AN016

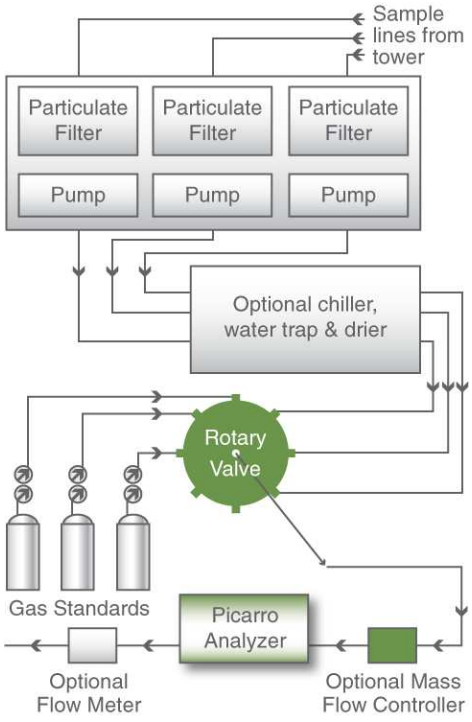
Automated Multi-Point Greenhouse Gas Measurement System

The simplicity of integrating Picarro analyzers into field measurement sites has enabled their deployment world-wide for GHG analysis

The KCRA Walnut Grove Tower (LBL/CALGEM) equipped with Picarro G1301 $CO_2/CH_4/H_2O$ analyzer with sampling at 30m, 100m and 480m heights.

Summary and Relevance

The Picarro analyzer with its automated valve sequencer can easily be incorporated into greenhouse gas monitoring stations (such as tall-tower installations) with the addition of a simple manifold system, allowing automated sampling from multiple heights and calibration verification from multiple calibration standards.

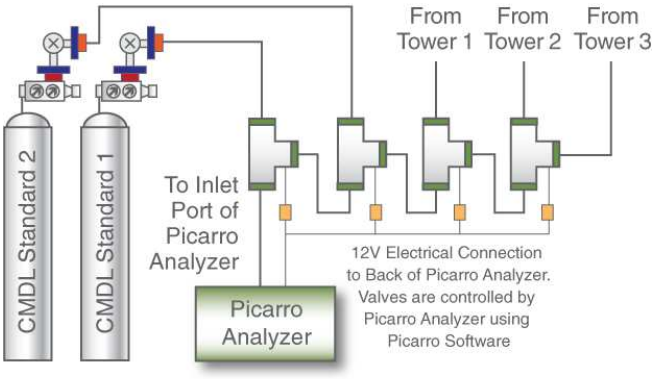


Typical setup diagram and component list for a switching manifold employing solenoid valves a tall tower sampling at three different heights and two different calibration standards.

Hardware Setup

Presented here are two examples of how a user might implement a valve manifold incorporating measurements at multiple points (i.e. heights along a tall tower) and multiple calibration gases. The number of sampling points and the number of calibration gases measured may vary (three calibration standards are recommended, though some users only use two). A setup incorporating solenoid valves is less costly than one using a rotary valve, but some users prefer a rotary valve for larger numbers of inputs as it can simplify the required plumbing (further, the analyzer only supports six solenoid valves). Some examples of components and suppliers are shown in the diagrams below. For tall tower instillations which often include tube lengths of hundreds of meters, it is often necessary to use a secondary, fast pump (>1L/min) to bring the air quickly down the long tubes to the analyzer's location. The analyzer then "sips" a small sample of this air stream

through the use of a bypass, as shown below. It should be noted that any sampling manifold, particularly if new regulators are used, may take days to weeks to fully stabilize and deliver repeatable gas concentrations. Further, gas bottles tend to deliver concentrations that may begin to change as they become empty. It is important to quantify these affects as well as temperature dependencies, particularly regarding gas bottles, when implementing the overall system.



Supplier	Description	Part #	Quality	Item
Swagelok	1/8"Male to 1/8NPT"	SS-200-1-2	12	
Swagelok	1/4"Male to 1/8"NPT	SS-4-TA-1-2	2	
Swagelok	1/8" connector	SS-200-set / SS-202-1	1 / 10	
Swagelok	1/4" connector	SS-400- set / SS-402-1	1 / 10	
Swagelok	Reducer	SS-200-R-4	2	
Swagelok	Manual Valve	SS-1GS4-A	2	
Parker	Three-way valve	091-0094-900	4	
Scott Gas	Regulator	5114B590	2	
Molex	Electrical Connector	43020-0200 / 43031-0007	4 / 4	
Molex	Electrical Connector	43025-0200 / 43030-0007	4 / 4	

Typical setup diagram and component list for a switching manifold employing solenoid valves a tall tower sampling at three different heights and two different calibration standards.

Depending on whether the user prefers to measure dry (as opposed to wet, ambient) air samples, optional equipment in the setup may include cryogenic and/or chemical (i.e. Dri-Rite) drying equipment. (Refer to Picarro application note AN018 for more information about measuring un-dried ambient air). Since the Picarro analyzer is based on precision spectroscopy that is not subject to interference from water vapor (unlike all NDIR-based analyzers such as those from Li-COR) it is not necessary to dry the air, this can greatly simply the hardware and maintenance of the overall measurement system. Other optional system components include mass flow controllers (MFC's) and flow meters to control and monitor the flow of both the air samples and the calibration gases.

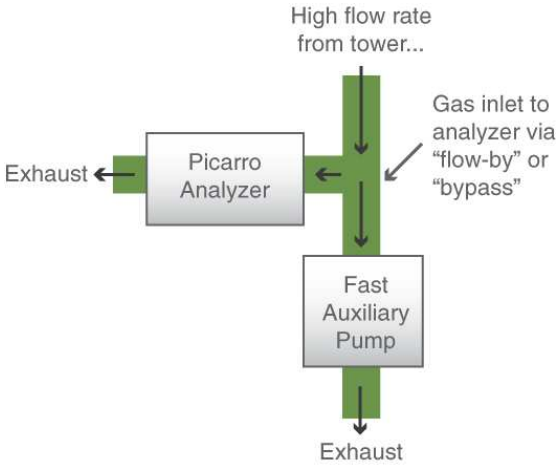
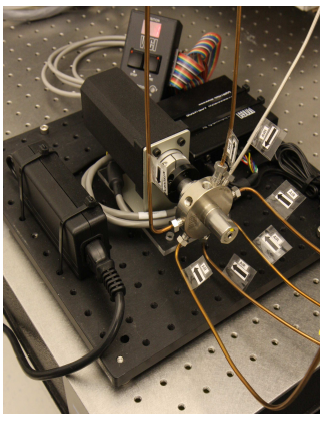


Diagram showing typical implementation of Picarro analyzer and a secondary pump to quickly draw in air from long as lines from the tower.

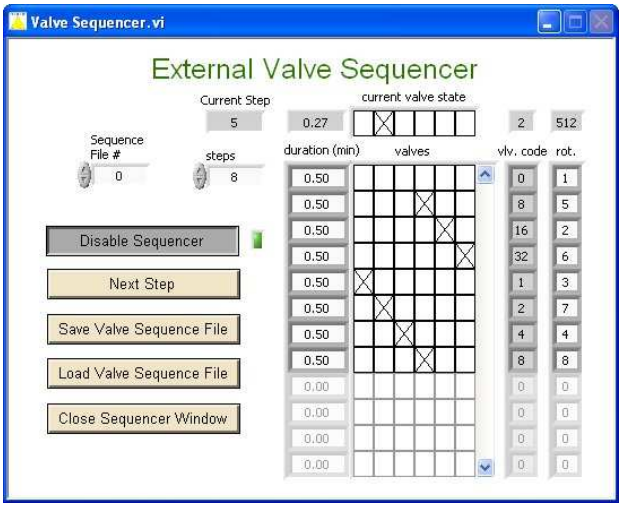
Inclusion of these components is not necessary but can aid in remote troubleshooting of the sample delivery system and aid in the delivery of a more

Photos of typical manifold using an 8-port multi-position rotary valve and a manifold using two solenoid valves.



consistent gas sample by stabilizing flow rates and pressure spikes before introduction into the analyzer. (The Picarro analyzer operates with a constant pressure inside the measurement cavity, but allows the flow rate to vary. In this way, it is able to quickly respond to and correct for sample pressure deviations.)

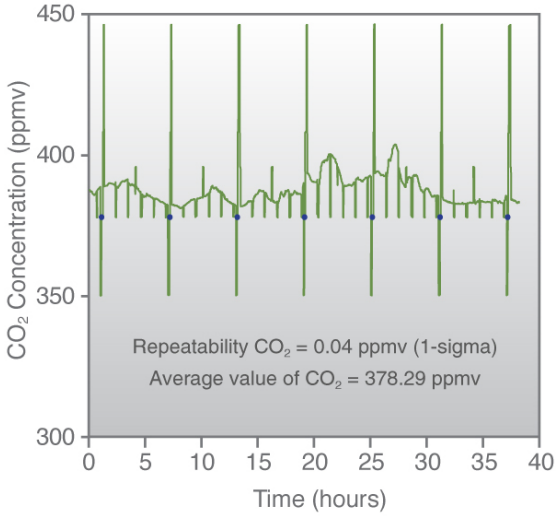
Picarro Valve Sequencer Software



Screenshot of Picarro valve sequencer software.

Included in the Picarro analyzer software is a valve sequencer module which allows the user to define, save, and recall several custom valve sequences, as well as to switch valves manually through the software. The analyzer can control up to six individual solenoid valves and one multi-position rotary valve. Several rotary valves are available, for example, from Valco (VICI) http://www.vici.com (i.e. 4, 8, 16 ports, with multiple configuration options accommodating different tubing, etc.). A specific, commonly-used valve can be obtained from Valco with all the necessary electrical and mechanical accessories to enable its immediate use with the Picarro analyzer. The solenoid valves plug directly into the analyzer (via provided cable with six 12V, 1A relay outputs). The rotary valve interfaces with the analyzer via a serial port specifically configured to interface with Valco valve actuators.

Example Data



Typical data taken at a NOAA field installation showing ambient measurements interleaved with measurements of various standards (spikes).

The data shown here is from a NOAA installation where ambient air is sampled and calibration standards are measured periodically, each for a few minutes to allow the sample delivery to stabilize and long enough for the analyzer to collect stable data which is then averaged over this period of time to provide the best measurement statistics for calibration verification. Interleaved with the calibration standard measurements are the air sample measurements – for tall tower measurements, these will be at alternating heights on the tower. The data is continuously logged by the analyzer and depending on the user's preference, may also be sent to an external datalogger and combined with other gas or meteorological measurements. Each datapoint is flagged with a value indicating which configuration of valves was actuated at that particular time, enabling the user to easily filter it for different tower heights and various calibration standards. The mean

values measured for each calibration standard are then used to create a linear correction by which to adjust the data if necessary.

Calibration Verification and Data Scaling

Although Picarro analyzers are among the most stable gas analyzers available, the accuracy required by the scientific community demands that the analyzer's calibration be periodically verified, and, if necessary, the data scaled to match the measured gas standards. Typically, the analyzers are thoroughly calibrated by the user before field deployment (often with four to six standard gases), but once in the field, the internal calibration is rarely adjusted, even over years of continuous use. Instead, typical field measurements employ three to four periodic calibration standard measurements. Each user will likely have a specific method for standardizing the data off-line after the data is recorded by the analyzer, again, not by actually adjusting the analyzer's internal calibration. Since the analyzer is almost perfectly linear in its response, it is only necessary to measure three calibration gases, spanning the range of typically-measured concentrations, in order to fully determine the requisite linear regression coefficients for scaling the data. Refer to Picarro application note AN015 for more information on analyzer calibration.

Photos of Penn State tower at Centerville, IA with sampling heights at 30m (100 ft) and 110m (360 ft) above ground level