



## SP3 Public Summary Report

*Based on the Del3.4.4 Feasibility study of an integrated 445 MWe oxy-fuel CFB supercritical boiler*

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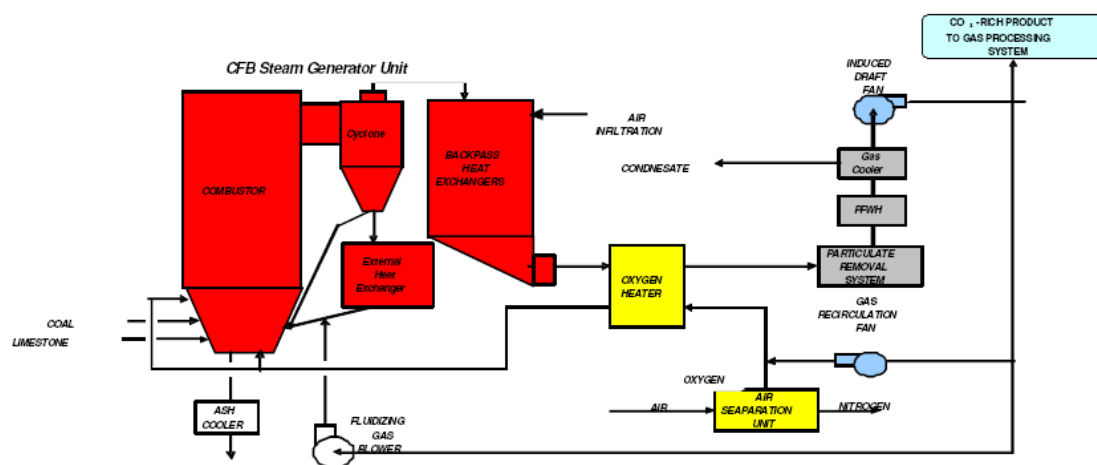
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Within the ENCAP's WP 3.4, a conceptual design for a greenfield advanced oxy-fuel Circulating Fluidized Bed (CFB) coal-fired power generation plant for CO<sub>2</sub> capture has been developed by ALSTOM Power Boilers. The main focus of the work carried out was the research, development and validation of applying the oxy-fuel combustion in CFB boilers.

The basic CO<sub>2</sub> capture concept using this oxygen-fired CFB technology is to replace combustion air with oxygen thereby creating a high CO<sub>2</sub> content flue gas stream that can be further processed into a high purity CO<sub>2</sub> end product for various uses or storage. The replacement of combustion air with high purity oxygen, as an additional benefit, significantly reduces the gas flow throughout the Boiler Island equipment while a cryogenic Air Separation Unit (ASU) is used to supply the oxidant for the combustion of coal rather than direct utilization of ambient air as in conventional CFB technology.



**Figure 1:** Oxy-fuel CFB concept

In an oxygen-fired CFB system, with the proper amount of recirculated gas, it is possible to obtain bed conditions within the furnace that are very similar to air firing using the appropriate systems that can be designed to have the same flue gas flow to coal flow ratio as with air firing and the same volumetric fraction of oxygen in the flue gas leaving the bed as that of the air-fired case. Furthermore, a critical advantage for oxygen-fired CFB type furnaces is the capability to reduce flue gas flow for a given coal input, by minimizing the recirculated flue gas flow, while maintaining the

furnace temperature. With an oxygen-fired CFB, a recycling loop of solid materials is used, by adjusting the heat pick up, to control the furnace temperature at an optimum operation level for combustion efficiency without any potential risk of agglomeration. The concept scheme offers significant opportunities for size and cost reduction in greenfield design.

Moreover, due to the inherent fuel flexibility associated with the CFB boiler, multiple fuels can be used such as coal, petroleum coke, biomass and a range of opportunity fuels.

In order to develop and validate the conceptual design of the advanced oxy-fuel CFB combustion, tests were carried out with bituminous coal and a petroleum coke in a CFB test facility under rich oxygen content in the oxidant. The tests covered a range of operating conditions regarding type of fuel, type of inert balance, furnace operating temperatures, oxygen contents in oxidant, outlet flue gas oxygen contents while the impact on emissions and carbon burnout was more specifically identified. The test program focused to the industrial case operating conditions and the demonstration of combustion performance with 90% O<sub>2</sub> in the oxidant stream sent to the furnace, thereby effectively minimizing the flue gas recycle. In addition, a coal combustion test with an N<sub>2</sub>/O<sub>2</sub> mixture oxidant simulating air fired conditions has been performed at the end of the program to be used as reference for comparison with O<sub>2</sub>/CO<sub>2</sub> mixture combustion especially to check CO emissions.

The experimental campaign generated a database of information regarding heat & mass balance, ash particle size distribution, sulfur capture efficiency under different Ca/S ratios, as well as NO<sub>x</sub> emissions. As result from the testing, the assumptions selected for the industrial design case of the 445 MWe oxy-fuel CFB are validated while the potential improvement for cost reduction of the technology by allowing to operate up to 90% O<sub>2</sub> fraction in the oxidant is opened.

The conceptual design for the greenfield advanced 445 MWe oxy-fuel CFB coal-fired power generation plant was based on a new generation of CFB technology (ALSTOM Power patented) targeting maximum boiler compactness for cost reduction purpose. This technology has been adapted to large oxy-CFB boilers, featuring a reduced flue gas flow, a divided back pass and more heat extraction from Fluid Bed Heat Exchanger (FBHE).

The cost analysis of the plant was performed. It includes the costs of all equipments on the site to the fence (excluding harbor and mining facilities but including coal yard for 30 days storage and coal handling equipment) but also includes the owner's costs for planning, designing and commissioning the plant and contingency. Finally, the risk analysis is dedicated to the identification of process and technological risks of the oxy-fuel concept using supercritical CFB boilers, their impact on the operation, their detection and the mitigation actions taken. The general approach used for this analysis was based on identification of specific aspects in the oxy-fuel CFB design and for each on the description of potential failure mode, potential effect of failure, potential cause, current controls and recommended action.

**Table 1.** Technical Data Summary for the bituminous coal design case

<b>Design case - Bituminous Coal</b>		Reference power plant	CO2 capture power plant	comment
				no
<b>Overall energy balance</b>				
Gross el. Capacity	MW	445,00	445,00	
Auxiliary power demand	MW	41,80	118,01	
Net capacity	MW	403,20	326,99	
Fuel mass flow	kg/s	36,50	35,40	
LHV	kJ/kg	25174	25174	
Net efficiency	%	43,88	36,69	
<b>CO2 balance</b>				
CO2 "input"				
C content of fuel	%	66,52	66,52	
Total theoretical CO2 input via fuel	kg/s	89,38	86,37	+ CO2 from limestone injection
CO2 input via air	kg/s	0,20	0	FBHE fluidization with Nitrogen from ASU
CO2 "output"				
Flue gas mass flow (to atmosphere)	kg/s	408,00	13,04	
CO2 content flue gas	%	21,42	63,4	%wt
CO2 emissions	kg/s	87,40	8,27	
CO2 to storage	kg/s	0,00	75,99	
CO2 "loss" due to unburnt carbon, etc.	kg/s	2,18	2,11	
CO2 capture performance				
Spec. CO2 emissions (C from fuel)	g/kWh	778,59	91,02	+ CO2 from limestone injection
CO2 avoidance rate (based on reference)	%		88,31	
CO2 capture rate (ENCAP design target)	%		90,19	

This work has demonstrated that oxygen-fired CFB is a feasible concept, close to the conventional CFB process with existing proven components. The boiler size is different due to the operating conditions and for the boiler island there is no foreseen degradation of availability, resulting from the process simplicity. The cryogenic air separation unit (ASU) is a proven unit for this size (3300 tpd), even with routine tele-operation in some plants and very long runs between shutdowns while no availability degradation is expected. The most critical points of oxy-fired CFB are mainly O<sub>2</sub>

injectors (70% O<sub>2</sub> content), back-pass fouling and O<sub>2</sub> heater. Furthermore, it has been noticed that CFB is the most suitable technology for biomass co-firing and the CO<sub>2</sub> not recovered in the CO<sub>2</sub> capture process (10% approx.) might be compensated by biomass co-firing. The value selected for O<sub>2</sub> fraction (70%) is not a limit of the process and higher values, up to 90%, have been investigated in this experimental work.

Some aspects of this technology remain to be addressed such as:

- The part load behavior
- Safety aspects related to O<sub>2</sub>/CO<sub>2</sub> containing enclosure
- Material risks concerning the heating of almost pure oxygen coming from ASU before being mixed to recycle stream
- The implementation of a 700°C steam cycle