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GUIDELINES

HOW TO IMPLEMENT THE NEW ABSORPTION CROSS-SECTION FOR OZONE CONCENTRATION MEASUREMENTS

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GUIDELINES

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1 SCOPE OF DOCUMENT

This document is aimed at providing guidance to ozone calibration laboratories, surface monitoring networks, and instrument manufacturers regarding the implementation of the new ozone absorption cross-section value, CCQM.O3.2019. Specific advice is provided in the different sections for the corresponding targeted audience.

WHY A NEW OZONE CROSS-SECTION AND HOW IT WILL AFFECT OZONE CONCENTRATION MEASUREMENTS

Comparable and accurate measurements of atmospheric ozone concentrations are essential for human health and the environment. There are a prevalence of standards and instruments based on the absorption of UV radiation at the mercury-line wavelength of 253.65 nm (air) for amount fraction measurements of surface ozone[1]. The uncertainty in the value of the ozone absorption cross-section per molecule is the biggest impediment to achieving accurate and SI-traceable values from ozone reference photometers and this value is an important anchor point for referencing the absorption cross-sections of ozone throughout the electromagnetic spectrum.

The results of several studies challenged the confidence in the conventionally accepted value for the ozone absorption cross-section at 253.65 nm (air). As ozone is highly reactive, the purity and uncertainty of the measured ozone concentration in the experiments of Bass and Paur [1] and others was difficult to quantify. This led to concerns of a potential bias in the reference absorption cross-section value. To quantify this bias, measurements based on UV absorption performed with a

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[1] “Amount fraction” is the short version of the term “amount-of-substance fraction” agreed by the CCQM. In this document, “concentration” can be used as an equivalent term.

Standard Reference Photometer (SRP) were compared to independent determinations of ozone concentration based on Gas Phase Titration (GPT). In two independent realizations of the GPT method, a 2 % − 3 % bias in the ozone reference absorption cross-section was observed by the National Institute for Environmental Studies of Japan (NIES) [2] and the BIPM [3], with the two methods reporting higher ozone concentrations than the SRP measurements. The most likely explanation was a systematic deviation in the ozone reference absorption cross-section, which usually represents the major uncertainty component in ozone measurements based on UV photometry. This bias is also consistent with expected changes at other wavelengths, detailed in the recommendations of the Absorption Cross-Section for Ozone (ACSO) committee [4], a joint initiative of the International Ozone Commission (IO3C), the World Meteorological Organization (WMO) and the Integrated Global Atmospheric Chemistry Observations (IGACO) O_3/UV Subgroup.

As a result, the Working Group on Gas Analysis of the Consultative Committee for Chemistry and Biology (CCQM-GAWG) convened a task group to review all published measurements of this quantity performed since 1950. It analysed literature values and uncertainties from fourteen independent sets of measurements spanning the years 1959-2016. From this study, a consensus value from a statistical analysis, 1.1329×10^{-17} cm^2 was recommended for the ozone absorption cross-section value with a standard uncertainty of 0.0035×10^{-17} cm^2 [4].

Implementation of this new value will lead to a significant improvement in the accuracy and coherence of surface ozone measurements. It is approximately 1.3 % lower than the conventionally accepted reference value, reported by Hearn [5], and has a smaller uncertainty. It will also improve the consistency of ozone measurements made throughout the electromagnetic spectrum, with the value at this wavelength providing a reference for other measurement systems.

2 KNOW YOUR INSTRUMENT

This section aims at helping users to clearly identify which ozone analyser they are using (section 3.1), how it is linked to a national, regional or global standard and which calibration strategy is followed (section 3.1.3), and the value of the ozone absorption cross-section in use (section 3.2). It ends with recommendations on flagging the ozone absorption cross-section being used in metadata, for those users who report their measured values to a data centre, typically as part of an environmental or climate observational programme (section 3.3).

2.1 Ozone analysers

2.1.1 Ultraviolet photometric method

The majority of ozone analysers are instruments based on the ultraviolet photometric method, as described in the ISO standard 13964:1998 “Air quality — Determination of ozone in ambient air — Ultraviolet photometric method”[2]. This method utilizes the absorption of a monochromatic radiation at the wavelength of 253.65 nm, emitted by a mercury discharge lamp, in the sample of air containing ozone.

These instruments include, at a minimum: a source of UV radiation which can emit light at 253.65 nm, one or two gas cell(s) in which the air sample is injected to absorb the UV radiation, and detector(s) to measure the intensity of the radiation after absorption.

There are many companies producing such instruments, and a variety of configurations can be found, such as:

- instruments configured with just one or two gas cells,
- different lengths of the gas cell(s) in which the absorption takes place,
- different materials for the gas tubing and the gas cell(s),
- the inclusion of an ozone generator or not,
- systems to control the temperature and/or the pressure,
- the presence of filters to purify the sampled air,

and other choices which can impact the quality of the measurement of ozone. Independent of such choices, all instruments based on the UV photometric method can deduce the ozone concentration in air samples by measuring the intensity of the light absorbed, which requires the ozone absorption cross-section at the wavelength of 253.65 nm to be known.

2.1.2 Nitric Oxide chemiluminescence and Gas Phase Titration

The nitric oxide (NO)-chemiluminescence method was approved as a Federal Reference Method (FRM) in the USA in 2015 and is described in the ISO standard 10313:1993. NO-chemiluminescence is the measurement of the intensity of chemiluminescence released by the gas phase reaction of ozone in air with NO gas. Although NO-chemiluminescence analysers do not use the ozone absorption cross-section values, they are calibrated by reference to certified ozone standards that are traceable to the NIST UV-based standard reference photometer (SRP). Therefore, NO-chemiluminescence analysers will follow the same guidance and

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[2] A list of written standards for ozone concentration measurements can be found in section 7.2

procedures as UV-based photometry analysers to update their measurement results through a calibration hierarchy.

2.1.3 Other ozone analysers

Any ozone analyser which is calibrated by reference to a certified ozone standard traceable to a primary instrument will follow the same guidance and procedures as UV-based photometry analysers to update their measurement results through a calibration hierarchy.

2.1.4 Metrological traceability

Metrological traceability (VIM3 2.41) is a property of a measurement result and means that the result of whatever level is connected to the realizations of SI-units by an unbroken chain of calibrations. This is also the case for the results of amount fractions of ozone in dry air.

On the primary level the traceability to the SI has to be established without reference to a measurement standard for a quantity of the same kind (VIM3 2.8). This means that all relevant input quantities for the calculation of an amount fraction of ozone in dry air *x*, as measured in a primary ozone photometer must themselves be SI traceable, as in the equation below which applies for dual cells UV photometers:

$$x = \frac{-1}{2\sigma L_{\text{opt}}} \frac{T}{P} \frac{R}{N_A} ln(D) \qquad (1)$$

where

- N_A is the Avogadro constant, 6.022 140 76 × 10^{23} mol^{-1}
- R is the gas constant, 8.314 462 618 J mol^{-1} K^{-1}
- σ is the absorption cross-section per molecule of ozone at 253.65 nm under standard conditions of temperature and pressure,
- L_{opt} is the mean optical path length of the two cells,
- T is the measured temperature of the cells,
- P is the measured pressure of the cells,
- D is the product of transmittances of two cells, with the transmittance (T_r) of one cell defined as

$$T_r = \frac{I_{\text{ozone}}}{I_{\text{air}}} \qquad (2)$$

where

- I_{ozone} is the UV radiation intensity measured from the cell when containing ozonized air, and
- I_{air} is the UV radiation intensity measured from the cell when containing pure air (also called reference or zero air).

The validity of this approach is verified in an ongoing key comparison BIPM.QM-K1) that confirms very good agreement between primary standards. In this comparison, SRP27 maintained by the BIPM is the agreed reference instrument against which all reference photometers are compared, either directly or indirectly via another reference photometer, such as SRP0 maintained by the NIST. This scheme is illustrated in Figure 1 below.

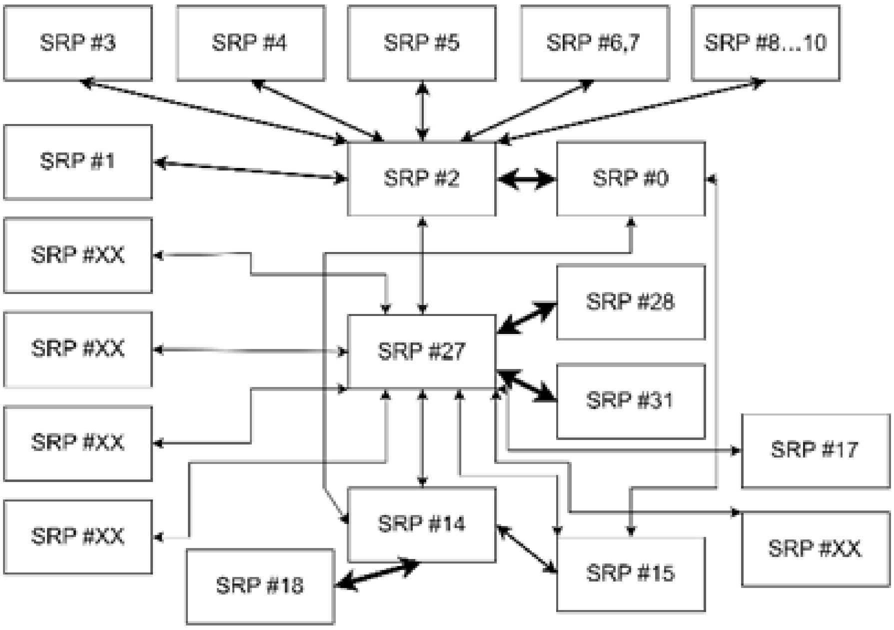

Figure 1 : Horizontal compatibility through traceability of input quantities for SRPs. The double-sided arrow indicates a comparison. The thickness of arrows stands for the frequency of comparisons.

The propagation of the quantity down to field level instruments according to the calibration hierarchy (VIM3 2.40) (traceability chain, VIM3 2.42) is then performed by calibration (VIM3 2.39) – most often over several levels (L1 to L4).

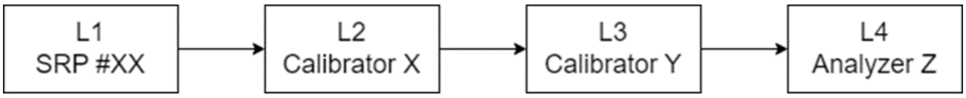

Figure 2 : Propagation of amount fraction of ozone in dry air through an unbroken chain of calibrations from a primary standard down to the field monitors, each step adding to the measurement uncertainty.

When calibrating an ozone analyser or calibrator (instrument, VIM3 3.1), the relation between the standard and the instrument is established and expressed in the form of a linear calibration function that may be used for correction.

Two main approaches for the dissemination of metrological traceability exist world-wide:

1. Adjustment (VIM3 3.11) or correction (VIM3 2.53): This approach uses the information gathered during calibration. With the adjustment approach, the offset and span settings in the instrument software are changed in conformity with the adjustment procedure defined. With the correction approach, the correction function is applied to the indicated values whereas the instrument

settings remain untouched. Both methods correct for known deviations and produce corrected, traceable values.

2. Verification (VIM3 2.44): This approach is often used in legal metrology and checks if the deviations (of values or calibration function variables) between standard and instrument are within the tolerances (also called maximum permissible errors MPE) that are agreed within a network. The network also determines the decision rules for conformity assessment by convention. When the results conform to the tolerance no action is required. When they do not conform, an adjustment procedure shall be performed based on the calibration function.

2.2 Ozone absorption cross-section value

Ozone standard reference photometers at National Measurement Institutes (NMIs) have previously used the value measured by Hearn in 1961 (code Hearn.1961) of the ozone absorption cross-section, equal to 1.147×10^{-17} cm^2 per molecule. As discussed in Rapport BIPM 2022/02 [6], it can happen that the exact value implemented in the data processing within an ozone photometer differs slightly from this value.

The new CCQM.O3.2019 value of the ozone absorption cross-section (stated as the same quantity) is 1.1329×10^{-17} cm^2 with a standard uncertainty of 0.0035×10^{-17} cm^2 (i.e. a relative standard uncertainty of 0.31 % relative). This new cross-section value is just over 1 % lower and its uncertainty is smaller than the uncertainty on the Hearn.1961 value. In practice the exact relative change in value and uncertainty between the Hearn.1961 and CCQM.O3.2019 cross-sections as implemented by the end-user will depend on the current numerical value being used in the photometer, which can differ by 0.025 % due to historical differences in conversion factors and rounding errors.

Rapport BIPM 2022/02 provides, in Table 1, the CCQM recommended value of the ozone absorption cross-section per molecule at 253.65 nm (in air) and its standard uncertainty with appropriate significant digits and rounding for use in documentary standards, expressed in the unit cm^2. It also provides values and uncertainties of three closely related quantities often found in the literature. These four values and uncertainties are reproduced in Table 1.

Table 1

Quantity	**Symbol**	**Value / unit**	**Standard uncertainty/ unit**
Absorption cross-section per molecule	σ	1.1329×10^{-17} cm^2	0.0035×10^{-17} cm^2
Mass absorption coefficient	α_m	1.4214×10^{-5} m^2 μg^{-1}	0.0044×10^{-5} m^2 μg^{-1}
Linear absorption coefficient at standard temperature and pressure (0 °C and 101325 Pa)	a_x	304.39 cm^{-1}	0.94 cm^{-1}
Absorption coefficient, at standard temperature and pressure (0 °C and 1 atm)	α_0	304.39 atm^{-1} cm^{-1}	0.94 atm^{-1} cm^{-1}

Appendix 2 of Rapport BIPM 2022/02 provides a table of the Hearn.1961 absorption cross-section expressed as different quantities, along with factors to convert from ozone amount fraction (nmol/mol) measured using a historical cross-section value to ozone amount fraction (nmol/mol) that would be measured using the CCQM.O3.2019 value of the ozone absorption cross-section [6].

For ozone analysers which perform measurements that are traceable to the SI through an unbroken chain of calibrations to standard reference photometers, the value of the ozone absorption cross-section used should clearly be stated on the certificate of calibration. In the unlikely event that this is not the case, the matter should be raised in the first instance with the calibrating laboratory, and (if necessary/appropriate) the relevant accreditation body.

2.3 Flagging and data use

To facilitate the change of the ozone absorption cross-section, surface ozone measurement networks, data centres, instrument manufacturers, research communities and metrology institutes are recommended to supply their ozone amount fraction data with the absorption cross-section value used for the measurement (Hearn.1961 or CCQM.O3.2019). This can be done either in the metadata of a time series, or as a flag for individual data entries in a time series.

For networks following the recommendation to add a flag, it is best that the implementation of the flagging/metadata is made before the change to the new cross-section value becomes effective (1 January 2025). Flagging or providing metadata stating the ozone absorption cross-section value of existing data series should be made before 1 January 2025. Information on the ozone absorption cross-section value should also be provided in the metadata or as a data flag for all future ozone amount fraction measurements at the latest from January 2025 onwards.

More background information and details can be found in a specific guidance document [7].

3 GUIDANCE FOR OPERATORS OF NIST SRP AND OTHER PRIMARY REFERENCE PHOTOMETERS

3.1 NIST SRP

The quantity implemented inside the control software of NIST SRPs is the absorption coefficient, at standard temperature and pressure (0 °C and 1 atm). NIST SRP users who have the latest **O3 Conductor** software (versions 2021 v03D and later) can choose which ozone absorption coefficient value they wish to use. All recent versions are currently setup for the Hearn.1961 value and there is a lock on the CCQM.O3.2019 value. This lock can be removed to allow use of the CCQM.O3.2019 value. The lock can then be put on the Hearn value once the change is implemented on 1 January 2025. The O3 Conductor software displays which ozone absorption coefficient value is used on the report template to avoid confusion.

NIST SRP users who are still using the outdated **SRP Control** software only have the Hearn value and no option to change to the CCQM.O3.2019 value. The SRP Control software was written in Visual BASIC version 6, which has not been supported by Microsoft for several years. Users of SRP Control software are invited to upgrade to the O3 Conductor software. In case of impossibility, all ozone concentration measurement results will need to be corrected.

3.2 KRISS Primary Reference Photometers

KRISS primary reference photometers, produced since 2011, use the Hearn.1961 value, 1.1476×10^{-17} cm^2. Users can check the actual value implemented in their photometers by clicking the ‘MENU’ on the front panel of the photometer controller (MENU > SETUP > FACTOR > ABSORPTION). In addition, users can change the value in the ‘ABSORPTION’ to the CCQM.O3.2019 value, which is 1.1329×10^{-17} cm^2, using keypads on the front panel of the controller.

3.3 UMEG (now LUBW)

The company LUBW (former name UMEG) manufactures ozone photometers which are intended to be used as a calibration standard. This instrument has no interface and no measurement recording. All calculations are performed in an Excel file, which also displays the ozone absorption coefficient. Users of this instrument should modify the value of the ozone absorption coefficient in the spreadsheet.

4 GUIDANCE FOR MONITORING NETWORK COORDINATORS AND INSTRUMENT OPERATORS

This section is aimed at providing guidance for those who run ozone monitoring networks and those who operate instruments in these networks. Because regional regulations and processes can differ, two examples are provided, one for Europe and one for the USA.

4.1 Deciding an implementation strategy

A network strategy plan is necessary to ensure the ozone absorption cross-section value is implemented in an effective and timely manner, while ensuring minimal interruptions to operations. The timeline below provides key milestones to meet the deadline of 1 January 2026.

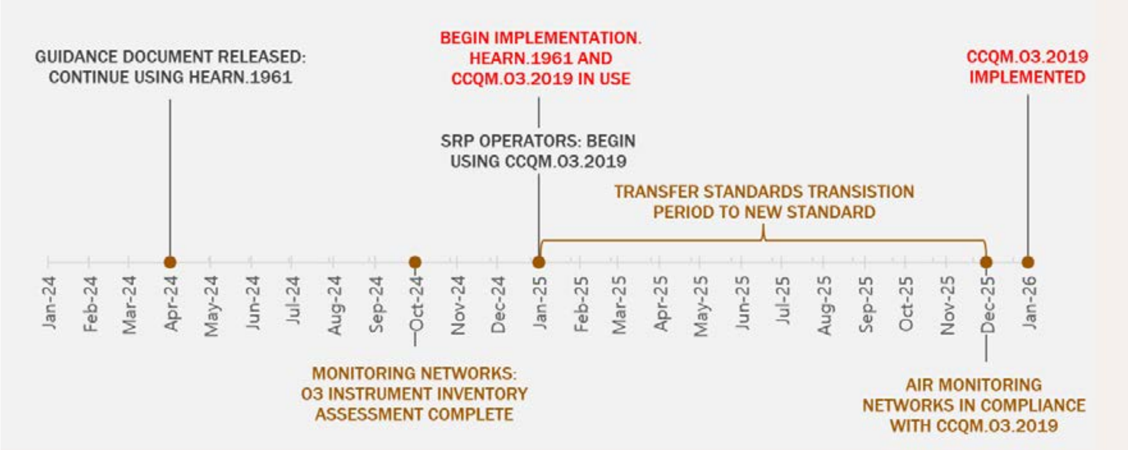

Figure 3 : Monitoring Network Implementation Timeline

There are several key factors that must be considered in developing and carrying out a network implementation strategy plan. Appropriate planning and organization of resources are needed to avoid duplication or gaps in the application of the ozone absorption cross-section value during the implementation period, which could jeopardize the accuracy of the air monitoring data.

Timeline: Generate and implement a timeline that works for your air monitoring network. This timeline must meet the CCQM.O3.2019 value implementation deadline of 1 January 2026.

Assess Instrument Inventory: Create a separate tracking system for the network ozone analysers, including standards at each level of calibration hierarchy. This can be an excel workbook or an addition to an already existing database system. Begin by recording the operating firmware version of your ozone instruments. Additionally, document whether the instruments are operating using the Hearn.1961 or CCQM.O3.2019 method for calculating the ozone display value.

Assess the metrological traceability: identify which approach is used for the dissemination of metrological traceability between the reference instrument of the network and field analysers (section 3.1.3).

Implement and Document: Begin implementation by conducting an “As-Is” verification (confirmation that performance requirements of the measuring system are achieved, before any adjustments are conducted). This is to ensure your instruments are still in control and your data collected over the previous 365 days are valid.

Documentation should include:

- New ozone instrument purchases and if they are operating using the CCQM.O3.2019 value;
- Instruments that received an As-Is verification (include parameters such as slope and offset); and
- Instruments that received an internal adjustment via comparison to a higher standard operating under the new CCQM.O3.2019 value (include parameters such as slope and offset).

Control Measures: Incorporate control measures to ensure instruments in the calibration hierarchy are following your network's implementation plan. For example, update documentation when new equipment is purchased, as it may be operating using the CCQM.O3.2019 value, and when adjustments or calibrations have been made to the instruments. Verify that all instruments have been updated, there has been no duplication of the CCQM.O3.2019 value causing an unnecessary multiplier and check for gaps to ensure all instruments are either operating using the CCQM.O3.2019 value or have received an adjustment via a higher standard which is operating using the CCQM.O3.2019 value. It is imperative to run control measures on a frequent basis and maintain the inventory of the network's ozone instrumentation and status, until all the network's instruments have been updated.

4.2 USA network example

Ensuring the validity of air monitoring data generated by the analyser at each monitoring station is essential. This data serves a multitude of purposes, including policy making, health assessment, environmental reporting, research studies, and more. To maintain the integrity of this vital data, both the air monitoring network and the Standard Reference Photometer (SRP) operators must adhere to a structured implementation procedure.

Before undertaking any verification adjustments, it is imperative to initiate the first step of a network implementation strategy plan with an initial verification test (As-Is verification). This includes transfer standards, station calibrators (1 point quality control/ zero/span check), and station analysers. This initial test confirms that the photometer was in control, thereby establishing the validity of the data over the previous certification period. Upon receipt of a Level 2 (or Level 3) transfer standard (bench or field), the operator of the Level 1 SRP will perform an initial verification using the Hearn.1961 value to ensure the instrument has maintained control during the previous certification period. If out of control, corrective action procedures and practices are to be followed to ensure the validity of the data. The SRP operator will continue with an internal adjustment (zero and span) to the Level 2 transfer standard, followed by a multi-point verification between the Level 2 transfer standard and SRP using the CCQM.O3.2019 value. As the network's Level 2 transfer standard ozone photometers are returned to the monitoring network from their annual verification, they will need to be treated as adjusted Level 2 transfer standards.

Ozone station analysers and station calibrators (1 point quality control/zero/span check) located at the air monitoring stations must have received the adjustment and verification by 31 December 2025.

To perform a verification with adjustment between an ozone transfer standard of higher authority to an ozone transfer standard of lower authority, the proper procedures outlined in the *Transfer Standards for Calibration of Air Monitoring Analysers for Ozone, Technical Assistance Document* must be followed:

https://www.epa.gov/system/files/documents/2023-11/o3_tad_508_20230906_final.pdf

It should be noted that there may be instances where instruments operating using the Hearn.1961 value, when compared to a higher standard operating the CCQM.O3.2019, are within required passing criteria per network regulations. In those instances, calibration or the internal adjustment of zero and span is performed to ensure the entire calibration hierarchy is adjusted in relation to CCQM.O3.2019.

The only exception to adjustment of ozone transfer standards and ozone analysers is when new instruments with updated firmware have been purchased from a vendor and are already operating with the CCQM.O3.2019 value and are within the required passing criteria per document.

By 1 January 2026, all air monitoring networks must have completed the implementation and must be adhering to the flagging and data use guidelines found in section 3.3.

No corrections and flagging of data will be made for the years up to and including 2024.

4.3 European network example

In Europe, transfer reference photometers are usually calibrated every six months against an SRP at an NMI. Analysers at air quality monitoring stations are calibrated every three months using these transfer reference photometers.

These frequencies of calibrations will not change upon the date of adoption of the CCQM.O3.2019 cross-section (1 January 2025), and there will be no immediate need to calibrate either transfer reference photometer or analysers at air quality monitoring stations, unless their re-calibration is already due.

Instead, calibrations will continue at the usual frequency. The CCQM.O3.2019 cross-section will be used from 1 January 2025, and will be rolled out through calibrations of reference photometers and analysers at air quality monitoring stations throughout 2025. All analysers at air quality monitoring stations should therefore be taking measurements using the CCQM.O3.2019 cross-section by no later than the end of 2026.

Data produced by ozone analysers at air quality monitoring stations during 2025 will be initially disseminated in near-real-time without correction. i.e data produced before and after the first calibration using the CCQM.O3.2019 cross-section will respectively, use the Hearn.1961 and CCQM.O3.2019 cross-section.

At the end of 2025 the annual data ratification process will correct the data produced using the Hearn.1961 cross-section to concentrations as if measured using the CCQM.O3.2019 cross-section, using the appropriate conversion factor in BIPM Rapport 2022-02. No corrections will be made to data from years up to and including 2024.

It is recommended that any websites which allow users to download ozone data during 2025 include a clear statement explaining the above process.

5 GUIDANCE FOR GROUPS MAINTAINING HISTORICAL RECORDS AND DATABASES OF SURFACE OZONE CONCENTRATIONS

In order to ensure consistency of ambient ozone measurement data based on UV-absorption at a variety of platforms, including ground-based in situ and remote sensing, sonde and satellite observations, it is important to inform the user community about the changes in ozone absorption cross-section values used for the calculation of ozone amount fraction. For that purpose, metadata associated with the measurement data needs to be flagged to clearly identify which cross-section value is used for measurement (CCQM.O3.2019 or Hearn 1961).

This can either be done in the metadata of a time series, or as a flag for individual data entries in a time series. Information on the ozone absorption cross-section value must also be provided in the metadata or as a data flag for all future ozone amount fraction measurements. Database managers are requested to prepare the metadata template with the flagging of which cross-section value is used for measurement (e.g., old data without any flag, only new data with a flag to indicate the new cross-section value is used). They should also request the data submitters to make it clear if their instruments are making measurements using the new cross-section value correctly, or to which absorption cross-section the measurements are referenced. It is particularly important in order to avoid confusion or mis-interpretation in the long-term trend analysis, caused by potential step function effects, especially over the transition period. In addition, managers should alert the data users to make it clear in their papers/reports which cross-section value is used for analysis.

6 REFERENCES

6.1 Peer reviewed papers

[1] Bass A.M. and Paur R.J. 1984 The ultraviolet cross-section of ozone I: Measurements. In: *Quadriennial Ozone Symposium,* ed C Zeferos and A Ghazi (Halkidiki, Greece: Reidel, Dordrecht) pp 606-616,

[2] Tanimoto H., Mukai H., Shigeru H. and Norris J.E., 2006, Intercomparison of ultraviolet photometry and gas-phase titration techniques for ozone reference standards at ambient levels, *J. Geophys. Res.*, **111**, D16313, 10.1029/2005JD006983

[3] Viallon J., Moussay P., Flores E. and Wielgosz R.I., 2016, Ozone Cross-Section Measurement by Gas Phase Titration, *Anal. Chem.*, **88**, 10720-10727, 10.1021/acs.analchem.6b03299

[4] Hodges J.T., Viallon J., Brewer P.J., Drouin B.J., Gorshelev V., Janssen C., Lee S., Possolo A., Smith M.A.H., Walden J., et al., 2019, Recommendation of a consensus value of the ozone absorption cross-section at 253.65 nm based on a literature review, *Metrologia*, **56**, 034001, https://doi.org/10.1088/1681-7575/ab0bdd

[5] Hearn A.G., 1961, The absorption of ozone in the ultra-violet and visible regions of the spectrum, *Proc. Phys. Soc.*, **78**, 932-940, https://doi.org/10.1088/0370-1328/78/5/340

[6] Davis R.S., Niederhauser B., Hodges J.T., Viallon J. and Wielgosz R.I. BIPM 2022 Units and values for the ozone absorption cross section at 253.65 nm (air) with appropriate significant digits and rounding for use in documentary standards **Rapport BIPM-2022/02** p 16, https://doi.org/10.59161/Rapport202202

[7] Zellweger C., Norris J.E., Niederhauser B., Travnicek W., Minkos A., Xu X., Lee S., Solberg S., Cooper O., Smit H.G.J., et al. BIPM 2024 Change in the value of the UV ozone absorption cross section: Recommendations for metadata provision **Rapport BIPM-2024/01** p 4, https://doi.org/10.59161/Rapport202401

6.2 Documentary standards

The list below includes all documentary standards identified by authors of these guidelines, sorted according to which value of the UV ozone absorption cross-section is recommended in the document:

6.2.1 Documentary standards recommending CCQM.O3.2019:

International Standard ISO 13964 (1998) /DAmd 1, Air quality - Determination of ozone in ambient air - Ultraviolet photometric method – Amendment 1 expected to be published in 2024

International Standard ISO 10313 (1993) /DAmd 1, Ambient air - Determination of the mass concentration of ozone - Chemiluminescence method – Amendment 1 expected to be published in 2024

European Standard EN 14625 (20XX), Ambient air - Standard method for the measurement of the concentration of ozone by ultraviolet photometry – expected to be published in June 2024

US EPA Code of Federal Regulations Part 50 Appendix D - Reference Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere (Chemiluminescence Method) – published November 2023

ASTM Standard D5110-98 (2022), Standard Practice for Calibration of Ozone Monitors and Certification of Ozone Transfer Standards Using Ultraviolet Photometry

ASTM Standard D5110-02 (2022), Standard Test Methods for Continuous Measurement of Ozone in Ambient, Workplace, and Indoor Atmospheres (Ultraviolet Absorption)

Japanese Standard JIS B 7957 (2006)/AMENDMENT 1: 2023, Continuous analysers for ozone and oxidants in ambient air – published September 2023

Australian Standard AS 3580.6.1 (2023), Methods for sampling and analysis of ambient air, Method 6.1: Determination of ozone - Direct-reading instrumental method

6.2.2 Documentary standards recommending Hearn.1961:

International Standard ISO 13964 (1998), Air quality - Determination of ozone in ambient air - Ultraviolet photometric method

International Standard ISO 10313 (1993), Ambient air - Determination of the mass concentration of ozone - Chemiluminescence method

Chinese Standard HJ 590 (2010), Ambient air - Determination of ozone - Ultraviolet photometric method

DOI https://www.bipm.org/doi/10.59161/Rapport202403