

Calpenn Associates, Inc.

FLUE GAS RECIRCULATION SYSTEMS FOR STOKER BOILERS

TYPICAL QUESTIONS AND ANSWERS

1. How does Flue Gas Recirculation work? What does it do?

Flue gas recirculation acts as a mixer. If you were to draw a black box around the furnace and had just air and fuel going into that black box and flue gas coming out the flue gas recirculation (FGR) could be visualized as becoming a large mixer, a paddle wheel inside the furnace. This mixer more intimately mixes the fuel and air and provides for better combustion. The air requirements are reduced substantially, and the air/fuel ratio can be reduced to levels approaching the stoichiometric point. The benefits of the process arise from this improved mixing; this improved air/fuel combustion and the resulting lower excess air requirement for the furnace. This can be viewed in two ways: one is that you have to heat less excess air going in, or conversely, you lose less heat in the stack by reducing the amount of excess air that is emitted to the stack, at the stack temperature. This improves the fuel efficiency of the furnace because for every pound of steam that you heat you have less air that you expel through the stack and this requires less fuel.

The flue gas also cools the fuel bed independently of the larger amounts of excess air that are used without the FGR system. The flue gas “decouples” the cooling requirements of the fuel bed. (to avoid clinkering) from the combustion requirements of the fuel bed (excess air for complete combustion). The FGR provides the bulk of the fuel bed cooling and the forced draft fan supplies the air for combustion at lower air/fuel ratios (excess air).

2. Flue Gas Recirculation has been around for years but what is different? What makes this recycle flue gas system better or more operable? What have you done to change things?

Most people do not know about FGR for stoker-fired boilers. FGR is a common technique in larger boilers, typically pulverized coal, gas or oil, where it has been used as a gas tempering process to improve the convective heat transfer in large boilers. When they turn down the load they use FGR to keep the mass flow over the convective sections at the same rate as you would at higher loads. But, FGR

on stokers, in this country, is not a common technology. In Europe it has been used on water-wall incinerators and on coal-fired stokers. The emphasis, in this country, has not been to use FGR because coal prices have been low. In Europe, where fuel is much more expensive, people have gone to energy saving processes, such as FGR, to improve their fuel efficiency. The process, which we are selling, has been demonstrated on many commercial applications, in this country. We are willing to **OFFER GUARANTEES OF EFFICIENCY** depending on the boilers condition and age. We offer guarantees of excess air reductions from the baseline case.

3. What are the main benefits of flue gas recirculation?

One of the main benefits is the **REDUCTION IN STACK PARTICULATE LOADING** and the **REDUCTION OF STACK OPACITY**. This can be accomplished in two ways. The main gas recirculation process, where the flue gas is taken downstream of the ID fan and brought back around, reduces the stack particulate in the range of 30 – 40%. This is without any special attention to improved dust collector performance. The opacity, by modifying the overfire air system, can also be controlled to less than the 20% opacity range at the low particulate level.

The addition of HOPPER EVACUATION into the FGR system increases particulate reduction and reduces opacity. This is an application where a portion or the entire FGR stream is taken from the hopper of the mechanical multi-clone dust collector. This stream is then used in the normal FGR manner, recirculated back and mixed with the forced draft air. The dust collector performance is improved from the mid 60% efficiency up to as much as 95% efficiency. In one application we were able to reduce the particulate emission on the order of 70% from the baseline case, all the while maintaining stack opacity well under 20%.

Another major benefit of FGR is **IMPROVED FUEL EFFICIENCY** due to the reduction in excess air. This feature was touched on in Question #1. Excess air reductions are generally greater than 50% resulting in fuel savings between 5 – 10% or more and payback periods under two years.

The FGR process can also, in some cases, offer the client **INCREASED STEAMING CAPACITY**. Instances where this might occur are in cases where the boiler is fan limited or particulate or opacity limited such that they can't reach their maximum steaming rate before running into one of these limits, either the ID or the FD fan runs out of capacity. A particulate or opacity limitation may occur before the maximum or the desired steam flow is achieved. In the cases where these things may happen, FGR can provide increased steaming capacity by removing one or all of these limits and restore, or in some cases, increase the steaming load of the boiler in question. The client can now generate more steam out of that particular boiler. This is a tremendous economic incentive in that it

can preclude the buying of a new boiler or adding or increasing steam generating capacity in one form or another for a client if he is marginal or needs slightly more steam generating capacity.

A summary of benefits is shown at the end of this list of questions.

4. How does hopper evacuation work? Why does it improve the dust collectors performance?

Removing a portion of the flue gas from the hopper of the dust collector reduces the re-entrainment of the fine particulate inside the dust collector. By taking a portion of this gas out of the hopper, the vortices that are created by the cyclones or turning vanes can be stretched out. These vortices are stretched out and the high velocity component of the vortices, which entrains the particulate, instead of going back up through the center of the cyclones, are now pulled out and evacuated. This prevents particulate re-entrainment from the hopper section of the dust collector and improves the overall multi-clone performance.

5. When we talk about energy savings, is it a function of the oxygen in the stack? In particular, we try to define where we are now and where we are going to be. How do we guarantee where we are now?

Where you are now can be fairly simply done if you have instrumentation that can measure the stack temperature and excess oxygen. Using that information, we can calculate what the boiler efficiency is and give an estimate of what your boiler efficiency will be. We can also estimate what the fuel savings will be after the FGR process has been installed. The same two parameters, stack temperature and excess oxygen, will permit the calculation of the fuel savings. Knowing the cost and amount of fuel burned over a year's period provides the payback period for the furnace retrofit with an FGR system.

6. What different kinds of stokers is this process applicable to? Will it give the same benefits on mass fed units as it does on spreaders?

We feel that the benefits are generally applicable to all kinds of stoker-fired units including mass fed, chain grates, spreaders, underfeeds, vibrating grate and even hand-fired stoker boilers. We believe the process has general application to the area of stoker-fired boilers. This includes coal-fired stoker boilers as well as stoker boilers that burn wood, tires agricultural waste, garbage and bagasse.

7. How do we make sure that the flue gas and air are properly mixed?

Each type of stoker boiler has differences that require a different approach in how the flue gas and air are mixed. Also, certain areas on the grate can tolerate more flue gas than other areas. Our proprietary mixing design takes into consideration where the flue gas needs to be distributed. Boilers with numerous air zones require more hardware because the flue gas must be tailored toward how much each of these zones can use efficiently. Temperature probes are also installed in the windbox in various locations to monitor where the flue gas is going. For boilers with multiple plenums we install balancing dampers at the tie-in locations that can be positioned to balance the temperature between the plenums.

8. When overfire air changes are made, is the recycled flue gas also supplied to the overfire air? What is changed in the overfire air system?

The answer to the first question is “yes”. In addition to internal furnace work, we enlarge the diameter of the openings on the jets both on the front and back wall. The manifolding to the overfire air jets is also enlarged. We supply a new overfire air fan that is capable of handling a flue gas / air mixture which then becomes the overfire jet gas medium. The rationale behind this is that we are trying to improve the penetration of the gas into the furnace to improve the mixing above the bed. This is accomplished by increasing the mass flow through the jets. However, we don’t want to increase the mass flow at the expense of increased excess oxygen in the furnace. The excess oxygen that would normally be put into the furnace by increasing mass flow is reduced by supplying a flue gas / air mixture which cuts back on the amount of air going into the furnace in the overfire air system.

9. Are the modifications to the overfire air system necessary? Do you have to add the main gas recirculation and modify the overfire air system?

Modifications to the overfire air system are not required for the FGR system to function properly. They do help to get a much better above bed mixing which helps reduce opacity as well as complete the burnout of combustibles. Adding flue gas to the overfire air will also allow for the better control of the excess air. It will also give a better staging effect because of better jet penetration into the furnace covering more area. We have also seen additional reductions of NO_x when FGR is added to the overfire air.

10. Can flue gas recirculation be applied to a boiler that has an air preheater?

Yes, the air preheater poses no problem to the FGR process. The flue gas itself acts as a vitiated air preheater so that in applications where there is no air preheater, the FGR tends to improve the combustion on the grate and recover some of the heat from the stack by the action of the vitiated air preheater. However, the bulk of the fuel savings come by reducing the excess air that the furnace needs to fire.

11. How do you control the system? What are the modes of controlling the gas recirculation to achieve the optimum benefits?

There are three levels of sophistication in the control system that we provide. If a boiler is an old design and doesn't have a modern control system we can specify a mechanical control scheme where the FGR fan control damper is slave to the forced drafter damper controller and biased to control the amount of gas recirculation admitted to the forced draft duct, depending on the opening of the forced draft duct damper.

A second type of control system is based on temperature. The temperatures required are:

1. Ambient Air
2. Flue Gas being recirculated
3. Mixture Temperature of flue gas and air in windbox

Using these three temperatures the %FGR can be calculated using the equation:

$$\%FGR = \frac{T_{mix} - T_{air}}{T_{fgr} - T_{air}}$$

Once the optimum %FGR is determined for each load a curve can be programmed into the controller to maintain a given %FGR versus load. This way the FGR system can be placed in either automatic or manual operation depending on the given situation.

A more sophisticated control system uses a measurement of excess oxygen in the flue gas/air mixture in the plenum to control a predetermined ratio of flue gas to combustion air that is admitted to the furnace. This control system can be visualized very much like an oxygen trim system that one might see on the stack of a boiler. But, this control system is integral in the loop of the air/fuel ratio control and acts as a trim on the excess air and controls the FGR ratio over the boiler load range.

12. What effect does the gas recirculation have on grate temperature? Will it increase or decrease the grate temperature and what effect does this have on the lifetime of the grate?

Laboratory tests and field measurements have shown that the grate temperatures are lower using the FGR process. This occurs for two reasons:

1. Flue gas has a greater heat capacity than air so it carries more heat away from the fuel bed. This higher heat capacity results because the mixture of carbon dioxide and water vapor contained in the flue gas absorb more heat than air alone which contains mainly oxygen and nitrogen.
2. The water vapor in the flue gas enters into a chemical reaction with the carbon in the coal via the water gas reaction, which produces carbon monoxide and hydrogen. This reaction is endothermic, which means it absorbs heat out of the fuel bed so that the fuel bed operates at a lower temperature.

These two major factors combine to reduce grate temperatures and increase its lifetime.

13. What effect does the gas recirculation have on grate plugging? Will it plug up the holes in the grate and limit the air going to the fuel bed?

The answer to this is no, we haven't seen or heard of any problems with grate plugging. Most of the particulate entrained in the flue gas drops out in the sifting hopper below the grate. This results because the velocity of the gas drops very dramatically from the forced draft fan duct into the windbox or sifting hopper plenum. The area of the plenum increases several orders in magnitude from that of the FD duct and the velocity becomes very low. Any particulate entrained in the flue gas drops out into the hopper, not through the grate. Any fine particulate that does stay entrained in the mixture passes through the holes and is filtered out by the fuel bed. The grate also has cleaning mechanisms on the return portion that act to keep the air passages open.

14. What's the life expectancy of the gas recirculation fan? Will this fan become a maintenance problem?

The FGR fan is an armored radial blade fan with scroll liners and blades of abrasion resistant (AR) materials. The fan specifications include a slow rotation speed (1800 rpm max) to reduce wear and increase lifetime. If hopper evacuation is used to extract the flue gas a secondary mechanical dust collector is recommended to extract the majority of the flyash from the FGR system before passing through the ducting, dampers and fan.

15. Does the FGR fan horsepower affect the economics of the process?

The power required by the new FGR fan is offset by the reduction in power required to drive the existing ID and FD fans. This comes about because the gas recirculation process lowers the overall excess air that these fans need to process from the baseline case.

16. How is the ductwork designed to prevent the buildup of particulate from the FGR gas stream?

The ductwork is designed with access doors and clean outs in areas of suspected accumulation. It is also designed with a minimum of horizontal runs. Gas flow velocities are maintained high enough that particulate entrainment is maintained in the gas stream. This is of particular concern when the process is using hopper evacuation and dust loadings are very heavy. Care and attention to the design of the duct work and fan placement is important to insure that the system operates properly and does not accumulate large amounts of ash in the ducting.

A SUMMARY OF BENEFITS

1. Excess air reductions in excess of 50%, which translates into fuel savings from 5% to 10%.
2. The fuel savings result in payback periods which are usually less than two years.
3. A major benefit is the reduction in stack particulate loading and opacity.
4. When flue gas is extracted from the hopper of a mechanical dust collector and used in the normal manner, the dust collector efficiency is increased and particulate reductions as high as 70% are possible.
5. An FGR System will cost less than half the cost of a conventional Hopper Evacuation/Baghouse System.
6. Opacity can be controlled at less than 20% over all load ranges.
7. NO_x reductions up to 70% are possible.
8. In some cases the FGR system can result in increased steaming capacity. For example, if the boiler is fan limited or particulate or opacity limited such that it can't be operated at the maximum steaming rate before running into one of these limits.
9. The FGR process produces lower grate temperatures, which prevents fuel bed clinker formation and allows the use of a wider range of lower fusion fuels.