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IMPROVEMENTS IN SMALL SCALE COAL COMBUSTION PLANT

Development of High Efficiency Cyclone Grit Arrestors

PROJECT SUMMARY 301

CLEANER FOSSIL FUELS PROGRAMME
– CLEANER COAL R&D PROGRAMME

OBJECTIVES

The aims of this project were:

- To develop a high efficiency cyclone grit arrestor suitable for retrofitting to existing coal-fired boilers. This would enable existing coal-fired boilers to meet future emissions limits in terms of particulates.
- To control particulate emissions rather than improving the combustion rates of poor quality coals.
- Cover the commercial and industrial segments with a range of boiler outputs from 0.6 MW_{th} - 6.5 MW_{th}.

SUMMARY

This project is concerned with the design and demonstration of a high efficiency cyclone grit arrester which could potentially achieve a particulate collection efficiency of in excess of 98%, making it suitable for reducing the emissions from boilers of this size and type.

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.

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 blowdown’.

Figure 1. High Efficiency Cyclones - Test Facility

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 through a separate, small, high efficiency cyclone.

After the cyclones were designed and fitted, trials were carried out using three different types of coal from Colombia, Russia and South Africa, which had varying properties in terms of calorific value, ash, moisture and volatile matter. The trials were carried out on both mid firing conditions and high firing conditions.

BACKGROUND

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 MW_{th} input, and 50 mg/m^3 for those between 10-50 MW_{th} input. These suggested figures raise considerable challenges for the industry.

The boilers which are being considering in this proposal are 0.6 MW_{th} - 6.5 MW_{th} output. Bag filter technology is available but when applied to smaller boilers the costs outweigh the benefits. Casella CRE Energy Limited (formerly CRE Group Limited) 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 Limited have installed a 0.8 MW_{th} output 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 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.

Casella CRE Energy Limited, project collaborators, have a conceptual design of a high efficiency cyclone arrester, 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.

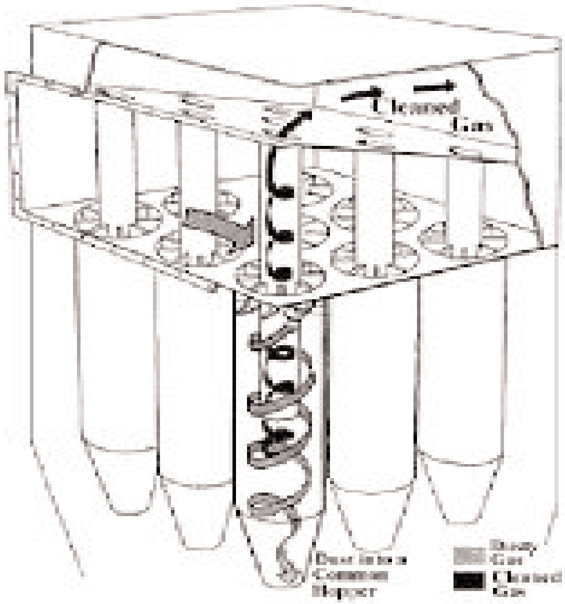


Figure 2. Conventional multi cell axial entry cyclone (Courtesy of The Combustion Engineering Association)

CYCLONE DESIGN AND TESTWORK

Grit arrestor design and installation

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 entry multicell cyclones have become the favoured design for application to coal fired boilers.

Although widely commercialised, the multicell cyclone design (Figure 2) is prone to an inconsistency of particulate collection performance. Despite having relatively small cyclone cells it is doubtful whether the inertial separation achievable via an axial entry arrangement can compete with a tangential inlet. A major problem of putting many small cells into a single enclosure, and requiring each to discharge particulates into a common dust hopper, is that particulates emerging from one cyclone cell can, under non-uniform gas flow conditions, be sucked into the reversing vortex of an adjacent cell and be emitted to atmosphere. This phenomenon is known as 'cross-talk' and is caused by gas flow maldistribution between the many cyclone cells within the common enclosure. Gas flow mal-distribution leads to differing vortex intensities within the individual cyclone cells. This leads to 'cross-talk' between adjacent cells.

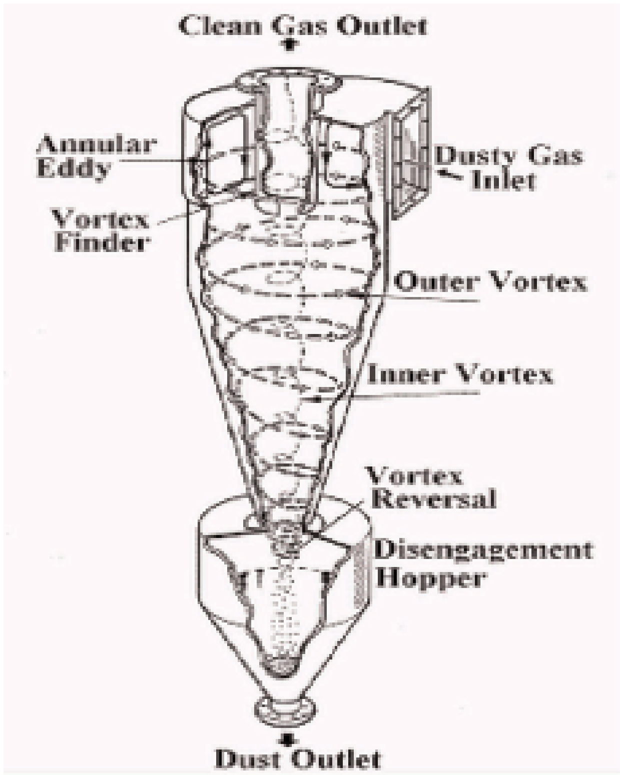


Figure 3. Tangential entry high efficiency cyclone (Courtesy of The Combustion Engineering Association)

This project therefore was concerned with developing a high efficiency tangential entry, multi cyclone with the further addition of `gas blow down`. Computer modelling resulted in an optimised design for the vortex finders, connecting ductwork and overall size of the cells with a predicted efficiency of 95 – 97%. This compared favourably to existing, well designed axial flow cyclones, which generally have an efficiency of around 90%.

Figure 3 illustrates the high efficiency, reverse-flow cyclone, a single cell device that generates an internal centrifugal vortex by virtue of the flue gases entering tangentially at velocities up to 20 m/s.
A further refinement that was added to the project is the technique known as 'gas blowdown'. 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.

The mechanism for this improvement is that blow down helps to overcome dust hopper cross talk.

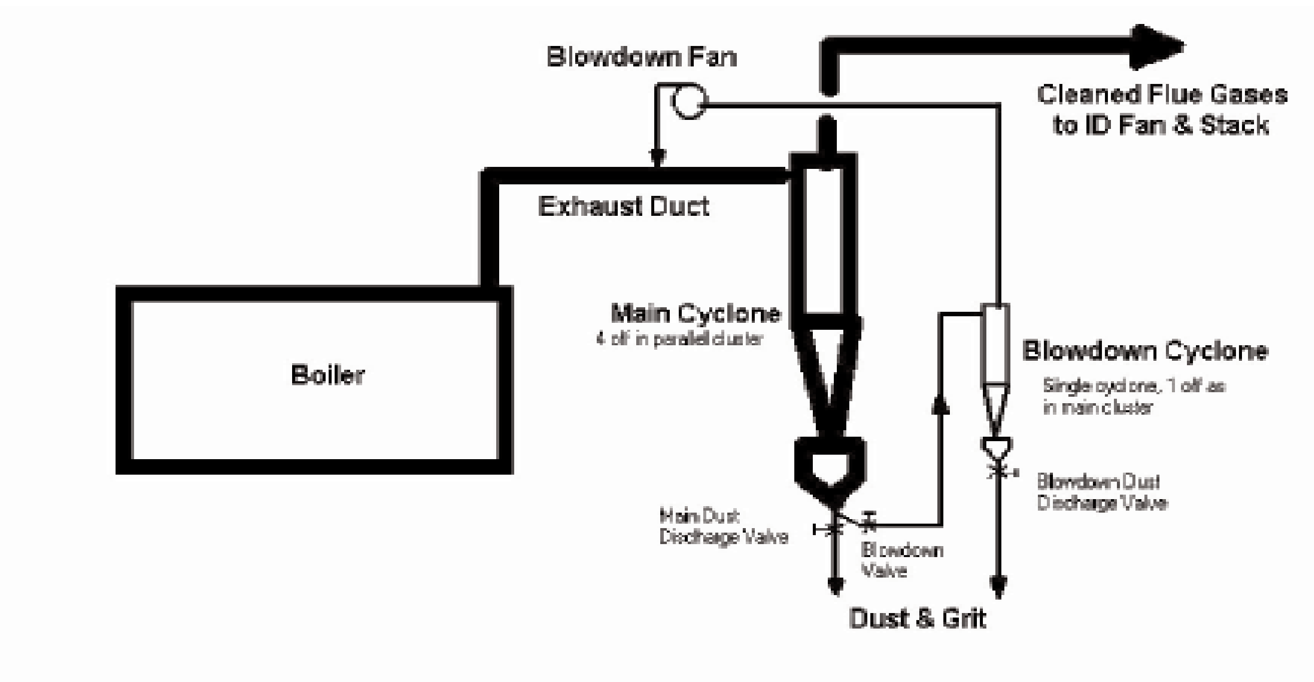
Figure 4 shows a schematice diagram of the installation including the gas blowdown.

Commissioning of boiler

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.

Before each test was commenced the boiler was cleaned and commissioned. This comprised calculating the correct amount of fuel required for maximum continuous rating (MCR) from the gross calorific value of each coal type, setting the coal bed depth through calibration of rotary feeder and grate speed, setting the inverters on the FD and ID fans and weighing the fuel.

Figure 3. Schematic diagram of high efficiency cyclones with gas blowdown



Cyclone blowdown test work

The test facility at James Proctor Limited, Burnley comprises of a Proctor chain grate stoker firing a three pass Hartley and Sugden Super Colifax smoke tube pressurised hot water boiler unit rated at 0.8 MWth output.

Flue gases pass from the boiler exit through the high efficiency grit arrestor comprising of four cyclone units and to atmosphere via a variable speed induced draft fan. From the base of the grit discharge gases and grits can be drawn down into a further single cyclone sized the same as the individual cyclones in the set of four. Gas rate through the blowdown cyclone is controlled via a slide valve in the inlet.

A separate fixed speed induced draft fan provides the suction for the blowdown system. The gas from the blowdown cyclone is returned to the flue gas duct prior to the entry into the main cyclone set.

The water system is pressurised to 1.5 barG, with heat from the boiler being distributed around the workshop area and dumped, as necessary, via 2 three-pass radiator units each rated at 0.5 MW_{th} output. As far as the coal is concerned, Colombian coal was chosen and would be used in the tests as an example of a premium quality coal for comparison purposes. South African coal was available in the quantities required and was chosen as an example of a poorer quality coal due to the low volatile matter content. Russian coal was tested as part of the project proposals.

The trials were carried out on both mid firing conditions and high firing conditions. Gas blow down was also tested in these conditions.

CONCLUSIONS

- 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 150 mg/m^3 proposed in the small combustion plant directive.
- 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.
- Under high firing rates the tests indicated the lowest stack concentration at blow down rates of around 20%.
- Results:

	Medium Firing Rate with 10% Blowdown	
COAL TYPE	Average Stack emissions	Overall cyclone efficiency
Colombian	31 mg/m^3	93.5%
South African	42 mg/m^3	95.4%
Russian	27 mg/m^3	97.9%

	High Firing Rate with 20% Blowdown	
COAL TYPE	Average Stack emissions	Overall cyclone efficiency
Colombian	53 mg/m^3	97.2%
South African	60 mg/m^3	95.5%
Russian	55 mg/m^3	96.7%

POTENTIAL FOR FUTURE DEVELOPMENT

Exploitation of the work undertaken in this project will take place through:

- Sourcing other types of coal and performing tests under the same conditions. This would confirm the suitability of the design for a wider range of coal types.
- Computer modelling to optimise design for different sized boilers.
- Identifying a commercial site and installing grit arrestor for full-scale demonstration project.

COST

The total cost of this project is £149,790, with the Department of Trade and Industry (DTI) contributing £50,000. The balance of funding was provided by the participants.

DURATION

30 months – December 2000 to June 2003

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FURTHER INFORMATION

For further information about this project see contractor report Improving Efficiency and Environmental Performance – Small Scale Combustion Plant, R281 URN 05/662 available from the helpline.

Further information on the Cleaner Fossil Fuels Programme, and copies of publications, can be obtained from:
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