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Model 410 Nitric Oxide Monitor™

The Model 410 Nitric Oxide Monitor™ is designed for the measurement of atmospheric nitric oxide (NO) in the concentrtion range 0-2,000 ppb (0-2 ppm) with a precison of ±1.5 ppb. When used in combination with the Model 401 NO_2 Converter, NO_x and NO_2 (by difference) are also measured. The detection principle of the Model 410 is based on the selective reaction of NO with ozone. The resulting ozone depletion is measured using the absolute method of UV absorbance and thus requires only infrequent calibration. By comparison, chemiluminescence NO_x instruments require nearly continuous calibration using a standard gas.

For applications where slightly smaller size and lower power consumption are necessary, you may still purchase our earlier Model 400 NO Monitor. See: Model 400

Theory of Operation

The NOzone™ technology employed by the Model 410 Nitric Oxide Monitor™ is based on the quantitative reaction of nitric oxide (NO) with ozone (O_3):

$$NO + O_3 \rightarrow NO_2 + O_2 + light \qquad (1)$$

This reaction has long been used as a gas phase titration for the measurement of either NO or O_3 in laboratory kinetics experiments, and the reaction is stoichiometric; i.e., one O_3 molecule is consumed for every NO molecule oxidized to NO_2 in the reaction. In the Model 410 Nitric Oxide Monitor™, a small concentration of ozone (~4 ppm) is added to the gas sample stream and the resulting decrease in concentration of ozone is measured by the absolute method of UV absorption. By providing adequate time for the reaction to go to completion, the decrease in ozone concentration is equal to the original concentration of NO in the gas stream.

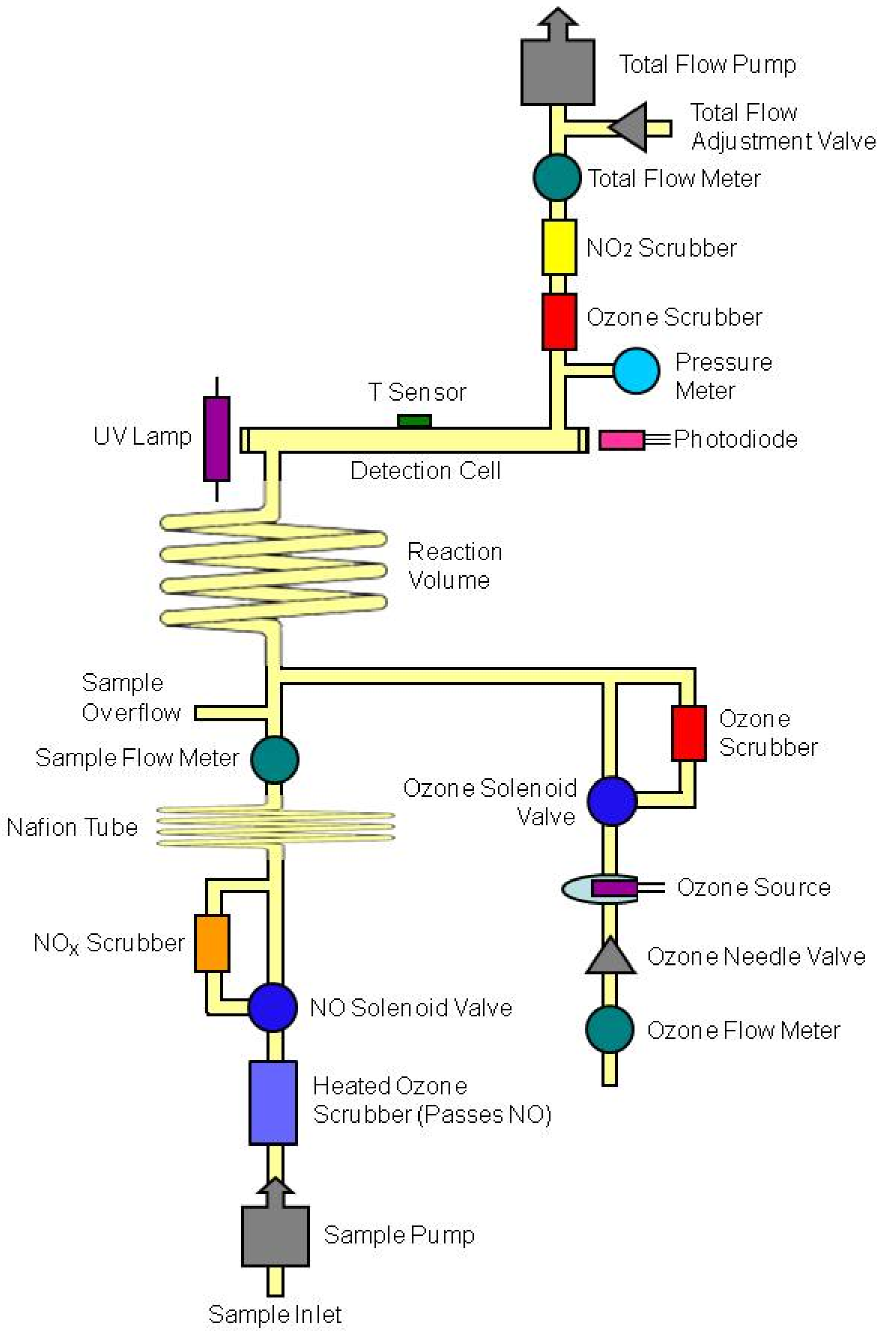

Fig. 1. Schematic diagram of the Model 410 Nitric Oxide Monitor.

Reaction 1 also is used in conventional chemiluminescence analyzers. Instead of measuring the change in ozone concentration, chemiluminescence detects the small amount of light produced in the reaction. That light is emitted by electronically excited NO_2 molecules formed in reaction 1. Chemiluminescence instruments are highly sensitive and have a very fast response time, but require frequent calibration using a gas standard.

Figure 1 above is a schematic diagram of the Model 410 Nitric Oxide Monitor. Here we trace the gas flow through the instrument beginning at the Air Inlet near the bottom of the diagram. A miniature air pump, the Sample Pump, draws sample air into the instrument and through a proprietary heated ozone scrubber at a flow rate of ~0.8-1.2 L/min. The air sample then passes through a miniature solenoid valve which alternately directs the flow through a NO_x scrubber or bypass. The flow then passes through a Nafion tube, a flow meter and into an overflow tee which vents part of the air sample. The Nafion tube equilibrates the humidity of the sampled air with that inside the instrument case, assuring that the humidity is the same in NO-scrubbed and unscrubbed air. The Total Flow Pump (top of diagram) draws air from the overflow tee, and through the detection cell. A bleed valve, the Total Flow Adjustment Valve, is used to provide adjustment of the total flow rate through the detection cell. Following the sampling tee, a small flow of 20-30 cc/min of ozonized air is added to the sample air stream. The flow rate of ozone/air is adjusted by use of the Ozone Needle Valve, and is set to produce an ozone concentration in the range of 3.5-4.5 ppm (3,500-4,500 ppb).

The sample air, either NO-scrubbed or unscrubbed, containing the added ozone next passes through a coiled reactor, which provides adequate reaction time (~3 s) for nearly all NO in the sample to react with ozone via reaction (1) above. Correction is made in the software for lack of complete reaction. That correction is typically less than 3%. Next the sample air passes through the Detection Cell where UV light intensity is measured. The air stream then passes through an Ozone Scrubber where O_3 is catalytically converted to O_2, through an NO_2 scrubber to remove the NO_2 produced in reaction (1), through the Total Flow Meter where the flow rate is measured, and into the instrument case.

Ozone is produced by pumping ambient air through a chamber containing a low pressure mercury lamp. The lamp has a fused silica window that passes highly energetic atomic emission near 185 nm in addition to the resonant emission at 254 nm. The wavelengths near 185-nm are absorbed by molecular oxygen (O_2) to produce oxygen atoms (O). Those oxygen atoms rapidly attach to O_2 via a termolecular reaction to form O_3.

$$O_2 + \text{photon} \rightarrow 2\ O \qquad (2)$$

$$O + O_2 + M \rightarrow O_3 + M \qquad (3)$$

Here, the photon has a wavelength near 185 nm, and M is any molecule, principally N_2, O_2, Ar and H_2O, in air. The molecule M catalyzes the combination of O and O_2 by removing excess relative translational energy. The flow rate of ozone/air and thus the ozone concentration is controlled by the Ozone Needle Valve. Flow rates and the actual ozone concentration produced are measured in a cycle at the beginning of an analysis by modulating the Ozone Solenoid Valve. This valve either allows the ozone/air mixture to enter the stream of gas being analyzed or diverts it through an ozone scrubber.

NO is measured by modulating the NO Solenoid Valve. A low-pressure mercury lamp is located on one side of the absorption cells, and a photodiode is located on the opposite side. The photodiode has a built-in interference filter centered on 254 nm, the principal wavelength of light emitted by the mercury lamp. Shorter wavelengths of light that could produce ozone are absorbed by the low-grade quartz envelope of the lamp itself and by the window of the detection cell, which passes 254-nm but not 185-nm light. The state of the NO Solenoid Valve is switched every 10 seconds in order to measure light intensities for sample air, I, and scrubbed sample air, Io. The values of I and Io are used to calculate the concentration of NO in the original air sample. In addition to a small correction for incomplete reaction, a correction is made for the small amount of dilution of the NO concentration by the added ozonized air.

Specifications

Measurement Principle	Titration of NO with Ozone with Detection of Ozone Depletion by UV Absorption at 254 nm
Precision and Accuracy	Higher of 1.5 ppb or 2% of reading
Data Storage	14,336 lines (10 s avg. = 1.4 days; 5 min avg = 1.4 mo.)
Time/Measurement	10 s (Data averaging options: 10 s, 1 min, 5 min, 1 hr)
Sample Flow Rate	1 L/min
Data Outputs	RS-232, LCD, 0-2.5 V Analog, 4-20 mA Optional, Flash Card Optional
Power Requirements	Typical: 11.4 watt Maximum: 22.3 watt (warmup)
Size	13.3 x 8.3 x 5.3 x in 33.7 x 20.0 x 13.3 cm
Weight	8.3 lb (3.7 kg)