R & D
facts

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Office of Fossil Energy
National Energy Technology Laboratory

Sequestration

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Gas/Water Interactions Project and the NETL Water Tunnel Facility and Hydrate Laboratory

Background

The release of CO_2 into aqueous environments for the purposes of sequestration is possible in deep saline reservoirs, water-filled coal seams and in water-filled depleted oil or gas reservoirs. An unintentional release of CO_2 could also occur in the ocean or in deep lakes if the CO_2 in a geologic formation leaked into or was otherwise in contact with an overlying or adjacent body of water (e.g. the Sleipner project). Understanding the physical, chemical and spatial fate of CO_2 in such environments is necessary for predicting the success of the sequestration strategy and any potential environmental consequences associated with it.

The research on this project began in the early 1990s when the concept of direct deep ocean injection of CO_2 was a major topic of international investigation. Early work on obtaining fundamental information regarding the dissolution of CO_2 in both freshwater and seawater, and the potential impact of CO_2 hydrate on this process was performed in existing small-scale laboratory pressure vessels in the NETL Hydrate Laboratory. To overcome some limitations of the small pressure vessels, a High-Pressure Water Tunnel Facility (HWTF) was proposed in 1994. A Low-Pressure Water Tunnel Facility (LWTF) was first built to determine the geometric and flow requirements necessary for stabilization of a CO_2 drop using both a countercurrent flow of water and flow conditioning devices. The facilities are currently being used to perform research in CO_2 storage site monitoring and leak mitigation. The systems are also being used to perform research on methane hydrates as part of the National Methane Hydrates R&D Program.

NETL's HWTF. Inset shows a hydrate-covered CO_2 drop that was stabilized in one of the observation and measurement windows by a countercurrent flow of seawater.

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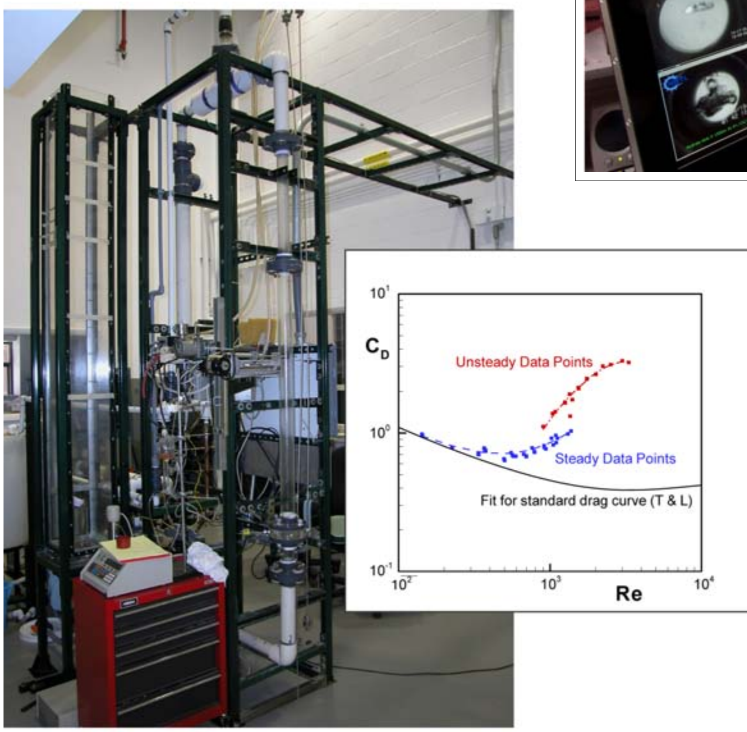
Ron Lynn, Chief Engineer for the HWTF, shown at the console that controls operation of the HWTF and performs real-time measurement of objects stabilized in it. The HWTF is seen behind a 2.5-cm thick Lexan window.



The LWTF showing the flow loop in the center (clear tubing connected to a white PVC loop) and the static fluid tank to the left. Inset shows a drag curve determined for drops of castor oil, a liquid CO_2 surrogate, which exhibits a bifurcation in hydrodynamic behavior.

The laboratory scale, high-pressure equipment in the Hydrate Laboratory and the LWTF have been used to provide important information on the formation and dissolution of CO_2 hydrate from dissolved CO_2, as well as the hydrodynamic behavior of particles that are analogous to liquid CO_2. The Hydrate Laboratory contains two environmental chambers that provide operational capabilities in the temperature range of -40 ºC to 200 ºC. One chamber is equipped with an explosion resistant interior that permits safe operation of flammable gases such as methane or natural gas. The pressure vessels currently available consist of two variable-volume viewcells with pressure ratings up to 135 MPa and a small-stirred autoclave with capacities of 50 and 100 mL. Precision syringe pumps are available for accurate metering of gases and liquids used in the research. The LWTF consists of a flow loop for testing the stability of liquid and solid objects in a countercurrent flow of water or other liquids compatible with the PVC and acrylic. It also contains a 2.4-m by 0.3-m square tank for examining the behavior, rising or falling, of liquid or solid particles in a static liquid medium. The HWTF consists of a 16-L flow loop with two windowed observation sections and various pumps for circulating and delivering liquids and gases.

All of the equipment is interfaced to National Instruments hardware and software. The HWTF also has extensive video capabilities that are interfaced to not only monitor and control the experiments but to perform real-time measurements of drop or particle size and motion. Research groups from Oak Ridge National Laboratory (ORNL) and the University of Massachusetts Lowell have successfully tested experimental concepts related to CO_2 sequestration in the HWTF. NETL researchers associated with these facilities are interested in pursuing other collaborations that would use the capabilities of this equipment to advance energy-related research.

Primary Project Goal

The primary goal of the project and its related facilities is to provide scientific information useful for assessing the technical feasibility of CO_2 sequestration options where the CO_2 is released into water-filled environments either from engineered systems, leaks or natural seeps.

Objectives

The objective is to provide a major facility for use in NETL's CO_2 sequestration activities that could also be used by others in this endeavor, as well as other energy research activities. The HWTF was NETL's first major CO_2 sequestration facility and has been successfully utilized as originally planned.

Specific Accomplishments

The goal of using NETL's HWTF to obtain fundamental information on the behavior of how CO_2 drops in seawater was achieved. The experimental phase consisted of a two-year effort that determined the dissolution rates of over 500 individual CO_2 drops under simulated deep ocean conditions down to as low as 3000 m in depth. The impact of hydrate formation was also studied. The results are currently being analyzed and assembled into manuscripts that will describe the mass transfer and solubility of $CO_{2,}$ both in the absence and presence of hydrate.

Experiments have also been completed in the LWTF that examined the hydrodynamic behavior of freely rising liquid drops that are low-pressure surrogates for liquid CO_2. This information has important implications in developing drag coefficient correlations that can be used to predict the free motion of CO_2 drops in aqueous environments. The results are being assembled into a manuscript.

Eilis Rosenbaum and Yi Zhang performing experiments in the Hydrate Laboratory. The blue and white structures are the environmental chambers in which various reactors are contained for both CO_2 sequestration and methane hydrate research.

Yi Zhang preparing a small autoclave for an experiment involving CO_2 hydrates in the Hydrate Laboratory

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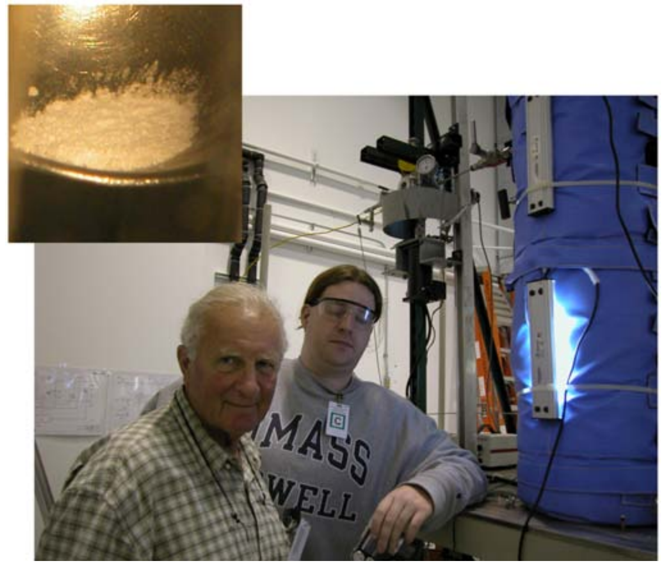
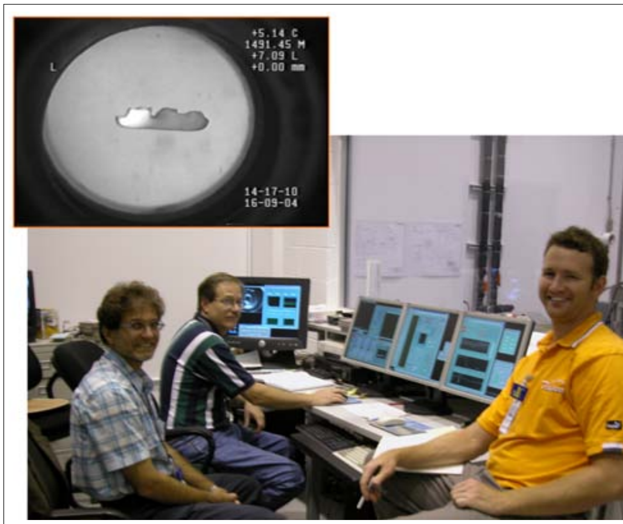
An important part of the research on this project is to understand the formation and dissolution of CO_2 hydrate in systems that contain dissolved CO_2. This factor, in addition to temperature and pressure, determines the potential formation conditions and stability of the hydrate. Precise interpretation of experimental results is made difficult by the rigorous demands for temperature uniformity and thorough mixing in the high-pressure system used for this research. After several years of work-testing various reactors and reactor configurations in the Hydrate Laboratory, a 100-ml stirred autoclave has been successfully configured and used to perform this work.



Prof. Dan Golomb and Peter Swett from UML. Inset shows calcium carbonate coated CO_2 drops in the HWTF that were formed by their process.

Benefits

This project and its associated facilities have provided important information that will be useful to researchers and modelers in the area of CO_2 sequestration. Other research has been performed in the area of methane hydrates which is not covered in this factsheet. The HWTF was not only essential in this effort, but also demonstrated NETL's capabilities as a leader in carbon sequestration science. This facility and the others mentioned above are now being assessed for research in other areas of CO_2 sequestration and energy related research. Collaborative ideas with other researchers, whether formal or informal, are welcome.



Dr. Costas Tsouris (left) and Dave Riestenberg (right) from ORNL along with Ron Lynn of NETL. Inset shows one of the hydrate/CO_2/seawater composite particles formed by the ORNL process in the observation and measurement section of the HWTF.