.

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