National Institute of Standards & Technology

Specifications

Standard Reference Instrument Series 6008

Ozone Standard Reference Photometer

Description: The NIST Standard Reference Photometer (SRP) [1,2,3,4] is a photometric instrument that accurately measures concentrations of ozone (O_3) in air up to 1000 nmol/mol by absorption of the 253.7 nm mercury line. The measurement principle is based on application of Beer-Lambert Law using an absorption cross-section of 1.147×10^{-17} cm^2/molecule. The NIST SRP design is a dual-cell system where the charging of each cell alternates between sample and reference sample streams. The measurement procedure uses a variable-length instrument cycle which minimizes the effects of lamp drift and absorption cell/detector biases. Each cell is approximately 89.5 cm in length. Comparisons spanning the past 30 years show agreement within 1 percent over the 0-1000 nmol/mol molar fraction range. New NIST SRPs typically agree with NIST SRP 2 (NIST's highest level ozone standard) to better than 0.3 %, and historically the one-standard-deviation spread of all NIST SRPs vs. NIST SRP 2 is 0.7 %. The SRP system includes an internal ozone generator and an automated control system which allows for automatic measurements against other NIST SRPs or calibrations of commercial ozone instrumentation via serial communication or analog signal measurement.

Currently, the NIST SRP serves as an International Reference Standard and is used by the *Bureau International des Poids et Mesures* (BIPM) as a reference for ozone measurements. International traceability to the *SI* for ozone measurements can be obtained through the BIPM or NIST.

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NIST SRP Uncertainty: Calculations using the Guide to the Expression of Uncertainty in Measurement [5] yields the combined standard uncertainty estimate below:

Uncertainty Budget Summary – SRP 2

Component (y)	Source	Distribution	Standard Uncertainty	Combined Standard Uncertainty μ(y)	Sensitivity Coefficient $c_i = \partial x/\partial y$	Contribution to μ(x), $\lvert c_i \rvert \cdot$ μ(y)/nmol mol^{-1}
Optical Path-length, L	Measurement scale Variability Divergence	Rectangular Rectangular Rectangular	0.005 cm 0.03 cm. 0.52 cm	0.52 cm.	$-x/L_{opt}$	$2.89 \times 10^{-3}\, x$
Pressure, P	P Gauge P difference between cells	Rectangular Rectangular	0.029 kPa 0.017 kPa	0.034 kPa	$-x/P$	$3.37 \times 10^{-4}\, x$
Temperature, T	T probe T gradient	Rectangular Rectangular	0.029 K 0.058 K	0.07K	x/T	$2.29 \times 10^{-4} x$
Ratio of intensities, D	Scaler resolution Repeatability	Rectangular Triangular	8×10^{-6} 1.1×10^{-5}	1.4×10^{-5}	$x/\mathrm{Dln(D)}$	0.28
Absorption cross-section, σ	Conventional value		1.22×10^{-19} cm^2/molecule	1.22×10^{-19} cm^2/molecule	$-x/\sigma$	$1.06 \times 10^{-2}\, x$

The effective number of degrees of freedom for all components is large therefore, the conventional 95% coverage factor of 2 is appropriate. The uncertainty budget above is summarised in one equation describing the uncertainty as a function of ozone mole fraction:

$$u(x) = \sqrt{(0.28)^2 + \left(1.1 \times 10^{-2}\, x\right)^2}\ nmol/mol$$

Power Requirements: 115 VAC, 50/60 Hertz. A power transformer (if necessary) of at least 360 VA will be adequate. The control computer (user supplied) can operate on your power service separate from the NIST SRP.

Air Supply: Minimum input pressure of 15 psig (34.7 psia, 239.2 kPa) of clean, dry air. Preferably, zero air containing no significant impurities, having less than 1 ppm (parts per million) total hydrocarbons by volume, and containing 20 - 21% oxygen. The NIST SRP has internal devices to control the amount of air required for operation. No external control is necessary. A zero air supply of 20 liters/min. will be adequate for most calibration work. These units are available through commercial suppliers of air monitoring equipment. A single NIST SRP draws 2 standard liters per minute (slpm) into each cell (4 slpm total), plus an excess in the sample and reference manifolds.

Laboratory Requirements: A lab with reasonably stable temperature, pressure, and humidity control. Large temperature drifts and cyclical changes can affect instrument stability. Humidity levels above 50 % have been shown to cause SRP detector drift. The entire NIST SRP system will fit on a normal desktop or laboratory bench top. Local exhaust for venting excess ozone is necessary to prevent high levels of ozone in laboratory.

Physical Dimensions: Electronics Module: 18.75 x 12.75 x 7.5 inches, (47.6 x 32.4 x 19.1 cm).
Pneumatics Module: 18.75 x 12.75 x 7.5 inches, (47.6 x 32.4 x 19.1 cm).
Optical Bench: 46.0 x 5.0 x 4.875 inches, (116.8 x 12.7 x 12.4 cm).

The SRP system is set up on a bench top with the optical bench setting on a stand and the electronics and pneumatics modules situated underneath. The **minimum** required bench top space is 46.0 x 17.0 inches (116.8 cm x 43.1 cm) with a necessary clearance height of approximately 27 inches (68.6 cm). Additional space is then required for the control computer, which will need to be located near the instrument, and another lab bench for setting up guest instruments to be calibrated.

Shipping Dimensions and Weight:

Included in an SRP purchase are two customs shipping containers.

Container 1: Instrument Modules and associated cables and interface components.
25 x 24 x 18 inches (63.5 x 61 x 45.7 cm) at 102 pounds (46.4 kg) with SRP.

Container 2: Optical Bench Module
9 x 9 x 53 inches (12.9 x 12.9 x 135 cm) at 58 pounds (26.4 kg) with SRP.

Delivery and Shipping: NIST will prepare packaging for shipment of the NIST SRP. Customers are responsible for covering the cost and arrangements for shipment FOB Gaithersburg, MD, USA, as well as all customs duties and import fees. The Harmonized Tariff Schedule number used is 9027.80.8000 Scientific Instrument.

Installation and Training: Installation, operations training, and additional measurement validation by comparison to NIST's traveling ozone standard, SRP 0 can be arranged if requested, but must be paid for separately.

General Items needed in the Laboratory for SRP operation and Maintenance:

- Zero air supply – specifications stated above under **Air Supply.**
- 115 VAC power – listed above under **Power Requirements**.
- Laboratory venting for excess ozone.
- Pressure Standard with traceability to primary standard.
- Digital multimeter- preferably with mV scale.
- Wrenches, preferably English, but Metric will work.
- Screwdrivers, both straight and Phillips, several sizes, especially small for potentiometers.
- Teflon tubing, clean ¼ inch (6.35 mm) outside diameter.

NIST Standard Reference Photometer-SRI 6008 System Configurations

6008 NIST Standard Reference Photometer with installation $90,684 US

a. Electronics Module
b. Pneumatics Module
c. Optical bench with stand
d. Control circuit card and inter-connection cables.
e. Operating software (Windows based fully automated control system).
f. Standard operating procedures manual (currently being updated).
g. Product information on commercial components used in the NIST SRP.
h. Complete set of instrument drawings and circuit diagrams.
i. A built-in Ozone Generator.
j. Sample/Reference Gas Manifold.
k. Temperature Calibrator.
l. Custom SRP shipping cases.
m. Validation against NIST SRP 2 (NIST's highest level ozone standard).

REFERENCES

[1] Paur, R.J., Bass, A.M., Norris, J.E., and Buckley, T.J., 2003. Standard Reference Photometer for the Assay of Ozone in Calibration Atmospheres. *NISTIR 6369*.

[2] Norris, J.E.; Band, A.H.; Biss, R.J.; Guenther, F.R.; Upgrade and Inter-comparison of the U.S. Environmental Protection Agencies Ozone Reference Standards; Proceedings of the 2004 Air and Waste Management Association Annual Conference.

[3] Viallon, J., Moussay, P., Norris, J.E., Guenther, F.R., and Wielgosz, R.I., "A study of Systematic Biases and Measurement Uncertainties in Ozone Mole Fraction Measurements with the NIST Standard Reference Photometer", Metrologia 43 (2006) 441-450.

[4] Norris, J.E., Choquette, S.J., Viallon, J., Moussay, P., Wielgosz, R.I.; and Guenther, F.R. (2013): Temperature measurement and optical path-length bias improvement modifications to National Institute of Standards and Technology ozone reference standards, Journal of the Air & Waste Management Association, 63:5, 565-574

[5] JCGM 100:2008; Evaluation of Measurement Data — Guide to the Expression of Uncertainty in Measurement (ISO GUM 1995 with Minor Corrections); Joint Committee for Guides in Metrology (JCGM) (2008); available at (accessed Feb 2011); see also Taylor, B.N.; Kuyatt, C.E.; Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results; NIST Technical Note 1297; U.S. Government Printing Office: Washington, DC (1994); available at http://www.nist.gov/physlab/pubs/index.cfm (accessed Mar 2011).

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