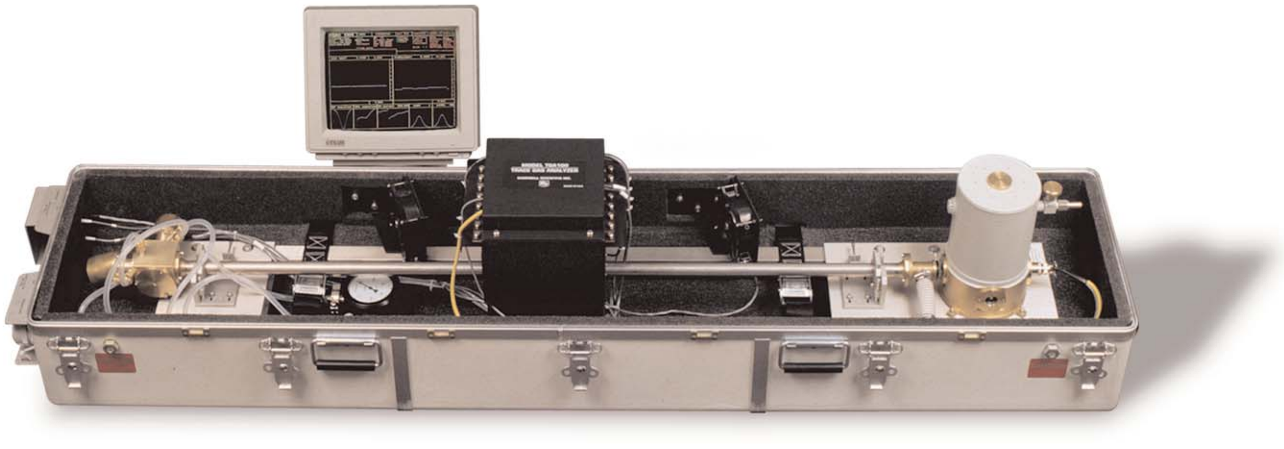
Trace Gas Analyzer*

TGA100



General Description

The Trace Gas Analyzer measures gas concentration using tunable diode laser absorption spectroscopy (TDLAS). This technique provides high sensitivity, speed, and selectivity. The TGA100 is a rugged, reliable, portable instrument designed for use in the field. Its simple design allows it to measure one of many gases by choosing appropriate lasers and detectors. In operation, a vacuum pump continuously pulls the sample gas through the analyzer, which measures the concentration of the target gas at a 10 Hz rate. The TGA computer provides the user interface that controls the analyzer, and calculates, displays, and stores real-time data. The TGA100 incorporates several features that make it ideal for measuring fluxes of trace gases using gradient or eddy covariance techniques.

Theory of Operation

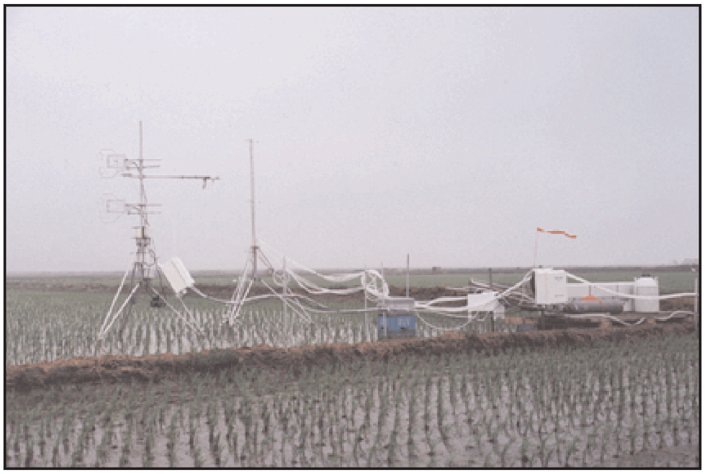
The Trace Gas Analyzer measures trace gas concentrations by scanning the output wavelength of a tunable diode laser over a single, isolated absorption line of the target gas to measure its absorption spectrum. The gas flows through the sample cell at low pressure to avoid line broadening at atmospheric pressure. This makes the technique selective, avoiding interference from other species that may have absorption lines nearby.

The tunable diode laser is simultaneously temperature and current controlled to produce a linear wavelength scan centered on a single selected absorption line of the target gas. The IR radiation from the laser is collimated and passed through a 1.5 m sample cell, where it is absorbed proportional to the concentration of the target gas. A beamsplitter directs most of the energy through a focusing lens to the sample detector, and reflects a portion of the beam through a second focusing lens and a short reference cell to the reference detector. A prepared reference gas having a known concentration of the target gas flows through the reference cell. The reference signal provides a template for the spectral shape of the absorption feature, allowing the concentration to be derived without measuring the temperature or pressure of the sample gas or the spectral positions of the scan samples. The reference signal also provides feedback for a digital control algorithm to maintain the center of the spectral scan at the center of the absorption line. The detector signals are amplified and converted in the TGA electronics, then digitally processed to calculate the concentration of the target gas in the sample cell.

The simple optical design avoids the alignment problems associated with multiple-path absorption cells. The number of reflective surfaces is minimized to reduce errors caused by Fabry-Perot interference.

*Patent Number 5,331,409

CAMPBELL SCIENTIFIC, INC.
815 W. 1800 N. • Logan, Utah 84321-1784 • (435) 753-2342 • FAX (435) 750-9540 • www.campbellsci.com



CH_4 and CO_2 profiles and EC fluxes, Sukmo-do, Korea

Measurement of Trace Gas Fluxes Using Micrometeorological Techniques

The TGA100 is ideally suited to measure fluxes of trace gases using micrometeorological techniques. In addition to a rugged design that allows it to operate reliably in the field with minimal protection from the environment, it incorporates several hardware and software features to facilitate these measurements.

The TGA100's sample rate, frequency response, sensitivity and selectivity allow trace gas fluxes to be measured using the eddy covariance (EC) method. It is designed to measure gas concentrations while synchronously collecting three-dimensional wind data from a CSAT3 Sonic Anemometer. It can also collect data from other instrumentation via a Campbell Scientific datalogger, or through its own auxiliary analog inputs.

The TGA100 also supports the measurement of trace gas fluxes by the gradient method. Based on user-supplied parameters, the TGA100 automatically controls the switching valves and computes the mean concentration at multiple sites, then displays real-time data and stores the results to a disk.

Trace Gas Species Options

The TGA100 can measure gases with absorption lines in the 1 to 11 micron range, by selecting appropriate lasers and detectors. The laser dewar has up to four positions available, allowing selection of up to four different species by rotating the dewar, installing the corresponding cable, and performing a simple optical realignment. Systems have been provided to measure nitrous oxide (N_2O), methane (CH_4), ammonia (NH_3), and carbon dioxide (CO_2) but many other species can also be measured. Multiple species can be measured simultaneously by using multiple TGA100s in a master/slave configuration with the master TGA collecting and recording data from up to four slave TGAs.

In some cases, one TGA100 can be configured to measure two gases simultaneously by alternating the spectral scan wavelength between two nearby absorption lines. This technique requires that the two absorption lines be very close together; it has been used to measure two isotopomers of carbon dioxide.

Operating Environment

The TGA's rugged enclosure and simple, robust, optical design allow it to maintain alignment and operate in the field. The optics and electronics are housed in an insulated fiberglass enclosure that shock mounts the optical bench and dampens temperature variations. If the TGA100 is operated in an open environment, the optional TGA Insulated Enclosure Cover and TGA100 Temperature Controller are recommended. The PC must be sheltered but can be located up to 150 m from the analyzer.

Laser Cooling Options

The laser must be cooled to as low as 80 K, depending on the individual laser. Two options are available to mount and cool the laser: the TGA100 LN2 Laser Dewar and the TGA100 Laser Cryocooler System.

TGA100 LN2 Laser Dewar

The TGA100 LN2 Laser Dewar holds 10.4 liters of liquid nitrogen, is mounted inside the analyzer enclosure, and includes a laser mount that can accommodate two lasers. A second laser mount can be added to accommodate an additional two lasers.

The hold time of the TGA100 LN2 Laser Dewar depends on the laser's operating temperature and the thermal conductance between the laser mount and the liquid nitrogen tank. The thermal conductance is set at the factory, depending on the laser's operating temperature, to provide at least 4 days operational hold time.

TGA100 Laser Cryocooler System

The TGA100 Laser Cryocooler System option uses a closed-cycle refrigeration system to cool the laser without liquid nitrogen. It includes a vacuum housing mounted inside the analyzer enclosure, a compressor mounted outside the enclosure, and 3.1 m (10 ft) flexible gas transfer lines (longer lines are also available). The TGA100 Laser Cryocooler System will operate continuously, with only periodic reevacuation needed to maintain the vacuum.

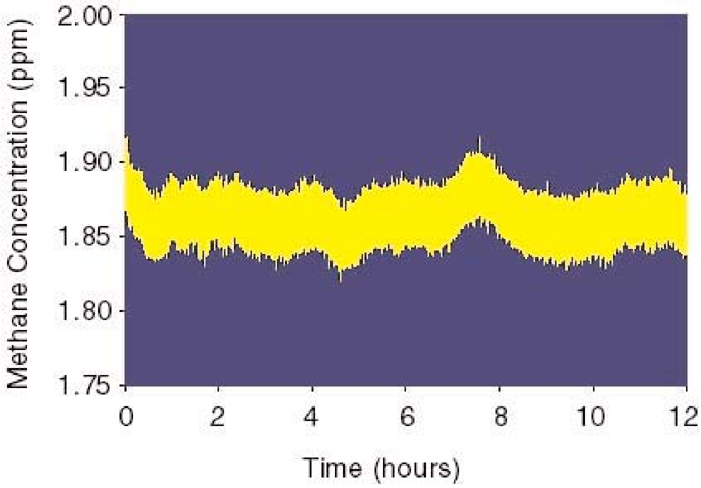
Similar to the TGA100 LN2 Laser Dewar, the TGA100 Laser Cryocooler System can accommodate one or two lasers, or up to four lasers with the optional second laser mount. The compressor must be sheltered and maintained at 10° to 35°C, and the gas transfer lines must be kept above 5°C. The TGA100 Laser Cryocooler System option adds 2.5 cm (1 in) to the length of the TGA100 enclosure.

Measurement Specifications

Sample Rate:	10 Hz	
Averaging Period:	0.1 sec	
Frequency Response (@ 4 liter/sec flow rate):	1.6 Hz	
Typical Noise (0.01 to 5 Hz bandwidth):	N_2O	1.5 ppbv
	CH_4	7 ppbv
	NH_3	2 ppbv
Typical Gradient Resolution (30 minute averaging time):	N_2O	0.03 ppbv
	CH_4	0.15 ppbv
	NH_3	0.06 ppbv

Absolute Concentration Measurements

The TGA100 has a small offset error caused by optical interference. This offset error changes slowly over time, with a standard deviation roughly equal to the short-term noise. The graph below shows a typical methane concentration time series, demonstrating this effect.



Methane concentration in a sample of compressed air. The short-term, long-term, and total standard deviations are: 6.5, 7.2, and 9.8 ppb.

Offset errors have little effect on flux measurements by either the gradient or eddy covariance technique, but may be important in other applications. For measurements of absolute trace gas concentration, the offset error can be removed by switching between a nonabsorbing gas and the sample gas, using the gradient mode of operation.

Auxiliary Inputs/Outputs

The TGA100 has both analog and digital I/Os. All data from auxiliary inputs are sampled at 10 Hz, and are synchronized with the TGA100 concentration measurements.

Three analog inputs in analyzer electronics:	±5 Vdc, 16 bits
Eight analog inputs in PC (optional):	±10 Vdc, 12 bits
Digital input from CSAT3 Sonic Anemometer:	wind speed (3 dimensions), sonic temperature, and diagnostic word

Two analog outputs have user-selectable ranges.

Sixteen digital outputs are used for switching sampling system valves.

Physical Specifications

Analyzer

Length:	211 cm (83 in)
Width:	47 cm (18.5 in)
Height:	55 cm (21.5 in)
Weight:	74.5 kg (164 lb)

Optional Cryocooler Compressor

Length:	31 cm (12 in)
Width:	45 cm (18 in)
Height:	38 cm (15 in)
Weight:	32 kg (71 lbs)

Power Requirements

Analyzer:	90-264 Vac, 47-63 Hz 50 W
PC:	115/230 Vac, 50/60 Hz 150 W
Optional Cryocooler Compressor:	100, 120, 220, or 240 Vac, 50/60 Hz 500 W

References to Example Applications

The TGA 100 has been used in the field for several years to measure trace gas fluxes. The following brief list gives a few examples of published results:

Simpson, I. J. et. al, 1995. "Tunable diode laser measurements of methane fluxes from an irrigated rice paddy field in the Philippines", J. Geoph. Res., 100, NO. D4, 7238-7290.

Wagner-Riddle, C., et. al.,1996. "Micrometeorological measurements of trace gas fluxes from agricultural fields and natural ecosystems", Infrared Physics and Technology 37, 51-58.

Simpson, I.J., et. al., 1998. "Micrometeorological measurements of methane and nitrous oxide fluxes above a boreal aspen forest", J. Geoph. Res. 102, D24: 29,331-29,341.

Simpson, I.J., et. al., "Ambient concentrations of methane and nitrous oxide at the southern boundary of the boreal forest", Atmospheric Environment, in press.

Staebler, R.M., et. al., "Measurements of the methane flux from a pond in the boreal forest by eddy covariance", submitted to Global Biogeochemical Cycles, August 1997.

Dias G.M., et. al., 1996. "Measuring ammonia flux from soil with a laser-based trace gas analyzer", Program with abstracts in conference Proceedings for the International Conference on Air Pollution from Agricultural Operations, sponsored by the American Society of Agricultural Engineers. Poster presentation, Feb. 7-9 1996, Kansas City, Missouri. Work accomplished during doctoral degree.

Brown H., et. al.,1997. "Nitrous oxide, nitric oxide, and ammonia fluxes following a fall application of swine manure.", Program with abstracts in Workshop on Greenhouse Gas Research in Agriculture, 75 pp. Sponsored by Agriculture and Agri-food Canada Research Branch. Poster presentation, March 12-14, 1997, Sainte-Foy, Quebec. Work accomplished during doctoral degree.

Grant, R. and Pattey, E. 1998. "Mathematical modeling of nitrous oxide emissions from an agricultural field during spring thaw", Global Biogeochem. Cycles.

CAMPBELL SCIENTIFIC, INC.

815 W. 1800 N. • Logan, Utah 84321-1784 • (435) 753-2342 • FAX (435) 750-9540

Offices also located in: Australia • Brazil • Canada • England • France • South Africa • Spain

Printed November 2002

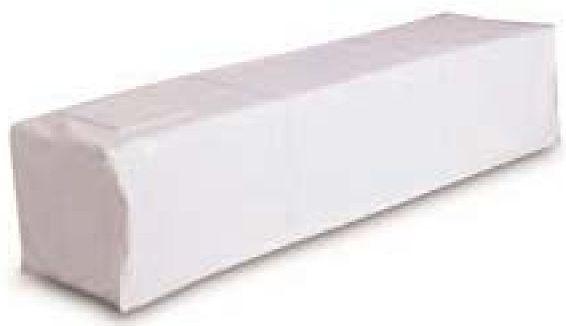
TGA100 Accessories

TGA100 Temperature Controller

The TGA100 Temperature Controller is recommended when the TGA100 is operating in the field without a shelter. It heats the TGA100 enclosure to prevent condensation and maintains a consistent temperature to reduce the errors associated with diurnal temperature changes. The TGA100 Temperature Controller has two independently controlled 60 W heaters that are factory-installed in the TGA100 enclosure. The temperature setting is 10° to 50°C.

Insulated Enclosure Cover

The TGA100 is housed in its own enclosure, and may be operated in the field without additional shelter. However, the TGA Insulated Enclosure Cover has a rain-proof, white exterior to reflect the sun's heat, and additional insulation to further dampen diurnal temperature fluctuations. It fits over the TGA100, attaching with integral hook-and-loop fasteners. It has a flap over the access hole in the top of the TGA100 enclosure for easy refilling of the LN2 laser dewar.



Vacuum Pump

Campbell Scientific offers two vacuum pumps to pull sample air through the TGA100. The RB0021 and the RB0040 are air-cooled, direct-drive, oil-sealed, rotary-vane pumps. They are supplied with oil, a suction hose (user-specified length), and all of the fittings needed to connect to the TGA100. Specifications are given for the 115 Vac, 60 Hz option, but other power options are available. The RB0021's capacity is adequate for most TGA100 applications; the RB0040 is available for applications requiring a larger capacity.

RB0021-L Specifications

Length:	44.2 cm (17.4 in)
Width:	29.2 cm (11.5 in)
Height:	26.9 cm (10.6 in)
Weight:	19 kg (42 lbs)
Capacity:	6 actual liters/sec @ 50 mbar
Power:	950 W

RB0040-L Specifications

Length:	70.1 cm (27.6 in)
Width:	35.6 cm (14.0 in)
Height:	26.7 cm (10.5 in)
Weight:	59 kg (129 lbs)
Capacity:	11 actual liters/sec @ 50 mbar
Power:	1.6 kW

Sample Gas Dryer

Accurate measurements of trace gas fluxes by eddy covariance or gradient techniques require variations in water vapor concentration be eliminated either by drying the sample gas before it is measured or correcting the trace gas flux as described by Webb, Pearman, and Leuning[1]. A sample gas dryer, the PD1000, is designed for use with the TGA100.

The PD1000 consists of a 200-tube, 48" Nafion® dryer element manufactured by Perma Pure, Inc., that is housed in a rugged dryer shell designed by CSI. The PD1000 includes a filter holder and spare filter membranes, rotameters to measure the sample and purge flow, needle valves to adjust the flow rates and pressures, and mounting hardware.

Length:	145 cm (57 in)
Weight:	9.3 kg (20.5 lbs)
Connections:	3/8" OD Swagelok

Interfaces to Other Measurement Devices

Many applications require coordinated measurements of other environmental parameters, such as wind velocity and temperature. For eddy covariance measurements, it is important to synchronize the wind and concentration measurements to avoid time jitter that would result in an error in the calculated flux. Consequently, we have designed interfaces to link the TGA100 to a CSAT3 Sonic Anemometer, CR9000 Measurement and Control System, or other TGA100s.

Sampling System

Campbell Scientific designs and manufactures sophisticated sampling systems for measuring trace gas profiles from multiple sites with a single analyzer. Simultaneous measurements of multiple gas species are possible using multiple analyzers. Operating techniques and the use of low volume manifolds minimize the equilibration time after intake switching. The system response, even for low flows, permits measurement of eight levels in one minute, eliminating the need for averaging volumes. Elimination of condensation in unheated sample lines provides an additional benefit.

[1] Webb, E.K., Pearman, G.I. and Leuning, R.: 1980, "Correction of flux measurements for density effects due to heat and water vapor transfer", Quart. J. Met. Soc. 106: 85-100.

Nafion is a registered trademark of E.I. Du Pont De Nemours and Company

CAMPBELL SCIENTIFIC, INC.
815 W. 1800 N. • Logan, Utah 84321-1784 • (435) 753-2342 • FAX (435) 750-9540
Offices also located in: Australia • Brazil • Canada • England • France • South Africa • Spain

Printed November 2002