2B Tech

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Model 211 Scrubberless Ozone Monitor™

The World's Most Accurate Ozone Monitor
Federal Equivalent Method (FEM)
Interference Free

The Model 211 Scrubberless Ozone Monitor uses the method of ultraviolet (UV) absorption in combination with our patented (US Patent No. 8,395,776 B2) gas-phase scrubber technology to measure ozone virtually free of interferences. The instrument is ideally suited for measurements of ozone in heavily polluted air where interference is likely from particulates, mercury, or VOCs. The Model 211 combines the stability of our proven dual beam ozone monitors with our selective scrubber technology to provide accurate ozone measurements in the most polluted air. The enhanced optical path length of 30 cm provides a precision of better than 0.5 ppb for 10-second measurements, and the instrument can output new ozone measurements as often as every 2 seconds. SD card data logging is now a standard feature. Designation of the Model 211 Ozone Monitor as a Federal Equivalent Method (FEM) was published in the *Federal Register* on June 18, 2014 (EQOA–0514–215).

Theory

Ozone monitors based on UV absorbance measure ozone by comparing the transmission of light through a detection cell. Light intensity measurements are made with ozone present (I) and with ozone removed (I_o), and the ozone concentration is calculated using the Beer-Lambert Law. Conventional ozone monitors remove ozone for the I_o measurement by passing the sample air flow through a solid scrubber (e.g., hopcalite or a series of metal oxide screens). Ideally, the solid-phase scrubber would destroy ozone but pass mercury and other UV-absorbing compounds. In that case, the values of I and I_o would be reduced by the same amount, and the interfering compounds would not affect the ozone measurement. In practice, however, mercury and aromatic compounds such as benzene, toluene, xylenes, phenols, etc. either adsorb or react at the solid-phase scrubber surface. As a result, conventional ozone monitors may report erroneously high ozone values by up to a few ppb on highly polluted days and possibly cause a region to be out of compliance with the EPA's ozone standard. The 2B Tech Model 211 Ozone Monitor removes interferences from all UV-absorbing compounds and mercury by using nitric oxide (NO) in a GPT (gas phase titration) reaction in place of a solid-phase scrubber according to the well-known reaction: $NO + O_3 \rightarrow NO_2 + O_2$.

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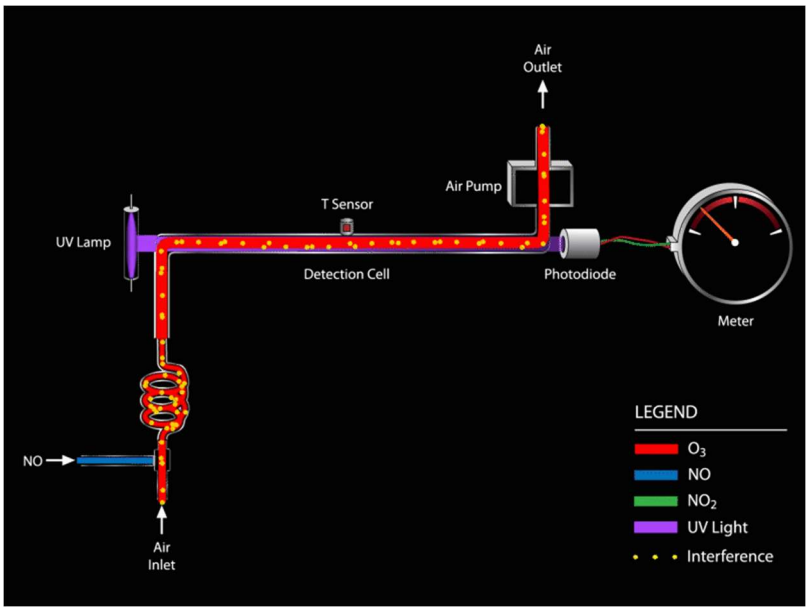

Click on the image on the left to see an animation illustrating the principle of a gas-phase NO scrubber for a single-beam instrument. A small amount (~5 ppm) of nitric oxide (NO; blue) is pulsed into the air flow every 2 seconds to destroy the ozone and produce nitrogen dioxide (NO_2; green) which doesn't absorb the 254-nm UV light. When ozone (red) is present, the signal at the photodiode is reduced due to absorbance by ozone. When ozone is destroyed by NO, the signal increases. The difference in measured light intensities is proportional to the ozone concentration. Because the potentially interfering species (benzene, toluene, xylenes, aldehydes, mercury, etc.; colored yellow) are always present and not modulated by NO, they do not contribute to the signal difference and thus do not interfere with the ozone measurement.

Like our Model 205 Ozone Monitor, the Model 211 is actually dual beam, with a measurement of the transmission of UV light through ozone-depleted air being made simultaneously with a measurement of UV light passing through unscrubbed air, thus increasing the precision and baseline stability of the instrument.
Nitric oxide can be added directly from a compressed gas cylinder or by photolysis of nitrous oxide (N_2O) provided from a N_2O cartridge (either a 16-gram cartridge to provide 8 hours of operation for portable applications; or an 8-gram cartridge for 4 hours of operation), lecture bottle (7 days), half-sized cylinder (8 mo) or full-sized cylinder (2 yr). The use of N_2O as a source gas eliminates the need for maintaining cylinders of toxic NO gas. Nitrous oxide is a relatively nontoxic gas sold as a consumer product as "Whippit" cartridges for making whipped cream. The same method for producing NO from N_2O is used in our Model 714 NO_2/NO/O_3 Calibration Source.

The Model 211 allows remote instrument operation via RS-232, choice of averaging time (2 s to 1 hr), analog voltage output (0-2.5 V), internal data logger, and SD flash memory card (now standard). Our free data display and graphing software allows continuous display of data which can be saved for offline analysis.

Features

- Interference-free measurement of ambient ozone
- DewLine™ for elimination of water vapor interference, a unique feature of 2B Tech instruments
- Inexpensive, simple, and robust instrument design in a 19” rack mount enclosure
- Internal data logger
- Flash card memory (SD card) for virtually unlimited, portable data storage
- Dual beam, long path (30 cm) optical bench with high precision (< 0.5 ppb)
- NIST-traceable calibration (calibration suggested annually)
- Internal long-life sample pump (20,000 hours)
- EPA Federal Equivalent Method (FEM) for compliance monitoring (EQOA–0514–215)
- Convenient user interface, including remote operation via RS-232 communication
- Internal NO generator from non-toxic, non-corrosive nitrous oxide (N_2O)

- Portable N_2O Source (provided) can use “Whippit”-type cartridges (use either 16-gram cartridge for 8 hours of operation, or 8-gram cartridge for 4 hours of operation)
- Very low NO concentration used in comparison to ozone monitors based on NO chemiluminescence

Specifications

Measurement Principle	UV Absorbance at 254 nm; Dual Beam
Certifications	Federal Equivalent Method (FEM), 0-500 ppb for 20-30°C: EQOA–0514–215; CE
Ozone Scrubber Technology	Gas-phase scrubber using NO, provided directly or by photolysis of N_2O (supplied by either compressed-gas cylinder or portable liquid cartridge)
Linear Dynamic Range	0-2,000 ppb (0-2 ppm)
Resolution	0.1 ppb
Precision (1σ; rms noise)	Greater of 0.5 ppb or 1% of reading for 10-s average
Accuracy	Greater of 1.0 ppb or 2% of reading
Limit of Detection (2σ)	1.0 ppb for 10-s average
NIST-Traceable Calibration	Yes
Flow Rate (nominal)	~2 Liter/min
Flow Rate Requirement	>1.2 L/min
Baseline Drift	<1 ppb/day; <3 ppb/year
Sensitivity Drift	<0.5%/day; <3%/year
Response Time, 100% of Step Change	20 s for 10-s averaging; 4 s for 2-s measurement mode
Measurement & Averaging Times	2 s, 10 s, 1 min, 5 min, 1 hr
Internal Data Logger Capacity	16,383 lines (10-s avg = 1.9 days; 1-min avg = 11 days; 5-min avg = 1.9 mo; 1-hr avg = 1.9 yr)
SD Card Logger Capacity	Minimum 2 GB (> 5-year capacity for 10-s measurement mode)
Ozone Units	ppb, pphm, ppm, µg m^{-3}, mg m^{-3}
Pressure Units	mbar, torr
Temperature Units	°C, K
T and P Corrected	Yes
Operating Temperature Range	10 to 50 °C
Operating Altitude Range	~0-13.5 km (150-1,013 mbar)
Power Requirement; Supplied by	11-14 V DC or 120/240 V AC, nominally 1 A at 12 V, 12 watt

110/220 VAC Power Pack	
Size	Rackmount: 17" w x 14.5" d x 5.5" h (43 x 37 x 14 cm)
Weight	14.7 lb (6.7 kg)
Data Outputs	LCD, RS232, SD card, 0-2.5 V Analog
Data Transfer Baud Rates	2400, 4800, 19200
Output Ranges	User-Defined Scaling Factor in Menu
DewLine™	Yes
Long-Life Pump	Yes, 20,000 hr
Flow Meter	Yes
Options	External Particle Filter; External USB Adapter

System Includes

- Model 211 Scrubberless Ozone Monitor
- AC Power Adapter (100-240 VAC to 12 VDC) with Country-Specific Plug
- Zeroing Cartridge
- Portable N_2O Source (use with either 16-gram or 8-gram N_2O cartridges, for 8 hr or 4 hr of continuous operation)
- SD Card (minimum 2 GB) and SD Card Reader
- Operation Manual on USB Stick
- Calibration Data and NIST-Traceable Calibration Certificate
- Instrument Birth Certificate
- One-Year Warranty

Options

- External particle filter
- External serial-to-USB adapter

Publications and Presentations Evaluating the Model 211

- W. M. Ollison, W. Crow and C. W. Spicer (2013) *Journal of the Air and Waste Management Association* **63**, 855-863, "Field testing of new-technology ambient air ozone monitors."
- T. Johnson, J. Capel and W. Ollison (2014) *Journal of the Air and Waste Management Association* **64**, 360-371, "Measurement of microenvironmental ozone concentrations in Durham, North Carolina, using a 2B Technologies 205 Federal Equivalent Method monitor and interference-free 2B Technologies 211 monitor."
- Russell Long (2015) "Evaluation and Proposal of a New Federal Reference Method for Ozone: Nitric Oxide Chemiluminescence," Briefing for NACAA, Office of Research and Development, National Exposure Research Laboratory, Environmental Protection Agency, January 14, 2015.
- John Birks, Peter Andersen, Craig Williford and Andrew Turnipseed (2015) "2B Tech Model 211 Scrubberless Ozone Monitor for Interference-Free Measurements," Air Monitoring Conference, Region 4, Environmental Protection Agency, Chattanooga, Tennessee, March 18, 2015.