ELSEVIER
CrossMark
Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 63 (2014) 6318 – 6322
Energy Procedia

GHGT-12

Advanced CO_2 Capture Pilot Plant at Tauron's coal-fired Power Plant: Initial Results and Further Opportunities

Lucyna Więcław-Solny[a], Adam Tatarczuk[a]*, Marcin Stec[a], Aleksander Krótki[a]

[a]*Institute for Chemical Processing of Coal, Zamkowa 1, 41-803 Zabrze, Poland*

Abstract

Institute for Chemical Processing of Coal in cooperation with industrial partners: TAURON Polska Energia S.A. and TAURON Wytwarzanie S.A. designed, constructed and operated pilot plant at Łaziska Power Plant in Łaziska Górne, Poland.
The carbon capture facility is based on amine post-combustion process technology and used 30 wt% aqueous ethanolamine solvent. Approximately 1000 kilograms of CO_2 can be captured per day from flue gas stream of 200 m^3_n/h of a 225MWe hard coal fired boiler. The plant captured its first tonne of CO_2 in August 2013. The purpose of this study is to present initial results from tests carried out at Łaziska Power Plant using different process flow sheets: heat-integrated stripping column and split flow process.
The tests provide valuable experimental evidence for modifications described in the literature, mainly through modelling and demonstrate that flow sheet modifications, despite the increase in plant complexity, are worth to consider.

Peer-review under responsibility of the Organizing Committee of GHGT-12

Keywords: PCC; post-combustion carbon capture; pilot plant;MEA; CCS

1. Introduction

As a part of the strategic research programme – "Advanced technologies for energy generation: Development of a technology for highly efficient zero-emission coal-fired power units integrated with CO_2 capture" a mobile CO_2 absorption pilot plant has been erected. The main purpose of the pilot plant is to demonstrate the post combustion technology in conjunction with coal-fired power plant.

* Corresponding author. Tel.: +48-32-271-00-41; fax: +48-32-271-08-09.
E-mail address: tatarczuk@ichpw.zabrze.pl

1876-6102
Peer-review under responsibility of the Organizing Committee of GHGT-12
doi:10.1016/j.egypro.2014.11.664

The pilot plant captures up to 1000 kg/day of CO_2 from the power plant's flue gases with CO_2 removal rate exceeding 90%. This paper summarizes the initial operation experience and selected, first results obtained are presented.

Proposed pilot plant's scale allows conducting test at economically reasonable cost giving realistic picture of CO_2 capture technology using amine scrubbing. It gives opportunity to determine the influence of the process parameters on plant's efficiency.

Acquired data will allow CO_2 capture units optimization and will be useful for scaling-up amine scrubbing CO_2 capture plants.

Fig. 1. The Pilot Plant at Tauron's Łaziska Power Plant, Poland.

2. Experimental

2.1. Chemicals and flue gas composition

Concentrated ethanolamine (MEA, CAS: #000141-43-5, technical grade) was obtained from Brenntag NV. 30 wt% aqueous solution of ethanolamine was prepared on site using mains water. Antifoaming agent: Silpian W-3 was purchased from Silikony Polskie sp. z o.o.

Table 1. Typical flue gas composition at Łaziska Power Plant, Poland.

Component	Composition
CO_2 (vol%)	13.5
H_2O (vol%)	5.5
O_2 (vol%)	11.0
SO_2 (mg/m^3)	100-200
NO_x (mg/m^3)	200-300
Dust (mg/m^3)	100
Temperature (°C)	80-100

Aqueous solution of sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$) used in pre-treatment column as desulphurization solution were purchased from POCH S.A.

Typical flue gas composition at Łaziska Power Plant is shown in Table 1.

2.2. Basic concept of the Pilot Plant

According to current standards, the concentration of sulfur oxides in the exhaust gas of coal-fired power plants should not exceed 200 mg/m^3_n [1]. However, this amount is insufficient for amine absorption technology, due to increased rate of amine degradation caused by sulfur oxides. To reduce rate of amine degradation, and therefore lower operation costs, Pilot Plant has additional desulfurization unit, reducing sulfur oxides concentration up to 20 mg/m^3_n. Sodium carbonate and bicarbonate solution is used in deep desulfurization unit. Sulfur oxides from flue gases are absorbed and the resulting sodium bisulfate solution is collected in column bottom.

Desulfurization unit allows in-depth analysis of impact of sulfur oxides in flue gases on amine solution degradation.

Desulfurized and cooled gas is fed into absorption column, the main element of carbon capture unit. Flue gas (approximate flow around 208 m^3_n/h) is passed up the absorber, countercurrent to amine solution. Next important part of Pilot Plant is heat recovery node. Rich solution, passed from absorber bottom to desorption unit is pre-heated by hot lean solution in heat recovery node. Proper heat recovery is crucial in reducing process energy demand. The efficient heat recovery from lean amine solution reduces evaporator energy demand because initially heated rich solution has higher temperature.

Apart from mentioned standard components, the pilot plant's flow sheet contains modifications allowing regeneration energy demand reduction and increase of CO_2 recovery. Following features are incorporated: heat-integrated stripping column and amine split flow. Applied flow sheet modifications are shown in Fig. 2.

Energy demand reduction and high performance with respect to CO_2 removal is achieved by splitting streams of the working solution [2]. A partly regenerated (semi-lean) amine solution is passed from the middle of the stripper to the middle of the absorption column, and a completely regenerated (lean) amine to the top. Beside lower energy consumption, the use of split-stream configuration allows to enhance CO_2 capture in the "upper" absorber section, therefore CO_2 in residue gas, leaving absorber, can be reduced, compared to a plant with a conventional flow sheet. Majority of CO_2 is captured in lower section of absorber by semi-lean amine, therefore in "upper" section of absorber, where lean amine is contacting remaining CO_2, higher degree of removal is achieved. When using the split flow option, either the rich amine loading or the overall circulation rate must be increased slightly since the semi-lean amine has a higher residual CO_2 loading than for a conventional flow plant, despite that split-stream configuration is beneficial due to decreased energy demands and higher CO_2 capture efficiency.

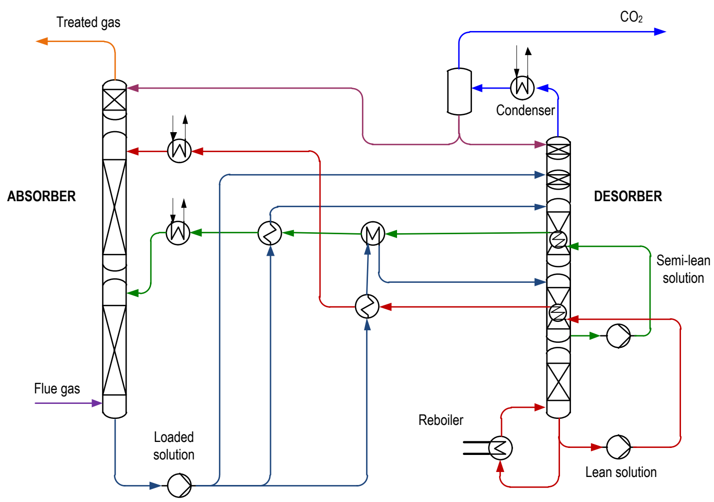

Fig. 2.The carbon capture unit of the pilot plant. Schematic shows process using heat-integrated stripper and split flow process. [3]

Second, important modification in flow sheet is heat-integrated stripper. The use of built-in heat exchangers integrated into the stripper (Fig. 2) changes stripper's temperature profile. This brings the equilibrium and operating conditions closer together along the length of the stripping column [4].

3. Operation experience and results

Within the 2013 over 550 hours of tests were conducted on the pilot plant. The activities at the pilot plant have been divided into following major tasks:

- May 2013 – the pilot plant's start up,
- June 2013 ÷ July 2013 – plant's tuning and initial tests,
- August 2013 ÷ November 2013 – significant test campaigns

Every test campaign lasted approximately 100 hours of continuous operation. Campaigns were divided into shorter periods during which the influence of different process parameters was investigated.

The greatest emphasis during test campaigns was on verification of process flow sheet modifications. Modifications presented above were described in the literature but mainly through modeling and pilot scale results are invaluable for verification of theoretical considerations.

Table 2. Comparison of the tests with single stream and split flow configurations.

Process flow sheet	CO_2 concentration in flue gas (vol%)	CO_2 Recovery (%)	Reboiler heat duty (MJ/kg CO_2)
Split flow with heat-integrated stripper	13.5	89	3.8
Single stream with heat integrated stripper		84	4.0

Table 2 summarizes the results of two tests comparing single and split flow process. The split stream process was designed to increase CO_2 recovery [5] and such theoretical proves were published by Oyenekan and Rochelle [6]. According to their studies total work should be reduced by 17% than of a conventional stripper. Initial pilot results showed reduction of reboiler heat duty and CO_2 recovery by at least 6% and further improvement is expected.

Table 3. Comparison of the tests with and without heat-integrated stripper.

Process flow sheet	CO_2 concentration in flue gas (vol%)	CO_2 Recovery (%)	Reboiler heat duty (MJ/kg CO_2)
Split flow with heat-integrated stripper	11.2	91	4.3
Split flow without heat-integrated stripper		84	4.7

Novel construction of the stripper was also verified during the test campaigns. Semi-lean amine and lean amine were passed through a heat exchangers built into the stripper, which caused the heat exchange between hot lean and semi-lean solutions and colder interior of the stripper. The remaining part of the heat was then exchanged in heat recovery node as in standard process flow sheet. The use of internal heat exchange caused the increase of the temperature of upper part of stripper and consequently better desorption. It resulted in higher CO_2 recovery by approximately 8% and reduced reboiler heat duty. The reduction is lower than value of 17%, predicted by Oyenekan and Rochelle's model [6], however further improvement is expected. Process parameters for that comparison are summarized in Table 3.

Due to variations of ambient temperature, changing flow sheet, estimation of heat losses on stripper and piping was not easy. Therefore reboiler heat duty in tables above is expressed as gross value (value contains actual heat duty and the heat losses). We believe that the use of gross reboiler heat duty is valid for such comparison purposes. The value of reboiler heat duty excluding the heat losses (net value) is approximately 10% lower.

4. Conclusions

The present paper reports on initial operation and presents general results achieved during the first tests. The pilot plant campaigns successfully demonstrated reliable operation allowing the removal of over 19000 kg of CO_2 from flue gases at TAURON Power Plant in Łaziska Górne, Poland.

The completed campaigns proved that split flow or heat-integrated stripper modifications reduce reboiler heat duty and increase CO_2 recovery.

In the coming years, the pilot plant will be used to evaluate advanced technological innovations like split streams of solvent or stripper's inter-heating in conjunction with novel solvents developed in the project [7].

Acknowledgements

The results presented in this paper were obtained during research co-financed by the National Centre of Research and Development in the framework of Contract SP/E/1/67484/10 – Strategic Research Programme – Advanced technologies for energy generation: Development of a technology for highly efficient zero-emission coal-fired power units integrated with CO_2 capture.

References

[1] Wilk A, Więcław-Solny L, Tatarczuk A, Śpiewak D, Krótki A. Effect of composition of absorption solution on carbon dioxide removal efficiency. . Przem Chem 2013;92:120–5.
[2] Leites IL, Sama DA, Lior N. The theory and practice of energy saving in the chemical industry: some methods for reducing thermodynamic irreversibility in chemical technology processes. Energy 2003;28:55–97. doi:10.1016/S0360-5442(02)00107-X.
[3] Szczypiński T, Tatarczuk A, Grudnik K. Optimization of amine-based CO2 capture from flue gas by flowsheet modification. Przem Chem 2013;92:106–10.
[4] Cousins A, Wardhaugh LT, Feron PHM. A survey of process flow sheet modifications for energy efficient CO2 capture from flue gases using chemical absorption. Int J Greenh Gas Control 2011;5:605–19.
[5] Polasek JC, Bullin JA, Donnelly ST. How to Reduce Costs in Amine Sweetening Units. Chem Eng Prog 1983;79:63–7.
[6] Oyenekan BA, Rochelle GT. Alternative stripper configurations for CO2 capture by aqueous amines. AIChE J 2007;53:3144–54. doi:10.1002/aic.11316.
[7] Wilk A, Więcław-Solny L, Krótki A, Śpiewak D. Impact of the composition of absorption blend on the efficiency of CO2 removal. Chemik 2013;67:399–406.