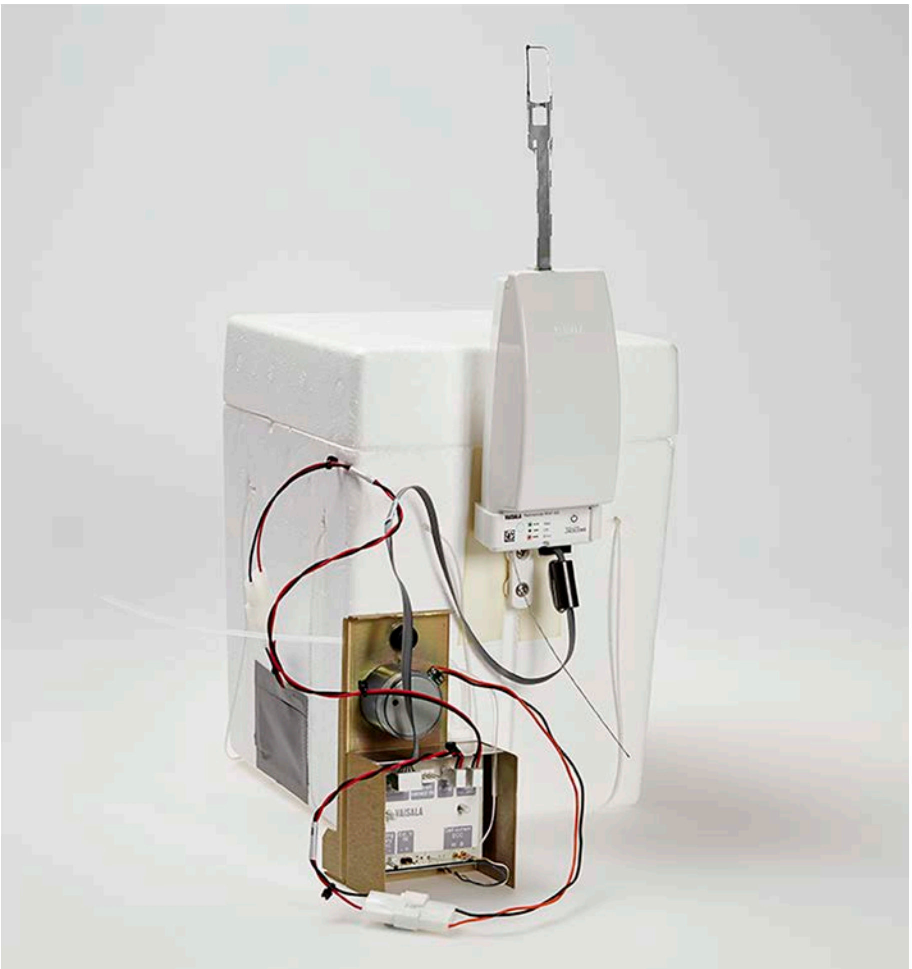
M211486EN-E

User Guide

Ozone Sounding with Vaisala Radiosonde

RS41



VAISALA

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1. About This Document

1.1 General Information

This manual provides information on assembling and operating an ozone sounding with RSA411 Ozone Interface Kit, Vaisala Radiosonde RS41, and an ozone sensor. The compatible ozone sensors are:

- ECC-6A from Science Pump Corporation. The Vaisala product code is ECC6AB and in MW41 software the sensor is identified with abbreviation **SPC**.
- Model Z from EN-SCI (formerly manufactured by Droplet Measurement Technologies). The Vaisala product code is 252164 and in MW41 software the sensor is identified with abbreviation **DMT**.

1.2 Version Information

Table 1 Document Versions

Document Code	Date	Description
M211486EN-E	January 2019	Updated information on the OIF411 ID data.
M211486EN-D	January 2018	Added lithium battery option for ECC-6A ozone sensor and information on KTU-3 Ozonizer Test Unit. Information on the radiosonde EPS covers was added.
M211486EN-C	December 2016	Updated information on securing the unwinder attachment for the sounding.

1.3 Related Manuals

Table 2 Related Manuals

Document Code	Name
M211667EN	*Vaisala Radiosonde RS41-SG and RS41-SGP User Guide*
-	*Vaisala DigiCORA Sounding System MW41 Online Help*
DOC-0336	*Droplet Measurement Technologies Model Z ECC Ozonesondes Operator Manual*
SPC-6A Manual© SPC	*Science Pump Corporation Operator's Manual Model 6A ECC Ozonesonde*
SPC TSC-1© SPC	*Science Pump Corporation Operator's Manual Ozonizer/Test Unit Model TSC-1*
DOC-101	*KTU 3 Ozonizer Test Unit Operator Manual*

Document Code	Name
-	*EN-SCI ECC Ozonesonde Operator manual*

1.4 Documentation Conventions

WARNING! Warning alerts you to a serious hazard. If you do not read and follow instructions carefully at this point, there is a risk of injury or even death.

CAUTION! Caution warns you of a potential hazard. If you do not read and follow instructions carefully at this point, the product could be damaged or important data could be lost.

Note highlights important information on using the product.

Tip gives information for using the product more efficiently.

Lists tools needed to perform the task.

Indicates that you need to take some notes during the task.

1.5 Trademarks

DigiCORA® is a registered trademark of Vaisala Oyj.

1.6 Product-Related Safety Precautions

Radiosonde RS41 has been tested for safety and approved as shipped from the factory. Note the following precautions:

WARNING! Conduct soundings in a safe environment and in accordance with all applicable restrictions and regulations.

WARNING! Do not use the radiosonde in an area with power lines or other obstructions overhead. Make sure that you check the area for such obstructions before using the radiosonde.

WARNING! Do not use the radiosonde without consultation and cooperation with local and other applicable aviation authorities.

WARNING! Do not modify the unit in any way, except as instructed in the manual.

WARNING! Do not use the radiosonde for any purpose other than for soundings.

WARNING! Vaisala recommends the use of parachute even if it is not required by applicable restrictions.

WARNING! The chemicals involved in an ozone sounding can be harmful, and must be handled with proper care. To ensure your working safety, take all the necessary precautions before beginning the preparations for a flight.
Read the sensor manuals carefully.
Follow the local laboratory work practices, regulations, and waste management guidelines.
Use disposable gloves to avoid dust and other contaminants. The gloves must be lint-free and made of artificial fabric or plastic. Note that the RSA411 Ozone Interface Kit does not include gloves.

1.7 Lithium Battery-Related Precautions

CAUTION! Take the following precautions when handling lithium batteries:

- Do not place the lithium battery in fire or apply heat to the battery.
- Do not pierce the battery with nails, strike the battery with a hammer, step on the battery, or otherwise damage the outer casing.
- Do not subject the battery pack to strong impacts or shocks.
- Do not expose the battery to water or salt water, or allow the battery to get wet.
- Do not disassemble or modify the battery. The battery contains safety and protection devices which, if damaged, may cause the battery to generate heat, rupture or ignite.
- Do not leave the battery in direct sunlight, or use or store the battery inside cars in hot weather. Doing so may cause the battery to generate heat, rupture, or ignite. Using the battery in this manner may also result in shortened life expectancy and loss of performance.
- Never short circuit, reverse polarity, disassemble, damage, or heat the battery over 100 ºC (212 ºF). If an exposed lithium battery does not start on fire, it will burn even more violently if it comes into contact with water or even moisture in the air.
- DO NOT SPILL WATER ON A BURNING BATTERY. A fire extinguisher must be used.

1.7.1 Transporting RS41 Radiosondes with Lithium Batteries

RS41 radiosondes with lithium batteries are classified as:

- UN 3091 Lithium metal batteries contained in equipment

Consignments must be packed, labeled, and documented according to the IATA packing instructions.

When transporting the radiosondes with lithium batteries, take the following requirements into account:

- The package must display a lithium battery handling label, similar to the one shown in the following example. The original radiosonde shipping package must be used for transport, and it already has the lithium battery handling label.

- The consignment must include a document indicating the lithium content, describing proper handling and procedures for damaged packages, and a telephone number for additional information.

Figure 1 Lithium Battery Handling Label

> If the lithium battery is faulty, do not transport it.

1.7.2 Transporting Ozone Sensors with Lithium Batteries

Ozone sensors with lithium batteries are classified as:

- UN 3091 Lithium metal batteries contained in equipment

Consignments must be packed, labeled, and documented according to the IATA packing instructions.

When transporting the radiosondes with lithium batteries, take the following requirements into account:

- The package must display a lithium battery handling label, see Figure 1 (page 11) for an example. The original ozone sensor shipping package must be used for transport, and it already has the lithium battery handling label.
- The consignment must include a document indicating the lithium content, describing proper handling and procedures for damaged packages, and a telephone number for additional information.

1.8 ESD Protection

Electrostatic Discharge (ESD) can damage electronic circuits. Vaisala products are adequately protected against ESD for their intended use. However, it is possible to damage the product by delivering electrostatic discharges when touching, removing, or inserting any objects in the equipment housing.

To avoid delivering high static voltages to the product:

- Handle ESD-sensitive components on a properly grounded and protected ESD workbench or by grounding yourself to the equipment chassis with a wrist strap and a resistive connection cord.
- If you are unable to take either precaution, touch a conductive part of the equipment chassis with your other hand before touching ESD-sensitive components.
- Hold component boards by the edges and avoid touching component contacts.

2. Product and System Component Overview

2.1 Introduction to Ozone Sounding with RS41

An ozone sounding with RS41 consists of an ozone sensor unit, RSA411 Ozone Interface Kit, and RS41 radiosonde. These are described in the sections below. Other equipment needed is also explained. For detailed information on the radiosonde, see *Vaisala Radiosonde RS41-SG and RS41-SGP User Guide*.

In an ozone sounding, the radiosonde is attached to a styrofoam flight box which contains the ozone sensor unit and the interface card. The battery for powering the ozone pump is placed in a compartment on the side of the box. For information on performing an ozone sounding with Vaisala Radiosonde RS41, see also *Vaisala DigiCORA Sounding System MW41 Online Help*.

> To further improve the design of Radiosonde RS41, the radiosonde now has EPS covers with plastic fasteners. This makes the radiosonde's look and feel slightly different from before, but the radiosonde performance is still on the same high level. The plastic covers have been removed to decrease the total plastic amount of RS41.

2.1.1 Ozone Sensor Unit

The ozone sensor unit is either of the following:

- Science Pump Corporation (SPC) Model ECC-6A ozone sensor
- EN-SCI, former Droplet Measurement Technologies (DMT) Model Z ozone sensor

The sensors are based on chemical reaction cells. The type of the sensors is electrochemical concentration cell (ECC). Air is sampled flow (by using a pump) and it goes to a reaction cell, in which the sampled ozone reacts in a solution, and the current developed in the reaction is detected and measured with an ozone interface. The ozone sensor units are thoroughly discussed in the sensor manufacturers' manuals (see Table 2 (page 7)) and Performance Review Literature listed in Table 27 (page 95).

The main parts of an SPC ECC-6A ozone sensor are seen in Figure 2 (page 14). Model Z ozone sensor is similar to the SPC sensor. Refer to the sensor manufacturer's manuals for more detailed information.

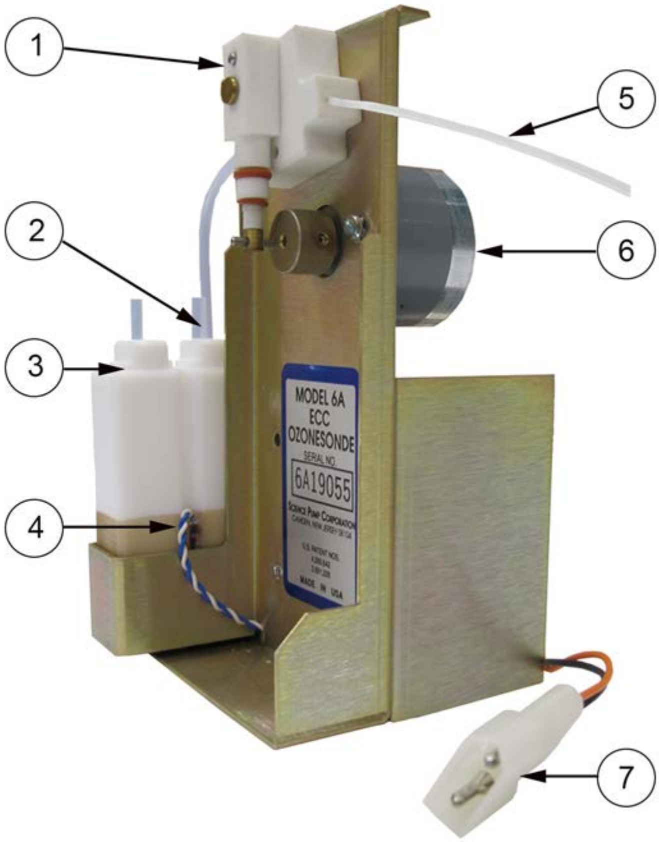


Figure 2 SPC ECC-6A Ozone Sensor Parts

1 Gas sampling pump
2 Ozone sensor cathode
3 Ozone sensor anode
4 Wires for interface
5 Air intake tube
6 Motor
7 Connector for pump battery

Note that the anode and cathode cells are in a different order in the ECC-6A and Model Z, see Figure 3 (page 15).

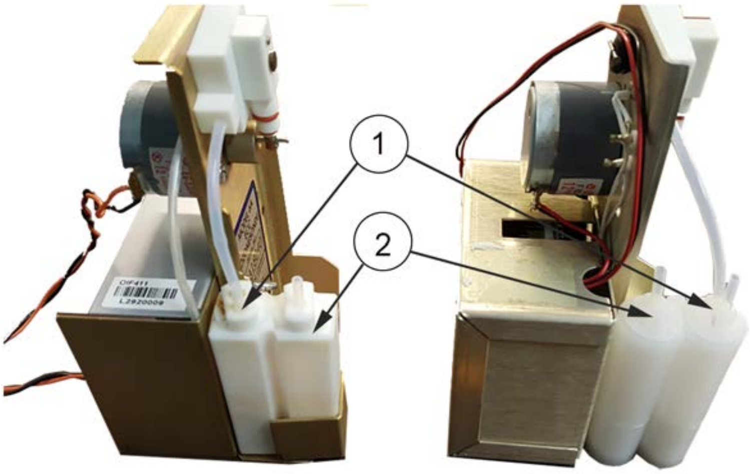


Figure 3 ECC-6A and Model Z Cathode and Anode

1 Cathode
2 Anode

2.1.2 Ozone Interface Kit RSA411

The RSA411 kit is used with Radiosonde RS41 and Science Pump Corporation's (SPC) ECC type sensors ECC-6A, or EN-SCI Model Z. The kit contains the items listed below.

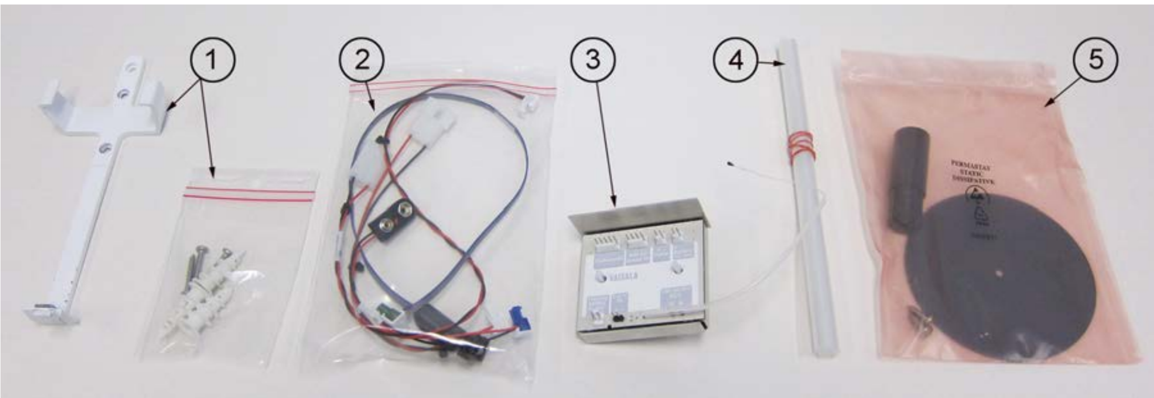


Figure 4 RSA411 Ozone Interface Kit Contents

1 Radiosonde holder with three plastic dowels and three screws for attaching the holder to the flight box wall. The plastic bag also contains two M3 nuts for attaching Ozone Interface Board OIF411 to Model Z ozone sensor frame. The M3 nuts are an alternative for the wing nuts included in OIF411.
2 Four cables: RS41-OIF411 cable CBL210224, OIF411 power cable CBL210225, OIF411 pump cable CBL210282, and OIF411 heater cable CBL210295.
3 Vaisala OIF411 with temperature sensor cable. The OIF411 temperature sensor is an NTC thermistor. OIF411 includes wing nuts for attaching it to ECC-6A ozone sensor frame.
4 RSU stabilizer, used with parachute or radar reflector.
5 Detainer for the radiosonde unwinder.

2.1.2.1 Ozone Interface Board OIF411

Ozone Interface Board OIF411 has four dedicated channels (ozone sensor current and temperature, battery voltage, and ozone pump current), and an additional voltage measurement channel for other purposes.

Figure 5 Ozone Sensor Interface Board OIF411

The terminals on OIF411 are marked with a sticker attached on the card. See Figure 6 (page 17) for details. The numbers in the figure refer to Table 3 (page 17).

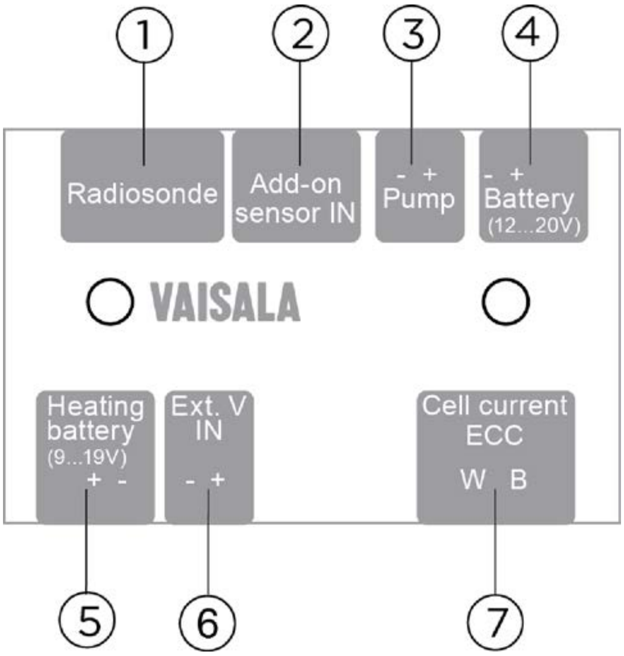


Figure 6 OIF411 Terminals Marked on Sticker

Table 3 OIF411 Terminals

Number	Connection	Cable Code
1	Radiosonde interface	CBL210224
2	Add-on sensor IN for optional XDATA sensors	
3	Pump motor	CBL210282
4	Ozone pump motor battery	CBL210225
5	Heating battery	CBL210295
6	Extra terminal	
7	SPC sensor W = white cable B = blue cable	

Figure 7 (page 18) shows the dimensions of OIF411. The dimensions are in millimeters.

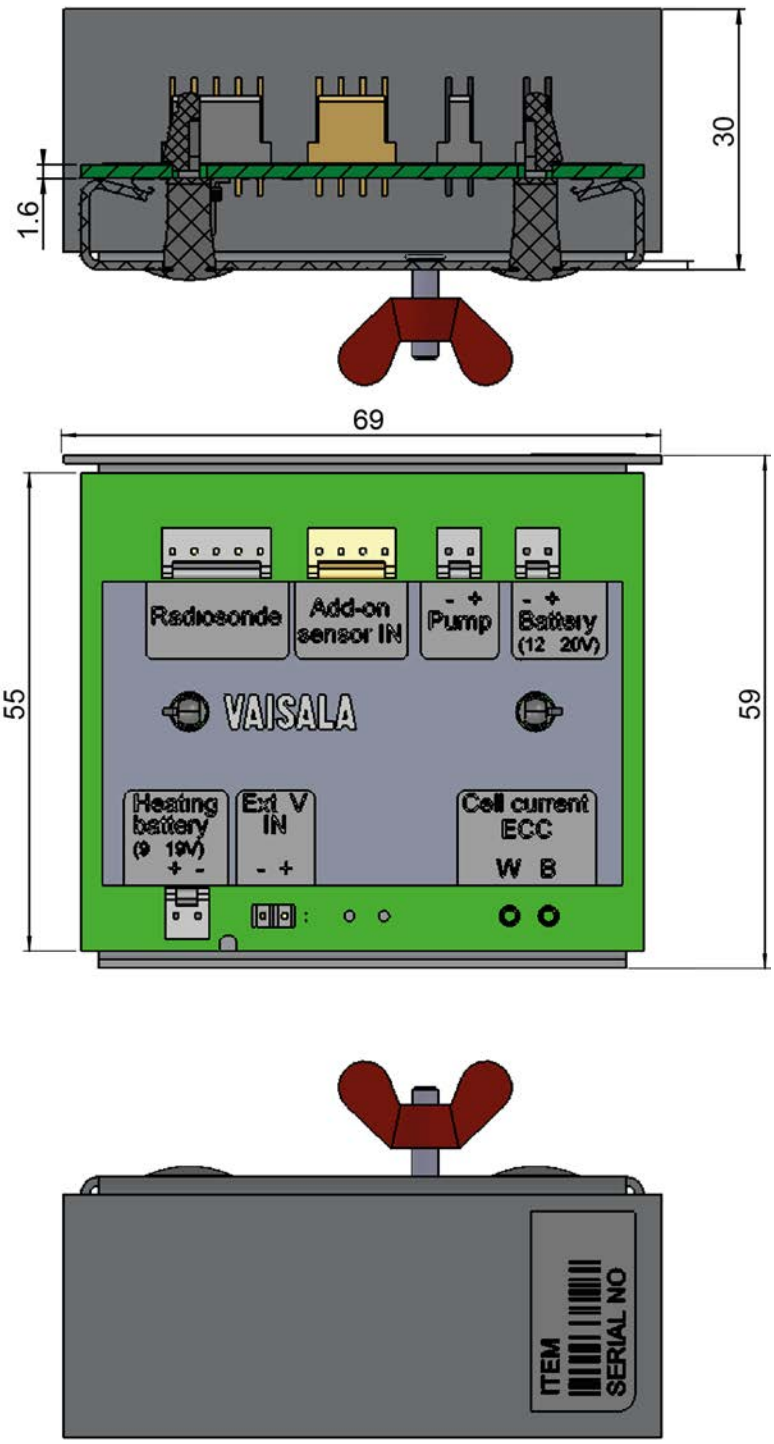


Figure 7 OIF411 Dimensions

2.1.3 Radiosonde RS41 Additional Sensor Interface

Figure 8 (page 19) shows details of the radiosonde additional interface connector. See also Table 4 (page 19) for details on the RS41 electrical interface and the additional sensor.

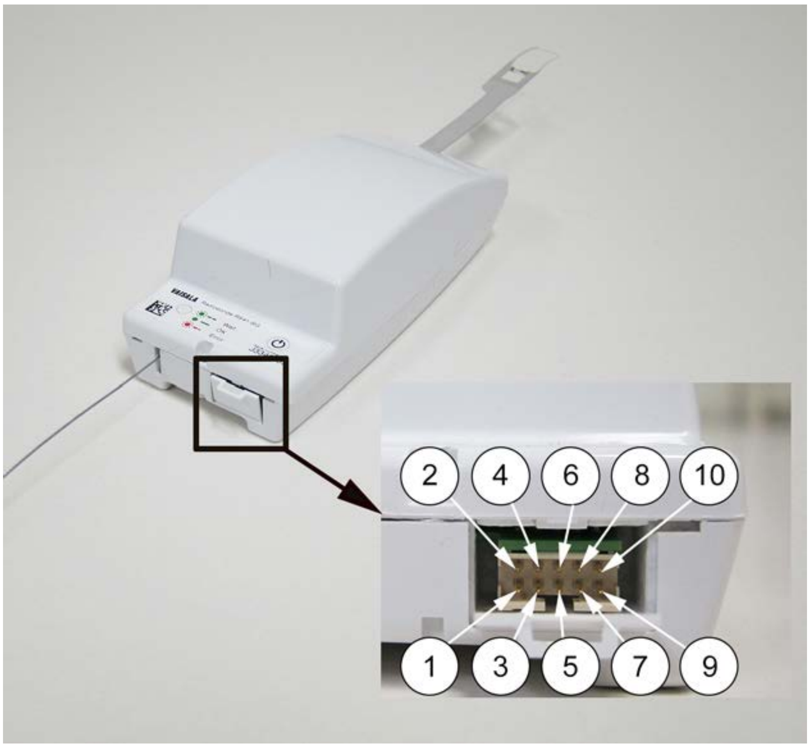


Figure 8 RS41 Additional Sensor Interface

Table 4 Electrical Interface of RS41 and the Additional Sensor

Radiosonde				Additional Sensor	
Pin	**Name**	**I/O**	**Function**	**Pin**	**Name**
1	GND	-	Ground		Common
2	RxD	I	Serial data from the additional sensor		Instrument Serial OUT
3	TxD	O	Serial data to the additional sensor		Instrument Serial IN
4 ... 10	Reserved		For Vaisala use only		Do not connect

2.2 Equipment and Material Needed

Several items are needed to prepare the ozone sensor and the radiosonde for a flight. The items listed below are included in the Vaisala Ozone Sounding Startup Kit and they are explained in more detail in the sections below:

- Ozonizer/Test Unit KTU-3 (or similar, from other manufacturers)
- Ozone destruction filter
- Pump test unit
- Laboratory ware set
- Ozone chemicals
- Air flow meter
  These items are valid when using the SPC ECC-6A ozone sensor or EN-SCI Model Z ozone sensor. Some sensor manufacturers also have their own startup kits. Note that these kits may not necessarily include all the required items for conducting an ozone sounding. For more details, refer to the sensor manufacturers' manuals.

2.3 Vaisala Ozone Sounding Startup Kit

Vaisala part number 25820OS.

Vaisala Ozone Sounding Startup Kit is used when preparing a new ozone sounding site. The kit includes materials and equipment for the sounding preparations. A list of the items and their part numbers are provided in Table 5 (page 20). More detailed information is given in the sections below.

In addition to Vaisala Ozone Sounding Startup Kit 25820OS, you need the ozonizer test unit. Vaisala offering includes the KTU-3 Ozonizer Test Unit, described in Ozonizer / Test Unit KTU-3 (page 21).

Table 5 Ozone Sounding Startup Kit

Pieces	Item	Vaisala Part Number
1	Ozone destruction filter	13197OS
1	Pump test unit	12785OS
1	Set of laboratory ware	13198OS
1	Ozone chemicals	13199OS
1	Air flow meter	1319OS
1	Balance	12771
1	Power supply	12767
1	Ozone documentation (includes several manuals)	

Also note the following points:

- The preparation startup kit delivered by SPC (see *Operator's Manual for Model 6A-ECC Ozonesonde*) differs from the Vaisala startup kit.
- The preparation startup kit delivered by EN-SCI (*Operator Manual for Corporation Model Z Ozonesonde*, or product brochure) differs from the Vaisala startup kit.
- Triple-distilled water and some other chemicals are not delivered, as they are easily available on the local sites.
- Documentation contains several manuals. Refer to Table 2 (page 7) for further details.

- Instructions for using the sounding software are needed to conduct a successful sounding. In addition to the instructions in this manual, MW41 sounding software contains an embedded on-line help with instructions for performing an ozone sounding.
- The Ozonizer/Test Unit TSC-1 is traditionally used for ozone sensor preparation. However, these days it is possible to substitute it with different models that have a digital ampere meter. A newer digital model is available from EN-SCI.

2.3.1 Ozonizer / Test Unit KTU-3

Vaisala part number 248823.

EN-SCI KTU-3 Ozonizer Test Unit is designed for conditioning ECC Ozonesondes with ozone and for checking the performance of the ozonesondes before flight.

Figure 9 EN-SCI Ozonizer /Test Unit KTU-3

KTU-3 measures the ECC cell and motor currents, and conditions and tests the ozone sensor. An additional digit is applied to the ECC cell current measurement, thus the result is with a resolution of 0.001 µA.

> "GAIN HIGH" is for special purposes only and should not be used in normal preparations.

2.3.2 Ozonizer/Test Unit TSC-1

This topic presents the Science Pump Corporation Model TSC-1 Ozonizer/Test Unit in more detail. Other options are also available, see Figure 11 (page 23).

Figure 10 Ozonizer/Test Unit TSC-1

> Vaisala recommends adding a digital ampere meter with a minimum resolution of 0.01 uA beside Ozonizer TSC-1, and checking the current from the digital ampere meter instead of the analog meter on TSC-1.

The Science Pump Corporation Model TSC-1 Ozonizer/Test Unit (or a similar equipment) is a necessary basic equipment for the preparations.

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

The Ozonizer/Test Unit and its operation are described in more detail in the SPC Operator's Manual for Model ECC-6A Ozonesonde and in the SPC Operator's Manual for Model TSC-1 Ozonizer/Test Unit. See Related Manuals (page 7) for a list of related manuals.

The following spare parts are available for TSC-1:

- Calibrator ECC ozone sensor, OTU-15. Vaisala part number 18955.
- Internal ozone filter, OTU-17. Vaisala part number 18960.
- Other spare parts mentioned in the TSC-1 manual are also available.

> For background current measurement, the ampere meter resolution must be 0.01 µA. This is difficult to achieve with an analog ampere meter, thus the GAW report 201 recommends the use of a digital model, for example, KTU-3 Ozonizer Test Unit.

Figure 11 EC Black Bench O3S Tester Made by EC

2.3.3 Ozone Destruction Filter

The ozone destruction filter eliminates ozone generated during testing. Table 6 (page 23) lists the parts required for the ozone destruction filter. However, the ASOPOS panel (Assessment of Standard Operating Procedures for Ozonesondes) recommends the use of purified, ozone-free air instead of the destruction filter. Refer to the GAW report 201 for more information. See Performance Review Literature (page 95) .

Table 6 Equipment Required for Ozone Destruction Filter

Item Required	Vaisala Part Number
Particle and ozone filter: Mine Safety Appliances (MSA) Company. Delivered by MSA as a single cartridge (part number 815185).	234561 (1 pc)
Funnel, 75 mm in diameter, tube diameter 8 mm, glass	12725
Connector tube 1: soft silicon tube approximately 5 cm long, inner diameter 6 mm, outer diameter 10 mm	12642OS (set of tubes)
Connector tube 2: soft vinyl tube approximately 60 cm long, I.D. 1/8″ (3.2 mm), O.D. 1/4″ (6.4 mm)	12642OS (set of tubes)
Connector tube 3: soft silicon tube approximately 2 cm long, inner diameter 2 mm, outer diameter 4 mm	12642OS (set of tubes)
Connector tube 4: Cut a piece of tubing from the ECC sensor air intake tube (2 cm), or order separately.	17348S (by the meter) or SPC spare part No. OTU-19
Electrical tape (Nitto 15)	4103

Assemble the ozone destruction filter components as shown in Figure 12 (page 24).

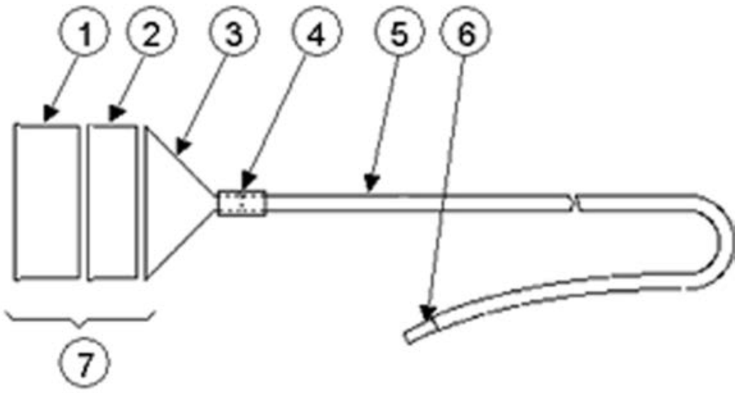


Figure 12 Ozone Destruction Filter

1 Catalyst
2 Ultra fiber
3 Funnel
4 Connector tube 1
5 Connector tube 2
6 Connector tube 3
7 Tape 1, 2, and 3 together with electrical tape

2.3.4 Pump Test Unit

Table 7 (page 24) lists the equipment needed for the pump test unit.

Table 7 Equipment Required for Pump Test Unit

Item Required	Vaisala Part Number
Vacuum/pressure gauge and connection screw. Range -1 ... 1.5 Bar, division 0.05 Bar. Includes connection parts for measurement gauge to tubing.	15240
Locking nut	
Connector tube 1: soft vinyl tube approximately 60 cm long, I.D. 1/8" (3.2 mm), O.D. 1/4" (6.4 mm)	12642OS (set of tubes)
Connector tube 2: soft silicon tube approximately 2 cm long, inner diameter 2 mm, outer diameter 4 mm	12642OS (set of tubes)
Connection tube 3: cut a piece of tubing from EEC sensor air inlet tubes to a length of approximately 3 cm, or order separately.	17348S (by the meter) or SPC spare part No. OTU-19

Set up the vacuum/pressure gauge as shown in Figure 13 (page 25).

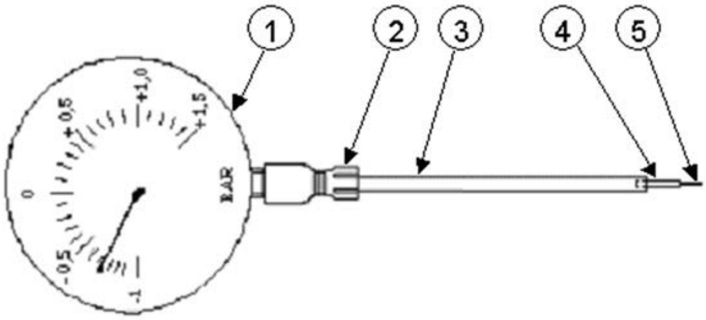


Figure 13 Vacuum/Pressure Gauge

1 Gauge and connection screw
2 Locking nut
3 Connector tube 1
4 Connector tube 2
5 Connector tube 3

Set up the pump unit following the steps below:

1. Insert connector tube 1 into the locking nut (see number 3 in Figure 13 (page 25)).
2. Push the tube over the tip of the connection screw on the gauge (number 1).
3. Gently tighten the locking nut over the connector tube onto the gauge (number 2).

> Be careful when attaching connector tube 1 to the connection screw tip. Be sure to tighten the locking nut gently to avoid damaging or tearing the connection tube. The condition of the connection tube can be checked by opening the locking nut.

4. Insert connector tube 2 (number 4) into connector tube 1 (number 3) by at least 5 mm.
5. Finally, insert the connector tube 3 (number 5) into connector tube 2 (number 4) by at least 1 cm.

2.3.5 Laboratory Ware Set

Bottles and glassware are needed, for instance, for preparing and storing sensing solutions, and for sensor cleaning. The set presented in Table 8 (page 25) is useful and can easily be obtained from any laboratory ware dealer. The set can also be ordered from Vaisala by referring to the part numbers listed in the table.

Table 8 Laboratory Ware Needed

Item	Pieces	Vaisala Part Number
Beakers (Pyrex glass)	1 pc, volume 250 ml (subdivision 50 ml) 1 pc, volume 50 ml	12721 12720

Item	Pieces	Vaisala Part Number
Cylinder (Pyrex glass)	1 pc, volume 100 ml (subdivision 1 ml)	12722
Volumetric flasks with stoppers (Pyrex glass)	1 pc, volume 1000 ml 1 pc, volume 500 ml 1 pc, volume 100 ml	12724 214857 12723
Bottles with stoppers (preferably colored glass)	2 pcs, volume 1000 ml 2 pcs, volume 100 ml	12738 + 12740 12739 + 12740
Funnels	2 pcs, mouth diameter 75 mm, pipe 10 mm, for liquids, glass 1 pc, mouth diameter 65 mm, pipe 10 mm, for powder, polypropylene	12725 12726
Spatulas	3 pcs, polypropylene or steel	12729
Basins (polypropylene or glass)	2 pcs, for powder weighing	12727
Syringes with needle	Disposable; total volume 3 ml, division. 0.1 ml (at least 0.5 ml). Plastic (Teflon) 2 pcs, Syringe 2 pcs, Syringe needle	12736 12737
Thermometer	1 pc, for room temperatures	232012

2.3.6 Ozone Chemicals

The chemicals used must be very pure, at least of Pro Analysis quality.

Table 9 Required Ozone Chemicals

Chemical Required	Amount	Vaisala Part Number
KI	1 kg	12743
KBr	0.5 kg	12744
$NaH_2PO_4 \cdot H_2O$	0.5 kg	12741
$Na_2HPO_4 \cdot 12H_2O$ (or $Na_2HPO_4 \cdot 7H_2O$)	0.5 kg	12742
Methanol (CH_3OH)		-
Glycerol		-
Acetone		-

2.3.7 Air Flow Meter

Table 10 (page 27) lists the equipment required for the Air Flow Meter. Section Using the Air Flow Meter (page 31) explains how the air flow meter is used in ozone sounding preparations.

Table 10 Equipment Required for Air Flow Meter

Item Required	Vaisala Part Number
Air flow meter tube. Burette with filling tube, capacity 100 ml	12733
Rubber bulb, capacity approximately from 50 to 80 ml	12734
Burette stand with two bossheads and two clamps	12730 (stand), 12732 (bosshead), 12728 (clamp)
Stop-watch, accuracy at least 0.1 s	12784
Connector tube 1: soft silicon tube approximately 5 cm long, inner diameter 6 mm, outer diameter 10 mm	12642OS (set of tubes)
Connector tube 2: soft vinyl tube approximately 60 cm long, I.D. 1/8" (3.2 mm), O.D. 1/4" (6.4 mm)	12642OS (set of tubes)
Connector tube 3: soft silicon tube approximately 2 cm long, inner diameter 2 mm, outer diameter 4 mm	12642OS (set of tubes)
Dishwashing liquid: Add about one teaspoon of dishwashing liquid and one teaspoon of glycerol to 1 dl of water.	

2.3.8 Other Equipment and Material

2.3.8.1 Balance

The balance must fulfill the following requirements:

- Measurement range must be from 0 to 500 g.
- Accuracy required is 0.01 g.

2.3.8.2 Thermometer

A thermometer is needed for measuring air temperature. It can be a mercury thermometer or an electrical thermometer.

The thermometer must be capable of measuring normal room temperature, a suitable measurement range is between -2 and +50 °C. The recommended thermometer subdivision is 0.1 or 0.2 °C.

2.3.8.3 Power Supply

A power supply rated at 5 to 18 VDC, 300 mA is required for the ozone pump motor. Refer to the manufacturers' manuals for details.

2.3.8.4 Protective Gloves

Use disposable gloves to avoid dust and other contaminants. The gloves must be lint-free and made of artificial fabric or plastic. Note that RSA411 Ozone Interface Kit does not include gloves.

2.3.9 Expendables and Spare Parts

After establishing an ozone sounding site, check the availability of expendables and spare parts. Making a list of these items is recommendable. A large variety of spare parts is available from Vaisala.

The list of expendables includes at least:

- Radiosondes, interfaces
- Sounding accessories (for example, balloons)
- Ozone solution chemicals
- Syringes, needles
- Protective gloves
- Triple-distilled or ion-changed water

See also Checklist for Equipment and Supplies for Flight Preparations (page 93).

3. Constructing an Ozone Sounding

3.1 Sounding Preparation Phases and Schedule

WARNING! The chemicals involved in an ozone sounding can be harmful, and must be handled with proper care. To ensure your working safety, take all the necessary precautions before beginning the preparations for a flight.
Read the sensor manuals carefully.
Follow the local laboratory work practices, regulations, and waste management guidelines.
Use disposable gloves to avoid dust and other contaminants. The gloves must be lint-free and made of artificial fabric or plastic. Note that the RSA411 Ozone Interface Kit does not include gloves.

Perform the preparations preferably at temperatures between +20 and +30 °C.

Preparing an ozone sounding consists of the following steps. See the sections below for more information.

- Preparations 7 to 3 Days Prior to Release (page 30).
- Preparation Steps on the Day of Release (page 34).
- Preparations Just Before Release (2 - 0 Hours) (page 35).

More detailed preparation instructions are given in *GAW Report No. 201 Quality Assurance and Quality Control for Ozonesonde Measurements in GAW Annex A*.

The ASOPOS panel recommends using the following as sensing solutions:
SPC6A: 1.0%, KI, full buffer (STT1.0)
DTM: 0.5% KI, half buffer (SST0.5)
The recommendation is only meant for new ozone sounding stations. The existing stations that perform long-term measurements must not change their sensing solution type or ECC type.

The ASOPOS panel recommends recording three different background currents:

- I_{B0}: after 10 minutes of ozone-free air before exposure of ozone.
- I_{B1}: after 10 minutes of ozone-free air after exposure of ozone (5 µA ozone equivalent of 170 - 180 ppbv).
- I_{B2}: at launch site after 10 minutes of ozone-free air.

I_{B2} equals to Vaisala I_{BG} = I_0, used in Vaisala scripts.

3.1.1 Preparing the Cathode and Anode Solutions

Sensor solution requirements are very strict. The ECC sensor solutions must be prepared using at least Pro Analysis chemicals and triple-distilled water.

See the applicable ECC ozone sensor manufacturers' manuals for instructions on how to prepare the cathode and anode solutions.

3.2 Preparations 7 to 3 Days Prior to Release

This phase consists of checking the overall performance of the ozone sensor, and charging the sensor with the sensing solution. A Model TSC-1 Ozonizer/Test Unit is used to check the overall sensor performance.

The purpose of these preparations is to make sure that the ozone sensor functions properly and can be used in an ozone sounding.

The limit values mentioned here are valid only for SPC ECC-6A ozone sensor. For other ozone sensors, create and use a modified checklist.

WARNING! The chemicals involved in an ozone sounding can be harmful, and must be handled with proper care. To ensure your working safety, take all the necessary precautions before beginning the preparations for a flight.
Read the sensor manuals carefully.
Follow the local laboratory work practices, regulations, and waste management guidelines.
Use disposable gloves to avoid dust and other contaminants. The gloves must be lint-free and made of artificial fabric or plastic. Note that the RSA411 Ozone Interface Kit does not include gloves.

CAUTION! During preparations the ozonizer produces a small amount of ozone. Avoid breathing the high ozone air exhaust. You can connect the cathode exhaust tubing to a Drierite desiccant column or other filter, or prepare the sensor in a fume hood.

Make sure to perform the initial preparations early enough, from 1 week to 3 days before the ozone sounding release. This must be done to attain a low sensor background current and a fast sensor response to ozone.

3.2.1 Using the Air Flow Meter

This procedure is meant to be carried out with no remarkable breaks (that is, breaks lasting over two hours).

> To avoid contamination, note the following precautions:
> Work in a clean environment with clean hands.
> Never operate the pump without the ozone destruction filter or purified air.
> Do not use a sensor loaded with solutions if the sensor is not connected to a powered interface (or if the anode and cathode wires are connected).

Arrange the air flow meter as shown in Figure 14 (page 32). The procedure for air flow measurement is described below. The numbers within brackets refer to the items in Figure 14 (page 32):

1. Fill the rubber bulb (4) and the flow meter tube with soap solution (8) almost up to the filling tube of the flow meter tube.
2. Connect the air flow meter to the sensor cathode air exhaust tube. This is done by slipping the connector tube 3 (9) over the short Teflon tube protruding from the top plug of the sensor cathode chamber.
3. With the radiosonde air pump operating, squeeze the rubber bulb (4) slightly to cause several soap bubbles to rise up the flow meter tube. Repeat the process several times, until the bubbles reach the top of the tube without breaking.
4. Now form only one bubble, and use a stop-watch to determine the time (t) required for the bubble to rise from 0 to 100 ml up the flow meter tube (5). Repeat the measurement three times to obtain a mean value.

> When the air flow is measured, make sure the sensor is charged with the sensing solution.

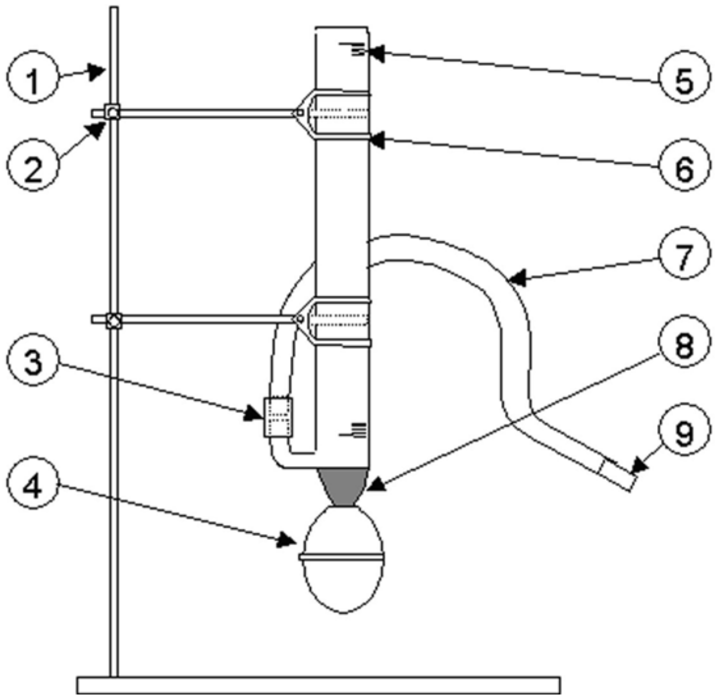


Figure 14 Air Flow Rate Measurement

1 Stand
2 Bosshead
3 Connector tube 1
4 Rubber bulb
5 Flow meter tube
6 Clamp
7 Connector tube 2
8 Dishwashing liquid
9 Connector tube 3

3.2.2 Preparation Steps 7 to 3 Days Prior to Release

To enable smooth operation, place all the necessary parts on a table, but leave some free space in front of the ozonizer, if necessary.

1. Write down the following information:
   Date: ________ Station: __________ Operator: ____________
2. Check the label on the flight box and record the information here.
   Ozone sensor number:
   Manufacturer:
   Date of manufacture:
   Pump pressure:______________ in Hg
   Pump voltage:______________ V DC
   Pump current:______________ mA
   Flow rate:_______________s/100 ml

3. Connect the ozone sensor to the ozonizer (motor, output, sensor leads).
   a. Turn on the ozonizer.
   b. Record I_{B0} before applying any ozone to the sensor:
      I_{B0}_______________µA
4. Condition the pump and the dry sensor with HI O_3 for 30 minutes.
5. After 10 minutes of HI O_3, check the following values from the ozonizer:

Table 11 Values in Ozonizer

Value	Measured	Limit Values
Pump voltage	_________ V	12 ... 13 V
Pump current	_________ mA	ECC-6A: < 115 mA; Model Z <100 mA
Head pressure	_________ Pa	> 700 hPa app. 20 in Hg
Vacuum (this is a minus value)	_________ Pa	> 500 hPa app. 14.8 in Hg

6. Turn off HI O_3. Run NO O_3 for 5 minutes.
7. Next, you must charge sensor cathode and anode. Use a different syringe for cathode and anode.
   Charge sensor **cathode** with solution 3.0 cm^3 and wait 2 minutes.
   Charge sensor **anode** with solution 1.5 cm^3.

   After using the syringes, rinse them carefully with distilled water.

8. Run NO O3 for 10 minutes. The current starts to decrease. Sensor background current after 10 minutes (typically the value is under 1.5 µA) on NO O_3: _______________µA
9. Run on moderate ozone (about 5 µA) for 5 minutes.
10. Check that the LCD display background current starts to rise to 5 µA or more. Use the OZONE CONTROL tube to adjust and maintain the current at 5 µA for 5 minutes.
11. Run on NO O_3 for 10 minutes. Check that O3 decreases by 70-80% in 1 minute. Record the background current: I_{B1}_______________µA
    The background current may be 0.2 to 0.5 µA at this time. It will decrease during the next days as the sensor is stored.
12. Switch everything off.
13. Add 3 ml to cathode.
14. Short-circuit the ozone sensor wires.
15. Put the ozone sensor back to the flight box and store it in a dark, clean-air environment at a temperature of 20 ... 25 °C until it is used.

After these preparations, a sensor cleaning process takes place, whereby both half cells (anode and cathode) and ionbridge get in balance.

3.3 Preparation Steps on the Day of Release

The CAL measurements are applicable when SPC's TSC-1 Ozonizer/Test unit is used. They can be ignored with the KTU-3 ozonizer.

1. Write down the following information:
   Date: __________ Station:___________ Operator: ____________
   Ozonesonde number: __________________
   Manufacturer: __________________
   Date of manufacture: __________________
2. Change cathode solution in SONDE (S) and CAL (calibrator, C; with TSC-1 only) sensors:

   S: _________ ml
   C: _________ml
   The ASOPOS panel recommends the following:
   a. Dump both solutions carefully (cathode and anode).
   b. Recharge cathode cell with 3.0 cm^3 cathode solution.
   c. Recharge anode cell with 1.5 cm^3 anode solution.
3. Condition SONDE (S) and CAL (C; with TSC-1 only) NO O_3 for 10 minutes.
4. Sensor's background currents (< 0.2 µA. ASOPOS recommendation 0.05 µA):
   ^{i}bc = _________ µA
   ^{i}bs= __________ µA (<0.05 µA; defined as I_{B0} by ASOPOS)
5. Condition SONDE and CAL (with TSC-1 only) sensors with 5±0.2 µA O3 for 5 minutes.

6. After 5 minutes of conditioning with about 5 µA O_3:
   i_c = µA __________ i_s = µA__________
   With NO O_3, check the sensor response test:
   $i_{0.51c}$: = __________µA $i_{0.5s}$: µA __________0.5 minute
   i_{1c}: = __________µA $i_{1s:}$ µA __________1 minute
   i_{2c}: = __________µA $i_{2s:}$ µA _________ 3 minutes
   i_{3c}: = __________µA $i_{3s:}$ µA _________ 5 minutes
   i_{10c}: = __________µA $i_{10s:}$ µA _______ 10 minutes (equals to I_{B1})
   Record cell current at t = 0, 0.5, 1, 3, 5, and 10 minutes (as recommended by ASOPOS i_{10s} = I_{B1} background current).
   Computed for calibration acceptance check out:
   (i_c-i_{bc}) t_c = __________ (i_s-i_{bs}) t_s = _______ (agree to within 5%. If necessary, take corrective action to get the desired result. See *Science Pump Corporation's Operator's Manual* for further instructions.)
   i_{1c} = __________ <0.20 (i_c-i_{bc})_______
   i_{1s} = __________ <0.20 (i_s-i_{bs})_______
   or, alternatively with DMT ozonizer:
   i_{1s} = _________ <0.20 (i_s-I_{B1})
7. Continue running the SONDE with ozone-free air, and connect the air flow meter to the exhaust port of the cathode cell.
   Measure:
   SONDE sensor air flow rate:
   t_s =_______ , __________ , __________ , __________ , __________ s
   CAL sensor air flow rate (with TSC-1 only):
   t_c =_______ , __________, __________ , __________ , __________ s
   T_{room} = _______°C; P_{room} =_______ hPa; RH_{room} = _______%

3.4 Preparations Just Before Release (2 - 0 Hours)

These preparations must be performed from 2 to 0 hours before the sounding balloon release. Table 12 (page 36) presents the workflow included in preparing the radiosonde and OIF411 for a sounding with sounding software MW41 45 minutes before the launch. The steps below provide more detailed information on the preparations.

Table 12 Workflow for Ozone Sounding Preparations 45 Minutes Before Launch

Time to Launch in Minutes	Ozone Sensor	Interface OIF411	Radiosonde RS41	Sounding Software MW41	Balloon and Accessories
45	Select battery type and any supplemental heat source needed, based on the previous flight's performance.	Attach interface board to pump frame.	Attach radiosonde holder to styrofoam flight box.	Start MW41 software.	Fill the balloon and attach the detainer/ unwinder/ parachute.
30	Start running the ECC on ozone-free air using an external power supply for the pump motor.		Activate and condition radiosonde.	Configure software for the ozone flight.	
20	Record background current.	Connect interface to RS41.		Record background current.	
15	Connect battery to ozone sensor pump (activate battery if needed), and heater battery, if required.		Attach radiosonde to the flight box.		Prepare the radiosonde for flight. Put ECC into to flight box if it is not there yet (for prewarming in cold weather flights).
10	Take the ozonesonde construction outside to acclimatize and record surface ozone.			Check telemetry data.	Attach radiosonde to the balloon.
0				Check telemetry data.	Release the balloon.

3.4.1 Starting Preparations

1. Write down the following information:
   Date: _________ Station :__________ Operator: ____________
   Ozonesonde number: _________________
   Manufacturer: _________________
   Date of manufacture: _________________
   Radiosonde serial number: _________________
   OIF411 serial number: _________________

3.4.2 Attaching Radiosonde Holder to Flight Box

Equipment and tools needed:

- A pen for marking the positions of the holder screws.
- A screwdriver for tightening the screws.
- Radiosonde holder with three plastic dowels and three screws, included in Ozone Interface Kit RSA411.

Figure 15 (page 37) shows how the radiosonde holder is attached to the flight box wall. See also the steps below.

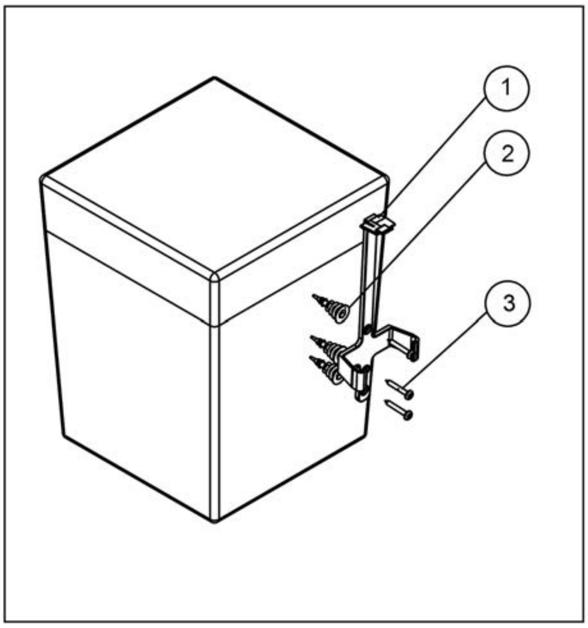


Figure 15 Radiosonde Holder Attachment

1 Radiosonde holder
2 Dowels
3 Screws

Figure 16 (page 38) shows the radiosonde holder measurements and its position in the flight box wall. In the figures presented in this section, the holder is positioned according to Vaisala recommendation, according to which the radiosonde sensor boom is above the flight box wall and the holder is attached on top of the sticker.

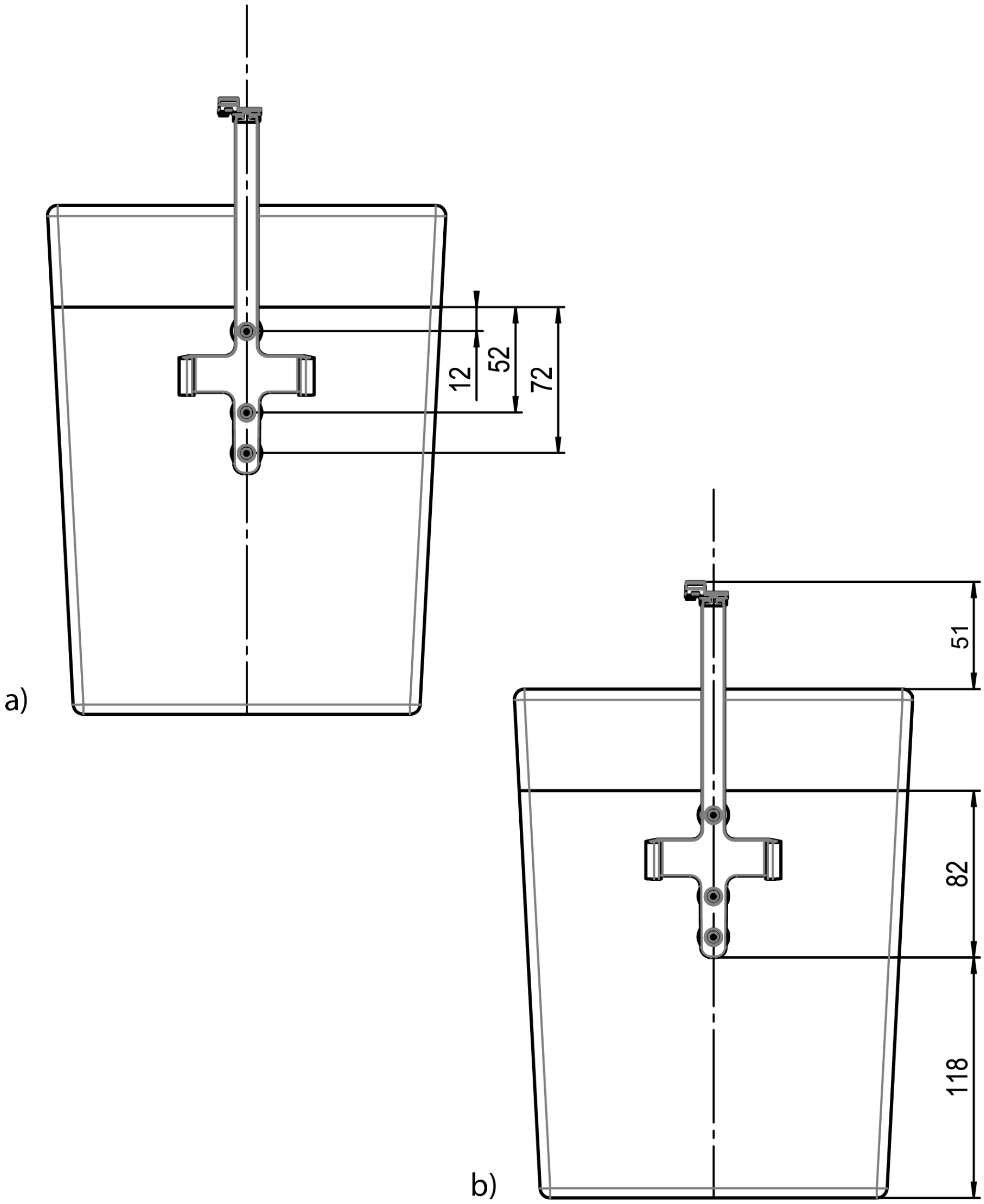


Figure 16 Radiosonde Holder Measurements (a) and Position (b)

1. The holder is attached on top of the sticker on the flight box wall. Press the radiosonde holder against the flight box wall and mark the holder screw positions with a pen.

Figure 17 Marking the Positions of the Holder Screws

2. Use a screwdriver to insert the dowels where the holder screw marks are. Use the three dowels included in the RSA411 kit.

Figure 18 Inserting the Dowels

3. Remove the tape cover before attaching the holder. The tape makes the radiosonde holder attachment extra secure.
4. Hold the radiosonde holder against the tape and use a screwdriver to attach it to the box wall with the screws provided in the RSA411 kit.

3.4.3 Attaching OIF411 to SPC's Ozone Sensor Frame

Figure 19 (page 41) shows how OIF411 is attached to Science Pump Corporation's (SPC) Model ECC-6A ozone sensor frame. See also the steps below. You do not need any extra equipment to attach OIF411 to the ozone sensor frame, the wing nuts needed are included in OIF411.

For instructions on attaching OIF411 to Model Z ozone sensor frame, see Attaching OIF411 to EN-SCI Ozone Sensor Frame (page 43).

CAUTION! Keep the sensor in an upright position. The sensor contains liquid.

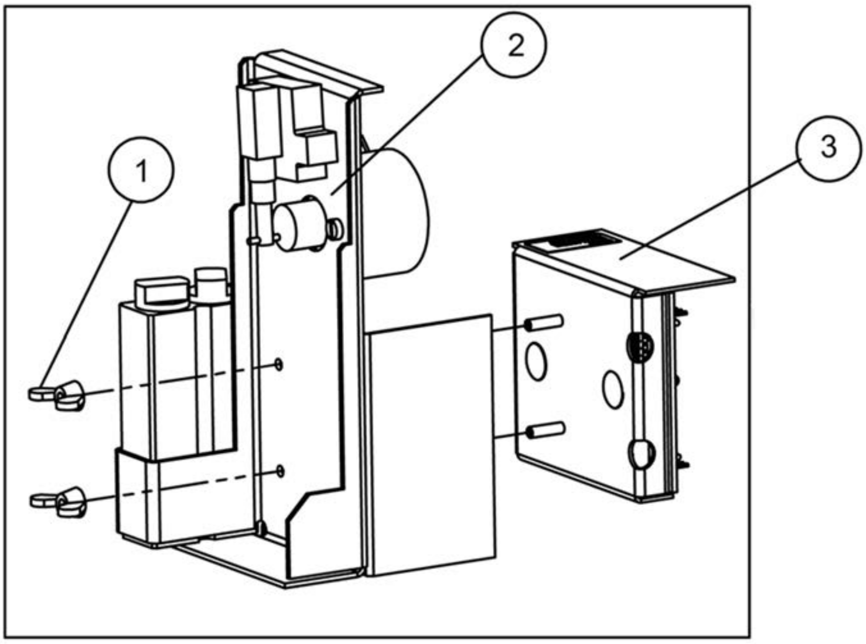


Figure 19 Attaching OIF411 to Ozone Sensor

1 Wing nuts
2 Ozone sensor frame
3 OIF411

To connect the ozone sensor frame and Ozone Interface Board OIF411:

1. OIF411 is equipped with two wing nuts at the back. Attach OIF411 to the ozone sensor with the wing nuts. See Figure 20 (page 42) for an illustration.

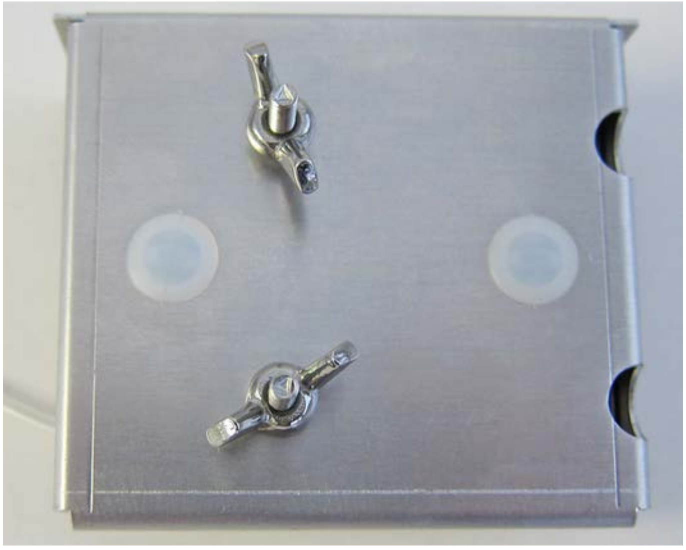


Figure 20 Wing Nuts on the Back of OIF411

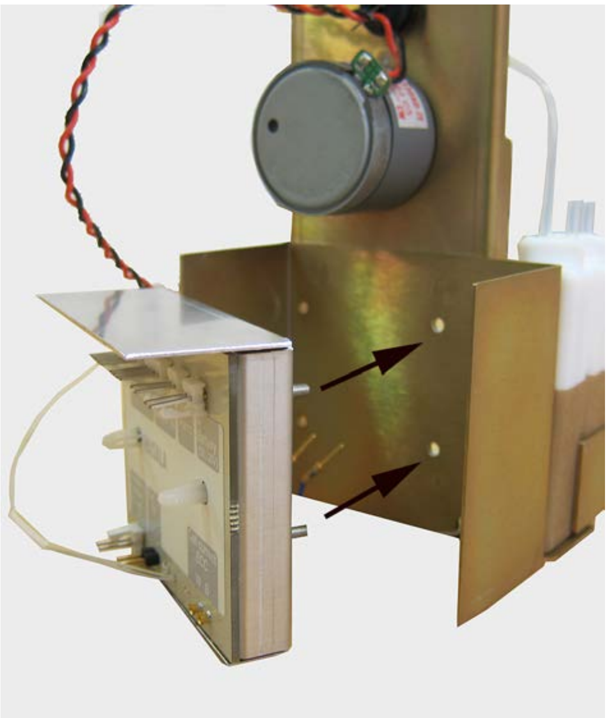


Figure 21 OIF411 Being Attached to the Ozone Sensor Frame

2. Tighten the wing nuts.

Figure 22 OIF411 Wing Nuts Tightened

3.4.4 Attaching OIF411 to EN-SCI Ozone Sensor Frame

In addition to OIF411 and the ozone sensor frame, you need the following equipment:

- Two M3 nuts included in RSA411 Ozone Interface Kit
- Drill with applicable drill bits
- Socket wrench for M3 nuts
- Screwdriver

CAUTION! Keep the sensor in an upright position. The sensor contains liquid.

Figure 23 (page 44) shows EN-SCI Model Z ozone sensor frame.

Figure 23 EN-SCI Model Z Sensor

To connect the ozone sensor frame and Ozone Interface Board OIF411:

1. Remove the wing nuts attached to OIF411.

2. Use a drill to make the holes in the ozone sensor frame bigger.

Figure 24 Drilling the Ozone Sensor Frame Holes

3. Attach OIF411 to the ozone sensor frame with the two M3 hex nuts, a screw driver and a socket wrench. Tighten the nuts.

Figure 25 Ozone Sensor Attached to the Model Z Frame with M3 Nuts

3.4.5 Connecting Ozone Sensor Wires to OIF411

Connect the ozone sensor wires to Ozone Interface Board OIF411.

The terminals on OIF411 are marked with a sticker attached on the card. See Figure 26 (page 46) for an example. The numbers in the figure refer to Table 13 (page 46).

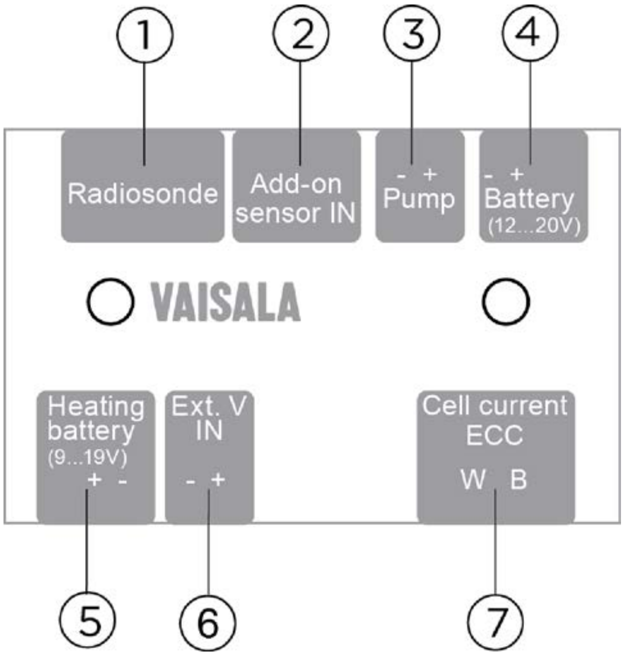


Figure 26 OIF411 Terminals Marked on Sticker

Table 13 OIF411 Terminals

Number	Connection	Cable Code
1	Radiosonde interface	CBL210224
2	Add-on sensor IN for optional XDATA sensors	
3	Pump motor	CBL210282
4	Ozone pump motor battery	CBL210225
5	Heating battery	CBL210295
6	Extra terminal	
7	SPC sensor W = white cable, B = blue cable	

1. Connect the white wire from the anode to the terminal on the corner of the interface marked with W.

2. Connet the blue wire from the cathode to the terminal marked with B.

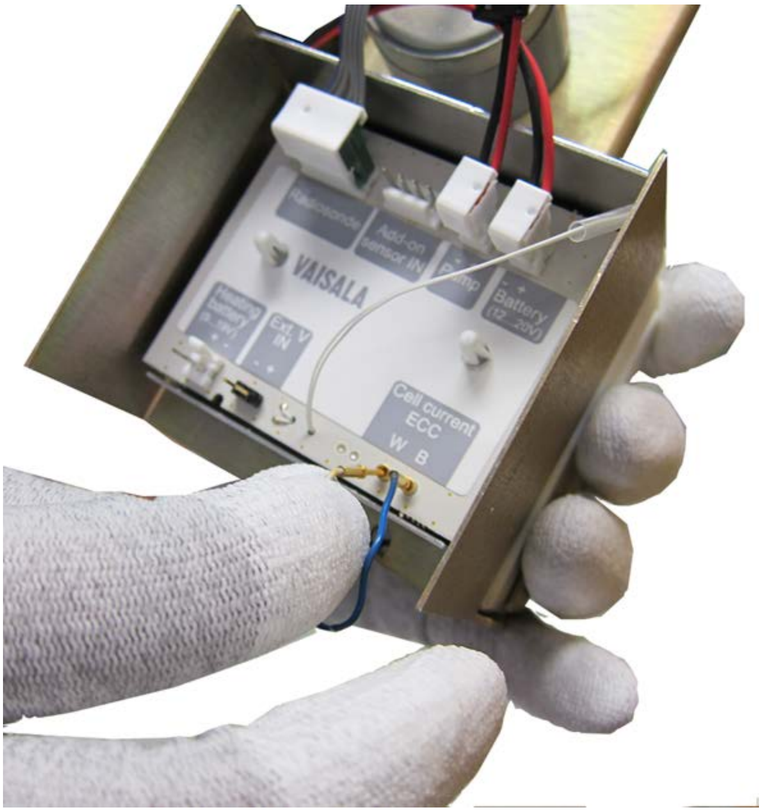


Figure 27 Connecting Sensor Wires to OIF411

3.4.6 Preparing the Radiosonde and OIF411

CAUTION! To avoid any problems with the sounding, do not use the sensor loaded (pump-powered) with solutions, if the sensor is not connected to a powered interface, or if the anode and cathode wires are connected. The pump is allowed to be used only with NO-OZONE, or when the destruction filter is connected. Never use HI-OZONE.

3.4.6.1 Connecting Ozone Sensor Pump to OIF411

Cable needed: CBL210282

- Connect the cable to the OIF411 terminal marked **Pump**.

Figure 28 Connecting Ozone Sensor Pump Cable

3.4.6.2 Connecting Ozone Pump Battery to OIF411

Cable needed: CBL210225

- Connect the ozone pump battery to OIF411 terminal marked **Battery (12 ... 20 V)**. At a later stage, place the battery in the empty compartment on the side of the flight box.

Figure 29 Connecting Ozone Sensor Battery Cable

3.4.6.3 Connecting Thermistor Cable to Ozone Sensor Pump

Insert the thermistor into the hole in the pump base of the ozone sensor by pushing the thermistor hose into the hole, as shown in Figure 30 (page 49). In the SPC sensor, the hole is below the air outlet of the pump.

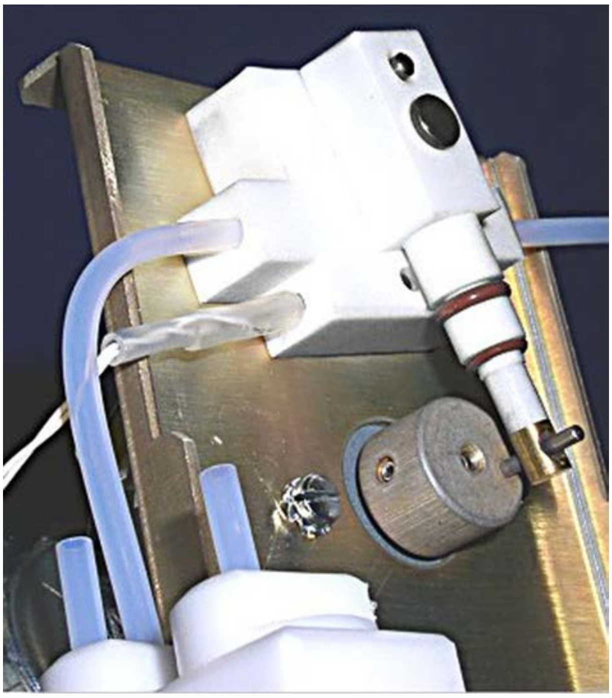


Figure 30 SPC ECC-6A with Thermistor Assembled

In the EN-SCI sensor, the temperature measuring hole is on the opposite side of the pump (and is connected through the frame).

Figure 31 EN-SCI Model Z with OIF411 Temperature Sensor Assembled

3.4.6.4 Connecting Additional Sensor Cable to OIF411

If you are using an additional sensor in the sounding, use the terminal marked **Add-on sensor IN** for the additional sensor cable.

3.4.6.5 Connecting Heating Battery to OIF411 (Optional)

Cable needed: CBL210295

The heating battery is used in extreme conditions. Heating turns on automatically when the ozone pump temperature drops under +5 °C, and turns off when the temperature rises above +7 °C. There is no risk of overheating the box. However, the applicability of the heating should be checked on each site separately.

1. Connect the heating battery wire to the **Heating battery** terminal on OIF411.
   a. Connect the red wire to the terminal marked with **+**.
   b. Connect the black wire to the terminal marked with **-**.

Figure 32 Connecting Heating Battery

2. Attach two-sided tape to the side and bottom of the battery to attach it to the sensor frame.

Figure 33 Two-Sided Tape Attached to the Battery

3. Make sure to pass the battery wires between the ozone sensor frame wall and the ozone sensor top cover and make sure that they are not twisted or under the sensor frame. See Figure 34 (page 51) for an illustration.

Figure 34 Battery Wires Running Between the Ozone Sensor Frame Wall and the Ozone Sensor

3.4.7 Preparing the Radiosonde with Ground Equipment

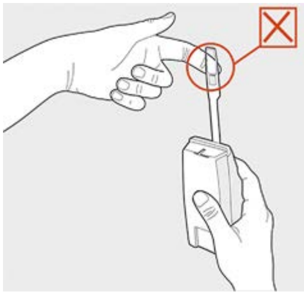
CAUTION! To be able to prepare an ozone sounding with MW41, you must import and activate the following scripts:

- *`OzoneCalculations.py`*
- *`OzoneMain.py`*
- *`OIF411.py`*

The scripts are included on the MW41 installation media, in folder *`ScriptLibrary\CalcOzone`*. The ozone sounding cannot be completed if any of these scripts is missing.

Import the scripts to the same Script Group and select *`OzoneMain.py`* as the main script. Make sure that Script group is set active. You do not need to set a command line argument. For more instructions, see MW41 online help, embedded in the MW41 software.

CAUTION! Do not touch the radiosonde sensors. They are fragile and can be easily contaminated.



1. Start MW41 sounding software, if you have not started it yet, and log in.
2. Attach the ozone destruction filter to the pump inlet tube.
3. Place the RS41 radiosonde on the ground check device. The radiosonde is switched on when you place it on the ground check device. The message `Preparation in progress` will be displayed in MW41.

   CAUTION! Do not connect Ozone Interface Board OIF411 to the radiosonde while the radiosonde is placed on the ground check device. Connecting OIF411 during the ground check will interrupt the preparations and MW41 will return to the Radiosonde selection window.

4. Before the preparation phase is completed, scroll the MW41 page down to the Special sensor window, and select **Ozone** from the drop-down list.

5. Fill in the information needed and click **Apply**. During this phase, the radiosonde LED light is red, but you can ignore it. It does not indicate an error at this point.

> The ASOPOS panel recommends 3.0 cm^3 for cathode solution volume.

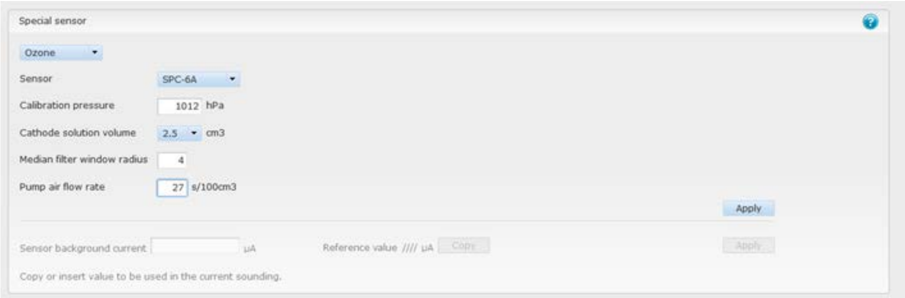


Figure 35 Ozone Sensor Information

During the ground check preparations, the radiosonde status in MW41 might display an error with the message `No add-on sensor data (filtered)`. You can ignore this message and proceed with the preparations, it has no effect on the ozone sounding.

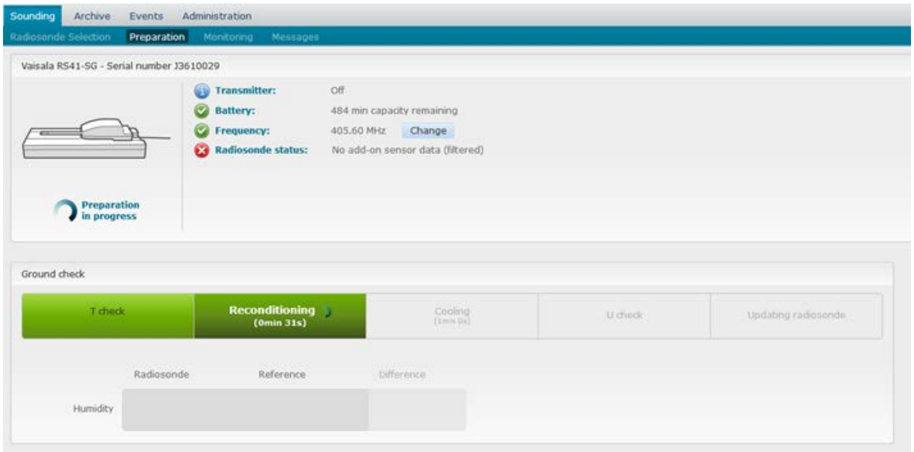


Figure 36 Radiosonde Preparation in Progress

6. When the message `Waiting for background current` is displayed, remove the radiosonde from the ground check device.

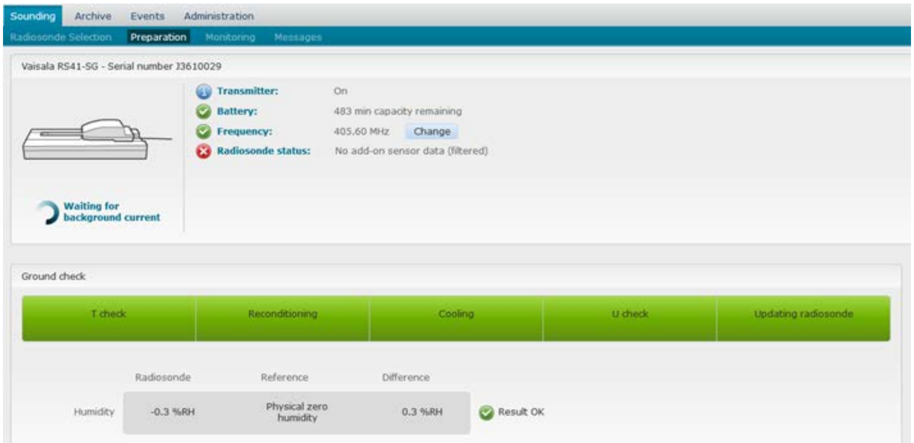


Figure 37 Waiting for Background Current

7. Connect OIF411 to the radiosonde using cable CBL210224. Do as explained below:
    a. Connect the radiosonde cable to the interface terminal marked **Radiosonde**.

Figure 38 Connecting Radiosonde Cable

    b. Connect the interface to the radiosonde.
    If you are using a radiosonde with EPS covers, you must break a small piece of the EPS cover to get access to the radiosonde interface. Use your finger, a pen or a small plastic spoon, as shown in the figure below. Do not use a metallic object.
    Slightly bend the piece and remove it.

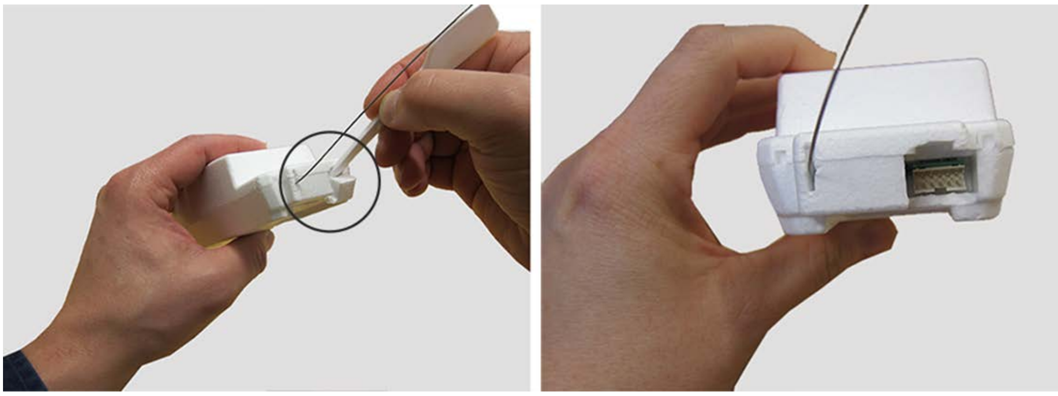


Figure 39 Bending and Removing Piece of EPS Cover

To avoid short-circuiting the radiosonde, use a non-metallic tool to break the EPS cover.

Before connecting the interface to the radiosonde, check that none of the pins on the radiosonde interface are deformed.

Figure 40 Checking Radiosonde Interface Connector

After this, firmly push the connector to the interface connector pins located inside the radiosonde, see Figure 41 (page 56) for an example.

Figure 41 OIF411 Connected to Radiosonde Interface Connector

After the connection, the radiosonde LED light is blinking green.

8. Attach the radiosonde to the holder in the flight box as instructed below:

> Detailed capacity information on the radiosonde battery is available in the radiosonde data sheet. OIF411 interface reduces the battery operating time by approximately 2 to 4%. If there are any delays in the sounding preparations or before the sounding starts while the radiosonde is powered from the battery, you can switch off RS41 by pressing the power switch. Switch the radiosonde back on before launching the balloon.

a. Hold the radiosonde holder with your other hand and place the radiosonde's bottom end to the holder first.

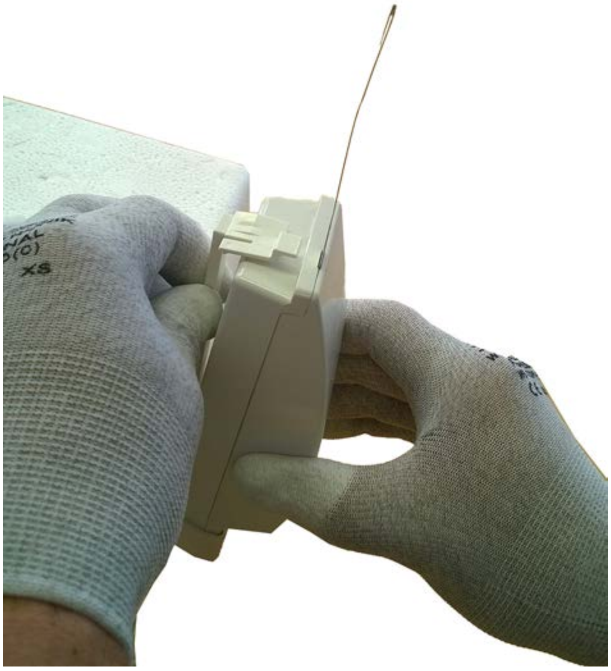


Figure 42 Attaching Radiosonde to the Holder

b. Use your finger to push the top part of the holder against the radiosonde so that the radiosonde is tightly attached to the holder.

Figure 43 Pushing the Holder into Place

c. If you attach the radiosonde in a lower position than shown here, push the holder against the flight box wall.

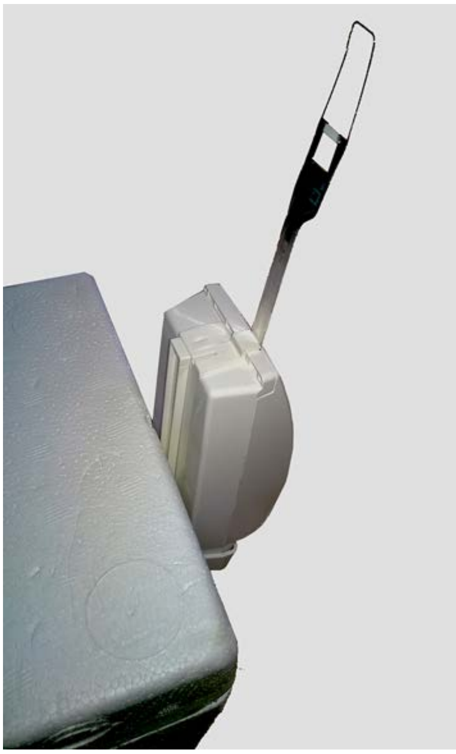


Figure 44 Radiosonde RS41 Attached to the Holder

9. After attaching the radiosonde, place the ozone sensor into the flight box. In this step, item a. below explains inserting SPC ozone sensor to the flight box. See item b. for EN-SCI sensor instructions.

   a. For an example of the SPC sensor inside the flight box, see Figure 45 (page 59). Make sure that the wires and tubes are led through the grooves in the flight box, indicated with the numbers in the figure.

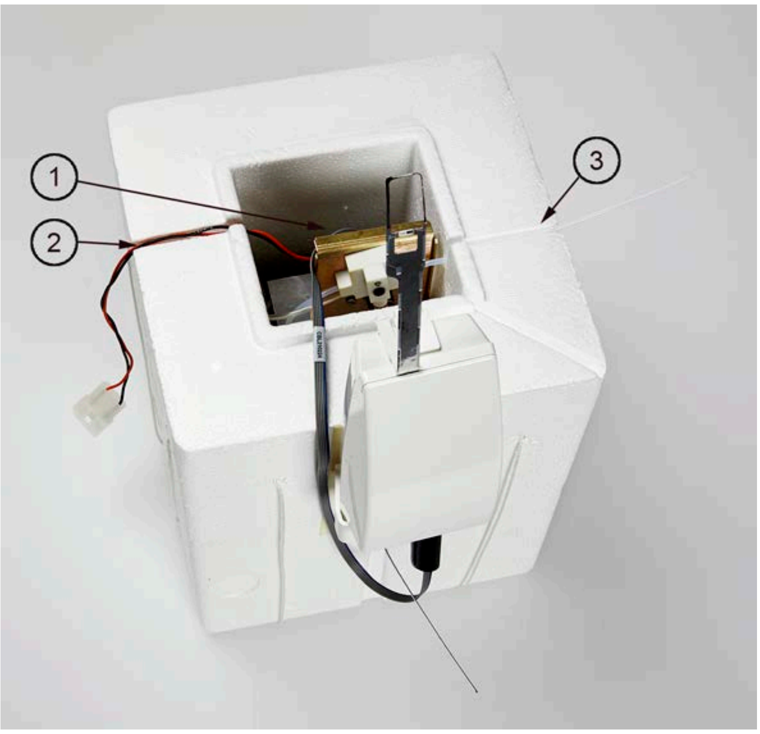


Figure 45 SPC Ozone Sensor inside the Flight Box

1 Ozone sensor placed inside the flight box
2 Pump motor battery wires led through the groove
3 Air tube led through the groove

   b. For an example of the EN-SCI sensor inside the flight box, see Figure 46 (page 60). Make sure that the wires and tubes are led through the grooves in the flight box. Optionally, you can prepare the ozone sensor outside the flight box. The GAW report 201 recommends setting the ozone sensor into the flight box during the measuring of the background current prior to the flight, but, for practical reasons, you can also prepare the ozone sensor outside the flight box.

CAUTION! In case of EN-SCI sensor, make sure to place the flight box cover (number 1 in Figure 46 (page 60)) and the ozone sensor inside the box (number 2) in the correct position and leave enough headspace for the pump. The cover must not touch the pump as it might prevent the pump from running. Number 3 indicates the radiosonde position on the flight box wall.

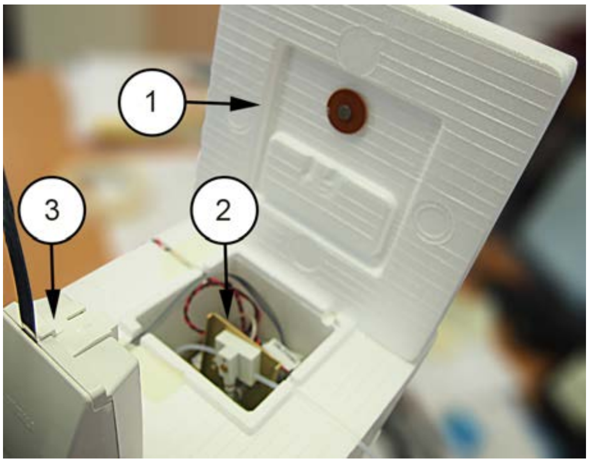


Figure 46 EN-SCI Ozone Sensor inside the Flight Box, Cover About to be Closed

1 Flight box cover
2 Ozone sensor placed inside the flight box
3 Radiosonde RS41-SG

10. Do not connect the pump motor wires to the battery yet, leave the connectors outside the flight box.

11. In this step, item a. below explains finalizing the flight box for SPC sensor. See item b. for EN-SCI sensor instructions.

    a. In case of SPC sensor, close the cover of the flight box and tape the seam between the cover and the body of the box. Do not tape the hanging strings.

    > Do not tape over the air outlet and air intake tube, as the measuring gas must be allowed to move in and out of the sensor box. See Figure 47 (page 61) for an illustration.

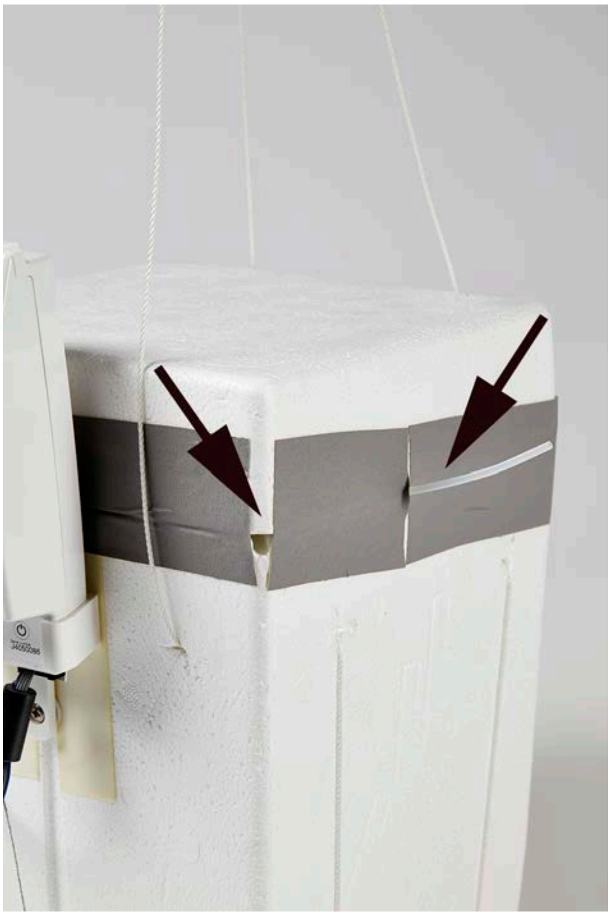
    

    Figure 47 Air Outlet Hole and Air IntakeTube Not Taped Over

    b. In case of EN-SCI sensor, it is a good idea to attach the flight box string with another string in two places (indicated with the arrows in Figure 48 (page 62)) so that the string does not hit the radiosonde sensor boom during the flight.

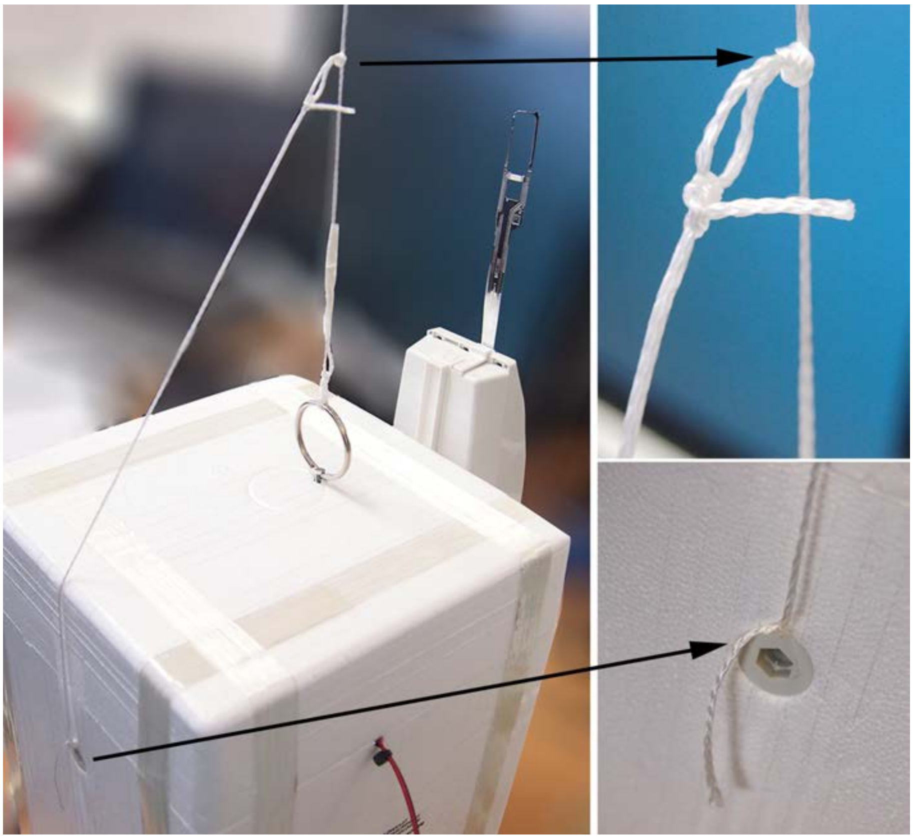


Figure 48 Supported Flight Box String in EN-SCI Ozone Sensor Flight Box

12. With ozone destruction filter on or ozone-free air flow connected, run the ozone sensor for 10 minutes and record the cell current I_{B2}:
Record I_{B2}: __________µA

> Background current is measured after the flight box is closed:
> - Close the cover of the flight box and tape the seam between the cover and the body of the box.
> - Do not tape the hanging strings. Do not tape over the air outlet and air intake tube, as the measuring gas must be allowed to move in and out of the sensor box.
>
> See Figure 55 (page 67) and Figure 47 (page 61).

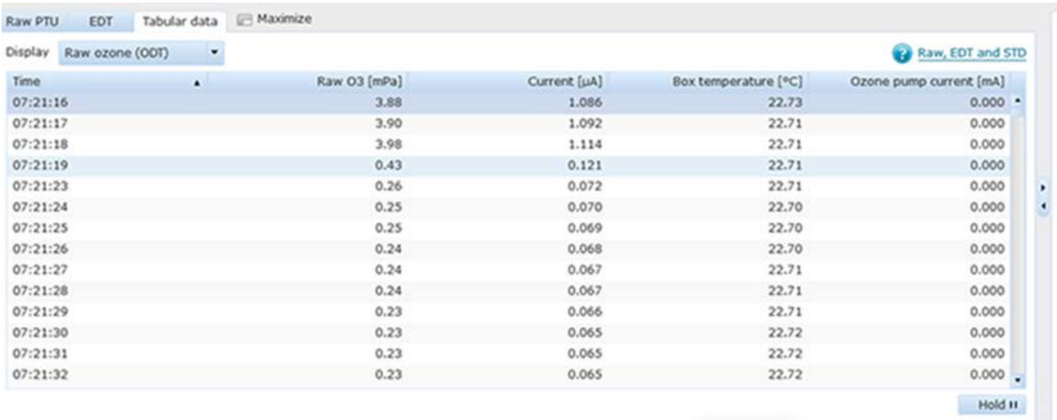
> The I_{B2} value equals to Vaisala $I_{BG} = I_0$, used in Vaisala scripts.

Always record the value indoors with destruction filter or ozone-free air connected, and after inserting the ozone sensor to the flight box.
At this stage, it is recommended to power the ozone sensor with an external power source, not with the ozone sensor battery.

13. MW41 proposes a background current. Use the value by clicking **Copy**.
    - You can either use the **Copy** button or enter the sensor background current in MW41 and click **Apply**.

Figure 49 Entering Sensor Background Current in MW41

14. In the Monitoring window, go to the **Tabular data** tab and select **Raw ozone** from the drop-down list. Make sure that ozone data is coming through, showing reasonable ozone current and ozone flight box temperature.
    The following information is displayed:



Time	Raw O3 [mPa]	Current [µA]	Box temperature [°C]	Ozone pump current [mA]
07:21:16	3.88	1.086	22.73	0.000
07:21:17	3.90	1.092	22.71	0.000
07:21:18	3.98	1.114	22.71	0.000
07:21:19	0.43	0.121	22.71	0.000
07:21:23	0.26	0.072	22.71	0.000
07:21:24	0.25	0.070	22.70	0.000
07:21:25	0.25	0.069	22.70	0.000
07:21:26	0.24	0.068	22.70	0.000
07:21:27	0.24	0.067	22.71	0.000
07:21:28	0.24	0.067	22.71	0.000
07:21:29	0.23	0.066	22.71	0.000
07:21:30	0.23	0.065	22.72	0.000
07:21:31	0.23	0.065	22.72	0.000
07:21:32	0.23	0.065	22.72	0.000

Figure 50 Viewing Raw Ozone Data in MW41

    - Time: time in seconds
    - Raw O3: ozone partial pressure
    - Current
    - Box temperature
    - Ozone pump current

15. Turn off the pump and either take off the ozone destruction filter or shut off ozone-free air flow.

16. Before starting the flight, connect the ozone sensor pump to its power supply as instructed in section Pump Motor Battery (page 65). Now, continue with section Constructing Sounding Accessories (page 63).

3.4.8 Constructing Sounding Accessories

Note that different installations are used depending on the components of the sounding. Always use an unwinder. An RSU stabilizer must be used if other than Vaisala-specific Totex parachute models are used.

Before you begin, see the general instructions and various sounding accessories presented in *Vaisala Guide to Sounding Preparations Technical Reference*.

The sounding construction depends on the radiosonde type and if either of the following is used:

- Radar reflector
- Parachute

Vaisala recommends always to use a parachute in ozone soundings.

1. When using a Totex parachute, attach the unwinder to the ribbon loop below the parachute spreader.
2. As the accidental breaking of the unwinder hook might cause the ozone sounding box to fall with great speed, Vaisala recommends that you tie the unwinder to the parachute spreader with a string for extra security.

   CAUTION! For extra security, Vaisala recommends that you tie the radiosonde unwinder to the Totex parachute spreader with a string, or tie extra strong tape around the unwinder hook.

   a. Thread the string through the hole in the unwinder hook (circled in Figure 51 (page 64)) and tie it around the parachute spreader. Make sure the string is slightly longer and looser than the ribbon loop.
   b. Another option is to prevent the unwinder hook from opening during the flight by tying extra-strong tape such as glass cloth tape, or equivalent, around the unwinder hook. If you do not have this kind of strong tape available, tie the unwinder with a string to the spreader, as explained above.
   c. If you like, you can also use both options at the same time.

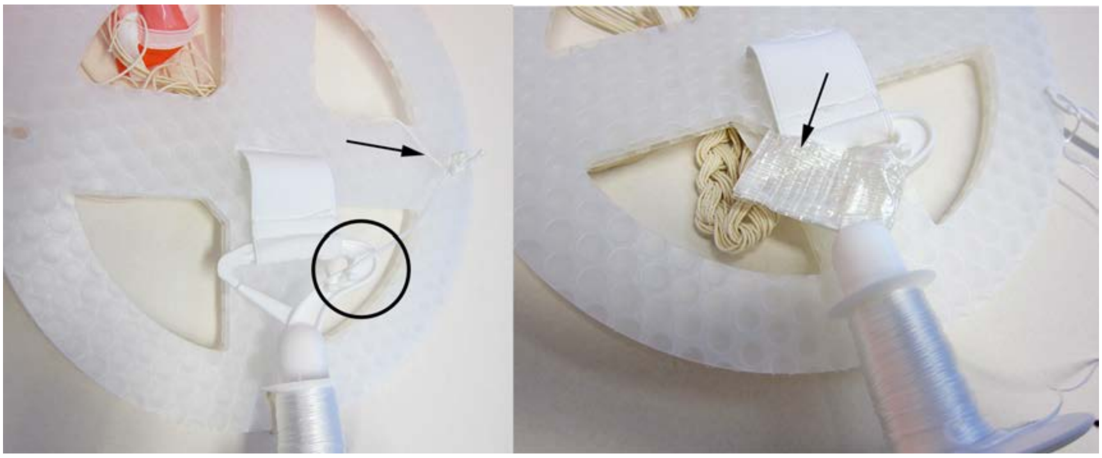


Figure 51 Securing Unwinder with String (on the Left) or Tape (on the Right)

3. Assemble the unwinder detainer to the radiosonde unwinder by pressing the detainer head into the radiosonde unwinder.
4. If you are using other than a Vaisala-specific Totex parachute model, or a radar reflector, connect the RSU stabilizer to the unwinder and prepare the balloon string connection. See Figure 52 (page 65) for an illustration.

Figure 52 RSU Stabilizer Attached to the Unwinder

> When DMT Model Z ozone sensor is used, the unwinder string is firmly attached to the ring hanger.

5. Continue sounding preparations by tying the flight box string to the unwinder stick.

> Balance the radiosonde payload by moving the string knot on the bottom of the flight box, and secure it with a piece of tape.

3.4.9 Pump Motor Battery

By default, ECC6AB ozone sensor is equipped with 2 x 9V Lithium batteries and a battery holder. The battery holder includes wires with a connector.

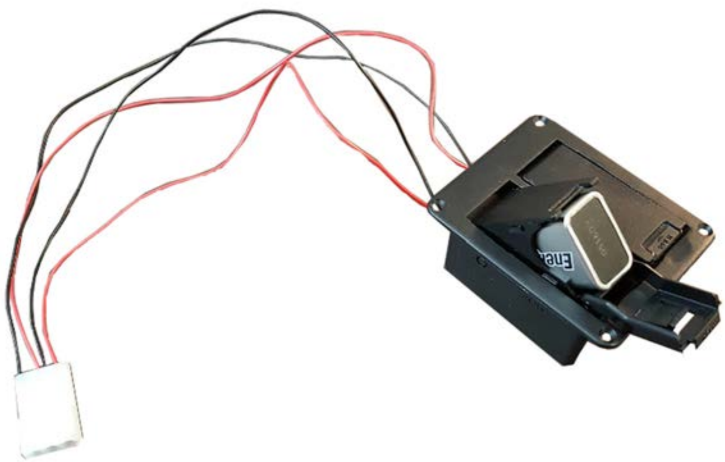


Figure 53 Battery Holder with Lithium Batteries, Wires, and Connector

1. Slide the battery holder into the ECC-6A ozone sensor styrofoam box but leave the battery wires outside.

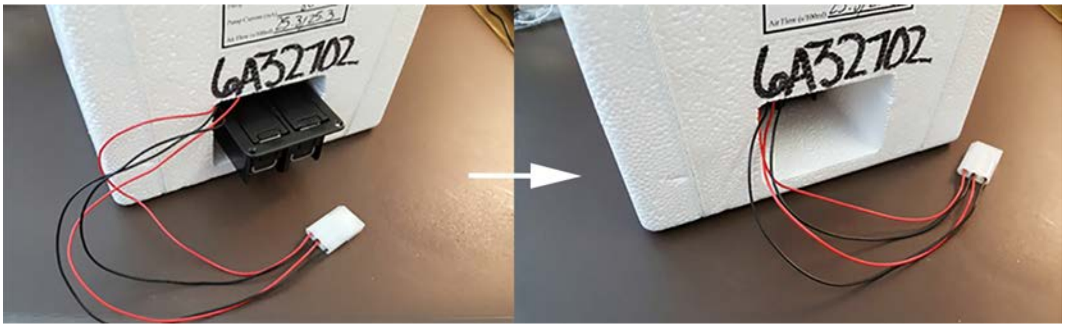


Figure 54 Batteries Inserted in the Ozone Sensor Styrofoam Box

> Ozone sensors may also use water-activated batteries, which have their own separate activation instructions. Follow the battery manufacturers' instructions.

2. After connecting the battery, check telemetry.

3. Take the flight box outside and connect the free-hanging battery cable with the ozone sensor battery cable.
   As the pump is quite noisy, you should be able to hear the ozone sensor pump running.

   Do not tape over the battery compartment, as the fumes from the battery must be allowed to move out of the box. See Figure 55 (page 67) for an example.

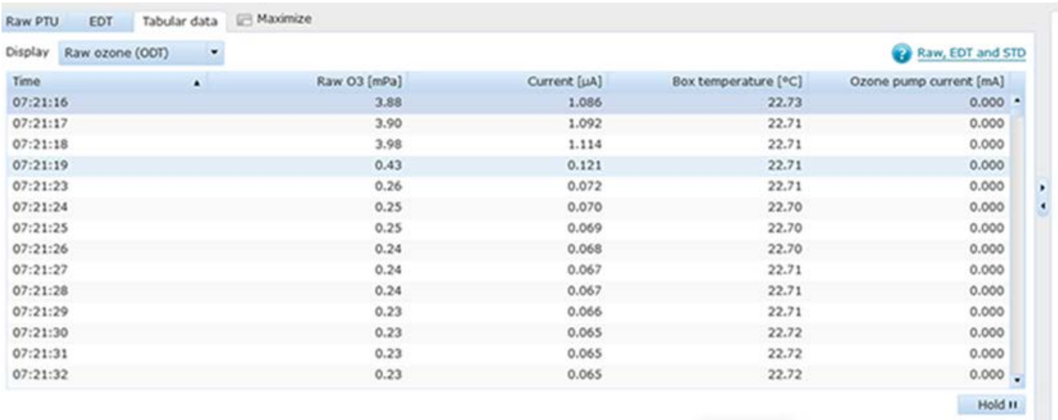
Figure 55 Taped Flight Box, Battery Connectors in Front

3.4.10 Recording the Surface Ozone

The ASOPOS panel strongly recommends that the ozone sensor has sampled surface air for at least 5 minutes before the launch; 10 minutes is recommended.

1. In the MW41 Monitoring window, go to the **Tabular data** tab and select **Raw ozone** from the drop-down list.

2. Make sure that ozone data is coming through, showing reasonable ozone current and ozone flight box temperature.



Time	Raw O3 [mPa]	Current [µA]	Box temperature [°C]	Ozone pump current [mA]
07:21:16	3.88	1.086	22.73	0.000
07:21:17	3.90	1.092	22.71	0.000
07:21:18	3.98	1.114	22.71	0.000
07:21:19	0.43	0.121	22.71	0.000
07:21:23	0.26	0.072	22.71	0.000
07:21:24	0.25	0.070	22.70	0.000
07:21:25	0.25	0.069	22.70	0.000
07:21:26	0.24	0.068	22.70	0.000
07:21:27	0.24	0.067	22.71	0.000
07:21:28	0.24	0.067	22.71	0.000
07:21:29	0.23	0.066	22.71	0.000
07:21:30	0.23	0.065	22.72	0.000
07:21:31	0.23	0.065	22.72	0.000
07:21:32	0.23	0.065	22.72	0.000

Figure 56 Viewing Raw Ozone Data in MW41

3.4.11 Launching the Balloon

1. Before launching the balloon, check the MW41 user interface to see that ozone sensor data is received.
2. When MW41 shows the message `Ready for release`, you can launch the sounding balloon.
3. After the release, check that the ozone data is stable in MW41.

3.4.12 Recording Post-Launch Data

1. After launching the balloon, enter the surface observation data in MW41.
MW41 user interface shows the appropriate data. Use the free text field for any additional data you wish to store in the database and be available for messages.
You can also write down the information here:
   - Launch time:
   - P_{surf} = __________ hPa
   - T_{surf} = __________ °C
   - U_{surf} = __________ % RH
   - Surface wind speed: __________m/s
   - Wind direction: __________
   - Sky condition: ____
   - Other information: ____

4. Ozone Calculation

4.1 Ozone Calculation Overview

The ozone data is combined with meteorological radiosonde data: pressure (P), temperature (T) and relative humidity (U) in the ground equipment. The measuring sample interval (measures each sensor once) of Radiosonde RS41-SG is one (1) second. OIF411 is scanned in phase with the radiosonde PTU measuring sequence. Therefore, all the measured data is synchronized.

4.2 Averaging and Eliminating Irrelevant Measuring Results

Noise filtering helps to eliminate erroneous data. Errors may originate from various different phenomena, for example, from electrical spikes.

The filtering is made by calculating the median of a given number of consecutive samples. The median is the middlemost sample in the order of magnitude. This algorithm cuts all remarkably higher and lower measurement results compared with other measurement results near the measurement (in a given time window). The filtering window (the number of consecutive samples, where the median is made) is given to the ground equipment during ozone sounding preparation.

The median calculation algorithm is well-defined for odd values only: number of filtering window length (1, 3, 5, 7, ...) (number of measurement samples in the window). Therefore, the filtering window is defined in the ground equipment as the window radius; from the middle to the last sample, or, equally, from the middle to the first sample. In other words, the window radius indicates how many samples before and after the corresponding sample will be taken with in the filtering window. The number of samples where the median is calculated is as follows (sample radius = window radius):

Filter Window Length = 2 × Window Radius + 1

The sample radius is the value given for the ground equipment. If the windows radius is defined as an Integer, the filter window is always an odd integer and the median algorithm is well-defined.

The ozone sensor response time is typically about 20 seconds, as indicated in the GAW report 201 (see Performance Review Literature (page 95) for details). To avoid cutting real ozone values of the measurement results, the median filtering window length must be clearly shorter than the sensor's response time. Note that the length is defined as the amount of samples. Therefore, different values for radiosondes with different sample rates must be used. A typical value for the window radius for RS41 is 4 (filtering window = 9 seconds).

The median filtering algorithm is disabled by setting the window radius to 0.

4.3 Ozone Partial Pressure Calculation

4.3.1 Ozone Sensor Operating Principle

The ozone sensor used within the ozonesonde is an iodine-iodide redox electrochemical concentration cell. It is made of two bright platinum electrodes immersed in potassium iodide solutions of different concentrations, contained in separate cathode and anode chambers, 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. Driving emf for the cell is derived from a difference of potassium iodide concentrations present in the two half cells.

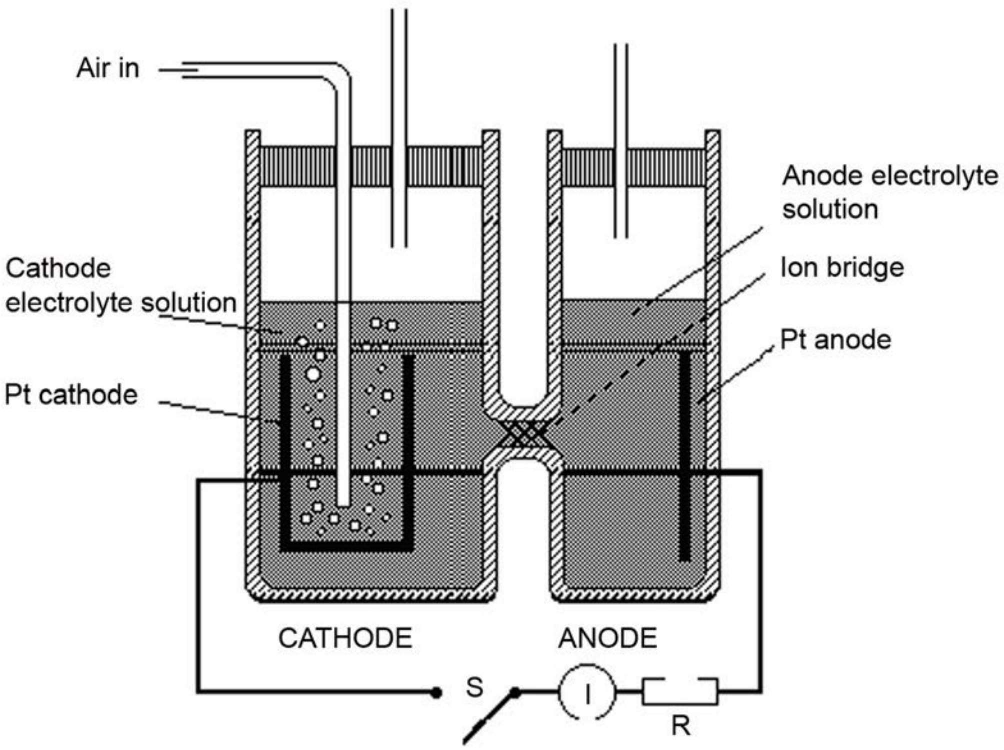


Figure 57 Electrochemical Cell Construction

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.

4.3.2 Ozone Sensor Reactions

The cell system is shown in Figure 57 (page 70). Platinum electrodes are chemically inert, and 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:

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

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

In the cathode chamber:

$3\ I^- \rightarrow I_3^- + 2\ e^-$

In the anode chamber:

$I_2 + 2\ e^- \rightarrow 2\ I^-$

These chemical reactions result in the following statement:

ONE O_3 MOLECULE CAUSES A CURRENT OF TWO ELECTRONS

The current is measured with the OIF411 interface.

> The reaction occurs with all oxidants (such as NO_2). The chemical reaction in sensor chambers 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 errors and variance.

4.3.3 Calculation of Local Ozone Values

The partial pressure of the ozone is a measure for local ozone concentration. Sometimes ppm_v values are used. Basic principles for this step of the calculations are given in the sensor manufacturer's manuals. See Related Manuals (page 7). As each molecule of ozone creates a current of two electrons, ozone concentration is:

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

C Ozone concentration in mmol l^{-1}
F 9.6485×10^4 C $(mol)^{-1}$ (Faraday constant)
I measured current in µA
t pumping time for 100 ml of air (seconds)

The partial pressure of ozone (P_3) is:

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

R = 8.31451 JK^{-1} mol^{-1} (Molar gas constant)

Finally:

$$P_3 = 4.3087 \cdot 10^{-4}(I - I_{BG}) \cdot T_p \cdot t \cdot C_{ef} \cdot C_{ref}$$

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 (I_{BG} equals to I_{B2}).
Tp Measured airflow 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} Additional correction factor

I_{BG} used in this manual is equal to I_0 used in the Vaisala scripts, and I_{B2} used in the GAW report 201, and the ASOPOS panel recommendations.

Each ozone sensor manufacturer has their own recommendations for calculating I_{BG}, Tp, and C_{ef}. See Related Manuals (page 7).

4.3.3.1 Background Current Correction (I_{BG})

Background current correction (I_{BG}) is caused by oxidants other than ozone (mainly O_2). Because the concentration of ozone without any additional oxidants needs to be measured, the background current has to be deducted from the measurement current.

The amount of oxidants (mainly oxygen) will decrease during sounding when ambient pressure decreases. The background current I_{BG} is counted from the following equation recommended for the SPC ECC-6A sensor.

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

I_0	Background current I_0 is measured using ozone destruction filter through which air is pumped during the sounding preparation activities, just before release.
P	Ambient pressure in hPa
P_0	Ambient pressure when I_o is measured in hPa ~ ground pressure
A0	0.00122504
A1	0.0001241115
A2	-2.687066×10^{-8}

The Model Z sensor recommended correction is constant:

$I_{BG} = I_o$

when I_o is measured just before release during sounding setup configuration.

By setting the background current $I_o = 0$, the background current correction is disabled.

The ASOPOS panel recommends the use of a constant, pressure-independent I_{B2} in the basic equation to determine the ozone partial pressure throughout the entire vertical profile. Pressure-dependent background can be done by:

$I_0 = (P/P_0) \times I_{B2}$

As a Vaisala equation, this is:

$I_{BG} = (P/P_0) \times I_0$

4.3.3.2 Pumping Time for 100 ml of Air (t)

The pumping time is measured during sounding preparations.

The value is entered in the ground equipment during sounding preparations.

4.3.3.3 Measured Airflow Temperature (T_P)

All sensors use measured values in a Vaisala application.

4.3.3.4 Pump Efficiency Correction (C_{ef})

The efficiency of the ECC-6A Ozonesonde air sampling pump decreases with altitude. Calculated ozone partial pressures must, therefore, be corrected for the efficiency loss. Correcting factors for ECC-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 14 (page 74), respectively. At pressure level (P) the value of C_{ef} is calculated using linear interpolation as a function of pressure.

The ASOPOS panel recommends the use of 3.0 cm^3 only.

Table 14 Ozone Partial Pressure Correction Factors

Ozone Partial Pressure Correction Factor C_{ef}		
Atmospheric pressure hPa	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

For other sensor manufacturers, the pump correction is very similar to the SPC ozone sensor; only the table values differ.

For Model Z, use the following table:

Table 15 Ozone Partial Pressure Correction Factors

P/hPa	C_{ef}
≤3	1.24
5	1.124
7	1.087
10	1.066
15	1.048
20	1.041
30	1.029
50	1.018

P/hPa	C_{ef}
70	1.013
100	1.007
150	1.002
≥200	1

4.3.3.5 Additional Correction Factor (C_{ref})

It might be necessary to scale the ozone measurement values with an additional correction factor. For instance, if another method (such as light absorption) 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.

This can be done in the ground equipment software by modifying one of the scaling calibration coefficients of the sensor. Preferably, the pumping time for 100 ml of air is used for this correction.

$t_{corrected} = t \times C_{ref}$

4.4 Total Ozone Calculation

Total ozone is the integrated ozone in a column, extending from the bottom to the top of the atmosphere. Thus, it is the sum of the total ozone measured from the sounding and the estimated residual ozone (for example, total ozone after burst).

$$TOTALOZONE = \Delta\Omega_S + \Delta\Omega_R$$

Table 16 Total Ozone Calculation

Item	Explanation
$\Delta\Omega_S$	Total ozone from the sounding
$\Delta\Omega_R$	Residual total ozone

In the software used in Vaisala equipment, the results of total ozone calculation are in Dobson Units (DU).

4.4.1 Total Ozone from Sounding

The total ozone from the sounding is calculated by summing up the amount of ozone in the layers between two measurement points as expressed in the equation below. When using the units indicated in the list below, the equation gives the total ozone in units of grams per square meter (g/m^2).

$$\Delta\Omega_s = \frac{\varepsilon_3}{g}\int_{pi} p_3 d\ln p_i = \sum_i \frac{\varepsilon_3(p_{3i} + p_{3i+1})}{g2}\ln\left(\frac{p_i}{p_{i+1}}\right)$$

Table 17 Total Ozone from Sounding

Item	Explanation
ε_3	1.6571, ratio of molecular masses of ozone and air
g	9.80665 m/s^2, acceleration of gravity
p_i ... p_{i+n}	Ambient pressure [hPa]
i	Index for a measurement point
p_{3i} ... p_{3i+n}	Ozone partial pressure [mPa]
M_3	48.00 g/mol, molar mass of ozone

When the constants are inserted into the equation, it reduces to:

$$\Delta\Omega_s = \sum_i 0.0845 \times (p_{3i} + p_{3i+1})\ln\left(\frac{p_i}{p_{i+1}}\right)$$

The equation above gives the ozone in grams per square meter (g/m^2).

A commonly used unit for total ozone is Dobson Unit (DU = 2.687 × 10^{20} molecules/m^2). To get the result in DUs, ozone grams must first be divided by molar mass of ozone 48.00 g/mol and then multiplied by Avogadro's number 6.02217 × 10^{23} molecules/mol. The result is ozone in molecules/m^2. The unit relation above is used to convert this to DUs.

The following equation gives the result in DUs when the partial pressures are given in mPa and ambient pressures in hPa.

$$\Delta\Omega_s = \sum_i 3.9449 \times (p_{3i} + p_{3i+1}) \ln\left(\frac{p_i}{p_{i+1}}\right)$$

4.4.2 Residual Ozone (Total Ozone after Balloon Burst)

After the balloon burst, the level of ozone is estimated by using the equation below with a constant mixing ratio ($p_{3i} = p_{3i+1} = p_{3END}$) up to ambient pressure 0 hPa. The equation changes to:

$$\Delta\Omega_R = \frac{\varepsilon_3}{g} \times p_{3END} \approx 7.8899 \times p_{3END}$$

When the pressure is given in hPa, the equation above gives the residual total ozone in DUs.

The total ozone can now be calculated from the equation:

$$TOTALOZONE = \Delta\Omega_S + \Delta\Omega_R$$

Another option is introduced in the GAW report 201. Post-calculation is possible, integrated ozone is reported, and residual can be calculated afterwards. It can also be changed in the script.

4.4.3 Ozone in µg/m³

Ozone density is, by definition:

$$\varsigma_3 = \frac{m_3}{V_3}$$

where m_3 = mass of ozone in volume V_3.

The ideal gas law is

$p_3 \times V_3 = n_3 \times R \times T$

where

p_3 partial pressure of ozone in mPa
n_3 mole number of ozone
R ideal gas constant
T temperature in K

gives

$$V_3 = \frac{n_3 \times R \times T}{P_3}$$

Combining the equations gives

$$\varsigma_3 = \frac{m_3}{n_3 \times R} \times \frac{P_3}{T} = \frac{M_3}{R} \times \frac{P_3}{T} \approx \frac{48.00 \times 10^2}{8.314510} \times \frac{P_3}{T} \frac{\mu g}{m^3}$$

where

M_3 Molar mass of ozone, 48.00 g/mol
P_3 Ozone partial pressure in mPa
T Temperature in K

This means that for ozone:

$$1 mPa \approx \frac{10 \times 48.00 \times 10^2}{8.314510} \times \frac{1}{T} \frac{\mu g}{m^3} \approx 5773.04 \times \frac{1}{T} \frac{\mu g}{m^3}$$

4.5 Accuracy of Ozonesonde Measurement

Certain sources of inaccuracy must be kept in mind when considering errors in ozone measurements. Errors can originate from the ozone sensor cell, the interface (converter), temperature and flow rate measurement, telemetry, or they can be random errors. The measurement procedure affects the accuracy. For example, if you measure only ozone partial pressure, you can do measurements in a way which is slightly different from the method you use when calculating total ozone in the end. It is also possible to improve measurement accuracy by developing the measurement methods in the sensing system.

Basic sources for errors and differences between measurement systems (the ECC system, light absorption measurement) are quite well known. Relevant literature is also available. See Performance Review Literature (page 95).

> The latest detailed technical data for the radiosonde and OIF411 can be found on the Vaisala website, www.vaisala.com.

> Detailed specifications for the ozone sensors are available directly from the manufacturers or from Vaisala.

5. Ozone Interface Board OIF411 Data Interpretation

5.1 Measurement Data

When Radiosonde RS41 is connected to Ozone Interface Board OIF411, it sends the OIF411 measurement data through the additional sensor interface. The following information is contained:

- Instrument type and number
- Ozone pump temperature
- Ozone current
- Battery voltage
- Ozone pump current
- External voltage measured once per second

OIF411 measurement data contains the following information:

```
xdata= <Instrument type is 05><Instrument number is 01><Ozone
pump T [0.01 °C]><Ozone current [0.0001uA]><Battery voltage
[0.1V]> <Ozone pump current [1 mA]><Ext. voltage [0.1V]>CR
```

This means that if OIF411 sends

```
xdata=050108CA186A0750B637CR
```

it is interpreted as shown in Table 18 (page 81):

Table 18 OIF411 Data Interpretation 1

	Instrument Type **2 Bytes**	**Instrument Number** **2 Bytes**	**Ozone Pump T** **[0.01 ºC]** **4 Bytes.** **MSB bit is a sign bit.**	**Ozone Current** **[0.0001 uA]** **5 Bytes**	**Battery Voltage** **[0.1V]** **2 Bytes**	**Ozone Pump Current** **[1 mA]** **3 Bytes**	**Ext. Voltage** **[0.1 V]** **2 Bytes**
Hex ASCII	05	01	08CA	186A0	75	0B6	37
Interpreted as	5	1	22.50	10.0000	11.7	182	5.5

5.2 ID Data

The radiosonde also sends OIF411 ID data, which contains:

- Instrument type and number
- OIF411 serial number
- Diagnostics word

- Software version once per minute

OIF411 ID data replaces OIF411 measurement data, but not the additional sensor data, sent once per minute.

The OIF411 ID data contains the following information:

```
xdata= <Instrument type is 05><Instrument number is 01><OIF
serial number><diagnostics word><SW version><I>CR.
```

This means that if OIF411 sends

```
xdata=0501G12345670000000AICR
```

it is interpreted as shown in Table 19 (page 82):

Table 19 OIF411 Data Interpretation 2

	Instrument Type 2 Bytes	Instrument Number 2 Bytes	OIF411 Serial Number 8 Bytes	Diagnostics Word 4 Bytes	Software Version 2 Bytes	ID Data
Hex ASCII	05	01	G1234567	0000	000A	I
Interpreted as	5	1	G1234567	1)	0xA=10 dec > SW version is 10/100= 0.10	Ignore Use data length to distinguish ozone and ID data.

1) *0000 = Default value, no diagnostics bits active*

0004 = Ozone pump temperature below −5 °C.

0400 = Ozone pump battery voltage (+VBatt) is not connected to OIF411.

0404 = Both "Ozone pump temperature below −5 ºC" and "Ozone pump battery voltage (+VBatt) is not connected to OIF411" are active at the same time.

5.3 Additional Data

If additional xdata-compatible sensor is connected to OIF411, it receives data from the additional xdata sensor, increments instrument number by 1, and sends this data immediately after receiving the CR.

Additional sensor data can be in any order (except that the OIF411 data always comes first), meaning that the instrument numbers are not in an ascending order. For example:

```
xdata=050108CA186A0750B637CRxdata=02030009000900090009000090009CRx
data=10021FF44487A04E0410018FLFCR
xdata=0304001000100010001000100010CR
```

If additional sensor CFH is connected to OIF411, OIF411 sends

```
xdata=050108CA186A0750B637CRxdata=10021DB6BC8795200443018FLFCR
```

where LF = line feed, CR = carriage return.

6. Storage and Transportation

6.1 Storage

Radiosondes must be stored and used in accordance with applicable instructions, the User Guide, and specifications issued by Vaisala.

Radiosondes must be kept in their original packaging (unopened vacuum envelopes) in a dry, ventilated indoor storage space, and within the following key environmental limits (ref. IEC 60721-3-1 class 1K2):

- Temperature +5 °C to +40°C
- Relative humidity below 85%

CAUTION! The unwinder string is not resistant to prolonged exposure to sunlight. Store the unwinders in their original unopened packages.

6.2 Transportation

Vaisala radiosondes must be transported in their original shipping packages. These packages are designed and built to survive and protect their contents in the environmental conditions described herein with the terminology and standards per standard IEC 60721-3-2. The transportation of radiosondes requires climatic conditions 2K2 and mechanical conditions 2M1 of this standard:

- Transportation in weather-protected conditions.
- Transportation using conventional means (car, truck, and / or aircraft), with free fall not exceeding 0.25 m in any circumstances.
- Following additional markings on packaging.

Appendix A. DigiCORA MW41 Ozone Data

A.1 Calculating Ozone Data in MW41

Ozone data is calculated by the scripting engine using raw ozone and EDT data. This information, along with the calculated ozone, can be archived for further inspection, for example, simulation. The MW41 installation media contains script interface documentation which provides more information on using the scripts. Ozone calculation is implemented with three script files:

- *`OzoneMain.py`*
- *`OzoneCalculations.py`*
- *`OIF411.py`*

A.2 Reporting Ozone Data in MW41

You can use the report template editor in MW41 to create an ASCII output of the calculated ozone data. The data may also be programmatically accessed via the script interface during the sounding. The ozone-related data can be exported in the following files: *calc_ozone.tsv* and *specsens.tsv*. For information on creating a report in MW41, see the on-line help.

Below is an example of an ozone data report output:

Elapsed time	HeightMSL	O3	BoxTemperature	IntegratedOzone	ResidualOzone	O3Voltage	O3Aux
s	m	mPa	°C	DU	DU	V	
0	28	1.57	23.58	0.00	12.38	13.414	107.865
1	34	1.56	23.58	0.01	12.30	13.700	108.000
2	38	1.53	23.58	0.02	12.10	13.900	110.000
3	42	1.53	23.59	0.02	12.10	13.800	104.000
4	48	1.55	23.59	0.03	12.24	13.500	107.000
5	56	1.57	23.59	0.04	12.39	13.600	112.000
6	64	1.57	23.59	0.05	12.35	13.600	111.000
7	70	1.57	23.59	0.06	12.36	13.700	109.000
8	77	1.57	23.58	0.07	12.39	13.800	109.000
9	84	1.64	23.58	0.09	12.95	13.700	106.000
10	92	1.64	23.58	0.10	12.91	13.500	105.000
11	99	1.64	23.58	0.11	12.96	13.700	120.000
12	105	1.65	23.57	0.12	12.99	13.900	108.000
13	108	1.64	23.57	0.12	12.97	13.700	107.000
14	111	1.67	23.57	0.13	13.14	13.600	113.000
15	116	1.67	23.57	0.14	13.19	13.700	112.501

Figure 58 Example of an MW41 Ozone Data Report Output

A.3 Archived Ozone Data in MW41

The calculated ozone data is stored in XML format in a zipped .mwx sounding archive file. Extract the .zip file to access the .xml file. The following tables in the archive file contain ozone-related data:

A.3.1 Additional Sensor Data from RS41

Table 20 AdditionalSensorData

Column Name	Type	Description
SOUNDINGIDPK	String	Unique sounding ID
RADIORXTIMEPK	Double	Radio time [s]
INSTRUMENTTYPEPK	String	Instrument type identifier
INSTRUMENTNUMBERPK	String	Instrument number
MEASUREMENTOFFSET	Double	Measurement time offset of the additional sensor data [s]
DATASRVTIME	String	Data server timestamp [yyyy-MM-dd HH:mm:ss.fff]
GPSTIMEOFFSET	Byte	Offset to the frame's GPS time [1/20 s]
XDATA	String	XData from additional sensor

A.3.2 Additional Sensor Data from RS92

Table 21 RS92SpecialSensorData

Column Name	Type	Description
SOUNDINGIDPK	String	Unique sounding ID
RADIORXTIMEPK	Double	Radio time [s]
DATASRVTIME	String	Data server [yyyy-MM-dd HH:mm:ss.fff]
HEADERDATA	UShort	Interface and sensor type
SENSORDATA	String	Sensor data

A.3.3 Calculated Ozone Data

Ozone layer data with pressure correction is applied.

Table 22 CalculatedOzone

Column Name	Type	Description
SOUNDINGIDPK	String	Unique sounding ID
RADIORXTIMEPK	Double	Radio time [s]
DATASRVTIME	String	Data server [yyyy-MM-dd HH:mm:ss.fff]

Column Name	Type	Description
PARTIALPRESSURE	Double	Calculated ozone partial pressure [mPa]
BOXTEMPERATURE	Double	Sensor box temperature [Kelvin]
O3CURRENT	Double	Bias and pressure corrected current [uA]
INTEGRATEDOZONE	Double	Ozone accumulated up to the current sounding level [DU] (Dobson Unit)
RESIDUALOZONE	Double	Estimated residual ozone above the current sounding level [DU] (Dobson Unit)
VOLTAGE	Double	OIF411: Battery voltage measurement [V] OIF92: Channel 3 data
AUX	Double	OIF411: ozone pump current value OIF92: channel 4 data

A.3.4 OIF411 or OIF92 Ozone Parameters

Table 23 OIF411Parameters / OIF92Parameters

Column Name	Type	Description
SOUNDINGIDPK	String	Unique sounding ID
DATASRVTIME	String	Data server [yyyy-MM-dd HH:mm:ss.fff]
SENSORTYPE	String	Sensor type code
SERIALNUMBER	String	OIF411: null OIF92: serial number
CALIBRATIONPRESSURE	Double	Applied calibration pressure [hPa]
SOLUTIONVOLUME	Double	Cathode solution volume [cm_3]
MEDIANFWRADIUS	Double	Median filter window radius
FLOWRATE	Double	Pump airflow rate [s/100 cm_3]
IOFFSET	Double	OIF411: null OIF92: offset correction for current measurement
IREFLIN	Double	OIF411: null OIF92: Iref linear temperature coefficient [1/k]
IREFQUAD	Double	OIF411: null OIF92: Iref quadratic temperature coefficient [1/K2]

Column Name	Type	Description
IREFZEROC	Double	OIF411: null OIF92: Iref at 0 C temperature [uA]
RNTC25	Double	OIF411: null OIF92: Sensor thermistor resistance at 25 C temperature [Ohm]
VREFCH3	Double	OIF411: null OIF92: Reference value for voltage channel [V]
VREFCH4	Double	OIF411: null OIF92: Reference value for AUX channel [V]
BGCURRENT	Double	Sensor background current [uA]

A.3.5 Ozone Results

Summary of calculated ozone data.

Table 24 OzoneResults

Column Name	Type	Description
SOUNDINGIDPK	String	Unique sounding ID
DATASRVTIME	String	Data server [yyyy-MM-dd HH:mm:ss.fff]
INTEGRATEDOZONE	Double	Ozone accumulated up to the sounding termination [DU] (Dobson Unit)
RESIDUALOZONE	Double	Estimated residual ozone above the termination level [DU] (Dobson Unit)
SENSORTYPE	String	Sensor type code
INTERFACETYPE	String	Ozone interface type (Undefined, OIF411, or OIF92)
SERIALNUMBER	String	OIF serial number
DIAGNOSTIC	Int	OIF411: diagnostic word OIF92: 0
BGCURRENTCORRMETHOD	String	Background current correction method
SMOOTHINGMETHOD	String	OIF411: null OIF92: method for smoothing measured data
CALIBRATIONPRESSURE	Double	Applied calibration pressure [hPa]
BGCURRENT	Double	Sensor background current [uA]
SOLUTIONVOLUME	Double	Cathode solution volume [cm_3]

Column Name	Type	Description
OZONEPRIORSTART	Double	Ozone at the surface level prior to the launch [DU] (Dobson Unit)
PRIORSTARTMEASDURATION	Double	Surface ozone measurement duration [min]

A.3.6 Raw Ozone Data

Ozone layer data without pressure correction.

Table 25 RawOzone

Column Name	Type	Description
SOUNDINGIDPK	String	Unique sounding ID
RADIORXTIMEPK	Double	Radio time [s]
DATASRVTIME	String	Data server [yyyy-MM-dd HH:mm:ss.fff]
PARTIALPRESSURE	Double	Raw (uncorrected) ozone partial pressure [mPa]
INTERMEDIATE	Double	Intermediate data being used in calculation
CURRENT	Double	Current measured by sensor [uA]
BOXTEMPERATURE	Double	Sensor box temperature [K]
VOLTAGE	Double	OIF411: Battery voltage measurement [V] OIF92: Channel 3 data
AUX	Double	OIF411: ozone pump current value [mA] OIF92: channel 4 data
EXTERNALVOLTAGE	Double	OIF411: external voltage measurement [V] OIF92: 0

Appendix B. Safety Instructions for Balloon Operators

Photocopy these instructions and place the list in clear view in the balloon filling shed and in the sounding compartment.

WARNING! New operator! Carefully study the instructions for using the hydrogen generator and for the correct method of inflation.

1. No smoking or naked flame allowed.
2. If possible, avoid wearing clothing made of nylon or other synthetic fibers to prevent a build-up of static charges. Do not wear shoes with rubber soles.
3. Wear protective glasses.
4. Regularly check that the gas tube fits securely to the gas cylinder or generator nozzle and to the balloon inflation nozzle.
5. Take care to prevent a gas leak in the shed when interrupting inflation to replace a gas cylinder.
6. Never use a repaired balloon.
7. Should a leak develop in the balloon during inflation, do not let gas escape from the balloon inside the shed if possible. Instead, release the defective balloon without load. It is not advisable to deflate the balloon, even outside the shed.
8. Do not touch the balloon with bare hands except when holding it by the neck. Wear soft cotton gloves.
9. Ensure that there are no pointed objects in the shed. Nails, hooks, hinges, padlocks, etc., are dangerous as they might scratch the inflated balloon. The balloon film is only 0.05 ... 0.1 mm thick upon launch; the slightest scratch could cause the balloon to burst prematurely.
10. Keep the doors of the shed shut while inflating the balloon on a windy day. However, ensure that the shed is properly ventilated.
11. No unauthorized person shall be allowed admittance to the shed while the hydrogen generator is in operation or balloon inflation is going on.
12. Ensure that all tools and other implements not essential for balloon inflation have been removed from the shed.
13. Do not take any electrical devices (cell phone etc.) to the balloon filling shed or close to the balloon inflated with hydrogen. Safe distance when outdoors is typically 1.5 meters.

14. Always keep the radiosonde at least 50 cm below the level of the gas nozzle and the inflated balloon, and at least 1.5 meters away from the gas cylinder/hydrogen generator, connectors, and tubing. Avoid taking the radiosonde inside the balloon filling shed, if possible.
15. Follow all regulations concerning hydrogen safety.

Appendix C. Checklist for Equipment and Supplies for Flight Preparations

This appendix contains the checklist for the equipment and supplies needed in the sounding preparations. You can mark the items in the Checked column.

Table 26 Checklist for Equipment

Equipment	Checked
Ozone sensor with styrofoam flight box and motor battery	
Radiosonde RS41	
Ozone Interface Board OIF411	
Balloon (plastic or rubber)	
5 meters of string (strength about 300 to 500 N), an unwinder and a detainer	
Parachute, 200-inch (500 cm) circumference (recommended)	
Short-circuit cable for the ozone sensor (optional)	
Ozone sensor interface - radiosonde extender test cable (optional)	
Bottle for the sensor cathode solution prepared according to the instructions	
Bottle for the sensor anode solution prepared according to the instructions	
Bottle for distilled H_2O	
Syringe, 3 ml volume (equipped with Teflon tube), for use with the sensor cathode solution	
Syringe, 3 ml volume, for use with the sensor anode solution	
Roll of firm tape, 2 inches (5 cm) wide	
Apparatus for measuring ozone sensor air flow rate	
Ozonesonde power supply for pump motor rated at 12 to 13 VDC, 300 mA	
SPC Ozonizer/Test Unit Model TSC-1 with adapter cables or equivalent from other manufacturers	
Ozone destruction filter or purified, ozone-free gas	
Thermometer graduated in degrees centigrade	
Hand-held pressure/vacuum gauge for pump tests	
Small strips of No. 600A sandpaper for grasping Teflon tubing	
Plastic squirt bottle filled with research-grade methanol	
Methanol and acetone for cleaning	

Equipment	Checked
Pair of lint-free gloves for laboratory work (made of artificial fabric or plastic, disposable)	

Appendix D. Performance Review Literature

Table 27 Performance Review Literature

Name	Details
Attmannspacher, W. and H.U. Dütsch	International Ozone Sonde Intercomparison at Observatory Hohenpeissenberg. Bericht des Deutschen Wetterdienstes, No. 120, 1970, 85 pp.
Attmannspacher, W and H.U. Dütsch	2nd. International Ozone Sonde Intercomparison at Observatory Hohenpeissenberg. Bericht des Deutschen Wetterdienstes, No. 157, 1981, 65 pp.
De Backer, Hugo, D. De Muer and G. De Sadelaer	Comparison of ozone profiles obtained with Brewer-Mast and Z-ECC sensors during simultaneous ascents. J. Geoph. Res., vol. 103, D16, 19641 - 19648. Johnson, B.J. , S.J. Oltmans, H. Voemel, H.G.J Smit, T. Deshler, and C. Kroeger (2002), ECC ozonesonde pump efficiency measurements and tests on the sensitivity to ozone of buffered and unbuffered ECC sensor cathode solutions. J. Geophys. Res., 107, D19 doi: 10.1029/2001JD000557. 1998.
Beekman, M. and G. Ancellet, D. Martin, C. Abonnel, G. Duverneuil and F. Eideliman, P. Bessemoulin, N. Fritz and E. Gizard	Intercomparison of tropospheric ozone profiles obtained by electrochemical sondes, a ground based lidar and an airborne UV-photemeter Atmospheric Environment Vol. 29, No. 9, pp. 1027-1042, 1995.
Brewer, A.W. and J.R. Milford	The Oxford-Kew Ozonesonde, Proc. Roy. Soc A, 256, 470, 1960.
Deshler, T., Mercer, H.G.J Smit, R. Stubi, G. Levrat, B.J. Johnson, S.J. Oltmans, R. Kivi, J. Davies, A.M. Thompson, J. Witte, F.J. Schmidlin, G. Brothers, T. Sasaki	Atmospheric comparison of electrochemical cell ozonesondes from different manufacturers, and with different cathode solution strenghts: The Balloon Experiment on Standards for Ozonesondes, J. Geophys. Res., 113, D04307, doi: 10.1029/2007JD008975. Komhyr, W. D. (1969), Electrochemical concentration cells for gas analysis, Ann. Geoph., 25, 203 - 210. 2008.
Godson, W.L.	The representation and analysis of vertical distributions of ozone, Quarterly Journal of the Meteorological Society, Vol. 88, No. 377, July 1962.
Hoegger, B.A. & all	Contribution of Switzerland to International Ozonesonde Intercomparisons. Proceedings of GAW-CH Conference Zurich, 14-15 October 1998. Swiss Agency for the Environment, Forests and Landscape (SAEFL), Environmental documentation No.110 Air, pp 43-47.
Johnson, Bryan J., Samuel J. Oltmans, H. Vomel, H.G.J. Smit, T. Deshler., and C. Kroger	Electrochemical concentration cell (ECC) ozonesonde pump efficiency measurements and tests on the sensitivity to ozone of buffered and unbuffered ECC sensor cathode solutions. J. Geophys. Res., 107 (D19), 4394, doi:1029/2001JD000557, 2002.
Kerr, J.B. & all	The 1991 WMO international ozonesonde intercomparison at Vanscoy, Canada. Atmosphere Ocean, Vol XXXII, No 4 pp 685-716, December 1994.

Name	Details
Kley, D., H.G.J. Smit, H. Vömel, H. Grassl, V. Ramanathan, P.J. Crutzen, S. Williams, J. Meywerk, S.J. Oltmans	Tropospheric water-vapour and ozone cross-sections in a zonal plane over the equatorial Pacific Ocean, Q.J.R. Meteorol. Soc. (1997), 123, pp. 2009-2040.
Komhyr, W.D.	Operations Handbook - Ozone Measurement to 40-km Altitude with 4A Electrochemical Concentration Cell (ECC) Ozonesondes (used with 1680-MHz radiosondes), NOAA Technical Memorandum ERL ARL-149,1986.
Komhyr, W.D., J.A. Lathrop, D.P. Opperman, R.A. Barns, and G.B. Brothers	ECC Ozonesonde performance evaluation during STOIC 1989, J. Geophys. Res., 100 9231-9244, 1995.
Komhyr, W.D.	Electrochemical Concentration Cell for Gas Analysis Ann. Geophys., t. 25, fasc. 1, 1969, pp. 203-210.
Schenkel, A., and B. Broder	Interference of some trace gases with ozone measurements by the KI method, Atmospheric Environment, 16, 2187-2190. 1982.
Schmidlin, F.J., B.A. Hoegger & all	Sondex96: A Field Experiment Conducted by NASA and SMI at Payerne,Switzerland. WMO Instruments and Observing Methods Report No 70, WMO Technical Conference on Meteorological and Methods of Observation (TECO-98), Casablanca Morocco, 13-15 May 1998, (WMO/TD No. 877), pp 193-196.
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Smit, H.G.J., W. Straeter, B. Johnson, S. Oltmans, J. Davies, D.W. Tarasick, B. Hoegger, R. Stubi, F. Schmidlin, T. Northam, A. Thompson, J. Witte, I. Boyd, F. Posny	Assessment of the performance of ECC-ozonesondes under quasi-flight conditions in the environmental simulation chamber: Insights from the Jülich Ozone Sonde Intercomparison Experiment (JOSIE), J. Geophys. Res., 112, D19306, doi:10.1029/2006JD007308. 2007
Smit, H.G.J. and D.Kley	Jülich Ozone Sonde Intercomparison Experiment (JOSIE) ; WMO Global Atmosphere Watch report series No. 130 (Technical document No.926) WMO, Geneva, 1998.
Smit, H.G.J.& all	The 1996 WMO International intercomparison of ozonesondes under quasi flight conditions in the environmental simulation chamber at Jülich, Proceedings XVIII Quadrennal Ozone Symbosium, Eds. R. Bojkov, and G. Visconti, L'Aquila, Italy, Sept. 1996.
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	SPARC-IOC-GAW Assessment of Trends in the Vertical Distribution of Ozone (1998), SPARC Report No.1, WMO Global Ozone Research and Monitoring Project Report No. 43, World Meteorological Organization, Geneva. Note: In this report performance investigations made before 1996 have been intensively evaluated by the SPARC-IOC-GAW assessment panel

Name	Details
Stübi R., G. Levrat, B. Hoegger, P. Viatte, J. Staehelin, F. J. Schmidlin	In-flight comparison of Brewer-Mast and electrochemical concentration cell ozonesondes, J. Geophys. Res., 113, D13302, doi:10.1029/2007JD009091. 2008.
WMO	Third WMO intercomparison of the ozonesondes used by the Global ozone observing System, Vanscoy Canada 13-24 May 1991, WMO/ Global Atmosphere Watch/WMO Global Ozone Research and Monitoring Project, Report No 27.

Technical Support

Contact Vaisala technical support at helpdesk@vaisala.com. Provide at least the following supporting information:

- Product name and serial number in the subject field
- Name and location of the installation site
- Name and contact information of a technical person who can provide further information on the problem

Vaisala recommends that you include a problem report when contacting Vaisala technical support. For more information, see *AWS310-SITE Configuration and Maintenance Manual*.

Vaisala Service Centers perform calibrations and adjustments as well as repair and spare part services. For Vaisala Service Center contact information, see www.vaisala.com/servicecenters

Recycling

Recycle all applicable material.

Follow the statutory regulations for disposing of the product and packaging.

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