

Analysis of a low NO_x burner re-fit of a tangentially fired boiler

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This study concerns an existing 260 million BTU/hr tangentially fired process boiler which was re-fitted with a low NO_x natural gas firing system. The re-fit involved changing the burners, the windbox and the Air/FGR ductwork, as shown, with the boiler, in figure 1.

After a year of operation, some very unusual damage was witnessed in some of the burners' Fuel-Lean ports. This was

rather puzzling to the manufacturer as this burner design had been tried and tested for almost 20 years without suffering such problems. The only difference between this particular unit and the other tangentially fired boilers where this technology was installed is in boiler capacity; all the

other boilers had capacities ranging from 500 to 1000 million BTU/hr. Due to the impossibility of carrying out any kind of experimental measurements inside the furnace area of an operating boiler, Cerrey S.A. de C.V., an industrial boiler manufacturer, requested that a CFD analysis of this boiler's operation be

carried out in order to determine the cause of these unusual problems.

In order to determine if the combustion system had any operational difficulties when fired according to design specifications, BMA first carried out a detailed furnace simulation (3.6 million cells). Details of the burner and windbox are shown in figure 2. The burner is divided into six zones: a lower Fuel-Lean port with pre-mixing chamber, a lower pure re-circulated flue gases (FGR) port, a central Fuel-Rich port, an upper FGR port, an upper Fuel-Lean port and an Over-Fire-Air (OFA) port. The pre-heated combustion air is diluted with FGR prior to entering the windbox with an average FGR mass fraction of 13%. The first simulation was carried out at 100% load using boundary conditions corresponding to a homogeneous Air/FGR mixture entering the windbox.

The results of the simulation showed that this firing system operates within specifications when subject to design conditions. Furthermore, no examples could be found of situations likely to cause the damage to the Fuel-Lean ports. Consequently, it was concluded that the problem with this unit probably lay upstream of the firing system. To explore this further, a second simulation (6.2 million cells) including all the Air and FGR ductwork was carried out at 60% load. The partial load operating conditions were chosen because, as this is a process



Figure 2: Tangentially fired burner

boiler, it spends half of its time operating in turndown mode, which is when it is deemed that the damage to the Fuel-Lean ports is most likely to occur.

Figure 3 shows the FGR mass fraction distribution in the ductwork and windbox. The pipes shown in red contain 100% FGR and lead either directly to the FGR ports or into the

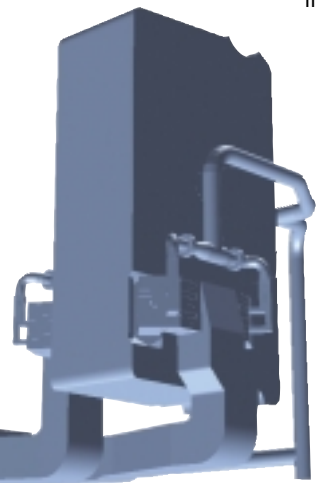


Figure 1: Boiler, burners, windbox & ductwork

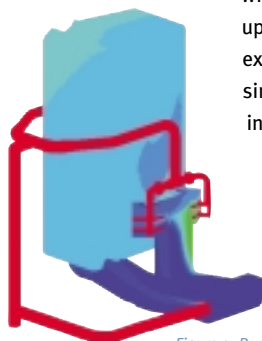


Figure 3: Ductwork Air/FGR distribution

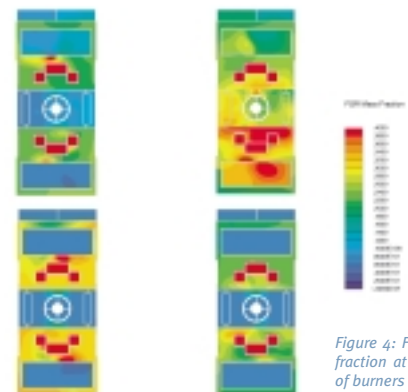


Figure 4: FGR mass fraction at the face of burners 1-4

pre-heated air stream. The figure clearly shows that that the FGR distribution within the

pre-heated air stream is uneven. Figure 4 shows the FGR mass fraction distribution at the burner face. Burners 1 and 2 have FGR concentration distributions that vary widely from port to port. Burners 3 and 4 have near-homogeneous FGR distributions; these are the burners that are located on the far side of the boiler and so there is more space for the FGR and air streams to mix. Nevertheless, the average FGR mass fraction at burners 3 and 4 is only 7%, which places the Fuel/Air/FGR mixture in the pre-mixing chamber within flammability limits. The FGR distribution imbalance was thus demonstrated to be the source of the damage to the Fuel-Lean ports caused by the mixture igniting within the port. The specified design concentration for FGR of 13% would have made this situation impossible.



Figure 5: Luminous flame contour

Figure 5 shows the resulting fireball. It is asymmetrical (Figure 6) as the flame from the Fuel-Rich port of burner 2 is severely lifted due to the very high FGR concentrations. This behavior was confirmed by visual inspection of the fireball through the boiler view-ports. Figure 7 shows flames developing inside the upper Fuel-Lean port of burner 3; this is the ultimate cause of the damage.

The STAR-CD simulations allowed BMA to pinpoint the cause of the damage as being the result of incomplete mixing of the pre-heated air and FGR streams. This mixing problem only presented itself on this small process boiler because the Air/FGR ductwork is considerably scaled down when compared to the larger installations where this technology had previously been installed. Consequently, the FGR stream has much less room to thoroughly

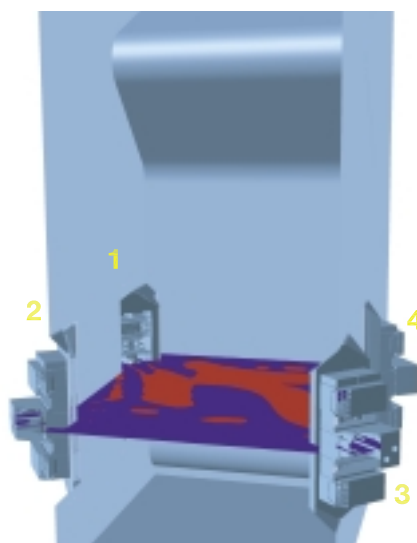
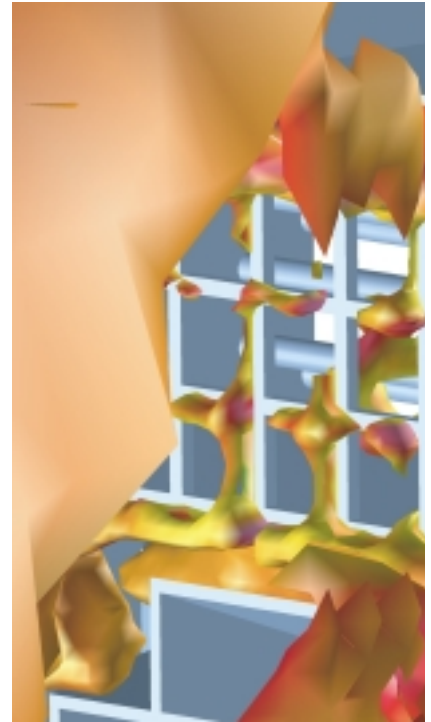


Figure 6: Luminous flame contour; Fuel-Rich port level

Fig7: Luminous flame contour – upper Fuel-Lean port – Burner #3



mix with the pre-heated air stream before the ductwork splits the flow to each side of the boiler. This behavior would have been hard to predict without CFD as most aerodynamic mixing phenomenon do not scale linearly with geometrical size and flow rates. In this case maintaining geometrical similarity with larger units was insufficient to ensure identical flow patterns.

In summary, the STAR-CD simulations showed that a problem that was first thought to be the result a serious flaw in the burner design was instead linked to a simple imbalance in the FGR distribution. This was a very important conclusion as the problem was easily remedied once it was identified, but failure to balance the FGR distribution would have doomed any attempts to eliminate the problem by modifying the burner design. ■

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