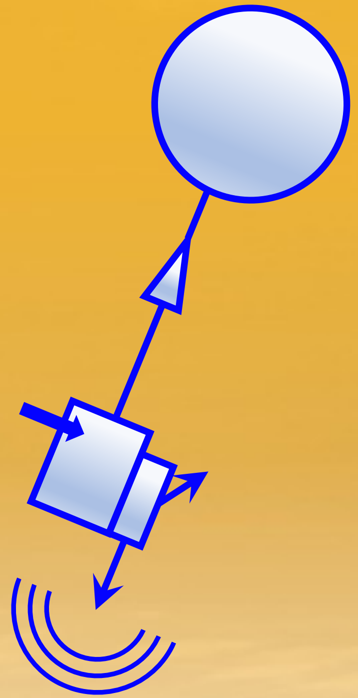
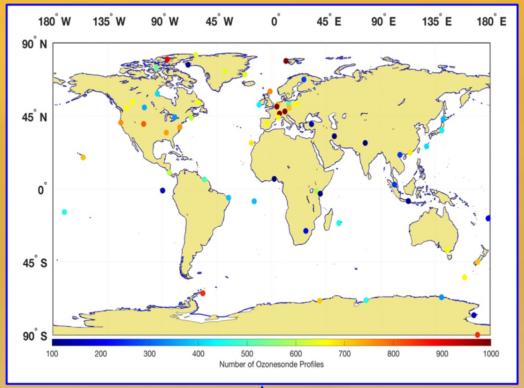
Ozonesonde Measurement Principles and Best Operational Practices

ASOPOS 2.0 (GAW Report No. 268)

(Assessment of Standard Operating Procedures for Ozonesondes)





Webinar No. 2: Hardware

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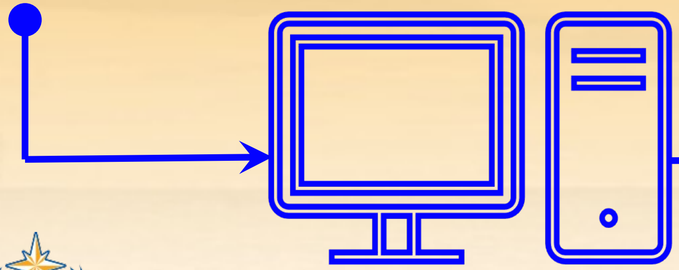

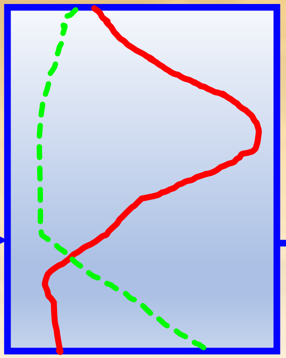

Version March 2024

WORLD METEOROLOGICAL ORGANIZATION

GRUAN

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NASA

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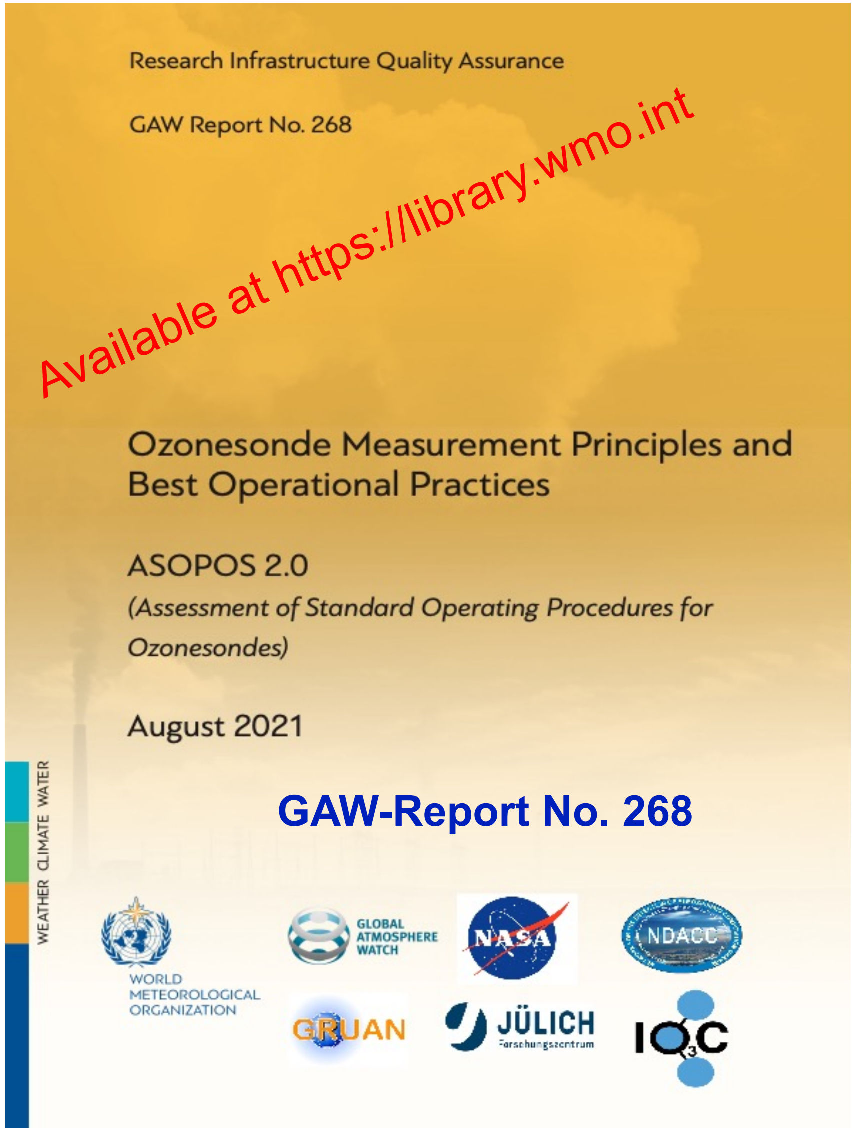
GLOBAL ATMOSPHERE WATCH

Preamble


Research Infrastructure Quality Assurance

GAW Report No. 268

Available at https://library.wmo.int

Ozonesonde Measurement Principles and Best Operational Practices

ASOPOS 2.0

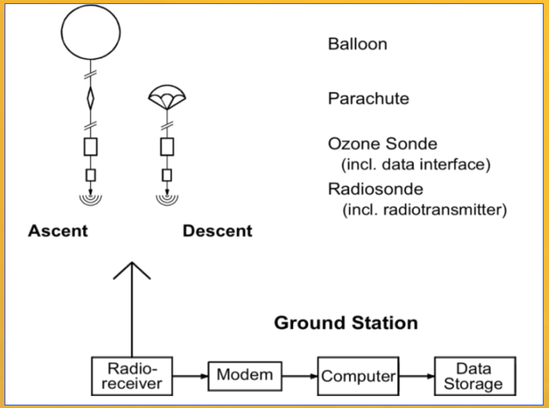
(Assessment of Standard Operating Procedures for Ozonesondes)

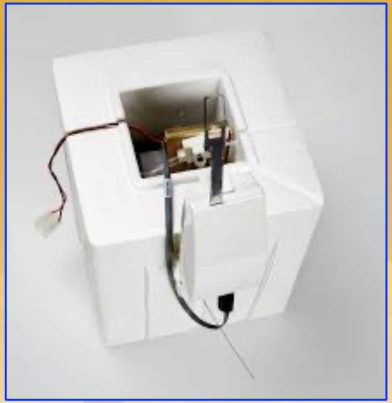
August 2021

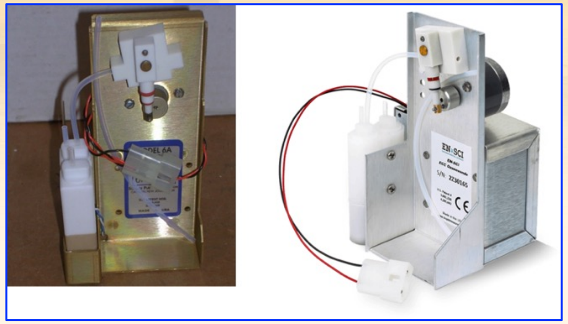
GAW-Report No. 268

- This ASOPOS 2.0 Report builds on the earlier ASOPOS 1.0 (GAW Report No. 201, 2014)
- In general, the hardware used for ozonesoundings has been described in Chapter 2 in general and in more detail in Annex A of the ASOPOS 2.0 Report (WMO/GAW Report No. 268).
- In this Webinar **only** most crucial and critical aspects of the hardware and their limitations will be highlighted and explained
- Because they have shown in practice to have a significant impact on the performance of the ozonesonde and the quality of the measured sounding data.

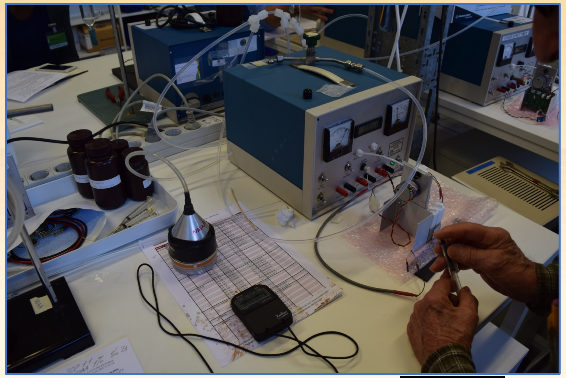
Outline





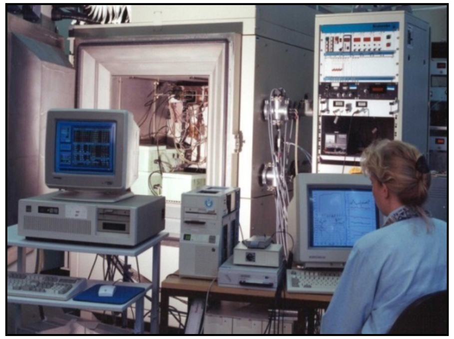


- Introduction
- Ozonesonde-Radiosonde-Interface
- Preparation: Working space and Hardware
- Proper Gas Filters
- Sensing Solutions & Laboratory Tools
- Regular Maintenance
- Key Notes

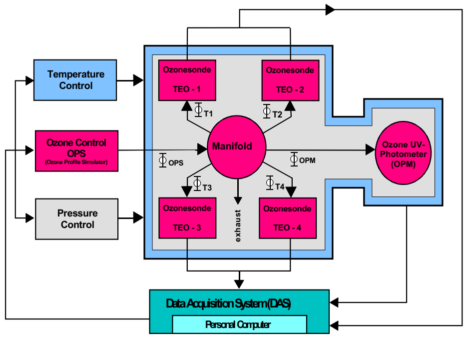


WORLD METEOROLOGICAL ORGANIZATION GRUAN JÜLICH Forschungszentrum NASA NDACC IO3C GLOBAL ATMOSPHERE WATCH

Introduction: 25 years of QA have learned us *(Chapter 1 of GAW No. 268)*



WCCOS



JOSIE

BESOS

25 years of quality assurance work (WCCOS) in the laboratory (e.g. JOSIE) and in the field (e.g. BESOS) have clearly demonstrated *(See also Webinar No.1, Part 1) that:*

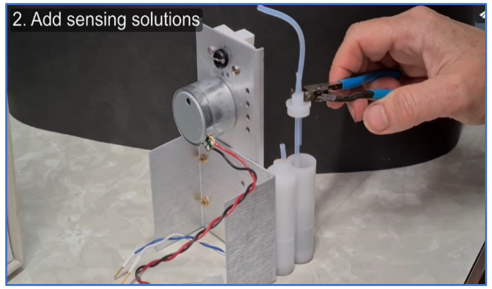
- ❑ Small changes of the ECC-instrument by the manufacturers or operating procedures at the sounding station can easily introduce artefacts of 5-15 % or even higher
- ❑ Well prepared ECC sondes can achieve 3 % precision
- ❑ Target of ASOPOS 2.0: 5 % overal uncertainty in the global ozonesonde network.
- ❑ But this is only achievable:
  - By following strict and unified SOPs
  - Using well maintained hardware for the preparation of the ECC-sonde
  - All handlings have to be done under cleanliness conditions *(See also Webinar No. 3 on SOPs).*

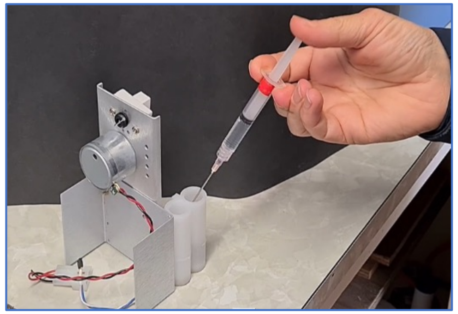
WORLD METEOROLOGICAL ORGANIZATION GRUAN JÜLICH Forschungszentrum NASA NDACC IO3C GLOBAL ATMOSPHERE WATCH

Introduction: The Achilles Heel of the ECC-Ozonesonde

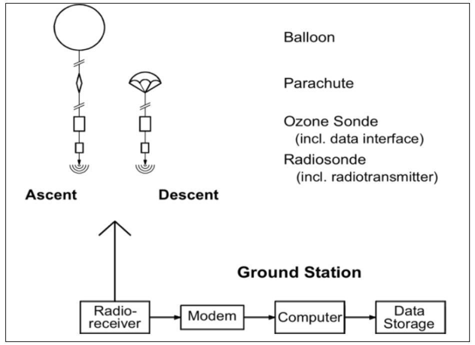
One of the most critical factors in ozonesonde preparation is the composition of chemical solutions in the electrochemical cells. The handling of the instrument and the cells during the preparation steps strongly affect the sonde performance once the sonde is launched. The best way to ensure accurate measurements is by having:

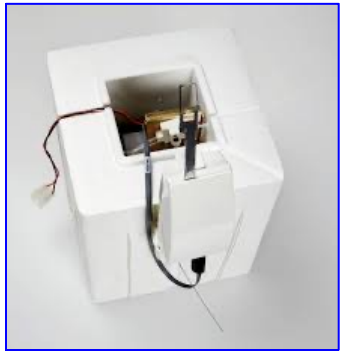
- ❑ Well-maintained, up-to-date hardware
- ❑ Proper handlings of chemicals and sensing solutions
- ❑ Clean working space





Introduction: Overview of the Hardware *(Annex-A of GAW No. 268)*





Balloon-Gondola:

1. OzoneSonde
   A. ECC ozone sensor
   B. Interface Board
   C. Radiosonde (incl. 403 MHz-Transmitter)
2. Styrofoam box
3. Balloon,
4. Unwinder,
5. Radar Reflector & Parachute

Data Receiving Unit (DRU):

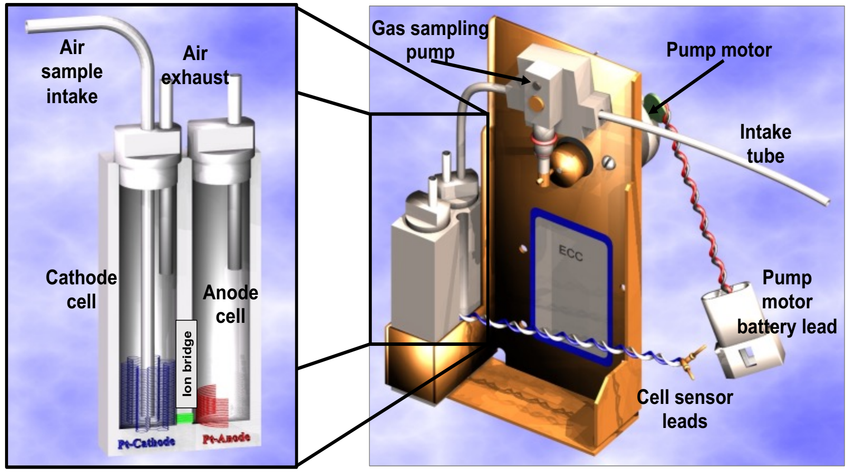
1. Antenna-Receiver-Modem-Computer
2. Flight Data Processing Software
3. Data Storage
4. Data Submission in Data Archive(s)

Pre-Flight Preparation :

1. Clean Laboratory to prepare the Sonde
2. Preparation Check Unit (e.g. KTU-3)
3. Zero ozone and purified air: Proper filter
4. Bubble Flowmeter
5. P,T and RH Laboratory Detectors
6. High graded chemicals (KI, KBr & Buffer)
7. High graded liquid water

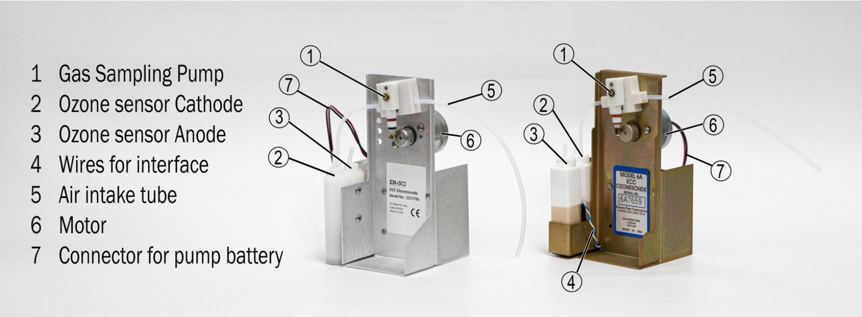
Maintenance:

1. Preparation Check Unit (PCU):
   - Zero-Purified Air Filter
   - UV-Lamp & UV-Quartz glass-cuvette producing ozone
2. Automatic flow meter:
   - Compare with bubble flow meter regularly



$$P_{O3} = 0.043085 * \frac{T_P}{(\eta_P * \eta_A * \eta_C * \Phi_{P0})} * (I_M - I_B) \quad \text{[E-2-1]}$$

pump temperature (T_P); *measured cell current* (I_M); *pump, absorption, and conversion efficiencies* (η_P, η_A, η_C); *pump flow rate* (Φ_{P0}); *background current I_{B1}* (I_B)



- A small pump forces ambient air through the low concentrated aqueous KI-sensing solution in the cathode chamber of an Electrochemical Concentration Cell (Komhyr 1969)
- Ozone is converted into iodine by the reaction:

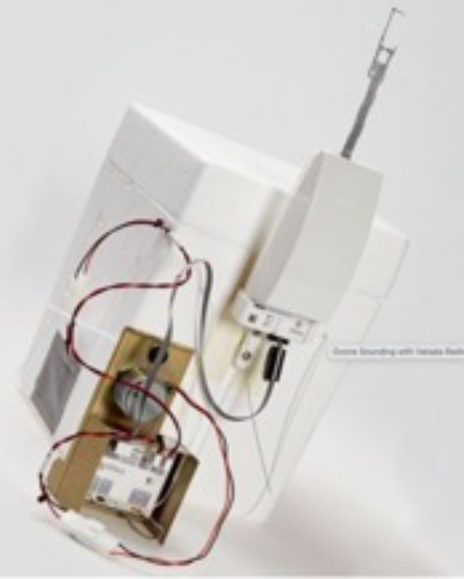
$$2KI + O_3 + H_2O \rightarrow I_2 + O_2 + 2KOH$$

- At a platinium cathode the Iodine is converted to Iodide by the uptake of 2 electrons by one Iodine molecule:

$$I_2 + 2e \xrightarrow{Pt} 2I^-$$

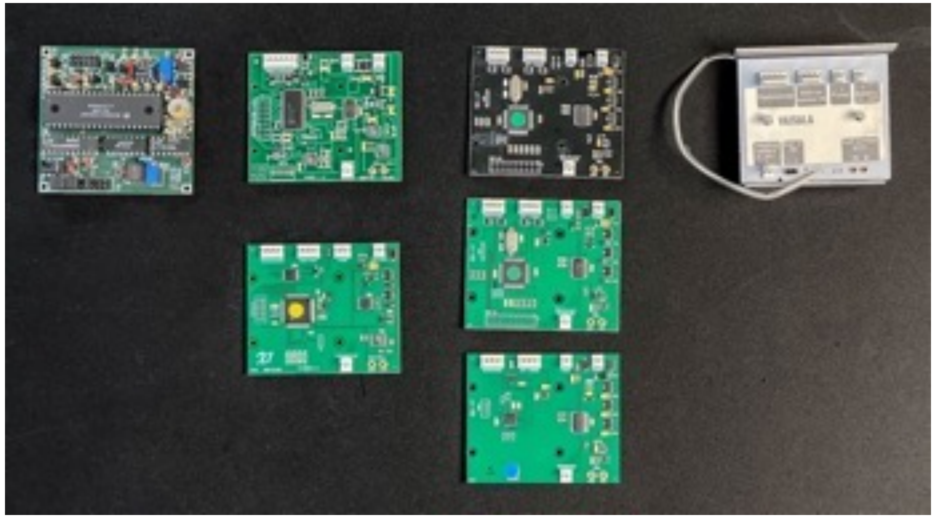
- In external electrical circuit a current is generated directly related to the uptake rate of ozone in the sensing cathode solution.
- Two manufacturers of ECC-ozonesondes (SPC and En-Sci)
- Three different KI-sensing solution types are used in the global sonde network

Radiosonde (RS) and Data Interface Board (DIB) *(Section 2.4 of GAW No. 268)*



Radiosondes can measure:

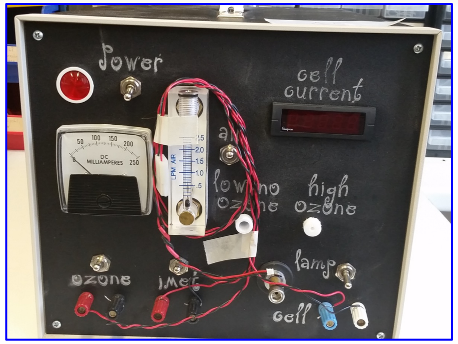
- P (Pressure)
- T (Temperature)
- U (Rel. Humidity)
- Wind (Direction and horizontal Velocity)
- GPS-Latitude
- GPS-Longitude
- GPS-Metric Altitude
- Geopotential Altitude derived from PTU



Data Interface Board can measure:

- Electrical current of ECC-sensor (I_M)
- Pump temperature (TP)
- Optional in addition:
  - Applied voltage of pump motor
  - Electrical current of pump motor
  - Temperature cathode cell solution
  - Rotation speed pump motor

Preparation Check Unit (PCU): Key Requirements *(Section 4.2.5 of GAW No. 268)*



Home Made

ENSCI-KTU-3

Home Made

- ❑ Provision for the flow of **purified and ozone-free air** (500–1000 ml/min) through the **use of appropriate gas filter techniques**
- ❑ High ozone source for conditioning (cleaning) of the inlet tube, pump, and when dry, also the cathode cell.
- ❑ Low ozone source (variable) that supplies 0–250 ppbv ozone at 500–1000 ml/min
- ❑ 12 V power to operate the pump motor.
- ❑ Measurement of applied voltage pump motor (0–20 V, uncertainty 0.05 V or better) and its current (0–250 mA, uncertainty 5 mA or better)
- ❑ Measurement of ECC cell current ***I_M (Incl. I_{B0} and I_{B1})*** (Range: 0–10 µA; Resolution: 0.005 µA: Uncertainty: 0.01 µA or better at $I_M < 1$ µA and 1% of I_M or better at $I_M > 1.00$ µA).

Preparation Check Unit (PCU): Some Critical Remarks

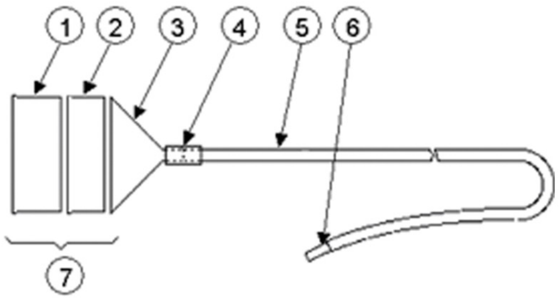
SPC: TSC-1 Unit

- It is strongly recommended that stations check their preparation unit to make sure that it has not been deteriorated over time: **Regular Maintenance is Important!**
- The ASOPOS Panel strongly recommend **NOT** to use the so-called calibrator cell with which some of the preparation units (e.g. TSC-1 Unit) are equipped.
- A number of preparation units are commercially available (e.g. Ensci's KTU-3 or SPC's TSC-1).
- **BUT: SPC TSC-1 Unit is out of time and needs an upgrade: Contact ASOPOS-Panel**

Placeholder Gasflow diagramm (To be Done)

Purified & Zero Air Supply: Proper Gas Filters (1)

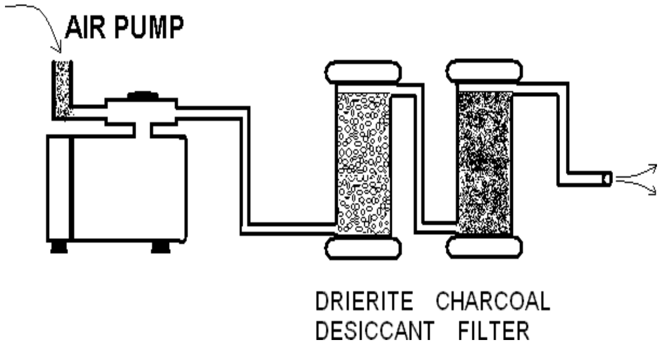
Examples of filters that only destroy ozone but **NOT** purify the air:



1: Catalyst
2: Ultra fiber

- ❑ Extreme important is to have accurate background current measurements (See Table 5-1 of Chapter 5 of GAW No. 268) of:
  - I_{B0}: Before exposure with ozone
  - I_{B1}: After exposure with ozone
- ❑ **Too high Background currents I_{B0} and I_{B1} will deteriorate the quality (e.g. uncertainty) of the ozone measurement**
- ❑ Unfortunately the relative simple gas filters (See left some different Ozone Destruction Filters) used by many stations (now and in the past) are only removing ozone but **NOT** purifying the air from impurities
- ❑ Therefore it is important to have ozone free air of high purity
- ❑ This can be achieved only by the use of an appropiate gas filter

Purified & Zero Air Supply: Proper Gas Filter (2)



Drierite Desiccant

Two-Stage Gas Filter

- **Proper gas filter must**
  - A. **dry the air**
  - B. **remove the ozone from the air**
  - C. **purify the air**
- This can best obtained by (a) filter(s) that contain(s) a cascade of
  - I. drierite desiccant (silicagel) with moist (color) indicator
  - II. active carbon or charcoal
  - III. optional: molecular sieve (4-6 Å)
- The filter have to be checked regularly if the silicagel is still dry (moist (color) indicator). All 2 or 3 filter stages can be heated at least at 100-200 °C for more than 24 hours in order to “clean” and “dry” the absorbers (Regular Maintenance!!).
- ASOPOS Panel recommends the station operators to check their filters and consult ASOPOS-Team how to proceed further.

Sensing Solutions: Requirements *(See Annex A of GAW No 268)*

Table 2-2 of GAW No. 268

Sensing Solution Type (SST)	KI [g/L]	P_H-Buffer		KBr [g/L]
		$NaH_2PO_4.H_2O$ [g/L]	$Na_2HPO_4.12H_2O$ [g/L]	
SST1.0: 1.0% KI & full buffer [(a)]	10	1.250	5.0	25
SST0.5: 0.5% KI & half buffer [(b)]	5	0.625	2.5	12.5
SST0.1: 1.0% KI & 1/10th buffer [(c)]	10	0.1250	0.5	25

Ozonesonde Test Kit

- Three different Sensing Solution Types (see left: ***SST1.0***, ***SST0.5*** and ***SST0.1***) are used in the global sonde network
- High-purity chemicals (***KI***, ***KBr*** and ***Na-Phosphate Buffer***)
- High-purity grade water to prepare aqueous anode and cathode sensing solutions
- It is important to follow general rules of cleanliness:
  - Clean laboratory tools (e.g. flasks, burettes, syringes etc.)
  - Clean handling: Recommended are single-use medical gloves
  - Following the practical guidelines of ASOPOS 2.0 as described in Annex A of GAW Report No. 268

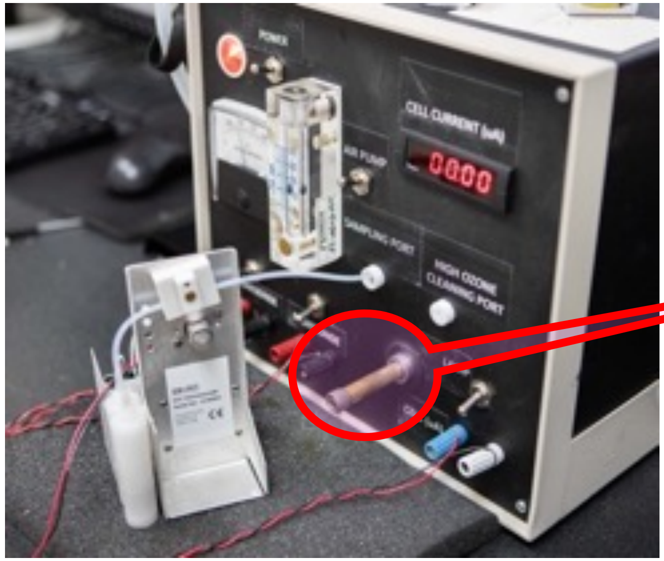
Preparation Laboratory: Requirements *(Annex-A of GAW No. 268)*

- **Clean Working Space:**
  - No Smoking
  - No Food
  - No Drinks
- **Clean Working Bench**
- **Ambient Air Detectors to record:**
  - Pressure (P: +/- 0.5 hPa)
  - Temperature (T: +/- 0.2 K)
  - Relative Humidity (RH: +/- 5 %)

Proper In-Flight Pump Temperatures

- A proper pump temperature is important so that no freezing or evaporation (by boiling) of the sensing solutions can occur in the course of the sounding.
- Important: Note that in the course of the sounding the solution temperature in the cathode cell generally becomes lower than the pump temperature: SPC-6A sondes by up to 5^{o}C and ENSCI sondes by up 10^{o}C.
- Optimum pump (i.e. cell) temperature should be **as low as possible** to prevent large losses of sensing solution (**evaporation or spraying**), particularly when reduced air pressures (< 20-30 hPa) increase the potential for boiling, but **not too low** to avoid **freezing**!
- Depending on the ECC sonde type the optimum pump temperature for SPC sondes should be 5-10 ^{o}C and for En-Sci sondes 10-15 ^{o}C over the course of the sounding, such that the temperature of the cathode solution is maintained above its freezing point.
- A proper in-flight pump temperature can be achieved through the use of :
  I. Passive heat source: Add an air free water bag/can as heat capacity
  II. Active (electrically) controlled heat source: only turned on when the pump temperature falls below a certain threshold and turned off when the pump temperature is above the threshold (can be integrated in the interface)

Maintenance: Preparation Check Unit (PCU)



Entry UV-Lamp

Housing UV-Cuvette

1. **Check the UV-Lamp (UV of 185 nm)**
   - Is there a change in the position of the <u>"movable UV-light shielding tube"</u> that is used to test the 5 µA cell current (more than 20% change in the full length of the shielding tube)?

   ➢ ***If yes, then install a new lamp.***

2. **Check the UV-Quartz glass cuvette cleanliness:**
   - Even if the UV-Lamp is okay, there can still be more than an apparent 20% change in full length of the shielding tube due to a degraded transparency from a dirty cuvette
   - In case the gas filter is okay, but the background currents $\boldsymbol{I_{B0}}$ and $\boldsymbol{I_{B1}}$ are systematically too high and NOT within the recommended values.

   ➢ ***If the cuvette is not clean, then replace it with a new one.***

Maintenance: Zero Ozone Air Supply and Automatic Flowmeter

1. **Zero Ozone-Purified Air Supply:**
   - Check Zero Ozone -Purified Air Filter (moist indicator), especially when background currents are NOT within recommended I_{B0} and I_{B1} values.
     - *If the filter has degraded, replace with a new (or regenerated) Zero Ozone-Purified Air Filter*
     - *The filter can be regenerated by removing moisture in the absorbent. Heated at 100-200^{o}C for at least 24 hours*
2. **Automatic flowmeter:**
   - If an automated flowmeter is used, compare and record the readings with a calibrated bubble flow meter about **every month**.
     - *If agreement not within 0.5-1%: the automatic flowmeter needs to be repaired/recalibrated by its manufacturer*

ASOPOS 2.0 Webinar No.2 Hardware: Key Notes

- Regular check and maintenance of the ground equipment at the station is important.
- It is strongly recommended that stations check their preparation check unit to make sure that it has not been degraded over time.
- Unfortunately the relative simple gas filters used by many stations in the network are improper and cause too high background currents I_{B0} and I_{B1}, which deteriorate the quality (e.g. uncertainty) of the measurement.
- Proper gas filters must (i) dry the air; (ii) remove the ozone and (iii) purify the air from impurities. Regular maintenance through exchange of gas filter is essential!!
- ASOPOS Panel recommends the station operators to check their filters and consult ASOPOS
- High graded purity of chemicals (KI, KBr and Na-Phosphate Buffer)
- High graded purity of water to prepare aqueous anode and cathode sensing solutions
- Important to follow the general rules of cleaniness in the laboratory and during preparation!!

Only then we can achieve the target to get an overall uncertainty of 5% !!!

Closing Remarks

- This webinar no. 2 is part of a series of ASOPOS Webinars:
  1. Introduction to ASOPOS 2.0: An Overview *(Anne Thompson & Herman Smit)*
  2. Hardware *(Herman Smit & Roeland Van Malderen)*
  3. SOP: Standard Operating Procedures *(Roeland Van Malderen, Peter von der Gathen, Gary Morris & Bryan Johnson)*
  4. Data Processing *(Herman Smit & David Tarasick)*
  5. Data Quality Indicators (DQI) *(Ryan Stauffer & Holger Vömel)*
  6. Meta Data and Software *(Ryan Stauffer & Roeland Van Malderen)*
- The webinars do not replace the Report or associated video clips, but only highlight the most important topics and updates from the previous ASOPOS 1.0 report (WMO/GAW Report No. 201).
- **Whenever you have questions or need advice, consult the authors of this webinar or any of the ASOPOS Team members listed above !!!**

Thank you for your attention. We look forward to future collaborations!!!