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ASSESSMENT OF ASH RE-FIRING AND MINERAL ADDITION

Impact on Plant Performance and Ash Disposal

PROJECT SUMMARY 343

CLEANER FOSSIL FUELS PROGRAMME
– CLEANER COAL R&D PROGRAMME

OBJECTIVES

The specific objectives of this project were as follows:

- To provide boiler operators with a relatively simple means of increasing cycle efficiency and reducing particulate emissions.
- To determine the optimum level of mineral additions using an Entrained Flow Reactor.
- To identify possible technical showstoppers using pilot scale combustion tests.
- To conduct a full scale ash re-firing test.
- To undertake a techno-economic assessment of ash re-firing and mineral addition and generate a set of guidelines for re-firing of pulverised fuel ash and mineral addition.

SUMMARY

Pulverised coal fired generation plant is expected to have a significant role in the world wide electrical power market for the foreseeable future. Emission standards have become tighter in recent years and plant is required to achieve ever more flexibility in operating regimes. These changes have resulted in increases in unburnt carbon in ash, changes in ash deposition patterns and increased pressure on Electrostatic Precipitator (ESP) performance.

A representative group of coals and minerals were used to investigate if ash re-firing and mineral addition were viable methods of improving boiler efficiency and reducing emissions. Laboratory scale tests were undertaken using the Imperial College

Figure 1. Didcot A Ash Blending – Side Load Hopper

Entrained Flow Reactor (EFR) to determine the most promising coal/mineral combinations for pilot scale testing. Pilot scale tests were then conducted using the RWE npower Combustion Test Facility (CTF). These results were used to predict the performance anticipated in a full scale plant trial.

Full scale tests of ash re-firing were then successfully undertaken on a 500MWe unit at Didcot power station. Techno-economic assessments based on the pilot and full scale trials were subsequently undertaken and a set of guidelines established for both re-firing of fly ash and mineral addition.

BACKGROUND

The drive to reduce CO_2 emissions in accordance with the Kyoto agreement requires improvements in efficiency of existing coal fired power plant in addition to building new higher efficiency plant.

Tighter emission standards have meant fitting of low NO_X burners. Changes in the electricity market have required plants to become more flexible. These changes have led to higher carbon in ash, variations to deposition patterns in boilers and increased pressure on ESP performance.

Unburnt carbon in ash represents one of the major losses in boiler efficiency and results in more fuel being burnt to achieve the required plant output. High carbon in ash also adversely affects the efficiency of ESPs due to changes in ash resistivity, so increasing dust emissions. Ash re-firing could reduce coal burn by up to 1% depending on ash quality and completeness of carbon conversion. Reduction in carbon in ash levels will significantly reduce the quantity of ash disposed of as landfill.

One of the consequences of fitting low NO_X burners has been to reduce the amount of bottom ash formed in the boiler, with a corresponding increase in the amount of fly ash going to the ESPs. These effects are considered to be a consequence of the lower flame temperatures and initial reduction conditions associated with low NO_X burners.

The majority of ash particles are essentially aluminosilicates derived from the clays and minerals present in the coal. They are largely molten at combustion temperatures

Ash particle viscosity is determined by chemical composition and temperature. The lower the viscosity, the more likely the ash particle will be retained within the boiler furnace as a boiler deposit.

The 'stickiness' of ash particles can be increased by changing the ash chemistry, thus enhancing the proportion of furnace bottom ash produced and increasing the chances of ash of particle agglomeration. It would also reduce the amount of fine ash entering the ESPs.

Previous brief studies using the EFR showed that small additions of calcite and dolomite would markedly change the nature of the ash and ash deposits.

The project aims to provide a simple cost effective means of improving combustion efficiency and reducing particulate emissions by re-firing ash and/or mineral addition to the coal.

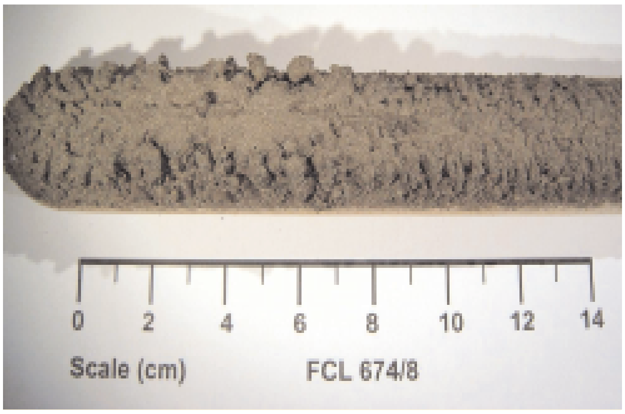

Figure 2. CTF deposite UK coal with 20% calcite

MINERAL ADDITION AND ASH RE-FIRING TRIALS

Four representative coals, including two UK, one South American and one South African quality, were initially selected together with five potential mineral additions namely:- Calcite, Albite, blast furnace slag, Dolomite and Orthoclase. The coal and mineral combinations were initially tested on the Imperial College EFR to identify the preferred candidates and combinations for further study and the pilot scale trials on the CTF.

The laboratory scale trials showed that the level of deposit sintering and deposition efficiency were primarily controlled by the properties of the coal ash rather than the mineral additive. No consistent variation in weight deposit with the nature of the mineral additive was observed.

Calcite and Albite (Feldspar) were identified as the most promising minerals for further investigation on the EFR and also for the pilot scale trials.

The pilot scale trials were then undertaken by RWE npower using the CTF located as Didcot. These trials were to examine the influence of coal type and the level of ash re-firing that was technically feasible and quality of blend that would be required for a full scale power station test.

Key issues to be considered during the pilot scale trials were;

- Would the ash cause the flame to become unstable?
- Would it affect NO_X generation?
- Would it result in reduced carbon in ash?
- Would it cause higher ash deposition?
- Would it cause higher dust emissions?
- Would ash re-firing result in problems with ash utilisation?

The CTF pilot scale trials showed that ash re-firing at up to 10% re-firing rate was technically feasible at full scale. Even at relatively high levels of ash re-firing using a British coal, the flame remained stable in spite of relatively poor flame conditions.

The CTF trials of calcite and albite mineral addition showed that the effect of temperature was not significant on either deposit type or deposition rate but there was considerable scatter in the data. Mineral addition appeared to give more friable and deposits and gave increased sintering especially under reducing conditions.

Characterisation of the deposits was undertaken Imperial College using SEM techniques. The mineral additions were found to have interacted with the coal ash in the deposit, to change the deposit microstructure and chemistry (more strongly for calcite than for albite).

For both CTF and EFR deposits, there were significant changes in deposit microstructure as the level of mineral addition increased.

The degree of deposit sintering increased and the porosity decreased. Also the chemical homogeneity of the deposits increased.

A matrix with a distinct composition, richer in CaO (calcite additions) or Na2O (albite additions) appeared and became abundant.

The calcite had transformed to lime and interacted with aluminosilicate coal ash particles, some of which had deposited and formed a lime-rich aluminosilicate melt.

The presence of a lime-rich melt significantly increased the degree of sintering and fusion of the deposit, and changed the nature of the crystalline phases that grew within the deposit.

The abundance of pure lime regions (calcite addition) or soda-rich regions (albite addition) in the deposits was low, indicating that the coal ash and additives had fully interacted in the deposit.

Characterisation of the CTF deposit samples showed that the increase in deposit CaO concentration with calcite addition was about the same as calculated. The increase in deposit Na2O concentration with albite addition was about one-third less than calculated, due to vaporisation of the Na2O. The full scale trials of ash re-firing were undertaken by RWE npower at Didcot power station at 5 and 10% levels. The key findings were:-

Plant performance at 5% re-firng level was comparable with firing coal only whilst at 10% ash re-firing rate the performance was constrained leading to reductions in output. SO_X, NO_X and CO emissions at 5% were similar to coal only operation but were higher than base line at 10% re-firing rate.

A simple on belt blending technique for the ash and coal was found to be satisfactory.

No operational problems were encountered at either 5 or 10% re-firing rates.

Dust emission levels were similar at all blend levels.

A techno-economic assessment of both ash re-firing and mineral addition was subsequently undertaken using the findings of the pilot and full scale tests as well as generic data on power station plant and handling processes.

The assessment showed that the type of ash re-firing scheme which was demonstrated to be technically feasible during the full scale test at Didcot was also financially viable. A 5% ash refiring scheme could lead to savings of in the order of £1million per year for a typical 2000Mwe power station.

High quality coal/ash blending systems may provide a superior blend but the additional cost of blending would probably outweigh any financial savings accrued.

A mineral addition scheme would incur significantly higher capital investment than the ash re-firing option tested at Didcot and would be unlikely to give a positive return on the investment in todays electricity market based on current fuel, mineral and plant maintenance costs.

Two MSc projects were undertaken at the University of Sheffield as complementary studies to the main ash re-firing project. The projects considered the interaction of CaO with aluminosilicate glass and also the fate of Ca, Mg and trace elements in re-fired fly ash.

The aluminosilicate glass project was unable to be completed within the timescale of the main project due to technical difficulties encountered with the production of stable glass pellets. The second project has provided considerable data on the mobility and leaching behaviour of power station fly ashes.

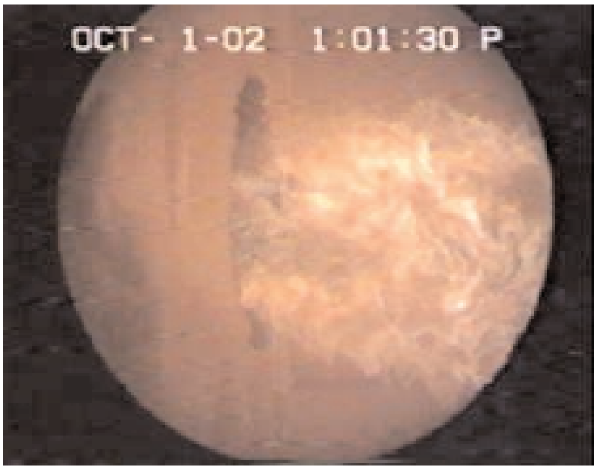

Figure 3. CTF Flame UK Coal with 20% Ash Addition

CONCLUSIONS

- There were no technical showstoppers to ash re-firing or mineral addition at levels of up to 10%wt on a 500 MWe generating unit
- 5% ash re-firing on a 500MWe unit appears both technically and financially viable. The economics are reasonably robust to changes in ash sales values and taxation, increases in capital costs, as well as reduced value of coal replacement and adverse changes in exchange rates.
- A simple belt blending process is adequate for a 5% re-firing rate and there is no need to use a higher quality blending system. Such systems may be technically feasible but are unlikely to be financially viable.
- Mineral additions in the form of calcite and albite(feldspar) appear technically viable but the financial case was not proven during the trials. There may however be specific plant where the additional costs for mineral addition may be offset reducing the impact of plant output losses due to high dust emission levels.
- Ash addition rates over 10% had a significant effect on NO_X levels and it was necessary to consider reducing plant output.
- Plant performance at 5% ash re-firing rate was comparable to coal only operations. SO_X, NO_X and CO emission levels were similar, whilst dust emission levels were found to be slightly higher.
- SO_X, NO_X and CO emission were all found to be higher than the coal base line for ash re-firing rates of 10%.
- At the pilot scale trials, poor flame conditions were encountered at relatively high levels of ash addition but the flame itself was still found to be stable.

- No operational problems were encountered at either 5 or 10% ash re-firing levels during the full-scale power station trials.
- Albite (feldspar) produced the highest level of increased deposition at the laboratory scale trials and calcite had the greatest effect on the degree of sintering.
- Significant increases in deposition rate were seen for both calcite and feldspar under both oxidising and reducing conditions during the pilot scale mineral addition trials.
- The pilot-scale mineral addition trials showed that temperature did not have a significant effect on either the deposition rate or the deposit type.

POTENTIAL FOR FUTURE DEVELOPMENT

This project has shown that ash re-firing is both technically and financially viable on existing coal fired power plant. It is believed that commercial scale replication of the concept could be undertaken by plant operators using the data gathered by this project as the basis for a full scale development.

The case for mineral addition was not proven either in technical or financial terms. The considerable scatter obtained in the deposition data requires further investigation and clarification.

The University of Sheffield project on interaction of CaO with aluminosilicate glass requires resolution of the technical problems in pellet production and also additional funding for it to proceed to completion.

COST

The total cost of this project is £328,500, with the Department of Trade and Industry (DTI) contributing £154,000. The balance of funding was provided by the participants.

DURATION

30 months – April 2002 to September 2004

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DTI/Pub FES 05/1690