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OXYCOMBUSTION AT LACQ CCS PILOT PLANT: PRELIMINARY ANALYSIS OF BURNER-BOILER PERFORMANCE

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At the end of 2006 Total launched the fully integrated CCS pilot plant in Lacq with Air Liquide as industrial partner. Oxycombustion of commercial gas was chosen by Total as it is one of the few promising technologies to capture CO_2 emitted from boilers for geological storage or enhanced oil recovery purposes. Accordingly, one of the goals of the Lacq CCS pilot plant is to develop and demonstrate the oxycombustion process addressing significant technology gaps such as combustion fundamentals, burner design and impact on boiler operation, heat distribution in the boiler, flue gases characteristics, flue gas purification technologies, and general process issues such as safety and reliability in the operations and procedures.

To enable the CO_2 capture using the oxycombustion technology, the existing air-fired boiler built in 1957 was retrofitted into an oxy-gas combustion unit. This 30 MWth oxyboiler was designed to deliver up to 40t/h of steam, at 60 Bar and 450°C, to the HP network of the Total Lacq sour gas production and treatment plant. The retrofit mainly consisted in installing specific oxyburners developed by Air Liquide, a flue gas recycle duct and a fan. Improvements on the sealing and insulation of the boiler were also done in order to limit air in-leakage. Pressurized smoke tests performed allowed locating and sealing the existing defects. An Air Liquide air separation unit installed on site feeds the oxygen to the oxy-boiler at purities from 95 to 99.9% v/v. The flue gases goes through a quench for moisture removal and the rich CO_2 stream is compressed, dehydrated and transported via pipeline to a depleted gas field, 30 kilometers away, where it is injected.

Boiler operation for oxycombustion implies different operation procedures including the ones associated with safety especially in the handling of oxygen. It should also take into account the recycling of the flue gases from the boiler outlet to the burners. This arrangement provides basically higher volume of gases in the boiler which allows keeping similar heat flux in the different boiler sections, such as per design, to avoid hot spots and early nucleation boiling. In addition to this, the boiler operation should be carried out in such a way that air in-leakages have to be avoided, or at least minimized. According to the oxycombustion principle for CO_2 capture, the nitrogen content in the flue gases is drastically reduced in order to increase the CO_2 concentration and to make the flue gas treatment process less energy intensive and perhaps less expensive. Thus, original air boiler operated typically under vacuum is now operated at slightly over atmospheric pressure.

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The Air Liquide oxyburner concept addresses the main technical issues for oxycombustion and also provides higher flexibility allowing starting up the system with air, making adjustment in the flue gas recirculation ratio (FGR) as well as in the different oxygen injection sections.

After all the preliminary tests for each equipment, the full pilot plant was fully operational starting in January 2010. The CCS pilot plant under operation will capture and store up to 100,000 tons of CO_2 over a 2-year period.

This paper specifically depicts the activities carried out to demonstrate the successful performance of the burner-boiler system, particularly using criteria such as flame stability and shape, heat flux, flue gases characteristics and safety issues within the range of operational conditions from the start-up, transient operation from air mode to oxygen mode and stable functioning, to the boiler shutdown.

Several tests were executed within the whole operating range of the boiler in order to gather reliable and reproducible measurements representative of the boiler performance. Boiler operation in air mode up to 30% of its capacity is normally used for start up purpose and achieving stable low load operation, before switching to oxygen mode. In the oxygen mode boiler load reached up to 95% of the design capacity. The different operating variables tested included the flue gas recirculation (FGR), the excess of oxygen, the boiler load and the primary/secondary oxygen ratio in the burner. To evaluate the burner-boiler performance and compatibility, the data acquisition system provides all information related to flow rates, temperatures and emissions recorded every few minutes. To evaluate the flame shape and stability the endoscope technique was used. The instrument was introduced through sampling ports specially arranged to provide a safe environment for the operator.

Through this CCS pilot plant, the start-up and continuous operation of a 30MWth air fired boiler retrofitted to oxygen firing has been a success. It has been demonstrated that the burners are flexible enough to meet the minimum and maximum heat input requirements for boiler steam production. The turndown ratio for the burner is 5:1, if the whole range of operation is considered starting in air mode up to 30% of boiler capacity and in oxygen mode up to 95% boiler capacity. The flames obtained were short and stable, even with high FGR.

The flames have been visualised by the endoscope technique through videos and photographs. They show that changes in the flue gas recirculation and in the primary/secondary oxygen ratio produce stable flames with different shape. The general trend is that the lower the flue gas recirculation and the lower the primary/secondary oxygen ratio, the longer the flames. This produces a consequent impact on temperature, heat transfer and emissions, particularly on NOx. In spite of this, no changes were observed on the flame root. The flames were very well attached to the burner and no significant disturbances were observed during the transition between different conditions. The Figure 1 below shows the different effects mentioned above, taken on one of the burners. Also, a good balance was observed for the 4 burners with no visible deviations of the flames, such as it is shown in the Figure 2.

In general, the boiler performance is based on the ability of the burner, the boiler, and the controls to work together. For this particular case, the technical criterion used to evaluate the boiler performance was mainly the fuel to steam efficiency according to:

$$\varepsilon = \frac{Heat\,Output}{Heat\,Input} = \frac{\left(M_{Steam} * H_{Steam}\right) - \left(M_{w} * H_{W}\right)}{M_{F} * High\,Calorific\,Value_{F}}$$

In addition to this, the evaluation of the steam quality and the temperature profile in the convection section of the boiler were also taken as a mean to assess the impact of the different variables on the boiler performance, and particularly on the heat profile.

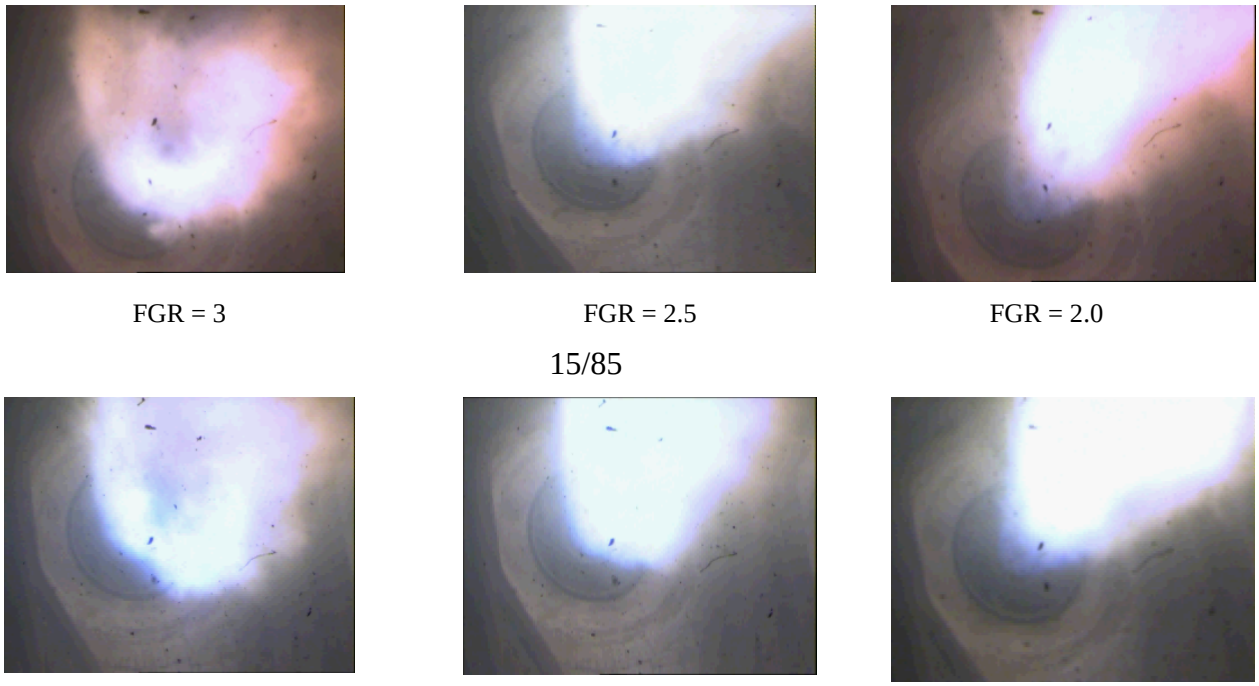
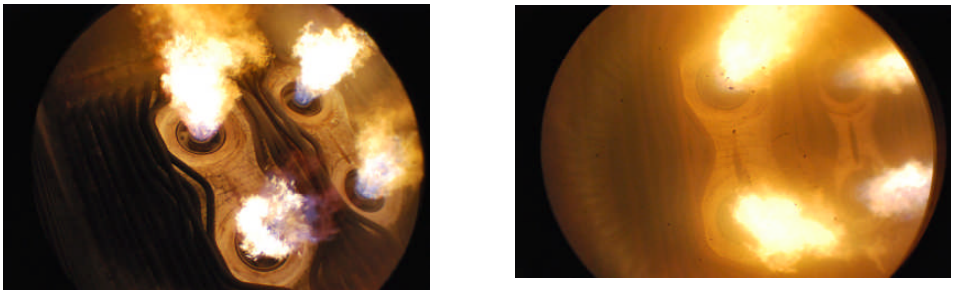


Figure 1. Impact of flue gas recirculation and primary/secondary oxygen ratio on flame shape and stability on one burner



(A) During preliminary tests (B) Steady state operation

Figure 2. Photographs of the flame for the four burners during the preliminary tests (A) and during the boiler stable operation (B)

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Preliminary results of the boiler “fuel to steam” efficiencies, without optimization of the operating variables are around 80 - 85 % according to the boiler load range evaluated. The burners provided the thermal input and the flame stability required through the whole operational range. The impact of the FGR on the emissions and on the boiler heat profile has been proved, particularly within this retrofitting scenario.

The next step regarding surface installation at Lacq will be to optimize the boiler operational conditions in order to assess more in detail the boiler efficiency and the heat profile. This will provide insides to have a better understanding of the oxycombustion in retrofitted boilers. In addition to this, it will be useful to scale up the technology to larger industrial demonstration projects and to finally assess the maturity of this technology.