CO₂ Capture by Integrated Pollutant Removal

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1. Introduction

There are three generally accepted approaches to the recovery of CO₂ from flue gas: precombustion capture, postcombustion capture and oxy-fuel combustion. In the case of oxyfuel air is replaced by relatively pure oxygen (~95% - 99+%) resulting in a flue gas that is primarily H₂O and CO₂. This article discusses modelling a retrofit of an existing PC power plant to oxy-combustion with CO₂ capture and an experimental program at a test boiler now in operation.

NETL has a patent on an oxyfuel flue gas treatment process known as Integrated Pollutant Removal (IPR®). This process incorporates the thermodynamic requirements for efficient multistage compression with energy recovery and CO₂ purification. The IPR® process uses condensing heat exchange after each compression stage to recover energy which is then used to pre/re-heat boiler comburant and boiler feedwater. Water condensed from flue-gas removes water soluble impurities such as NOₓ, SOₓ and Hg from the CO₂ stream. This work includes both computer modeling and verification with a physical system. The experimental work is a lab scale IPR® unit at the Jupiter Oxygen Burner Test Facility. A more generic computer model of the process using Aspen includes the process itself as well as accompanying water-treatment for captured flue-gas water. This effort also includes some corrosion studies.

2. Next

Air-fired combustion flue gas is primarily nitrogen and carbon dioxide while oxy-fired combustion products are mostly carbon dioxide and water vapor. The purity of the carbon dioxide water vapor stream depends heavily on the purity of the oxygen used. Oxygen used for oxy-combustion of coal ranges from 95 – 99 vol % with the balance...
being mostly nitrogen, argon, and helium. Another factor influencing products of combustion purity is infiltration of air which increases the nitrogen content of the flue gas.

IPR® uses direct heat exchange (spray tower) followed by multiple stages of compression and cooling with heat recovery to produce a sequestration ready CO₂ stream. Because the IPR® process uses off-the-shelf chemical engineering unit operations in a unique way it is possible simply purchase the equipment required to build an experimental facility and to model the process using standard engineering modeling software (Aspen). The lab scale IPR® system is designed to process approximately 50 kg/hr of flue-gas. Data gathered from the physical system include pressure, temperature and flow, as well as gas and liquid compositions at each process step. Results to date show that much of the NOₓ, SOₓ and possibly Hg are removed in the water that condenses in the IPR® compressor-intercooling steps. It is expected that pressure also plays a role in the oxidation state (and thus, solubility) of gas-components such as NOx and SOx, which in turn effect the capture rate of Hg. Flue gas products of oxy-combustion are analyzed using FTIR, ZrO₂ O₂ sensor, and GC. Gas species under consideration are H₂O, CO₂, CO, NO, NO₂, N₂O, HCl, H₂S, SO₂, COS, Ar, He, N₂, H₂, and O₂.

Computer modeling using software specifically designed for power-plant modeling (Gatecycle) and more general chemical engineering software (ASPEN) are used to examine the thermal integration of IPR® with the power-plant. These models help to predict distribution of flue-gas materials within the various stages of IPR®. The models are built both at full power-plant scale and at smaller scale to match the physical system which currently processes a slip-stream from an oxy-fired test-boiler. Data from the physical system inform the models for verification.

Encouraging preliminary results show the spray tower is effective removing gaseous sulphur compounds and the majority of water from the resultant oxy-coal gas product stream. During a demonstration campaign in Dec 2010, a 95% reduction in the SO₂ was achieved across the spray tower reducing SO₂ from an average of 9500 ppm to 460 ppm. Water in the flue gas was reduced from an average of 30 vol % to 6.5 vol % and HCl from an average of 36 ppm of HCl to of 5 ppm. Most of the remaining sulphur and chloride compounds report to the water removed during subsequent compression stages of IPR®. However, NOx compounds and CO seem are mostly unaffected by the spray tower and compression condensation and thus become more concentrated in the resultant compressed CO₂ IPR® product.

Capturing CO₂ from fossil-fuel combustion provides an opportunity for tapping a significant water-source which can be used as in the power-plant and its peripherals. Water condensed in the IPR® process contains fly ash particles, sodium and sulphur species as well as heavy metals, cations and anions. The target for water treatment is zero liquid-discharge from IPR®. To date, flocculation/coagulation and reverse osmosis have been identified as potential treatment technologies. Results for first-step treatment of flue-gas-derived water show flocculation can reduce most cations and fine particulate by at least 90%. Anions are hardly removed from waste water using flocculation experiments. Remaining supernatant should be amenable to reverse osmosis for anion removal and clean-up of remaining cations. Fast, in-line treatment of water for re-use in the IPR® seems, from flocculation-test results, to be a practical step for minimizing water requirements for CO₂ capture.

Corrosion measurements are being added to the system, tracking corrosion in real time using electrochemical corrosion sensors. These data are applied to material selection and will also inform process optimization. The IPR® system can be thought of as two linked sections, one low-pressure and the other high-pressure with temperatures ranging from 15º C to 170º C across both systems. The environment in the low-pressure system is predominately an acidic aqueous environment laden with chlorides is certain sections and the high-pressure system is predominately an acidic gaseous environment. Inline 316 SS and Inconel 625 corrosion probes and electrochemistry-based corrosion measurement technology will be used to study in-situ the internal corrosion of the IPR® System in nine locations and the corrosion resistance of 316 SS and Inconel 625 in these environments. The corrosion rates of the 316 SS and Inconel 626 will be correlated with process and operational events over time to determine the effect of the operational events on the corrosion rates. This will provide information on which metal is
more corrosion resistant in the IPR® environments and which process and operational events can be modified to reduce the corrosion.

3. References