DEVELOPMENT OF A HIGH-PRESSURE WATER TUNNEL FACILITY FOR OCEANIC SEQUESTRATION RESEARCH

Poster Presentation

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DEVELOPMENT OF A HIGH-PRESSURE WATER TUNNEL FACILITY FOR OCEANIC SEQUESTRATION RESEARCH

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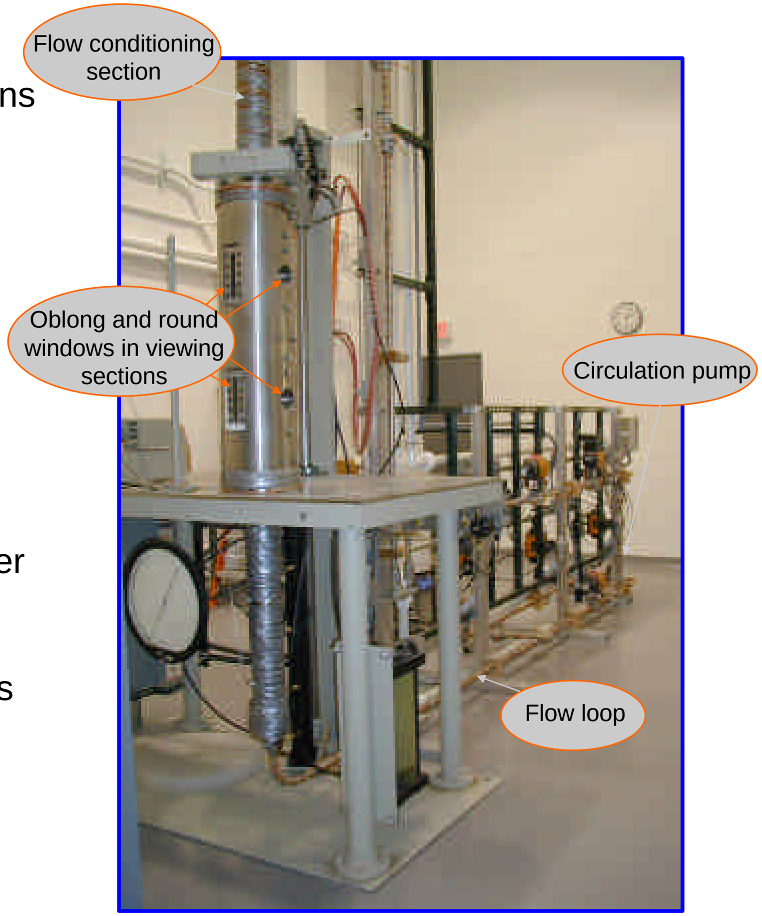
NETL has developed a unique Water Tunnel Facility (WTF) for obtaining fundamental information on the fate of CO_2 under conditions simulating its injection into the deep ocean. The WTF consists of a **High-Pressure Water Tunnel Facility** (HWTF) for performing experiments in a simulated deep-ocean environment and a **Low-Pressure Water Tunnel Facility** (LWTF) for obtaining important design and engineering parameters associated with the HWTF.

The HWTF utilizes a countercurrent flow of water or seawater and specialized flow conditioning elements to stabilize a CO_2 bubble or drop in a viewing section for extended observation periods. This poster describes the design of the HWTF and the flow conditioning elements required for droplet stabilization. Initial data obtained under simulated oceanic sequestration conditions are also presented.

The HWTF is shown at the right. The high-pressure system consists of a flow loop and two windowed viewing sections. The system can operate with either a downflow or upflow of water, permitting the stabilization within the viewing sections of rising or sinking objects, respectively.



High-Pressure Water Tunnel Facility (without insulation)

Water Tunnel Concept for Fluid Particle Stabilization

- **Hydrodynamic requirements for holding fluid objects in free suspension.**
  (B.B. Maini and P.R. Bishnoi, *Chem. Engrng. Sci.* **36**, 1981)
  - Drag on object should equal the buoyancy force.
    - **Countercurrent flow of water**
  - Axial velocity should gradually increase with height to provide vertical stability.
    - **Divergent viewing section ($x_2 > x_1$)**
  - Velocity profile across divergent viewing section should be axially symmetric with a local minimum at the center to provide lateral stability.
    - **Flow conditioning elements**
  - Flow should be free of large-scale turbulence.
    - **Flow conditioning elements**

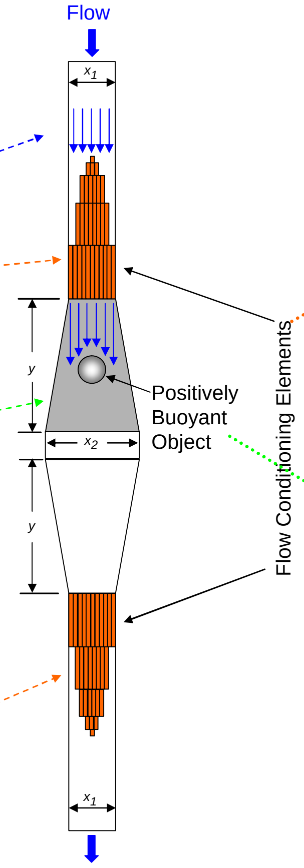
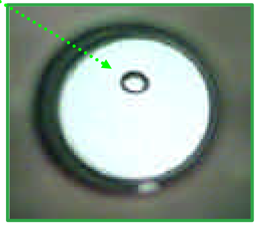


Diagram of a water tunnel design for both rising and sinking objects.

(Rising object shown with countercurrent downward flow. Sinking object would be in lower tapered section with upward flow for stabilization.)

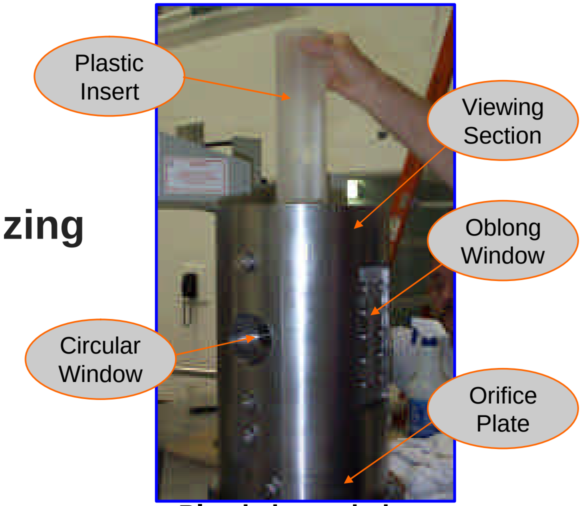
Flow Conditioners Tested in the LWTF



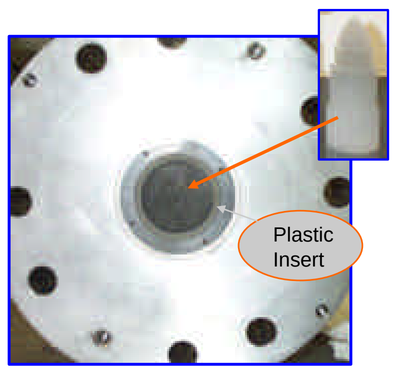
Rising CO_2 drop (2000 m depth simulation) stabilized in viewing window of HWTF.

HWTF Specifications and Components

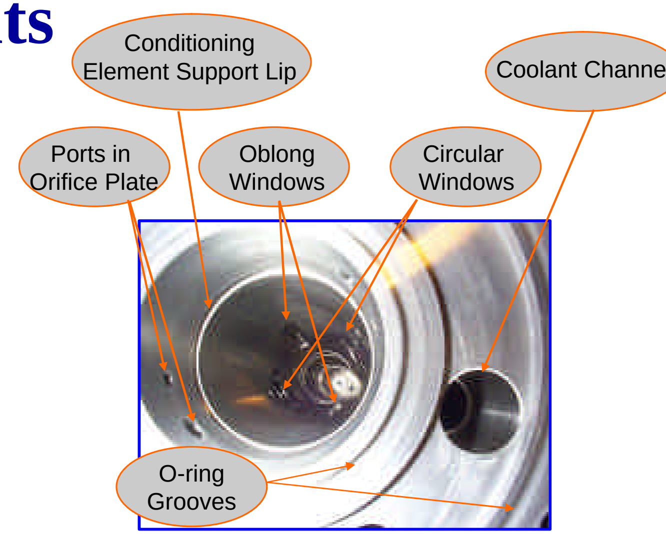
- **Simulate deep ocean environments to 3460 m.**
  - Pressure rated to 346 MPa.
  - 316 stainless steel
- **Reversible flow for stabilizing both rising and sinking objects.**
  - <~2700 m CO_2 rises.
  - >~2700 m CO_2 sinks.
- **Plastic inserts permit modification of internal configuration.**
  - Can be configured for a variety of gases and liquids.
- **Multiple observation and access ports**
  - Four circular windows
  - Four oblong windows
  - Twenty access ports on viewing sections and orifice plates



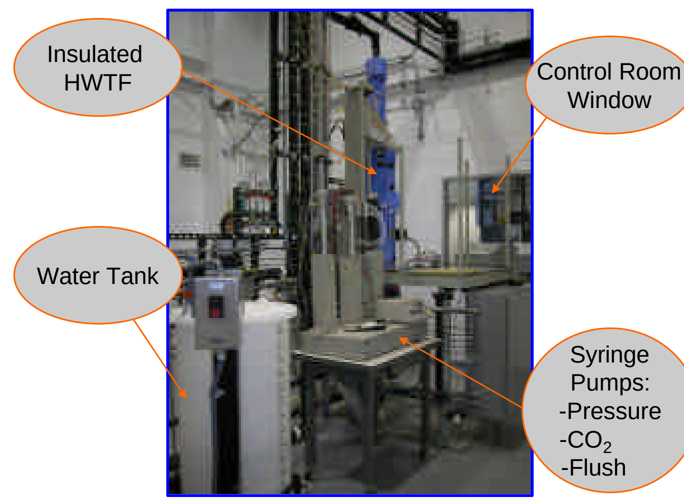
Plastic insert being placed in viewing section



Flow conditioner and plastic insert in top section



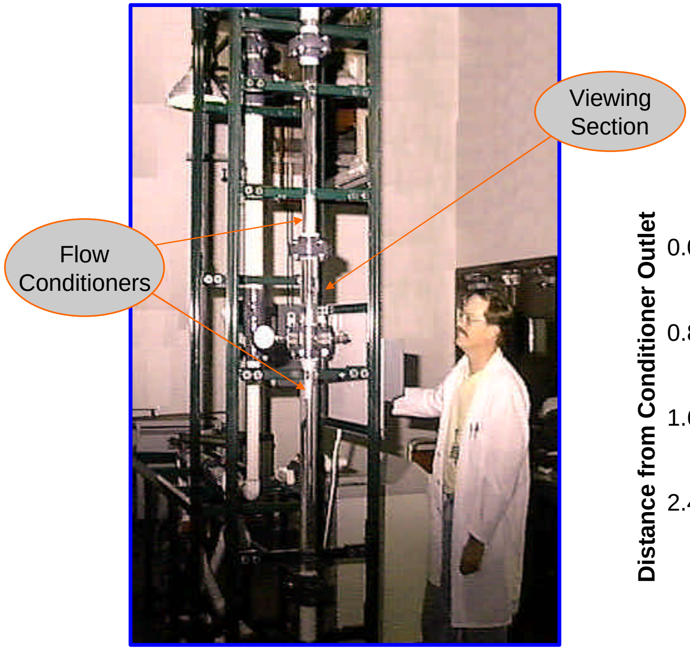
View of inner (80 mm) bore of viewing section (no insert)



Syringe pumps and water tank

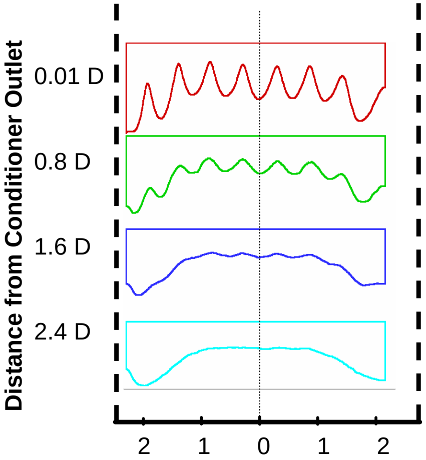
Determining Design Parameters in the LWTF

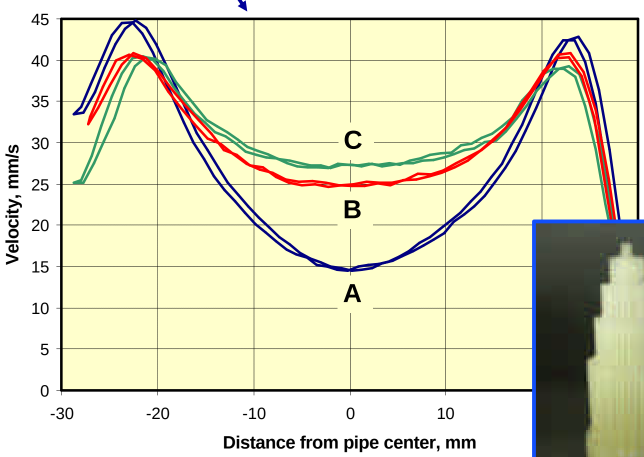
- **The LWTF, shown below, is used to examine design parameters for the viewing sections and the flow conditioning elements used in the HWTF.**
  - Based on work in the LWTF, a divergent angle of 1.65^{o} for the plastic insert in the viewing sections was chosen for the initial work in the HWTF.



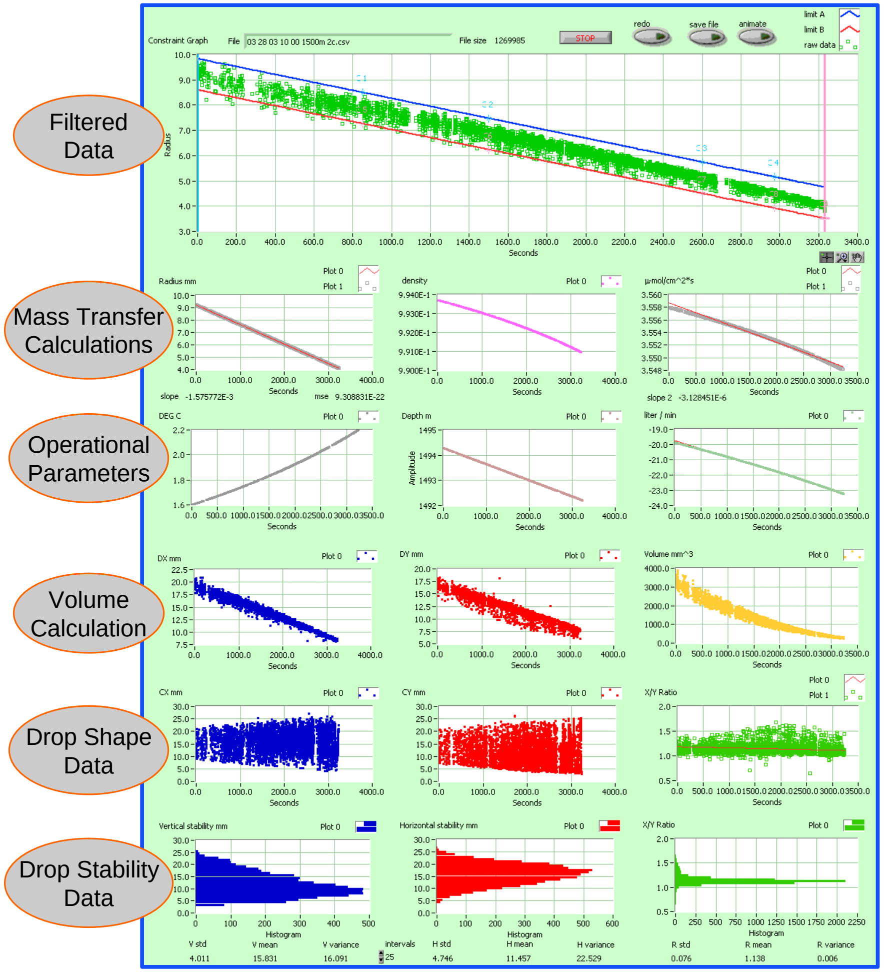
Low-Pressure Water Tunnel Facility

- **Using a specially ported viewing section in the LWTF and a computer-controlled traversing Pitot tube, velocity profiles were measured at various positions in the viewing section with a variety of flow conditioning elements.**
  - The chart at the left below shows velocity profiles for a typical flow conditioner at different positions (equivalent diameters, D) below its outlet. The influence of the jets from the individual tubes in the conditioner have smoothed out at a distance of about 2.0 D. Based on this information, the main viewing windows in the HWTF were positioned between 2.2 D and 2.8 D from the bottom of the flow conditioner.
    - The chart at the right below shows velocity profile measurements for three conditioners of the type shown in the inset. The lengths were varied from 130 mm (A) to 105 mm (B) to 90 mm (C). A flow of 5 L/min was used. It is evident that the length of the conditioner affects the depth of the velocity minimum in the pipe center. Based on this and other information from the LWTF, a conditioner similar to (A) was chosen for the initial work in the HWTF.



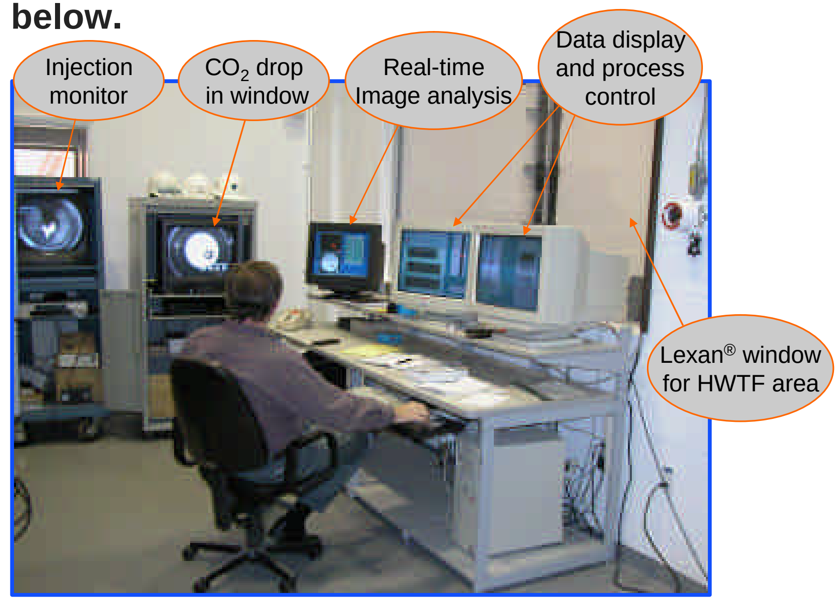


HWTF Operation and Performance



Example of data analysis and reporting for a typical experiment.

- **Machine vision programs are used to:**
  - Monitor and predict drop position.
  - Maintain drop position in window by controlling pump speed and positioning of flow control valves.
  - Real-time image analysis of drop.
- **Subsequent data processing provides detailed information on drop size, mass, dissolution, shape, and stability** (example at left)**.**
- **A view of the HWTF Control Room is shown below.**



HWTF Control Room

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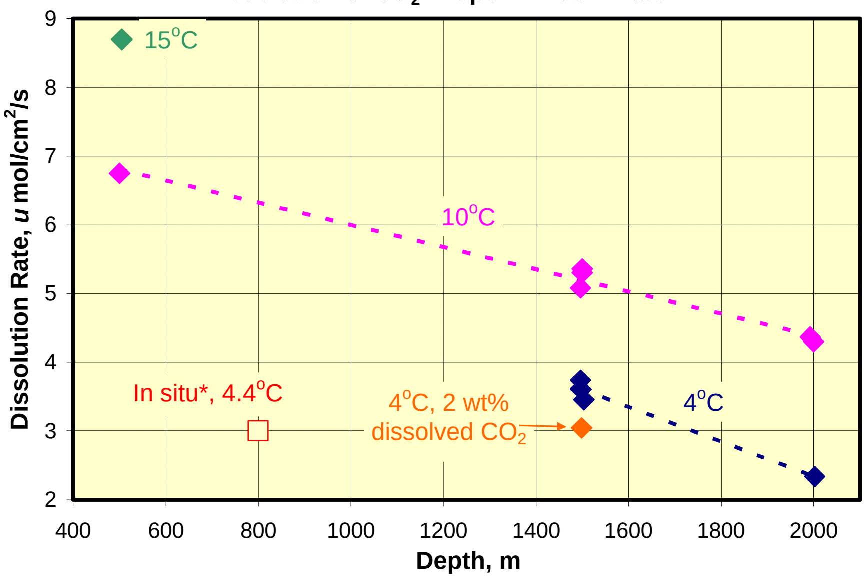
Initial Results and Future Research

- **The chart below shows data obtained to date in the HWTF.**
  - These initial experiments were performed in fresh water purified by reverse osmosis.
    - For comparison, the *in-situ* data point obtained by Brewer et al.*, is also shown.

Dissolution of CO_2 Drops in Fresh Water



*Brewer, P.G. et al., *Environ. Sci. Technol.* **2002**, 36, 5441-5446.

- **Research on the fate of CO_2 in the deep ocean in the newly commissioned HWTF is just beginning.**
  - Data will be obtained on the dissolution of CO_2 as a function of temperature, pressure (depth), amount of dissolved CO_2, and salinity.
- **Similar information will also be obtained for more realistic CO_2 samples.**
  - The impact of impurities such as N_2, O_2, SO_2 and H_2S, at levels anticipated from CO_2 capture technologies being developed for combustion and gasification processes, will be determined.
- **The HWTF is also designed to study natural gas components.**
  - Such information is needed for predicting the impacts of deep sea releases of natural gas associated with drilling operations, gas hydrate exploration and recovery, and natural vent systems.
- **The HWTF is also available as a User Facility.**
  - To explore your ideas or for additional information please contact Robert P. Warzinski at robert.warzinski@netl.doe.gov.