Improving Efficiency and Environmental Performance – Small Scale Combustion Plant

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by

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DTI CLEANER COAL TECHNOLOGY R&D PROGRAMME

Project No: 216 **Final report**

Project Title: Improving Performance of Small Scale Coal Combustion Plant.

Proposer: James Proctor Limited.

Organisation with whom contract should be placed: As above.

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Other organisations formally involved in the project: CRE Group Limited.

Objectives.

The objective of the work is to develop a high efficiency cyclone grit arrestor suitable for retrofitting to existing coal fired boilers, such that coals with a wide range of ash contents can be utilised.

Starting Date and Duration:
Start: 01/12/2000
Duration: 2.5 Years

This proposal is fully consistent with the outline proposal "Improving the Efficiency and Environmental Performance of Small Scale Coal Combustion Plant for Increased Export Opportunities" as submitted to Mott Macdonald in January 2000.

There is no objection to the above information being incorporated in a computer database for management purposes.

EXECUTIVE SUMMARY

There are thousands of coal-fired boilers in the commercial and industrial sector throughout the world with the biggest impact on the environment being particulate emissions. The market area in terms of boiler output is from 0.6MWth – 6.5MWth output and the number of boilers when aggregated, results in a large potential source of pollutants. The types of combustion equipment commonly used in this sector in China, India and the CIS are chain grate or travelling grate stokers.

Present emission limits, in terms of particulates, are set in the initial draft of the Small Combustion Plant Directive at 150 mg/m^3 for boilers less than 10 MWth input, and 50 mg/m^3 for those between 10-50 MWth input.

For small chain grate fired boilers, one of the main environmental problems is excessive emission of particulate matter to the atmosphere. The use of modern control systems and a well designed grate assist significantly in reducing the 'lift-off' of particulate matter from the fire bed. Bag filters, electrostatic precipitators and scrubbers are technologies which are capable of reducing particulate emissions to acceptable levels, but these technologies have high capital costs and are expensive to operate.

Low efficiency mechanical dust collectors (cyclones) are still widely used in small scale coal fired boiler plant and their purchase price and maintenance costs compare very favourably with other forms of flue gas clean up equipment. This project is concerned with the design and demonstration of a high efficiency cyclone arrestor, which could potentially achieve a particulate collection efficiency of in excess of 98%, making it suitable for cleaning up the emissions from boilers of this size and type. The successful particulate and emissions reductions would enable coal to be utilised for heating and process applications in the smaller range of boilers in terms of environmental acceptability. In countries such as India, China and the CIS, which currently burn low-grade coal as their primary energy source, the impacts of this work could make a major contribution to minimising the environmental impact of such utilisation.

All cyclone designs apply the same basic principle of inducing the particulate laden flue gases to swirl around inside the cyclone body for sufficient time and with sufficient vigour that grit and dust is centrifuged to the inside wall surface and is carried downwards to the dust outlet. The point of separation of the flue gases from the particulates occurs at the base of the cyclone body, where the gases reverse direction and vortex back upwards to the central clean gas outlet tube (the vortex finder). A good cyclone design minimises the amount of dust, which is re-entrained into the reversing gas flow. Conventional axial flow designs, which are fitted, to the majority of boilers in the commercial and industrial sector are in practice inefficient, with average particulate emissions of 200 –300 mg/m3. Gas flow maldistribution leads to differing vortex intensities within the individual cyclone cells. This leads to 'cross-talk' between adjacent cells and hence low efficiencies. The cyclone design in this project is of the tangential entry type cyclone but with particular emphasis on the entry and exit ducting design and the vortex tube design. A further refinement that was added to the design is a technique known as 'gas blow down'. This involves pulling a small quantity (5-15%) of the main gas flow out of the dust hopper of the cyclones, either together with, or separately from, the collected particulates. The blow

down gas flow is then directed through a separate, small, high efficiency cyclone before recombining with the remaining main flow. The aim for this technique is that the action of pulling a blow down gas flow out of the dust hopper improves the efficiency of the main collector.

James Proctor Ltd have installed a 0.8MWth output smoke tube boiler in their factory fitted with a chain grate stoker. After careful design, the new cyclone grit arrestor was fitted to the plant and it was used to test this type of back end clean up on a variety of coals. After the cyclones were designed and fitted the trials were carried out using three different types of coal from Colombia, Russia and South Africa, which had a varied type of coal properties.

The trials were carried out over two, 2-week periods on both mid firing conditions and high firing conditions. Gas blow down was also tested in these conditions with tests being conducted at 5%, 10%, 15% and 20% blow down rates.

For all the tests and all three-test coals the stack emissions were less when the blow down system was in operation.

Generally, the tests indicated the lowest stack concentration at blow down rates of around 10% under medium firing rates. For both Colombian and Russian coals overall cyclone collection efficiency was 96.4% and 97.9% respectively.

Under high firing rates the tests indicated the lowest stack concentration at blow down rates of around 20%. For both South African and Russian coals overall cyclone collection efficiency was 95.5% and 96.7% respectively.

The results exceeded expectations in terms of measured particulate emissions with low rates being achieved in both high and medium fire tests, significantly below the 150mg/m3 proposed in the Small combustion Plant Directive. If further work was carried out then it could be possible to achieve further reductions in emissions as some of the test results showed emissions levels at around 50-60mg/m3.

It is recommended that further work should concentrate on sizing the cyclones for differing boiler sizes. This would involve computer-modelling work utilising the data from the test results. Further test work under the same conditions should also be carried out utilising a wider range of coals. A full-scale demonstration project would then be possible at a chosen commercial site in the UK.

Contents

High Efficiency Cyclones

INTRODUCTION

The original proposal was concerned with improving the design, efficiency and environmental performance of appliances suitable for burning `low grade` coal. The market area in terms of boiler output is from 0.6MWth – 6.5MWth that covers typically the commercial and industrial segments. The types of combustion equipment commonly used in this sector in China, India and the CIS are chain grate or travelling grate stokers. It should be noted that `low grade` coal refers to coal that is typically burnt on chain grate and travelling grate stokers in the sector countries. These may have a slightly higher ash content than UK coals but also may have a slightly lower volatile content but in any case the coal utilised in the tests would be representative of coals that can be burnt on chain grate stokers without any major combustion problems as the aim of the project is to control particulate emissions rather than improving the combustion rates of poor quality coals.

TECHNICAL BACKGROUND TO THE PROJECT

The biggest environmental impact of this scale of coal-fired boiler is particulate emissions. Present emission limits, in terms of particulates, are set in the initial draft of the small combustion plant Directive at 150 mg/m^3 for boilers less than 10 MWth input, and 50 mg/m^3 for those between 10-50 MWth inputs. These suggested figures raise considerable challenges for the industry. The boilers, which we are considering in this proposal, are 0.6MWth - 6.5MWth output. Bag filter technology is available but when applied to smaller boilers the costs outweigh the benefits. CRE Group Ltd has been working on the design of a high efficiency cyclone grit arrestor, which if successful would be the answer to the problem of particulate collection on small boiler plant.

James Proctor Ltd have installed a 0.8MWth smoke tube boiler in their factory fitted with a chain grate stoker. The new cyclone grit arrestor was fitted to the plant and it was used to test this type of back end clean up on a variety of coals. After successful tests the system could be retrofitted to any existing boiler plant in Europe and indeed anywhere else in the world. This would establish real and significant export opportunities for the UK within these countries. The number of existing boiler plants within this range runs into tens of thousands, so the environmental benefits are clear. As regards to new boiler plant, the successful particulate and emission reductions would enable coal to be a viable fuel for heating and process applications in the smaller range of boilers in terms of environmental acceptability. In countries such as India, China and the CIS, which currently burn low-grade coal as their primary energy source, the impacts of this work could make a major contribution to minimising the environmental impact of such utilisation.

Pollutant emissions are of great concern to existing and potential users of coal burning equipment. For small chain grate fired boilers, one of the main environmental problems is excessive emission of particulate matter to the atmosphere. The use of coal transportation and handling systems, which do not significantly degrade the fuel, together with modern control systems and a well designed grate assist significantly in reducing the 'lift-off' of particulate matter from the fire bed. However, to further reduce particulate emissions to levels, which will comply with ever more stringent emissions legislation, an advanced type of high efficiency particulate arrester system is needed. Barrier filters, electrostatic precipitators and scrubbers are technologies

which are capable of reducing particulate emissions to acceptable levels, but these technologies have high capital costs and are expensive to operate. Low efficiency mechanical dust collectors (cyclones) are still widely used in the mineral mining and quarrying industry, their purchase price and maintenance costs compare very favourably with other forms of flue gas clean-up equipment, and they are compact relative to their gas volume handling capacity. Apart from gradual performance deterioration due to erosion and corrosion, there is little to go wrong. CRE has a conceptual design of a high efficiency cyclone arrestor, which could potentially achieve a particulate collection efficiency of in excess of 98%, making it suitable for cleaning up the emissions from boilers of this size and type.

GRIT ARRESTOR DESIGN AND INSTALLATION

The CRE high-efficiency design incorporates a technique known as gas blow-down, whereby a small part of the gas flow passing through a cyclone is drawn away from the cyclone body in a way that enhances the cyclone's particle collection performance beyond that expected relative to the quantity of gas withdrawn. Most frequently this gas flow is drawn downwards through the solids off take hopper, hence the term "blow-down".

The reason for this enhancement in performance has been attributed to the following mechanisms:

a) the gas bleed from the base of the cyclone helps to carry particles away from the reversal zone between the inner and outer vortices and so reduces their chance for re-entrainment.

b) the gas bleed helps to redistribute the bulk gas flow more evenly through the cells (in a multicell cyclone) so that "cross-talk" between adjacent cells, otherwise known as "cross-hopper ventilation", is reduced.

c) there is an increased gas velocity within the cyclone body, which improves centrifugal action, such that inertial forces are increased and assist collection of the finer particles.

A high efficiency cyclone grit arrestor will be designed by CRE for this specific application. The demonstration unit will be installed on the new chain grate stoker fired boiler at James Proctor's factory. The demonstration grit arrestor will have the capability of being operated with or without blow down.

Following design, manufacture, installation and commissioning, the cyclone system will be tested under different boiler operating conditions while burning a range of tests coals from around the world. The purpose of the tests is to evaluate the performance of the unit in reducing particulate emissions from the boiler.
Measurements of flue gas particulate burden at the cyclone inlet and outlet will be made concurrently at each operating condition. Testing will be carried out in accordance with BS 3405:1983 using staff and procedures accredited by the United Kingdom Accreditation Service (UKAS). The test matrix will include the following:

- High and low fire boiler operation