A Novel Approach for Obtaining Bubble Dissolution Measurements at Sea

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Abstract: A Hybrid system for measuring the dissolution of gas bubbles in an oceanic environment was developed utilizing the Coastal Systems Station's Light Scattering Bubble Counter (LSBC). The LSBC independently measures flow velocity and bubble size, and is capable of distinguishing bubbles from particulate matter. In the hybrid system, the dynamic range of the LSBC measurements is 50 microns to about 300 microns in radius. The system is filled at depth in the sea, purged of all gas, and then closed from the outside environment. A steady flow is established and clean air is forced through a ceramic fritted disk to create the initial bubble population. This bubbly mixture is re-circulated through the system at a nominal flow rate of 22 liters/min, which corresponds to a velocity of 30 cm/s through the LSBC aperture. The bubble radii are continuously measured using the LSBC, resulting in time-dependent bubble size distributions. These distributions are used to estimate bubble dissolution rates for the size range indicated.

INTRODUCTION

There has been extensive interest in the formation, size distribution, and evolution of oceanic bubbles for many years. Over a wide frequency range, air bubbles in the ocean can act as strong acoustic targets, as well as significant noise sources (1). Large plumes of bubbles formed by breaking waves or surface ships can last for tens of minutes at varying depths. These plumes can considerably affect performance of sonar systems in shallow water, or in any operation close to the sea surface. The rate of dissolution of individual bubbles (as a function of size and depth) \( \frac{dW}{dt} \) is required to accurately model bubble evolution in surface ship wakes. This paper describes the development of a system to measure bubble dissolution rates \textit{in situ} at various depths.

Previous investigations to determine dissolution rates have been laboratory based efforts using artificial or filtered seawater. Wyman et al. (2) measured dissolution rates of bubbles introduced into stirred seawater under pressure. The work showed the dissolution rate to be independent of temperature, and that the rate of dissolution did not change significantly as a function of the initial bubble radius (1.5-2.5 mm). Wyman did find, however, that the dissolution rate increases with increasing hydrostatic pressure until the external pressure reaches between 3 and 4 atmospheres. More recently, Detsch (3) found that over a radii range of 50-500 \( \mu \)m, bubble dissolution is highly dependent on the dissolved gas concentration. He also found temperature to have little effect and the rate of dissolution to be independent of initial bubble radius.

SYSTEM DESCRIPTION

The Bubble Dissolution Measurement System (BDMS), shown in Figure (1), was designed to measure bubble dissolution rates \textit{in situ} at varying depths. It consists of the Light Scattering Bubble Counter (LSBC), a peristaltic pump housed in a pressure vessel, and a rigid frame. Not shown are the compressed gas bottles, air hose, manifold, and cables to a controlling computer. The LSBC performs the required bubble sizing and counting from which the bubble dissolution rate estimates are calculated (4).

The LSBC was developed in the mid 1980s to measure bubble size distributions in the ocean. The unit is calibrated to measure bubble radii over the range of 50-300 \( \mu \)m. The LSBC uses an optical scattering technique to detect and size bubbles. It consists of a cylindrical orifice, through which a steady flow is generated. A white light source is masked to produce two sample volumes, spaced 7mm apart, in the direction of the flow. In the size range of interest, the scattering amplitude is a monotonic function that is proportional to the bubble radius. The instrument is calibrated by generating individual bubbles below the LSBC orifice and correlating the rise time (terminal...
velocity) with the peak voltage of the scattered pulse from the bubble. An independent estimate of the bubble radius can be made from the terminal velocity, using the relation developed by Stokes, with corrections by Langmuir and Blodgett (5).

![Diagram of Bubble Dissolution Measurement System](Image)

**FIGURE 1.** Bubble Dissolution Measurement System

The BDMS is lowered to a specified depth and filled through valves on the top and bottom of the system. The pump is cycled in both directions to purge all air from the system. Once this is complete, the valves are closed to the outside environment and a steady flow is produced through the LSBC orifice in the direction shown. The peristaltic pump used is capable of flow rates up to 45 LPM in either direction without affecting the bubble dynamics. With the flow steady, a distribution of bubbles is introduced into the flow by forcing air through a ceramic fritted disk. The bubble generation system consists of a compressed air tank, a 0-50 psi regulator, a 3-way pneumatically actuated ball valve, and associated hose and fittings. A pressure differential is created across the disk by slowly increasing the regulated air pressure at the face. At an over-pressure of 9 psi (above the hydrostatic pressure), air begins to flow through the disk. Once the bubble population is established, measurement of the bubble radii begins.

**RESULTS**

An experiment was performed in September 1997, in St. Andrew's Bay, Panama City, Florida. A number of runs were made with the system lowered to depths of 1, 5, 3, and 6 meters. All physical aspects of the system operated properly during the trial and bubble radii were recorded by the LSBC, showing a clear evolution of BSD that qualitatively agrees with results from previous authors. The most obvious observation was the increase in dissolution rate with depth. A numerical technique for calculating individual bubble dissolution rates from the evolving BSD is currently under development.

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**REFERENCES**


