HAIS Fast-O3 Instrument

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Principle of Operation:

The operating principle of the O_3 instrument is the measurement of chemiluminescence from the reaction of nitric oxide (NO) with ambient O_3 using a dry-ice cooled, red-sensitive photomultiplier employing photon-counting electronics.

Reaction Vessel Chemistry:

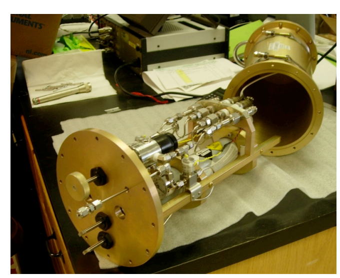
$$O_3 + NO \rightarrow NO_2^* + O_2$$

$$\rightarrow NO_2 + O_2$$

$$NO_2^* \rightarrow NO_2 + h\nu \quad (600 \text{ nm} < \text{wavelength} < 2800 \text{ nm})$$

$$NO_2^* + M_i \rightarrow NO_2 + M_i$$

The reagent NO (grade >99%) is supplied from a commercially purchased lecture bottle filled to a maximum pressure of 500 psig. Since NO is a toxic gas, the small high pressure cylinder, its regulator, and several safety features are contained inside a specially designed pressure safe vessel that is vented overboard the aircraft.



Ambient air is sampled through a standard HIMIL inlet protruding outside the aircraft boundary layer. Ambient air sample flow is controlled to 500 sccm, while the NO reagent is introduced to the reaction vessel in near-excess flow of ~ 4 sccm. Gas flows as well as the reaction vessel temperature (35 ± 0.1°C) and pressure (10 ± 0.05 torr) are all controlled at constant conditions resulting in maximum stability of the detected signal and instrument sensitivity.

The instrument sensitivity of roughly 2000 cps/ppbv (count-per-second per part-per-billion-by-volume) is determined from calibrations performed on the ground before and after each flight or set of back-to-back flights using a UV absorption based calibrator (TECO model 49PS) operated with high-quality ultra-pure air. A near-linear calibration curve is generated in 100 ppb intervals from 0 to 1 ppm. This calibration range is sufficient to measure O_3 mixing ratios over the altitude range of the aircraft.

Hardware Description:

The fast-O3 instrument has been specifically developed for use onboard HIAPER, the NSF/NCAR G-V aircraft. The instrument requires several accessories in addition to the instrument module to operate effectively. Therefore, the total Fast-O3 equipment rack consists of several major components. The fast-O3 instrument module (~25 lbs) houses the reaction vessel and PMT. A small scroll pump (~30 lbs) allows operation of the instrument's reaction vessel at the desired pressure and flow rate. A nitric oxide containment vessel (26 lbs) supplies the reagent NO to the reaction vessel in the instrument. The DAQ (~45 lbs) which acts as a power supply unit as well as data recording system for the chemiluminescence signal as well as several instrument housekeeping signals. For SEAC^{4}RS, the pump and DAQ, as well as inlet, are shared with the NO-NO_2 instrument.

A preliminary O_3 mixing ratio is transmitted to the aircraft data system, from which it is transmitted to the ground for real-time display via aeros.

Instrument Performance:

Background: 100-1000 cps (counts per second). Is higher at higher altitude. Is measured periodically during flight.

Detection Limit: 0.1 ppbv (parts per billion by volume) at 1 s at high altitude (worst case), and 0.01 ppbv at 1 s at low altitude (best case).

Sensitivity: ~2000 cps/ppbv. Varies according to operating conditions for a given project, but very stable over the course of a project.

Accuracy: 5%

Precision: Depends on mixing ratio. Expressed as a percentage, it improves with mixing ratio, with inverse-square-root dependence, and worsens with altitude. At high altitude, it is ~0.9 ppbv (0.9%) at 100 ppbv (1 s).

Time Response: 1 Hz (Instrument can have 5 Hz capability, depending on inlet configuration.)

Linear Range: 0 ppbv → 1000 ppbv (O3)

Publications Describing the Instrument:

Ridley, B. A., and F. E. Grahek, A small, low flow, high sensitivity reaction vessel for NO chemiluminescence detectors, *J. Atmos. Oceanic Technol.,* 7, 307-311, 1990.

Ridley, B. A., F. E. Grahek, and J. G. Walega, A small, high-sensitivity, medium-response ozone detector for measurements from light aircraft, *J. Atmos. Oceanic Technol.,* 9, 142-148, 1992.
