Understanding Performance Specifications of Gas Analyzers for Eddy Covariance

Technical Note

Manufacturers of scientific instruments publish technical specifications to communicate performance characteristics of an instrument to potential customers. These specifications are often difficult to understand. Specifications for two different instruments may appear similar on paper, but in real-world applications the performance of the two instruments may differ greatly.

Figure 1. They're all phones, right? How much difference could there be?

At LI-COR Biosciences, we pride ourselves on being transparent with our product specifications. We understand that you need to know the details of how an instrument performs and we strive to provide thorough and truthful specifications about our instruments.

Let's explore some examples that illustrate this point:

Can you tell how the specification was computed?

Although the specifications for two instruments may look the same, the way they are computed may be quite different. It is important to understand these differences when comparing specifications.

Why is this important?

Peak-to-peak (the distance between high and low values) and root mean square (square root of the average of the squares; RMS) are common ways to present the precision of a measurement system. Without knowing this information, it is unclear how two systems compare to each other.

What to look for

When evaluating specifications of an instrument, pay careful attention to the way that the precision specification is presented. Is it peak-to-peak, RMS, or some other metric? LI-COR provides RMS (Table 1) for our eddy covariance analyzers.

Table 1. When comparing specifications, observe whether the metric for computing the specification is given.

LI-7500RS Specifications	
CO_2 Analysis	
Calibration range	0–3000 µmol mol^{-1}
Accuracy	Within 1% of reading
Zero drift (per °C)	±0.1 ppm typical; ±0.3 ppm max
RMS noise (typical @ 370 ppm)	@5 Hz: 0.08 ppm @10 Hz: 0.11 ppm @20 Hz: 0.16 ppm
Gain drift (% of reading per °C @ 370 ppm)	±0.02% typical ±0.1% max
Direct Sensitivity to H_2O (mol CO_2/mol H_2O)	±2.00E-05 typical ±4.00E-05 max

Are the terms "accuracy" and "precision" used properly?

The specific meanings of the words "accuracy" and "precision" may be confusing.

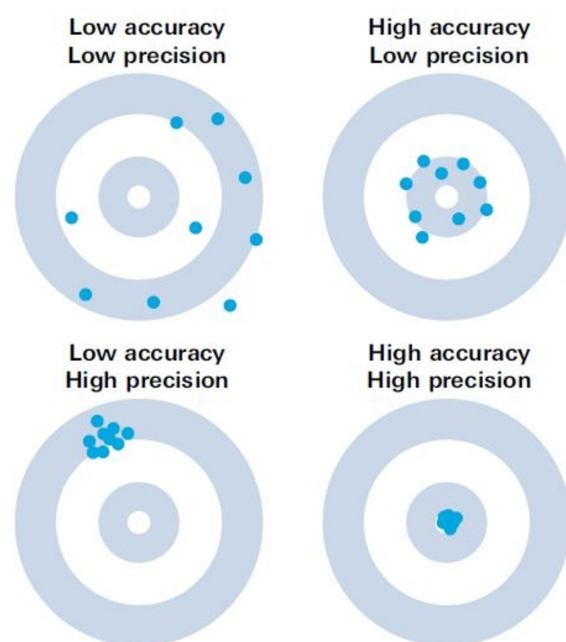

Figure 2. Accuracy and precision have specific meanings when describing the performance of scientific instruments. This figure presents a traditional way of understanding the two terms, different from newer and more complex SI definitions and some engineering definitions.

Why is this important?

Misunderstanding the terms will lead to confusion about the characteristics they describe. As shown in Figure 2, the traditional definition of accuracy describes how close the measurement is to the actual value. The traditional definition of precision refers to the repeatability of a measurement—whether you get the same value each time you try. An instrument with good precision but low accuracy can provide incorrect data. For the purpose of flux measurements, however, high precision at a fast sampling rate is much more critical than measurement accuracy.

What to look for

LI-COR gives a specification for precision (RMS noise) and a separate specification for accuracy (see Table 2). Does the other manufacturer provide both accuracy and precision specifications? Are they for the entire range of instrument performance or just for a narrow sub-range? If the documentation is translated from the original language, are these words translated correctly?

Table 2. Traditionally defined, precision and accuracy mean distinctly different things. When evaluating specifications, observe how the terms are used, whether both are given, and what range of environmental conditions they cover (temperature, humidity, wind speed, etc.).

LI-7500RS Specifications		
CO_2 Analysis		
Calibration range		0–3000 µmol mol^{-1}
Accuracy		Within 1% of reading
Zero drift (per °C)		±0.1 ppm typical; ±0.3 ppm max
RMS noise (typical @ 370 ppm)	@5 Hz:	0.08 ppm
	@10 Hz:	0.11 ppm
	@20 Hz:	0.16 ppm
Gain drift (% of reading per °C @ 370 ppm)		±0.02% typical ±0.1% max
Direct Sensitivity to H_2O (mol CO_2/mol H_2O)		±2.00E-05 typical ±4.00E-05 max

Are the units given in the SI standard?

Are the units given in the International System of Units standard (SI)? Specifications may be expressed using different units, making comparison difficult.

Why is this important?

If the units are different, the values must be converted for a valid comparison. Sometimes, conversion is difficult or impossible without additional information.

What to look for

The LI-COR specification for H_2O analyzer precision is given in SI units of mmol mol^{-1}. Specifications for other analyzers should be converted to mmol mol^{-1} for comparison.

Table 3. Units used to describe a specification should be given in the SI standard.

LI-7500RS Specifications		
H_2O Analysis		
Calibration range		0–60 mmol mol^{-1}
Accuracy		Within 2% of reading
Zero drift (per °C)		±0.03 mmol mol^{-1} typical; ±0.05 mmol mol^{-1} max
RMS noise	@5 Hz:	0.0034 mmol mol^{-1}
(typical @ 10 mmol mol^{-1} H_2O)	@10 Hz:	0.0047 mmol mol^{-1}
	@20 Hz:	0.0067 mmol mol^{-1}
Gain drift (% of reading per °C @ 20 mmol mol^{-1})		±0.15% typical ±0.30% max
Direct Sensitivity to CO_2 (mol H_2O/mol CO_2)		±.02 typical ±0.05 max

Are the conditions used to derive the specification the same for both products?

Specifications may appear the same, but may be different in real settings if they were tested under different conditions, such as the baseline CO_2 or H_2O concentration.

Why is this important?

If two specifications were derived under different conditions, there is no way to know whether the performance characteristics of two instruments are comparable without additional information.

What to look for

The specification for LI-COR CO_2 analyzer precision is given at 370 ppm. Specifications from other systems may give precision at a different concentration. These differences may affect the performance of the instrument in real-world applications.

Please note: *The units µmol mol^{-1} and parts per million (ppm) are equivalent.*

Table 4. The conditions under which the specifications were derived should be the same if two reported specifications are compared.

LI-7500RS Specifications		
CO_2 Analysis		
Calibration range		0–3000 µmol mol^{-1}
Accuracy		Within 1% of reading
Zero drift (per °C)		±0.1 ppm typical; ±0.3 ppm max
RMS noise (typical @ 370 ppm)	@5 Hz:	0.08 ppm
	@10 Hz:	0.11 ppm
	@20 Hz:	0.16 ppm

Are important specifications missing?

Flow distortion and related errors should be specified when an object is located in or near the flow path of a sonic anemometer. Instruments featuring a sonic anemometer and gas analyzer integrated into a single instrument often feature a part of the analyzer inserted near the flow path. The resulting distortion errors should then be specified for each wind direction.

Why is this important?

If an object such as an analyzer is positioned too close to the anemometer, flux calculation errors result from the distortion of natural airflow through the anemometer. Because it is difficult to correct for these errors, it is better to position the analyzer farther away. A small, easily verifiable correction can be made for the distance between the analyzer and anemometer.

What to look for

The specifications for an instrument that integrates a sonic anemometer and gas analyzer should contain information about errors related to flow distortion if the analyzer is positioned in or near the anemometer flow path.

LI-COR analyzers can be positioned at the ideal distance and position relative to the sonic anemometer, based on wind conditions at the research site. A small correction is applied for the slight separation between the analyzer and anemometer.

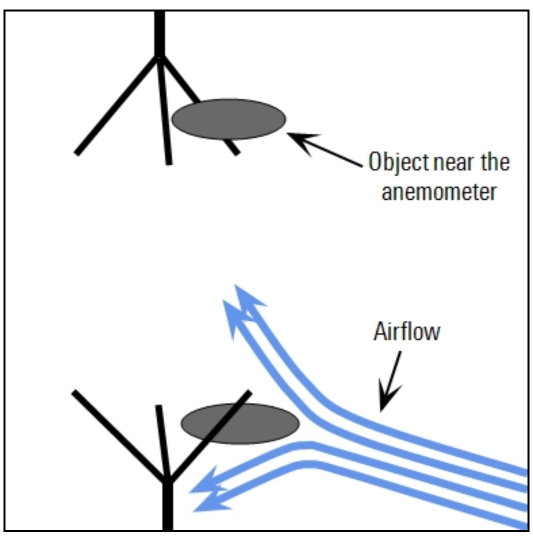

Figure 3. Airflow distortion caused by objects close to the sonic anemometer flow path can cause large errors in flux calculations.

Are data storage and on-board flux calculation capabilities given?

Eddy covariance measurements generate large amounts of raw data that need to be recorded. Raw data also need to be processed on-site (automated) or later on a computer.

Why is this important?

Most eddy covariance installations are in remote locations. Data storage, remote communication, and on-site automated flux calculations will minimize the need for site visits and reduce data loss from undetected system failures.

What to look for

Is storage available for the raw data collected over several months? Can fluxes be fully computed on-site, with all industry-standard corrections applied? Each LI-7500RS or LI-7200RS CO_2/H_2O analyzer includes a 16 GB industrial grade USB flash drive for data storage. Each analyzer also includes the SmartFlux™ System for computing fully corrected final fluxes with sophisticated, industry-standard EddyPro® Software in real time.

Do the specifications apply to a wide range of environmental conditions?

For eddy covariance use, gas analyzers must work well in a wide range of outdoor conditions.

Why is this important?

Flux results will be incomplete or inaccurate if the gas analyzer cannot perform well on a consistent basis.

What to look for

Make sure the specified operating temperature range is sufficient for your research site. LI-COR analyzers are specified for -25 to 50 °C, but can often be characterized to -40 °C on request.

Table 5. An eddy covariance analyzer should tolerate a wide temperature range.

LI-7500RS Specifications	
General	
Analysis Type	Absolute, non-dispersive infrared spectroscopy
Data Storage	16 GB removable industrial grade USB storage device included
Data Communication	Ethernet, Synchronous Devices for Measurement (SDM; >50 Hz), RS-232 (115,200 baud; 20 records per second max), 6 DACs (0-5 V; 300 Hz)
Inputs	Four analog input channels (differential; bi-polar; ±5 V; 300 Hz)
Operating Temperature Range	-25 to 50 °C (-40 °C verification test available on request)
Power Requirements	10.5 to 30 VDC
Power Consumption	12 W nominal (up to 30 W during startup)

Does a particular bad specification negate other good specifications?

In some cases, you may need to rule out a gas analyzer based on a single specification, in spite of other good specifications. For instance, some gas analyzers require a flow pump with extremely large power consumption.

Why is this important?

If a required flow pump consumes 600 watts, for instance, the gas analyzer will not be suitable for solar power supplies, even if the gas analyzer itself consumes very little power.

What to look for

Make sure your solar power system can meet total system power demand, even with a period of cloud cover. LI-COR's LI-7500RS and LI-7200RS gas analyzers can operate easily on solar power. We can provide the proper solar supply package for your eddy covariance system and your research site.

Table 6. Analyzer power consumption should be considered when solar power supplies will be used.

LI-7500RS Specifications	
General	
Power Requirements	10.5 to 30 VDC
Power Consumption	12 W nominal (up to 30 W during startup)
Detector	Thermoelectrically cooled lead selenide
Bandwidth	5, 10, or 20 Hz, user-selectable

Appendix: Summary of key advantages

A careful approach to performance and specifications distinguishes LI-COR eddy covariance gas analyzers from other analyzers. However, there are other features of the instruments that convey advantages and benefits to researchers.

The LI-7200RS Enclosed CO_2/H_2O Analyzer and LI-7500RS Open Path CO_2/H_2O Analyzer are optimized for eddy covariance installations. Advantages include:

- Log complete eddy covariance datasets and fully compute flux results in real time with the SmartFlux™ System
- Low power requirements, suitable for a solar power supply
- High stability under large ambient temperature variations with temperature-regulated optical filters and detector
- Full range of installation options for various configurations, including omni-directional sampling
- Chosen by flux networks around the world, including FluxNet, AmeriFlux, NEON, CERN, and ICOS
- Compatibility with FluxSuite™ Software, a secure web service that provides real-time results and status information from your eddy covariance sites

For more information, see: "Questions to consider when evaluating gas analyzers".

LI-COR Biosciences - Global Headquarters

4647 Superior Street
Lincoln, Nebraska 68504
Phone: +1-402-467-3576
Toll free (USA and Canada): 800-447-3576
Fax: +1-402-467-2819
envsales@licor.com • envsupport@licor.com • www.licor.com/env

Regional Offices

LI-COR GmbH, Germany
Serving Andorra, Albania, Cyprus, Estonia, Germany, Iceland, Latvia, Lithuania, Liechtenstein, Malta, Moldova, Monaco, San Marino, Ukraine, and Vatican City.
LI-COR Biosciences GmbH
Siemensstraße 25A
61352 Bad Homburg
Germany
Phone: +49 (0) 6172 17 17 771
Fax: +49 (0) 6172 17 17 799
envsales-gmbh@licor.com • envsupport-gmbh@licor.com

LI-COR Ltd., United Kingdom
Serving Denmark, Finland, Ireland, Norway, Sweden, and UK.
LI-COR Biosciences UK Ltd.
St. John's Innovation Centre
Cowley Road
Cambridge
CB4 0WS
United Kingdom
Phone: +44 (0) 1223 422102
Fax: +44 (0) 1223 422105
envsales-UK@licor.com • envsupport-UK@licor.com

LI-COR Distributor Network: www.licor.com/env/distributors

977-15932
01/2016