Flue Gas Recirculation For NOx Reduction

General Remarks

Flue gas recirculation (FGR) can be a highly effective technique for lowering NOx emissions from burners, and it's relatively inexpensive to apply. Most of the early FGR work was done on boilers, and investigators found that recirculating up to 25% of the flue gases through the burner could lower NOx emissions to as little as 25% of their normal levels. Word of this success has spread, and now operators of industrial processes are interested in learning if FGR can do the same for them.

How does it work?

FGR lowers NOx in two ways:

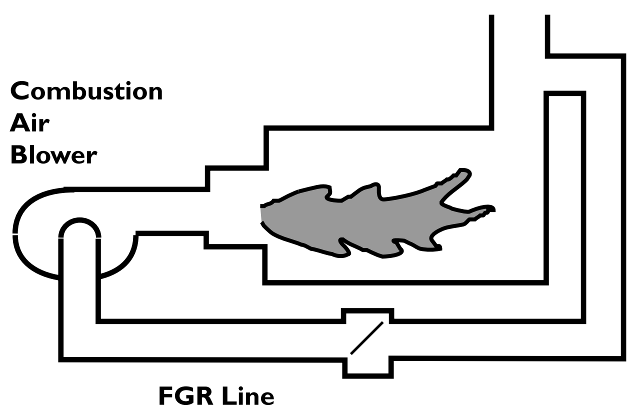
1.) The cooled, relatively inert, recirculated flue gases act as a heat sink, absorbing heat from the flame and lowering peak flame temperatures.

2.) When mixed with the combustion air, recirculated flue gases lower the average oxygen content of the air, starving the NOx-forming reaction for one of the ingredients they need.

How is it done?

The simplest way is to use the combustion air blower to suck the flue gases out of the stack and blend them with fresh air before they go into the burner (Figure 1). This technique is also known as air vitiation, and it has been applied to many types of burners without any other modifications. The second way is to use a separate blower to pull the flue gases from the stack and push them through some sort of manifold or bustle ring into the flame. This normally requires factory-modified burners. Both methods seem to be equally effective, although certain burner designs may respond better to one method than the other. Air vitiation has a number of practical advantages, so the rest of this article will deal with that method.

Figure 1:
FGR by Air Vitiation



How is % FGR defined?

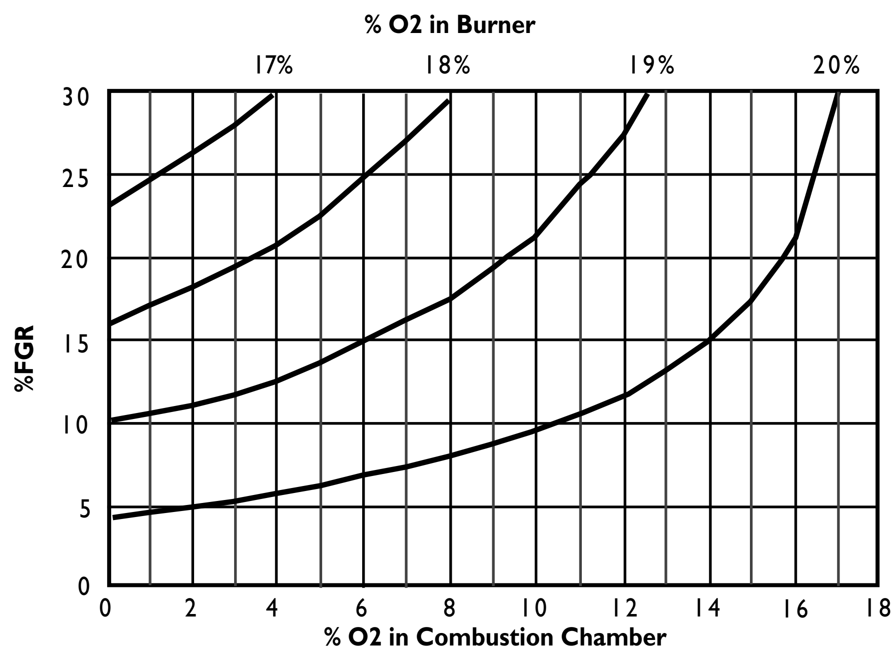
There's no accepted standard. Many people define it as the percentage of the total flue gas flow that is routed back into the burner. We prefer to treat it as the precentage of flue gases in the combustion air/flue gas blend going into the burner. This simplifies some of the selection calculations and lets us relate everything to the percent oxygen in the combustion air, which seems to be the most important factor in NOx reduction.

Can you use FGR everywhere?

Unfortunately, no, and one of the objectives of this article is to give you some idea of the processes that do qualify. As we mentioned above, FGR works by lowering both the flame temperature and the oxygen in the combustion zone so the process flue gases have to be relatively cool and have a fairly low oxygen content. A modern boiler, for example, has flue gases no higher than 600°F and 5% O_2 conditions ideal for FGR systems. However, many industrial processes have flue gases that are too hot or too high in oxygen to be useful.

Experience suggests that reducing the NOx emissions of modern industrial burners to 30 ppm or less (corrected to 3% O_2 as now required by some air quality districts, requires lowering the average oxygen content of the burner air to 18% (fresh air contains 20.9% O_2). Knowing that and the oxygen content of the process flue gases, you can determine the % FGR you need from Figure 2. Say for example, the combustion chamber contains 4% O_2 and you need 18% O_2 in the burner to get the needed reduction in NOx Figure 2 reveals that you need a little over 20% FGR to do the job.

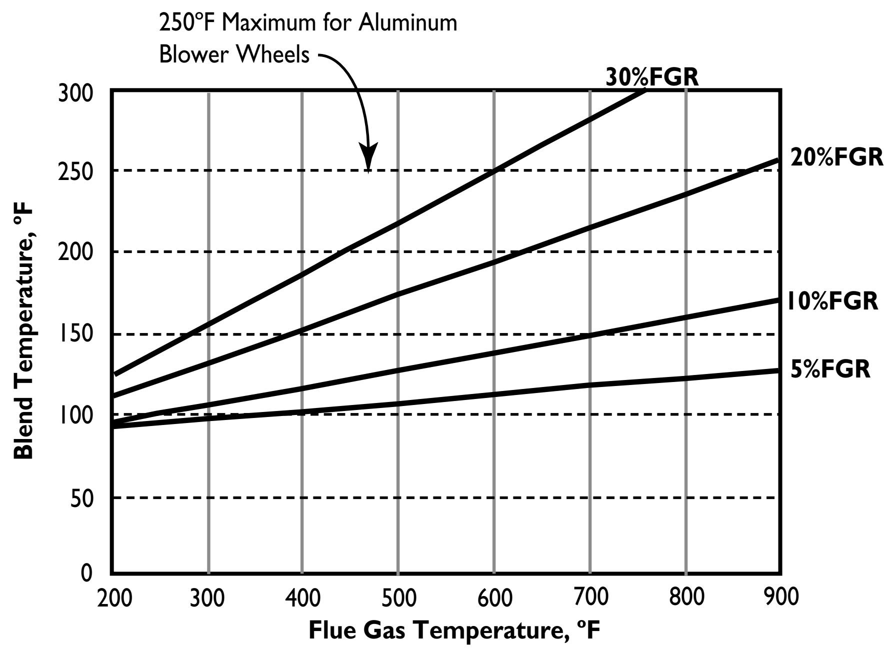
Figure 2:
% FGR vs. Oxygen in Burner & Chamber



The other thing to consider is the temperature of the air/flue gas mixture in the combustion air blower. Let's say the manufacturer says the blower shouldn't be exposed to more than 250°F, and the flue gas temperature is 700°F. The blend temperature chart (Figure 3) shows that a mixture containing 20% of 700°F flue gases, the rest 80°F air, will have a temperature of 210°F, which is below the limit for the blower, so you have the makings of a good FGR installation

On the other hand, if regulations allow up to 40 ppm of NOx, you may be able to use less FGR (higher oxygen content in the air/flue gas blend), which permits using it on applications with higher flue gas temperatures and oxygen levels.

Figure 3: Blend Temperature Chart

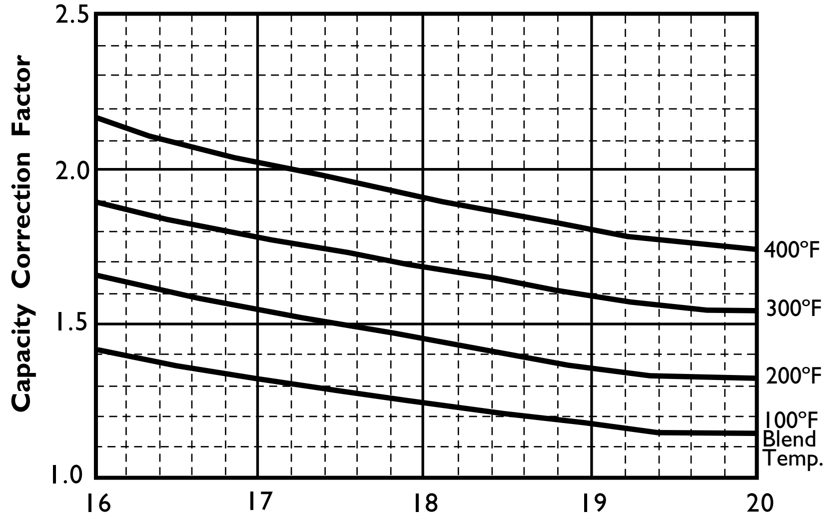


What other things do you have to consider ?

There are several.

The first is loss of burner capacity. If you replace 20% of the combustion air with low oxygen flue gases, the burner has to be downrated to compensate for the reduced weight of oxygen flowing through it. You'll also suffer an additional capacity loss because the flue gas/air blend is at elevated temperature. In the case of our burner with a 210ºF blend containing 18% O_2 the burner capacity is only about 67% of standard. The remedy is to start with an oversize burner to net the input you need. In this case, you'd need a burner with a capacity equal to 1/0.67=1.5 times your actual Btu requirements. Figure 4 shows capacity correction factors for various flue gas/air blend temperatures and oxygen contents.

Figure 4:
Burner Capacity Correction Factors



The second is loss of burner stability and flexibility. The good side of slowing down a combustion reaction is reduced NOx; the bad side can be higher emissions of carbon monoxide and unburned hydrocarbons, or combustibles In extreme cases, combustion may be so severely affected that the burner goes unstable over part or all of its operating range. Consequently, FGR isn't something that can be applied at random. It requires, at the least, a knowledge of how the burner will operate under these conditions, and often calls for a burner specially modified to operate well with FGR. It's a good idea to involve your burner supplier from the beginning.

Third, you have to be careful in designing an FGR piping and control system. It has to allow the required flow of flue gases under all anticipated operating conditions, has to be able to turn down with the firing rate of the burner to avoid problems with burner performance and contamination of mom air, and has to be insulated or guarded to protect people nearby.

Summary

FGR can be an effective way to lower NOx emissions on industrial heating processes provided the flue gas temperatures and oxygen levels permit the required level of blending with combustion air. However, there are some side effects —loss of burner capacity, potential for higher combustible emissions, burner instability, and safety considerations —that make it advisable for you to consult with your combustion equipment supplier before proceeding He can recommended burners best-suited for the purpose and aid you in selecting and designing the system.