the ENERGY lab

PROJECT FACTS

Carbon Capture

Supersonic Post-combustion Inertial CO_2 Extraction System

Background

The mission of the U.S. Department of Energy Office of Fossil Energy's (DOE FE) Carbon Capture Research & Development (R&D) Program, implemented through the National Energy Technology Laboratory (NETL), is to develop innovative carbon dioxide (CO_2) emissions control technologies for fossil fuel-based power plants. The Carbon Capture R&D Program portfolio of pre- and post-combustion CO_2 emissions control technologies and related CO_2 compression is focused on advancing technological options for new and existing power plants to enable cost-effective CO_2 capture for beneficial use or storage of CO_2 and ensure that the United States will continue to have access to safe, reliable, and affordable energy from fossil fuels. The DOE FE/NETL goal is to demonstrate second-generation technologies that can capture 90 percent of the CO_2 at less than $40 per metric ton (tonne) in the 2020-2025 timeframe. DOE is also committed to extend R&D support to even more advanced transformational carbon capture technologies that will increase competitiveness of fossil based energy systems beyond 2035.

Post-combustion CO_2 capture technologies are applicable to conventional pulverized coal (PC)-fired power plants, where the fuel is burned with air in a boiler to produce steam that drives a turbine generator system to produce electricity. The CO_2 is exhausted in the flue gas at atmospheric pressure and a concentration of 10–15 percent by volume. Post-combustion separation and capture of CO_2 from PC-fired plants is a challenging application due to the low driving force resulting from the low pressure and dilute concentration of CO_2 in the waste stream, trace impurities in the flue gas that affect removal processes, and the parasitic energy cost associated with the capture and compression of CO_2. Carbon capture technologies developed by the DOE program may also be applied to natural gas power plants after addressing the R&D challenges associated with the relatively low concentration of CO_2 in the flue gas, typically 3-4 percent, of natural gas plants. One novel approach to CO_2 capture utilizes an aerothermodynamic technology. This technology does not use a solvent, sorbent, or membrane, but rather supersonic gas velocity to separate and capture CO_2.

Project Description

Alliant Techsystems Operations and ACENT Laboratories have teamed with the Electric Power Research Institute and The Ohio State University to further development of a unique aerothermodynamic inertial separation technology for post-combustion CO_2 capture. The inertial CO_2 extraction system (ICES) is derived from aerospace applications and converts vapor-phase CO_2 contained in flue gas to solid (dry ice) via supersonic expansion followed by inertial separation. The ICES represents a novel approach to post-combustion CO_2 capture that is completely different from competing technologies.

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PARTNERS

ACENT Laboratories
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PROJECT DURATION

Start Date	**End Date**
10/01/2013	09/30/2016

COST

Total Project Value
$3,749,591

DOE/Non-DOE Share
$2,999,951 / $749,640

PROJECT NUMBER

FE0013122

U.S. DEPARTMENT OF ENERGY

In the ICES, coal-fired flue gas is directed to a converging-diverging nozzle and expanded to supersonic velocities. The process of aerodynamic expansion to high velocity results in the conversion of potential energy contained in the form of pressure and temperature into kinetic energy. The rapid temperature and pressure decrease produced from this conversion results in condensation of undesirable constituents of flue gas including the desublimation of CO_2. The high density of the solid phase constituents of the flow allows for inertial separation by centrifugal forces induced by flow path curvature. Previous DOE-funded research has resulted in one key remaining technical challenge: the generation of CO_2 particles greater than approximately 2.5 µm (micrometers) in effective diameter to ensure efficient inertial migration. Hence, the key objective of the project is verification of CO_2 particle growth to a size that permits them to migrate to a compact layer adjacent to one wall where they can be readily removed by a boundary layer capture duct. Additionally, the exhibition of efficient diffusion of the CO_2-depleted flow to atmospheric pressure is planned. A major project outcome will be confirmation of the feasibility of the inertial CO_2 separation in a compact device without any moving parts or consumables.

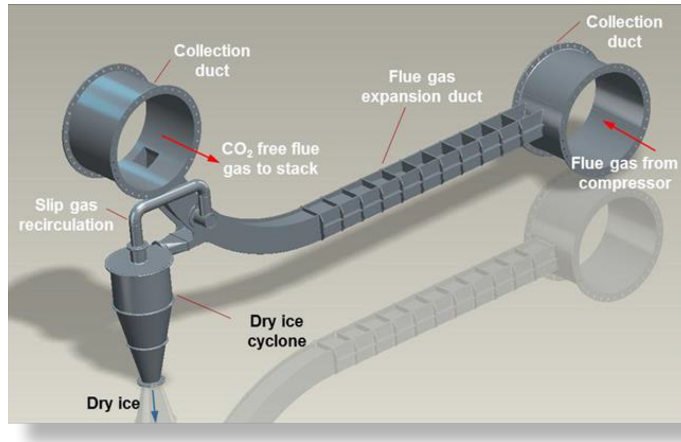
ICES does not require external media or chemical processes such as those used with solvent or sorbent technologies, and, due to high flow velocity, is characterized by a very small system volume compared to membrane systems. ICES technology has the ability to achieve steady capture conditions very rapidly after start up. Unlike conventional technologies that require thermal conditioning of the separation media, ICES only requires a few seconds of system pre-evacuation using a steam ejector to initiate supersonic flow and be ready for service. A previous preliminary techno-economic analysis with conservative assumptions predicted the cost of CO_2 captured at $41.80 per tonne, which is approaching the DOE Carbon Capture Program's 2025 goal. The ICES is characterized by a footprint approximately 25 percent the size of an equivalent amine system, is readily scalable, reduces parasitic plant load from capture and compression, and includes steps for capture, purification, and highly efficient pressurization.

Primary Project Goal

The primary project goal is to further develop the novel ICES method for post-combustion CO_2 capture by conducting bench-scale development and testing to advance the technology for potential future pilot-scale testing with coal-fired flue gas. Achieving this goal will make progress toward meeting the DOE goal to demonstrate second-generation technologies that can capture 90 percent of the CO_2 at less than $40 per tonne in the 2020–2025 timeframe.

Objectives

The specific project objectives are to increase the solid CO_2 particles to the size required to support efficient migration in the ICES turning duct, separate and capture the migrated CO_2 particles, and show diffusion of the CO_2-depleted flue gas flow to atmospheric pressure with losses consistent with projected system economics.



Configuration of an individual ICES unit

Planned Activities

- Conduct a detailed laboratory-scale investigation and analysis of the mechanisms underlying CO_2 condensation, nucleation, and particle growth.
- Develop and/or improve predictive models for supersonic condensation and particle physics using experimental data.
- Develop and test capture duct and flow diffuser systems using surrogate flue gas seeded with solid CO_2 particles of the size required for efficient migration.
- Conduct a series of bench-scale tests to investigate and validate the efficacy of several particle growth strategies.
- Conduct bench-scale testing of the complete ICES incorporating the selected particle growth method with the optimized capture duct and diffuser systems to enable the integrated testing of CO_2 condensation, migration, removal, and flow diffusion.
- Complete an updated techno-economic analysis based on the newly developed ICES configuration.
- Develop an environmental, health, and safety assessment for the ICES system as deployed at a pulverized coal-fired power plant.

Accomplishments

Project awarded in September 2013.

Benefits

The novel ICES CO_2 separation technology has numerous benefits over conventional technologies. The small footprint and very low parasitic load required for deployment of the ICES system at power plant scale enables retrofit options that are not likely to be possible with competitive approaches using absorption, adsorption, and membrane technologies. The successful completion of the project will result in a very high performing and compact CO_2 system to separate flue gas from coal and other fossil fuels that will be ready for pilot-scale testing.