

# Recycle flue gas to cut emissions, Improve boiler performance

Combining flue gas from a coal-fired boiler with fresh combustion air can slash the required excess air flow by more than 50%, reduce SO<sub>2</sub>, NO<sub>x</sub> and Particulate emissions, and, in some cases, trim the size of downstream equipment

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Flue-gas recirculation has been used in the past on oil and pulverized coal-fired boilers to reduce thermal NO<sub>x</sub> formation. Now the technique has been extended to reduce emissions from, and to improve the operating efficiency of coal-fired stoker-fed boilers. The following are some of the potential benefits of flue-gas recirculation, shown in pilot tests on a 100,000 lbs/hr spreader-stoker firing western Kentucky coal:

- A 50% or greater reduction in the excess air required for stable operation and for inhibiting the fusion of ashes into clinkers. Lower excess air translates directly into fuel savings and reduced NO<sub>x</sub> formation.

- A 33% or greater reduction in particulate emissions and opacity, depending on where the recycle stream is extracted after the boiler.

- The possibility of increased steaming capacity in retrofits if the existing boiler was limited by fan capacity, stack opacity, particulate emissions, or furnace pressure.

- A reduction in the size of equipment downstream of the boiler-ductwork, dust-collection equipment and scrubbers because of the reduced stack-gas flow and emissions.

When fully realized, these benefits may combine with the traditional advantages of stoker-fired boilers, especially their greater solid-fuel flexibility and lower capital costs, to

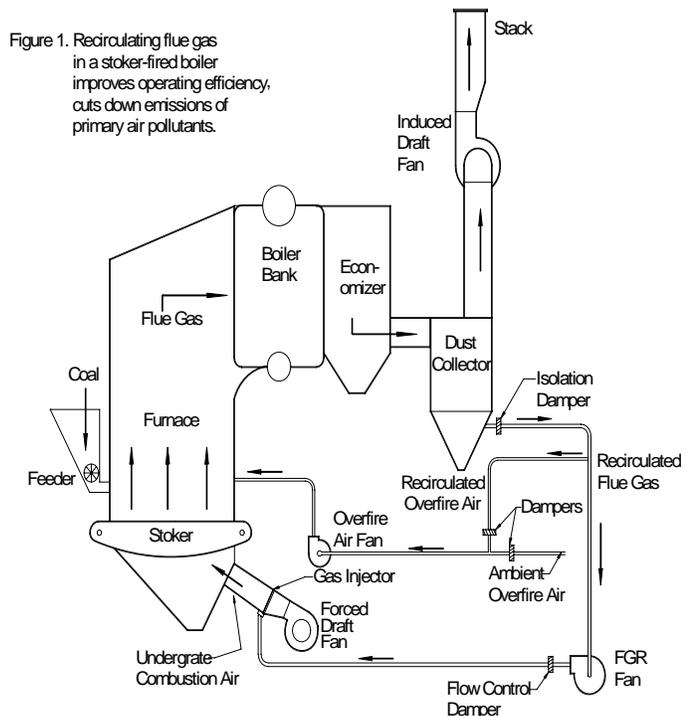


Figure 1. Recirculating flue gas in a stoker-fired boiler improves operating efficiency, cuts down emissions of primary air pollutants.

keep them competitive with pulverized coal-fired and atmospheric fluidized-bed boilers.

## The concept

A persistent problem with stoker fired boilers is that the fuel and air usually do not have adequate time to mix properly within the fuel bed area. One reason is that a certain mass flow of air in excess of that required for combustion must be supplied to cool the fuel bed and to

prevent the formation of clinkers in the ash. Even use of overfire air and different grate designs have not solved the problem completely.

The simultaneous requirements of mixing and cooling can be met by replacing some of the combustion air with flue gas. This recirculation improves boiler efficiency by reducing required excess air and stack gas heat losses. Recirculation improves mixing by reducing the concentration of O<sub>2</sub> in the combustion air, almost to the

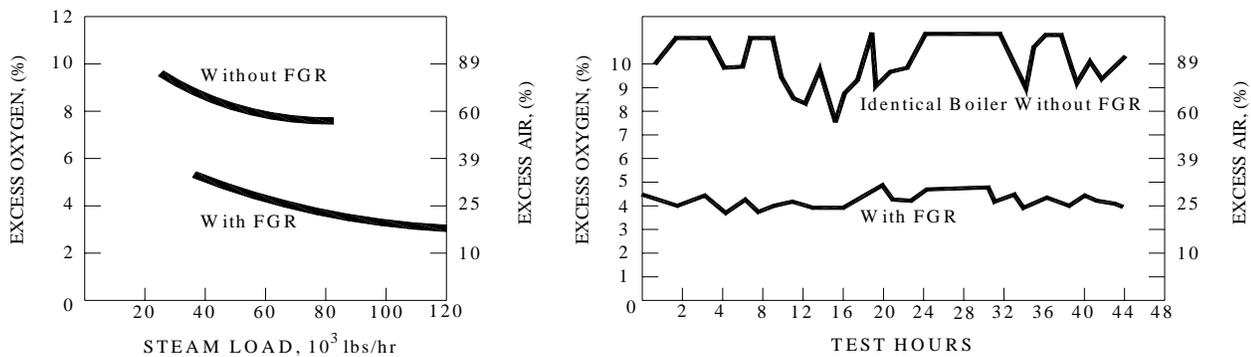


Figure 2. Required excess air can be reduced by more than 50% left: graph at right shows two identical boilers firing same quality coal. Operation is more stable with the recirculation feature over this testing period.

flammability point, before combustion stability problems are encountered.

The moisture in the flue gas improves the reactivity of the carbon in the coal via a water/gas reaction, which improves carbon utilization in the furnace. Because this reaction is endothermic, it helps keep the fuel bed cool by absorbing additional heat.

A flue gas recirculation system also functions as a direct-contact air heater. But the increase in combustion-air temperature does not adversely effect the grate since the fuel bed actually operates at a lower measured temperature. Gas temperatures immediately above the bed have been determined to be approximately 250°F cooler with flue gas recirculation.

If the flue gas is taken from the hopper section of a mechanical dust collector, collection efficiency is improved. The particulate matter in the flue gas recycle stream – a large percentage of that entering the collector – is efficiently filtered out by the fuel bed, at least those particles greater the 10 microns. The degree of improvement depends on the grind size of the coal and whether the cyclone collector is upstream or downstream of the economizer. If the recycle stream evacuates the dust hopper, then further improvements in emissions arise from reduced re-entrainment in the dust collector.

Flue gas can also be recirculated to the overfire air ports. Here, the goal is

to promote mixing of the fuel volatiles from the bed with the unused O<sub>2</sub> in the combustion air passing through the fuel bed. Although the boiler could be run with overfire air supplied totally by the recirculation system, tests show that a mixture of 50% flue gas and 50% air is easier to control. This technique reduces the excess air introduced above the fuel bed.

**Hardware modifications**

To install a flue gas recirculation system, a series of flues is connected to the boiler system along with a fan (Fig. 1). The flue gas is extracted after the boiler convective sections and is injected into the stoker undergrate air duct downstream of the forced draft fan. A distribution nozzle system ensures that the fresh combustion air and recycled flue gas mix properly before flowing through the grate.

A flow control damper, located on the discharge of the recirculation fan, is positioned by a local drive unit that receives a signal from a controller that is mounted on the boiler control panel. The operator can remotely operate this damper by hand or automatically. In the automatic mode, the recirculation control signal follows the forced draft flow controller and can be biased to set the ratio of recirculated flue gas to combustion air. On manual, the operator sets the percent recirculation as desired.

The recirculation feature allows operation at reduced combustion air flow, but the boiler operator must make adjustments. To make these adjustments, he needs to consistently measure combustion air flow and flue gas flow in the recycle loop. Measuring the excess O<sub>2</sub> content of the flue gas and air/flue gas mixture is one way to set the amount of recirculation properly, or the percent recirculation can be read on the flow controls and then related to the boiler efficiency by graphical methods.

Modifications to the overfire air system are required if recirculated flue gas is used here. In the pilot test unit, the diameter of each overfire air jet was increased from ¾ inch to 2 inch, increasing the nozzle flow area by a factor of seven and allowing significantly more air to flow through the jets.

A further improvement to the overfire air system involves installing sidewall overfire air jets. In the test unit, four jets on each sidewall were located midway between the front and back of the furnace, one foot above the grate. These jets were supplied from the same manifold feeding the front and back jets.

**Test verify performance**

After the flue gas recirculation system was installed on the test boiler, the excess O<sub>2</sub> measured lower at all loads

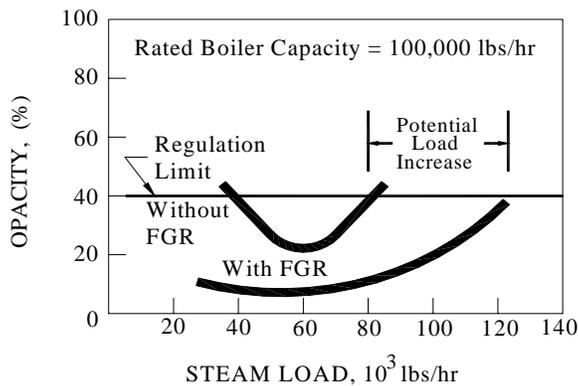


Figure 3. Flue gas recycle lifted load restrictions on this boiler because of opacity.

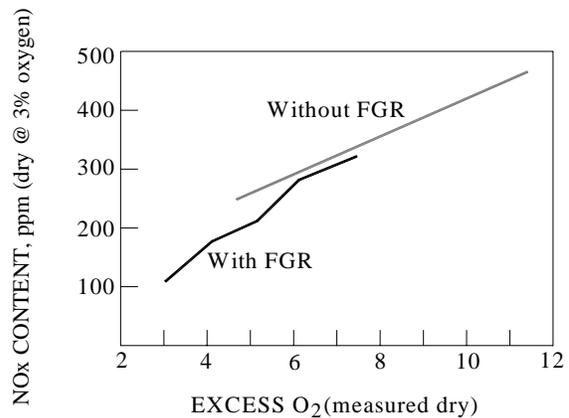


Figure 4. Flue gas recirculation is a proven method for lowering NOx emissions.

(Fig. 2), representing a significant improvement in boiler efficiency. Fuel savings compared to boiler operation without modifications were calculated to be between 6% and 7%, or nearly \$150,000 per year, based on current coal usage and price.

Fig. 2 also illustrates how flue gas recirculation provides smoother operation over time. Excess O<sub>2</sub> is plotted over a 44-hour test period for two identical boilers, one with recirculation and one without. Coal used during this test had been in storage for many years and consisted of a large percentage of fines. Clinker-free operation was more difficult without flue gas recirculation, as shown by the more erratic fluctuations in the excess O<sub>2</sub>.

**Emissions reductions** are another big factor in performance. Fig. 3 shows opacity as a function of boiler load with and without recirculation (the data do not include the overfire air modifications). At this particular site, boiler capacity was limited by opacity regulations to 80,000 lbs/hr. Flue gas recirculation extended the allowable capacity to 120,000 lbs/hr without exceeding opacity limits. Use of flue gas recycle in the overfire air system lowered opacity still further.

The lower excess air requirements also result in NOx reductions as shown in Fig. 4. Some speculate that this is

because of a degree of natural staging that takes place when fuel-bed stoichiometries are lowered and when overfire air is used to combust volatiles from the grate. NOx emissions approached 100 ppm at the lowest excess O<sub>2</sub> levels.

A 40-hour test was run to compare the particulate emission reductions available from recirculating flue gas. The average of five EPA Method 5 particulate tests at two different boiler loads was used as a yardstick. At 60,000 lbs/hr and a 30% gas recirculation rate, particulate emissions were reduced by 42%. This figure decreased to 33% when boiler capacity was 80,000 lbs/hr and the recycle rate was 20%.

## Consider in-situ SO<sub>2</sub> control with flue gas recirculation

There is potential for in-situ SO<sub>2</sub> control with a flue gas recirculation system. Since the fuel bed operates at a lower temperature than with a conventional undergrate air system, it can trap the sulfur as a solid sulfide or sulfate and be disposed of with the boiler ash. To illustrate; the fuel bed operates in the 2200-2500°F range with recirculation, a temperature range that

is compatible with a moderate degree of sulfur capture by calcium. Conventional stokers operate in the 2700-2800°F range. Calcium occurring naturally in fuel or entering as part of a limestone/coal fuel pellet is then available to react with the fuel sulfur during the combustion process.

Laboratory tests with a 20 lb/hr stoker burning a coal/limestone pellet showed a 50% reduction in SO<sub>2</sub> emissions. The calcium-to-sulfur molar ratio was 1:3.

This feature has potential significance, considering the forthcoming SO<sub>2</sub> emissions regulations for industrial boilers. Even if a scrubber or other SO<sub>2</sub> control is necessary, required capacities of control may be less.