SCIENCE PUMP CORPORATION

OPERATOR'S MANUAL

MODEL 6A ECC OZONESONDE

6th June 2014
Vaisala Update

Contents

1. INTRODUCTION

Science Pump Corporation has manufactured and distributed the vast majority of balloon-borne ozonesondes used since the introduction of the ECC type ozonesonde. Scientists and investigators worldwide have flown well over 15,000 ozone soundings using SPC ozonesondes. SPC has now re-engineered the basic ECC type ozonesonde and developed the SPC Model 6A ECC ozonesonde. The model 6A incorporates several new features and improvements over previous ozonesondes See Figure 1

A re-engineered nonreactive Teflon-PTFE gas-sampling pump will provide the user with a significantly improved level of performance consistency and reliability during flight.

A new electronically governed pump motor will eliminate the r.f. Interference experienced with previous motors, which were mechanically governed.

Inserting temperature sensor into the ozonesonde pump base can monitor the Model 6A-ozonesonde-pump temperature.

The Model 6A ozonesonde is easily prepared for use and when flown with Vaisala meteorological equipment is capable of providing accurate ozone data on an absolute scale.

Figure 1 Ozonesonde with Vaisala OIF92 interface

Various intercomparisons have been carried out with different types of ozone measurement systems. The Vaisala Ozone Measurement System has been tested in international WMO intercomparisons. The report on these can be found in Ref. /13/. Ref. /6/ gives a good review on the accuracy of different types of ozone sensors.

The ECC-6A Ozone Sonde in combination with Vaisala interface to Vaisala Radiosondes have been tested according to applicable provisions of EU directives by Vaisala and have been found to be in conformity with these.-

Specifications

Ozonesonde Size: 19.1 x 19.1 x 25.4 cm, including weatherproof polystyrene flight box.

Ozonesonde Weight: Approximately 600 grams including battery.

Pump Characteristics: minimum pressure, 670 hPa

Minimum vacuum, 670 hPa

Current draw less than 115 mA

Air flow rate 194-223 ml $min.^{-1}$

Operating Temperature Range: 0° to 40° C (temperature inside the flight box must be above 0° C)

Operating Pressure Range: Sea level to 3 hPa

Measurement Principle: Coulometric, employing a patented electrochemical concentration cell *, and a patented nonreactive Teflon gas sampling pump**.

Sensitivity: 2 to 3 parts per billion by volume ozone.

Noise: Less than 1 % of full scale

Estimated Measurement Uncertainty: less than +/- 10 % of indicated value.

* US Patent No. 3,681,228

** US Patent No. 4,285,642

2. BASIC PRINCIPLES OF OZONE MEASUREMENT

2.1 Ozone Sensor Operating Principle

The ozone sensor used within the ozonesonde is an iodine-iodide redox electrochemical concentration cell made of two bright platinum electrodes immersed in potassium iodide solutions of different concentrations contained in separate cathode and anode chambers that are fabricated from polytetrafluoroethylene (Teflon TFE resin). The chambers are linked together with an ion bridge that serves as an ion pathway and retards mixing of the cathode and anode electrolytes, thereby preserving their concentrations. The ECC sensor does not require application of an external emf for operation. Driving emf for the cell is derived from a difference of potassium iodide concentrations present in the two half cells. See Figure 2

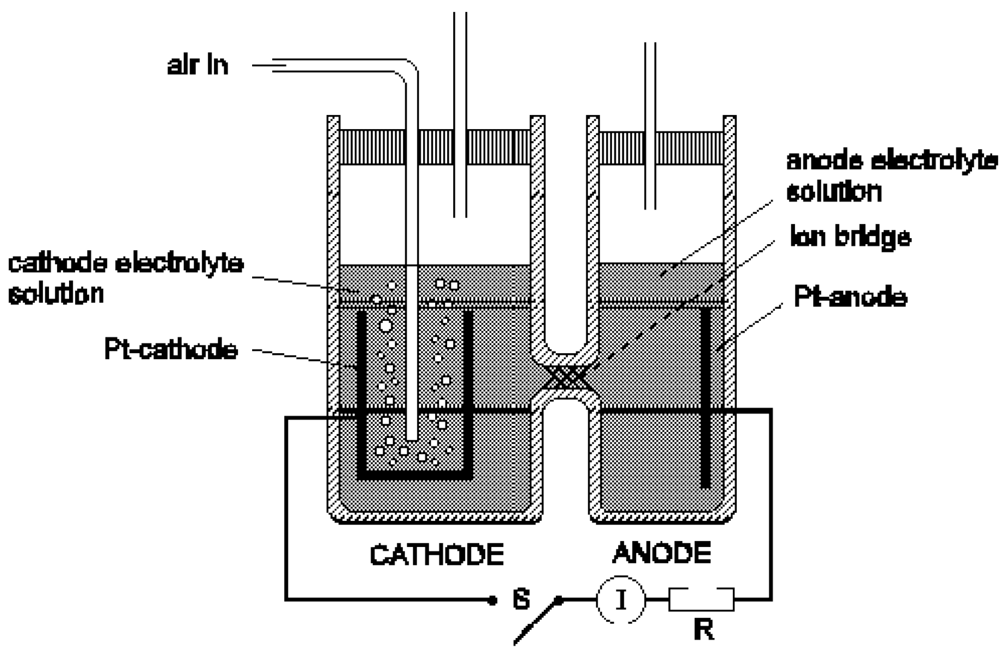


Figure 2 Electrochemical cell construction

A chemical reaction starts as soon as ozone (in air) flows into the cathode solution. The reaction is an iodide-iodine redox reaction. The current can be measured when the switch S is closed. R is the load resistance of the circuit.

Sensor Solutions

Sensor solution requirements are very strict. The ECC sensor solutions should be prepared using at least pro analysis chemicals and triple distilled water.

(1) Cathode Solution:

To 500 ml of distilled water add:

(a)	10.00 g	KI
(b)	25.00 g	KBr
(c)	1.25 g	$NaH_2PO_4 \cdot H_2O$
(d)	5.00 g	$Na_2HPO_4 \cdot 12\ H_2O$
	or 3.73 g	$Na_2HPO_4 \cdot 7\ H_2O$

Shake vigorously to dissolve the chemicals and add triple distilled water to get 1000 ml of cathode sensing solution.

NOTE

Total volume of 1000 ml is a NOAA preference /1/ and gives a KI solution of 1 % . This causes a 5 % error in the indicated ozone amount, but evaporation (i.e. solution concentration increase) during sounding reduces the error higher up to nearly zero. If the total volume is 650 ml /3/, the error during sounding is ± 2.5 %. When the KI solution concentration is 2 % (volume 500 ml), the error is irrelevant as long as the evaporation of the solution is not relevant.

(2) Anode Solution:

Pour 50 ml of the cathode solution (prepared as described above) into a 100 ml bottle. Add 90 g of KI crystals and shake vigorously to dissolve the crystals. The solution is saturated and all crystals will not be dissolved.

(3) Storage:

Store the cathode and anode sensing solutions in the dark at a temperature of 20 to 25 °C.

After a couple of months of storage an old solution should be discarded and a new solution prepared. However, solutions stored in optimum environment endure storage time of 4 to 6 months. The condition of the solutions is checked during flight preparations by measuring the time response of the sensor.

If the storage time is going to be long and part of the 1000 ml solutions will most likely be discarded, it is naturally possible to prepare smaller portions. To prepare, e.g. 500 ml of the cathode solution, a 500 ml filling bottle is needed.

The solutions are buffered (pH = 7) because the stoichiometry of the reaction is strongly pH dependent / 4 /. However, the pH-value of the solutions is not exactly 7 in all conditions due to differences in the total water content of the solutions.

2.2 Ozone Sensor reactions

The cell system is shown in Figure 2. Platinum electrodes are chemically inert and they do not take part in chemical reactions. Electrochemical reactions take place in the boundary layers of the electrodes. As soon as air that contains O_3 molecules is bubbled through the cathode solution the following total reaction occurs:

$$2\,KI + 0_3 + H_2O \rightarrow 2\,KOH + I_2 + O_2 \qquad (1)$$

Iodine, I_2, is formed and the I_2 concentration of the solution starts to increase. If the external circuit is closed (switch S, Figure 2), reaction 1 is followed by reactions 2 and 3:

In the cathode chamber

$$3\,I^- \rightarrow I_3^- + 2\,e^- \qquad (2)$$

In the anode chamber

$$I_2 + 2\,e^- \rightarrow 2\,I^- \qquad (3)$$

The total cell reaction is a redox reaction:

$$3\,I^- + I_2 \rightarrow I_3^- + 2\,I^- \qquad (4)$$

Reactions 2 and 3 are the rate determining reactions because the ions must be transferred to the electrode surfaces.

Reactions in the cathode and anode chambers are different because of different I concentrations / 3 / and the reaction direction is as shown because of the driving internal electromotive force (emf).
The emf (E) can be calculated approximately from the Nernst equation:

$$E \approx -\frac{0.0591}{2}\log K \qquad (5)$$

where

E = is the emf produced within the cell (at 25 C°)

$$K = \frac{(a_1)_{I_3^-}}{(a_4)_{I_2}} \cdot \frac{(a_3)^2_{I^-}}{(a_2)^3_{I^-}}$$

where

a_1, a_2 are the activities respectively, of the tri-iodide and iodide within the cell anode chamber; and

a_3, a_4 are the activities respectively, of the iodide and iodine within the cell cathode chamber.

At equilibrium K ≈ 1.

Activity is approximately equal to concentration.

In short:

Ozone enters the cathode chamber, reaction 1 takes place and iodine concentrations are changed ⇒ K, is no more equal to 1 and the emf is no more equal to zero.

Reactions 2 and 3 take place and I^- and I^-_3 concentrations change ⇒ finally K ≈ 1 again. See / 3 / for more information about reactions.

Conclusion: EVERY O_3 MOLECULE CAUSES A CURRENT OF TWO ELECTRONS. Because the equilibrium constant is very high the reaction is quantitative and can be used to measure the ozone concentration.

NOTE

1. The reaction occurs with all oxidants (e.g. 0_2).
2. The chemical reaction in sensor chambers / 2 / is affected by the sensor dimensions, air bubbling rate, the total liquid volume of the sensor, and the temperature of the sensor solution. These factors introduce some basic error and variance.

2.3 Calculation of Local Ozone values

The partial pressure of ozone is a measure for local ozone concentration. Sometimes ppm_V values are used. Basic principles for this step of calculations are given in refs. / 1 /, / 2 / and / 3 /. As each molecule of ozone creates a current of two electrons, ozone concentration

$$c = \frac{I \cdot t}{F \cdot 2 \cdot 100\ \text{ml}}$$

where

c =	ozone concentration in m mol l^{-1}
F =	$9.6487 \cdot 10^{4}$ C $(\text{mol})^{-1}$ (Faraday constant)
I =	measured current in μA
t =	pumping time for 100 ml of air, in seconds

The partial pressure of ozone (P_3) is

$$P_3 = C \cdot R \cdot T_{air} = \frac{R}{F \cdot 2 \cdot 100\ \text{ml}} \cdot I \cdot T_{air} \quad t$$

R = $8.31431\ JK^{-1}\ mol^{-1}$

$$P_3 = 4.307 \cdot 10^{-4} (I - I_{BG}) \cdot Tp \cdot t \cdot C_{ef} \cdot C_{ref}$$

where

P_3 =	partial pressure of ozone in mPa
I =	measured ozone current in μA
I_{BG} =	current caused by oxidants other than ozone (mainly O_2) in μA.
Tp =	measured air flow temperature in K from pump base.
t =	pumping time for 100 ml of air in seconds
C_{ef} =	correction due to reduced ambient pressure for pump
C_{ref} =	Note that if another (e.g. light absorption) method is usable for measuring total ozone concentration, partial pressure values can be corrected to fit the inferred total ozone value with the total ozone measurement in question. If not used, $C_{ref} = 1$.

SPC Corp. has studied a considerable amount of pump efficiency data generated by environmental chamber tests of our Model 6A as well as data generated by tests of previous SPC ozonesonde models. These studies indicate that the Model 6A pump efficiencies are significantly more consistent than previous SPC ozonesonde models. SPC will continue to study the pump performance of the Model 6A ozonesonde and as results are verified SPC may revise the correction factors for the Model 6A in the future.

REMARKS:

1. Pumping time for 100 ml of air

   Factory-measured value is printed on the ozonesonde, but the pumping time is measured during sounding preparations. The "calibrated value" is used.

2. Measurement of sonde temperature

   Thermistor calibration is not necessary because the accuracy is ± 0.2 °C.

3. Background current correction (I_{BG}) is caused by oxidants other than ozone (mainly O_2).

   To be able to calculate the current caused by other oxidants than ozone, measurements made before sonde release must be repeated: Background current I_o is measured using ozone destruction filter through which air is pumped. This means that the sensor current measured on surface (pressure P_o) must be corrected by I_o.

   Because one correction I_o at pressure P_o is known, Table 1 below can be used to determine corrections at other pressure levels. The correction I_{BG} can be calculated from the column having the correct I_o at P_o in Table 1. For instance, if I_o = 0.2 when P_o = 1000 hPa, I_{BG} = 0.12 when 595 < P < 485.

Pressure interval in hPa	Values of sensor current correction in µA				
1070 - 951	0.25	0.20	0.15	0.10	0.05
950 - 830	0.23	0.18	0.14	0.09	0.05
829 - 711	0.20	0.16	0.12	0.08	0.04
710 - 596	0.18	0.14	0.11	0.07	0.04
595 - 485	0.15	0.12	0.09	0.06	0.03
484 - 379	0.13	0.10	0.08	0.05	0.03
378 - 279	0.10	0.08	0.06	0.04	0.02
278 - 191	0.08	0.06	0.05	0.03	0.02
190 - 114	0.05	0.04	0.03	0.02	0.01
113 - 57	0.02	0.02	0.02	0.01	0.01

Table 1 Corrections for Sensor Oxygen Sensitivity

The correction can also be calculated directly from equation

$$I_{BG} = \frac{(A0 + A1 \times P + A2 \times P^2)}{(A0 + A1 \times P_0 + A2 \times P_0^{\ 2})} \times I_0$$

P = ambient pressure in hPa

A0 = 0.00122504

A1 = 0.0001241115

A2 = $-2.687066 \cdot 10^{-8}$

4 . Pump Efficiency Correction (Cef)

The efficiency of the SPC Model 6A Ozonesonde air sampling pump decreases with altitude. Calculated ozone partial pressures must, therefore, be corrected for the efficiency loss. Correcting factors for Model 6A pumps, with ECC sensor cathodes filled with 2.5 cm^3 sensing solution and 3.0 cm^3 sensing solution, are shown in Table 2, respectively. At pressure level (P) value of C ef is calculated by using linear interpolation as a function of pressure.

Atmospheric pressure hPa	**Ozone partial pressure correction factor C_{ef}**	
	Sensor cathode solution volume 2.5 cm^3	Sensor cathode solution volume 3.0 cm^3
2.0	1.160	1.171
3.0	1.124	1.131
5.0	1.087	1.092
10.0	1.054	1.055
20.0	1.033	1.032
30.0	1.024	1.022
50.0	1.015	1.015
100.0	1.010	1.011
200.0	1.007	1.008
300.0	1.005	1.006
500.0	1.002	1.004
1000.0	1.000	1.000

Table 2 Ozone Partial Pressure Correction Factors

SPC Corp. has studied a considerable amount of pump efficiency (Cef)data generated by environmental chamber tests of our Model 6A as well as data generated by tests of previous SPC ozonesonde models. These studies indicate that the Model 6A pump efficiencies are significantly more consistent than previous SPC ozonesonde models. SPC will continue to study the pump performance of the Model 6A ozonesonde and as results are verified SPC may revise the correction factors for the Model 6A in the future.

2.4 Accuracy of Ozone Measurement

2.4.1 General

Various intercomparisons have been carried out with different types of ozone measurement systems. The Vaisala Ozone Measurement System has been tested in international WMO intercomparisons. Reports on these can be found in ref. / 13 /. Ref. / 6 / gives a good review on the accuracy of different types of ozone sensors.

Total ozone can be calculated from the sounding data and compared with the total ozone measurement by light absorption. If 0.8 < correction < 1.3 (for the ECC sonde), WMO does not recommend use of the data.

2.4.2 Factors Affecting Measurement Accuracy

Reference literature for this paragraph appears under refs. / 1, 2, 3, 4 /.

The order of the following listing does not reflect the order of magnitude for the error.

1. Stoichiometry of 0_3 reaction. The stoichiometry in the sensing solution is strongly pH dependent. In pH = 7, it is 1:1. At low 0_3 concentrations stoichiometry is not accurately known.

2. Buffering of the sensing solution.

3. Concentration of I^- ions. In a 2 % KI solution, all 0_3 reacts. When the KI concentration is 1.5 %, the error caused by evaporation is ±2.5 %. Also liquid boiling during sounding contributes to error.

   The sensing solution described in paragraph 2.2 is a 1.5 or 1.0 % KI solution. Laboratory tests show that if the concentration of chemicals in the solution is doubled, ozone values indicated by ECC sensors increase by 5 %. Since, during a typical ozone sounding, the volume of solution within the sensor is reduced by about 1/5th due to evaporation, the error introduced into indicated ozone amounts immediately before flight termination, relative to ozone values measured near ground level, is only about 1 %. See Figure 3.

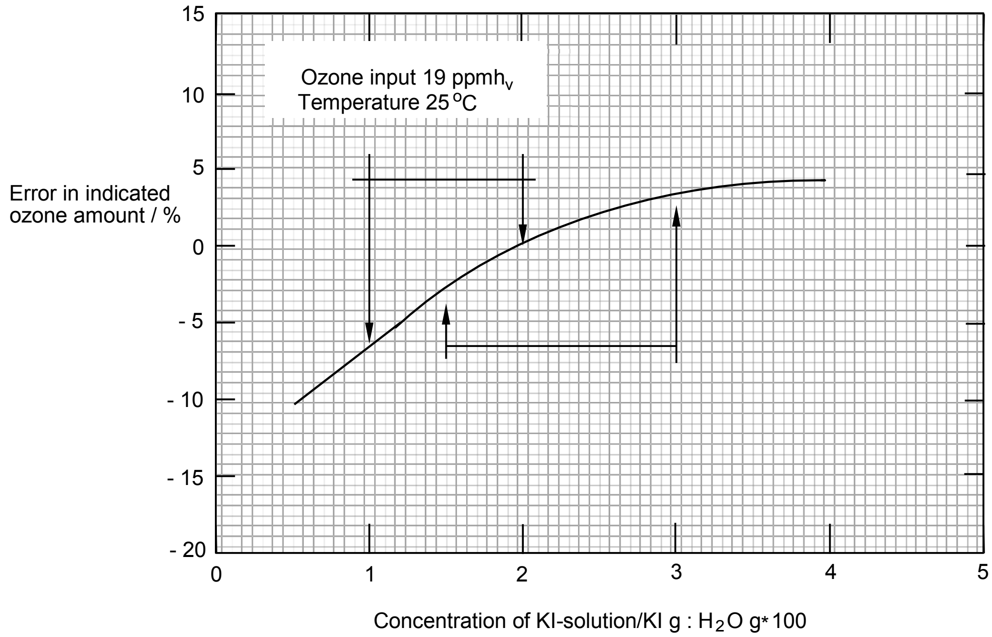


Figure 3 Error in Ozone Measurement vs. Concentration of KI Solution in Sensor Cathode Chamber / 3 /

4. Total volume of 1000 ml is a NOAA preference /1/ and gives a KI solution of 1%. This causes a 5% error in the indicated ozone amount, but evaporation (i.e. solution concentration increase) during sounding reduces the error to nearly zero. If the total volume is 650 ml /3/, error during sounding is $\pm$ 2.5 %. When the KI solution concentration is 2% (volume 500 ml), the error is relevant as long as the evaporation of the solution is not irrelevant.

5. Air flow rate error due to temperature variation:

   The air flow rate vs. temperature coefficient of the Teflon gas sampling pumps has been experimentally determined / 2 / to be approximately 0.065 % per degree centigrade. This corresponds to a decrease of nearly 1.5 % in the flow rate as the temperature decreases by 20 °C. This temperature effect is not specifically compensated in the ozone data because the uncertainty associated with flow rates at low pressures is considerably greater due to other causes.

6. Dimensions of sensor cells and electrode areas affect everything: best flow rate, best (I^-)...

7. Homogeneity of bubbling with respect to cathode.

8. Changes of sensor solution quantity affect response time, ability to react on pumped gas, etc. ECC uses 2.5 ml of sensor solution for low soundings, 3.0 ml for high.

Reference / 2 / gives the basic theory and measurements for response time in Figure 4 as a function of ozone input in Figure 5 with different load resistance. In Figure 6 sensor response time has been depicted as a function of temperature. The values for maximum current and (t.63) and (t.90) are also given in Figures 4 and 5.

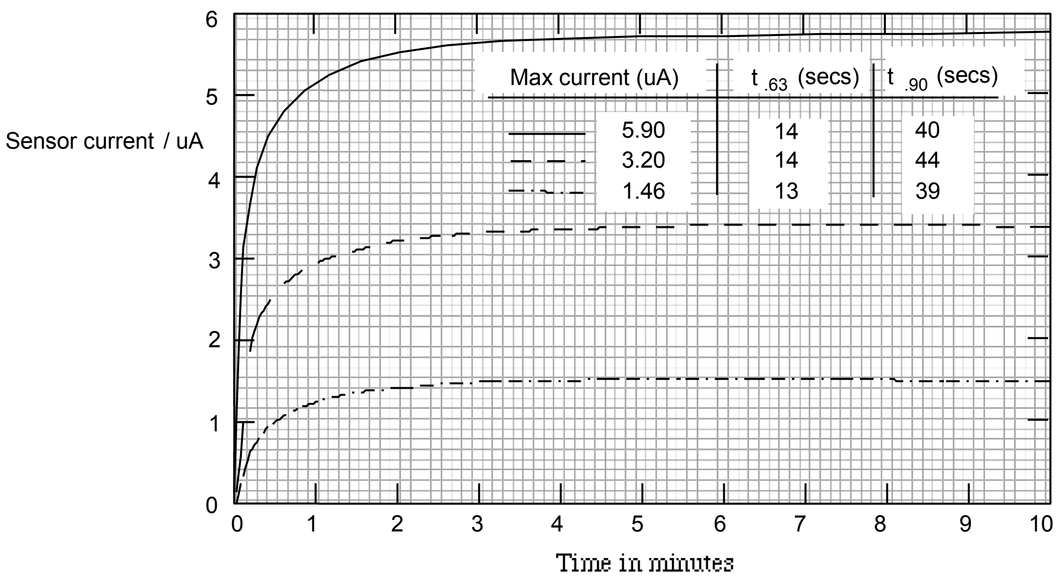


Figure 4 Variation of ECC Sensor Response Time with Ozone Input at 25 °C and with 1000 Ω External Sensor Load /2/

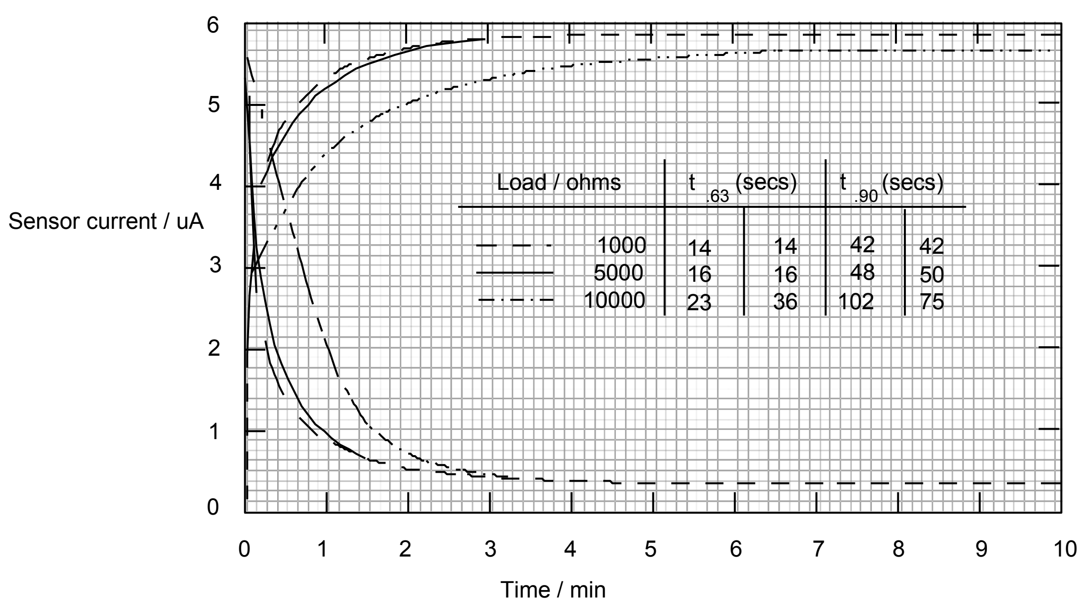


Figure 5 ECC Sensor Response Time vs. Load Resistance at 25 °C / 2 /

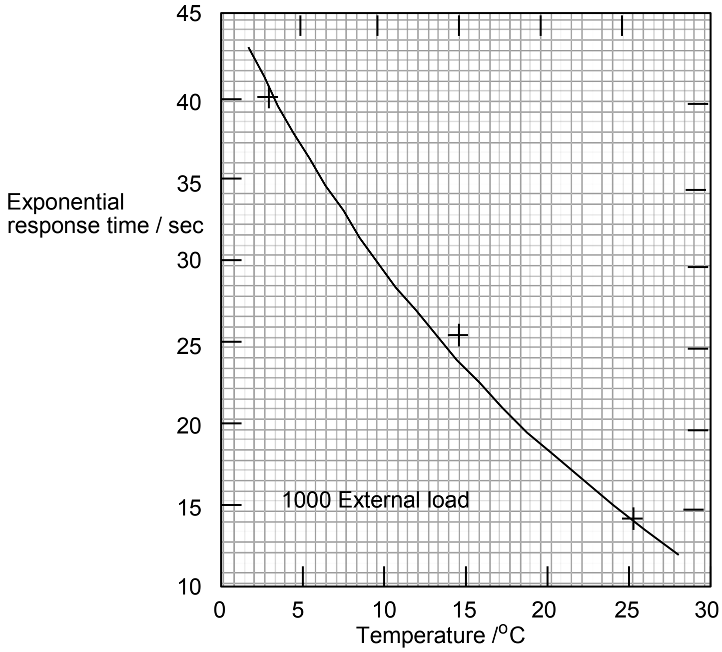


Figure 6 ECC Sensor Response Time vs. Temperature. Crosses represent experimental points /2/

9. Quality of sensor preparations
10. Other reactive gases (oxidants)
11. Gas bubbling

2.5 Ozonesonde Unit

The ozonesonde is the Science Pump Corporation Model 6A unit. The sensor is packed in a fairly large box of Styrofoam. Details of the sonde set up and the ozone electrochemical cell are shown in Figures 7 and 8. When delivered by Science Pump Corp or Vaisala the battery connector is of MOLEX type. When delivered from Vaisala the Model 6A is furnished with a string hanger for balloon string.

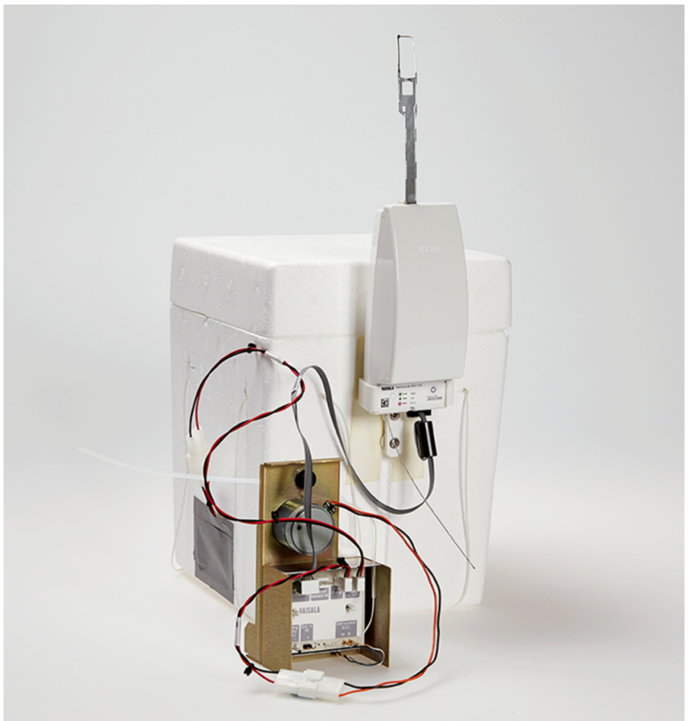


Figure 7 Model 6A Balloon-borne Electrochemical Concentration Cell (ECC) Ozonesonde with a Vaisala RS41 Radiosonde and interface.

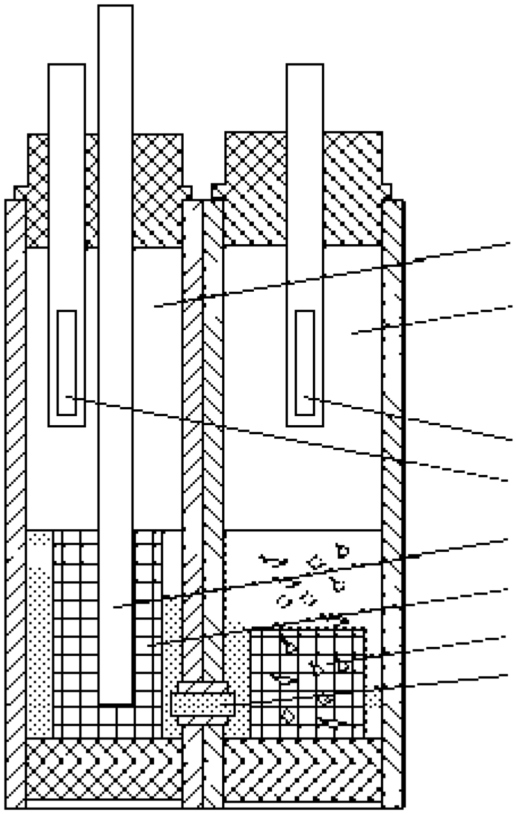


Figure 8 Construction Details of a Basic ECC Ozone Sensor

The specifications of the ECC Model 6A are maintained by Science Pump Corporation. The sensor has been used up to 40 km. The temperature inside the casing must be above the freezing point. The evaporation of the sensing solution limits the operation time of the sensor to 2 ... 3 hours. The accuracy of the sensor has been reported in many scientific articles.

Dimensions and weight of the ozonesonde box:

Base length x width:	19 x 19 cm
Height:	26 cm
Weight without battery and interface:	600 g

2.6 Ozonesonde Battery

The wet battery (12 VDC) for the ozonesonde is delivered by the Science Pump Corporation. Figure 9 shows some details.

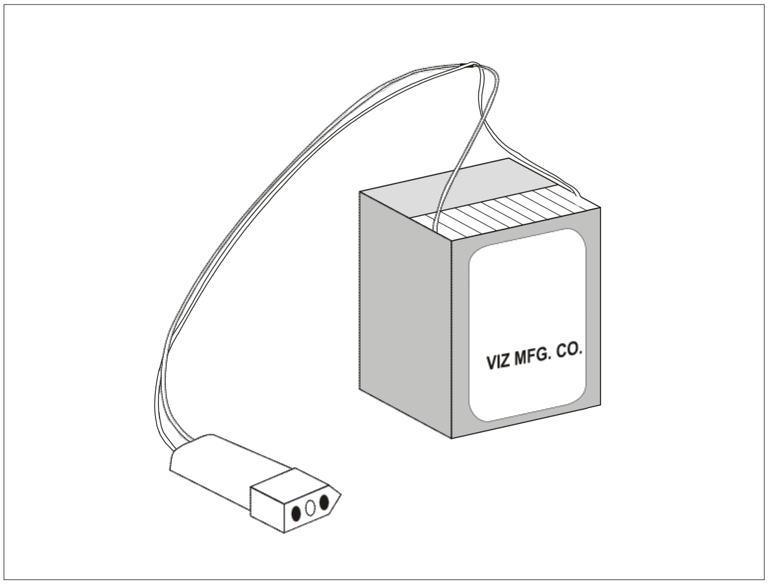


Figure 9 Wet Battery for the Ozonesonde Motor

The current wet battery type is VIZ P/N 3510-200 manufactured by VIZ MFG CO. (USA). The battery is inside a foil package. User instructions are included.

Dimensions (approx.):	4 x 4 x 6 cm
Weight, dry:	95 g

NOTE

1) The wet battery is inserted into the battery compartment at the bottom of the flight box.

2) The activation instructions of the producer of the battery must be followed. The instructions are included with the battery.

3) When delivered by Science Pump Corporation or Vaisala, the battery has molex connectors.

Also lithium dry cells, Panasonic type BR 2/3A, can be recommended as the power source. Connect batteries in series as shown in Figure 10.

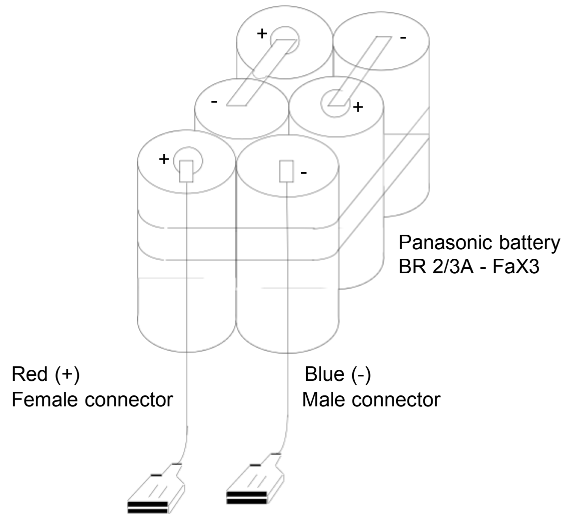


Figure 10 Lithium Battery Pack for the Ozonesonde Motor

Battery leads are 8 1/2 inches (21.6 cm) long, AWG 22 stranded copper wire.

Note: Science Pump Corporation and Vaisala uses Molex connectors: Connector MOLEX 1396 body, with MOLEX 2871 or red lead (+) - 3M Company female connector, P/N MNV18 - 250 - DFIX and blue lead (-) - 3M Company male connector, P/N MNV18 - 250 - DMIX

Wrap the battery pack in heat-shrink plastic to insulate electrically conductive surfaces.

NOTE

If a lithium battery pack is used, insert the pack into the sonde flight box with the ECC instrument (if possible). Fill the battery compartment located at the bottom of the flight box with insulating material, and seal the opening with tape to prevent excessive cooling of the sonde within the box. A wet battery is always placed in the battery compartment at the bottom of the flight box.

3. EQUIPMENT AND MATERIALS NEEDED FOR OZONE SOUNDING PREPARATIONS

When preparing an ozonesonde for flight there are a number of steps involved. A necessary basic instrument for the preparations is the Science Pump Corporation Model TSC-1 Ozonizer/Test Unit . TSC-1 Unit is shown in Figure 11.

3.1 Ozonizer/Test Unit

The model TSC-1 Ozonizer/Test Unit has been designed for conditioning ECC ozonesondes with ozone and for checking the performance of the sondes prior to balloon release.

The specifications for the Ozonizer/Test Unit:

Size	47 x 28 x 29 cm
Weight	10.5 kg
Power requirements	110 V, 1 A, 60 Hz or 220 V, 0.6 A, 50 Hz

Figure 11. shows the front face of TSC-1.

Figure 11 Science Pump Corporation TSC-1 Ozonizer/Test Unit

The components of the Ozonizer/Test Unit:

1. A high (HI) ozone source for conditioning the sonde pump and dry sensor with ozone.

2. A zero-to-low (NO/LO) ozone source, for checking the sensor background current, and for conditioning the ozone sensors charged with sensing solutions.

3. An ozone CALIBRATOR, composed of an ECC sensor and Teflon pump, against which the performance of the SONDE Teflon pump and sensor can be compared.

4. Meters for checking the current drain (mA) of the CALIBRATOR and SONDE pump motors at 12.3 VDC (middle left and right, respectively, in Figure 11).

5. Microammeters (0-10 μA) for measuring CALIBRATOR sensor and SONDE sensor output currents (top left-hand and right-hand meters of Figure 11 are connected to the CALIBRATOR and the SONDE sensors, respectively).

6. A Microammeter (0-100 μA) for checking the performance of the ECC sonde electronic transducer and electromechanical commutator (top middle, Figure 11). **Note that this is not used with the Vaisala Ozone Measurement System.**

   The Science Pump Corporation operator's manual for TSC-1 Ozonizer/Test Unit contains more detailed information.

CAUTION

When repeatedly recharging the calibrator sensor cathode with the sensing solution and reinstalling the top plug of the sensor cathode, BE CAREFUL NOT TO DISTORT THE PLATINUM CATHODE SCREEN. Otherwise, sensor malfunction can occur. Always store the Ozonizer/Test Unit in a clean-air environment with plastic caps covering the NO/LO OZONE and HI OZONE ports.

3.2 Ozonesonde Flight Preparation Start-Up Kit

The start-up kit, available from Science Pump Corporation of Camden, NJ contains all the required equipment and materials necessary to properly test and prepare ECC Ozonesondes. The kits are designed for use with Science Pump's model TSC-1 Ozonizer Test Unit. If spare parts are needed please fax SPC or see Vaisala part #'s .

The Start-Up Kit includes the following items:

Qty	Description
1	Air flow Meter , used to measure air flow rate of ECC Sonde. (Figure 12)
1	Ozone Destruction Filter, eliminates ozone generated during testing. (Figure 13)
1	Vacuum Pressure Gauge, to measure proper pressure/vacuum. (Figure 14)
1	Balance to properly measure chemicals.
1	Labware Set, includes necessary glassware to prepare and properly store solutions.
1	Syringe Set (4) used to charge sensor and extract spent solution.
1	All chemicals necessary to prepare anode and cathode solutions.

Note: The start-up kit, available from Science Pump Corporation of Camden do not include items only used with Vaisala system components. Vaisala complete start-up kit part number is 25820 OS.

3.2.1 Air Flow Meter

Vaisala part number 131960S

1. Equipment required (Figure 12):

   (a) Flow meter tube (burette with filling tube), capacity 100 ml.
   Vaisala part No. 12733.

   (b) Rubber bulb, capacity approx. 50-80 ml. Vaisala part No. 12734.

   (c) Burette stand with bossheads and clamps.
   Vaisala part Nos. 12730 (stand), 12732 (bosshead),
   12728 (clamp).

   (d) Stop-watch, accuracy at least 0.1 s.
   Vaisala part No. 12784.

(e) Connector tube 1: Soft silicon tube approx. 5 cm long, ID 6 mm, OD 10 mm.

(f) Connector tube 2: Soft vinyl tube approx. 60 cm long, ID 1/8" (0.32 cm), OD 1/4" (0.64 cm).

(g) Connector tube 3: Soft silicon tube approx. 2 cm long, ID 2 mm,

and OD 4 mm.

Set of connection tubes, item e, f and g above.
Vaisala part No. 126420S.

(h) Soap solution: Add about 1 teaspoon of liquid detergent and 1 teaspoon of glyserol to 1 liter of distilled water or SPC supplies pre-mixed solution called snoop.

2. Arrange the apparatus as shown in Figure. 12.

3. Fill the rubber bulb and burette with soap solution to just below the filling tube of the burette (Figure 12).

4. Connect the apparatus to the sensor cathode air exhaust tube. This is done by slipping the connector tube 3 of the apparatus over the short Teflon tube protruding from the top plug of the sensor cathode chamber.

5. With the sonde air pump operating, squeeze the rubber bulb slightly to cause several soap bubbles to rise up the burette. Repeat the process many times until bubbles reach the top of the burette without breaking.

6. Now form one bubble, and using a stop-watch determine the time t required to displace the bubble 100 ml. Repeat the measurement several times to obtain a mean value. Record the result. Enter this result in the ozonesonde record when releasing the sonde.

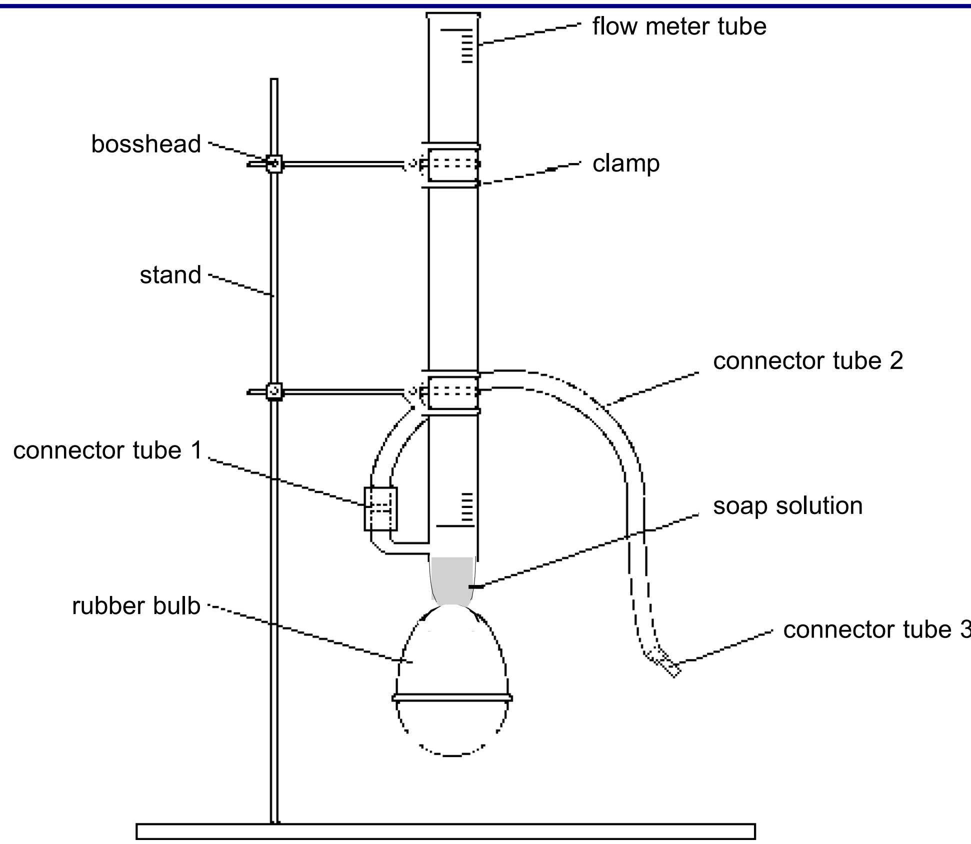


Figure 12 Apparatus for Measurement of Ozone Sonde Air Flow Rate

NOTE

When the air flow is being measured, the sensor should be charged with the sensing solution.

3.2.2 Ozone Destruction Filter

1. The following parts are required for the ozone destruction filter-the whole set-up is Vaisala part No. 13197OS:

   (a) Mine Safety Appliances Company chemical cartridge filled with granular catalyst to decompose ozone. Delivered by MSA a single cartridge (part No.463532) or 10 pcs lot (part No.466204) Vaisala part No. 12769 (1pc)

   (b) Mine Safety Appliances Company ultra filter cartridge. Delivered by MSA as a single cartridge (part No.459322) or a 10 pcs lot (part No. 464035).
   Vaisala part No. 12770 (1 pc).

   (c) Plastic or glass funnel, 75 mm in diameter, tube dia. 8 mm. Vaisala part No. 12725.

   (d) Connector tube 1: Soft silicon tube approx. 5 cm long, ID 6 mm, and OD 10 mm.

   (e) Connector tube 2: Soft vinyl tube approx. 60 cm long, ID 1/8" (0.32 cm), OD 1/4" (0.64 cm).

   (f) Connector tube 3: Soft silicon tube approx. 2 cm long, ID 2 mm, and OD 4 mm.

   (g) Connector tube 4: Connector tubing for ECC-sonde. Cut a piece of tubing from the ECC sensor intake tube (approximately 2 cm long), or Science Pump Corporation spare part No. OTU-19. Also, Vaisala part No. 17348S.

   Set of connector tubes, item d, e, and f above. Vaisala part No. 12642OS.

   (h) Electrical tape. Vaisala part No.12524.

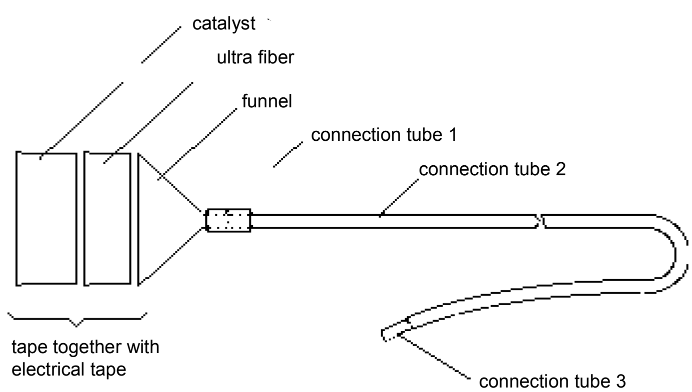


Figure 13 Ozone Destruction Filter

3.2.3 Pressure gauge

1. Equipment needed for the vacuum/pressure measurement gauge- the whole set-up is Vaisala part No. 127850S:

   (a) Simple vacuum/pressure measurement gauge, range 0 ... 0.6 Bar pressure to 0 ... 1 Bar vacuum. Connection parts for measurement gauge to tubing. Vaisala part No. 15240 includes both.

   (b) Connector tube 1: Soft silicon tube approx. 5 cm long, ID 6 mm, and OD 10 mm.

   (c) Connector tube 2: Soft vinyl tube approx. 60 cm long, ID 1/8" (0.32 cm), OD 1/4" (0.64 cm).

   (d) Connector tube 3: Soft silicon tube approx. 2 cm long, ID ~1,8 mm, and OD ~3.7 mm.

   (e) Connection tube 4: Cut a piece of tubing from ECC sensor air inlet tubes to approx. 2 cm length. Science Pump Corporation spare part No. OTU-19, tubing 12 AWG PTFE. Also, Vaisala part No. 17348S.

   Set of connector tubes, items b,c, and d above. Vaisala part No. 12642OS.

2. Set up the apparatus as shown in Figure 14.

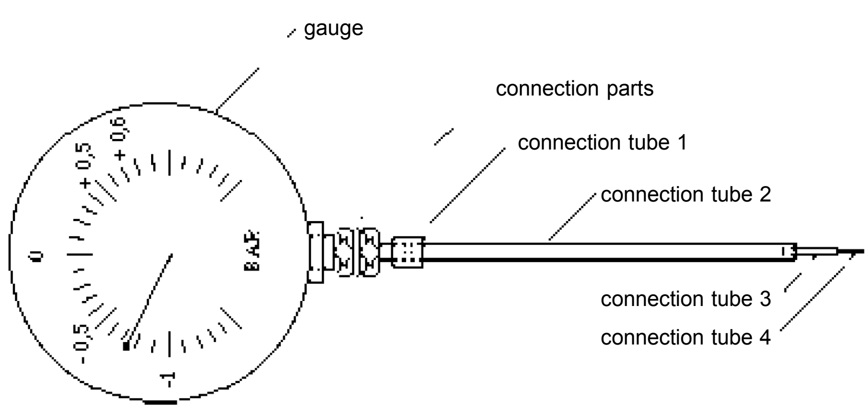


Figure 14 Vacuum/Pressure Gauge

3.2.4 Chemicals

Chemicals must be very pure, at least Pro Analysis quality. Set of chemicals is Vaisala part No. 13199OS.

Item	Vaisala part No.	
KI	12743	1 Kg
KBr	12744	0.5 Kg
$NaH_2PO_4 \cdot H_2O$	12741	0.5 Kg
$Na_2HPO_4 \cdot 12H_2O$ (or $Na_2HPO_4 \cdot 7H_2O$)	12742	0.5 Kg
Methanol (CH_3OH)	-	
Glycerol	-	
Acetone	-	
Triple distilled water	-	

3.2.5 Laboratory Ware

Bottles and glassware are needed for preparing and storing sensing solutions, for sensor cleaning, etc. The following set is useful and easily obtained from any laboratory ware dealer. They can also be ordered from Vaisala referring to the part numbers. The whole set of laboratory ware is Vaisala part No. 13198OS.

Two beakers (Pyrex glass):
1 pc., volume 250 ml (subdivision 50 ml). Vaisala part No. 12721.
1 pc., volume 50 ml. Vaisala part No. 12720.

Cylinder (Pyrex glass):
Volume 100 ml (subdivision 1 ml). Vaisala part No. 12722.

Bottles with Stoppers (preferably colored glass) 1 pcs 1000ml Vaisala part No. 12738 & 12740, 1 pcs 100 ml Vaisala part No. 12739 & 12740.

Two volumetric flasks with stoppers (Pyrex glass):
1 pc., volume 1000 ml Vaisala part No. 12724.
1 pc., volume 500 ml. Vaisala part No. 214857.

1 pc., volume 100 ml. Vaisala part No. 12723.

Two funnels (pyrex glass) mouth diameter 80mm. Vaisala part No. 12725.

Funnel (polypropylene):
Mouth dia. 65 mm, pipe dia. 10 mm, for powder handling.
Vaisala part No. 12726.

Three spatulas (polypropylene or steel):
Vaisala part No. 12729.

Two basins (polypropylene or glass):

For powder weighing. Vaisala part No. 12727.

Two syringes (plastic, preferably Teflon)
One modified syringe Disposable; total volume 5 ml, division 0.1 ml (at least 0.5 ml). Syringe, Vaisala part No. 12736, 100 pcs.
Syringe needle Vaisala part No. 12737, 100 pcs.
Thermometer (1pc.) for room temperatures Vaisala parts No. HST12

3.2.6 Others

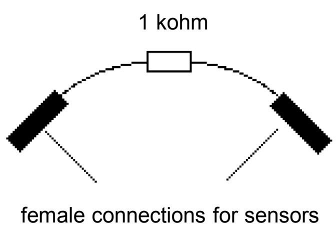
Balance

Range: 0 - 310 g
Accuracy: 0.01 g

Vaisala part No. 12771

Short Circuit Cable for Ozone Sensor

Not delivered by Vaisala or Science Pump Corp..



Power Supplies

A general-purpose power supply for ECC-6A and radiosonde,10-20 VDC/ 300 mA Vaisala part No. 12767

4. INSTRUCTION FOR OPERATOR

It is strongly recommended that the instructions below are placed well in view in the room where the ozonesonde preparation is done.

4.1 General Instructions

(a) Do not smoke near an operating ozonesonde. Smoke can adversely affect the performance of the instrument.

(b) The tubing connections to the sonde air pump are made using press-fitted Teflon tubing. Use small strips of No. 600A sandpaper to grasp the tubing firmly when connecting or disconnecting.

(c) When preparing the ECC sonde for flight, record the steps performed and results obtained in the check list.

(d) Work in clean conditions. Use clean equipment and lint-free gloves.

(e) To avoid contaminants do not pump air through pump and/or sensor before launch without using a filter.

(f) After having charged the sensor with the solutions do not pump high ozone concentrations (current > 8 μA) through the sensor.

(g) While pumping air through a charged sensor, always use a short circuit cable to connect the sensor wires if the ozone interface is not in use and power is not on. This is important to avoid the charging effect of the sensor.

(h) Make the final preparations and fly the ozonesonde on the same day. It is possible to fly an ECC ozonesonde soon after charging of the sensor if the sensor conditioning procedure is modified. Especially important is to recharge the sensor **cathode** with fresh sensing solution and condition the sensor with ozone-free air several times until a background current of less than 3 μA is attained. Continue preparing the sonde according to the instructions and then set it aside for 2 to 3 hours prior to launch.

(i) Wet battery fumes can destroy ozone.

(j) Lithium in the lithium batteries is a hazardous waste in nature and it readily ignites in air.

4.2 Handling Chemicals

(a) Study the characteristics and handling of the chemicals from appropriate literature. Observe the local legislation and regulations concerning the storage, handling and waste treatment.

(b) Always use plastic gloves when handling the chemicals. Take into account that PVC (polyvinylchloride) and neoprene withstand acetone, most other plastics dissolve in it.

(c) Do not eat during work.

(d) Keep chemicals in a safe place. The storage of flammable chemicals must be specially designed. The sensor cathode and anode solutions should always be stored in a dark place in dark bottles at a temperature of +20 to 25 °C

(e) Take care of proper ventilation, do not breath chemical vapors.

(f) Wash your hands after work.

(g) Always use clean equipment, do final cleaning with double-distilled water.

(h) Use tools instead of fingers as far as possible.

Some characteristics of chemicals used when preparing the ozonesonde:

Methanol

Methanol is a highly volatile and flammable liquid (boiling point 56 °C). Even very dilute solutions can burn. Methanol forms explosive mixtures with air.

Breathing methanol vapors causes headache and nausea. Swallowing even small amounts can cause damage to eyesight and in severe cases blindness.

Methanol is a skin irritant.

Acetone

Acetone is volatile and flammable liquid (boiling point 65 °C) and it forms explosive mixtures with air.

Breathing acetone vapors irritates the respiratory organs and mucous membranes. Larger concentrations cause dizziness and continuous exposure can induce symptoms in the nervous system, e.g. fatigue, irritability and sleep disturbances.

Acetone irritates the skin and continuous contact can cause eczema.

Other chemicals

Also, other chemicals used are poisonous and skin irritants. The chemicals with crystal water should not be used at temperatures above 60 °C because of evaporation of the water.

5. FLIGHT PREPARATIONS

The preparations can be divided into few main steps: 1) preparations 3 days to 1 week prior to release, 2) preparations on the day of release, 3) preparations just before release

The first two steps are described in this manual since they concern only the ozone sensor. The last two steps concern ozone sensor integration to sounding system and are described in Vaisala ozone sounding system manuals.

5.1 Preparations 3 Days to 1 Week prior to Release

The first step in preparing the ECC sonde for use is to check the overall performance of the instrument, and to charge the sensor with the sensing solution. The sensor must be charged 3 days to 1 week before flight time to attain low sensor background current and fast sensor response to ozone.

A Model TSC-1 Ozonizer/Test Unit is used to check the overall instrument performance (see paragraph 3.1). Science Pump Corporation Operator's Manual Ozonizer Test Unit Model TSC-1 gives also general description of the instrument and spare part list.

Proceed as follows when preparing the instrument for use:

Note:The numbers below refer to the flight preparation checklist in Chapter 6.

1. **Take out the check list for preparations and record all necessary information during preparations**. Remove the sonde from its polystyrene box and plastic bag, and connect the Teflon air intake tubes to the pump. Fill the factory set calibration values and other information considering the sensor in the checklist.

NOTE

Check that the input voltage selector switch located in the back of the Ozonizer/Test Unit is turned to correct voltage (110 or 220 V AC)

2. Connect the ECC ozonesonde motor, and sensor leads to the Ozonizer/test unit. After 10-15 minutes of running, check the mA meter of the Ozonizer/Test Unit for current drawn by the sonde pump. It should be below 115 mA. If the current is too high, the internal gas path should be cleaned with an acetone flush as follows. Remove the ECC cell from the holder on the ozonesonde. Connect the sonde pump motor to a power source. Turn the sonde upside-down, while running. Squirt acetone into the pump intake side,

while holding the exhaust side with your thumb using a paper towel (squirt hard, but be careful not to squirt the acetone near your face or label). Remove your thumb and turn the sonde to upright position. Let the pump run for an additional 10 - 15 minutes. Recheck the current draw. If necessary, repeat the cleaning two or three times. If the current draw has decreased to acceptable limits, reconnect the ozonesonde and continue preparations.

If, after the acetone cleaning, the current draw does not decrease to less than 115 mA the operator has the following options:

a. Discontinue preparation of the subject ozonesonde and make arrangements to return it for warranty repair or replacement by Science Pump Corporation. Please make sure to remove the sonde from the flight box and remove the solutions from the cell chambers.

b. Take the following additional remedial action(s) to reduce the current draw:

Cylinder Reaming Operation: Remove the piston from the pump cylinder, insert a 0.1570-inch D (0.3988-cm D) straight flute chucking reamer into the cylinder using an electric hand drill. Reassemble the pump taking care to orient the piston in the cylinder in the same way in which it was originally positioned. Begin pump operation again and check the motor current. If it is still excessive, repeat the reaming operation, but with progressively larger diameter reamers, i.e., 0.1580 inch D (0.4013 cm D) and 0.1590 inch D (0.4039 cm D).

After a proper pump motor operation is attained, check the pressure and vacuum developed by the pump using a pressure/vacuum gauge. Pump pressure should be at least 20 inches Hg = 10 psi (670 hPa) and pump vacuum should be at least 20 inches Hg (670 hPa).

If you experience a loss in vacuum, you may increase vacuum by applying slight pressure in a rotary motion to the pump cylinder 0-ring with, for example, thin long-nosed pliers, but be careful not to increase current more than 115 mA

If you experience a loss in pressure, you may increase pressure by tighten the pump spring.

You could experience a loss in vacuum and/or pressure, if particles are between the matting surface of the cylinder and the base piece, disassemble and clean with acetone. Also you should check the accuracy of the vacuum/pressure gauge, and the tubing connection to the gauge to make sure there are no leaks.

NOTE

Avoid touching the Teflon portion of the pump piston with your fingers. When working ,take care at all times, that the pump samples Ozonizer/Test Unit air, or air passing through an ozone destruction filter (see paragraph 3.2.2), and not room air. Otherwise, the pump will get contaminated.

3. Begin conditioning the sonde pump and dry sensor with a high ozone output. The pump air intake tube should be inserted tightly into the HI OZONE port of the Ozonizer/Test Unit, since the sonde pump draws highly ozonized air from the unit.

CAUTION: Air containing HI OZONE should never be passed through the charged sensor, otherwise normal sensor operation will be disturbed.

To produce high ozone, turn ON the POWER and the ozonesonde pump motor, then turn ON the UV LAMP of the Ozonizer/Test Unit.

The AIR PUMP switch must be turned OFF and the OZONE CONTROL tube must be pulled out of the chassis of the Ozonizer/Test Unit as far as possible.

Blue light visible through a hole in the front of the OZONE CONTROL TUBE indicates that the UV lamp is ON. During the conditioning, you should be able to smell ozone coming out of the sensor. Otherwise, the Ozonizer/Test Unit may be defective, or its controls incorrectly set.

4. When the sonde pump and dry sensor have been conditioned with high ozone for at least 30 minutes, turn off the UV LAMP switch of the Ozonizer/Test Unit and push the OZONE CONTROL tube into the unit as far as possible. Turn OFF ozonesonde pump motor.

Withdraw the sonde air intake tube from the HI OZONE port of the test unit and insert tubing, using black vinyl cap with hole, into the NO/LO OZONE port until tubing can not go any further and back-up slightly. Turn the AIR PUMP switch to the ON position.

Turn ON the ozonesonde pump motor. Run the sonde with ozone-free (no ozone) air passing through it for about five minutes to remove ozonized air from the pump and sensor. Turn OFF ozonesonde pump motor.

5. Now charge the sensor with the sensing solution as follows:

(a) The sensor **cathode** must always be charged first. Using a Teflon-tipped syringe especially reserved for use with the **cathode** sensing solution, inject 3.0 cm^3 of the cathode sensing solution into the sensor cathode chamber. This is the chamber containing a large platinum screen and air inlet. When reinstalling the top plug of the cathode, make sure that the air intake tube is correctly centered within the cathode chamber by inserting the tube carefully over a small Teflon rod projecting out of the bottom plug of the sensor cathode chamber.

NOTE

A 3.0-cm^3 volume of cathode sensing solution is generally used in sondes flown with plastic balloons reaching burst altitudes near 40 km. The flight time for these soundings is about 2.5 hours. For shorter flights with rubber balloons reaching altitudes of 30-35 km, the sensor cathodes can be charged with a 2.5 cm^3 volume of the sensing solution. Sensor response time becomes faster, and measured ozone profiles exhibit more detail.

(b) Next, using a syringe especially reserved for dispensing the **anode** solution, inject 1.5 cm^3 of the **anode** sensing solution into the sensor anode chamber.

6. Run the sonde on the Ozonizer/Test Unit with ozone-free air for 5 to 10 minutes (see step 4) Sensor current, indicated on the top-right Microammeter, will typically decrease from over 5.0 μA to 1.0 μA or less.

   If the current decrease has not happened within the 5 minutes, disconnect the ozonesonde from the test unit, connect the blue and white leads of the ECC cell together using a piece of tape or a short circuit cable and set the ozonesonde aside for 1 to 2 hours. During this time the ion bridge material will get completely soaked through. When the time has elapsed, remove the tape (or cable) and reconnect the ozonesonde to the Ozonizer/Test Unit. Insert the ozonesonde air intake tube into the NO/LO OZONE port and restart Step 6.

   If a normal response is still not observed, repeat the procedure above, but set the ozonesonde aside for a minimum of 12 hours. After removing the tape or cable withdraw the cathode solution and replace with a fresh solution. Reconnect the ozonesonde to the Ozonizer/Test Unit and run on ozone-free air for 5 to 10 minutes. Proceed to test according to Step 7. If the results of Step 7 are not normal, the ECC cell should be considered as defective and it should be discarded.

7. Set the Ozonizer/Test Unit controls for a low ozone output (produces a sensor output current of about 5 μA). This is done by turning the UV LAMP switch to the ON position and pulling the OZONE CONTROL tube partially out of the instrument chassis. Check that AIR PUMP switch is in the ON position (also SONDE MOTOR ON).

   You should now observe a positive response to ozone in the top-right Microammeter. Turn off the UV LAMP. The Microammeter readings should slowly fall to the level of the zero ozone values.

8. Continue running the sonde on ozone-free air for 10 minutes. Switch OFF the UV lamp and the AIR PUMP. Disconnect the sonde from the Ozonizer/Test Unit and cover the NO / LO and HI OZONE ports with plastic caps in order to prevent dust from entering the ports and store the instrument in a dark, clean-air environment at a temperature of 20-25 °C until ready for use. Connect the sensor cell wires together electrically, so that electrochemical cleaning reaction can continue during storage.

5.2 Preparation on the Day of Release

On the day of release, preparations start with ozone sensor testing and preparation and continue as sensor integration to measurement interface and radiosonde including also sounding system star-up.

Ozone sensor preparation and testing:

First you should have at hand two or three ECC-instruments, the operation of which has been checked and the sensors charged with the sensing solution at least 3 days earlier. Use the instrument, which has been charged first.

A Model TSC-1 Ozonizer/Test Unit is used to check the instrument performance (see paragraph 3.1). Science Pump Corporation Operator's Manual Ozonizer Test Unit Model TSC-1 gives also general description of the instrument and spare part list.

9. Connect the ECC ozonesonde motor leads to the Ozonizer/test unit. Insert the sensor intake tube (of the pump) into the NO/LO OZONE port.

a) Turn on the power to the Ozonizer/Test unit.
b) Switch on the air pump.
c) Operate the sonde pump motor for 5 minutes with NO OZONE air.

10. Set the AIR PUMP switch to ON position. Disconnect the air intake tube of the sensor cathode from the sonde pump. Restart, run the sonde pump with NO OZONE air and measure the pressure and vacuum developed by the pump with a hand-held pressure/vacuum meter, and record the results. Do not let room air access the pump.

11. Set the AIR PUMP switch to OFF position. Insert the air-intake tube of the sonde pump into the HI OZONE port of the test unit. Restart and condition the **sonde pump alone** with high ozone for 10-20 minutes (see step 3).

CAUTION

Air containing HI OZONE should never be passed through the charged sensor, otherwise normal sensor operation will be disturbed.

12. While the conditioning is progressing, remove at least the cathode solution from the sensor, and replenish with 3.0 cm^3 of fresh sensing solution. Replace the top plug of the sensor cathode, but **do not** connect the Teflon tube of the plug to the pump. It is preferable to also change the anode solutions. Connect the sensor wires to the test unit.

    Now prepare the ozone calibrator of the Ozonizer/Test Unit by withdrawing the sensing solution from the cathode chamber of the calibrator sensor, and replenishing with 3.0 cm^3 of fresh cathode solution. It is preferable to change also the anode solutions. Take care not to damage the electrodes.

13. After 10 - 20 minutes (see step 11) of conditioning of the pump with high ozone, turn OFF the UV LAMP switch and turn ON the AIR PUMP switch of the test unit (and push the ozone control tube all the way into the test unit chassis). Turn the SONDE MOTOR OFF.

    Insert the ozonesonde air-intake tube deep inside into the NO/LO OZONE port of the test unit. Turn the SONDE MOTOR to the position ON. Flush the pump with O_3-free air for few minutes, then connect the sensor cathode Teflon tube to the sonde pump. Check that the sensor wires are connected to the test unit.

    Turn ON the CALIBRATOR MOTOR switch of the test unit. Continue operating for 10 minutes to condition the sonde and calibrator sensors with ozone-free air.

In the next steps, the calibration of the sensor is checked at one point (around 5 µA). Therefore, the background current and the flow rate must be measured.

14. After 10 minutes of conditioning with ozone-free air, the top-left calibrator sensor Microammeter and the top-right sonde sensor Microammeter should each indicate less than 0.2 µA of sensor background current, i_{bc} and i_{bs}, respectively.

    If this current is higher for either of the sensors, withdraw the cathode sensing solution from the sensor, and replace with fresh solution. Continue conditioning with ozone-free air for another 10 minutes. Record on a checklist the observed values of i_{bc} and i_{bs}.

15. Begin to condition the sensor electrolyte solutions with ozone. Turn on the UV LAMP switch, and pull the OZONE CONTROL tube out of the instrument front panel for one to two centimeters. Current readings (due to

ozone entering the calibrator and ozone sensors) of the two Microammeters should slowly increase.

During the next several minutes, continue to adjust the position of the OZONE CONTROL tube so that maximum readings on the Microammeter stabilize at about 5 µA. Continue conditioning with low ozone for an additional 10 minutes.

16 During conditioning, measure the calibrator and ECC sonde airflow rates, t_c and t_s (see paragraph 3.2.1), and record the values. Record temperature; pressure and the relative humidity of the room (see step 15-16). Record temperature pressure and the relative humidity of the room.

17. At the end of the 10-minute LO OZONE conditioning interval, record the calibrator sensor and sonde output currents i_c and i_s. Now the calibration can be checked by computing the products

$$(i_c - i_{bc})\, t_c \sim (i_s - i_{bs})\, t_s ,$$

which should agree to within about 5 %. If not, corrective action is needed.

Next, check the sensor response times as follows:

Simultaneously, turn OFF the UV LAMP switch, push in OZONE CONTROL tube start the stopwatch. Read and record at 1-minute intervals, for 3 minutes. The calibrator and sonde output currents i_{1c}, i_{2c}, i_{3c}, and i_{1s}, i_{2s}, and i_{3s}. The 1-minute data should yield:

$$i_{1c} < 0.20\, (i_c - i_{bc})$$

and

$$i_{1s} < 0.20\, (i_s - i_{bs}),$$

indicating satisfactory sensor response times to changes in ozone. The equation above means that in one minute the sensor must indicate 80 % of the change in ozone amount. Continue to operate in order to reach the level of values i_{bc} and i_{bs}. If the ozone drop-off does not occur quickly enough take corrective action.

Push the OZONE CONTROL tube into the Ozonizer/test chassis, and turn off CALIBRATOR MOTOR, SONDE MOTOR and POWER to the test unit. Disconnect the sonde from the unit.

Ozone sensor integration to measurement interface and radiosonde including also soundig system star-up

The preparation work hereafter depends on used measurement interface, used radisonde type and used sounding system and are thereby described in Vaisala ozone sounding system manuals. The Vaisala Ozonesonde User's Guides, gives a description of the ozonesonde construction and the basic equipment needed for preparations.

The detailed step-by-step preparation instructions are part these of Vaisala Ozonesonde User's Guides. Also the detailed checklist for actions hereafter is included in Vaisala manuals, check list for earlier preparations is in chapter 6 of this document.

General ozone sensor related instructions:

It is necessary to perform general sensor and system check before sounding release:

1) When running the pump always attach ozone destruction filter to pump inlet tube. This prevents sensor contamination for indoor air.

2) Run ozonesensor for 10 min. (with ozone destruction filter on) for sensor background values. Background sensor current must be ≤ 0.2 μA

Measure also surface pressure in hPa. Background sensor current and surface pressure values are used to calculate the background sensor current correction (see chapter 2.3 of this manual.

3) Activate ozonesonde battery according to manufacturers instructions as late as possible (not more than 20-30 min. prior to release) and pack battery into battery compartment in styrofoam case sonde (do not connect ozonesonde motor battery wires)

4) After tests stop running the pump and remove destruction filter.

5) Take ozonesonde outside and <u>connect pump motor battery wires</u> for ground ozone measurements (if needed) and sounding start.

6. CHECK LIST FOR FLIGHT PREPARATIONS

6.1 Advance Preparations 3-7 Days prior to Release

1. Date ________ Station ___________ Operator ______________

   NOTE: Record information below or place removable label here.

   Ozonesonde No. _______________
   Manufacturer _______________
   Date of manufacture _______________
   Pump pressure _______________ in Hg
   Pump voltage _______________ V DC
   Pump current _______________ mA
   Flow rate _______________ s/100 ml

2. Connect ECC sonde to Ozonizer/test unit (motor, output, sensor leads). ______

3. Condition pump and dry sensor with HI O_3 for 30 min. ______
   After 10 min. of HI O_3:

	measured		limit values
Pump voltage:	_________	V	12-13 V
Pump current:	_________	mA	< 115 mA
Head pressure:	_________	Pa	≥ 670 hPa ≈ 20 in Hg*
Vacuum:	_________	Pa	≥ 670 hPa ≈ 20 in Hg**

4. Shut off HI O_3, run NO O_3 for 5 minutes. ______

Charge sensor cathode with solution: $2.5\ cm^3$ ______
$3.0\ cm^3$ ______

Charge sensor anode with solution: $1.5\ cm^3$ ______

6. Sensor background current after 5 min. on NO O_3. ______ μA

7. Sensor response to LO O_3 (5 μA): ______

8. Run on NO O_3 for 10 min. ______
and store sonde in dark clean-air environment
at a temperature of 20-25 °C until use.

---

* Normal, 700-900 hPa / or =/> 10 psi

** Normal, 700-900 hPa

6.2 Preparations on the Day of Release

6.2.1 Ozone sensor preparation and testing (day of release):

Date ________ Station _____________ Operator ______________

Ozonesonde No. _________________

Manufacturer _________________

Date of manufacture _________________

9. Run sonde motor for 5 minutes on NO O_3. ______

10. Pump performance check:

	measured		limit values
Pump voltage:	_________	V	12-13 V
Pump current:	_________	mA	< 115 mA
Head Pressure:	_________	Pa	≥670 hPa ≈ 20 in Hg (10 psi)
Vacuum:	_________	Pa	≥670 hPa ≈ 20 in Hg

11. Condition pump only with HI O_3 for 10-20 min. ______

12. Change cathode solution in SONDE (S) and CAL (calibrator, C) sensors: S: _____ ml
C: _____ ml

13. SONDE (S) and CAL (C) sensors conditioned with NO O_3 for 10 min. ______

14. Sensors background currents (<0.2 μA):
i_{bc} = ____________ μA; i_{bs} = __________ μA

15-16. Condition SONDE and CAL sensors with 5 ±0.2 μA O_3 for 10 min. ______
Measure:
SONDE sensor air flow rate: t_S = _____, _____, _____ s
CAL sensor air flow rate: t_C = _____, _____, _____ s
T_{room} = _________°C; P_{room} = _____ hPa; RH_{room} _____%

17. After 10 min. of conditioning with about 5 μA O_3:
i_C = __________ μA; i_S = _____________ μA

Sensor response test:

		Time (min.)
i_{1C} = ________ μA	i_{1S} = _________ μA	1
i_{2C} = ___________ μA	i_{2S} = ___________ μA	2
i_{3C} = __________ μA	i_{3S} = _________ μA	3
i_{10C} = _________ μA	i_{10S} = ________ μA	10

Computed for calibration acceptance check out:

$(i_c - i_{bc}) t_c =$ ______ $\approx (i_s - i_{bs}) t_s =$ ________ (agree to within 5 %)

$i_{1c} =$ ______ $< 0.20 (i_c - i_{bc}) =$ __________

$i_{1s} =$ ______ $< 0.20 (i_s - i_{bs}) =$ __________

6.2.2 Preparations just before (0-2 h) Release (See Vaisala User's Guides)

Work is related to ozone sensor integration to measurement interface and radiosonde including also soundig system star-up:

The preparation work hereafter depends on used measurement interface, used radisonde type and used sounding system and are thereby described in Vaisala ozone sounding system manuals. The Vaisala Ozonesonde User's Guides, gives a description of the ozonesonde construction and the basic equipment needed for preparations.

The detailed step-by-step preparation instructions are part these of Vaisala Ozonesonde User's Guides. Also the detailed checklist for actions hereafter is included in Vaisala manuals, check list for earlier preparations is in chapter 6 of this document.

General ozone sensor related instructions:

It is necessary to perform general sensor and system check before sounding release:

1) When running the pump always attach ozone destruction filter to pump inlet tube. This prevents sensor contamination for indoor air.

2) Run ozonesensor for 10 min. (with ozone destruction filter on) for sensor background values. Background sensor current must be ≤ 0.2 μA

Measure also surface pressure in hPa. Background sensor current and surface pressure values are used to calculate the background sensor current correction (see chapter 2.3 of this manual.

3) Activate ozonesonde battery according to manufacturers instructions as late as possible (not more than 20-30 min. prior to release) and pack battery into battery compartment in styrofoam case sonde (do not connect ozonesonde motor battery wires)

4) After tests stop rung the pump and remove destruction filter.

5) Take ozonesonde outside and <u>connect pump motor battery wires</u> for ground ozone measurements(if needed) and sounding start.

6.3 Possible Sources of Error in the Sonde System

(a) If change of the sensor cathode solution does not reduce the sensor background current, check pump contamination by using the sensor with a pump known to be clean.

Try to clean the contaminated pump with reagent-grade acetone, then condition it with HI OZONE. If contamination of the pump is not the problem, try using freshly made sensor cathode solution.

(b) If the sonde and calibrator sensor currents do not agree, taking into account the air flow rates through the sensors, check the flow rate of the air from the Ozonizer/Test Unit NO/LO OZONE port. This should be more than about 900 ml/min. (+/- 100 ml/min.).

While doing the above, note that for smaller flow rates the output of the sonde sensor can depend on the location of the sonde air intake tube in the NO/LO OZONE port.

If the trouble persists, replace the **anode** sensing solution of the CALIBRATOR sensor of the ozonizer/test unit. Repeat the procedure in step 12., but also replace anode sensing solution of the calibrator sensor of ozonizer/test unit/.

(c) If there are negative ozone currents or varying erroneous levels, they can be caused by RF disturbances. Check the interface grounding and overall functioning. If OK, see also Vaisala Users Guides. Check that the interface coefficients in the PC program are correct.

(d) If the interface temperature thermistor is not OK, check that the thermistor wires are not broken.

(e) If the signal shows zero for ozone, check the ozone sensor connections to the interface.

(f) Check connections of air tubes.

(g) If the fit between the cylinder and piston of the sonde Teflon pump is too tight and the reamers do not help (see 5.1 step 2.) remove the piston from the pump and insert its brass end into a 1/4-inch (0.64-cm) hand drill. Use a strip of fine-grit (e.g. No. 600A) wet/dry sandpaper placed over an elongated, rigid, flat strip of aluminum. Turn on the drill and carefully sand a uniform layer of Teflon material from the piston surface. Take good care not to sandpaper away too much of the Teflon material.

Now clean the piston with acetone and reinsert it into the pump cylinder. Check that the pump develops at least a 20-inch Hg vacuum. Prior to use, the pump must be reconditioned with high ozone.

(h) Check wire connections.

(i) For further information see also Vaisala related manuals

7. BASIC CONFIGURATION OF THE OZONESOUNDING WITH VAISALA RADIOSONDE

The weight of the total ozonesonde assembly, ready for launch, is approx. 1030 g.

The sounding flight setup may include parachute, radar reflector etc.

Also radiosonde flight setup depends on used measurement interface, used radisonde type and used sounding system.

The sounding setup preparation is described in Vaisala ozone sounding system manuals. The figure 15 below gives an example (RS41 radiosonde).

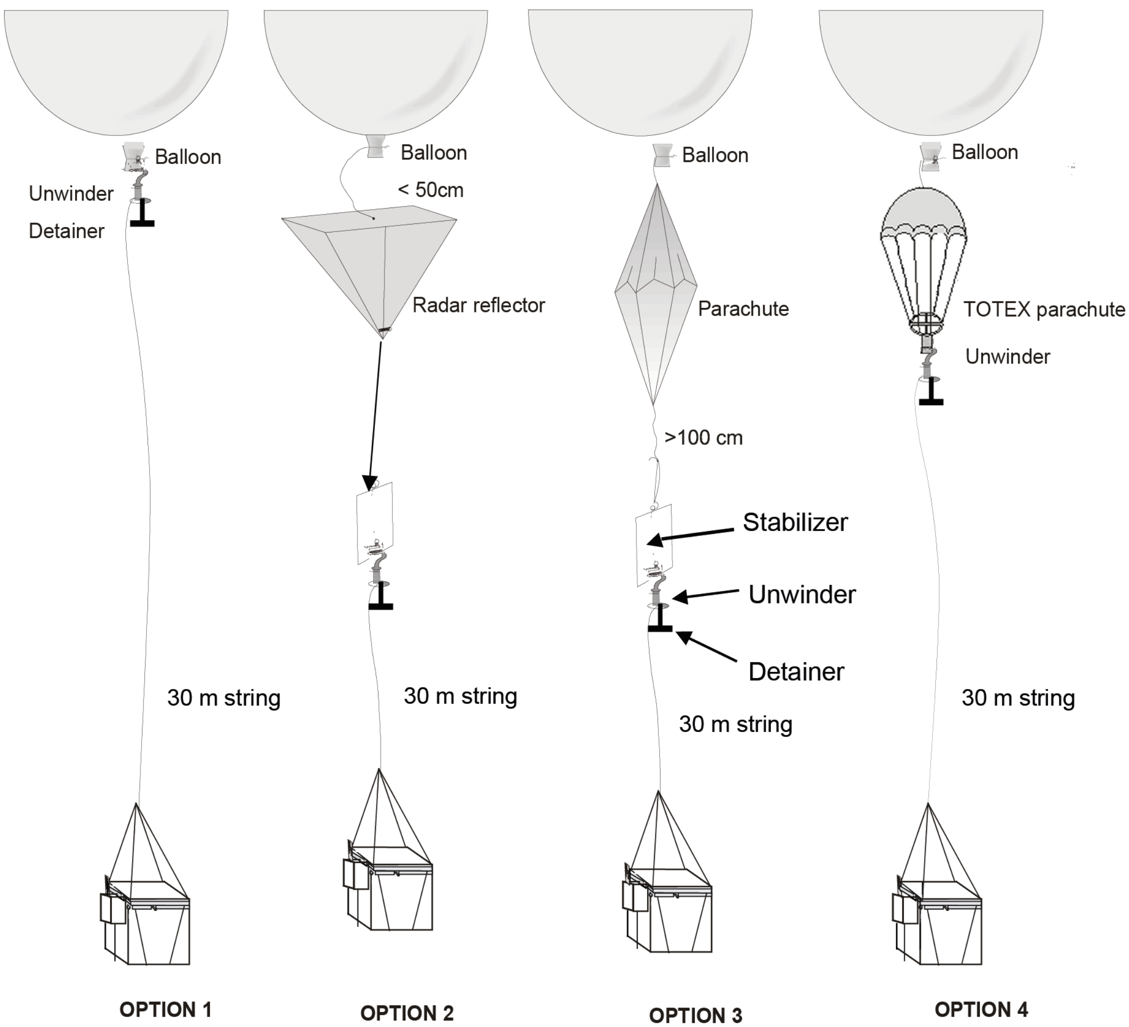


Figure 15 Preparing the Sonde Assembly, example with RS41 radiosonde

8. REUSE OF AN OZONESONDE

An ECC ozonesonde can be used over and over again provided it is not excessively damaged during flight, the interface can also be reused.

Upon receipt of a recovered ozonesonde, recondition as follows:

1. Cut away the ozonesonde from the radiosonde and discard the radiosonde.

2. Remove the ozonesonde from its polystyrene box, and discard the batteries. Separate the interface card from the ozone sensor.

3. Discard the air intake tube; replace it with a new tube made of Teflon 'spaghetti', size AWG. No. 12.

4. Remove the sensor from the sonde, and wash the cathode and anode chambers with distilled water.

   Fill the chambers with distilled water, let stand for 1 hour or longer until the ion bridge appears to be cleaned (white in color)., continue to rinse several times with distilled water. Reassemble the sensor within the sonde sensor holder.

5. Disassemble the Teflon gas sampling pump, taking care to note how the piston is oriented relative to the cylinder. Wash all Teflon parts first with tap water, then with distilled water, and finally with very pure methanol to remove any impurities from the pump base piece, cylinder and piston.

   After reassembling the pump into its original configuration, activate the pump motor and squirt 1 or 2 cm^3 of methanol into the operating pump for final cleaning.

6. Using a stroboscope, check the pump motor speed. It should be nearly constant and about 2400 r.p.m. at motor voltages of 12 to 15 V.

7. Finally, using a model TSC-1 Ozonizer/Test Unit, check the ozonesonde sensor and Teflon pump for correct performance.

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