



A recent upgrade of 48 burners has made Ferrybridge C power station a leader in NO_x emissions reduction

Historic power station is cutting edge on NO_x control

Following an extensive burner upgrade project, the new ultra-low NO_x burners have not only breathed new life into the UK's Ferrybridge power plant, but have made it a world leader in NO_x reduction.

Electric power has been generated at Ferrybridge in Yorkshire since 1924 when the original coal fired station was commissioned. Ferrybridge C was completed in 1968 and was a state-of-the-art four unit power station, burning locally-sourced coal and delivering baseload power to the grid. At that time, emissions, such as nitrogen oxides (NO_x) were of little concern.

Fast forward to the 1990s and Ferrybridge C – like every other power plant in the UK – was generating in a very different environment. Privatisation and deregulation of the sector, combined with binding emissions reduction targets, began to impact on power station hardware, operating procedures and plant efficiencies.

By the mid-1990s, low NO_x burners had been fitted to meet a new upper NO_x limit of 650mg/Nm³. While these 'first generation' low NO_x burners did meet that target, they also caused adverse knock-on effects, including longer flames and undesirably high levels of carbon-in-ash (CiA).

John Goldring, managing director of RJM International, a leading provider of emissions reduction equipment and solutions for the power

generation sector, says: "These downsides can be explained by the fact that while these low NO_x burners were originally designed to operate at 15 per cent excess air, our own on-site observations confirmed that they were actually firing at sub-stoichiometric conditions.

"When we explored this further, we concluded that over time, the boilers had much higher levels of in-leakage air, compared to the original design intent. This means that the induced draft (ID) fans were already operating at capacity and physically unable to deliver additional levels of excess air," he added.

When the second round of NO_x reductions set a new upper limit of 500 mg/Nm³ in 2008, additional measures were required and many power stations began supplementing what the 'first generation' low NO_x burners were delivering through the addition of boosted overfire air (BOFA), and/or selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) systems.

Once again, for many power stations, meeting the 500mg/Nm³ target meant that existing, relatively minor combustion problems were significantly exacerbated.



According to Goldring: "A number of stations went down the BOFA route, rather than go to SCR or SNCR, as it was the most cost-effective fix, but our site survey at Ferrybridge confirmed that adding BOFA to the first generation low NOx burners was causing a considerable drop in windbox pressure – up to 50 per cent – when 15–25 per cent of the combustion air was re-directed to the BOFA ports.

"Our combustion calculations also showed that where the plants suffered from high air in-leakage the velocity of the coal at the burner nozzle could even be exceeding the register air velocity."

What this meant for the Ferrybridge power station was that the fires were becoming even longer, levels of carbon monoxide (CO) were higher and the temperature control in the superheater and reheater areas was becoming significantly compromised (see Figure 1), resulting in very expensive tube failures and unplanned outages.

"In fact, it was this problem with very high temperatures in the superheater and the convective section that first brought us into contact with the team at Ferrybridge," says Goldring.

"Clearly, there was incompatibility between the way in which these first generation low NOx burners were working with the BOFA systems and so we carried out a full site survey, using a range of procedures including RJM's in-house developed computational fluid dynamic [CFD] analysis tools.

"Our aim was to define and understand the burner and boiler dynamics, and to enable us to make performance comparisons – in the virtual world – between the existing burners and our own ultra-low NOx burners."

CFD ANALYSIS PREDICTED 25 PER CENT CUT IN EMISSIONS

RJM's CFD programme for Ferrybridge included three separate models. Firstly, a single burner model for comparative burner performance, secondly a full furnace model to review the combustion in the furnace, and thirdly, a further full furnace model including the superheater and reheater convective heat exchangers, so that RJM could understand what might be causing the elevated metal temperatures at those locations.

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Running the models with the existing first generation low NOx burner at a stoichiometry of <1.0 and comparing it to the performance of RJM's ultra-low NOx burners produced some very impressive results across a number of different criteria.

In terms of flame length, the RJM ultra-low NOx burner delivered a much shorter fire than the existing burner, as demonstrated by CO concentration in Figure 2, taken from the single burner model work.

Using a CFD temperature slice across the boiler, from Figure 3 it is clear that combustion was not happening in the right place and that the fire was concentrated on the rear wall because of low secondary air velocity and too high a momentum of coal.

"When we considered the knock-on effects to the convective pass and the potential impact on superheater and reheater metal temperatures, the CFD output was too compelling to ignore," says Goldring.

Figure 4 shows the CFD full furnace with the convective pass added. The model shows how high levels of carbon and CO are bypassing the BOFA section and combusting to carbon dioxide (CO₂) (left), whereas all combustion should be concentrated within the main part of the furnace, as demonstrated by the new ultra-low NOx burner comparison (right).

"All of these factors impact on NOx," says Goldring. He explains that when looking at overall NOx performance, Figure 5 shows that RJM's new ultra-low NOx burner was predicted to deliver a reduction of 25 per cent compared to the existing low NOx burner – even when running at higher stoichiometry, i.e. with a lower BOFA flow.

RJM drew four key conclusions from the CFD modelling undertaken at Ferrybridge: it could deliver lower CO by optimising the dynamics

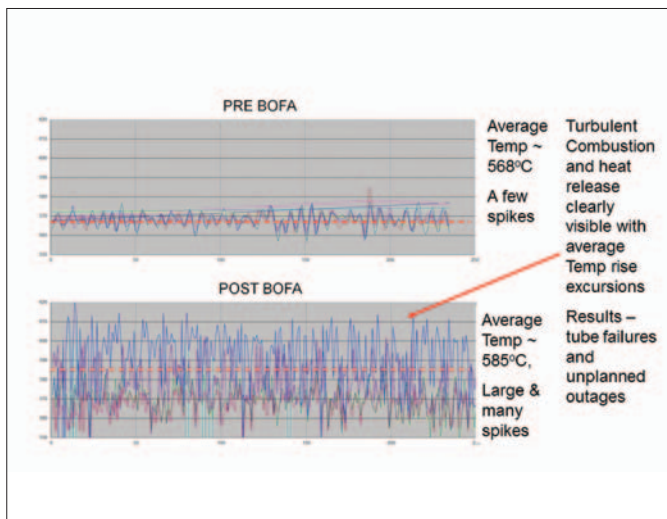


Figure 1: Pre- and post-BOFA superheater header temperatures, 500 MWe Pt data

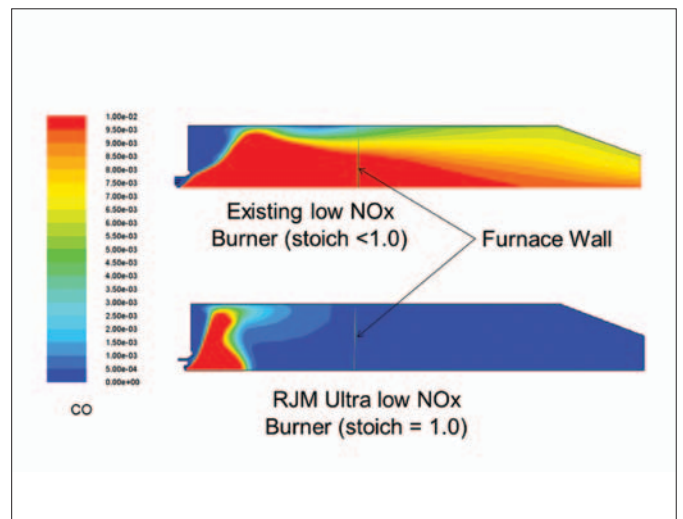
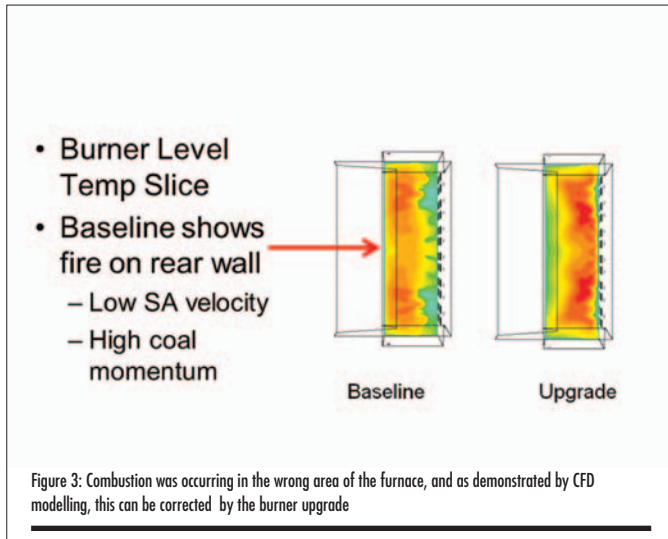
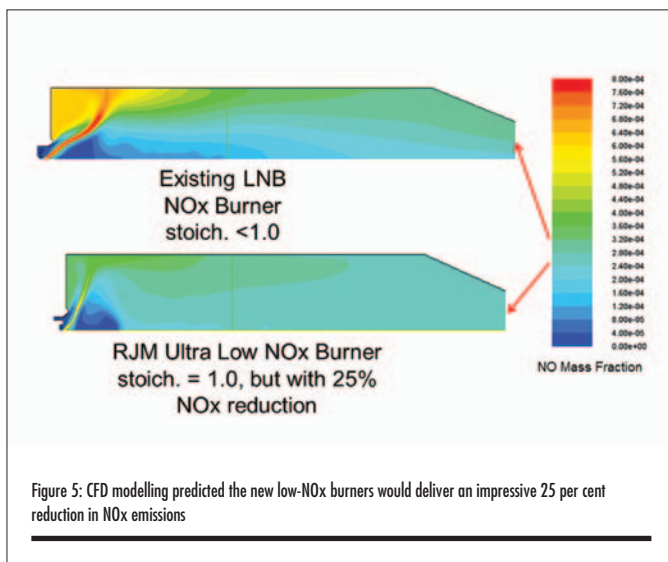
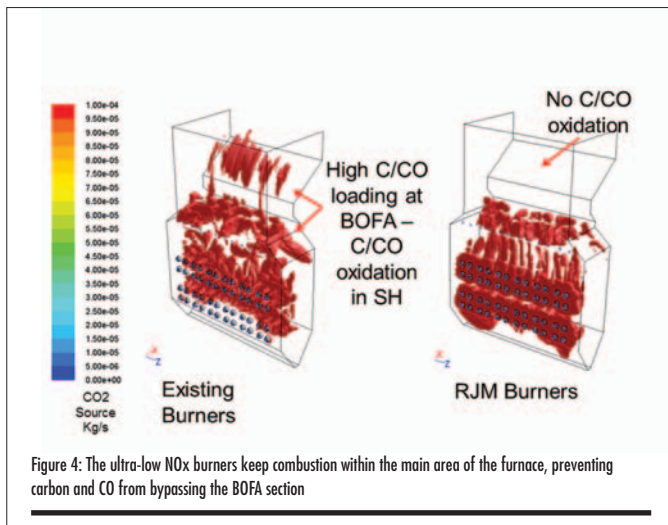


Figure 2: Comparison of CO concentration modeling for the low NOx and ultra-low NOx burners (10 000 ppm max.)



FERRYBRIDGE POWER HISTORY

- 1924: Ferrybridge A Built
- 1927: Ferrybridge A commissioned
- 1927: Operated by the West Yorkshire Power Company
- 1948: Nationalised and operated by the CEGB until privatisation in 1990
- 1957: Ferrybridge B commissioned
- 1966: Ferrybridge C commissioned
- 1976: Ferrybridge A closed
- 1992: Ferrybridge B closed
- 1990: Ferrybridge acquired by Powergen
- 1999: Ferrybridge acquired by Edison
- 2001: Ferrybridge acquired by AEP Energy
- 2004: Ferrybridge acquired by SSE



of the burner; deliver considerably reduced and compliant NOx levels; produce power with a much lower carbon 'loading' at the BOFA ports; and raise burner O₂ and thus reduce the BOFA air flow.

INNOVATIVE BURNER REMOVES SCR/SNCR REQUIREMENT

Having completed the full furnace CFD survey, the plant operators at Ferrybridge ordered a full refit for 48 ultra-low NOx burners to be installed on Unit 3 with some additional work to be carried out on the existing BOFA nozzles.

Guy Sharp, technical support engineer at Ferrybridge, explains: "The 20-week planned outage went very smoothly and the burner project was well organised with staged deliveries of burner components. All components were installed safely, efficiently and within budget.

"And thanks to the full CFD survey, this gave us a full complement of settings for the burners to start us off with. In fact, we didn't adjust them from the CFD settings at all and commissioning and optimisation was completed in just four days, with the full burner retrofit firing at full load right from day one."

Table 1 and Figure 6 clearly show how the CFD data are confirmed by the actual readings from the control room on Unit 3.

Sharp says: "We've been running consistently for six months now and we're pleased to say that our original problem of high metal temperatures in the convective section is under control, plus we've got a stable furnace with an excellent emissions performance in terms of NOx, CO and dust."

Goldring says that thanks to the new ultra-low NOx burner, plants such as Ferrybridge which do not have SCR or SNCR can look ahead to the new 2016 Round 3 NOx limit of 200mg/Nm³ with confidence.

Instead of having to consider an SCR system which might cost between £50–100 million (\$80–160 million) per unit, it could instead achieve that target with much lower capital expenditure, allied to the combustion of realistic quantities of biomass co-firing.

"Despite what we read in the papers, there is a strong future ahead for coal-firing in this country and I am pleased that at RJM we are able



PARAMETER	BASELINE RAD. & CONV.	RJM MED S. RAD. & CONV.
O ₂	3%	3%
CiA	>8%	<7%
NOx (mg/Mn ³ @ 6% O ₂)	~500	<350
CO (ppm)	high	<200
Peak flame temp. (°C)	1754	1776

Table 1: Expected performance from CFD furnace models

to make a real contribution to keeping these important coal fired stations generating cleanly and efficiently," stresses Goldring. ●

John Goldring and Guy Sharp will present a detailed paper on the installation of the new ultra-low NOx burners at Ferrybridge at POWER-GEN Europe in Cologne, on Tuesday 12 June, in *Track 4: Coal Fired Power Plants, Biomass Combustion and Waste to Energy: Session 1: Air Pollution Control I*. Presentation title: Results from study on low-NOx combustion at SSE Ferrybridge power plant.

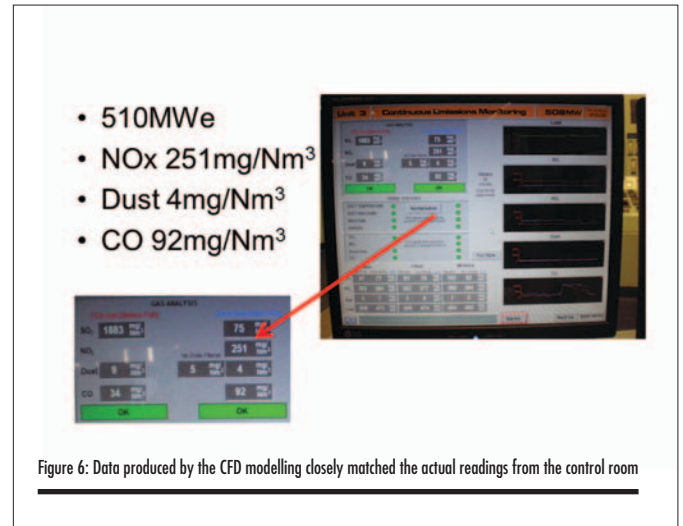


Figure 6: Data produced by the CFD modelling closely matched the actual readings from the control room

For more information on SSE’s Ferrybridge power station, please visit www.sse.com/Ferrybridge/

For more information on RJM International and its emissions reduction technologies, please visit www.rjm-international.com