2nd Oxyfuel Combustion Conference

CIUDEN CFB boiler technological development

Iñaki Alvarez[a], Francisco Muñoz[a], Monica Lupion[a], Pedro Otero[a], Arto Hotta[b], Reijo Kuivalainen[b], Javier Alvarez[c]

[a] *Fundación Ciudad de la Energía CIUDEN, II Avenida de Compostilla nº2 24400 Ponferrada, Spain*
[b] *Foster Wheeler Energia Oy, Relanderinkatu 2, 78201 Varkaus, Finland*
[c] *Foster Wheeler ES, c/ Gabriel García Márquez, 2 28232 Las Rozas Madrid, Spain*

Keywords: Oxycombustion; CCS test facility; CFB boiler, CO_2 capture

1. Introduction

One of the current European initiatives in terms of R&D on CCS is the El Bierzo Technological Centre for CO_2 Capture and Transport (TCCT), which is supported by the Spanish Government through the Fundación Ciudad de la Energía (CIUDEN). CIUDEN is a research and development institution created by the Spanish Administration in 2006 and fully conceived for collaborative research in CCS and CCTs thus contributing to the strengthening of the industrial and technological base in Spain and by extension in Europe [1].

CIUDEN TCCT comprises two different technologies on oxycombustion: Pulverised Coal (PC) and Circulating Fluidised Bed (CFB). This paper will focus on the design and main characteristics of the 30 MWth oxyCFB boiler.

The CFB unit design allows either the operation under conventional combustion with air or under oxycombustion conditions (Flexi-Burn® concept). The size of this experimental boiler is sufficient to allow the scaling of the results to commercial units while maintaining the investment cost and operating expenses relatively low. In this way, multiple fuels and operating conditions can be tested economically in this experimental unit [2].

Foster Wheeler is the technological provider of the Flexi-Burn® Circulating Fluidised Bed unit in CIUDEN's TCCT. Commissioning of the CFB boiler is intended for July 2011.

The design of the CFB boiler considers the particular requirements of a testing unit, which includes a wide range of measurement points and the option to vary the operating conditions with the maximum flexibility and versatility possible meeting the necessary requirements and boundary conditions. By the same token, the ease of maintenance and inspection of all unit components have been maximized as well as increasing the usual instrumentation to gather additional data from future operation.

As a result, the oxyCFB boiler is versatile and flexible boiler system equipped with a large number of additional devices and designs which together configure a unique unit and important tool for experimentation with the aim of developing oxyCFB technology.

Main features of the CFB boiler are included in Table 1.

Furnace dimensions (height, width, depth) (m)	20x2.8x1.65
Thermal power (MW_{th})	15 conventional (air) mode
	30 total oxycombustion mode (O_2 + recirculated flue gases)
Maximum steam flow (t/h)	47.5
Superheated steam temperature (ºC)	250
Superheated steam pressure (bar)	30
Feed water temperature (ºC)	170
Outlet boiler flue gases temperature (ºC)	350-425

Table 1: Main features of the CFB boiler

2. CFB boiler description

CIUDEN 30 MWth CFB boiler is a natural circulation, balanced draft, circulating fluidized bed boiler, which is designed to test circulated fluidized bed combustion using either air or a mixture of recirculated flue gas and oxygen as oxidant. The CFB boiler operates on the circulating bed principle where solid material is separated from the flue gas stream in a hot separator which removes it downwards to the loop seal through the cyclone downcomer.

The mayor components of the boiler are combustion chamber, solids separator, loop seal and INTREX™ superheaters located in a separate fluidized bed chamber (Figure 1).

- (**1**) combustion chamber – water wall furnace
- (**2**) solid separator for the recirculation of bed material
- (**3**) ash sealing-direction device
- (**3a**) ash duct to the furnace
- (**3b**) ash duct to the cooler
- (**4**) furnace cooler - INTREX™
- (**5**) heat recovery zone
- (**6**)steam cooled walls with an convective evaporator bank
- (**7**) economizer

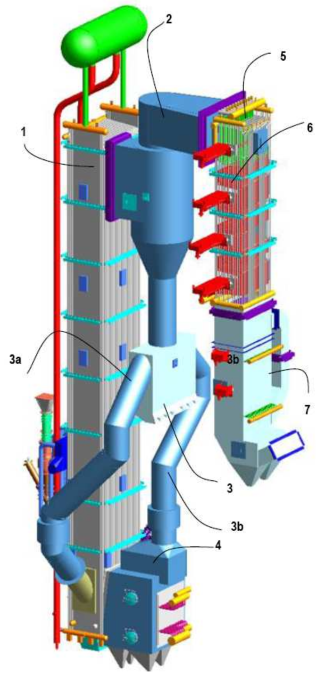

Figure 1: Main components of the oxyCFB boiler

Solid material is led through the cyclone downcomer to the loop seal. Part of this recovered solid material is returned directly to the furnace and the rest is cooled in a final superheater box before entering the furnace for combustion temperature control.

Ammonia injection in the cyclone provides proper gas mixing and reaction temperature for ammonia to reduce NOx emissions. Limestone injection is required to control SO_2 emissions within the environmental permitted level and make-up sand is used to maintain the proper bed characteristics.

Fine solids (fly ash) and flue gas are removed at the top of the cyclone towards the convection section of the boiler. Part of the flue gas is recirculated to the boiler by the respective oxidant fans. Recycled fly ash is fed to the lower part of the furnace in order to increase retention time and reduce unburned material.

Bottom ash is removed from the bottom of the furnace through one ash drain to maintain furnace material balance and bed material quality. Control of bed inventory and quality is an essential function of the CFB combustion system.

Depending on the operation mode, the oxidant required for combustion is obtained by mixing the following gases:

- Recirculated combustion gases, cleaned and cooled in the gas treatment system.
- Ambient air.
- Oxygen

The oxidant required is divided into independent streams, each one of them with a specific function, entering the furnace at different levels:

- Primary oxidant through the grid fluidizes the bed, which provides low oxygen atmosphere.
- Primary oxidant through upper nozzles provides remaining oxidant for appropriate lower combustion atmosphere.
- Secondary oxidant at different levels provides oxidant atmosphere to complete combustion process and control the combustion emissions.
- High pressure oxidant assures bed return to furnace by fluidizing loop seal and furnace cooling system bed.
- Transport oxidant helps fuel and limestone to enter the furnace at the appropriate velocity

Feedwater is heated by the economizer and steam is produced in a natural circulation combustor circuit comprising downcomers, evaporative surface, riser tubes and steam drum. Saturated steam leaves the drum through the saturated steam transfer to the convection cage, which is the first superheating stage. Steam is then led to the two superheaters of the INTREX where there are three desuperheating stages.

The fuel flexibility of CIUDEN oxyCFB boiler allows the utilization of a wide range of coals with simultaneous co-firing of biomass. At oxycombustion mode, fuel is burned with a mixture of recirculated flue gas and oxygen instead of air. The absence of air nitrogen produces a flue gas stream with a high concentration of CO_2, and therefore easier to capture [3].

3. OxyCFB Testing Programme in CIUDEN TCCT

CIUDEN´s R&D TCCT programme is focused on the validation of the full chain of CCS technologies and the data acquisition for scaling-up the units, both of them particularized in oxycombustion. To achieve these objectives, a specific testing campaign has been designed considering the wide range of possibilities of the plant.

CFB R&D programme aims to develop and demonstrate a power plant concept based on CFB technology combined with CCS. Some goals of the programs related to CIUDEN CFB unit, after conducting the tests to be carried out in the TCCT are to:

- Demonstrate oxy-combustion in a CFB of 30 MWth.
- Generate data for models validations.
- Generate the knowledge base for the scale-up.
- Determine optimum operating parameters to allow sizing of new full scale oxy-fired units.
- Obtain data on the combustion behaviour of different coals in conventional and oxycombustion conditions.
- Compare the performance between air and oxy combustion modes in order to be able to relate the air combustion experience to oxy conditions
- When operating in air mode, provide the flue gas stream for testing and demonstration of post-combustion carbon capture equipment.
- When operating in oxycombustion mode, provide a rich CO_2 gas stream for the testing of process equipment used for CO_2 purification and compression
- Obtain data to evaluate the impact that oxycombustion might have on the combustion, emissions and on radiant and convective boiler surfaces.

Preliminary test programs will be designed to investigate the effects of the following parameters:

- Temperature level: bed temperature at low, medium and high level
- Excess O_2 concentration
- Oxidant concentration

- Fluidization velocity
- Flue gas recycle
- Sorbent at the bed.
- Bed inventory: normal or high
- Pollutant emissions as a result of varying operating conditions
- SO_2 abatement
- Corrosion / fouling / agglomeration

4. Conclusions

The paper includes the description and the testing programme of CIUDEN Technological Centre for CO_2 Capture and Transport (TCCT) in Northwestern Spain, in particular the oxyCFB 30 MW_{th} system. The configuration combines CFB's intrinsic advantages (fuel flexibility and low SO_x and NO_x emissions) with oxygen-firing for carbon capture and storage (CCS). It must be pointed out that the CFB technology appears to be ideally well suited to oxygen-firing combustion.

The installation, first of its class, will provide real basis for the design and operation of flexible and competitive oxycombustion facilities at demonstration scale, thus accelerating the deployment of CCS technologies. In this way, results will be scaled up and applied to a 300 MW_e oxyCFB supercritical oxycombustion Power Station (OXYCFB300 Compostilla Project [4, 5]) in order to validate CCS technology at industrial level.

References

[1] V J Cortes. State of development and results of oxy-coal combustion research initiative by CIEMAT in Spain. 2nd IEAGHG International Oxy-Combustion Network Meeting. Windsor, USA. January 2007

[2] M Lupion; B Navarrete; P Otero; V J Cortes. CIUDEN CCS Technological Development Plant on oxycombustion in Coal Power Generation. 1st International Oxyfuel Combustion Conference. Cottbus, Germany. September 2009

[3] M Lupion, R Diego, L Loubeau, B Navarrete. CIUDEN CCS Project: Status of the CO_2 Capture Technology Development Plant in Power Generation. GHGT-10. Amsterdam. September 2010

[4] The OXYCFB300 Compostilla Project. SET-PLAN Conference. Madrid, Spain. June 2010

[5] The OXYCFB300 Compostilla Project. Berlin Fossil Fuel Forum. Brussels, Belgium. May 2010

This investigation was co-financed under the FP7 FLEXI BURN CFB Project (Development of High-Efficiency CFB Technology to Provide Flexible Air/Oxy Operation for a Power Plant with CCS, Grant Agreement number: 239188) and the EEPR09-CCS-COMPOSTILLA Project (European Union's European Energy Programme for Recovery programme). The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein.

SEVENTH FRAMEWORK PROGRAMME

Co-financed by the European Union
European Energy Programme for Recovery