



CARBON DIOXIDE SCRUBBING USING SEAWATER



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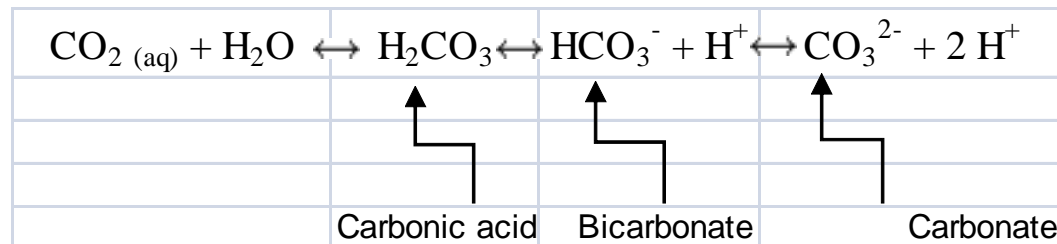
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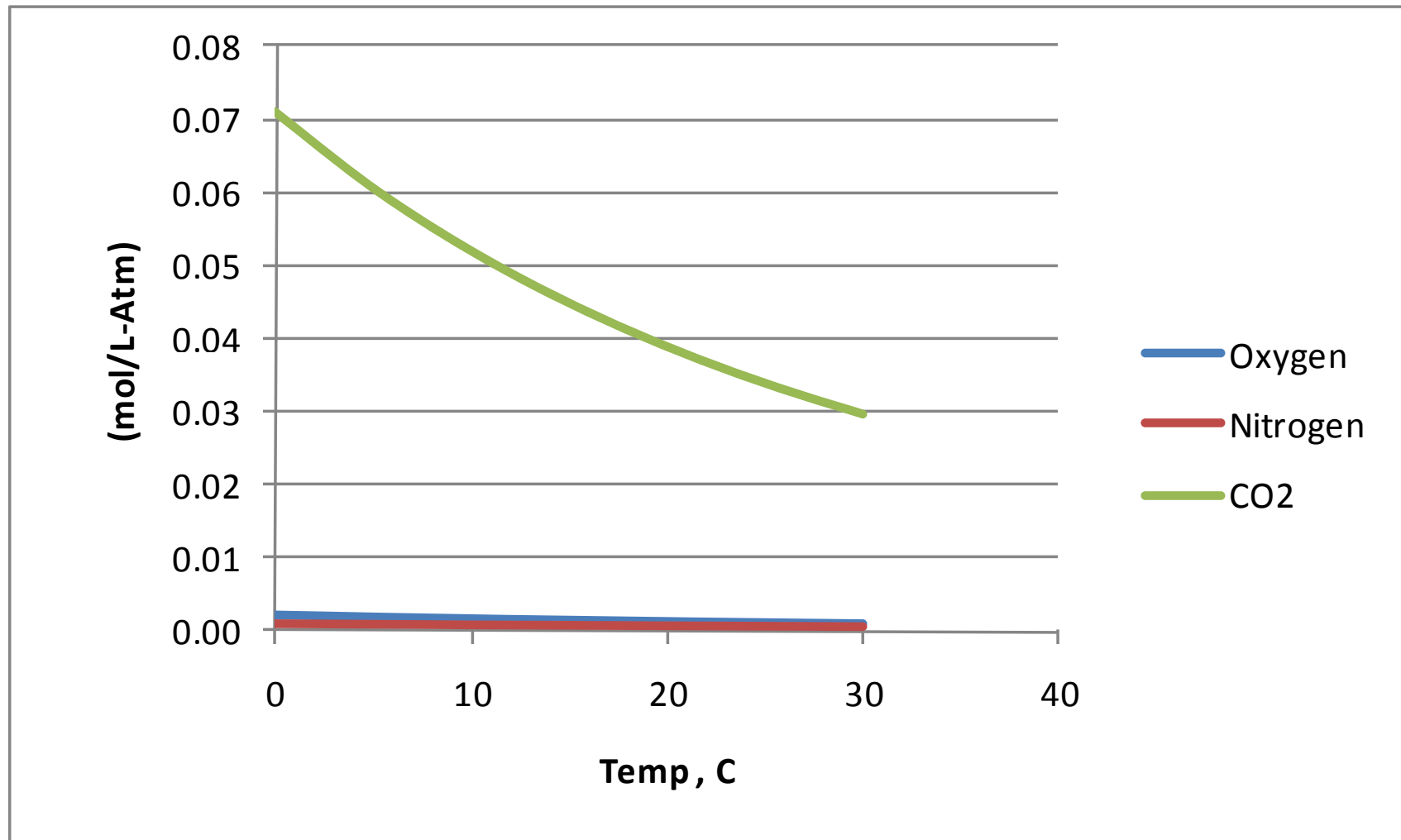
ONR ONGOING
2011 Undersea Medicine Review



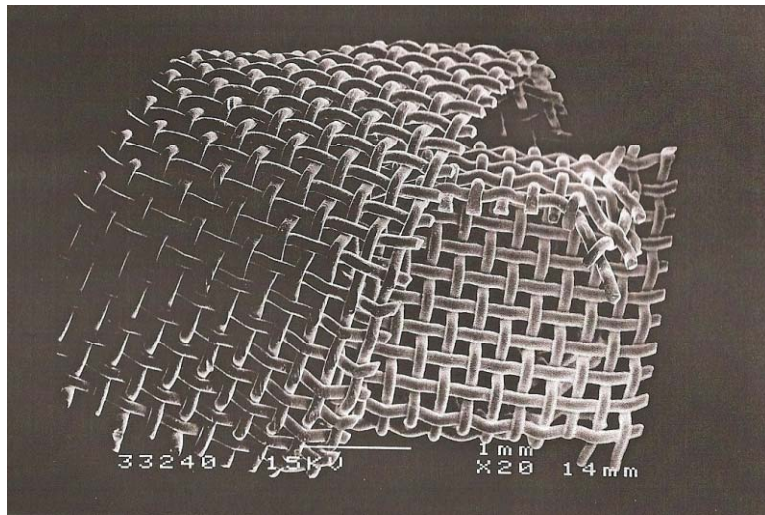
Estimated that 50% of the CO₂ produced by humans is absorbed by the oceans.



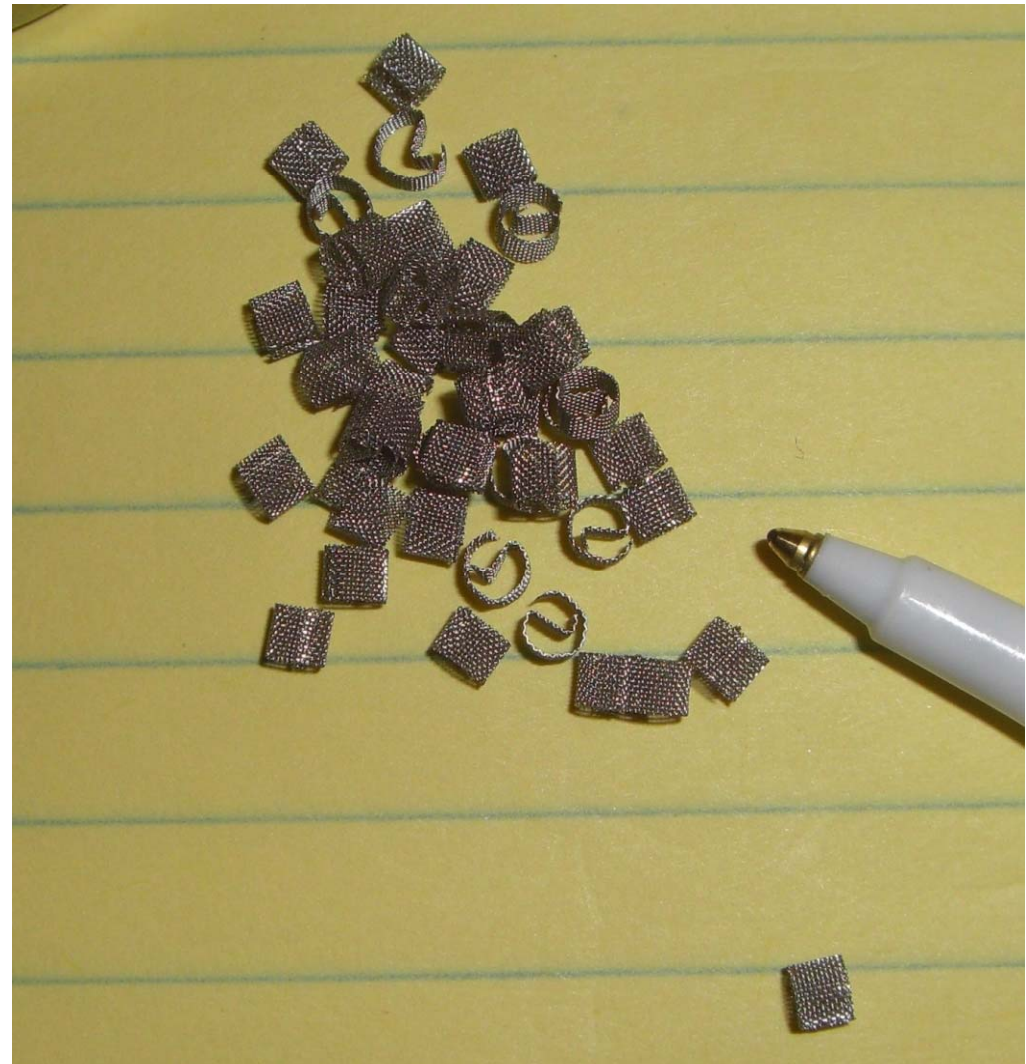
Solubility Selectivity and Temperature Dependence



CO₂ Absorption Using Seawater



Dixon Rings

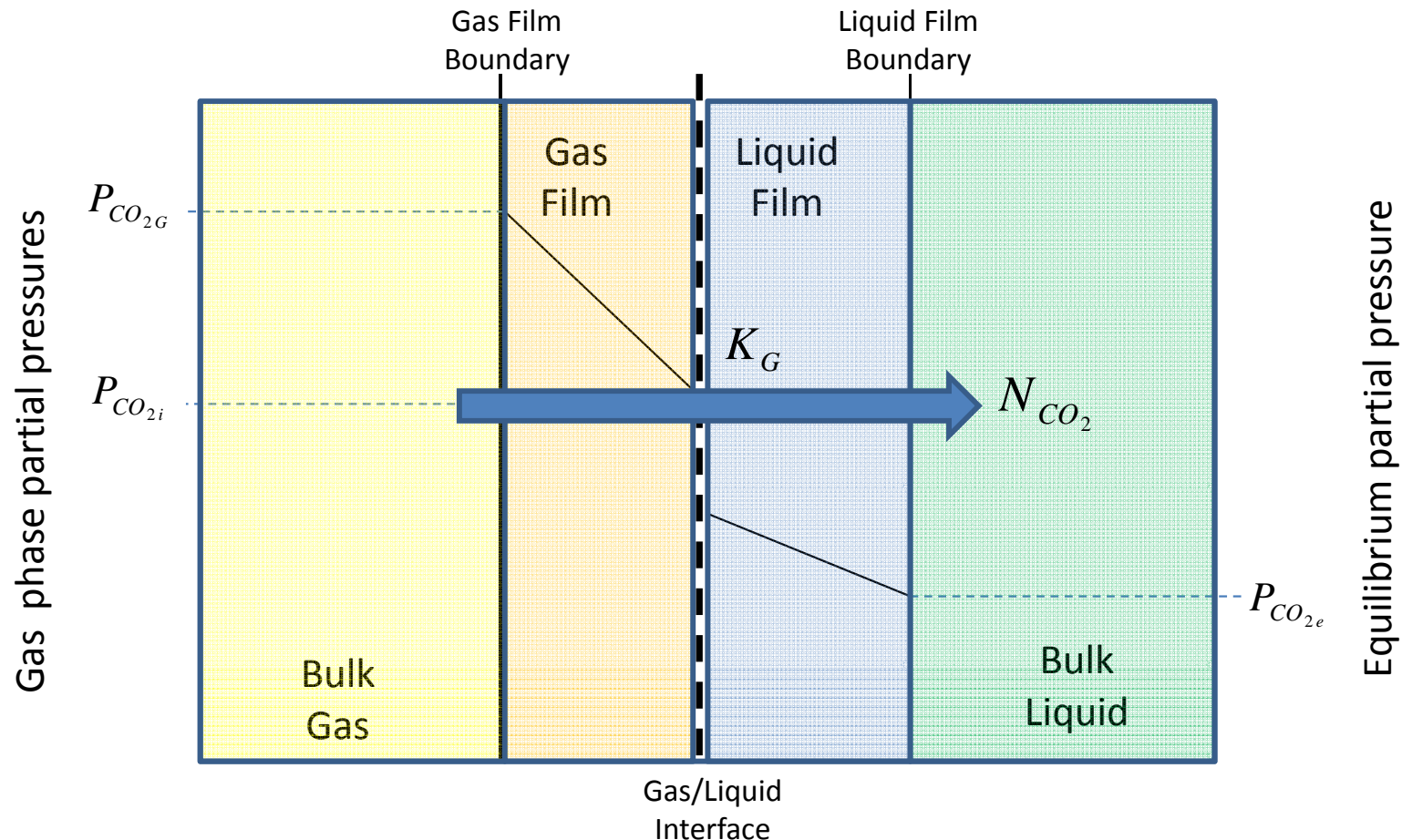




FY2011 Project Summary

- **CO₂ transport process simulations**
- **Initial laboratory absorption trials**
- **Design modifications to absorption column to vary temperature, pressure, salinity levels**
- **CO₂ transport enhancement trials**
- **A technical paper outlining initial simulations submitted to IEEE Conference -- Oceans 2011 to be held during 19-22 September 2011 in Kona, Hawaii**

CO₂ Transport Simulations



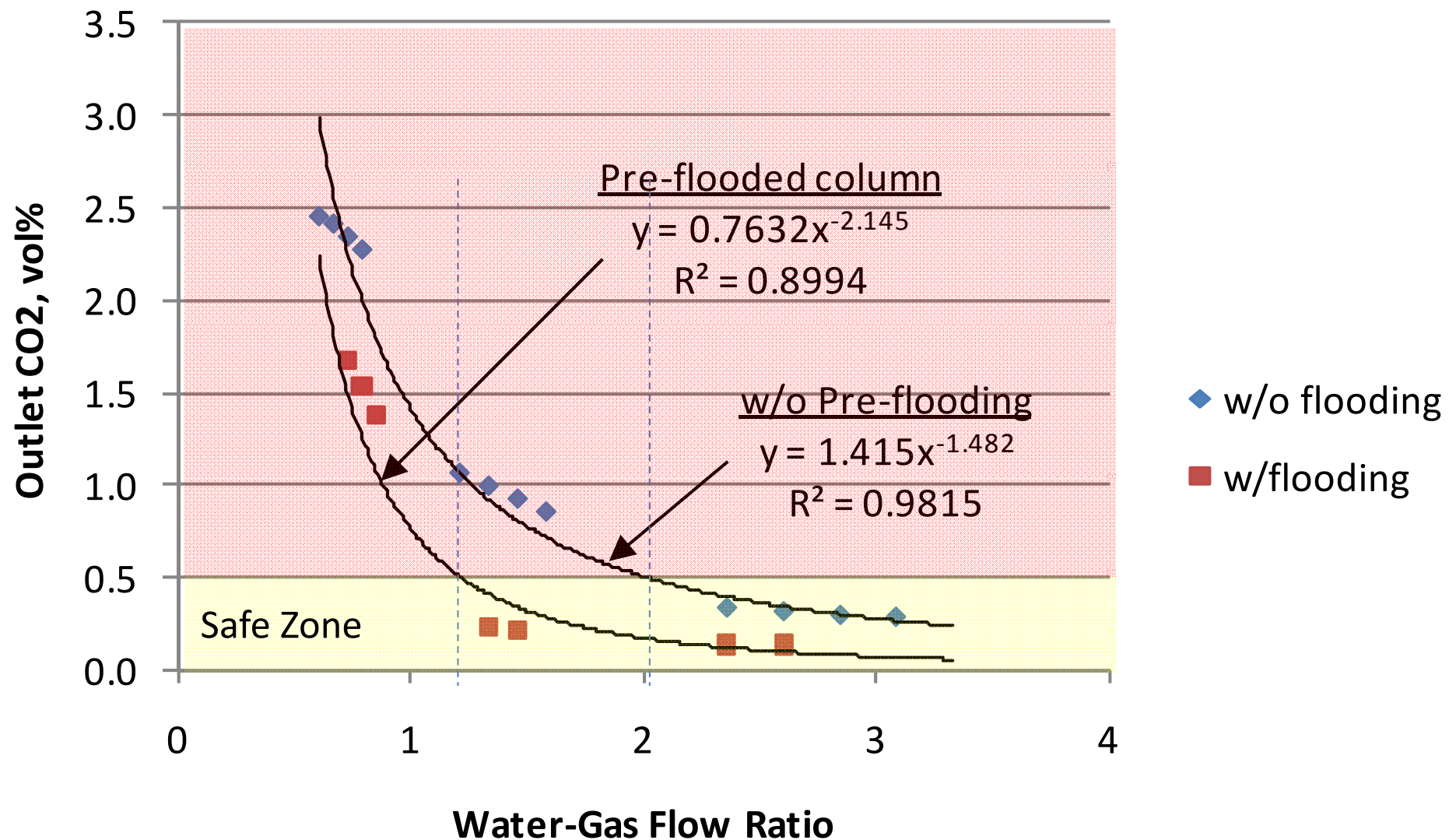
$$\frac{dy_z}{dz} = \frac{K_G a P}{G_m} \left(\left(m \frac{G_m}{L_m} - 1 \right) y_z - m \frac{G_m}{L_m} (y_2) \right)$$

$$y_{CO_2} = \frac{P_{CO_2}}{P}$$

Where $K_G a$ is the overall mass transfer coefficient (based on equilibrium concentrations)

Initial Absorption Trials

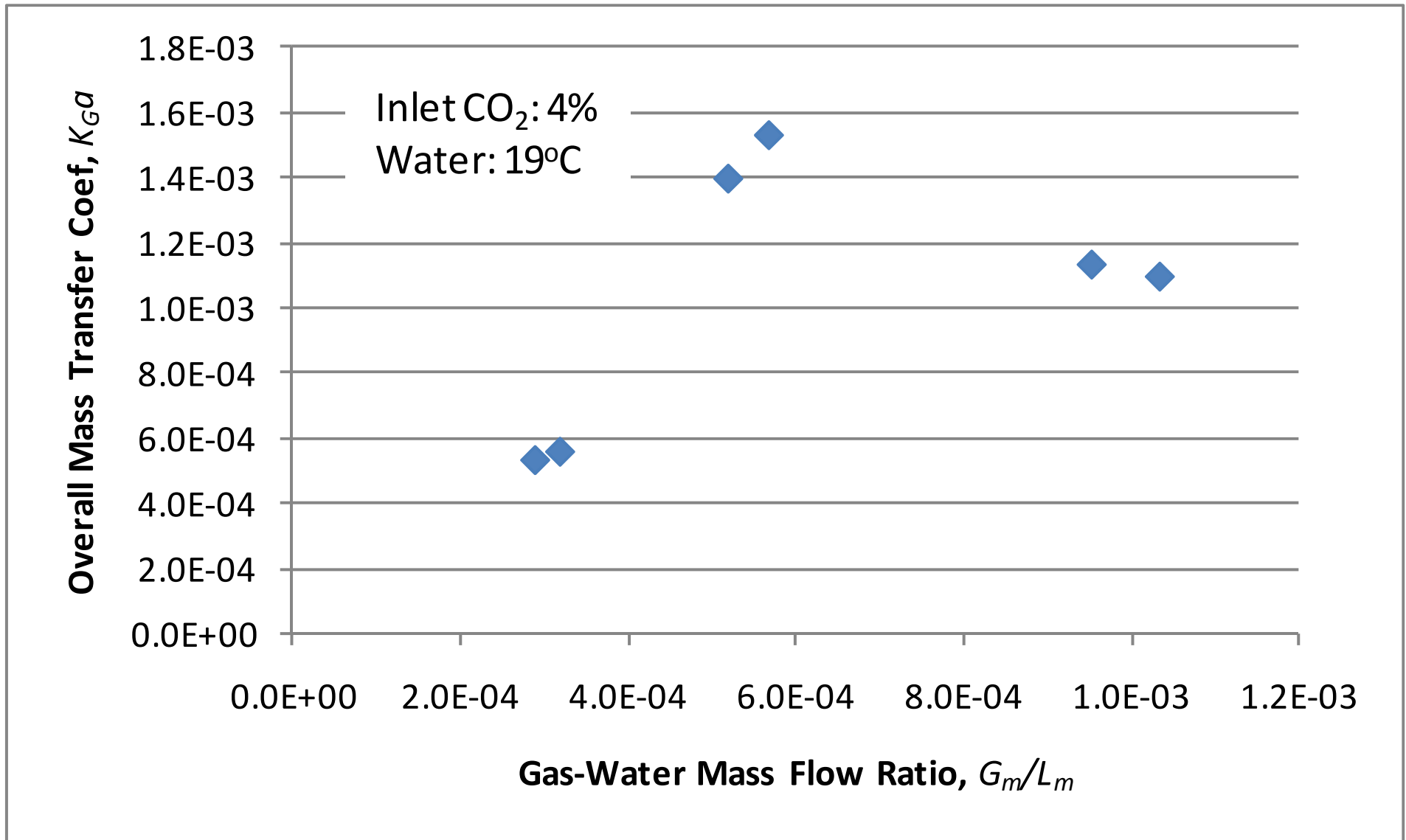
Outlet CO₂ Levels With Varying Water- Gas Flow Ratios
1 atm (absolute), Freshwater, 4.0% CO₂ Inlet; 19 °C



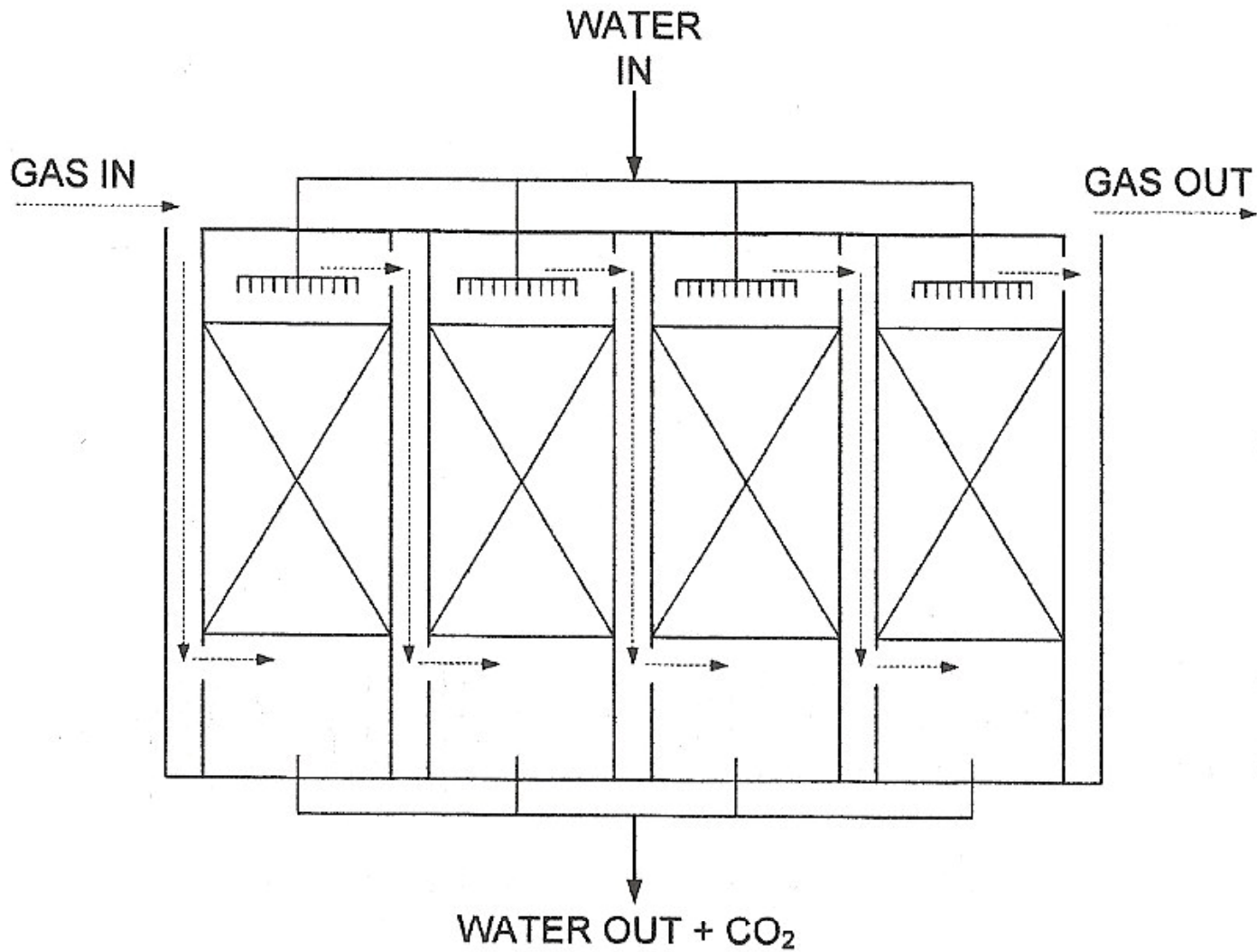


Summary of Initial Absorption Trials

1 atm (absolute), Freshwater, 4.0% CO₂ Inlet; 19 °C



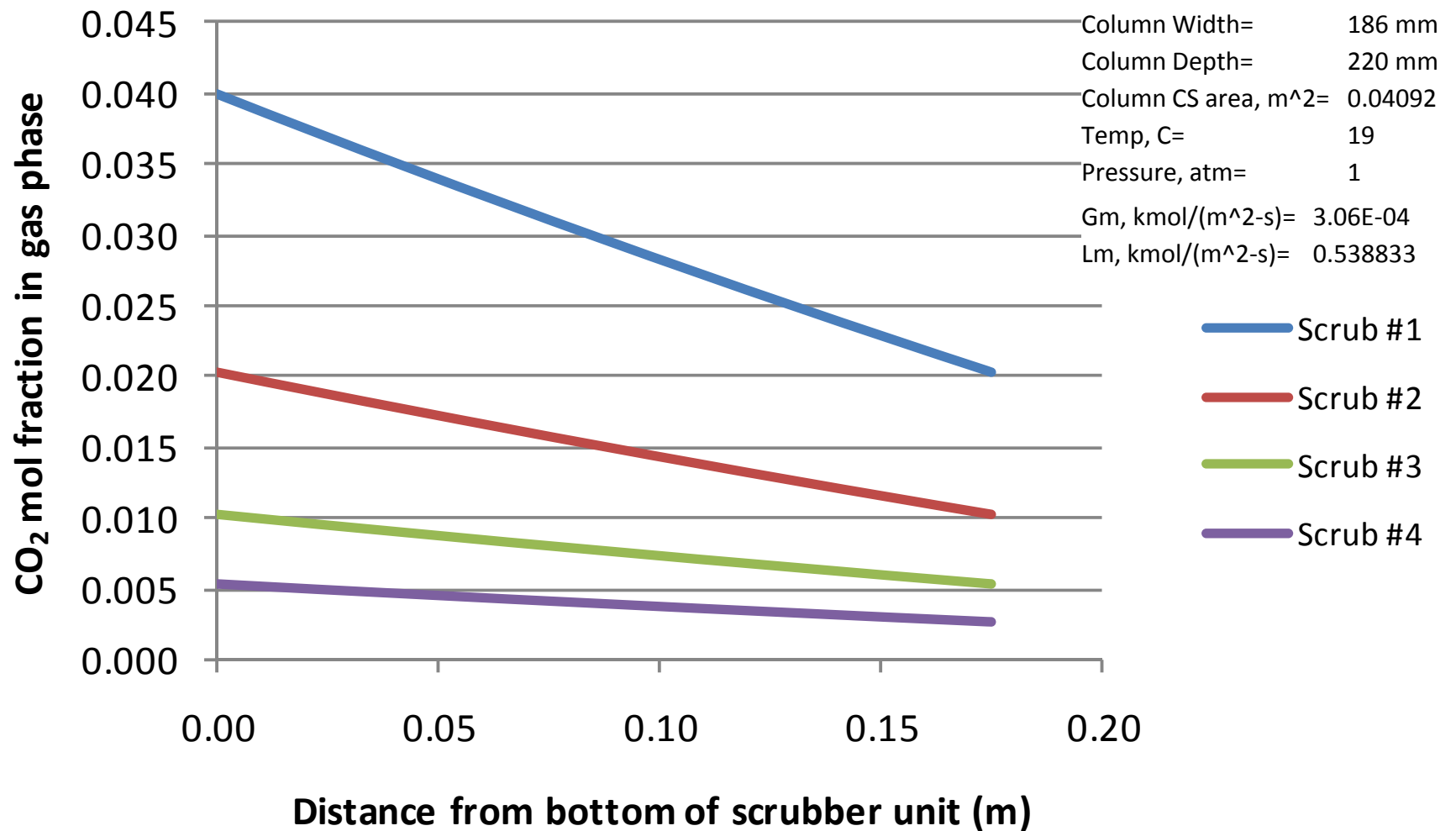
Multi-Pass Scrubber Concept





Simulation of 4-Pass Scrubber System

Using same G_m , L_m , and $K_G a$ as Test #3





CO₂ Transport Enhancement Using Carbonic Anhydrase

- Carbonic anhydrase is a naturally-occurring enzyme in our blood that accelerates absorption of CO₂ from cells for transport to lungs to be expelled
- Accelerates reaction rate about 5000-fold (reaches complete equilibrium in fraction of second compared to nearly 100 seconds in plasma without carbonic anhydrase)
- A pilot study is underway to utilize this catalyst to enhance seawater absorption of carbon dioxide
- Laboratory trials are underway to coat Dixon rings with carbonic anhydrase¹ to accelerate CO₂ absorption in seawater



¹ The carbonic anhydrase being used in this study was obtained from bovine erythrocytes (Product #C3934, Sigma-Aldrich, Inc).



What's Next

- Complete laboratory trials to characterize CO₂ absorption rates as function of
 - Temperature Sept 2011
 - Pressure
 - Salinity
 - Gas-water flow ratios
- Complete CO₂ transport enhancement trials Fall 2011
- Design and fabricate prototype scrubber Fall 2011
- Conduct laboratory testing of prototype scrubber FY 2012
- Conduct field trials with prototype scrubber Fall 2012