

GAS SENSING SOLUTIONS

Overview of innovative gas sensing instruments for several applications and markets



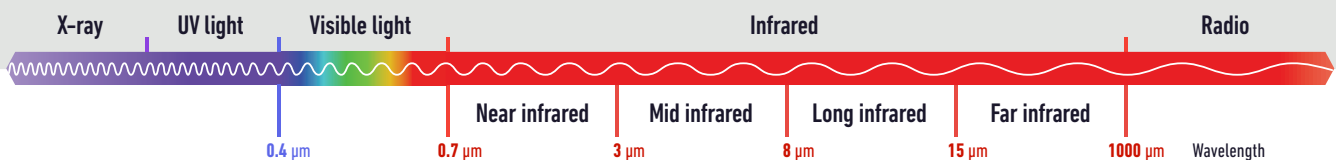
GAS SENSING TECHNOLOGIES

Advanced Energy delivers innovative gas sensing instruments for several markets, including global energy, industrial materials, and advanced technologies.

Our gas portfolio consists of gas modules and instruments that provide superior sensitivity over other gas detection techniques.

As the pioneer in trace and multi-gas analysis and monitoring solutions, Advanced Energy delivers a complete range of Photoacoustic Spectroscopy (PAS)

and Non-Dispersive Infrared (NDIR) based systems for all kinds of environments and applications. PAS and NDIR instruments are highly accurate, stable, and provide a direct measurement independent of background, and does not require carrier gases or consumables.



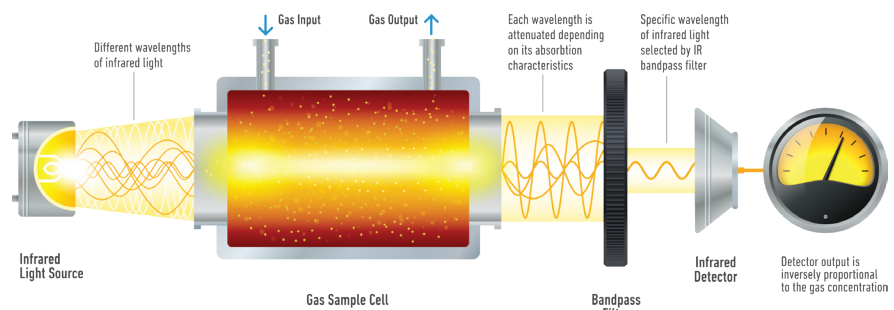
NDIR — NON-DISPERSIVE INFRARED GAS SPECTROSCOPY

Non-Dispersive Infrared (NDIR) quantifies known gases. While the technology has long existed, Advanced Energy's Andros® brand pioneered NDIR gas analysis for automotive emissions and patient monitoring. NDIR is the heart of our suite of SmartDGA products designed for Dissolved Gas Analysis (DGA) of transformers and load tap changers (LTCs). With Andros NDIR modules, the cost of gas measurement is greatly reduced because our modules can measure multiple gases and field calibration is not needed using our unique single path approach.

The main components of NDIR gas sensors are: an infrared (IR) source (lamp), a gas sample chamber or light tube, an optical bandpass filter and the infrared detector. The gas is pumped or diffuses into the sample chamber and the gas concentration is measured optically by its absorption of a specific wavelength in the IR spectrum. The IR light is directed through the sample chamber towards the detector. The detector has an optical filter in front of it that eliminates all light except the wavelength that the selected gas molecules can absorb (see diagram).

The IR signal from the source is modulated so that thermal background signals can be offset from the desired signal. In some applications, it may be necessary to compensate for the presence of non-target gases

which absorb in the same portion of the IR spectrum. Our applications engineers and scientists work closely with customers to determine what is required for a precise and accurate gas measurement.

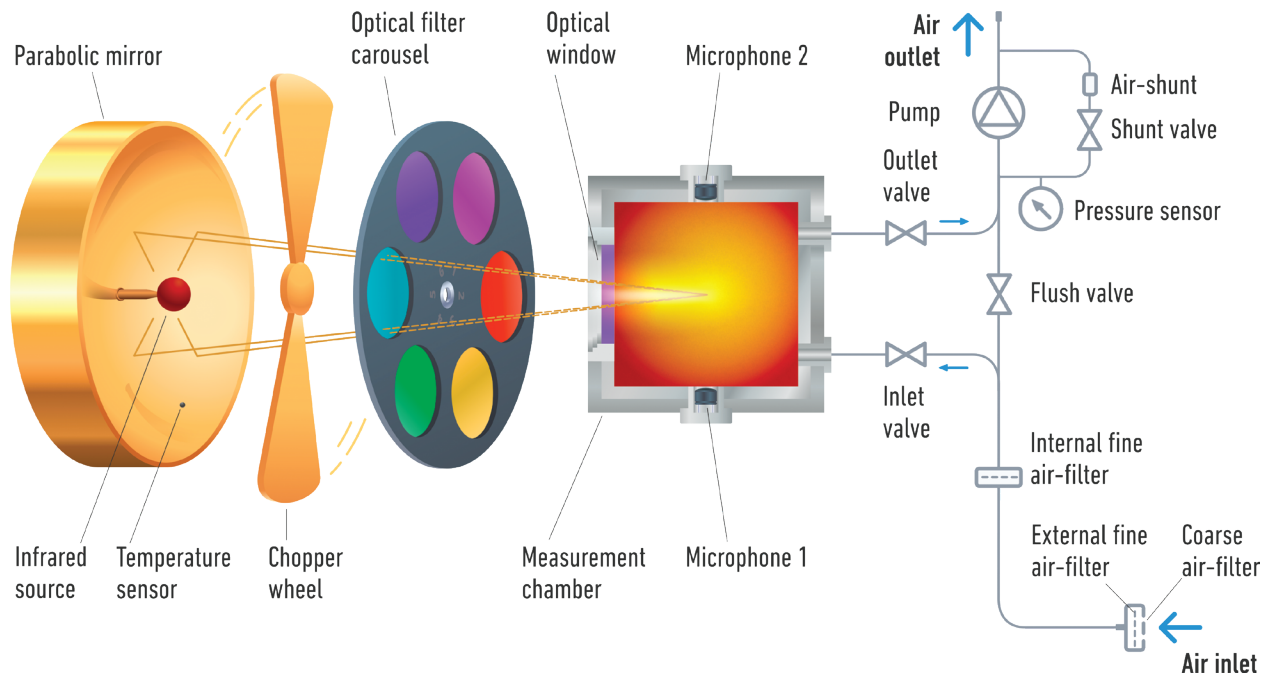


PHOTOACOUSTIC SPECTROSCOPY

Photoacoustic Spectroscopy (PAS) gas instruments were pioneered and perfected by Innova®. With PAS, the absorption (proportional to the concentration) is measured directly and not relative to a background, making PAS highly accurate and stable. Furthermore, all gases and vapor in small volumes can be monitored sequentially in a single measurement chamber as it is possible to detect up to five substances and humidity to be monitored individually.

In a PAS instrument, the gas to be measured is irradiated by modulated infrared light of a pre-selected wavelength. The gas molecules absorb some of the light energy and convert it into an acoustic signal which is detected by microphones.

The IR-source is a spherical, heated black body. An ellipsoidal mirror focuses the light into a closed PAS cell through a window after it has passed the light chopper and the optical filter. The chopper rotates and effectively switches the light on and off. The optical filter is a narrow-band state of the art IR interference filter. If the frequency of the light coincides with an absorption band of the gas in the cell, the gas molecule will absorb part of the light. The higher the concentration of gas in the cell, the more light will be absorbed. As the gas absorbs energy, it is heated and therefore expands and causes a pressure rise. As the light is chopped, the pressure will alternately increase and decrease, thus generating an acoustic signal. The acoustic signal is detected by two microphones. The electrical output signals from the two microphones are added in an amplifier, before they are processed.



Benefits of NDIR and PAS Technologies

Accurately Measure

- Concentrations from ppb, ppm to percent range
- Compensated for temperature, pressure, and humidity interference

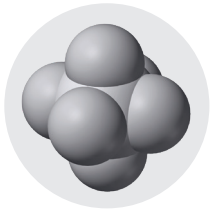
Simplify Gas Detection

- Monitor up to 3 gases simultaneously with a single NDIR sensor, up to 5 gases + water vapor for PAS instruments, and up to 9 gases simultaneously with SmartDGA
- Fast response time
- Easy set-up and remote control operations

Protect Valuable Resources

- Detect harmful gases
- Reduce risk to human health and safety
- Preserve natural resources
- Comply with gas emission standards

SF₆ LEAK MEASUREMENT SOLUTION



Sulfur Hexafluoride (SF₆) is one of the most potent greenhouse gases, with a Global Warming potential of more than 22,000 times than that of CO₂. Over the past decades, manufacturers have replaced oil high-voltage switch gears with SF₆-insulated units. Today, the power utility industry uses roughly 80% of all SF₆ produced worldwide.

SF₆ FILLED EQUIPMENT TESTING

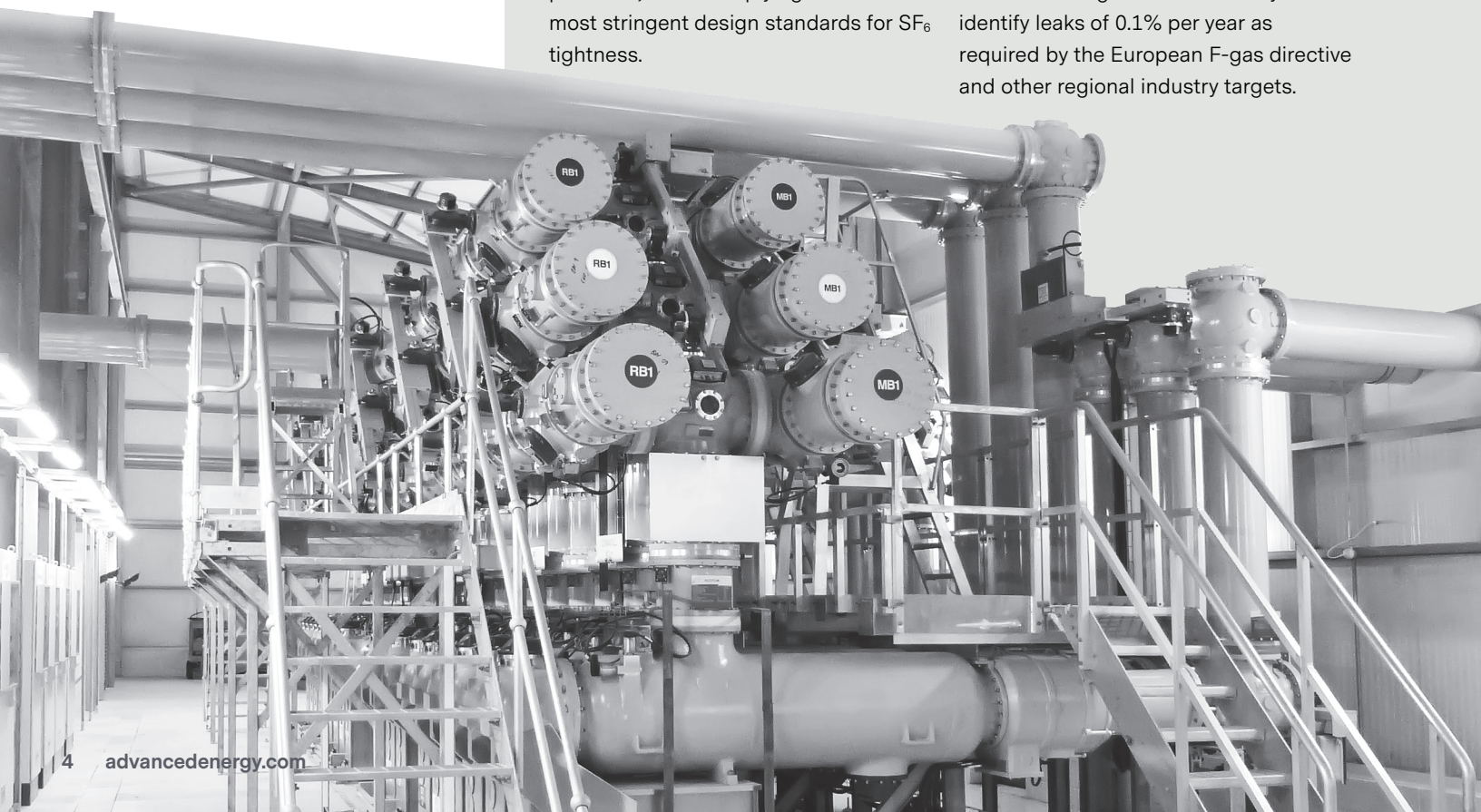
Photoacoustic infrared spectroscopy is actually listed as the state-of-the-art and most sensitive technique for quantitative tightness test by the reference document in the industry: SF₆ Tightness Guide, CIGRE Technical Brochure 430 – WG B3.18.

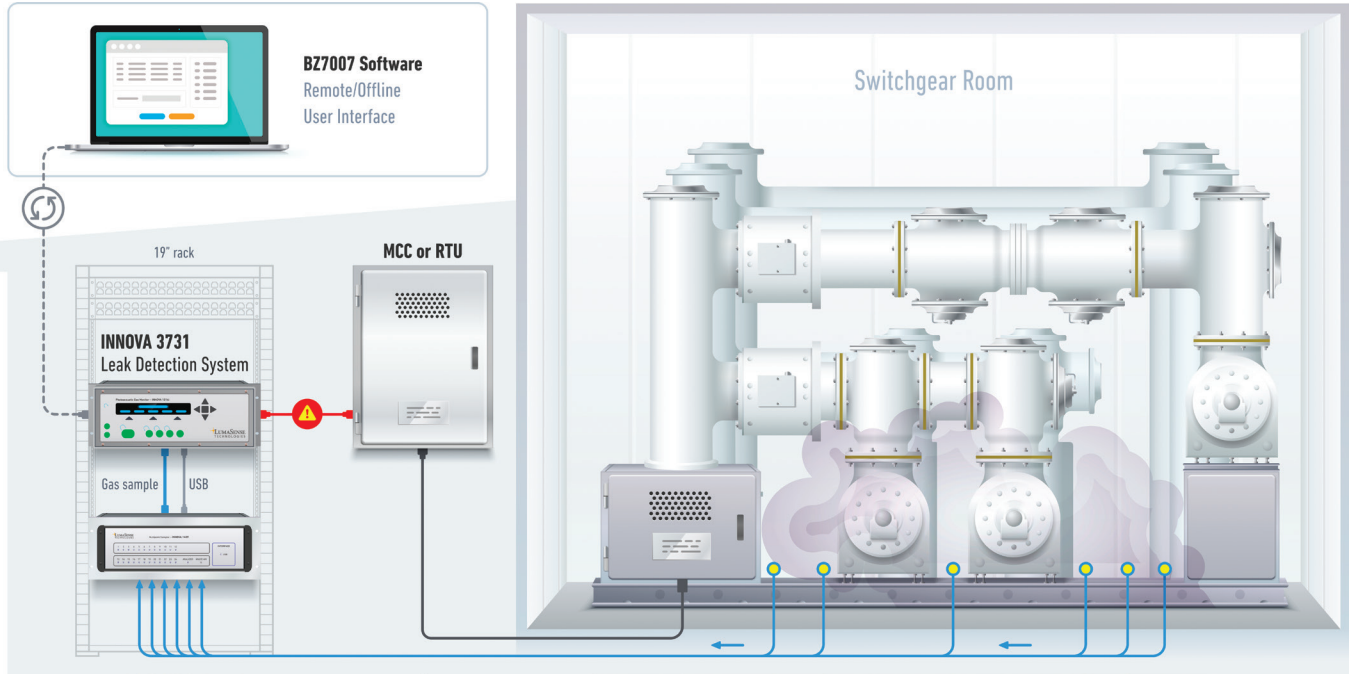
The low detection limit and high accuracy of our SF₆ Leak Detector enables manufacturers to complete their quality tests more efficiently, in a shorter time, and with great precision, while complying with the most stringent design standards for SF₆ tightness.

SF₆ LEAK MONITORING IN SUBSTATIONS

Leverage the same inherent measurement capabilities and benefit from the highly stable and low maintenance rate of the PAS instrument with the reliable SF₆ leak monitoring solutions for enclosed substations.

The ultra-sensitive SF₆ Leak Detector has a low detection limit of 0.006 ppm and is bundled with a multi-point sampler and monitors up to 24 different locations that can be distributed across the substation. This is the only solution sensitive enough to automatically identify leaks of 0.1% per year as required by the European F-gas directive and other regional industry targets.





SF₆ Leak Detection System – 3731

- Stationary standalone multipoint monitoring for direct leak detection in large enclosed volume
- Ultra-sensitive, with a limit of detection at 6 ppb
- High reliability with self-test routines
- Available in 12 or 24 channels, with sampling lines that can extend to 75 m
- Exceptional accuracy with auto-compensation for temperature and pressure fluctuations, and for water vapor interference
- Measurements stored in internal memory, with easy export to remote PC via user-friendly BZ7007 software

LumaSoft Gas Multi Point 7880

- Synchronizes the sampling functions of the sampler units to the measurement cycle of the Photoacoustic Gas-Monitors
- Displays measurement data in either a table or a graphical window; data can be displayed in a Channel or Gas view mode
- Alarm reporting for each gas at each measurement location
- Measurement data stored in SQL Server 2014 database
- Online access to the measurement data via built in OPC Server
- Login-secured access to measurement data



INDUSTRIAL MATERIALS SECTOR

Industrial Combustion Monitoring

Industrial pollution can be mitigated monitoring waste gases such as carbon dioxide (CO_2), Hydrocarbons (CH_x) and oxides of nitrogen (NO_x).



ANDROS 6500 GAS MODULE

- Measures CO , CO_2 , and Hexane or Propane up to high concentrations with NDIR
- Measures O_2 , NO and NO_2 with chemical sensors





INDUSTRIAL MATERIALS SECTOR

Industrial Hygiene

Industrial hygiene (IH) is the science of anticipating, recognizing, evaluating, and controlling workplace conditions that may cause workers' injury or illness. Industrial hygienists use environmental monitoring and analytical methods to detect the extent of worker exposure and employ engineering, work practice controls, and other methods to control potential health hazards.

Innova Photoacoustic Gas Monitors have a long track record of successful deployments which encompass a broad range of applications in the fields of Industrial Hygiene (or Occupational Safety and Health) or Indoor Air Quality monitoring.

Stationary Applications

- VOC ambient monitoring in facilities that use organic solvents in their processes
- Toxic gases area monitoring in electronics

Mobile Applications

- Waste anesthesia monitoring in hospitals
- Leakage detection and monitoring
- Vapor intrusion and contaminant spread characterization

INNOVA 1512





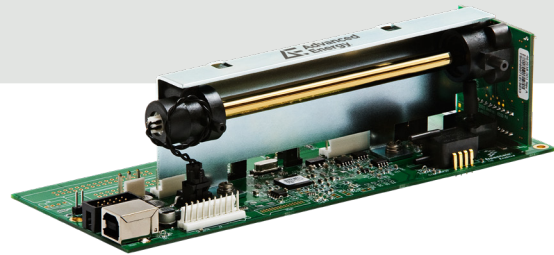
INDUSTRIAL MATERIALS SECTOR

Refrigerant Gas Leak Detection

Refrigerant gas leak detection is becoming a high priority due to the risk to the environment, the increasing price of refrigerant gas, and the high price for repair of major leaks. The need for accurate refrigerant gas detection is also driven by tightening regulations such as the European F-Gas Directive and EN378 legislation.

FOR SYSTEM INTEGRATORS

- The Andros 6552 NDIR gas module with two gas channels can be applied to any type or combination of refrigeration systems that may employ CFC, HFC, HCFCs and CO₂.
- Low power consumption and low maintenance designed to meet or exceed EN 14624, performance of mobile leak detectors and of room controllers of halogenated refrigerants.



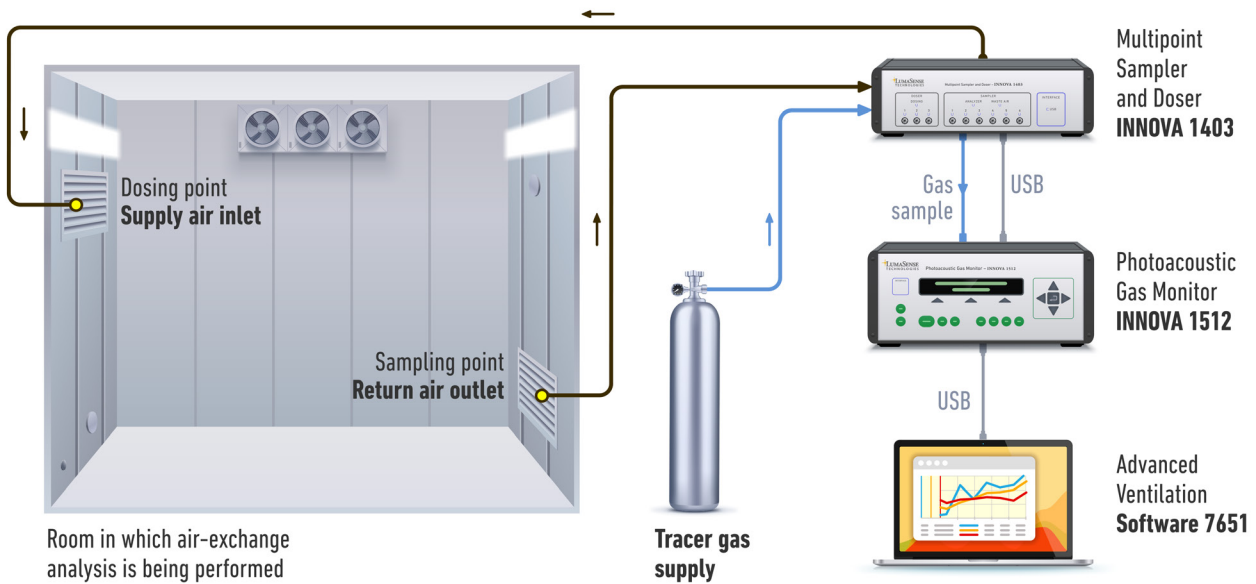
FOR END USERS

- The Innova 1314i can address the needs of end users with a unique area monitoring system featuring ppb detection levels using photoacoustic technology.
- The trace gas detector Innova 1314i can be bundled with a multi-zone sampling systems with up to 24 channels.

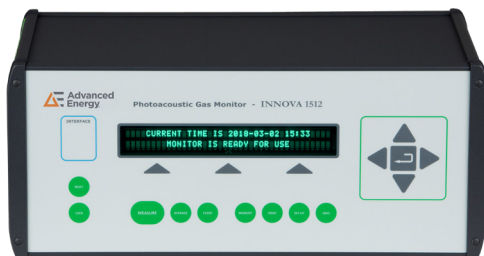
Ventilation Performance

Advanced Energy's Tracer Gas Solutions help designers, commissioning engineers, and specialized consultants (eg. forensic) to analyze and characterize with superior accuracy the key characteristics of complex ventilation systems: high-quality standard buildings, critical duty, passenger cabins, etc.

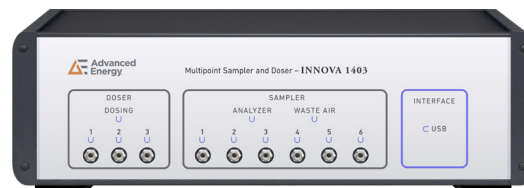
A typical air-exchange analysis system shown with an application example. The aim of the analysis is to determine the size of the air-exchange in the mechanically ventilated room. The diagram shows only the dosing and one sampling point for clarity. All functions of the system is controlled by the Application Software 7650.



INNOVA 1512



INNOVA 1403

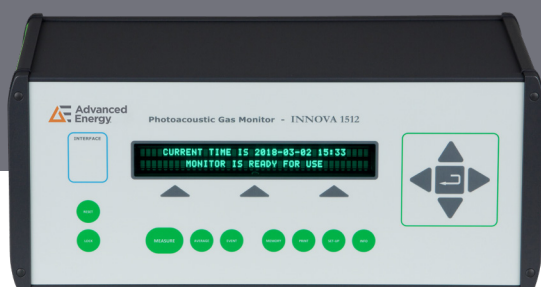




OTHER MARKETS

Environmental Emissions

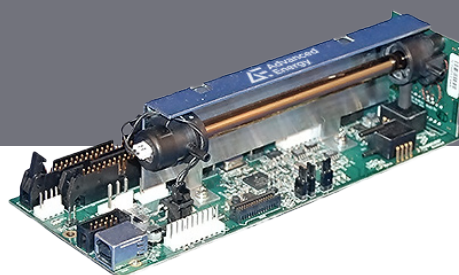
There is an expanding list of environmental and emission applications where gas sensing solutions are needed. Our Innova gas instruments have measured NH_3 in swine and poultry stables, CH_4 in cattle and poultry stables, N_2O from stables and fertilizer, CH_4 from decomposing biomass, and in greenhouses and rice cropping.



INNOVA 1512

The Innova 1512 is a versatile gas monitor broadly used in research and development projects like:

- Agriculture emission reduction from soils, manure, and livestock housing
- Greenhouse gas emissions monitoring
- Remedial soil contamination system efficiency



ANDROS 6511

Andros 6511: gas module is used for greenhouse gas and landfill methane monitoring:

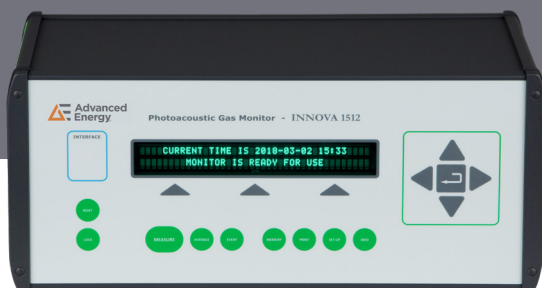
- Continuous, real-time measurement of multiple components including methane and carbon dioxide
- Special version extremely stable (non zero request) compatible with Gas industry explosive environment



OTHER MARKETS

Soil Science Emissions

Greenhouse gas (GHG) emissions studied in soil science include: soil respiration and biomass degradation produce CO_2 and CH_4 and Nitrogen inputs from fertilizers lead to emission of N_2O and NH_3 . The most common, least expensive method for measuring GHG fluxes involves periodic gas sampling from static flux-chambers: the emission rate (or efflux) is derived from the concentration increase.



INNOVA 1512

- The Innova 1512 monitor enables the parallel reading of up to 5 gas concentrations plus water vapor.
- Measurement logs are conveniently stored in the internal memory and can be easily analyzed using the user-friendly LumaSoft application software, then exported into spreadsheet format for further processing.

LUMASOFT GAS SOFTWARE



Automotive Emissions Monitoring

Advanced Energy is the pioneer manufacturer of NDIR-based gas modules for the automotive testing industry with an installed base exceeding 450,000 units.

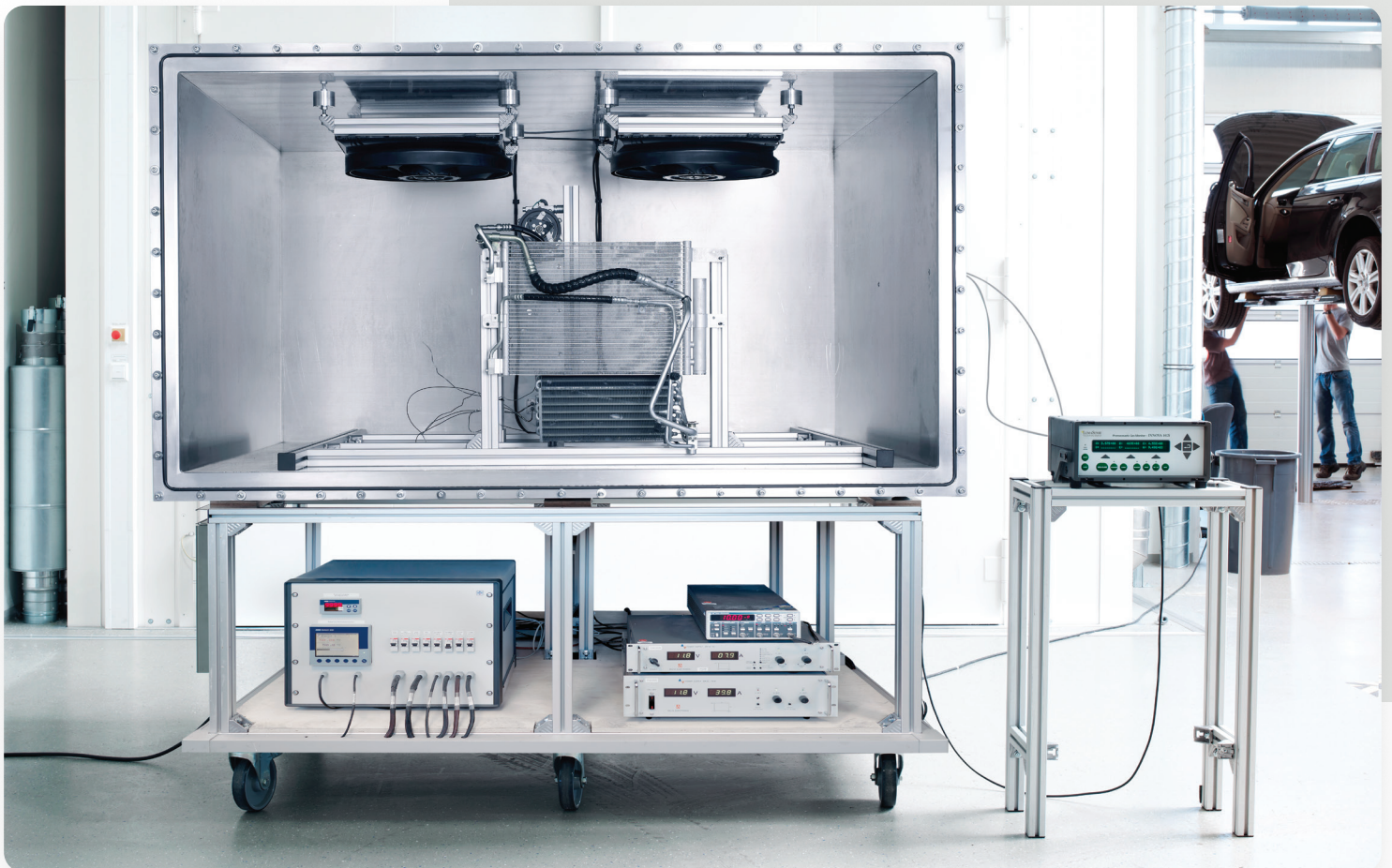
For vehicle exhaust gas and SHED evaporative testing, the Innova 3433 multi gas monitor offers highly accurate and reliable measurements. For vehicle diagnostic, inspection, and maintenance programs our Andros 6500 series gas module offers:

— Unparalleled accuracy and performance through simplicity of design and implementation.

— Easy integration and upgrade with flexible configuration thanks to the Andros operating system and development software.

— Low power consumption, low maintenance and cost of ownership.

Test set-up at IPETRONIK (in Germany) with the Innova 1512 for monitoring emission values of R134a or HFO-1234yf.





SHED Chamber

Photoacoustic Gas Monitor
INNOVA 3433



Embedded
Sampling Pump

Data Acquisition System
or LumaSoft Gas Software



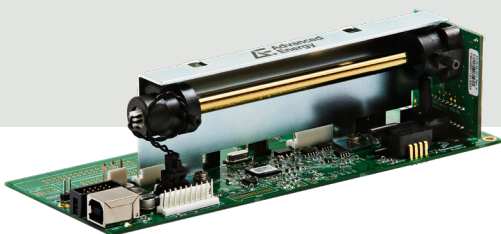
RS232

Modern automobiles are manufactured with sophisticated sensors, computer controls, and on board diagnostics (OBD). Even when all systems are operating correctly, engine emissions can be higher than the original regulatory standards. Many failures cannot be determined by OBD diagnostics alone, so the only way to know how well the engine is performing is to measure the tail pipe emissions using an NDIR based diagnostic instrument.

- The Andros 6500 Auto Emissions gas module is manufactured and tested to meet the limits defined in any of the worldwide requirements to ensure the OEM is receiving the highest measurement performance capability.
- The Andros 6500 is designed to meet and exceed ISO 3930/OIML R99, Class 0 and BAR 97 specifications.

For vehicle testing and engine design validation, several gases (NH_3 , EtOH, and N_2O) need to be measured. Advanced Energy's Innova 3433 Multi Gas monitor is used to measure evaporation emissions (SHED) and vehicle exhaust gas (Constant Volume Samples CVS) approved by EPA and CARB. The Innova 1512 can also be used for measurements of Mobile Air Conditioner emissions R134a and HFO-1234yf.

ANDROS 6500



INNOVA 3433





OTHER MARKETS

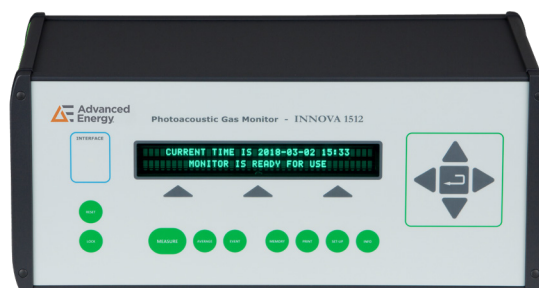
Sordet Gas Filter Testing

With higher and higher concerns around indoor environment quality, in particular concerning airborne pollutants like ammonia, carbonyls, or other volatile organic compounds (VOC), air purification and air cleaning solutions are gaining importance and a regulatory frame exists with design and test standards applying to the qualification of air purification media.

Advanced Energy's Gas Solutions are trusted by multiple advanced filtration materials and respiratory equipment manufacturers worldwide, which rely on their exceptional performances to characterize and test the critical specifications of their products.

- The Photoacoustic Multi-Gas Monitor Innova 1512 is an analytical solution to support the characterization of breakthrough time for air purification materials based on sorption.
- Capable of monitoring any gas that absorbs in the mid-IR spectrum, with detection limit usually in the ppb range. The gas selectivity is achieved by the choice of appropriate optical filters among the 27 filters available in our portfolio.

INNOVA 1512





OTHER MARKETS

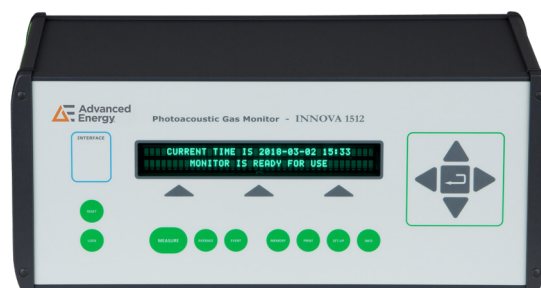
Photocatalytic Material Testing

Photocatalytic materials have multiple applications which consist for the majority in catalyzing value-added physico-chemical processes. These processes usually involve a gas reaction, catalyzed on a solid substrate, and which is activated by daylight and, typically, absorption of UV irradiation.

The Photoacoustic Gas Monitor Innova 1512 is a very relevant instrument with regard to the measurement needs met by photocatalysis scientists. It has been selected by multiple research teams in the world, which value in particular the following features:

- Multi-gas instrument enabling the monitoring of reactants and products with a unique instrument
- High versatility and easy customization: the selection of gases of interest is made simply by choosing the appropriate optical gas filters
- Embedded pump and very low sampling volume: the gas monitor can be integrated in a closed-loop configuration with a small-size reactor

INNOVA 1512





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ABOUT ADVANCED ENERGY

Advanced Energy (AE) has devoted more than three decades to perfecting power for its global customers. AE designs and manufactures highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes.

AE's power solutions enable customer innovation in complex semiconductor and industrial thin film plasma manufacturing processes, demanding high and low voltage applications, and temperature-critical thermal processes.

With deep applications know-how and responsive service and support across the globe, AE builds collaborative partnerships to meet rapid technological developments, propel growth for its customers and power the future of technology.

PRECISION | POWER | PERFORMANCE | TRUST

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