

## **Underway pCO<sub>2</sub> System Description**

**Laboratory:** NOAA/AOML

**Name/Vintage:** Explorer System, built by Dave Chipman in 2000

**Reference:** general operating principle described in Wanninkhof and Thoning (1992) and Feely et al. (1998)

**Where installed:** Royal Caribbean's Explorer of the Seas (cruise ship)

**Location of Data:** Current observations (raw data): [www.rsmas.miami.edu/rccl/obs/ex-rt-obs.pl](http://www.rsmas.miami.edu/rccl/obs/ex-rt-obs.pl) .  
Processed data: TBA

**Analyzer:** LI-COR 6252 (analog output) infrared (IR) analyzer

**Method of analysis:** Differential analyses relative to a reference gas, which is close to the CO<sub>2</sub> concentration of the middle standard. Measures dried equilibrator headspace gas. Gas flow is stopped prior to IR readings.

**Drying method:** Equilibrator headspace sample gas first goes through an air filter and a thermoelectric refrigerator (~6 C). The sample and standard gases pass through a Perma Pure (Nafion) dryer and a short column of magnesium perchlorate before reaching the analyzer. The counter flow in the Perma Pure tube is the reference gas.

**Equilibrator (setup, size, flows):** Equilibrator fabricated using a filter housing (ColeParmer, U-010509-00) with ~0.5 L water reservoir and ~0.8 L gaseous headspace. Water flow rate: ~1.5 L/min. Headspace recirculation rate: ~80 ml/min.

**Standards (number, concentrations, frequency):** Three standards are used with approximate concentrations of 300 ppm, 360 ppm, and 420 ppm. All three standards are run once an hour.

**Source of calibration and accuracy:** The standards come from CMDL and are traceable to WMO scale. Stated accuracy of the standards is 0.07 ppm from 330 to 420 ppm and 0.2 ppm for higher or lower standards. The reference gas comes from Air Products with a target concentration of 350 ppm. The reference gas is measured every hour. These measurements indicate that the various tanks of reference gas are within 30 ppm of the target concentration.

**Standard consumption:** Less than 1 tank a year for standards. Every 4 to 6 weeks for reference gas.

**Operating cycle:** Hourly cycle with sequence:

Three gas standards (2.0 minute flush @ 50-60 ml/min, 6 seconds of no flow, 10 IR readings within 9 seconds)

One reference gas (2.0 minute flush @ ~5 ml/min, 6 seconds of no flow, 10 IR readings within 9 seconds)

Twenty samples from equilibrator headspace (2.3 minute flush @ 80 ml/min, 6 seconds of no flow, 10 IR readings within 9 seconds)

During headspace measurements, the sample outflow of the IR analyzer is recirculated to the equilibrator. During standard measurements, the sample outflow of the IR analyzer is vented to the atmosphere. The reference outflow of the IR analyzer is always vented to the atmosphere.

**Parameters recorded/frequency :** At the end of each phase (every ~2.5 minutes), the following is recorded to disk resulting in a data file of about 3.7 Megabyte per month

PHASE: standard, reference, water

PC\_DATE

PC\_TIME

YEAR\_DAY: calculated from computer date and time

IR\_VOLTS: analyzer voltage CO<sub>2</sub> channel  
 IR\_CONC: concentration determined from 2<sup>nd</sup> order polynomial fit of preceding standards  
 EQ\_TEMP: temperature determined from an empirical polynomial function determined from laboratory calibration for thermistor in equilibrator  
 EQ\_TEMP\_OHM: resistance of thermistor in equilibrator  
 WATER\_FLOW: Flow (L/min) from the calibration applied to the voltage output of the water flow meter in front of equilibrator  
 GAS\_FLOW: Flow (ml/min) from the calibration applied to the voltage output of the water flow meter in front of equilibrator  
 IR\_TEMP: from temperature sensor in IR analyzer  
 PRESSURE: pressure in laboratory  
 SST: sea surface temperature from the ship's TSG  
 SAL: salinity from the ship's TSG  
 LATITUDE  
 LONGITUDE  
 TWIND\_SPD: true wind speed from ship's sensor  
 TWIND\_DIR: true wind direction from ship's sensor  
 RWIND\_SPD: relative wind speed from ship's sensor  
 RWIND\_DIR: relative wind direction from ship's sensor  
 FLUORO: fluorescence from ship's sensor  
 O2: oxygen from ship's sensor

#### **Hardware details**

**Temperature measurements:** Thermistor positioned in upper water in equilibrator, calibrated against a Hart thermometer

**Pressure measurements:** Setra model 270 pressure transducer (800-100 mbar)

**Operating software:** National Instruments LabView 6.1

**Computer interface boards and sensors read:**

**Boards:** NI 4351 A-D for USB, ER-8 relay board

A/D 24 bit- voltage LI-COR CO<sub>2</sub> channel (0-5 V)

A/D 24 bit- voltage LI-COR temperature (0-5 V)

A/D 24 bit- voltage Setra pressure transducer (0-5 V)

A/D 24 bit- resistance, constant current – thermistor equilibrator

A/D 24 bit- voltage McMillan water flow meter

A/D 24 bit- voltage Aalborg gas flow meter

Position, hydrographic, and wind data is received via Ethernet connection from shipboard computing system.

#### **Approximate Size and Footprint**

Box with valves and LI-COR: 21" wide by 12" deep by 28" high

Equilibrator in plastic enclosure: 22" wide by 14" deep by 33" high

Thermoelectric refrigerator: 12" wide by 11" deep by 16" high

Computer: 18" wide by 14" deep by 20" high

Interface and terminal boards: 11" wide by 14" deep by 9" high

#### **"Unique" Hardware or operating principles worth highlighting:**

- a. Thermoelectric refrigerator replacing glass condenser
- b. Water sensor in enclosure around equilibrator to detect leaks or spills

#### **What improvements would you incorporate in this system?**

Improve ease of installation. Decrease consumption of reference gas.