IEAGHG Information Paper 2018-IP31; 2018 NETL CO_2 Capture Technology Project Review Meeting: Solvents

This year, several projects developing physical/chemical solvents or enhancing processes based on chemical absorption were presented. Compared to the previous meeting on 2017, this year the technologies presented are being tested at larger scale. While few solvents are being tested since few years ago and are at an advanced stage, such as piperazine, others are new scale-up processes. Still, the screening process for solvents selection is challenging. While many researchers and developers trust on new combinations based on the chemistry of the solvents, this procedure can be tedious.

Not only solvents for chemical absorption (post-combustion) were presented, but also some research on physical solvents for pre-combustion. In addition, we have seen different approaches for chemical absorption:

1) bi-phasic solvents, which show the advantage of regenerating only part of the solvent. The CO_2 is absorbed and that produces a phase separation (one rich in CO_2 and another one almost without CO_2). Only the phase rich in CO_2 is regenerated, reducing the stripper size and costs associated;

2) salts-based solvents, which might show a lower energy requirement for regeneration;

3) water lean solvents, which also decrease the energy required for regeneration;

4) amine-based mixed solvents, which try to take advantage of a fast reaction with CO_2 of one of the amines, and a lower heat of absorption exhibited by the other one.

Current efforts are focused on defining which are the desirable properties and how a better chemical absorption can be properly defined. Additionally, we see that the performance of the chemical absorption with advanced solvents is still compared with the traditional 30% (w/w) MEA solutions. Although this basis scenario could be obsolete, the solutions presented show some enhancement over that case.

Another area of development is integration. We know that advanced stripper and absorber configurations are essential to optimize the chemical absorption process. In this meeting, we have seen a noticeable advance in that area, such as advanced regeneration through electrochemical process, two-stage solvent regeneration, solvent split-stream integration, flue gas heat recovery, and water use minimization.

It is obvious that a proper combination of strategies will be key to reach the new generation of chemical absorption processes. IEAGHG is carrying out a technical study to incorporate research on the topics we believe are essential for the next generation: 1) to define desirable properties; 2) to establish an updated benchmark case; and 3) to give an overview of advanced configurations for the integration of carbon capture technologies. Keep an eye on our website, results will be published in early 2019.

The table below includes a summary of the projects presented in this meeting. The highlighted cells include projects focused on integration.

Mónica García
21/08/2018

Project Title	Duration	Coordinator	Info	Website
A high performance physical solvent for pre-combustion capture	-		The application of this solvent is pre-combustion in IGCC-CCS. Although some foaming issues were found with an initial candidate, it was solved by getting another formulation. Properties of this solvent include: molecular weight 620g/mol, density 0.987 g/ml, and viscosity 8.1 cP at 40°C. The solvent shows good CO_2 selectivity over H_2 and is hydrophobic (there is not competition for H_2O absorption). The absorption was simulated with Aspen Plus and the project team produced 60L to use for further tests in the University of Kentucky.	-
A data mining method for the identification of new physical solvents	-		This work included an in-house computation database based on the chemical functional group interactions with CO_2. 23,000 compounds from NIST were included and an integrated automatic computational approach was developed. CSSH-1 was selected due to promising properties for CO_2 pre-combustion capture.	-
Development of a novel biphasic CO2 absorption process with multiple stages of liquid-liquid phase separation for post-combustion carbon capture	10/01/2015 – 12/31/2018	University of Illinois at Urbana-Champaign	This project aims to demonstrate the advantages of a two liquid-phases solvent, based on the regeneration of only one of the phases (lower energy consumption and enhancement of mass transfer rate). Tests will be carried out at lab and bench scale (up to 10KWe, heat supplied by an electric stream generator and with a simulated gas with 30% CO_2) to extract results which will serve as inputs for a techno-economic study for a conceptual coal-fired power plant retrofitted with the technology. 80 solvents were screened from which 2 solvents were selected. A combined flash and stripping was compared with the single stripping. The heat duty in the single stripper was slightly lower than the combined one but it required higher pressure. Corrosion was tested during the use of 3 solvents (2 innovative ones and compared to MEA) and little difference was observed between the solvents proposed in this project, more significant on the stripper and absorber bottoms. Both resulted in lower corrosion than MEA. 20% of CAPEX can be reduced, mainly due to a smaller absorber, 43% lower energy consumption, both compared with MEA-based chemical absorption.	FE0026434
Large bench scale development of non-aqueous solvent carbon dioxide capture process for coal fired power plants utilizing real coal derived flue gas	01/01/17-30/09/2018	RTI International	The objective is to develop a non-aqueous solvent(s) (NA(s)), aiming to increase the solvent performance and design, and to build unique process modifications for the Tiller plant (Norway) (propane+ coal derived fluegas), reducing the energy penalty below 2GJ/tonne CO2. The process was running for 350 hours with the coal +propane fluegas and 50 hours with coal fluegas. The goal is to study scalability, emissions, degradation of the solvent and long-term performance.	FE0026466
Fluor Advanced solvent testing and evaluation at TCM	-	Fluor	Fluor is testing their water lean solvent formulation to make the chemical absorption process more efficient. The results at TCM show 2.74 GJ/t CO_2. CAPEX represents 63% of the costs while OPEX represents 37%. The project team is focusing the effort in cutting down both cost figures.	-

Engineering scale testing of transformational non-aqueous solvent-based CO2 capture process at Technology Centre Mongstad	5/1/18 to 04/30/19 & 05/1/18 to 10/31/20	Research Triangle Institute (RTI)	The objective is to test and evaluate a non-aqueous solvent at TCM (10MWe) after testing at Tiller facilities (approximately 0.6 MWe). Specific challenges include to monitor the emissions, minimize the rise on the absorber temperature and maximize the solvent performance. The project team is working with this solvent since 2010, selected from a phase of solvent screening, lab scale evaluation and preliminary tests at lab and bench scale. Up to now, the solvent has been tested during 543 h under parametric testing and 1043 h on stream for long-term testing (both using coal-fired fluegas). The solvent showed low HSS formation and the water balance can be controlled by tuning the temperature of the water wash. The corrosion was lower than using the traditional MEA solution and the specific reboiler duty was around 2.1-2.3 GJ/tCO2 captured. One of the main concerns of this kind of solvent is the viscosity. In this case, the lean solvent showed 3.48-4.7 cP and the rich one 18-20 cP.	PPT from the kick of meeting
Evaluation of piperazine with advanced flash regeneration for CO_2 capture from coal-fired flue gas	01/10/2010 – 31/12/2018	URS Group, Inc.	The objective of this project is to integrate at bench scale the advanced stripper configuration and the advanced piperazine-based solvent, aiming to evaluate the robustness of this integrated system, and optimize the equipment design and energy performance of the advanced stripper. The project will identify and resolve other potential operational and design issues including process control, corrosion, foaming, and solids precipitation. Results are promising, combining the benefits given by both technologies.	FE0005654
Large pilot testing of Linde/BASF advanced post/combustion CO_2 capture technology at a coal-fired power plant	04/04/2018 – 03/08/2019	University of Illinois at Urbana-Champaign	The objective is to obtain a capture rate of 90% (95% CO_2 purity), and to demonstrate at 10 MWe at an existing coal-fired power plant, increasing the TRL of this technology and enhance the energy consumption compared to traditional chemical absorption systems. Based on the 1.4 MW test, the cost of capture is 42-57$/t CO_2 captured. Host sites for further testing are being studied and evaluated for the carbon capture integration.	FE0031581
Engineering scale demonstration of mixed salt-process for CO_2 capture	01/07/2018-30/06/2021	SRI International	The focus of the project is to demonstrate the ammonia-based, mixed salt process at TCM. Issues like water management, TEA validation, process reliability, testing/data collection and identification of the technology gap analysis for large scale applications are included in the project plan.	-
Development and bench-scale testing of a novel biphasic solvent-enabled absorption process for post-combustion carbon capture	6/4/2018-2021	University of Illinois at Urbana-Champaign	This solvent has been characterized along the time, and additional characterization tests will be carried out. The main objective is to model (ASPEN plus, including thermodynamic and process scales), design and fabricate a 40KWe integrated capture unit and test it at the Abbott power plant after lab and bench-scale testing with simulated and real fluegas. Results will help to complete the TEA of this technology. Degradation and aerosol generation will be taken into account. Volatile losses will be studied in a 10KWe unit.	-
Mixed-salt based transformational solvent technology for CO_2 capture	01/06/2018-30/05/2021	SRI International	The mixture includes potassium carbonate, ammonium salts and an additive, with heat of reaction of 35-50 KJ/mol. Absorber operation at 20-40° C at 1 atm and regeneration at 90-120°C. Low energy requirement for stripping and enhanced kinetics at high temperature, which reduces the packing height and reduce water evaporation. Tests will be carried out at lab and bench scale.	-

Flue gas aerosol pre-treatment technologies to minimize PCC solvent losses	01/01/2018-30/11/2020	Linde LLC	Two technologies to decrease aerosol emissions (in high concentrations, >102 particles/cm^2, 70-200 nm particle size range) will be the focus on this project: A high velocity water spray (developed by RWE and tested in the lignite fired coal power plant in Noederaussem) and a novel electrostatic precipitator (developed by Washington University and tested in NCCC). The cost of electricity can be slightly reduced compared to the standard process. The systems will be tested independently. The target is to have a particles removal of 98% without impacting dramatically the energy consumption.	-
Electrochemically mediated amine regeneration in CO_2 scrubbing processes	01/08/2017 – 31/07/2020	Massachusetts Institute of Technology	During this project, lab tests will be carried out to study the regeneration of solvents through reduction/oxidation with responsive materials and metal ions. This process eliminates the need of steam in the regeneration step.	FE0026489
Uky-CAER heat integrated transformative CO_2 capture process in pulverized power plants	01/04/2018 – 31/07/2019	University of Kentucky Research Foundation	The main objective is to enhance the plant efficiency by process intensification, two-stage solvent regeneration, heat integration, and an advanced solvent. Technologies have been tested previously and have showed robustness. The expected output is to reduce capital cost, energy consumption, and environmental impact, as well as address load change. Preliminary results show a 19-28% of reduction of cost electricity compared to the DOE reference case 12. Cost of CO_2 captured is 34.52$/t CO_2 and 119$/MWh. With a duel fuel system, the reduction is even higher (25.26 $/$CO_2$ captured). The work plan includes more than 2000 of operational hours, monitoring the air emissions, solvent stability, corrosion and advanced controls (model predictive control and fast response variables). An ASPEN Plus model has been complete (thermodynamic and process scales). It is planned to scale-up the system to 10MWe.	FE0031583
ION Engineering commercial carbon capture design &costing	30/05/2018 – 29/11/2019	ION Engineering, LLC	The project is based on the water-lean solvent developed by ION and will go one step further through testing the integration with advanced configurations such as solvent split-stream integration, flue gas heat recovery, and water use minimization. After testing in TCM during the previous project, the technology will be integrated to capture the fluegas from the two coal-fired units in the Nebraska Public Power district (1.365MW).	FE0031595
Initial Engineering, testing, and design of a commercial scale post-combustion CO_2 capture system on an existing coal-fired generating unit	01/07/2018-31/12/219	University of North Dakota	The tasks include the design of a fully integrated PCCC for Milton R Young Unit 2 (477 MW lignite-fired unit), evaluate KS-1 solvent and complete the TEA and FEED. The capture technology is the MHI capture technology based on the KM CDR process (technology used at Petra Nova). 95% capture is expected, 12,157 t CO_2/day, and monitoring the aerosols including an aerosol mitigation technology.	-
A process with decoupling absorber kinetics and solvent regeneration through membrane dewatering and in-column heat transfer	01/05/2018 – 30/04/2021	University of Kentucky	The objective is to test this intensified CO_2 capture process at large bench scale (0.1 MWth) with coal-fired flue gas at a cost of approximately $30/t CO_2 captured. The cost reduction is expected based on a potential decrease of the absorber size by up to 50 % (reducing CAPEX and OPEX), and providing a secondary point of vapor generation which results in an energy savings of up to 30 %. A printed 3D structured packing will be used to control the absorber temperature profile and a two-phase flow heat transfer prior the stripper will be used.	FE0031604