

# CO<sub>2</sub>-free hydrogen production in a coal gasification pilot plant

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## ABSTRACT

Coal gasification represents one of the most promising technology for large, medium and small scale hydrogen production for distributed power generation. Currently, the application of “zero emissions” hydrogen production and power generation technologies involves very high capital and operative costs. This need a great scientific and technical effort in order to optimize processes and equipments, thus reducing the hydrogen production cost.

In this field, Sotacarbo is tuning technologies for the development of integrated processes for the combined production of hydrogen and electrical energy through coal gasification, with CO<sub>2</sub> separation. The process has been tested in a pilot platform, located at the Sotacarbo Research Centre in Carbonia (South-West Sardinia, Italy).

The platform includes two different units, both based on fixed-bed air-blown gasifiers (Wellman-Galusha technology): a 5 MWth demonstrative plant (with a fuel capacity of 700 kg/h of coal) and a 200 kWth pilot plant (feed with 35 kg/h of coal). While the demonstrative plant has been developed for the optimization of the gasification process and for the definition of the start-up and shut-down procedures, the pilot plant has been designed to develop and optimize the whole syngas treatment line for hydrogen production and power generation. Therefore, downwards the gasification process, the pilot plant includes a syngas depulverization system, followed by two different syngas treatment lines: a power generation line, with a cold gas desulphurization process and a syngas-feed internal combustion engine, and a hydrogen production line, which includes a hot gas desulphurization processes, an integrated CO-shift and CO<sub>2</sub> absorption system, a PSA section for hydrogen purification. A simplified scheme of the plant is shown in figure 1. Both plants operate at atmospheric pressure.

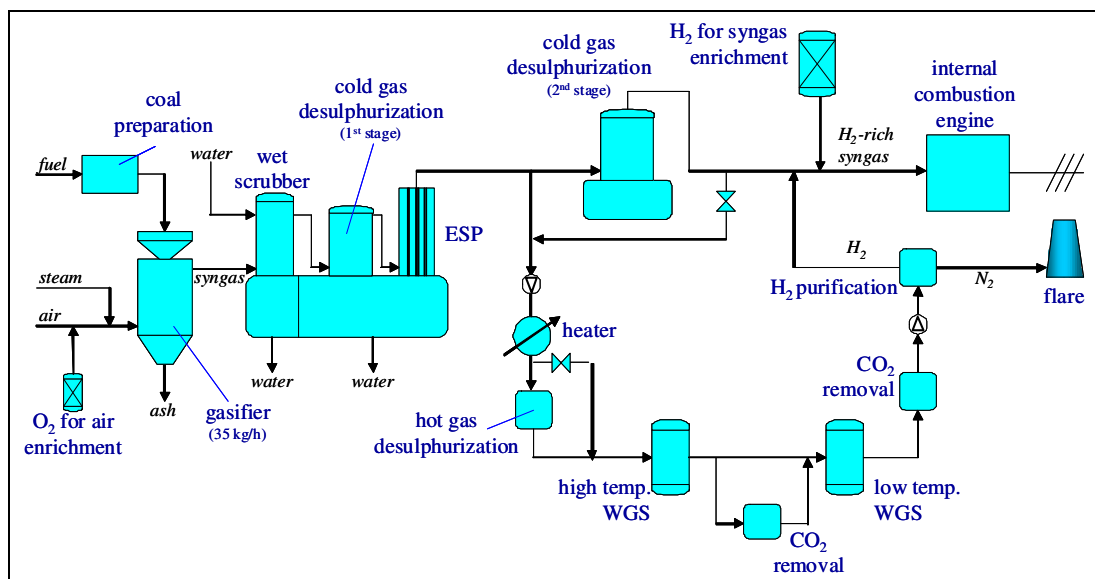


Figure 1. Pilot plant simplified scheme.

The CO<sub>2</sub> capture system is based on a chemical adsorption process which uses a 5M monoethanolamine (MEA) solution as solvent. This system allowed to achieve a CO<sub>2</sub> separation efficiency of about 85%, but it is possible to increase the efficiency up to 90-92%. The pilot plant, during about 250 operating ours between June 2008 and March 2009, has been tested in different operating conditions. In particular three kinds of feedstock have been used: a low sulphur coal from South Africa, a high sulphur coal from Sulcis coal basin, in South-West Sardinia, and a mixture of both these coals.

This paper reports a critical analysis of the main results obtained in the first experimental campaigns on the pilot plant, with particular reference on coal gasification, hydrogen production and CO<sub>2</sub> separation.

In particular, the optimum operating gasification conditions with the three kinds of feedstock have been reported. The raw syngas is characterized by a hydrogen concentration of about 37% (in volume and dry basis), while the concentrations of carbon monoxide and dioxide are about 18-22% and 11-13%, respectively. The gasification of 35 kg/h of coal involves the production of about 130 Nm<sup>3</sup>/h of syngas, characterized by a lower heating value of 6.5-7.5 MJ/kg. The temperature profiles into the gasifier in different operative conditions have been also reported, and the maximum temperature during the steady state operation is slightly lower than 900 °C.

As for hydrogen production, about 45% of hydrogen comes from the steam injection into the gasification section, 36% comes from steam injected in the CO-shift section, 18% comes from coal while the remaining 1% comes from the gasification air (both coal and air have been considered with its moisture content). Globally, the gasification of 35 kg/h of coal, considering that only 20% of produced syngas is sent to the hydrogen production line, allows to produce 1.3-1.6 kg/h of hydrogen, characterized by a purity of about 97%.

A preliminary study has been carried out, in cooperation with ENEA (the Italian National Agency for Energy end Environment), in order to evaluate the possibility to use a mixture of oxygen and carbon dioxide as gasification agent. Considering a commercial application of the technology, the recirculation of separated CO<sub>2</sub> should allow to substitute the nitrogen of the gasification air and to have a significant increasing of the CO<sub>2</sub> concentration in the decarbonation system. During the experimental tests in the pilot plant, the gasification agent has been simulated by using a gas mixer, fed with oxygen and carbon dioxide stored in bottles.

**Keywords:** coal-to-hydrogen, carbon capture, CO<sub>2</sub>-free, experimental plant.

**Proposed Topic:** pre-combustion CO<sub>2</sub> capture