

Underway pCO₂ 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 .
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 CO₂ 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 CO₂ channel
 IR_CONC: concentration determined from 2nd 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: fluorosence 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 CO₂ 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.