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CO (Carbon Monoxide Mixing Ratio System) Handbook

SC Biraud

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Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
CF	Central Facility
CO	Carbon Monoxide
DQ	Data Quality
ESRL	National Earth System Research Laboratory
LBNL	Lawrence Berkeley National Laboratory
NOAA	National Oceanic & Atmospheric Administration
PC	personal computer
SGP	Southern Great Plains
STS	Site Transfer Suite
QC	Quality Control
TE48C	Thermo Electron 48C

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Carbon Monoxide (CO) Mixing Ratio System

2.0 Mentors' Contact Information

Sébastien C. Biraud, Research Associate
Climate Science Department
Earth Sciences Division
Mail Stop 50A-4037
Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 94720
Phone: (510) 486-6084
Fax: (510) 486- 7775
Email: SCBiraud@lbl.gov
Website: http://esd.lbl.gov/about/staff/sebastienbiraud

Marc L. Fischer, Staff Scientist
Atmospheric Sciences Department
Environmental Energy Technologies Division
Mail Stop 90K
Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 94720
Phone: (510) 486-5539
Fax: (510) 486-5928
Email: mlfischer@lbl.gov
Website: http://eetd.lbl.gov/env/mlf/

3.0 Vendor/Developer Contact Information

Lawrence Berkeley National Laboratory (LBNL) staff built the CO system around a 48C-TL trace level gas filter correlation CO analyzer. Thermo Electron Corporation is the vendor of the CO analyzer. For instrument repair and maintenance contact:

Thermo Electron Corporation
Service: Air Quality Instruments
27 Forge Parkway
Franklin, MA 02038
Tel: 1 (866) 282-0430
Fax: 1 (508) 520-1460

4.0 Instrument Description

The main function of the CO instrument is to provide continuous accurate measurements of carbon monoxide mixing ratio at the ARM SGP Central Facility (CF) 60-meter tower (36.607 °N, 97.489 °W, 314 meters above sea level). The essential feature of the control and data acquisition system is to record signals from a Thermo Electron 48C and periodically calibrate out zero and span drifts in the instrument using the combination of a CO scrubber and two concentrations of span gas (100 and 300 ppb CO in air). The system was deployed on May 25, 2005. Below is a list of main components used in the process of building the CO system:

Thermo Electron Gas Analyzer Model 48C:

- Zero Noise: 5.0 ppb RMS (120-second averaging time)
- Zero Drift (24 hour): less than 100 ppb
- Response Time: 60 seconds (30-second averaging time)
- Precision: 10.0 ppb
- Sample Flow Rate: 0.5 liter/min
- Operating Temperature: 20°→ 30°C (may be safely operated over the range 5°–45°C)
- Power Requirements: 90–100 VAC; 210–240 VAC, 50 Hz, 100 Watts

Tylan mass flow controller (FC-2900)

- Flow: 0.5 LPM
- Step Response Time: 1 second (dependent on step request and conditions)
- Accuracy: ± 1.0% full scale
- Linearity: ± 0.5% full scale
- Repeatability: ± 0.2% full scale
- Valve: Normally open or normally closed solenoid
- Supply Voltage: ± 12 VDC to ± 18 VDC
- Supply Current: 110 mA nominal (125 mA max @ ± 18 VDC)
- Power Consumption: 3.3 watts @ ± 15 volts
- Input/Output Signal: 0-5 VDC

MKS Pressure controller (model 640)

- Pressure: 100 PSI
- Supply Voltage: 15 VDC ± 5%
- Supply Current: 200 mA max
- Input/Output Signal: 0–5 VDC

Vaisala Dewpoint Transmitter DMT142:

- Operating Dewpoint Temperature: -50°C → +60 °C (-76°F → +140 °F)
- Accuracy: ±3 °C (± 5.4 °F)
- Withstands condensation

5.0 Measurements Taken

Carbon monoxide mixing ratio in dry air.

6.0 Links to Definitions and Relevant Information

6.1 Data Object Description

Data are presented in two levels of processing: a1 and b1. Each level of processing has a corresponding filename. For more detailed information on processing, please see the Data Quality section. In summary:

- 'a1' files: sgpcoC1.a1.YYYYMMDD.HHMMSS.asc. First level of processing where raw data are time stamped every 5 seconds. "YYYYMMDD" denotes year, month, day of the file. "HHMMSS" denotes hour, minute, and second of the file. All data are in ASCII format.
- 'b1' files: sgpcoC1.b1.YYYYMMDD.HHMMSS.cdf. Second level of processing where data are quality-checked and corrections for offset and span are applied.

The variable for CO mixing ratio is named "co". Typical daytime values are 60 ppb <co< 600 ppb. The corresponding quality control variable is qc_co (dimensionless).

6.2 Data Ordering

CO data collected are distributed through the ARM Data Archive and are updated every month.

6.3 Data Plots

Datastream 1: Quick views of the CO system data collected in the past 24 hours are available at http://co2anal.lbl.gov/worldview/co/daily/co-yest.html

Datastream 2: Quick views of the CO system data in the past week are available at http://co2anal.lbl.gov/worldview/co/weekly/co-week.html

Datastream 3: Quick views of the CO system data in the past month are available at http://co2anal.lbl.gov/worldview/co/monthly/co-month.html

Datastream 4: Quick views of the CO system data in the past year are available at http://co2anal.lbl.gov/worldview/co/yearly/co-year.html

6.4 Data Quality

Data quality is evaluated by inspecting Quality Control (qc) flags and variables in the processed datastream and is achieved in two stages.

The first stage of the data processing reads in raw data files (a0) to produce intermediate a1 files. These a1 daily files contain time stamped 5-Hz data but are not yet corrected for sensor offset and drifts. It is also worth noting that from time to time the CO system has "hiccups" (mostly related to the Windows operating system), and a0 data contains truncated lines. These lines are purged during the a0 to a1 processing.

The second stage of data processing reads a1 files to calculate CO mixing ratios and associated qc flags (see Table 1). The processing flows as follow:

- Calculate average concentrations for each channel (sampled, zero, and span air).
- Correct for offset of the instrument.
- Find calibration data and correct for drifts.
- Write output file in netCDF format.

Table 1. "warning" and "bad" quality control flag scheme.

qc Flag Associated to Variable	Units	"Warning" Condition	"Bad" Condition
CO	ppb	50 < CO < 60 600 < CO < 800	CO < 50 CO > 800
int_temp	˚C	25 < int_temp < 30 40 < int_temp < 45	int_temp < 25 int_temp > 45
chamber_temp	˚C	35.0 < chamber_temp < 42.4 47.5 < chamber_temp < 55.0	chamber_temp < 35.0 chamber_temp > 55.0
agc	Hz	$1.90e^{5}$ < agc < $1.95e^{5}$ $2.05e^{5}$ < agc < $2.1e^{5}$	agc < $1.9e^{5}$ agc > $2.1e^{5}$
pres_TE48C	Torr	790 < pres_TE48C < 800 820 < pres_TE48C < 830	pres_TE48C < 790 pres_TE48C > 830
flow_TE48C	LPM	0.40 < flow_TE48C < 0.45 0.55 < flow_TE48C < 0.60	flow_TE48C < 0.40 flow_TE48C > 0.60
pres_control	Torr	785 < pres_control < 795 805 < pres_control < 815	pres_control < 785 pres_control > 815
flow_control	LPM	0.40 < flow_control < 0.45 0.55 < flow_control < 1.00	flow_control < 0.40 flow_control > 1.00
dpt	˚C	-15 < dpt < -10	dpt > -10.0

Output files include quality control flags. Almost every variable 'x' is associated with a qc flag named 'qc_x'. The values of qc flags values and definitions are shown in Table 1 and Table 2.

Table 2. Quality Control (qc) flag values.

qc Value	Relevant Condition
0	value not suspect
1	value in a range that might point toward a problem (warning).
2	value below minimum or above maximum threshold (bad)

7.0 Technical Specification

7.1 Units

See Table 1.

7.2 Range

60 to 1000 ppb.

7.3 Accuracy

4 ppb.

7.4 Uncertainty

The CO system provides carbon monoxide mixing ratio in dry air in ppbv units. Uncertainty of the instrument is estimated to be on the order of 5 ppb.

7.5 Input Voltage

105–125 VAC, 60Hz.

7.6 Input Current

100 Watts.

7.7 Input Values

N/A

7.8 Output Values

Carbon monoxide mixing ratios
Selectable voltage
4–20mA, RS-232, RS-485

8.0 Instrument System Functional Diagram

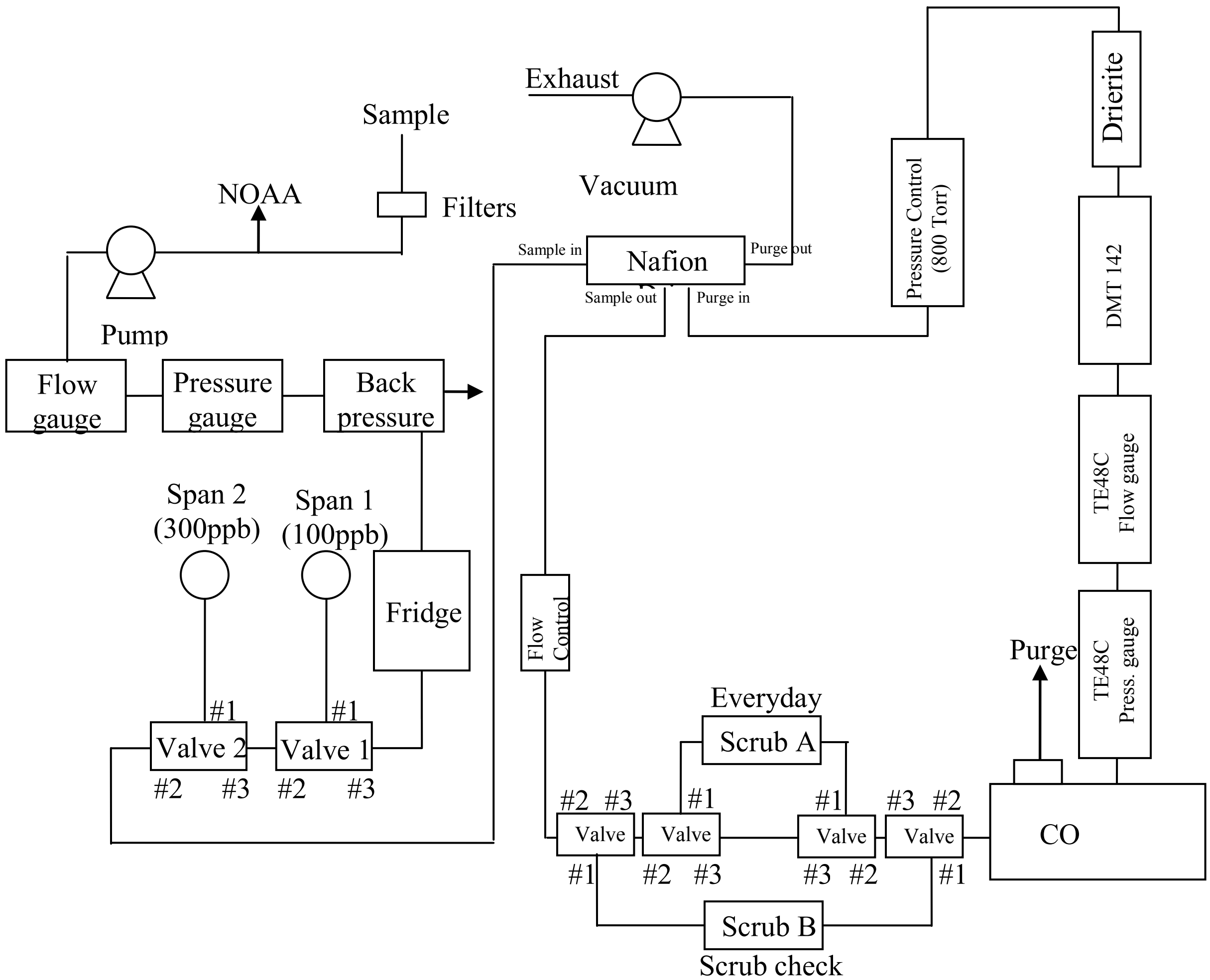

Figure 1. Plumbing diagram.

9.0 Instrument/Measurement Theory

The Model 48C is based on the principle that carbon monoxide (CO) absorbs infrared radiation at a wavelength of 4.6 microns. Because infrared absorption is a non-linear measurement technique, it is necessary for the instrument electronics to transform the basic analyzer signal into a linear output. The Model 48C uses an exact calibration curve to accurately linearize the instrument output over any range up to a concentration of 10,000 ppm.

The sample is drawn into the Model 48C through the Sample bulkhead, as shown in Figure 2. The sample flows through the optical bench. Radiation from an infrared source is chopped and then passed through a gas filter alternating between CO and N_2. The radiation then passes through a narrow bandpass interference filter and enters the optical bench where absorption by the sample gas occurs. The infrared radiation then exits the optical bench and falls on an infrared detector.

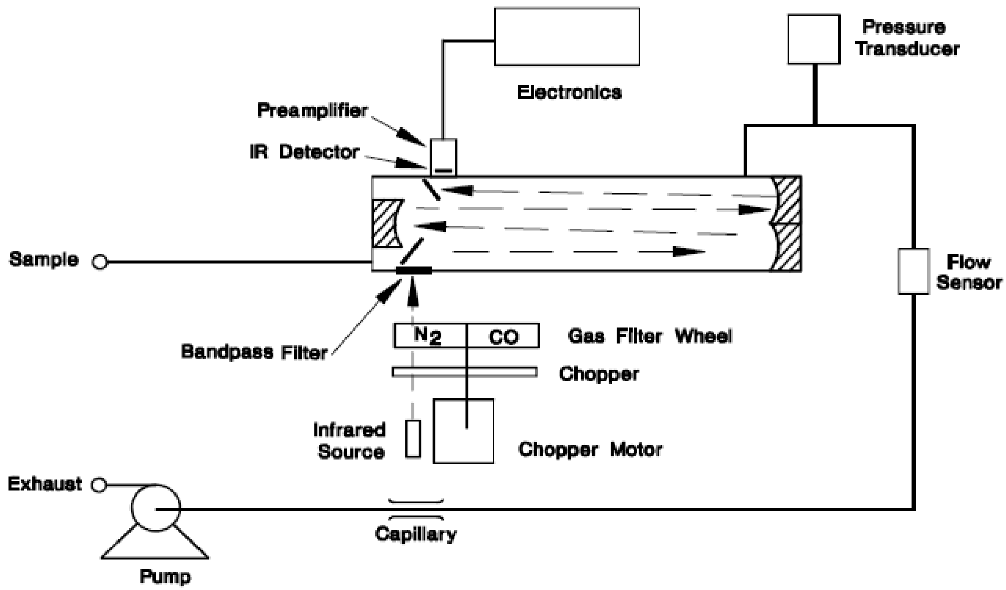

Figure 2: Model 48C flow diagram

The CO gas filter acts to produce a reference beam that cannot be further attenuated by CO in the sample cell. The N_2 side of the filter wheel is transparent to the infrared radiation and therefore produces a measure beam that can be absorbed by CO in the cell. The chopped detector signal is modulated by the alternation between the two gas filters with an amplitude related to the concentration of CO in the sample cell. Other gases do not cause modulation of the detector signal, since they absorb the reference and measure beams equally. Thus, the GFC system responds specifically to CO concentrations.

10.0 Setup and Operation of Instrument

We measure one sample for 5 minutes at a time; the reported value is the average of the last 2 minutes. Every 6 hours, we run two calibration standards certified by the National Oceanic & Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) at approximately 100 and 300ppb. Sample CO concentration is calculated with the standards run before and after it.

Data from the CO Analyzer are transmitted to a personal computer (PC) located in an instrument shed at the base of the 60-m tower. The PC collects and stores the ASCII datastream from the gas analyzer using LABVIEW software. The raw data are transferred to LBNL, processed into the ARM Data Archive format, and inspected for problems on a daily basis. Processed files are sent to the ARM Data Archive using the Site Transfer Suite (STS) on a weekly basis.

11.0 Software

- LABVIEW (data acquisition)
- IDL (data processing)

12.0 Calibration

Samples are bracketed by two secondary calibration standards. These standards have been calibrated against two primary NOAA ESRL-certified standards. Concentrations of these primary standards are shown in Table 3.

Table 3. Primary standards specifications.

Manufacturer	Type	Serial #	Mixture	Concentrations	Performed by	Date
SCOTT MARRIN	150A	CA05962	CO in air	95±1 ppb	NOAA - D. Kitzis	12/1/2003
SCOTT MARRIN	150A	CA05909	CO in air	292.5±2.9 ppb	NOAA - D. Kitzis	12/1/2003

13.0 Maintenance

ARM staff performs preventive maintenance checks weekly and post-preventive maintenance reports on the Internet. ARM carbon staff at LBNL checks these reports on a weekly basis. Instrument mentor Sébastien Biraud routinely views graphical displays produced at LBNL. The displays include graphs of CO concentrations, flow rate, pressure, automatic gain control, and dew point temperature.

14.0 Safety

15.0 Citable References

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Parrish, DD. JS Holloway, and FC Fehsenfeld. 1994. "Routine, continuous measurement of carbon monoxide with parts per billion precision." *Environmental Science and Technology* 28: 1615–1618.

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