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OPERATIONS HANDBOOK--OZONE MEASUREMENTS TO 40-km ALTITUDE WITH MODEL 4A ELECTROCHEMICAL CONCENTRATION CELL (ECC) OZONESONDES (USED WITH 1680-MHz RADIOSONDES)

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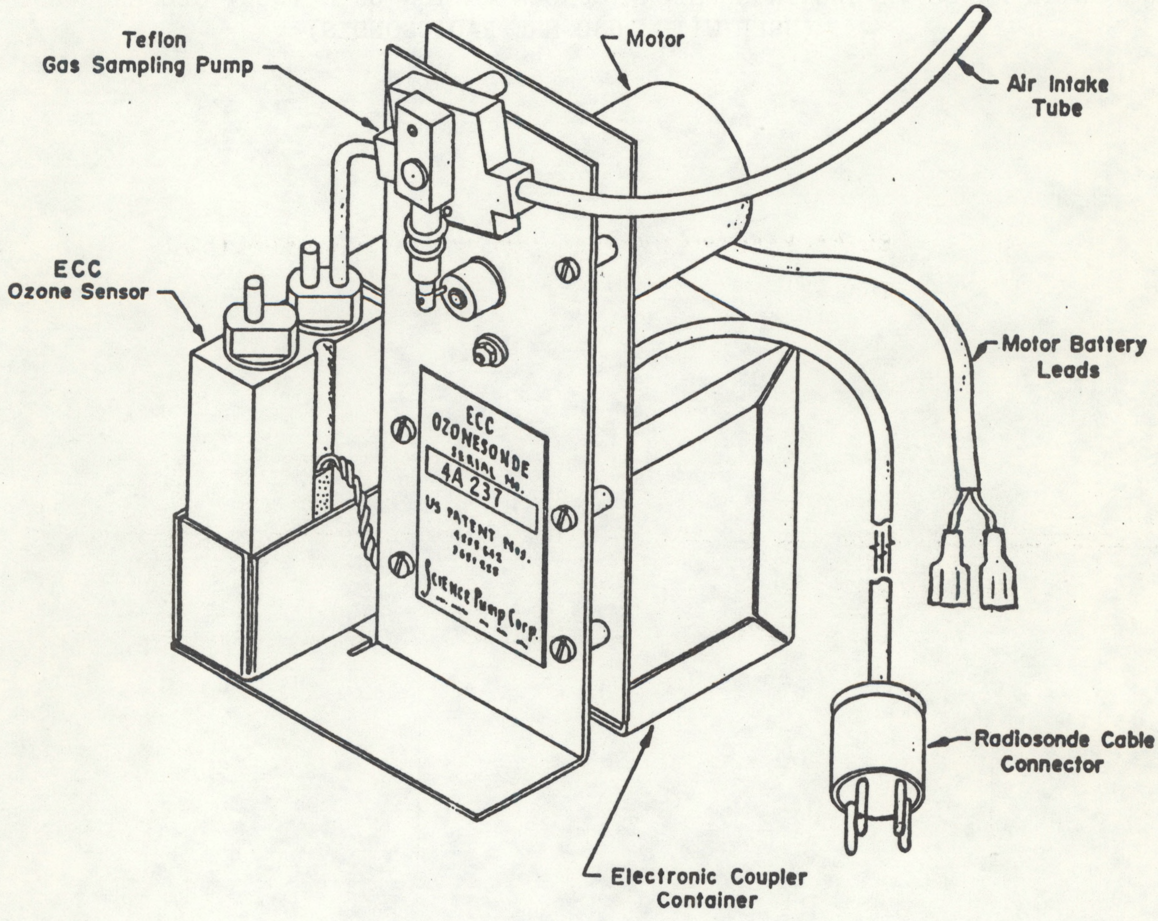

MODEL 4A BALLOON-BORNE
ELECTRO-CHEMICAL CONCENTRATION CELL (ECC)
OZONESONDE

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FOREWORD

Electrochemical concentration cell (ECC) ozonesondes are flown by balloon at a number of stations throughout the world to obtain data on atmospheric ozone vertical distributions to near 40 km altitude. This handbook gives information about the instrumentation (including the balloon vehicles), and provides instructions concerning preparation of the instruments for flight, data reduction, and data archiving. The instructions are intended to standardize operation of the instruments so that different users might obtain data of comparable quality.

A video tape with narrative, showing how ECC ozonesondes are prepared for use, is available upon request from NOAA/GMCC, R/E/AR4, Boulder, Colorado 80303, for training purposes. Instructions in this Handbook supersede, those given in the video presentation, which differ in a few details.

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OPERATIONS HANDBOOK--OZONE MEASUREMENTS TO 40-km ALTITUDE WITH MODEL 4A ELECTROCHEMICAL CONCENTRATION CELL (ECC) OZONESONDES (USED WITH 1680-MHz RADIOSONDES)

W. D. KOMHYR

ABSTRACT. Operation of balloon-borne electrochemical concentration cell (ECC) ozonesondes is described, and instructions are provided for preparing the instruments for use, flying them coupled to 1680-MHz radiosondes, and processing and archiving the data.

1. INTRODUCTION

The electrochemical concentration cell (ECC) ozonesonde (or sonde) is a simply designed, lightweight, compact, and inexpensive balloon-borne instrument developed in the NOAA Air Resources Laboratory (Komhyr, 1964, 1969; Komhyr and Harris, 1971) for use in measuring the vertical distribution of atmospheric ozone. The instrument is readily prepared for use (see Appendix A), and is potentially capable of providing ozone data accurate on an absolute scale.

The ozone sensor used within the sonde is an iodine-iodide redox electrode concentration cell made of two bright platinum electrodes immersed in potassium iodide solutions of different concentrations (see Appendix B) contained in separate cathode and anode chambers that are fabricated from polytetrafluoroethylene (Teflon TFE resin). The chambers are linked together with an ion bridge that serves as an ion pathway and retards mixing of the cathode and anode electrolytes, thereby preserving their concentrations. The electrolyte in each chamber also contains potassium bromide and a buffer, with the concentrations of these chemicals the same in each half cell.

The ECC sensor does not require application of an external emf for operation. Driving emf for the cell is derived from a difference of potassium iodide concentrations present in the two half cells. The working equation for the cell at 25° is

$$E \approx -\frac{0.0591}{2}\log\frac{(a_1)_{I_3^-}}{(a_4)_{I_2}}\cdot\frac{(a_3)^2_{I^-}}{(a_2)^3_{I^-}} \tag{1}$$

where E is the emf produced within the cell;

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

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

For an open-circuited cell first charged with solution, a potentiometer measurement reveals E to be about 0.13 V. If the cell leads are, however, connected together, e.g., through a microammeter, the 0.13 V emf forces iodide in the vicinity of the anode to give up electrons to the anode, while electrons are extracted by iodine in solution from the cathode. A momentary current surge may be observed on the microammeter during which time the concentration of I_3^- in the anode electrolyte is increased, while the concentration if I_2 in the cathode electrolyte is decreased. Corresponding activities a_1 and a_4 change until the condition

$$\beta = \frac{(a_1)_{I_3^-}}{(a_4)_{I_2}}\cdot\frac{(a_3)^2_{I^-}}{(a_2)^3_{I^-}} \approx 1 \tag{2}$$

is attained, and the cell emf drops to nearly zero. The above relation defines a sensitive "working" equilibrium state for the cell. If, for example, the concentration of I_2 in the cell cathode chamber is increased by some method, β becomes less than 1. This causes the cell emf to become positive [eq. (1)] so that once again iodine molecules in the vicinity of the cathode tend to accept electrons from the cathode and be converted to iodide, while iodide in the vicinity of the anode is forced to give up electrons to the anode and be converted to iodine. The current flowing in the cell external circuit is, therefore, directly related to the rate of conversion of iodine to iodide, or iodide to iodine.

Within the ozonesonde, I_2 is produced in the cell cathode chamber when air containing ozone is bubbled through the cathode electrolyte. I_2 is formed according to this relation:

$$2KI + O_3 + H_2O \rightarrow 2KOH + I_2 + O_2 \; . \qquad (3)$$

Conversion by the cell of iodine to iodide occurs, and the ozone concentration in the sampled air (in parts per million by volume, PPMV) may then be calculated from the equation

$$PPMV(O_3) = \frac{0.4307\ T}{PF}\ I \qquad (4)$$

where I is the ozone current in microamperes flowing through the cell, and F is the flow rate in milliliters per second of the air being sampled at a pressure P in millibars and temperature T in kelvins.

In practice it is observed that the cell puts out a background current, i_a, when air from which ozone has been removed is bubbled through it. The value of i_a is usually less than 0.1 μA. The ozone current, I, used in eq. (4) is, therefore, defined by

$$I = i_{obs} - i_a \qquad (5)$$

where i_{obs} is the cell output current during ozone measurement.

The air pump used within the sonde is of unique design that permits pump operation without the use of ozone-destroying lubricants. All pump components that come in contact with sampled air are fabricated from Teflon reinforced with 15% glass fibers, a substance that is inert to ozone.

The minute current (0-6 μA) emitted by the electrochemical concentration cell during the measurement of ozone is impressed upon a simple two-transistor transducer, the resistance of which varies with the magnitude of the impressed current. Data telemetry is accomplished by periodic connection of the transducer, by means of a mechanical sequencing switch, to a 1680-MHz transistorized radiosonde. The sequencing switch used is of the "stepper" type, the duration of each "step" being about 3½ seconds.

Telemetered signals are air pressure, air temperature, humidity, ozone, ozonesonde box temperature, "ozone zero," and "ozone calibrate." The last two types of signals provide in-flight calibration of the ozone data telemetry system.

The instructions contained herein are intended to standardize operation of Model 4A ECC ozonesondes manufactured by Science Pump Corporation, Camden, New Jersey 08104. Preparation of the instruments for flight is accomplished with the aid of a Model TSC-1 Ozonizer/Test Unit, also manufactured by Science Pump Corporation (see Appendix C). The ECC sondes are flown coupled to 1680-MHz transistorized radiosondes manufactured by VIZ Manufacturing Company, Philadelphia, Pennsylvania 19144. (See Appendix D for modification of the radiosondes for use with the ECC ozonesondes.) Hypsometer radiosondes and plastic balloons are used for soundings attaining maximum altitudes of about 40 km. For lower altitude soundings (<33 km), standard radiosondes and rubber balloons may be used.

2. PREPARING THE ECC OZONESONDE FOR FLIGHT

Note 1: Smoking should be avoided in the vicinity of an operating ozonesonde; otherwise, the performance of the instrument may be adversely affected.

Note 2: Tubing connections to the sonde air pump are made using press-fitted Teflon tubing. Use small strips of No. 600A sandpaper with which to grasp the Teflon tubing firmly when making or breaking pump connections.

Note 3: When preparing the ECC sonde for use, record on a checklist (see Appendix A.2) the steps performed and results obtained.

2.1 Advance Preparation 3 Days to 1 Week Prior to Release

The first step in preparing the ECC sonde for use is to check the overall performance of the instrument, and to charge the sensor with sensing solution. Initial charging of the sensor must be done 3 days to 1 week before flight time in order to attain low sensor background current and fast sensor response to ozone. A Model TSC-1 Ozonizer/Test Unit (see Appendix C) is used to check the overall instrument performance. The unit consists of a variable ozone source for conditioning the sonde air intake tube, pump, and sensor with ozone; a power supply for operating the sonde; and electrical meters for checking the sonde motor/sensor characteristics. Built into the ozonizer/test unit is an ECC ozone sensor calibrator, against which the ozonesonde sensor output can be compared.

Proceed as follows in preparing the instrument for use:

(a) Remove the sonde from its polystyrene box and plastic bag, and connect the Teflon air intake tube packed with the instrument to the pump.

(b) Activate the sonde electronic coupler by inserting two 1.35-V mercury batteries into the coupler battery holders. Squeeze the battery terminals together by hand if necessary to ensure that the batteries are held firmly in place.

(c) Connect the ECC ozonesonde motor, signal output, and sensor leads to the ozonizer/test unit, and begin conditioning the sonde pump and dry sensor with a high ozone output. The pump air intake tube should be inserted snugly into the HI OZONE port of the ozonizer/test unit since the sonde pump draws highly ozonized air from the unit. For high ozone to be produced, the U.V. LAMP switch of the ozonizer/test unit must be turned to the ON position, and the OZONE CONTROL tube must be pulled out of the chassis of the ozonizer/test unit as far as possible. Blue light visible through a hole in the front of the OZONE CONTROL TUBE indicates that the U.V. lamp is ON. During the conditioning you should be able to smell ozone coming out of the sensor. Otherwise, the ozonizer/test unit may be defective, or its controls incorrectly set.

(d) After 5-10 minutes of conditioning, check the milliampere meter of the ozonizer/test unit for current drawn by the sonde pump. It should be between 90 and 120 mA. If the current is too large, the fit between the piston and cylinder is too tight and may cause excessive frictional heating. Continue operating the pump for 20 minutes to see if the current decreases. If it does not, remove the piston from the pump cylinder, insert a 0.1570-inch D (0.3988-cm-D) reamer into the cylinder and rotate it several times. Reassemble the pump taking care to orient the piston in the cylinder in the same way in which it was originally positioned. Begin pump operation again, and check the motor current. If it is still too large, repeat the reaming operation, but with progressively larger diameter reamers, viz., 0.1580 inch D (0.4013 cm D) and 0.1590 inch D (0.4039 cm D). If reaming the pump cylinder does not help, take remedial action described in Section 6.4. Should pump current become too low, increase it by applying slight pressure in a rotary motion to the pump cylinder O-rings using, for example, thin long-nosed pliers.

Avoid contacting the Teflon portion of the pump piston with your fingers when handling the piston. Also, when working on the pump take care at all times to have the pump sample ozonizer/test unit air, or air passing through an ozone destruction filter (Appendix E), and not room air; otherwise, pump contamination may occur.

(e) After proper pump motor operation is attained, check the pressure and vacuum developed by the pump using a pressure/vacuum gauge. Pump pressure should be at least 16 inches Hg, and pump vacuum should be at least 13 inches Hg. Applying pressure by hand to the sonde gear train frame to distort it slightly may cause an improvement in the performance of the pump.

(f) Continue conditioning the sonde with high ozone. As conditioning proceeds, observe the readings of the middle of the three microammeters located on the upper front panel of the ozonizer/test unit (Appendix C). The meter readings change as the sonde commutator switching occurs (see Section 4). OZONE and OZONE ZERO signals should read approximately 32 μA. To obtain correct readings, adjust the sonde transducer potentiometer. The SONDE BOX temperature and the SONDE CALIBRATE signals will then read about 70 and 65 μA, respectively. If correct microammeter readings are unattainable, or the readings are erratic, see Section 6.1 for remedial action.

(g) After the sonde pump and dry sensor have been conditioned with high ozone for at least 30 minutes, turn off the HI OZONE switch of the ozonizer/test unit, and push the OZONE CONTROL tube into the unit as far as possible. Withdraw the sonde air intake tube from the HI OZONE port of the test unit and insert it, instead, into the NO/LO OZONE port. Turn the AIR PUMP switch to the ON position. Run the sonde with ozone-free (no ozone) air passing through it for a minute or two to remove ozonized air from the pump and sensor.

(h) Now charge the sensor with sensing solution as follows:

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

NOTE: A 3.0-cm^3 cathode sensing solution is used in sondes flown with plastic balloons reaching burst altitudes near 40 km. Flight time for such soundings is about 2.5 hours. For shorter flights that occur when rubber balloons are used, reaching altitudes of 30-35 km, the sensor cathodes may be charged with 2.5 cm^3 sensing solution. Sensor response time then becomes faster, and measured ozone profiles exhibit more detail.

(2) Next, using a syringe especially reserved for dispensing anode solution, inject 1.5 cm^3 anode sensing solution into the sensor anode chamber. Rinse the syringe with distilled water prior to storage.

(3) The sensor cathode and anode solutions should always be stored in a dark place at a temperature of 20° to 25°C.

(i) After charging the sensor with solution, run the sonde on ozonizer/test unit ozone-free air for about 5 minutes. The sensor current, as observed on the top, right-hand microammeter, will decrease from more than 5.0 µA to 1.0 µA or less. Now set the ozonizer/test unit controls for a low ozone output, one that produces a sensor output current of about 4 or 5 µA. This is done by turning the U.V. LAMP switch to the ON position and pulling the OZONE CONTROL tube partially out of the instrument chassis. You should now observe a positive response to ozone on the top right-hand microammeter. Next, unplug the sensor leads from the ozonizer/test unit, and plug them into the sonde transducer. Observe the top center microammeter of the ozonizer/test unit as sonde commutator switching occurs. Positive ozone signals, that is, greater than OZONE ZERO signals, should be indicated by the meter. Now turn off the U.V. LAMP switch. The microammeter readings should slowly fall to the level of the OZONE ZERO signals (about 32 µA on the meter).

(j) Continue running the sonde on ozone-free air for 10 minutes. Then disconnect the sonde from the ozonizer/test unit, remove the batteries from the sonde transducer, and store the instrument in a dark, clean-air environment at a temperature of 20°-25°C until ready for use.

(k) Prior to storing the ozonizer/test unit, cover the NO/LO and HI OZONE ports with plastic caps to prevent dust from entering the ports.

2.2 Preparation on the Day of Release

On the day of release you should have on hand two or three instruments whose operation has been checked, and whose sensors were charged with sensing solution at least 3 days earlier. Use the instrument that was charged earliest in time.

(a) First, install new Hg batteries into the sonde transducer. Disconnect the sensor cathode and air-intake tubes from the pump. Connect the ozonesonde sensor, motor, and output leads to the ozonizer/test unit.

(b) Turn power on to the ozonizer/test unit, and operate the sonde pump motor for several minutes. Measure the pressure and vacuum developed by the pump with a hand-held pressure/vacuum meter, and record the results.

(c) Connect the air-intake tube to the pump, and insert it into the HI OZONE port of the test unit. Condition the sonde pump with high ozone for 10-15 minutes. (IMPORTANT: Air containing HI OZONE should never be passed through the charged sensor; otherwise normal sensor operation will be disrupted.)

(d) While the conditioning is progressing, remove only the cathode solution from the sensor, and replenish with 3.0 cm^3 of fresh sensing solution. Replace the top plug of the sensor cathode, but do not connect the Teflon tube of the plug to the pump.

(e) Now prepare the ozone CALIBRATOR of the ozonizer/test unit for use by withdrawing the sensing solution from the cathode chamber of the CALIBRATOR sensor, and replenishing with 3.0 cm^3 of fresh cathode solution.

(f) After 10-15 minutes of conditioning of the pump with high ozone, turn OFF the U.V. LAMP switch and turn ON the AIR PUMP switch of the test unit. (Also push the ozone control tube all the way into the test unit chassis.) Insert the ozonesonde air-intake tube into the NO/LO OZONE port of the test unit to a distance of about 10 cm. Flush the pump with O_3-free air for about a minute, then connect the sensor cathode Teflon tube to the sonde pump. Turn ON the CALIBRATOR MOTOR switch of the test unit. Continue operating for 10 minutes to condition the sonde and calibrator sensors with ozone-free air.

(g) After 10 minutes of conditioning with ozone-free air, the top left-hand calibrator sensor microammeter and the top right-hand sonde sensor microammeter should each indicate less than 0.2 µA of sensor background current, i_{bc} and i_{bs}, respectively. If this current is higher for either of the sensors, withdraw the cathode sensing solution from the sensor, and replace with fresh solution [see also Section 6.3(a)]. Continue conditioning with ozone-free air for another 10 minutes. Record on a checklist (Appendix A.2) the observed values of i_{bc} and i_{bs}.

(h) Now begin conditioning the sensor electrolyte solutions with ozone. Turn on the U.V. LAMP switch, and pull the OZONE CONTROL tube out of the instrument's front panel a centimeter or two. The current readings (due to ozone entering the calibrator and ozone sensors) of the two 0-10 μA meters should slowly increase. During the next several minutes, continue adjusting the position of the OZONE CONTROL tube so that maximum readings on the microammeters stabilize at about 5 μA. Continue conditioning with low ozone for an additional 10 minutes. During the conditioning, measure the calibrator and ECC sonde air flow rates, t_c and t_s (see Appendix F), and record the values. Record also the sonde and calibrate motor voltages and currents. Record room temperature, and room relative humidity.

At the end of the 10-minute LO OZONE conditioning interval, record the calibrator sensor and sonde output currents i_c and i_s. Compute the products

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

which should agree to within about 5%. [See Section 6.3(b) for remedial action, if necessary.]

Next check the sensor response times as follows: Turn OFF the U.V. LAMP switch and, simultaneously, using a stopwatch, read and record at 1-minute intervals, for 3 minutes, the calibrator and sonde output currents i_{1c}, i_{2c}, i_{3c}, and i_{1s}, i_{2s}, and i_{3s}. The 1-minute data should yield

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

and

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

indicating satisfactory sensor response times to changes in ozone. Continue operating for 10 minutes and record the values i_{bc} and i_{bs}. If the ozone dropoff does not occur quickly enough, see Section 6.3(c) for remedial action.

(i) Push the OZONE CONTROL tube into the ozonizer/test unit chassis, and turn off power to the test unit. Disconnect the sonde from the unit. Plug the sonde sensor leads into the sonde transducer, taking care to ensure correct polarity (blue wire pin plugs into the socket nearest the battery). Replace the sonde, which is now nearly ready for flight, into its polystyrene box. Tape the sonde air intake tube to the flight box. Affix a piece of masking tape to the flight box just above the ECC sensor cathode air exhaust tube to serve as a splash guard. Install lithium air pump batteries into the sonde box.

Note: The battery compartment located near the bottom of the sonde box is to be used only for water-activated-type batteries (see Appendix G) If lithium dry cells are used to power the sonde air pump, the battery compartment should be filled with insulating material and taped shut to prevent excessive cooling of the sonde during flight.

To allow the sonde sensor background current to continue to decrease, at least one-half hour should pass before final launch preparations are begun.

During this time, the ozonesonde should not be subjected to large temperature fluctuations. Final flight preparation should be performed in a room with temperature about 25°C.

2.3 Flight Package Preparation and the Balloon Launch

For ozone soundings to near 40-km altitude, the ECC sondes are flown with 1680-MHz hypsometer radiosondes and 146,000-ft^3 (4.13×10^3 m^3) plastic balloons. Hypsometer radiosondes have a special sensor for accurate pressure measurements in the atmosphere above 10 mb. (Non-hypsometer radiosondes may be used for ozonesonde launches with rubber balloons that attain lower maximum altitudes.)

(a) At the launch site, turn on the radiosonde receiving gear. Insert a shorting plug into the radiosonde gray cable connector, and power the radiosonde with an auxilliary 18 V-d.c. power supply. Set the radiosonde baroswitch according to standard procedures for correct pressure (Appendix H). This is accomplished with the aid of an accurately calibrated aneroid or mercury barometer. Insert a humidity measuring element into the radiosonde, and expose the radiosonde temperature thermistor element. Record all temperature and humidity element calibration data on the radiosonde chart record, and on the checklist (Appendix A.2).

(b) Insert a thermometer into the sonde box (through a hole punched in the sonde box cover when working at cool temperatures; the hole should subsequently be taped shut). Affix an ozone destruction filter (Appendix E) to the sonde air intake tube. Set the ozone and radiosonde instruments about 8 ft (2.4 m) apart to minimize radio frequency interference; then electronically couple the instruments with a gray extender cable (see Fig. 1). Turn on the ozonesonde motor. Tune the radiosonde receiving gear to obtain signals from the ozonesonde/radiosonde. Now join the blue and white wires protruding from the side of the radiosonde. Low reference signals will begin coming in intermittently at near 95 chart ordinates on the receiver chart record. Adjust a knob on the receiver to set the low reference signals exactly to 95 ordinates. This knob must be adjusted from time to time during flight to keep the reference signals at 95 ordinates.

(c) Next, identify the OZONE ZERO signal traces on the chart record. They appear at about 30 chart ordinates, at 2-minute intervals (see Fig. 2). If necessary, turn the ozonesonde transducer potentiometer to adjust the position of the signal traces to near 33 ordinates. (If, however, the ozonesonde is to be released in a polar region in the spring when stratospheric ozone amounts are very high, the OZONE ZERO signals should be set at 25

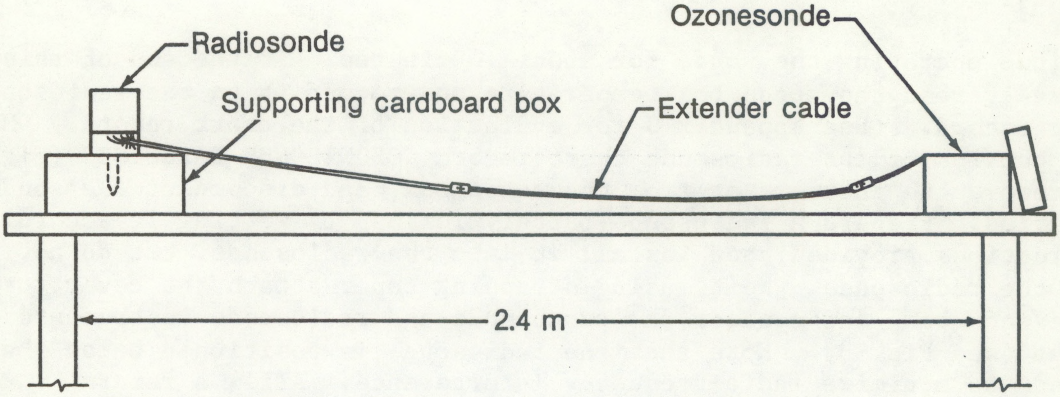


Figure 1. Laboratory set-up for minimizing radio-frequency pickup from the radiosonde by the ECC sondes.

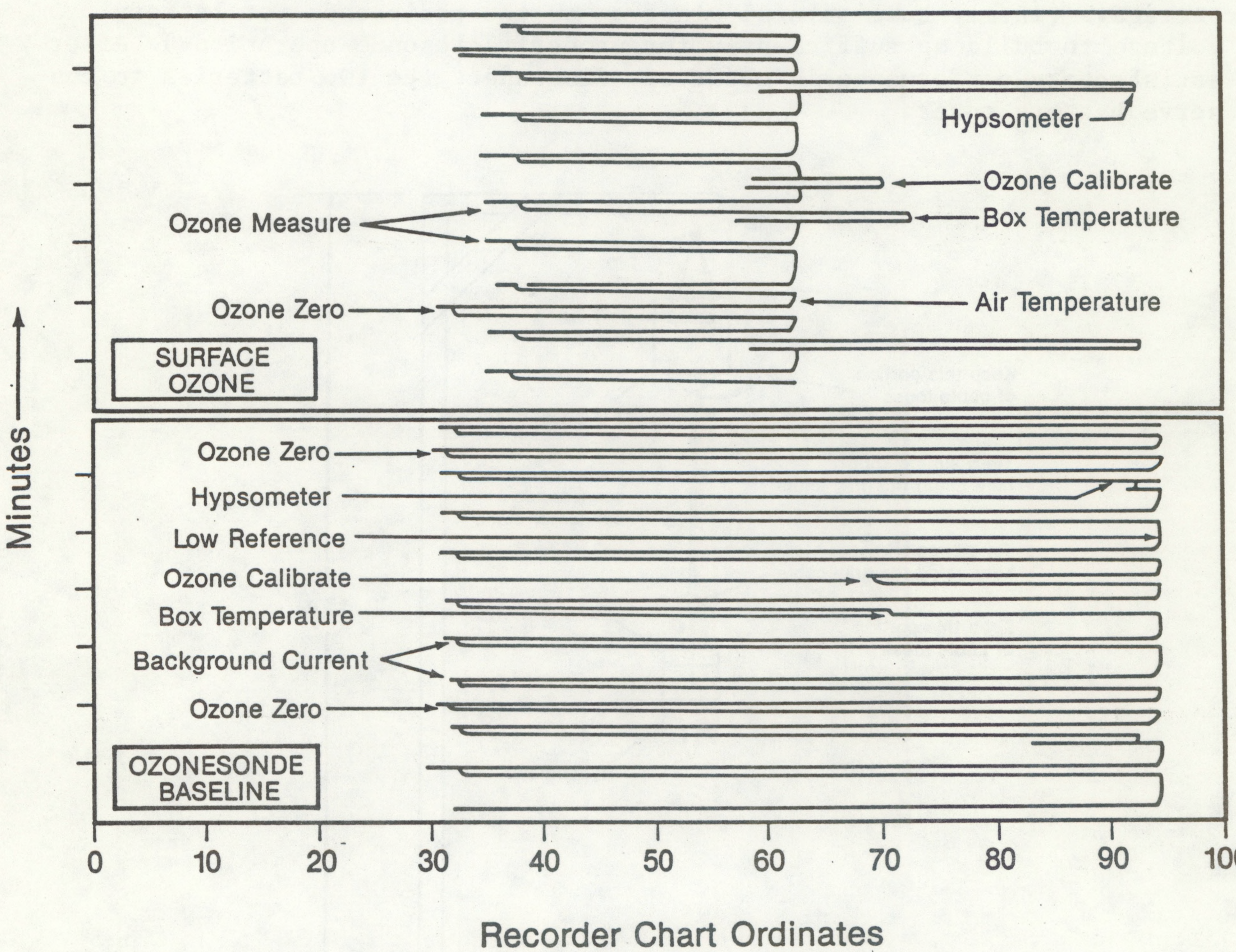


Figure 2. Sample radiosonde chart record.

chart ordinates; otherwise, the ozone SIGNAL traces may go off scale during flight).

(d) Continue operating the sonde for about 10 minutes. At the end of this time interval, read the sonde box temperature and record it on the radiosonde chart record. (See Appendix J for evaluation of the chart record.) Mark this portion of the radiosonde chart record "OZONESONDE BASELINE" (Fig. 2). Now remove the thermometer from the sonde box, and disconnect the sonde pump batteries. Prepare a radiosonde battery for use by wetting it according to instructions provided, and install it into the radiosonde, but do not activate the radiosonde. Next, using strapping tape, attach the cover to the ozonesonde box, and connect the ozonesonde and radiosonde instruments for flight (see Fig. 3). Note that the radiosonde is positioned below the ozonesonde to minimize radio-frequency interference. Affix a return address/award notice to the top of the sonde box with tape, and suspend the instrument package from the room ceiling pending balloon inflation. You may now temporarily connect the radiosonde and ozonesonde batteries to the two instruments, with the ozone destruction filter (Appendix E) attached to the sonde intake, for a final check on the overall performance of the instrument package. (It may take several minutes for the radiosonde wet battery voltage to build up sufficiently for proper radiosonde operation.) After satisfactory performance is observed, disconnect the two batteries to conserve battery power.

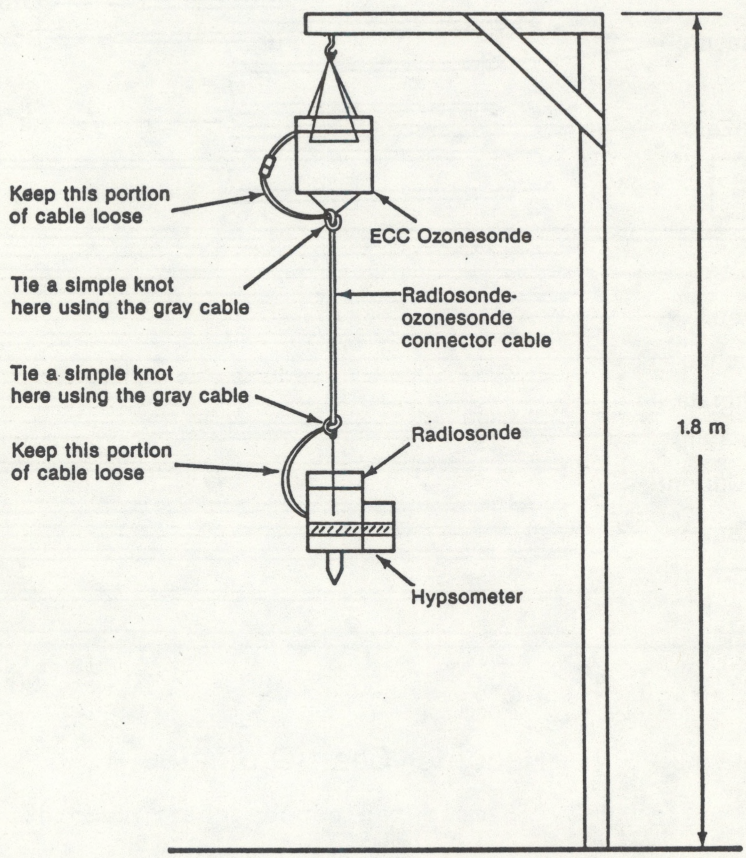


Figure 3. The method of connecting the ozonesonde and radiosonde instruments for flight.

(e) The next step is to inflate the 146,000-ft^3 (4.13×10^3 m^3) plastic balloon with helium in preparation for flight (see also Section 3). First, prepare the instrument pay-out reel by threading the string straight up and through the hole from the opposite side of the ratchet gear. Tie a double string to the other end of the reel for later attachment to the balloon.

(f) To inflate the plastic balloon, begin by removing the balloon in its sealed bag from the shipping container and placing the bag on a clean floor of the inflation shelter. Cut the top of the bag and shield the bottom of the balloon with the bag material. Locate the fill tube which is folded on the top of the balloon and enclosed in a small bag. Remove the tube from the bag and extend the tube to the helium supply inflation hose. To prevent bursting the inflation tube while filling, avoid twisting the tube while connecting it to the inflation hose. Slowly begin the flow of helium, holding the balloon collar with its trailing material above the floor. As the bubble begins floating, pulling approximately 15 ft (4.6 m) of material upward, check beneath the tied ends of the bundle enclosing the bulk of the balloon to make sure that no part of the balloon is pinched. Tie to the bottom of the balloon hutch-clutch a weight of 5300 g. (The hutch-clutch is a cloth-wrapped section of the balloon that separates the inflation bubble from the rest of the balloon bundle.) Continue inflating the balloon until the entire balloon and weight are lifted from the ground. Attach an additional heavy object as an anchor. Tie-off the inflation tube. Tie the rope end of a pay-out reel to the rope harness tied to the bottom of the balloon.

After balloon inflation has been completed, carry the ozonesonde package outdoors, and suspend it from a wooden pole at a height of 6 ft (1.8 m) above the ground (see Fig. 3). The pole should be located away from metal objects, e.g., a wire fence, to prevent possible radio-frequency interference. Connect battery terminals to activate the ECC ozonesonde pump motor and the radiosonde. Now adjust the radiosonde receiver controls to obtain the ozonesonde signals. Continue operating the sonde for 10 minutes to get a measurement of surface ozone. (The surface ozone measurement should be omitted if the launch is made in very cold weather in polar regions, to prevent excessive cooling of the instrument package.)

After 10 minutes, <u>disconnect the radiosonde blue and white wires and cut off the bare ends of these wires</u>; otherwise the meteorological data will be lost during flight. Now fill the hypsometer sensor with hypsometer fluid. Carry the ozonesonde package to the balloon inflation shelter.

At the balloon, while one person holds the hutch-clutch, cut string and plastic to release the hutch-clutch from the folded balloon bundle. Gather the folded balloon and place it into a plastic-lined paper box, positioning the material so that the plastic beneath the bubble pays out first. Tie the pay-out reel to the bottom of the balloon. If there is a chance of the balloon touching the sides of the doorway, attach protective plastic curtains to the doorway sides. Tie the wax string of the pay-out reel to the harness loop of the ozonesonde package. With one person holding the hutch-clutch, one person carrying the balloon box, and a third person holding the instrument package, move out of the shelter door. Carry the balloon bubble upwind of the instrument, with the box in the middle. Release the balloon bubble. As the bubble rises, maneuver the position of the box and instrument beneath it so that the instrument is lifted as nearly vertical as possible.

The exact time of release must be noted on the radiosonde chart record.

3. PLASTIC/RUBBER BALLOONS AND THE BALLOON TRAIN

For soundings to near 40-km altitude, use 146,000-ft^3 (4.13×10^3 m) plastic balloons (manufactured in the United States by Raven Industries, Inc., Sioux Falls, South Dakota 57117 or Winzen International, Inc., Minneapolis, Minnesota 55420). The balloons are made from 0.025-inch-thick (0.063-cm-thick) plastic material and weigh 19 to 21 pounds (8.6 to 9.5 kg). About three tanks of helium gas (approximately 700 ft^3 (19.8 m^3) at S.T.P.) are required for inflation per balloon. During inflation, tie to the bottom of the balloon hutch-clutch a weight of 5300 g. Inflate the balloon until the entire balloon and the weight are lifted off the ground.

Smaller, 19,000-ft^3 (538-m^3) plastic balloons are also available from the manufacturers named above. Balloon wall thickness is 0.035 inch (0.089 cm). Balloon weight is about 7.5 lb (3.4 kg). Approximately 350 ft^3 (9.9 m^3) of helium is required to fill the balloon. Balloon float weight to be used during inflation is 3100 g. The balloons carry ECC sondes to altitudes of 8-10 mb.

When ECC sondes are flown with rubber balloons, maximum pressure altitudes attained will generally be between 20 and 7 mb, depending on balloon size, quality, and stratospheric temperatures. Balloons weighing 1200, 2000, and 3000 g should be inflated to barely float weights of about 2500, 2700, and 3000 g, respectively.

Adjust the weights recommended above (if necessary) to attain average balloon ascent rates of about 300 m/min. Somewhat more helium (or hydrogen) may be required when stratospheric temperatures are very cold, or the flights are made at night.

The instrument package should be suspended about 30 m below the balloon. Cord wound on a ratchet-type reel facilitates balloon release. In cold climates, attach a snap-type clip to the reel cord and a metal ring to the ozonesonde suspension harness for quick connection of the sonde package to the balloon train.

If a release is made in a densely populated region, a parachute of diameter about 1.5 m should be suspended by a cord 10 m below the balloon. Suspend the instrument package 25 m below the parachute. When conducting ozone soundings from a flight control area (e.g., in the vicinity of an airport), check with your local aviation authority for regulations regarding balloon releases.

4. OZONESONDE SIGNAL SWITCHING SEQUENCE

The sequence in which data are transmitted by the ozonesonde-radiosonde during flight is illustrated in Fig. 4.

One revolution of the commutator wiper takes 2 minutes. During this time six ozone measurements are made at intervals of 20 seconds. Note that the ozone zero signal is transmitted when the commutator wiper is at the 3 o'clock position, while the ozone calibrate signal is transmitted when the wiper is at the 9

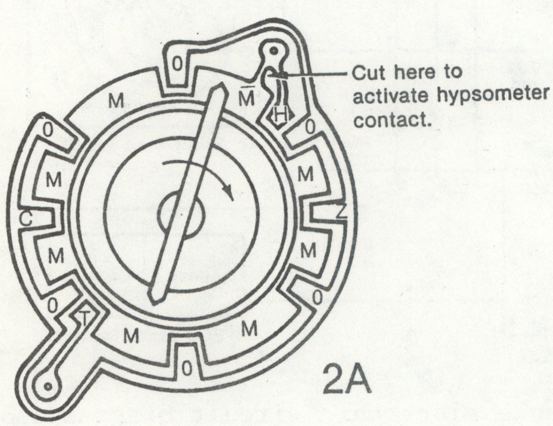


Figure 4. Schematic diagram of sequencing switch deck 2A.

o'clock position. When the wiper contacts the "T" segment the temperature inside the ozone instrument package is measured, while the "M" segments permit transmissions of normal radiosonde data--pressure, temperature, and humidity.

A hypsometer contact on the commutator deck provides air pressure data every 2 minutes. To activate the contact, cut the copper strip that joins the hypsometer (H) contact to the meteorology (M) contacts (see Fig. 4). When using non-hypsometer radiosondes, the cut is not made and meteorological data are transmitted.

A schematic diagram of the ECC sonde electronics, including commutator deck 2A, is given in Fig. 5.

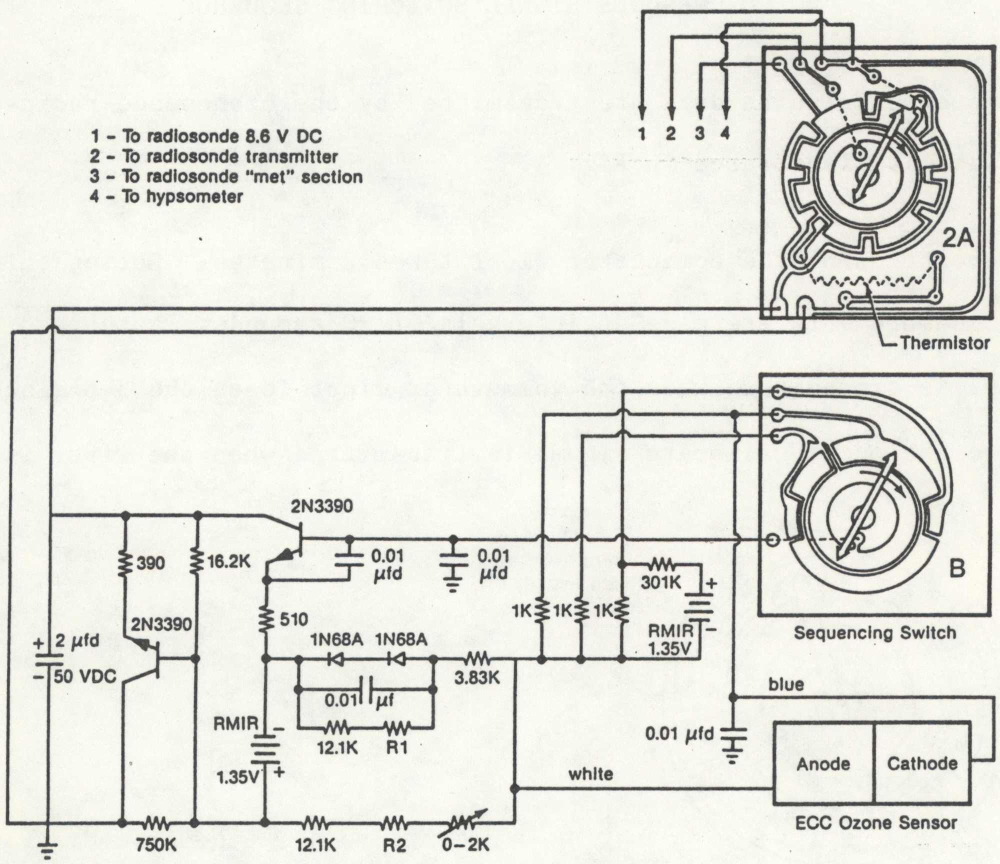


Figure 5. ECC-4A ozonesonde electronic circuit diagram.

5. LOW REFERENCE RECORDER ADJUSTMENT, CHART SPEED

To facilitate reduction of radiosonde and ozonesonde data, the frequency control knob on the radiosonde recorder should be adjusted periodically to maintain the low reference radiosonde signal at 95.0 chart ordinates. Operate the recorder at a chart speed of 1 inch/min.

6. POSSIBLE FAULTS, REPAIRS

6.1 Erratic Ozonizer/Test Unit Readings

(a) If microammeter readings are erratic during checking of the ozonesonde with the test unit, the commutator decks may require cleaning. Try stopping the sonde motor, and with a screwdriver, rotating the sonde wiper gear several revolutions in the direction opposite to that in which the blades normally rotate. If this does not correct the problem, clean the decks with lens tissue moistened with acetone. To gain access to the decks, it is necessary to remove the electronic transducer from its mounting screws (two wires leading from the transducer to commutator deck 2A need not be unsoldered). During reassembly, check to see that both commutator wipers contact the commutator plates properly.

(b) Should the commutator wiper be turned manually during cleaning, it is necessary that the wiper be positioned correctly on one of the small segments of the switch deck before power is applied to the pump motor; otherwise, jamming of the gear train may occur. Should the gear train jam, disconnect the power from the sonde, and crank the pump eccentric drive by hand in a counterclockwise direction. This will free the wiper gear, and permit correct positioning of the wiper on the deck.

(c) If the microammeter readings cannot be adjusted to 32 μA by turning the coupler potentiometer screw, or if the "C" segment reading is not 65 μA ± 3 μA, check the transducer battery voltages and replace batteries, if necessary. Battery voltages should be 1.35 V.

6.2 Noise Exhibited on Chart Record Traces

(a) Sonde commutator may require cleaning. See 6.1(a) above.

(b) Battery may need better contact. Compress battery clips together.

(c) Pump motor may be excessively noisy due to sparking of motor commutator and brushes. Defective motor should be replaced with a new one.

(d) Occasionally an instrument may exhibit an ozone trace with a slight wave in it due to radio-frequency pickup. The amplitude of such a wave is normally less than one-half a recorder chart ordinate, corresponding to an "ozone" current of about 0.05 µA. An error of that magnitude may usually be ignored. Shifting the instrument from one position in the room to another during calibration may improve signal stability.

6.3 ECC Sensor Problems

(a) If changing sensor cathode solution does not lower sensor background current, check for pump contamination by using with the sensor a pump that is known to be not contaminated. Try cleaning the contaminated pump with reagent-grade methanol and acetone, then conditioning with high ozone (see also Appendix I). If pump contamination is not a problem, try using freshly made sensor cathode solution.

(b) If the sonde and calibrator sensor currents don't agree, taking into account the air flow rates through the sensors [Section 2.2(h)], check to see that the flow rate of air emanating from the ozonizer/test unit's NO/LO OZONE port is more than about 700 mℓ/min. (For smaller flow rates, the output of the sonde sensor may be highly dependent on the location within the NO/LO OZONE port of the sonde air intake tube.) If the trouble persists, replace the anode sensing solution of the CALIBRATOR sensor of the ozonizer/test unit, and repeat instructions outlined in Section 2.2(h).

(c) If the response time of the CALIBRATOR ozone sensor to changes in ozone is not fast enough, replace old sensor anode solution with fresh solution. If the difficulty persists, replace the old sensor with a new one. If the sonde sensor exhibits slow response to ozone, recharge the sensor with freshly made cathode and anode sensing solutions. If the difficulty persists, replace the sonde sensor with a new sensor.

6.4 Teflon Pump Piston/Cylinder Adjustment

If the fit between the cylinder and piston of the sonde Teflon pump is too tight, and the reaming operation described in Section 2.1(d) does not help, proceed as follows: Remove the piston from the pump and insert its brass end into a 1/4-inch (0.64-cm) hand drill. Use a strip of fine-grit (e.g., No. 600A) wet/dry sand paper placed over an elongated, rigid, flat strip of aluminum, turn on the drill, and carefully sand a uniform layer of Teflon material from the piston surface. Great care must be taken not to sand away too much of the

Teflon material. Now clean the piston with acetone, and reinsert it into the pump cylinder. Check to ensure that the pump develops at least a 16-inch Hg vacuum. Prior to use, the pump must be reconditioned with high ozone.

6.5 Preparing and Flying an ECC Ozonesonde on the Same Day

It is possible to fly an ECC ozonesonde soon after charging of the sensor if the sensor conditioning procedure outlined in Section 2.1(i) is modified. Specifically, recharge the sensor cathode with fresh sensing solution and condition the sensor with ozone-free air several times until a background current of less than 0.3 μA is attained. Continue preparing the sonde for use according to instructions provided in Section 2, then set it aside for 2 to 3 hours prior to launch.

6.6 Reconditioning ECC Ozonesondes

Recovered ECC ozonesondes may be used over and over again provided that they are not damaged excessively during flight. The procedure to be followed in reconditioning a used ozonesonde is outlined in Appendix I.

7. DATA PROCESSING AND ARCHIVING

The ECC sonde data should be processed and archived in accordance with procedures described in Appendixes J and K, respectively.

8. REFERENCES

Komhyr, W. D. A carbon-iodine (CI) ozone sensor for atmospheric soundings. Proc. Atmospheric Ozone Symposium, Albuquerque, NM, 1964.

Komhyr, W. D. Electrochemical concentration cells for gas analysis. Annals de Geophysique, 25, No. 1, 203-210, 1969.

Komhyr, W. D., and T. B. Harris. Development of an ECC ozonesonde, NOAA Technical Report ERL 200-APCL 18, U.S. Dept. of Commerce, 1971.

APPENDIX A

PREPARATION OF THE ECC OZONESONDE FOR RELEASE

A.1. Equipment and Supplies Required

(1) 1 - ECC-4A ozonesonde, with polystyrene flight box.

(2) 1 - 1680-MHz viz hypsometer (or non-hypsometer) transistorized radiosonde, modified in accordance with instructions outlined in Appendix D; hypsometer fluid.

(3) 1 - Balloon (plastic or rubber).

(4) 1 - Balloon pay-out reel.

(5) 1 - Parachute, 200-inch (500-cm) circumference (may be optional).

(6) 1 - Ozonesonde pump motor battery. Lithium batteries are preferred.

(7) 2 - Ozonesonde electronic transducer battery, Mallory type RM1R.

(8) 1 - Radiosonde baseline shorting plug.

(9) 1 - Ozonesonde-radiosonde extender test cable.

(10) 1 - Bottle sensor cathode solution prepared according to instructions given in Appendix B.

(11) 1 - Bottle sensor anode solution prepared according to instructions given in Appendix B.

(12) 1 - Bottle distilled H_2O (for cleaning syringes after use).

(13) 1 - Syringe, 3-mℓ capacity equipped with Teflon tube, for use with sensor cathode solution.

(14) 1 - Syringe, 3-mℓ capacity, for use with sensor anode solution.

(15) 1 - Roll creped masking tape, 2 inches (5 cm) wide.

(16) 1 - Apparatus for measuring sonde air flow rate (see Appendix F).

(17) 1 - Ozonesonde power supply rated at 12.0-15.0 V d.c., 300 mA.

(18) 1 - Radiosonde power supply rated at 18-20 V d.c., 300 mA.

(19) 1 - Model TCS-1 Ozonizer/Test Unit.

(20) 1 - Ozone destruction filter (see Appendix E).

(21) 1 - Thermometer graduated in degrees Celsius.

(22) 1 - Hand-held pressure/vacuum gauge.

(23) 1 - Supply of small strips of No. 600A sandpaper for use in grasping sonde Teflon tubing.

(24) 1 - Plastic squirt bottle filled with research-grade methanol.

(25) 1 - Can opener.

(26) 1 - Operations Handbook - Ozone Measurements to 40-km Altitude With Electrochemical Concentration Cell (ECC) Ozonesondes.

A2. Checklist

(1) Advance Preparation 3-7 Days Prior to Release — Notes

Date__________ Stn.__________ ECC Sonde No.__________

Sonde label:
- Date Manufactured: __________
- Pump Pressure : __________ in Hg
- Pump Volts : __________ V d.c.
- Pump Current : __________ mA
- Flow Rate : __________ s/100 mℓ

Inspect wiring, solder joints: __________

Install test RMIR Hg battery and connect ECC sonde to ozonizer/test unit (motor, output, sensor leads): __________

Condition pump and dry sensor with HI O_3 for 30 min: __________

After 10 min of HI O_3:

	No Adj.	After Adj. (if needed)	
Pump Voltage :	______	______	V
Pump Current :	______	______	mA
Vacuum (>13) :	______	______	in Hg
Head Pressure (>7.5):	______	______	psi
(>15) :	______	______	in Hg

Commutator switching OK: __________

Shut off HI O_3, NO O_3 for 1 min: __________

Charge sensor <u>cathode</u> with sol'n: 2.5 cm^3 __________

3.0 cm^3 __________

Charge sensor <u>anode</u> with sol'n: 1.5 cm^3 __________

Sensor background current after 5 min on NO O_3 ______ μA

Sensor response to LO O_3 (4-5 μA) OK: __________

Plug sensor into coupler; observe switching: __________

Sonde amplifier response to LO O_3 OK: __________

Run on NO O_3 for 10 min: __________

Remove Hg batteries before storing: __________

(2) Preparation on the Day of Release | Notes

Date ____________

Install new Hg batteries: ________

Run sonde motor for 5 minutes on NO O_3: ________

Pump performance check:
- Pump Voltage : ________ V d.c.
- Pump Current : ________ mA
- Vacuum (≥13) : ________ in Hg
- Head Pressure (≥7.5): ________ psi
- (≥15) : ________ in Hg

Condition pump only with HI O_3 for 10-20 min: ________

Change cathode sol'n in SONDE and CAL sensors: ________

SONDE(S) and CAL(C) sensors conditioned with NO O_3 for 10 min: ________

Sensor background currents (≤0.2 μA):
i_{bc} = ________ μA; i_{bs} = ________ μA

Condition SONDE and CAL sensors with 5 μA O_3 for 10 min: ________

SONDE sensor air flow rate: t_s = ____, ____, ____ s

CAL sensor air flow rate: t_c = ____, ____, ____ s

T_{room} = ________ °C; RH_{room} = ________ %

After 10 min of conditioning with 5 μA O_3:

i_c = ________ μA; i_s = ________ μA

Sensor response test:
i_{1c} = ________ μA i_{1s} = ________ μA
i_{2c} = ________ μA i_{2s} = ________ μA
i_{3c} = ________ μA i_{3s} = ________ μA
i_{10c} = ________ μA i_{10s} = ________ μA

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

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

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

Adjust transducer potentiometer (~30 μA): ________ μA
Pack sonde in flight box: ________
- Splash flap over sensor ________
- Hole in lid for thermometer ________
- Attach reward notice ________

(3) At the Flight Site | Notes

Date ____________________

Radiosonde: Serial No ___________
Baroswitch No.___________, Hypsometer No.__________

Air Temp. Element: Lot No.___________
Resistance ___________ R.D. No. ___________

Hygristor Element: Lot No.___________
Resistance ___________ R.D. No. ___________

Attach O_3 filter; thermometer in box: __________

Join blue and white wires of radiosonde to obtain signal at 95 recorder chart ordinates: ___________

Join radiosonde and ozonesonde with extender cable; power instruments with test batteries: _______

Run sonde for 10 min on O_3 filter for O_3 sensor background: _________
Adjust O_3-ZERO signal (if needed): _________ chart ord.
Calibrate T_{box}: _________ ord. = _________ °C

Baseline Radiosonde:
Surface pressure: __________ mb
Set baroswitch to surface pressure: __________
Water-activate battery; install battery and hygristor; fold-out thermistor: __________
Couple O_3-sonde and radiosonde: _________

Obtain 10 min surface O_3 (except in cold): __________
Hypsometer fluid in: _________
Adjust low reference signal on recorder to 95 ordinates: _________
Separate and cut blue and white radiosonde wires: _________
Adjust radiosonde transmitter frequency (if necessary): __________

(4) Post-launch Data

Launch Time: _________
Surface Wind: ________ knots; Wind Direction ________
Sky Condition: ______________________________________

Keep low reference radiosonde signal adjusted at 95 chart ordinates throughout the flight:___________

APPENDIX B

PREPARATION OF SENSING SOLUTION

ECC sensor solution should be prepared from reagent-grade chemicals and double or triple distilled water.

(1) Cathode Solution

To 500 mℓ distilled water add:

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

Shake vigorously to dissolve the chemicals, then add distilled water to make up 1000 mℓ of cathode sensing solution.

(2) Anode Solution

Fill a 100-mℓ plastic bottle one-half full with 50 mℓ cathode solution (prepared as described above). Add 125 g KI crystals to the solution, and shake vigorously to dissolve the crystals.

(3) Storage

Store the cathode and anode sensing solutions in a dark place at 20 to 25°C. After several months of storage old solution should be discarded and new solution prepared for use.

APPENDIX C

OZONIZER/TEST UNIT

The Model TSC-1 ozonizer/test unit has been designed for conditioning ECC ozonesondes with ozone, and for checking the performance of the sondes prior to release by balloon. A photograph of the front face of the unit is shown on the in Fig. C1.

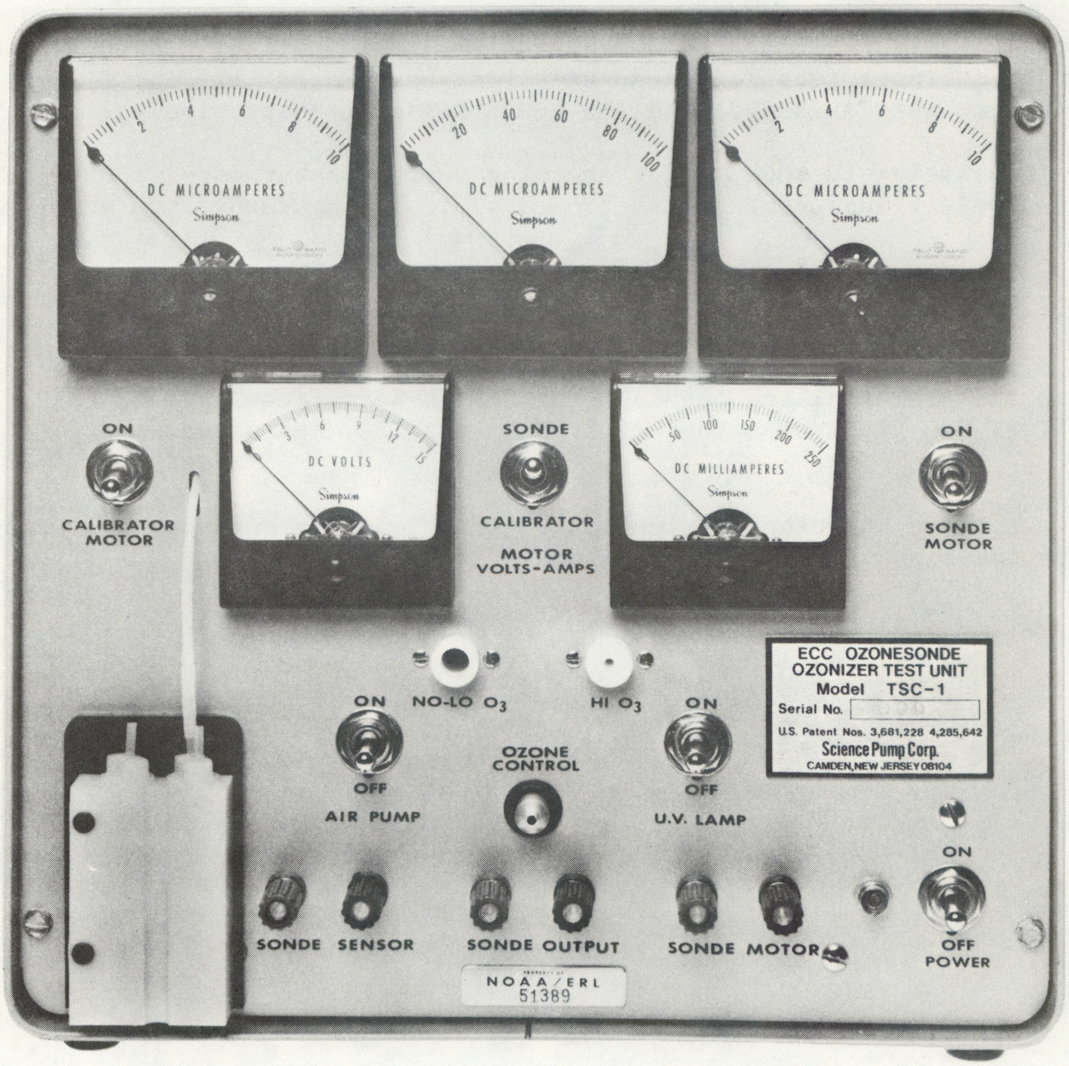


Figure C1. Model TSC-1 ozonizer/test unit.

Components of the ozonizer/test unit:

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

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

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

(4) Meters for checking on the current (mA) drain of the CALIBRATOR and SONDE pump motors at 12.3 V d.c. (middle left and right, respectively, of Fig. C1);

(5) Microammeters (0-10 μA) for measuring CALIBRATOR sensor and SONDE sensor output currents (top left-hand and right-hand meters of Fig. C1 are connected to the CALIBRATOR and the SONDE sensors, respectively); and

(6) A microammeter (0-100 μA) for checking on the performance of the ECC sonde's electronic transducer and electro-mechanical commutator (top middle, Fig. C1).

CAUTION:

(a) When repeatedly recharging the CALIBRATOR sensor cathode with sensing solution and re-installing the top plug of the sensor cathode, BE CAREFUL NOT TO DISTORT THE PLATINUM CATHODE SCREEN; otherwise, sensor malfunction will occur.

(b) Always store the ozonizer/test unit in a clean-air environment, with plastic caps covering the NO/LO OZONE and HI OZONE ports.

APPENDIX D

MODIFICATION OF VIZ 1680-MHz TRANSISTORIZED RADIOSONDES (For use with ECC-4A Ozonesondes)

(1) Remove the three screws that hold the printed circuit board to the radiosonde.

(2) Separate the front part of the board from the radiosonde, and with a sharp knife or razor blade, cut a conductor line on the printed circuit board as shown in the diagram in Fig. D1.

(3) Wiring connections at Amphenol 91-MPF4S are:

pin 1 - white
pin 2 - red
pin 3 - black
pin 4 - green.

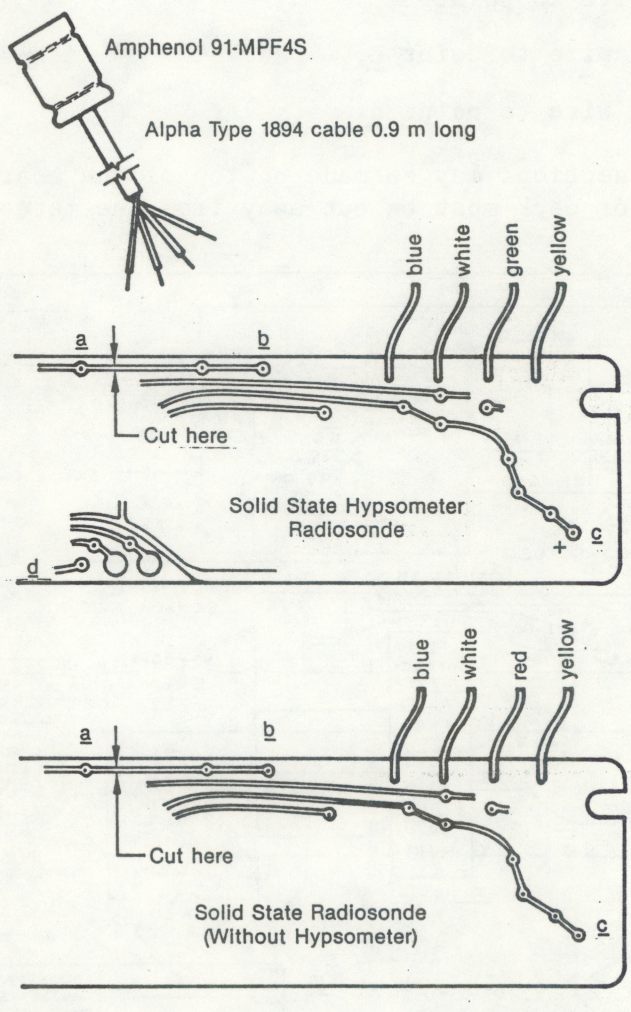


Figure D1. Method of connecting an ozonesonde/radiosonde signal cable to the radiosonde electronics board.

(4) For radiosonde <u>without</u> hypsometer (see Figs. D1 and D2):

(a) Solder the black wire of the ozonesonde/radiosonde connector cable to a on the printed circuit board;

(b) Solder red wire to point b;

(c) Solder white wire to point c;

(d) The green wire of the cable is not used.

NOTE: The solder connections may be made on the top of the board. Hypsometer contact H on 2A commutator deck must be shorted to the meteorological contacts M (see Fig. 4).

(5) For radiosonde <u>with</u> hypsometer (see Figs. D1 and D2):

(a) Solder the black wire of the ozonesonde/radiosonde connector cable to a on the printed circuit board;

(b) Solder red wire to point b;

(c) Solder white wire to point c;

(d) Solder green wire to point d.

NOTE: The solder connections may be made on top of the board. Hypsometer contact H on 2A commutator deck must be cut away from the meteorological contacts M (see Fig. 4).

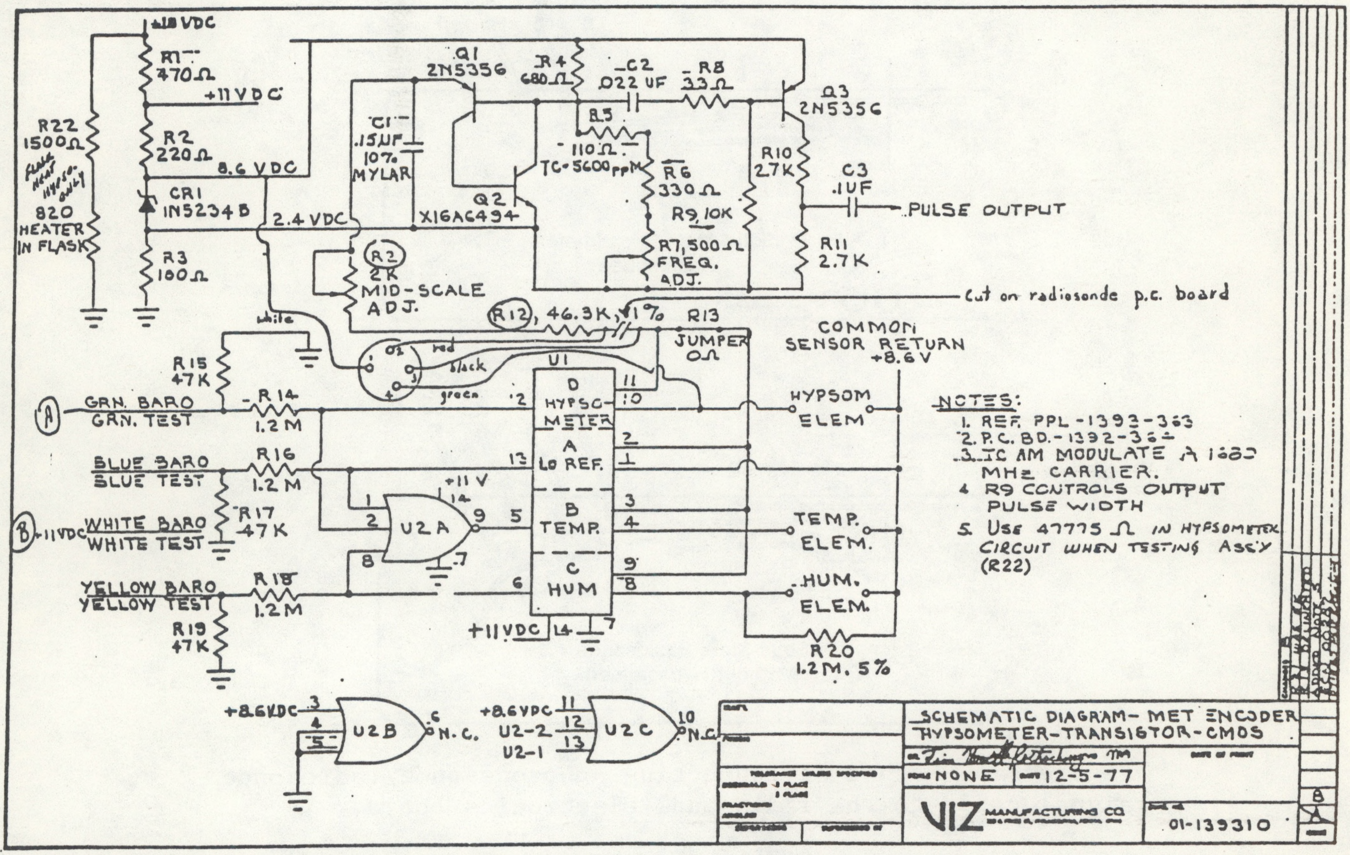


Figure D2. Electronic circuit diagram of transistorized hypsometer radiosonde.

APPENDIX E

OZONE DESTRUCTION FILTER

(1) Components required for the ozone destruction filter:

(a) Mine Safety Appliances Company No. 466204 chemical cartridge filled with granular catalyst to decompose ozone.

(b) Mine Safety Appliances Company No. 464035 ultra filter cartridge.

(c) Plastic funnel, 2½ inches (6.4 cm) in diameter.

(d) Tygon tubing, 2 ft (61 cm) long, 1/4 inch (0.64 cm) O.D. and 1/8 inch (0.32 cm) I.D.

(e) Teflon tubing, 3 inches (7.6 cm) long, AWG No. 10, standard wall.

(f) Teflon tubing, 3 inches (7.6 cm) long, AWG No. 12, thin wall.

(g) Electrical tape.

(2) Assemble the components as shown on the diagram in Fig. E1.

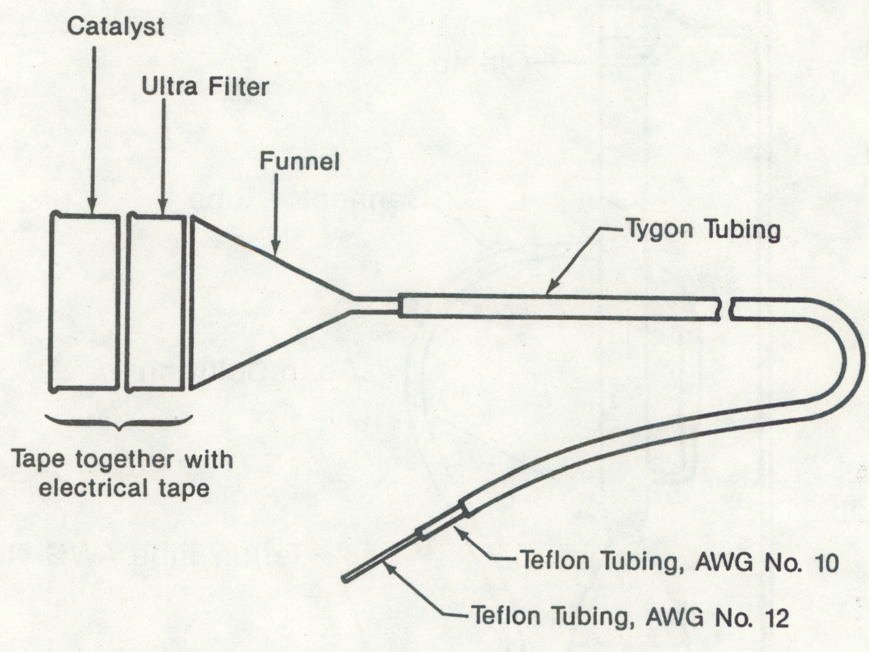


Figure E1. Ozone destruction filter.

APPENDIX F

MEASUREMENT OF OZONESONDE AIR FLOW RATE

(1) Equipment required (see Fig. F1):

(a) Burette with filling tube, e.g., Fisher No. 3-711, 100-m capacity;

(b) Rubber bulb, e.g., Fisher No. 14-070, 60-m capacity;

(c) Stop watch;

(d) Burette stand with clamp;

(e) Tygon tubing, approximately 2 ft (61 cm) long, 1/8 inch (0.32 cm) internal diameter.

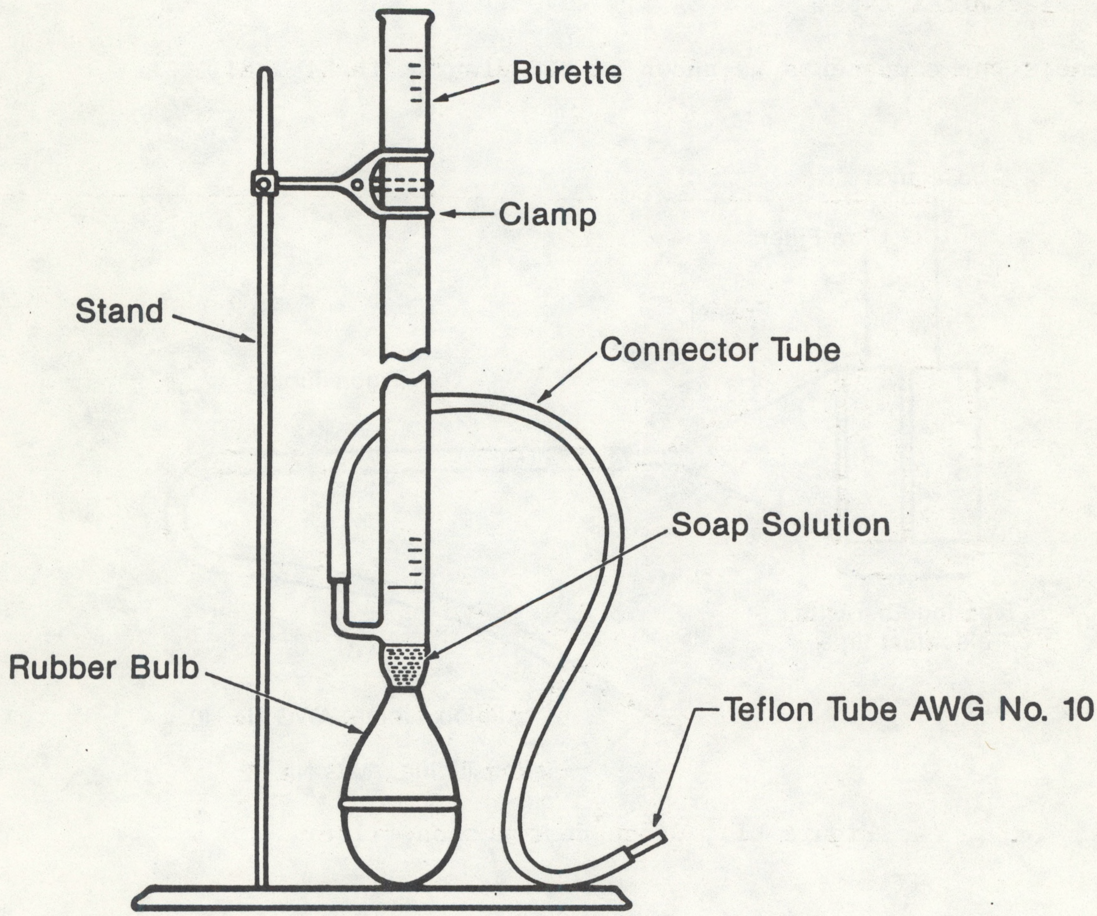


Figure F1. Apparatus for measurement of ozonesonde air flow rate.

(f) Teflon tubing, thin wall, approximately 1 inch (2.54 cm) long, AWG No. 10;

(g) Soap bubble solution. It may be made by adding 1 teaspoon of liquid detergent and 1 teaspoon of glycerol to 1 cup of water.

(2) Arrange the apparatus as shown in the diagram of Fig. F1.

(3) Fill the rubber bulb and burette with soap bubble solution to just below the filling tube of the burette (see Fig. F1).

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

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

(6) Now cause one bubble to form, and using a stop watch determine the time t required to displace the bubble 100 mℓ. Repeat the measurement several times to obtain a mean value. Record the result. (Subsequently enter this result on the ozonesonde record when releasing the particular instrument.)

IMPORTANT: At the time of the air flow measurement, the sensor should be charged with sensing solution.

APPENDIX G

OZONESONDE AIR PUMP BATTERIES

(1) Standard batteries are nominal 12 V d.c. water-activated batteries. For flight, they are inserted into the battery compartment of the ECC ozonesonde flight box.

(2) Preferred batteries are lithium dry cells, Panosonic type BR 2/3A. Connect batteries in series as shown in the diagram in Fig. G1.

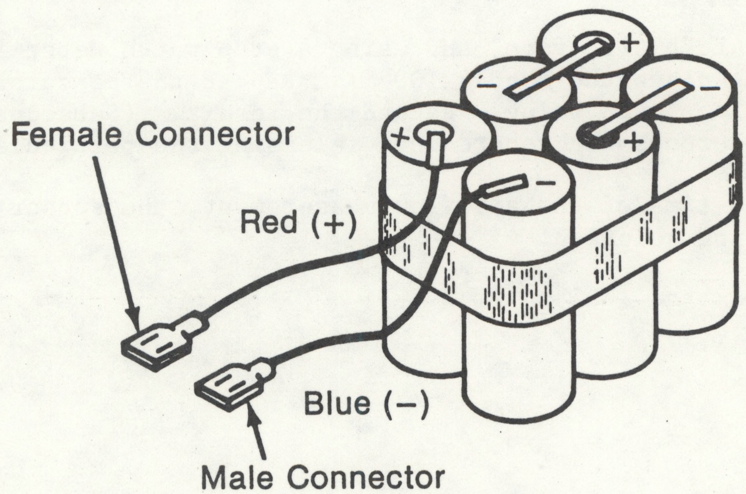


Figure G1. Panasonic battery BR 2/3A - F2X3.

(a) Battery leads are 8½ inches (21.6 cm) long, AWG #22 stranded copper wire.

(b) Red lead (+) - 3M Company female connector, P/N MNV18-250-DFIX.
Blue lead (-) - 3M Company male connector, P/N MNV18-250-DMIX.

(c) Encase battery pack in heat-shrink plastic to insulate electrically conductive surfaces.

<u>NOTE:</u> For flight, the battery pack is inserted into the sonde flight box with the ECC instrument. Since the battery compartment located at the bottom of the flight box is not used, fill it with insulating material, and seal the opening with tape to prevent excessive cooling of the sonde within the box.

APPENDIX H

SETTING THE RADIOSONDE BAROSWITCH

(1) Use an accurately calibrated aneroid or mercury barometer to determine the station pressure in millibars. Record this pressure on the radiosonde baroswitch calibration chart. On the chart, circle the two consecutive pressure contact numbers between which the station pressure lies. (Pressure contacts are numbered 1, 2, 3, ... 179.) Call the contact with the higher pressure C1, and the other C2.

(2) Use a clean eraser to rub the surface of the radiosonde baroswitch printed circuit (p.c.) board to remove oxidation. Now wipe the board with a piece of silicon-oil-impregnated lens tissue.

(3) Next, set the baroswitch pen arm (with pointed electrical contact) on the p.c. board by flipping the pen-arm wire lifter to the "down" position.

(4) Activate the radiosonde by supplying 18 V d.c. power to it, and by inserting a shorting plug into the connector of the gray cable wired to the radiosonde. (The shorting plug connects contacts 2 and 3 of the plug.) Also, check to ensure that colored (white, blue, yellow, and green) test wires on the side of the radiosonde are disconnected from each other.

(5) With the aid of a magnifying glass, check the location of the pen-arm contact point on the p.c. switchboard. Rotate the toothed adjustment wheel of the baroswitch to position the pen-arm contact point on the reference contact (5, 10, 15, 20, etc.) closest to C1 but of lower number than C1. During this operation, the radiosonde receiving gear should be receiving signals from the radiosonde. As the pen arm is moved, the frequency of audio tones coming from the receiver will change, depending on whether pressure, temperature, or humidity signals are being broadcast.

(6) Use receiver chart recorder signal traces, as well as different signal tones, as guides when rotating the toothed adjustment wheel to move the pen arm to higher numbered contacts until contact C1 is <u>just</u> reached. Now begin counting the number of clicks, N, of the toothed adjustment wheel as the wheel is turned to move the pen arm to <u>just</u> reach contact C2. Record N.

When setting the baroswitch at station pressure, P, the toothed adjustment wheel must, therefore, be turned N' clicks from the beginning of contact C1 in the direction of contact C2 where

$$N' = N \cdot \frac{P_{C1} - P}{P_{C1} - P_{C2}} .$$

P_{C1} and P_{C2} are pressures in millibars at contacts C1 and C2.

(7) To set the baroswitch at station pressure , repeat steps (5) and (6) until the pen arm just reaches contact C1. Rotate the toothed adjustment wheel an additional N' clicks.

APPENDIX I

RECONDITIONING TYPE 4A ECC OZONESONDES

Upon receipt of a recovered ozonesonde, recondition as follows:

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

(2) Remove the ozonesonde from its polystyrene box, and discard the transducer mercury batteries.

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

(4) Remove the sensor from the sonde, and wash the cathode and anode chambers vigorously with tap water. Rinse with distilled water. Fill the chambers with distilled water, let stand for 1 hour, then rinse several times with distilled water. Reassemble the sensor within the sonde sensor holder.

(5) Disassemble the Teflon gas sampling pump, taking care to note how the piston is oriented relative to the cylinder. Using a razor blade and a pointed knife (e.g., an Exacto knife with a No. 11 blade), gently scrape impurities from the pump base piece, cylinder, and piston. Wash all Teflon parts first with tap water, then with distilled water, and finally with highly pure methanol. After reassembling the pump into its original configuration, activate the pump motor and squirt 1 or 2 cm^3 of methanol into the operating pump for final cleaning.

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

(7) Check the gear train for proper operation. Straighten any bent part of the gear train frame.

(8) Remove the four nuts from the sonde transducer, and lift the transducer from its mounting screws. (The two wires leading from the transducer to communtator deck 2A need not be unsoldered.) Using paper tissue moistened in acetone, thoroughly clean the transducer commutator decks. Reassemble the transducer on to its mounting screws. Be sure to set the commutator wiper on one of the small segments of deck 2A; otherwise, jamming of the gear may occur.

(9) Finally, using a model TSC-1 ozonizer/test unit, check the transducer and the ozonesonde Teflon pump for correct performance (see Section 2.1).

APPENDIX J

EVALUATION OF THE CHART RECORD

Evaluation of the chart record entails solution of the equation given below for selected atmospheric pressure levels:

$$P_3 = 4.307 \times 10^{-3}\ I\ T_b\ t$$

where

P_3 is the ozone partial pressure in micromillibars;

I is the sensor current due to ozone in microamperes;

T_b is the sonde box temperature in degrees Kelvin;

t is the time in seconds taken by the pump to force 100 mℓ of air through the sensor.

(1) Drawing the Signal Profiles - The first step in evaluation of the chart record consists of drawing profiles for the following signal traces: ozone; ozone zero; ozone calibrate; and box temperature. Using a sharp pencil, carefully draw the profiles by joining successive traces with a straight edge (except in the case of ozone signal traces, through which draw a smooth curve). Use discretion when drawing the profiles to avoid outlining spurious signals that may arise because of instrument malfunction. Where a large adjustment is made in low reference signal on the chart record, an abrupt shift will occur in the levels of the ozone and box temperature signals. Indicate the occurrence of this shift on the chart record by showing appropriate discontinuities in the signal profiles.

(2) Selecting Ozone Levels - Ozone partial pressures are required for the following mandatory and significant levels: surface pressure, 1000, 700, 500, 300, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3 mb, tropopause level(s), levels of prominent maxima and minima of ozone partial pressure, and minimum pressure level reached by the balloon. Facility in picking levels is normally acquired through experience. In general, the total number of levels selected for a flight reaching 10 mb should not exceed 40.

(3) Determining Values of I - The sensor output current, i_{obs}, consists of two nearly independent currents: that due to ozone, I, and that due to oxygen, i_a.

$$i_{obs} = I + i_a \, .$$

Obtain a particular value of i_{obs} from the chart record as follows: Place an ozone data scaler [e.g., a 10-inch (25.4 cm) ruler having 0.10-inch (0.254

cm) divisions] on the chart record at the ozone level of interest, taking care to position the zero of the scaler on the ozone zero trace. Now read the ozone signal scale divisions, s, and the ozone calibrate signal scale divisions, k. Deduce the "corrected" ozone signal scale division from the relation:

$$S = 294s/k \ .$$

The sensor output current, i_{obs}, is then obtained from the plot of i_{obs} vs. S given in Fig. J1.

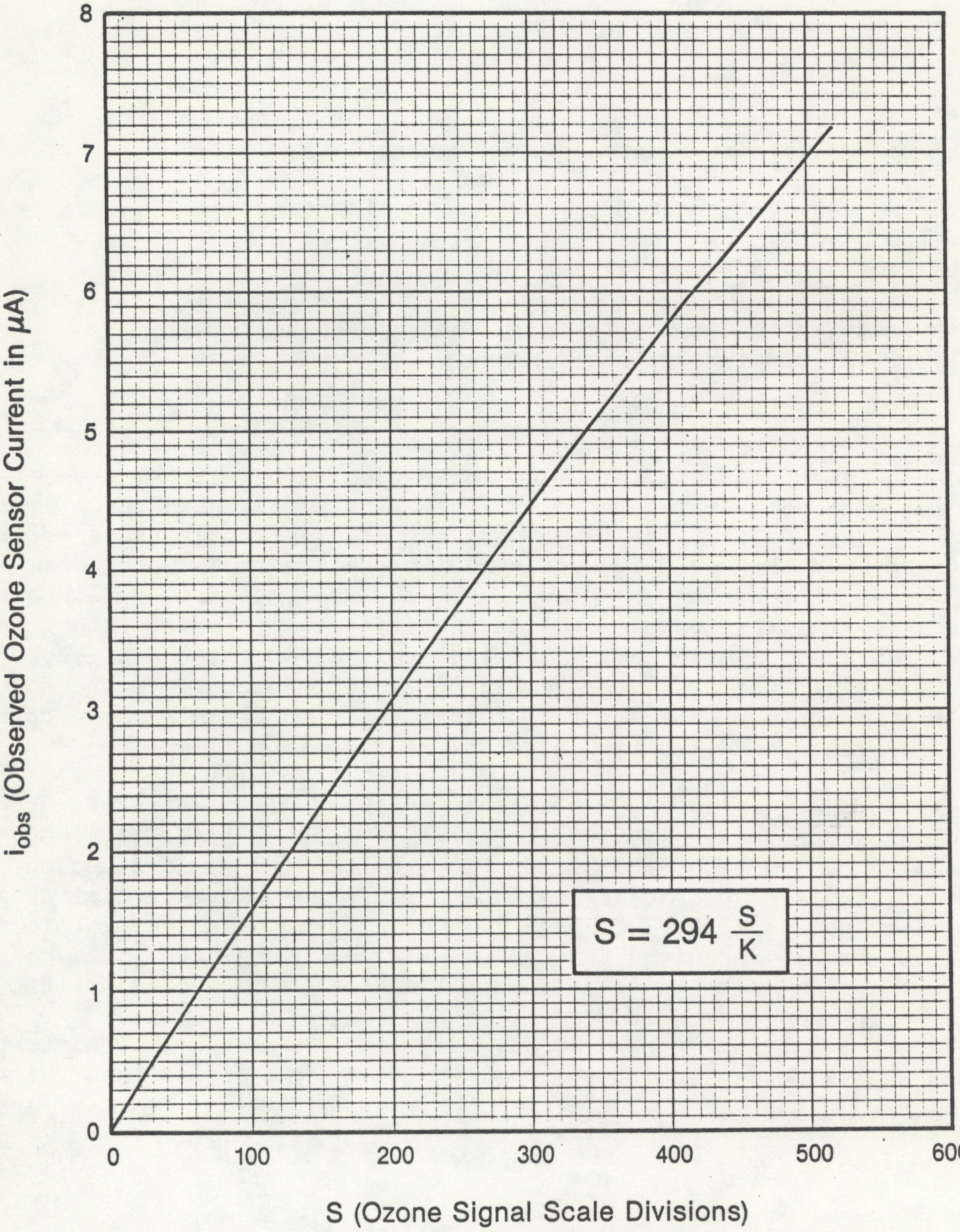


Figure J1. Calibration curve for ozonesonde model ECC-4A.

It is necessary to subtract appropriate values of i_a from the deduced values of i_{obs} to obtain values of I. Experiments have indicated that the background current decreases with atmospheric pressure as the ECC sonde is borne upward by balloon; hence, Table J1 has been prepared relating i_a to pressure. To use Table J1, first compute the value of $i_{obs} = i_a$ from the "OZONESONDE BASELINE" portion of the record chart [see Section 2.3(d)]. Identify the column in Table J1 in which this value of i_a appears taking into account the station pressure, and for ozone levels selected at reduced pressures determine appropriate values of i_a by reading down this column.

Table J1: Corrections for sensitivity of sensor to oxygen

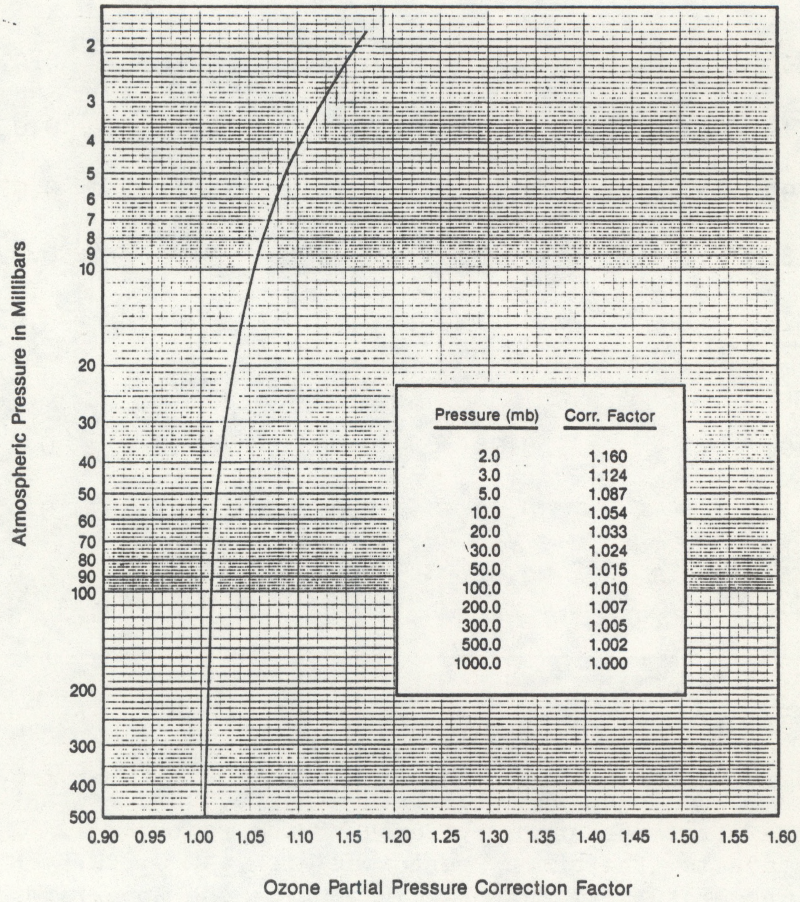
Pressure Interval in millibars	Values of i_a				
1070 - 951	0.25	0.20	0.15	0.10	0.05
950 - 830	0.23	0.18	0.14	0.09	0.05
829 - 711	0.20	0.16	0.12	0.08	0.04
710 - 596	0.18	0.14	0.11	0.07	0.04
595 - 485	0.15	0.12	0.09	0.06	0.03
484 - 379	0.13	0.10	0.08	0.05	0.03
378 - 279	0.10	0.08	0.06	0.04	0.02
278 -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

(4) Determining Sonde Box Temperature, T_b - The thermistor employed for measuring the ozonesonde box temperature is the same as that used for measuring the air temperature by means of the radiosonde. Evaluation of the box temperature is, therefore, performed with the U.S.W.B. No. 230B Radiosonde Temperature Evaluator. In setting the temperature evaluator, be careful to use the baseline data recorded during the "OZONESONDE BASELINE" portion of the chart [see Section 2.3(d)].

(5) Sonde Air Flow Rate - Values of t for ozonesondes are determined in accordance with instructions provided in Appendix F.

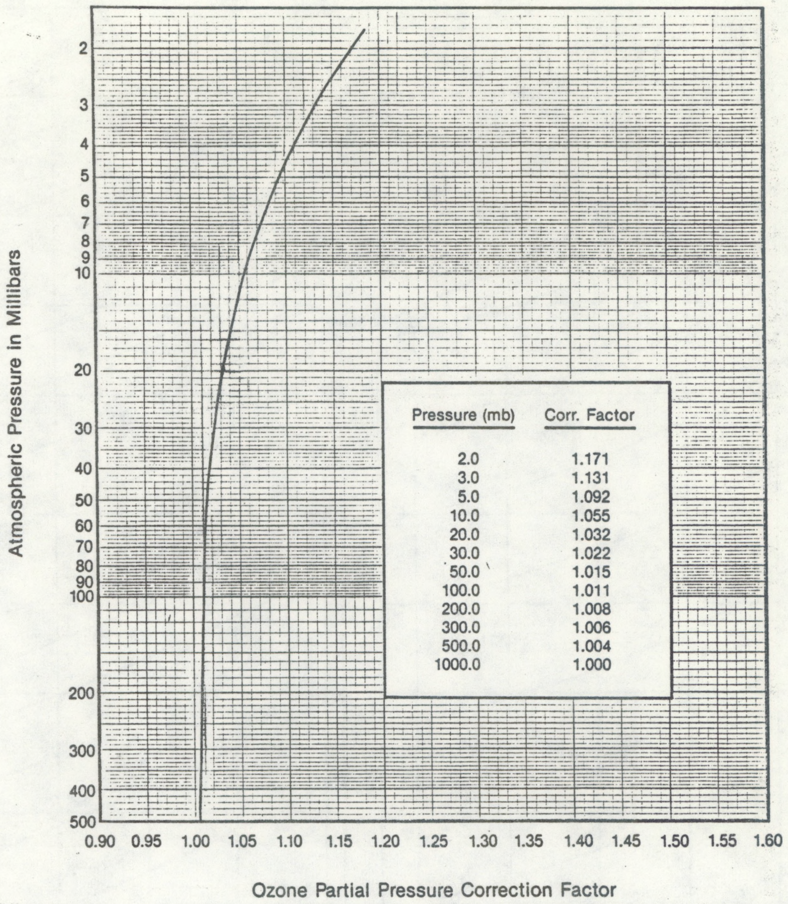
(6) Corrections for Pump Motor Slow-down - Pump speed may be monitored during flight by observing the period of the sonde commutator switching cycle, i.e., the distances (e.g., in inches) on the radiosonde chart record between successive recordings of the OZONE ZERO signals. Use data occurring early in the flight as reference when correcting ozone data for pump motor speed variations. For example, if the distance on the chart between successive OZONE ZERO traces early in the flight is 2.05 inches, but at, say, 10 mb increases to 2.32 inches, correct the calculated ozone amount at 10 mb by the factor 2.32/2.05 = 1.132.

(7) Pump Efficiency Corrections - The efficiency of the sonde air sampling pumps decreases with altitude. Calculated ozone partial pressures must, therefore, be corrected for the efficiency loss. Correction factors for Model 4A pumps, with ECC sensor cathodes filled with 2.5 cm^3 sensing solution and 3.0 cm^3 sensing solution, are shown, respectively, in Figs. J2 and J3. Determine appropriate correction factors (C.F.) from the appropriate graph, and multiply calculated values of ozone partial pressures (p_3) by the factors to obtain corrected data.



Pressure (mb)	Corr. Factor
2.0	1.160
3.0	1.124
5.0	1.087
10.0	1.054
20.0	1.033
30.0	1.024
50.0	1.015
100.0	1.010
200.0	1.007
300.0	1.005
500.0	1.002
1000.0	1.000

Figure J2. Ozone partial pressure correction curve (corrections for decreased pump flow rates at reduced ambient pressures; ECC sensor cathode charged with 2.5 cm^3 sensing solution.



Pressure (mb)	Corr. Factor
2.0	1.171
3.0	1.131
5.0	1.092
10.0	1.055
20.0	1.032
30.0	1.022
50.0	1.015
100.0	1.011
200.0	1.008
300.0	1.006
500.0	1.004
1000.0	1.000

Figure J3. Ozone partial pressure correction curve (corrections for decreased pump flow rates at reduced ambient pressures; ECC sensor cathode charged with 3.0 cm^3 sensing solution.

(8) Normalizing ECC Sonde Data to Dobson Spectrophotometer Total Ozone Data - If accurate Dobson spectrophotometer data are available at the time of an ECC ozonesonde sounding, the sonde data should be normalized to the total ozone amount measured by the Dobson instrument. The normalization procedure is as follows:

(a) For soundings attaining a maximum altitude of ≤15 mb, do not normalize the data since it is unlikely that the ozone mixing ratio is constant above the altitude of balloon burst.

(b) For soundings reaching maximum altitudes between 15 and 7.8 mb, plot the sonde data on an ozonagram (see Fig. J4), and integrate the area under the curve to obtain the amount of ozone (in milli-atm-cm) measured by the sonde from ground level to the altitude of balloon burst. Next, assume that above balloon-burst altitude the ozone mixing ratio is constant, with value measured at flight termination. By integration, obtain the amount of ozone (in milli-atm-cm) present above the maximum altitude reached by the balloon. Combine the two ozone values to obtain the atmospheric total ozone amount (in milli-atm-cm) measured by the ECC sonde. Now multiply all ECC sonde ozone values by the ratio

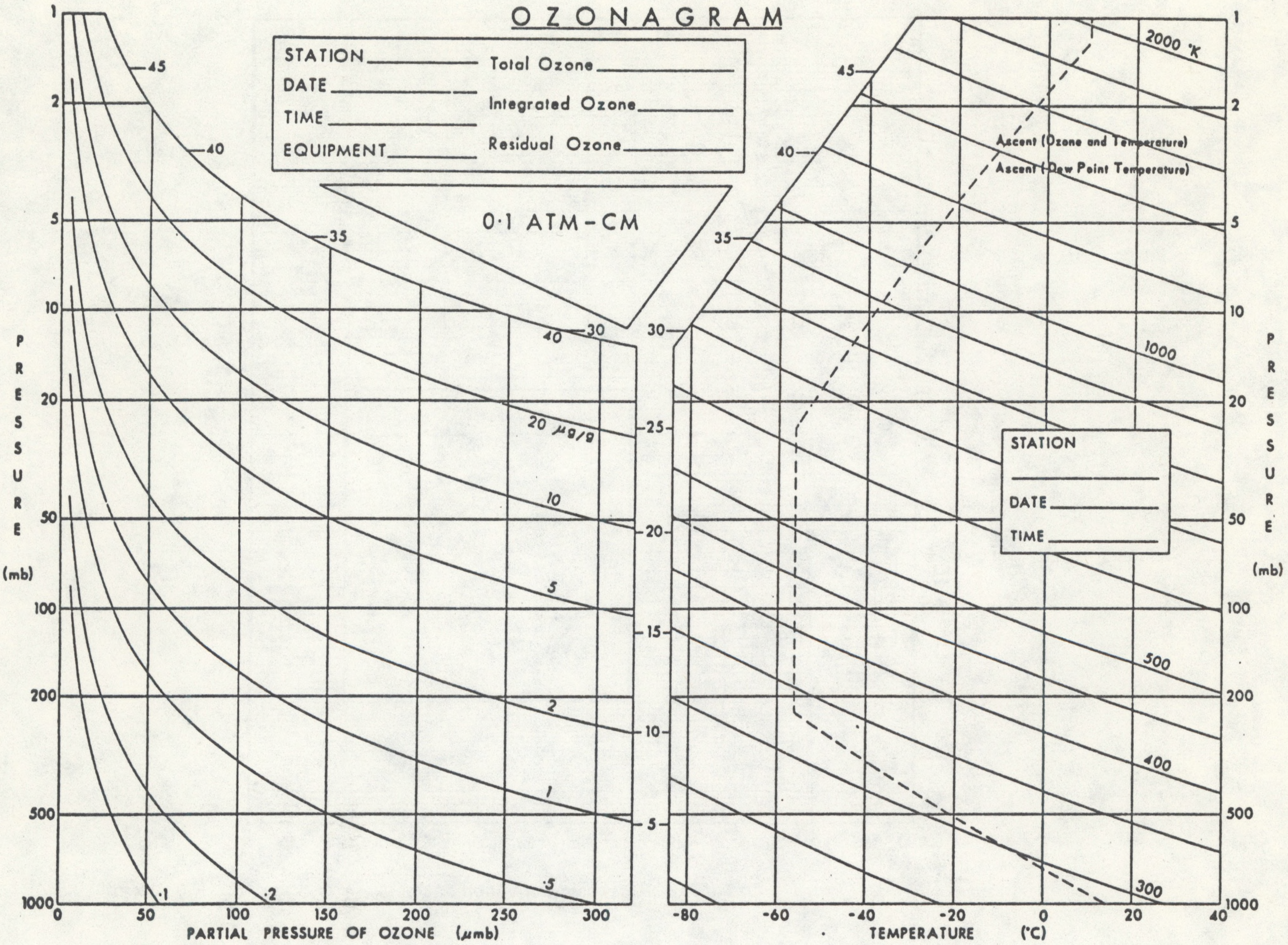


Figure J4. Ozonagram for plotting ozonesonde and air temperature data.

$$\frac{\text{Dobson Spectrophotometer Total Ozone}}{\text{ECC Sonde Total Ozone}}$$

to obtain normalized ECC sonde data.

(c) Because ECC sonde data above about 7.8 mb are not as reliable as data below this pressure altitude, use the following method when normalizing ECC sonde data for soundings reaching altitudes greater than 7.8 mb: Determine the total ozone amount measured by the ECC sonde as in (8b) above, but integrate the sonde data only to 7.8 mb. For the constant ozone mixing ratio above 7.8 mb, use the value measured at 7.8 mb. As in (8b) above, form the ratio

$$\frac{\text{Dobson Spectrophotometer Total Ozone}}{\text{ECC Sonde Total Ozone}}$$

and multiply all ECC ozone values by this ratio to obtain ECC sonde data normalized to Dobson spectrophotometer total ozone.

NOTE: ECC sonde ozone values, normalized as described here, are the data to be archived at the World Ozone Data Center in Canada (see Appendix K).

(9) Empirical Correction to ECC Sonde Data - Intercomparison of ECC ozonesonde data and ozone vertical distributions obtained with more sophisticated and expensive ozone instruments suggest that ozone values measured by ECC sondes may be too low above about 10 mb. The reason for the low values, if real, is currently unknown, but may be due to a bias in the pump efficiency curve used in the data processing.

Assuming that the values above 10 mb are too low, users of ECC sonde data (archived at the WMO Ozone Data Center in Canada) may apply the following empirical corrections to the data:

$$y = 1.749 - 0.807 \ln x + 0.297(\ln x)^2 - 0.0367(\ln x)^3$$

where

y = correction factor, and
x = air pressure in mb.

Additional research is needed to verify the adequacy of these corrections.

(10) Data Tabulation - Data extracted from the radiosonde chart record should be tabulated on a form such as that shown in Fig. J5. Such tabulated data are suitable for card punching and computer processing.

(11) Computation Form - A sample computation form, useful for hand processing of the ozonesonde data, is shown in Fig. J6. Note that space is also provided on the form for tabulation of rawinsonde data.

(12) Ozonagram - Observational data should be plotted on an ozonagram such as the one shown in Fig. J4. Use a planimeter to deduce the area under the ozone curve in units of milli-atm-cm, i.e., the value of $(\Omega\Omega\Omega)_p$ (see Appendix K).

OZONESONDE/RADIOSONDE DATA IN RECORDER CHART ORDINATES

Station:________________ Date:________________ Inst. No. ________________

Time (min)	Press. (mb)	O_3 Zero	O_3 Calib.	O_3 Meas.	Box Temp.	C.F. Motor		Air Temp.	R.H.		Azim.	Elev.
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
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29												
30												
31												
32												
33												
34												
35												

Figure J5. Form for tabulating ozonesonde and radiosonde data extracted from the radiosonde chart record.

Station__________ Date__________

COMPUTATION FORM

Inst. No.__________ t = __________

O_3 Level	Contact	P_a(mb)	T_a(°C)	s	k	s/k	S	$i_{obs.}$	i_a	I(μA)	T_b(ord.)	T_b(°C)	T_b(°K)	$(p_3)_u$	$(C.F.)_1$	$(C.F.)_2$	$(p_3)_c$	$(p_3)_n$		Ht.	ddd	fff

Notes:

t = Sonde pump air flow rate in s/100 mℓ.

$(p_3)_u$ = 0.004307t × IT_b.
= Ozone partial pressure uncorrected for sonde pump motor speed variations and air pump efficiency changes.

$(C.F.)_1$ = Motor speed correction factor.

$(C.F.)_2$ = Pump efficiency correction factor.

$(p_3)_c$ = 0.004307t × IT_b × $(C.F.)_1$ $(C.F.)_2$
= Ozone partial pressure measured by the ECC sonde and corrected for pump motor speed variations and an pump efficiency changes.

$(p_3)_n$ = Ozone partial pressure normalized to Dobson spectrophotometer total ozone.

Figure J6. Computation form for hand processing of ECC ozonesonde data.

APPENDIX K

DATA ARCHIVING

Canada collects and publishes ozone data on a worldwide basis under sponsorship of the World Meteorological Organization. Data collection and publication arrangements are described in Guide Book No. 2 (1981), which is available free of charge from the Canadian Atmospheric Environment Service to meteorological services and research organizations that have a reciprocal arrangement with the Atmospheric Environment Service for exchange of publications (automatically including all groups that supply ozone data and all those that regularly subscribe to the issues of "Ozone Data for the World"). Individual copies of the Guide Book are available to other organizations and individuals for 25 cents payable to the Receiver General of Canada.

The mailing address for archiving of the ozone data is

World Ozone Data Centre
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario
Canada M3H5T4

The data should be forwarded to Canada for publication on a bimonthly basis, as soon as possible after the end of February, April, June, August, October, and December. The frequency of publication of the data depends on the clarity of the entries on the data sheets transmitted and the promptness with which the data are supplied.

The ozonesonde data should be recorded on WMO/OMM Form No. 0-3B MSC-9710, a copy of which appears as Fig. Kl. Details concerning data entry are as follows:

Environment Canada
Atmospheric Environment

Environnement Canada
Environnement Atmosphérique

VERTICAL DISTRIBUTION OF OZONE
DISTRIBUTION VERTICALE D'OZONE

WMO / OMM | MSC / SMC

Country / *Pays*	Station	Equipment / *Équipement*
U.S.A.	HILO	ECC

ISN	NN	YYMMJJ	GG		λ S ΩΩΩ	Ωp	X	corr. factor *facteur de corr.*	Significant comments / *Remarques importantes*
1	4	6	12	14	17	22	25	27	32
109	01	190685	19		00284	26	99	1.022	ECC

ISN	NN	YYMMJJ	GG		PPPP	P3	TTT	ddd	fff	PPPP	P3	TTT	ddd	fff	PPPP	P3	TTT	ddd	fff	PPPP	P3	TTT	ddd	fff
1	4	6	12	14	17	21	24	27	30	33	37	40	43	46	49	53	56	59	62	65	69	72	75	78
109	02	190685	19		1016	10	23			1000	11	22	52	2	700	37	9	166	2	500	18	-7	120	3
109	03	190685	19		300	17	-33	1	5	200	10	-55	344	6	150	24	-66	301	10	100	47	-69	63	10
109	04	190685	19		70	51	-66	84	7	50	87	-62	93	18	30	131	-53	93	18	20.0	140	-47	84	16
109	05	190685	19		10.0	90	-42	83	17	7.0	56	-35	87	28	5.0	32	-27	115	15	3.0	13	-23	85	26
109	06	190685	19		868	13	14	88	4	778	20	11	73	5	757	13	9	75	4	738	18	5	99	4
109	07	190685	19		717	30	9	127	3	678	28	7	138	2	624	29	6	107	3	607	20	4	96	2
109	08	190685	19		573	19	0	229	1	540	38	-2	143	4	495	16	-7	121	4	479	41	-7	120	5
109	09	190685	19		424	23	-14	121	4	178	9	-60	331	6	125	21	-72	337	11	108	19	-73	33	11
109	10	190685	19		75	32	-67	88	7	92	36	-67	109	7	83	52	-68	119	9	79	50	-69	123	8
109	11	190685	19		72	44	-66	89	5	68	59	-66	79	9	62	52	-66	79	12	54	81	-61	88	14
109	12	190685	19		46	102	-60	96	16	42	102	-59	99	16	16.4	126	-47	95	26	10.8	98	-40	89	19
109	13	190685	19		8.5	76	-42	91	22	6.0	43	-28	85	26	3.8	20	-23	20	3	2.6	11	-24	107	13
109	14	190685	19		2.4	9	-22	73	42	2.3	0	-21	114	17										
	15																							
	16																							
	17																							
	18																							
	19																							
	20																							
	21																							

0000 63-9857 01/76

Figure K1. Form for archiving ECC ozonesonde data.

(1) At the top of the form, enter the names of the country and station, and the type of equipment used to measure the vertical distribution of ozone.

(2) Line/Card 1

(a) Columns 1 - 3 Enter the ozone station identifier.

(b) 4 - 5 Preprinted card number

(c) 6 - 11 Enter date, as follows: Day, Month, and Year, (i.e., 1 December 1969 is coded 011269).

(d) 12 - 13 GG, time to nearest hour GMT, for balloon release.

(e) 14 - 16 are for use by the World Ozone Data Centre

(f) 17 - 21 λSΩΩΩ where ΩΩΩ refers to the total amount of ozone applicable to the vertical distribution, as measured by a spectrophotometer or similar instrument. λS are as defined for form O-1B, and in the preface of "Ozone Data for the World."

(g) 22 - 24 Ω_p, the short form of $(\Omega\Omega\Omega)_p$, is the total amount of ozone above or below the lowest pressure level reached by the ozone sounding instrument. For optical sondes, $(\Omega\Omega\Omega)_p$ is the total amount of ozone above the lowest pressure reached. For chemical sondes, $(\Omega\Omega\Omega)_p$ is the total amount of ozone below the lowest pressure reached. Units are milli-atm-cm.

(h) 25 - 26 Instrument type code. This is the code figure for the instrument used to measure the vertical distribution, as given in the list below:

1 - Brewer	10 - Mast
12 - Paetzold	13 - Regener
15 - Vassy	16 - Carbon Iodine

99 - Other; please detail in "significant comments"

(i) 27 - 31 Correction factor. This is the factor by which the measured partial pressures have been multiplied in order to achieve agreement between the total ozone obtained by vertical integration of the sounding values and the total ozone obtained from the independent measurement reported as ΩΩΩ in columns 19-21.

(j) 32 - 80 Significant comments.

(3) Line/Card 2

(a) Columns 1 - 16 These are completed as for Line/Card 1.

(b) 17 - 20 PPPP, total atmospheric pressure in mb.

(c) 21 - 23 P_3, short form of $(P_3P_3P_3)$, the ozone partial pressure in μmb (10^{-6} mb).

(d) 24 - 26 TTT, air temperature in degrees Celsius or in coded form as given in volume B, WMO publication no. 9. TP.4.

(e) 27 - 29 Wind direction in whole degrees.

(f) 30 - 32 Wind speed in m/s.

(g) 33 - 80 To be completed as for columns 17-32. (Successive pressure-level data are written across the page on line two, then across the page on line three, ... etc.).

(4) Line/Card 3 - 21

(a) These lines/cards are to be completed as for line/card 2.

Data should be provided for the following levels: Surface, 1000, 700, 500, 300, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2 and 1 mb, the tropopause level(s), levels of prominent maxima or minima of ozone partial pressure, and for the minimum pressure level reached by the instrument. There should be no blank PPPP or P_3 data fields within the body of the ozonesonde flight data, but missing temperature or wind data fields should be left blank.