Progress Report Submitted to the OTIC Program, LDEO

Development of Recording CO_2-CH_4-O_2-pH-Salinity Sensor System for Field and Borehole Measurements in Aquifer Studies

by

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(Duration = 12 months, Total budget = $ 19, 898)

(December 17, 2009)

ABSTRACT

The objective of this project is to develop a multi-sensor field operation package, which will be used for time-series measurements of CO_2, methane, oxygen, pH, temperature and conductivity (salinity) for aquifer waters flowing out of a well head. This will allow us to continuously monitor chemical changes in aquifer waters that are induced by natural or anthropogenic causes. The system, which is encased in a weather-proof case, will be battery-powered and designed to record the data for a period of one month in field conditions. A small water-gas equilibrator using a hydrophobic membrane has been developed, and been coupled with a mini-CO_2 detector. The results of preliminary tests show that the equilibrator response time is less than 1 minute, and the CO_2 detector response is linear up to 2,000 ppm CO_2. Sensors for temperature and conductivity (salinity) and an electronic interface unit to the digital data logger have been purchased.

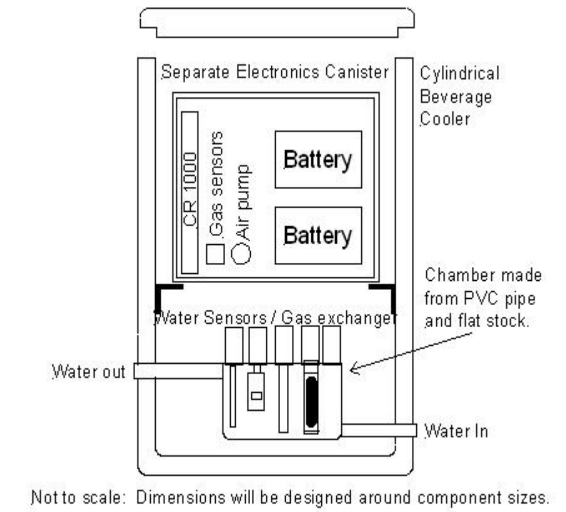
This report describes the progress made during the 4 month period since the beginning of the project in August, 2008.

1. PRESENT STATUS

1-A) System Configuration:

Our design objective is to make the system is as small as possible and housed in a single weather-proof container in order to simplify deployment in the field. Figure 1 shows a sketch of the system, which consists of three chambers, a) sensor chamber, b) sample water chamber, and c) electronics chamber which includes a data logger, gas detectors and batteries. A primary consideration is the ease of access to the sensors in case one or more of them needed replacement in the field. Other considerations include proper isolation of the batteries from the rest of the electronics which could be achieved with a bulkhead. Also if lead/acid batteries are used the battery compartment will need to be vented to the outside. The final dimensions of the system and compartments have not been determined yet, and will be dictated by the size of batteries which will be large enough to supply power to the gas circulation pump, sensors and data logger for a period at least one month with a data acquisition rate of 1 per hour for each sensor.

Figure 1 – Configuration of the system. The top chamber is for the electronics and batteries; the lower chamber is for the sensors; the sample water flows through the lower sensor chamber and around the outside of the sensor chamber for added thermal stability.



1- B) pCO_2 Measurement:

Partial pressure of CO_2 (pCO_2) in water is measured by determining the CO_2 concentration in a carrier gas equilibrated with water through a gas exchanger. A small volume gas exchanger/equilibrator has been constructed using a 10 cm long bundle of about 200 strands of micro-porous tubes (Figure 2). Carrier gas is pumped through the equilibrator and an IR CO_2 detector using a micro-circulation pump (KNF Neuberger micro-pump, 1.5" x 1.5") in the upper chamber of Figure 1. For CO_2 detection, we purchased a Senseair K30 "CO_2 engine" on the basis of its small size (2" x 2") and low power requirements, and modified it to suit our configuration. Although this is an inexpensive OEM product, our tests show that it has a linear response over a range of 100 to 2,000 ppm with satisfactory precision and stability (Figure 3). We are testing the effects of water molecule interference on the CO_2 detection.

Our preliminary tests show that response time of the equilibrator-CO_2 detector unit is less than 1 minute at a pumping rate of 30 cc/min.

Figure 2 - Water-gas equilibrator. This is made of a bundle of 200 micro tubes (white oval shaped in the plastic casing) made of hydrophobic membrane. This is immersed in water, and the carrier gas circulated in the tubes is equilibrated with gases dissolved in surrounding water through the membrane.

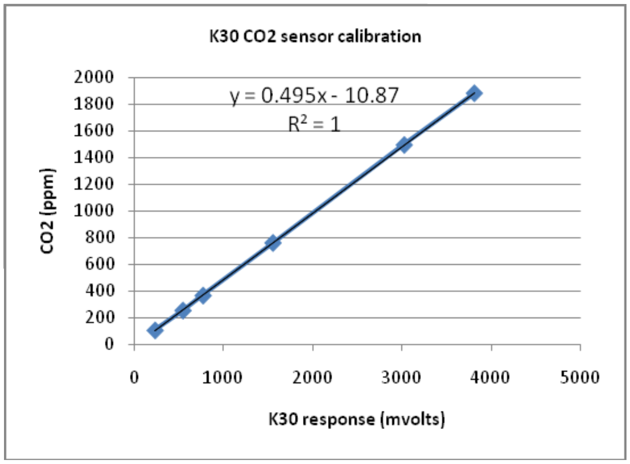


Figure 3 – Calibration of the K30 CO_2 sensor from 100 ppm to 2,000 ppm CO_2 (mole fraction), showing a linear response.

1-C) Temperature Measurement:

A submersible thermistor probe was constructed using a 10 Kohm glass coated YSI thermistor element. It has been calibrated using a NIST traceable mercury thermometer (0.01 °C accuracy) and interfaced successfully with the CR1000 data logger.

1-D) Data Logger and System Controller:

A Campbell Scientifics CR 1000 data logger (Figure 4) was chosen for our data acquisition and system control. The small size, low power and high flexibility of this device make it an ideal choice for the system control and data logging for our multiple sensor instrument package. The CR 1000 with its *Loggernet* software is an excellent instrument development tool, and we gained proficiency in programming it. While connected to a computer, real time monitoring of the data acquisition allows the user to instantly assess the efficacy of the program and to display or collect data from the attached sensors. Figure 4 shows the unit temporarily wired with various sensors for testing in the lab. The carrier gas circulation pump for pCO_2 measurements (shown in the upper left in Figure 4) is also powered directly from the CR 1000 and the speed control voltage can be regulated manually with a small potentiometer connected to the CR 1000's 5 VDC source. The data storage capacity of the unit is large enough for a duration of 1 month at a data acquisition rate of one per hour for each sensor. The data will be unloaded to a lap-top computer for analysis.

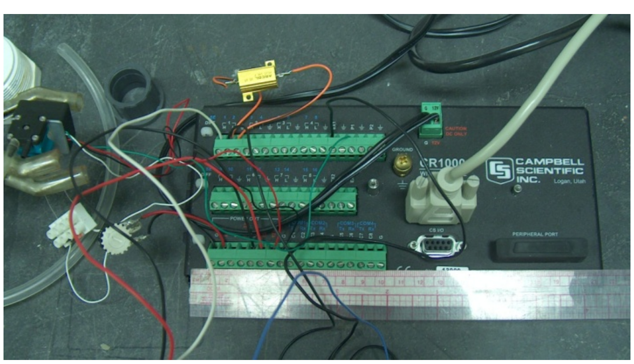


Figure 4 – CR 1000 data logger is connected to a lap-top computer and is used for system control and data logging.

2. FUTURE PLANS AND NEXT STEPS:

2-A) We plan to measure methane concentrations in water using an equilibrator-detector method similar to that developed for pCO_2 measurements. Since a water-gas equilibrator has been completed already as presented earlier, we are now looking for a methane gas detector, which is capable to detecting less than 10 ppb methane.

2-B) A major decision has to be made with regard to oxygen sensor. From the point of view of stability and sensitivity, Aanderaa Optode model 3830 (Attleboro, MA) is most desirable. However, since it costs $2,600, which is about 2.5 times the originally budgeted amount, we are withholding our decision until the other sensors are purchased. Other oxygen sensors which are based on chemical reactions are less expensive, but are inferior to the optode sensor because of the poor long-term stabilities and drifts in calibrations.

2-C) For pH sensor, we have selected Campbell Scientifics ISFET pH Sensor Model CS525-6-PT ($530.00). This can be connected directly to the Campbell Data Logger CR1000. This is being ordered.

2-D) A Sensorex conductivity transmitter (Model CT1000, $306.50, Garden Grove, CA) has been ordered. This provides an interface of an electrical conductivity (salinity) sensor (already purchased) to the Data Logger CR 1000.

2-E) According to our original plan, Tarik Hussein (ET) was to work on the electronics, and Tim Newberger was to test and calibrate the sensors and configure the system. However, Tarik left Lamont before he worked on this project, and Tim has so far steadily making progress without additional ET support. A replacement for Tarik is being sought and may be hired in a few months time. Meanwhile, Tim may be able to spend additional time to complete the project without ET help. We are closely monitoring the progress to see if further ET support is needed.

3. BENEFITS REALIZED:

Until we tested the proposed system successfully in the field conditions, we are not ready for exploring new funding. However, we plan to use the system during an aquifer water monitoring project which has been provisionally approved by EPA. One of the major questions being addressed in this project is to study possible impact of industrial CO_2 leaked into aquifer waters. Our multi-sensor recording system would put us in a highly competitive position in future research projects including near- and far-field observations for the dispersion of CO_2 within an aquifer system as well as across geologic formations. OTIC support has been critically important to accomplish these initial steps.