Choosing the healthy option:
A low-carbon future

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If a coal-fired power plant can get its carbon-in-ash content low enough, it can sell the ash to cement manufacturers. However, the plant must also adhere to strict emissions control. PEi examines how RJM International engineers achieved this feat at AES Kilroot, Northern Ireland’s largest power station.

AES Kilroot is Northern Ireland’s largest power station, located on Belfast Lough, east of Carrickfergus. It was commissioned over 20 years ago and today supplies the province with up to 440 MW of power when burning coal and 520 MW when firing fuel oil.

Two years ago, as part of its preparation to meet the increasingly stringent nitrogen oxides (NOx) emission thresholds laid down by the Large Combustion Plant Directive (LCPD) and scheduled for introduction on 1 January 2008, the plant embarked on a major investment programme to improve its emissions performance. In order to assist with this process, AES Kilroot hired RJM International, a specialist provider of emissions reduction technologies with a strong track record of success in this field.

RISING TO THE CHALLENGE
The challenge faced by RJM International was significant. The primary task was to reduce NOx emissions to the new LCPD threshold of 500 mg/m$^3$ six per cent $O_2$ for coal firing and 400 mg/m$^3$ three per cent $O_2$ for oil firing. However, it had to do so in such a way that CO emissions were not adversely affected, $O_2$ in the form of levels of excess air would not increase significantly as this affects boiler efficiency and finally that carbon-in-ash (CiA) levels would not rise beyond the saleable limit of seven per cent CiA as a result of the NOx reduction work; in fact the contracted levels were below this level to provide some margin. In addition, the modifications needed to be made during a relatively short outage period, and the unit needed to return to service ready to generate reliably.
What’s the deal with carbon-in-ash?

CiA is an important factor because if a power station can get its CiA levels low enough, it can sell the ash to cement manufacturers, which can then use this by-product of combustion to produce a blended cement – where a percentage of the clinker is replaced by power station ash – or sell it to concrete manufacturers that can substitute a percentage of the cement with power station ash. A similar substitution process exists for steel works slag and many concrete-makers have separate silos of both ash and slag which they can draw upon in the manufacturing process.

If the power station cannot bring the CiA level down low enough (typically to around seven per cent carbon or less) then the carbon-rich ash has to be disposed of elsewhere, typically in landfill. Needless to say, there are serious environmental pressures on companies to reduce the amount of material going to landfill, not to mention the high and ever increasing cost of disposal in this way.

Alternatively, ash with CiA below seven per cent, can be sold to a cement or concrete manufacturer which turns the cost into a multi-million pound revenue stream. This financial return can pay back the cost of the combustion system retro-fit in less than two years.

In recent years, within the UK, many generators have had to install two-stage combustion systems (low NOx burners and Over-Fire Air) to meet the NOx limits set by the LCPD, but have struggled to maintain saleable ash and boiler efficiency at the same time. Therefore, the real challenge to the technology providers remains providing the legal NOx levels, but with no detriment to the ash and boiler efficiency.

Within the industry, the addition of Separated Over Fire Air (SOFA) ports to a tangential-fired boiler is one of the standard ways to address NOx emissions and the plant at AES Kilroot was no exception to this, having been fitted with SOFA ports and an Alstom low NOx concentric firing system (LNCFS II) in 1997 in order to meet the then current LCPD threshold of 650 mg/m². This was achieved by comparing the coal injection points vertically to around seven per cent carbon or less) then the carbon-rich ash has to be disposed of elsewhere, typically in landfill. Needless to say, there are serious environmental pressures on companies to reduce the amount of material going to landfill, not to mention the high and ever increasing cost of disposal in this way.

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CFD MODELLING

The performance data from the test-firing achieved in Stage 1 was then entered into RJM International’s proprietary CFD modelling programme. The computer model is then run and appropriate adjustments made, based on sound combustion technology and RJM experience, until the outputs in terms of data - including the emissions values - achieved with the CFD model are consistent with the values measured from during the plant test.

Once this bench-marking equivalence has been reached, with the computer model actually reflecting plant behaviour under normal operating conditions, then the real work can begin. RJM International technicians and engineers make virtual changes to the model, one at a time, to see what impact each change has on all the other parameters.

For the issue of unburned carbon at AES Kilroot, CFD analysis confirmed that not only was some of the coal leaving the furnace in an unburned state, but also that the majority of this unburned coal was coming from the lowest coal injection point, even though these particles spent the longest time in the furnace. This was achieved by comparing the coal injection points vertically to around seven per cent carbon or less) then the carbon-rich ash has to be disposed of elsewhere, typically in landfill. Needless to say, there are serious environmental pressures on companies to reduce the amount of material going to landfill, not to mention the high and ever increasing cost of disposal in this way.

Clearly, a number of options exist to resolve this, including such things as changing the size of the coal particles, changing the velocity at which the coal enters the furnace, balancing the four coal inputs from a single mill at each corner of the furnace (to ensure consistent volumes) and changing the speed and direction of the air which provides the O₂ to enable the combustion process to take place.

All of these options were explored via the CFD model and it was only the optimum solutions which made the transfer from computer-based binary data to actual, physical changes on site. Of the real changes made, one was modifying the SOFA ports to smaller area nozzles with different angles of injection, and another was to modify two out of four of the existing Loesche dynamic mill classifiers to the latest Loesche technology.

Another advantage of the CFD modelling system is that the plant can be ‘run’ in the virtual dimension on a range of different input fuels. Most UK plants ‘run’ in the virtual dimension on a range of different input fuels. Many of the readings taken at these key points were then re-measured, using specialist, third-party calibrated instruments. RJM International then consulted the engineering drawings of the plant and carried out a full physical inspection of the plant, as a cross-check to the drawings. This is a useful process to go through as additional site modifications to such things as ducting routes and internal/external dimensions are not always accurately reflected in the drawings.

Another hallmark of RJM International’s approach is to use scale models of certain plant components where CFD modelling is not appropriate. For AES Kilroot, the RJM team built a 1:15 scale model of the combustion air delivery system and the furnace out of perspex (see photographic image below).
Wind tags were attached at all crucial points and air flow patterns were observed at a range of different air temperatures, air pressures and air velocities. Physical changes were then made to the set-up to achieve changes in air trajectory performance, one of which included a feature to create additional pressure drop to drive additional air flow to the SOFA ports.

RIG-TESTING
As well as being configured to fire coal, AES Kilroot can burn oil. To ensure LCPD compliance on oil, RJM International carried out performance testing and ran the CFD modelling process to bring emissions down to the new levels. As testing confirmed that droplet size was a key factor, RJM took an existing gun and put it on a test rig to check the quality of the atomized spray. One of the modifications resulting from the test procedure was a redesign of the oil nozzle to give a finer spray, meaning complete combustion can still take place but with a reduced quantity of air.

So thanks to a combination of a range of measuring and testing procedures RJM International was able to devise and install a number of engineering solutions which not only fell well below the new LCPD requirements, but did so in a way that did not adversely affect other criteria such as CO, CIA and plant efficiency.

In addition, RJM International was able to do so on time and with minimal commissioning time, in this case just a few days. This is another important factor for generators as commissioning time can drag on for months or even years, whilst engineers try to find the right settings to meet the guarantees and ensure LCPD compliance.

A COMPLEX PROCESS
John Goldring, managing director of RJM International explains: "Emissions reduction is a complex field, combining mathematics, physics and chemistry, but by carrying out very detailed analysis of plant performance under different operating conditions and input fuels, we were able to understand exactly what was going on at each stage in the combustion process.

"Armed with this information, we were then able to develop and implement a series of engineering solutions to change the performance behaviour of the plant on a consistent basis."

"We also wanted not just to meet all the latest LCPD requirements, but come in well below the current thresholds, so that the plant had a good margin which would endure for a number of years. Secondly, we wanted to meet those thresholds without upsetting any other parameters, most notably CIA levels, and I am pleased to say we have more than achieved this by providing >50 per cent NOx reduction and >50 per cent CIA reduction with a comparable fuel to the performance of the original low NOx system."

"Finally, from a practical point of view, what we wanted to end up with for the plant operators was a simple set of operational procedures so that the desired emission levels can be maintained, no matter which input fuel is being fired," said Goldring.

And the work undertaken by RJM International seems to have gone down well at AES Kilroot. Lyle Woodard, project manager at AES Kilroot, said: "This was a very challenging project technically and in terms of schedule. The results have exceeded expectations; after several months of operations it appears that we will be able to maintain our entire coal diet, emissions are well below required limits, and we have seen significant improvements in efficiency, CIA, and particulate emissions over the baseline measurements taken just before the outages."

RJM International delivers emissions reduction solutions to power plants and large combustion plant all over the world

Core offer includes:
- Site surveys
- CFD modelling
- Low NOx burner modifications
- OFA, SOFA and BOFA systems
- NOx tempering
- Air flow balancing
- Physical airflow modelling
- Fuel flow balancing
- Combustion optimisation
- SNCR/SCR

RJM International is a member of the IFRF and a registered supplier on the Achilles Utilities Vendor Database

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