Profiles

Developments in circulating fluidised bed combustion

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Fossil fuels will remain the primary energy source for electric power generation for the foreseeable future, and coal is the principal fossil fuel of power generation. Coal can be expected to remain an essential energy source well into the twenty-first century due to its low cost and broad availability. However, given that coal-fired power plant represents one of the largest producers of CO_2 emissions, it is prudent public policy to promote the development and early application of clean technologies for coal utilisation in high efficiency power cycles. Circulating fluidised bed combustion (CFBC), as an alternative to pulverised coal combustion (PCC) for power generation, offers several benefits. CFBC boilers are extremely flexible, allowing a wide range of fuel qualities and sizes to be burned. Emissions of SOx and NOx are significantly reduced without the addition of expensive flue gas emissions control systems. This is due to the fact that the combustion temperature in a CFBC boiler (800–900ºC) is significantly lower than in a PCC boiler (1300–1700ºC), which results in considerably reduced NOx formation compared to PCC. The majority of the sulphur in the coal is captured by limestone that is injected into the furnace; about 90–95% SO_2 reduction can be achieved. The lower combustion temperature also limits ash fouling and corrosion of heat transfer surfaces allowing the CFBC to handle fuels that are difficult to burn in a PCC boiler. Even though the combustion temperature of a CFBC boiler is low, the circulation of hot particles provides efficient heat transfer to the furnace walls and allows a longer residence time for combustion and desulphurisation reaction. This results in good combustion efficiencies, comparable to PCC boilers.

CFBC technology was developed to burn low grade and/or difficult-to-burn fuels. Many existing CFBC units are fired with waste coal and serve to clean up waste piles left over from mining activities. CFBC technology has been employed for power generation for over 25 years and the technology is still evolving. Almost all of the existing CFBC power generating units are small in size (≤330 MWe compared to >1000 MWe for a PCC boiler), and use subcritical steam conditions that makes CFBC systems less efficient than supercritical/ultra-supercritical PCC plants. The poorer economy of scale and lower efficiency of the CFBC plants result in higher plant costs and has limited its deployment.

Over the last decade, significant advances have been made in scaling-up CFBC units and in the adoption of supercritical (SC) steam cycles. Alstom and Foster Wheeler both adopted once-through boiler technology in their large SC CFBC boiler design. In 2009, the first supercritical and the largest hard coal fired 460 MWe CFBC power generating unit was successfully commissioned in Lagisza, Poland. More coal-fired SC CFBC power plants with unit sizes of 550 and 600 MWe are under construction or being commissioned in South Korea and China. Today, SC CFBC boilers with capacities up to 800 MWe are commercially available. It is anticipated that future CFBC power plants will routinely use advanced steam parameters. In addition to the increase in size and the use of advanced steam cycles, the engineering designs of the CFBC furnace, solid separation system, ash cooler, as well as the arrangement and designs of heat exchangers continue to be innovated and improved. The operation of the CFBC systems have also been optimised. Many problems encountered in the early years of operating CFBC plants have been addressed by innovative and better designs leading to improvements in plant reliability and availability, and plant economics. CFBC technology is emerging as a real competitor to PCC system.

Today, power generators are facing the challenge of reducing CO_2 emissions, which is likely to lead to substantial changes in the way the power is produced and consumed. For CO_2 emissions control, intensive R&D is ongoing to develop and commercialise technologies for carbon capture and storage (CCS). For PCC and CFBC boilers, oxyfuel combustion systems that produce high purity CO_2 exhaust streams ready for carbon capture are under development. The basic concept of oxyfuel firing with today's PCC and CFBC technologies is to replace combustion air with pure oxygen. However, firing coal in pure oxygen would result in a flame temperature too high for existing furnace materials. In order to allow conventional combustion equipment to be used, the combustion temperatures have to be moderated by recycling a proportion of the flue gas and mixing this with the incoming oxygen. The remainder of the flue gas that is not recirculated comprises mostly CO_2 and water vapour.

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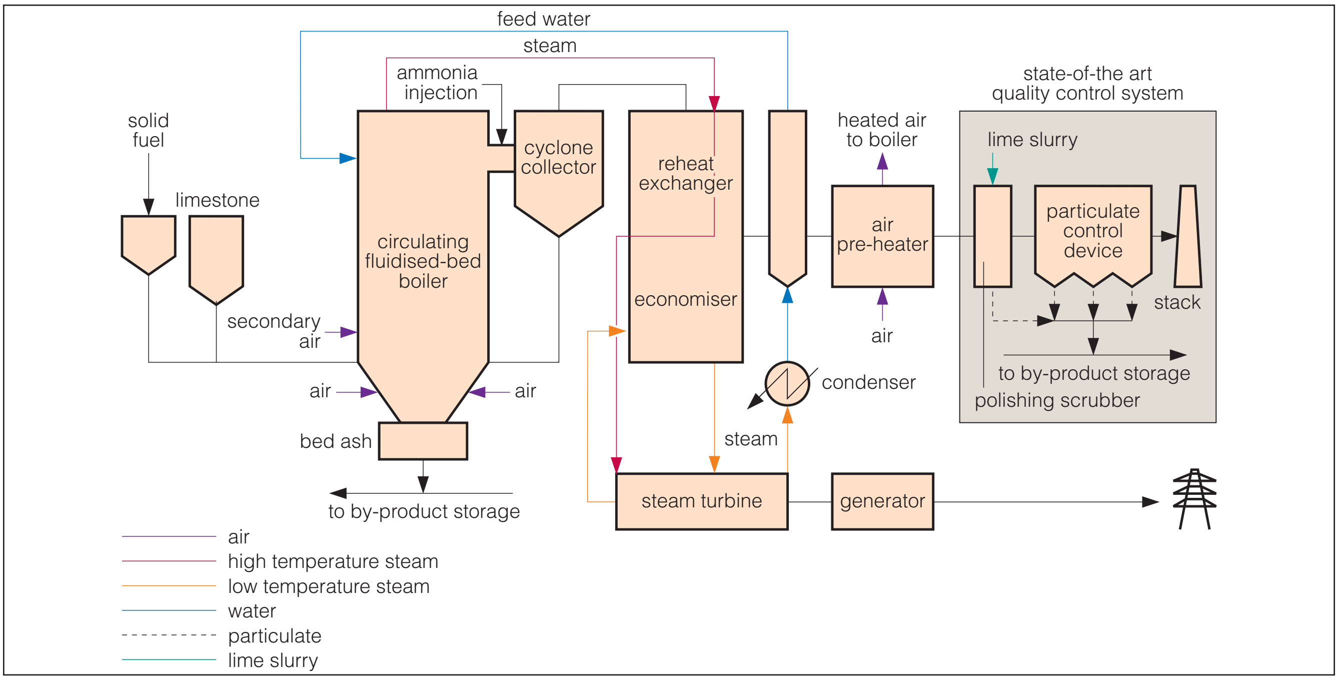

A CFBC power generation plant

The water vapour is easily separated by condensation, producing a stream of CO_2 ready for sequestration. An optimised oxyfuel combustion power plant will have ultra-low emissions.

A power generation technology based on oxy-CFB with CO_2 capture will provide typical benefits of CFBC boilers, in particular the fuel flexibility. In addition, higher O_2 concentrations in the combustion gas are expected to increase combustion efficiency and reduce the flue gas flow rates and thus increase the boiler efficiency. Smaller furnace volumes may reduce costs of the boiler island. Also, oxy-CFB technology may have some advantages over oxy-PC combustion designs. When oxyfuel combustion is applied to a CFBC boiler, the combustion temperature can be controlled by recycling a portion of the cooled solids to the furnace through a fluidised bed heat exchanger, therefore minimal flue gas recirculation is required. This characteristic allows the oxy-CFB boiler to be made smaller and less expensive in a new unit application.

Fundamental studies into various aspects of oxyfuel combustion have been carried out in facilities from laboratory to pilot scale in research centres and universities around the world. Oxyfuel combustion based CFBC power plants concepts are being developed and validated. Currently, Foster Wheeler is the primary developer of oxy-CFB technology. It has been developing an oxy-CFB combustion system called Flexi-Burn CFB. One of the current European R&D initiatives focusing on CCS is the Technological Centre for CO_2 Capture and Transport, which is supported by the Spanish Government through the Fundación Ciudad de la Energía (CIUDEN). A 30 MWth pilot-scale oxy-CFB demonstration unit at CIUDEN was commissioned in September 2011 and a series of tests on coal have been carried out. The test results from CIUDEN's demonstration unit will be used to validate the design of the OXYCFB300 Compostilla Demonstration Project's 300 MWe SC oxy-CFB boiler. The OXYCFB300 commercial demonstration plant has already attracted EU funding of €180 million for pre-feasibility studies, with the intention of operating in 2015.

Oxy-CFB technology is developing rapidly, in particular with the commissioning of the first pilot-scale oxy-CFB test facility at CIUDEN in Spain. Oxy-CFB technology will evolve as the industry gains experience and incorporates new innovations.

Each issue of *Profiles* is based on a detailed study undertaken by IEA Clean Coal Centre, the full report of which is available separately. This particular issue of *Profiles* is based on the report:

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Qian Zhu
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IEA CLEAN COAL CENTRE
Gemini House
10-18 Putney Hill
London SW15 6AA
United Kingdom

Tel: +44 (0)20 8780 2111
Fax: +44 (0)20 8780 1746
e-mail: mail@iea-coal.org
> **Internet:** www.iea-coal.org