Advancing CO_2 Capture Technology: Partnership For CO_2 Capture

primary project goals

The University of North Dakota Energy and Environmental Research Center (UNDEERC) conducted pilot-scale testing to evaluate and validate a range of carbon dioxide (CO_2) capture technologies to develop key technical and economic information that can be used to examine the feasibility of capture technologies as a function of fuel type and system configuration.

technical goals

- Integrate a high-efficiency, flexible post-combustion capture system with existing pilot-scale combustion and emission control systems to evaluate the performance of several capture techniques and technologies in flue gas streams derived from selected fossil fuels, biomass, and blends.
- Conduct testing of oxy-combustion for selected fuels and blends in one or more of UNDEERC's existing pilot-scale units.
- Evaluate the performance of emerging CO_2 capture technologies under development and identify key challenges associated with each for both pre-combustion and post combustion platforms
- Perform systems engineering modeling to examine efficient and cost-effective integration of CO_2 capture technologies in existing and new systems.

technical content

UNDEERC constructed two pilot-scale systems and performed experiments on several advanced CO_2 capture technologies and compared them to monoethanolamine (MEA). Flue gas derived from one of two pilot combustors was used as the CO_2 source. The pilot combustors are highly versatile; able to fire virtually any fuel and configurable with all of the primary pollution control devices including electrostatic precipitators, fabric filters, selective catalytic reduction for nitrogen oxide (NO_x) control, and flue gas desulfurization.

Baseline testing was conducted using MEA to gather information to characterize each of the units. The results obtained by using MEA in the CO_2 absorption system were used as a standard by which all other solvents were compared. Data collected included CO_2 removal, CO_2 purity, required regeneration heat, and effects of sulfur oxide (SO_x), NO_x, particulate matter, and trace metals.

Baseline testing of the oxy-combustion system followed similar procedures as the absorption system. The data collected can be used to identify potential challenges concerning this technology. These challenges include effects of mercury (Hg) capture, flame stability, fouling, slagging, and heat-transfer issues.

technology maturity:
Pilot Scale

project focus:
Partnership for CO_2 Capture

participant:
University of North Dakota Energy and Environmental Research Center

project number:
FC26-08NT43291

predecessor projects:
N/A

NETL project manager:
Andrew Aurelio
isaac.aurelio@netl.doe.gov

principal investigator:
John Kay
UNDEERC
jkay@undeerc.org

partners:
Arthur Gallagher, Atco Power, Black & Veatch, Baker Hughes, Cansolv Technologies, CO_2 Capture Project Consortium, Constellation Power Source Generation, C-Quest Technologies, GE Global Research, Hitachi, Huntsman Petrochemical, Metso Power, Midwest Generation, Minnesota Power, Nebraska Public Power District, North Dakota Industrial Commission, Neumann Systems Group, PPL Montana, Saskatchewan Power, Sulzer, TransAlta Utilities, and University of Wyoming

start date:
05.01.2008

percent complete:
100%

Figure 1: UNDEERC post-combustion CO_2 capture test facility

Carbon dioxide capture technologies were selected and tested. Two flue gas pretreatment technologies were evaluated. The Partnership for CO_2 Capture worked with Cansolv Technologies Inc. to test the operability of a benchmark solvent and an improved formulation for sulfur dioxide (SO_2) removal. The testing indicated that choice of solvent should be made based on both SO_2 removal effectiveness and energy input required for regeneration rather than on solvent operability. The second pretreatment technology tested was a flue gas filtration technology manufactured by Tri-Mer Corporation which combines particulate, NO_X, and SO_2 control. This test showed that their capture was highly dependent on temperature, ammonia injection rate, and amount of sorbent used. The Sorbacal sorbent SPS achieve higher levels of SO_2 removal than their SP sorbent, and the Tri-Mer system effectively removed impurities prior to post-combustion CO_2 capture (though SO_2 levels may need additional trimming).

Two post-combustion solvents were also tested. Korea Carbon Capture and Sequestration R&D Center's (KCRC) Solvent-B showed 90 percent capture with approximately 40 percent lower liquid/gas ratio and 30 percent lower regeneration energy input than MEA at the same capture level. CO_2 Solutions Incorporated proprietary technology uses the enzyme carbonic anhydrase as a catalyst with a salt solution. Testing showed no degradation in performance of the enzyme catalyst, no generation of toxic waste by-products, and showed the ability to use low-grade heat for regeneration, allowing for reduction of cost of CO_2 capture.

Nine membranes for hydrogen/CO_2 separation were provided by Commonwealth Scientific and Industrial Research Organization (CSIRO) for pre-combustion testing using syngas from EERC's fluidized-bed gasifier with warm-gas cleanup. Membrane performance increased with increases in temperature.

A detailed process-modelling effort was undertaken using Aspen Plus software to develop the basis for determining cost of CO_2 capture using advanced post-combustion capture technologies and techniques including the solvents from KCRC and CO_2 Solutions. Also, three power plants were modeled using Carnegie Mellon's Integrated Environment Control model to show the effects that capture would have on net power production, water usage, and revenue requirements for various levels of capture.

Laboratory testing was performed to determine the feasibility of measuring residual amine and nitrosamines potentially emitted in stack flue gases using Fourier transform infrared spectroscopy (FT-IR).

This project placed a strong emphasis on the integration of total systems so that the economic and environmental benefits of carbon capture could be further understood and potentially implemented by utility stakeholders.

Testing of proprietary solvents was conducted on a small industrial 1 tonne/day CO_2 catch and release test system. The system utilized real combustion flue gas generated in a pilot combustor located adjacent to the capture system with typical flue gas conditions given in Table 1. Proprietary membrane testing was conducted utilizing UNDEERC's gasification pilot systems. Table 2 lists the typical conditions of the syngas for membrane testing.

Table 1: Typical Flue Gas Conditions

Flue Gas Flow 250 kg/hr		Composition						
Pressure	Temperature	vol%				ppmv		
psia	°C	CO_2	H_2O	N_2	O_2	CO	SO_x	NO_x
14.7	40	15.6	11.0	80.1	4.2	25	295	200

Table 2: Typical Syngas Conditions

Syngas Flow 2,200 kg/hr		Composition							
Pressure	Temperature	vol%							ppmv
psig	°C	CO	H_2	O_2	N_2	CO_2	CH_4	hydrocarbons	H_2S
309	325	2.63	37.64	0.12	11.96	47.92	2.83	0.04	4,095

technology advantages

UNDEERC has obtained experimental data for a variety of advanced CO_2 capture technologies and oxy-combustion systems. Beyond showing a clear comparison of various approaches, this work has resulted in several improvements to solvents and membranes. Data from this program led directly to an improved sulfur capture solvent being produced by Cansolv Technologies. KCRC took the data obtained to focus their development pathway, focusing on a solvent which displays potential for future performance improvement. CO_2 Solutions Incorporated utilized data generated to further develop their technology to take advantage of waste heat availability which shows potential to reduce capture costs. Finally, CSIRO advanced their early stage development of a membrane that shows great promise for pre-combustion CO_2 capture. These advancements are moving concepts toward application, producing concepts and technologies that reduce the cost of CO_2 capture.

R&D challenges

Retrieving enough information on existing technologies to make appropriate selections for testing and integrating the technologies into total systems.

status

Final report is completed.

available reports/technical papers/presentations

SUBTASK 2.18 – ADVANCING CO_2 CAPTURE TECHNOLOGY: PARTNERSHIP FOR CO_2 CAPTURE (PCO_2C) PHASE III, Final Report, J.P. Kay, at al. March 2016.*https://www.osti.gov/scitech/servlets/purl/1320560*

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Kay, J.P.; Fiala, N.J., "Comparative Evaluation of Advanced Postcombustion CO_2 Capture Technologies," Paper presented at the 38th International Technical Conference on Clean Coal & Fuel Systems, Clearwater, FL, June 2–6, 2013.

Pavlish, B.M.; Kay, J.P.; Laumb, J.D.; Strege, J.R.; Fiala, N.J.; Stanislowski, J.J.; Snyder, A.C., "Subtask 2.5 – Partnership for CO_2 Capture – Phases I and II", Final Report (September 1, 2010–April 30, 2013) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-08NT43291; EERC Publication 2013-EERC-08-17; Energy & Environmental Research Center: Grand Forks, ND, August 2013.

Hildebrandt, K.; Kay, J.P., "Integration of Postcombustion CO_2 Capture into Existing Coal-Fired Power Plants," Topical Report for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-08NT43291; Energy & Environmental Research Center: Grand Forks, ND, March 2012.

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