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by

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UNITED STATES ARMY ELECTRONICS COMMAND

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ABSTRACT

This guide describes the preflight instrument preparation and data reduction procedures for the rocket-borne ozonesonde developed by the Atmospheric Sciences Laboratory, White Sands Missile Range. Basic system components are outlined, and the theory of operation is discussed. The ozonesonde is used for the measurement of ozone concentration to within ± 10% in the mesosphere and stratosphere after deployment from an Arcas rocket vehicle.

CONTENTS

INTRODUCTION AND THEORY

The presence of atmospheric ozone results from a combination of processes involving photodissociation and recombination. Ozone is formed mainly from molecular oxygen. It is then destroyed directly by photodissociation and by recombination with atomic oxygen. Since the photochemical distribution of ozone depends on the availability of solar ultraviolet radiation for the various photodissociation processes and on atomic and molecular densities for the various recombination processes, the equilibrium distribution first increases and then decreases with height.

The most widely used means of determining the vertical distribution of ozone has been the Götz Umkehr (1934) method which utilizes measurements made with the ozone spectrophotometer during a period when the zenith angle of the sun is between 90 and 60 degrees in either the morning or afternoon.

The need for a device to measure atmospheric ozone quantitatively and automatically in the highest layers of the atmosphere as well as near the surface led to the development of spectrometric, chemical and chemiluminescent detectors. The chemical sonde developed by Brewer (1960) uses an aqueous solution of chemicals and thus is limited to altitudes at which the solution does not boil. The chemiluminescent detector developed by Regener (1964) does not require any external source of radiation energy and is of a dry chemical type. It can be used at extremely high altitudes and will operate independently of the presence of solar radiation as compared to the spectrometric sonde developed by Paetzold (1961).

A rocket-borne ozonesonde (Randhawa, 1967) has been developed at the Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico. This instrument utilizes the chemiluminescence principle for ozone detection and is deployed by a small meteorological rocket (ARCAS) in the mesosphere. The sample bottle is evacuated as it is carried to low pressures of high altitudes. Flow into the bottle results from the differential pressure as the instrument, after ejection from the rocket vehicle, descends on a 5-meter diameter radar-reflective parachute. Ozone in the environment flows over the detector (Rhodamine B and silica gel), and the photons produced by the destruction of ozone molecules on the chemiluminescent material are monitored by the photomultiplier tube. The intensity of the emitted light is directly proportional to the ozone flux entering the detector. This flux is equal to the product of ozone concentration and the flow rate. Thus, to measure ozone concentration, the flow rate into the detector must be known.

The photomultiplier current produced by the impact of photons is the input to the amplifier-modulator circuit which is basically a reset integrator. The integration time (sensitivity) is determined by the value of the sensitivity adjust capacitor. When the integrator resets, a pulse is generated which is amplified and applied to the transmitter. This gives 100% pulse modulation of the transmitter. The period of the pulse train is determined by the input current and thus gives a form of pulse frequency modulation compatible with the GMD-1 and TMQ-5 recorder. Two controls and a reference timer are also incorporated in the circuit. One control sets the zero position of the signal, and the other sets the position of the reference. A block diagram of the ozonesonde is given in Fig. 1.

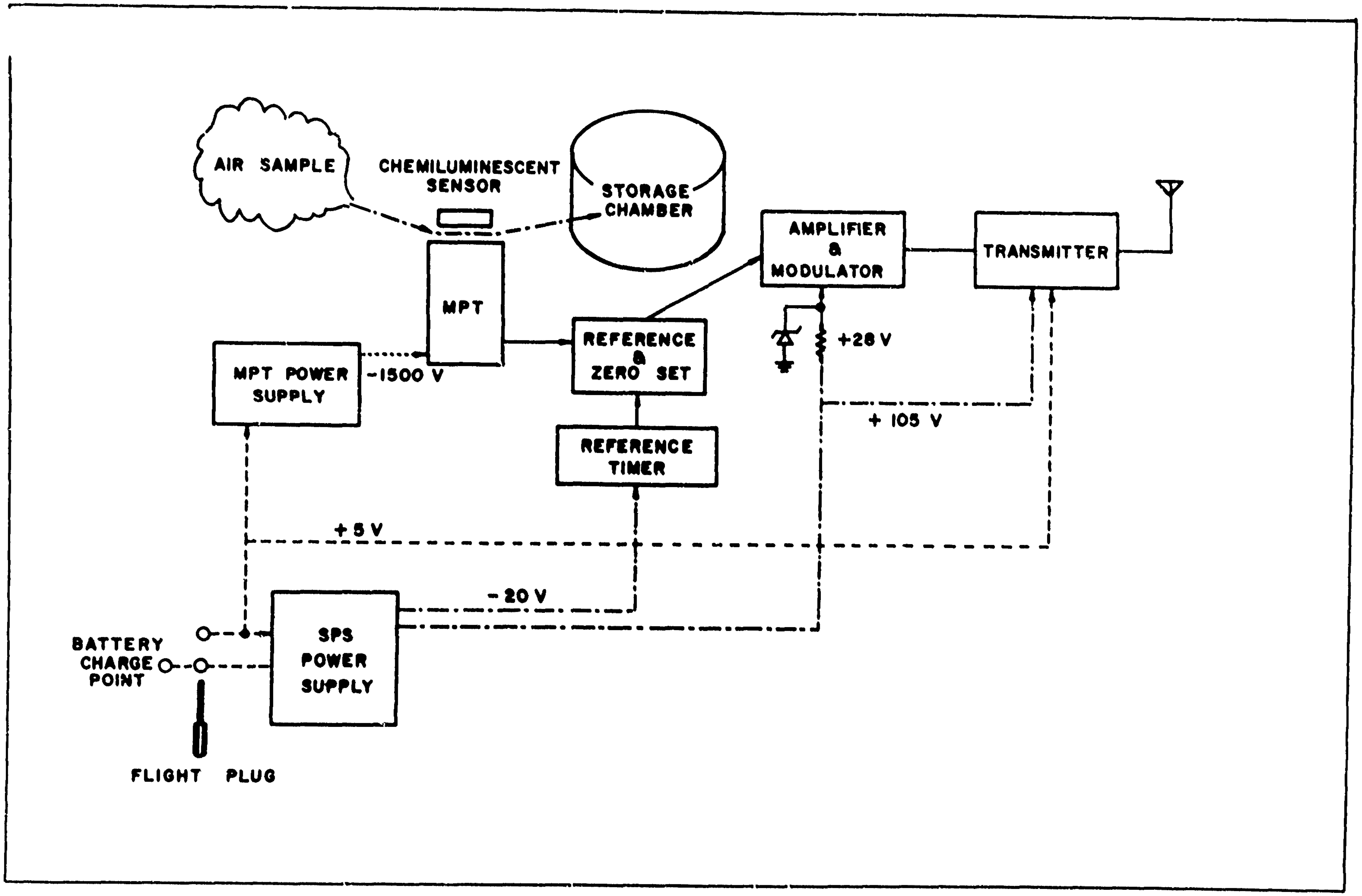


FIGURE 1. BLOCK DIAGRAM OF THE ROCKET-BORNE OZONESONDE.

SPECIFICATIONS

a.	Overall height:	46 cm
b.	Largest diameter:	10.0 cm
c.	Average weight:	2.4 kg
d.	Power Supply:	Four nickel-cadmium D Size cells, four-ampere-hours, rechargeable
e.	Battery life (fully charged):	2.5 hours
f.	Power conversion:	DC to DC
g.	Current:	1.8 amp
h.	Circuitry:	Transistorized (except for RF oscillator) and mounted on printed circuit board
i.	RF Source:	6562/5794A electron tube
j.	RF Output:	500 milliwatts
k.	Antenna:	1/2 wavelength dipole
l.	Frequency:	1680 MHz, tunable
m.	Sensor:	Rhodamine B, adsorbed on fine silica gel powder
n.	Nose Cone:	No. 5 with 30 cm extension
o.	Compatibility:	Arcas-type missile

THE INSTRUMENT:

The rocket-borne ozonesonde consists of three main parts: Power supply, photomultiplier tube and sampling chamber, and telemetry circuit. It is shown schematically in Fig. 2 which also exhibits the disposition of parachute container and extended nose cone. The air sample passage has been redesigned and is made of black plexiglass (Fig. 3). Four regular "D" size nickel-cadmium rechargeable batteries (4 amp-hr) comprise the instrument power pack. The transmitting section of the instrument is the same as the one for the Stratospheric Temperature Sonde STS-1 (1967). The complete circuit diagram of the instrument is shown in Fig. 4.

CHEMILUMINESCENT DISKS:

The chemiluminescent disks are prepared according to the procedure described by Regener (1966). The basic substance, Rhodamine B, is adsorbed on fine silica gel powder and applied to a black plexiglass disk. Since the chemiluminescent material deteriorates when exposed to light, the disks should be stored in complete darkness, under moderate refrigeration, and in dry air.

CHARGING OF THE POWER SUPPLY:

The amplifier and modulator circuit board has three terminals (black, yellow and orange) for the purpose of charging the power supply. Charge the batteries for 14 hours at 400 milliamps from a constant current power supply by connecting positive to the orange and negative to the black terminal. It is always better to recycle the charging procedure two to three times for charge stability. A fully charged power supply should read approximately 5.5 volts. Keep the power supply on trickle charge at 18 milliamps when not ready for flight.

FLIGHT PREPARATION:

Flight preparation requires about 9 square feet of bench space next to the TMQ-5 recorder in a warm, dry room. Set up the ozone generator (Regener, 1964) for preflight calibration. Follow the instructions which are furnished with the generator. There are four adjustments to be maintained:

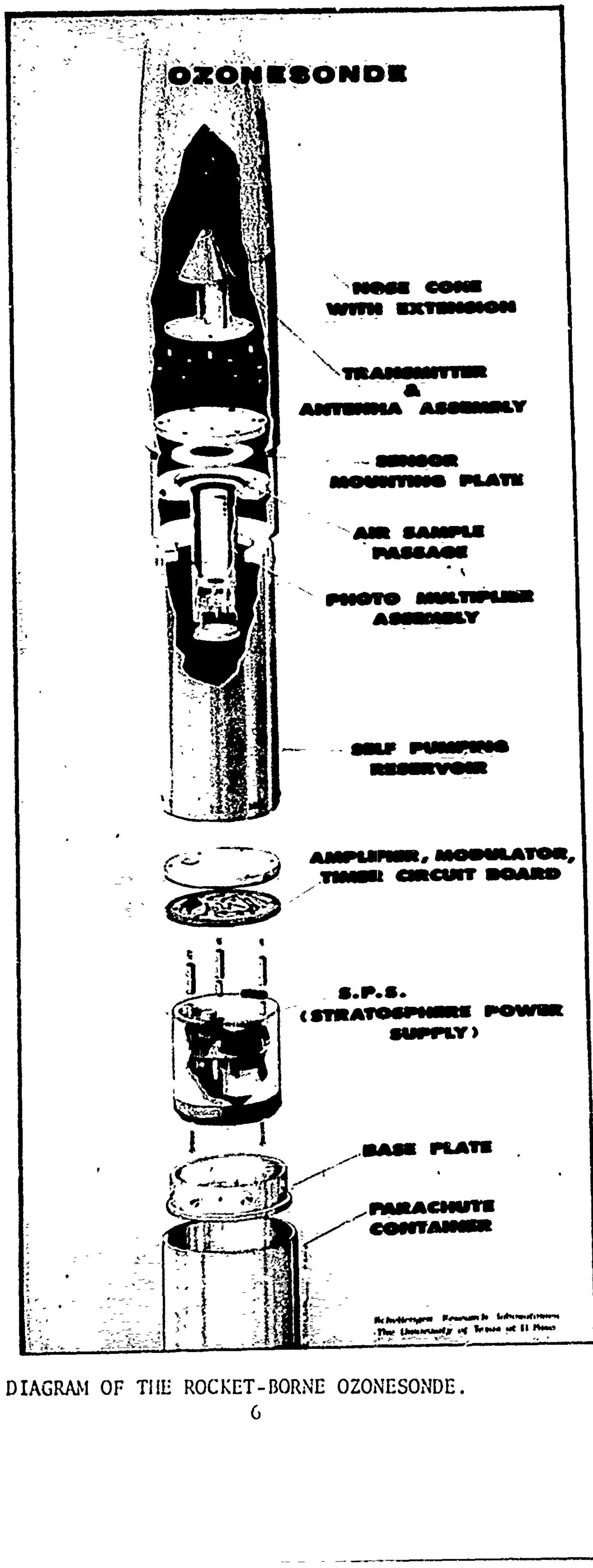
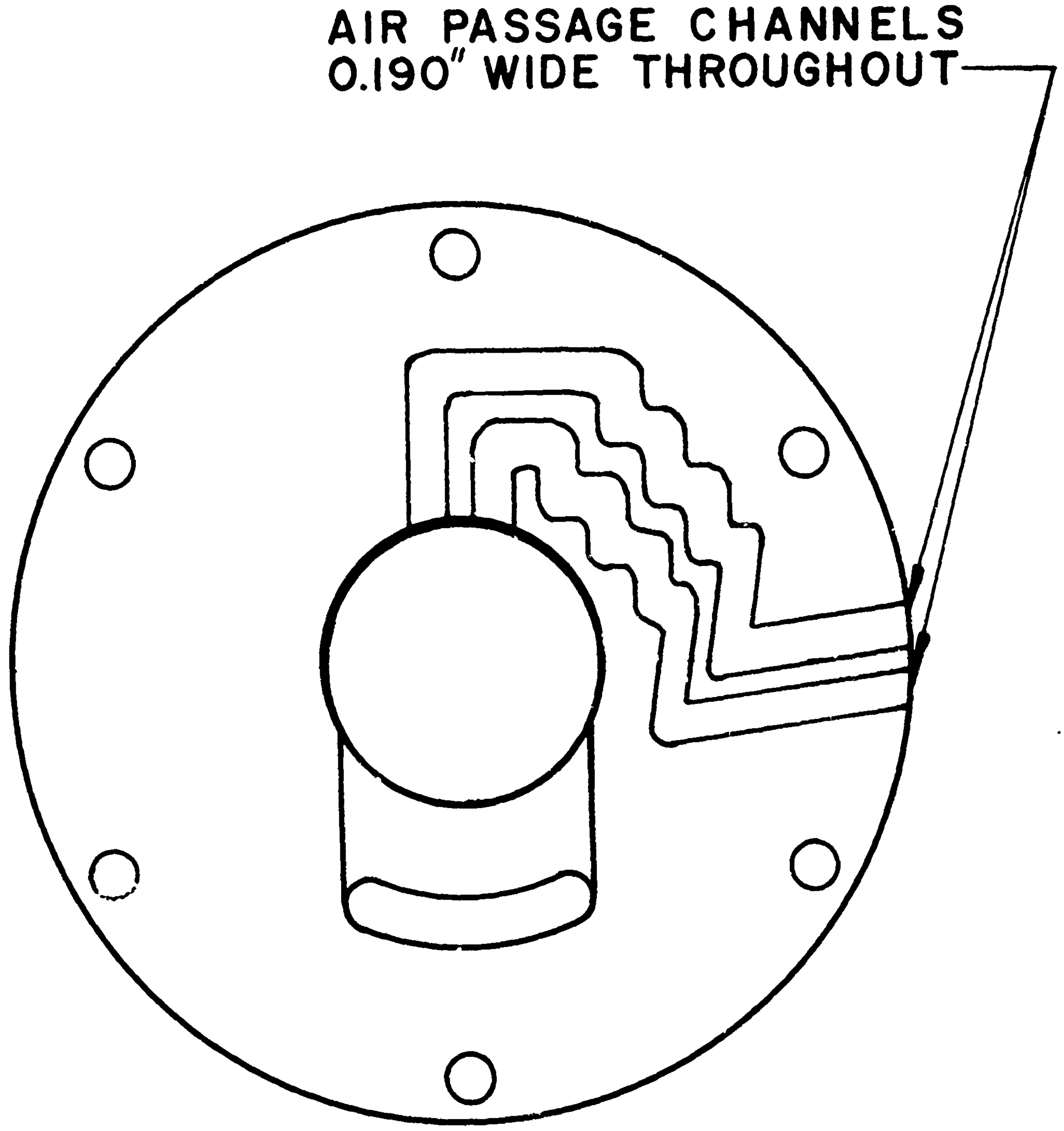


FIGURE 2. SCHEMATIC DIAGRAM OF THE ROCKET-BORNE OZONESONDE.



AIR SAMPLE PASSAGE PLATE

FIGURE 3

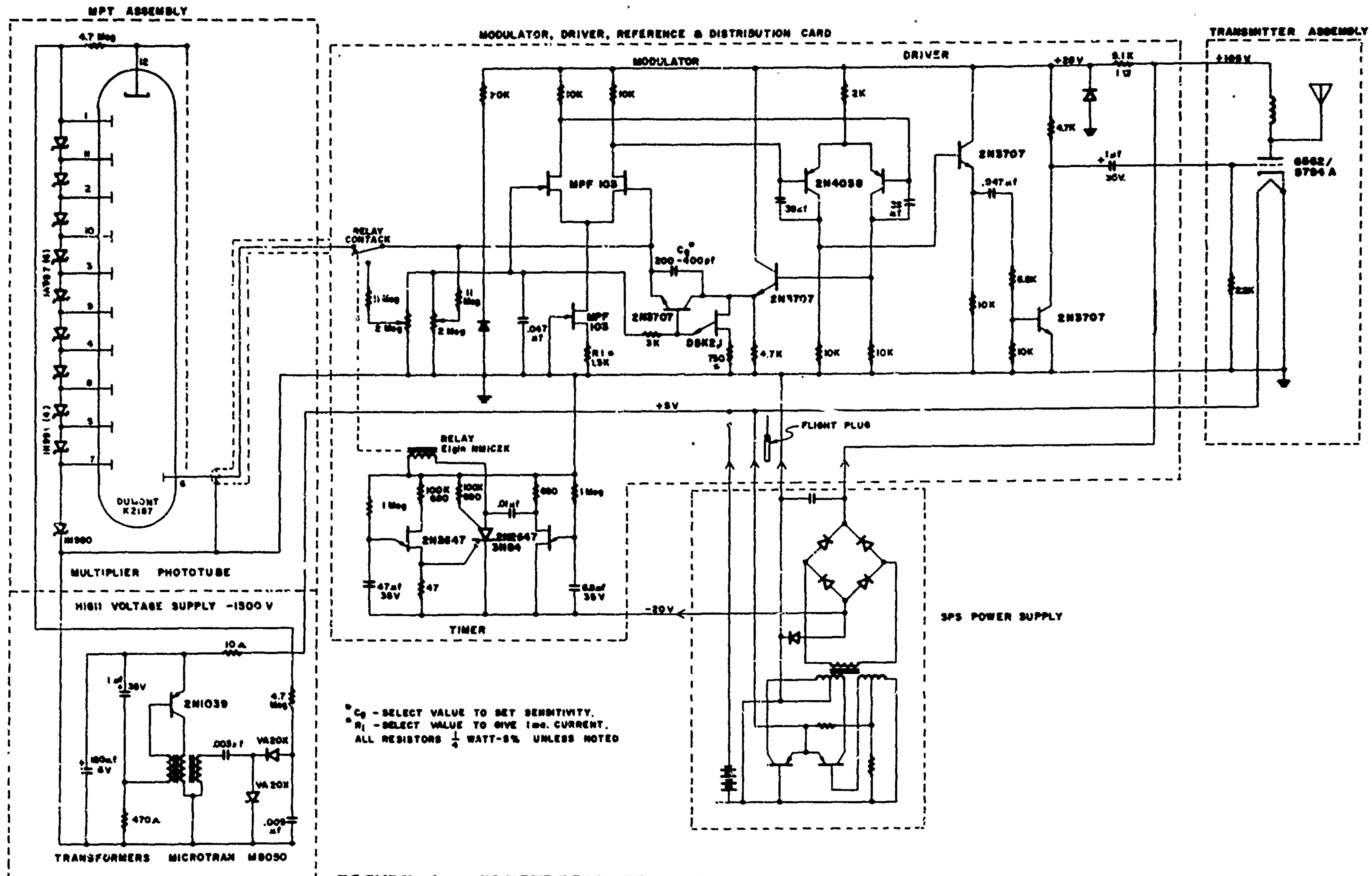


FIGURE 4. ELECTRICAL CIRCUIT DIAGRAM FOR THE ROCKET-BORNE OZONESONDE.

(a) Lamp Current: 13.0 milliamperes

(b) Air flow gauge: 10.0 cm

(c) Oxygen flow gauge: 10.0 cm

(d) Lamp temperature: Null balance

A calibration curve supplied with the instructions gives the ozone output of the generator as a function of shutter position.

Calibration and Preflight Adjustment:

Insert the chemiluminescent disk into the mounting plate of the ozonesonde quickly, to avoid unnecessary exposure to light and moisture. Remove the side plug from the reservoir and let the sonde "breathe" high-density ozone furnished by the generator for ten to fifteen minutes.

Approximately one hour before flight time, initiate this procedure:

1. Direct the GMD system toward the ozonesonde.

2. Connect the ozonesonde to external power supply (5.0 volts). Observe proper pin polarity (negative to black and positive to orange).

3. Adjust the frequency control on the tube cavity for the desired frequency setting.

4. With no ozone flowing through the passage of the ozonesonde, adjust the zero position (dark current) between 15 and 20 ordinates of the TMQ-5 recorder chart and adjust the reference signal near 50 ordinates by means of the two controls provided on the circuit board.

5. Next, let the ozone flow into the sonde at a rate of 200 cc/min and set the concentration at 200 gammas (micrograms per cubic meter). Record this calibration on the chart long enough that the ozone deflection is stabilized. A lower concentration (100 gamma) calibration may also be recorded on the chart. The ozone deflection in the case of 200 gammas should be of the order of 30 ordinates. Adjustments in the sensitivity control capacitor of the amplifier circuit should be made if ozone deflection is too low or too high.

6. Repeat Step 5 with internal power supply by unplugging the external power and inserting a pin in the yellow terminal.

7. After calibration, unplug the pin for the internal power supply, insert the side plug of the reservoir and cover the inlet passage

temporarily with black tape so that no moisture diffuses into the passage to change the sensitivity.

8. Place some insulating foam around the amplifier and modulator circuit board to keep it warm during flight.

9. Take the ozonesonde to the rocket launch pad. Fifteen minutes before launch time insert internal power supply flight pin, remove black tape from the inlet passage, and join the instrument to the rocket along with the 30 cm extended #5 nose-cone.

10. Launch rocket and track by the GMD-1 and radar systems.

DATA REDUCTION PROCEDURE:

1. From the TMQ-5 record, choose significant data levels, every five seconds at first and then increase the time interval as the descent rate decreases.

2. Tabulate the ozone ordinate, reference ordinate and elapsed time at each level.

3. Calculate the correct ozone ordinate by the following equation:

$$O_{ct} = \frac{O_{zo}}{O_{rt}} O_t$$

where O_{ct} is the corrected ozone ordinate at the time t, O_{zo} the reference ordinate at t = 0 (during the calibration), O_{rt} the reference ordinate at the time t, and O_t the ozone ordinate at time t.

4. The intensity of the emitted light is directly proportional to the ozone flux entering the detector. This flux is equal to the product of ozone concentration and the flow rate, i.e.,

$$\text{Flux} = k\ d\ (\text{ordinates}) = \rho_3 F$$

where k is the constant of proportionality, ρ_3 is the ozone concentration (gamma) and F is the flow rate. From the calibration procedure, knowing the ozone concentration and flow rate, calculate the value of k.

5. To determine the flow rate when the instrument is descending on a parachute, the following procedure is adopted. The rate of flow into the reservoir while the instrument is descending on the parachute is given by

$$\text{Flow rate} = \frac{V_i\, T_a}{P_a\, T_i}\left[\frac{dP_i}{dt} - P_i \frac{d \ln T_i}{dt}\right]$$

where

V_i = Bottle volume

T_i = Air Temperature inside the bottle

P_i = Pressure inside the bottle

T_a = Ambient external temperature

P_a = Ambient external pressure

t = Time

This expression is simplified by assuming

$$P_i = P_a \text{ and } T_i = T_a.$$

Thus the flow rate expression reduces to

$$\text{Flow rate} = V_i\left[\frac{d \ln P_a}{dz} - \frac{d \ln T_a}{dz}\right]\frac{dz}{dt}$$

where dt has been replaced by dz, and $dz/_{dt}$ is the fall velocity of the instrument. Atmospheric temperatures are obtained from the rocket sounding and the radiosonde flight nearest in time to the ozonesonde sounding. Atmospheric pressures are derived by using the hypsometric equation. Height data and fall velocity are obtained from the radar.

6. Calculate the flow rate at each data level.

7. Knowing the constant of proportionality (k) and flow rate, tabulate the ozone concentration versus altitude.

8. Divide the ozone concentration by 21.4 to convert into 10^{-3} $cm/_{km}$ units or use the following formula to change it to partial pressure units.

$$P_3 \text{ (Micromillibars)} = \frac{1.73\ \rho_3 \text{ (Gamma) } T \text{ (K)}}{1000}$$

9. As the ozonesonde is deployed, it is possible that for ten to fifteen minutes, the ozone signal may overshoot the TMQ-5 chart. To avoid this loss of data, use of a counter in conjunction with the TMQ-5, or a tape recorder, or both if available is recommended.

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13. ABSTRACT
This guide describes the preflight instrument preparation and data reduction procedures for the rocket-borne ozonesonde developed by the Atmospheric Sciences Laboratory, White Sands Missile Range. Basic system components are outlined, and the theory of operation is discussed. The ozonesonde is used for the measurement of ozone concentration to within plus or minus ten percent in the mesosphere and stratosphere after deployment from an Arcas rocket vehicle.

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