Instruction manual for IQSY auroral photometer

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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

INSTRUCTION MANUAL

FOR

IQSY AURORAL PHOTOMETER

M. D. WATSON

OTTAWA

JULY 1964

CONTENTS

FIGURES

PLATES

I. AURORAL PHOTOMETER SYSTEM

Unit No.	Unit	Function
1.	Photometer Head	Detects Aurora (4 wavelengths)
2.	Amplifier/Control Chassis (A/C Chassis)	Produces signal roughly proportional to logarithm of intensity of auroral light — controls operation of Head (Unit 1)
3.	400 c/s Supply/Timer (S/T Chassis)	Provides 400 c/s power to drive timer, which, in turn, is programmed to operate "Control" Panel (Unit 2) — can be operated from storage battery (Unit 6) to maintain timing independent of 60 c/s power failure
4.	Recorder (Esterline-Angus)	Records signal produced by Amplifier (Unit 2) — records, on side pen, timing marks generated by timer (Unit 3) and Control Panel (Unit 2)
5.	Connecting Cables	Interconnect above units
6.	12 V Storage Battery	Provides standby power for 400 c/s Supply/Timer (Unit 3) only
7.	Calibrator	Provides absolute calibration of auroral intensities (when standardized against black body source)

A block diagram of the auroral photometer system is shown in Fig. 1.

II. DESCRIPTION OF APPARATUS*

1. INTRODUCTION

Although auroral activity is not expected to be great during the International

* This description is taken from an article in Can. J. Physics (1964) 42: 1587-1592

Years of the Quiet Sun (IQSY), this period nevertheless provides a useful opportunity for commencing a long-term program of auroral photometry extending to, or past the next sunspot maximum. Such a program is being planned, and will involve absolute intensity measurements of the aurora, at four wavelengths, with a time resolution of 1 minute.

Four installations are planned at present: at Resolute Bay, N.W.T. (74°41'N, 94°55'W), Baker Lake, N.W.T. (64°19'N, 96°02'W), Great Whale River, Que. (55°17'N, 77°47'W), and Lake Traverse, Ont. (45°57'N, 78°03'W). The last site is that of the Algonquin Radio Observatory, operated by the Radio and Electrical Engineering Division of the National Research Council. Other sites may be used in future years.

Simplicity and stability are necessary requirements of any photometer which is to operate over a long period of time with a minimum of attention. Elaborate optical and electronic systems have therefore been avoided. Unfortunately, the requirement of unattended operation leads to somewhat complicated control circuitry, but it is hoped that generous de-rating of components and prolonged testing will eliminate most chances of failure.

The photometer is designed to measure absolute intensities of the following four features of the auroral spectrum: the $[OI]_{32}$ 5577A line; the H(2^2P^0-4^2D) 4861 A line (Hβ); the N_2^+ First Negative (0, 0) band at 3914 A; and a sample of the "background" continuum around 5400 A. The instrument will be calibrated with an incandescent light-source, which, in turn, will be standardized against a black body source [1,2].

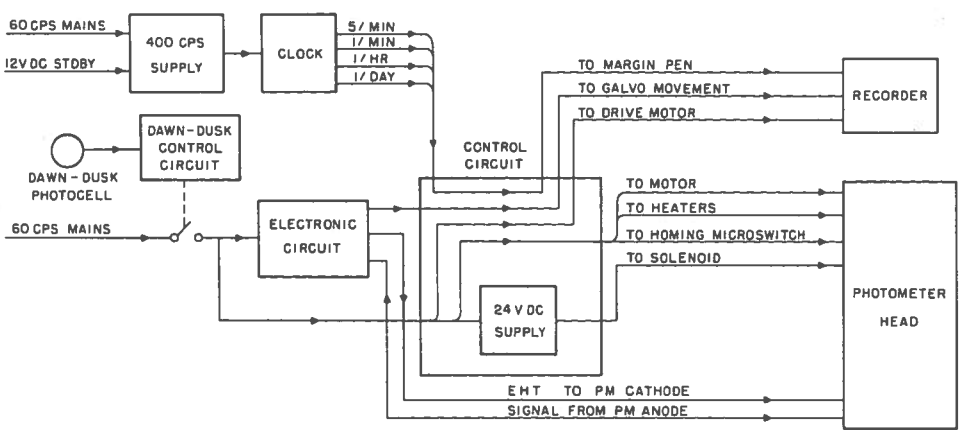

Fig. 1 Block diagram of photometer system

2. PHOTOMETER HEAD

The Head (Plate I) is designed to be mounted outdoors, remote from the rest of the photometer. It is, therefore, made relatively weathertight and is heated electrically by strategically placed resistance elements.

The optical system is very simple, being composed of a flat glass window, an aperture, a set of interference filters (of which only one is in use at a given time), and the photocathode of a type-1P21 photomultiplier. The latter is the field stop for the system. The field of view is a square 15° on the side, and the aperture is 3.23 cm^2 in area. The interference filters are Baird-Atomic multi-layer dielectric filters with characteristics given in Table I. An opaque "filter" is also provided for reading the dark current of the photomultiplier.

TABLE I

TYPICAL FILTER CHARACTERISTICS

Nominal peak wavelength (A)	Actual peak wavelength (A)	Half-width (A)	Peak transmission (%)
3914	3910	63	33
4861	4860	15	50
5400	5390	50	65
5577	5570	50	55

The four filters and the opaque "blank" are mounted on a pentagonal turret to suit the side-window geometry of the 1P21 photomultiplier (Plates II and III). The turret is driven around by a small 10 rpm motor which is normally held under stalled conditions by a pawl and five-sector ratchet wheel. The pawl is raised momentarily every 12 seconds by a remotely controlled solenoid, and the motor is then allowed to rotate the filter turret through 72° to bring the next filter into place. A cam and microswitch are mounted on the turret shaft so that the microswitch is opened whenever the blank is before the photomultiplier. This allows the "homing" feature described in Section 4 below. The wiring diagram is shown in Fig. 2.

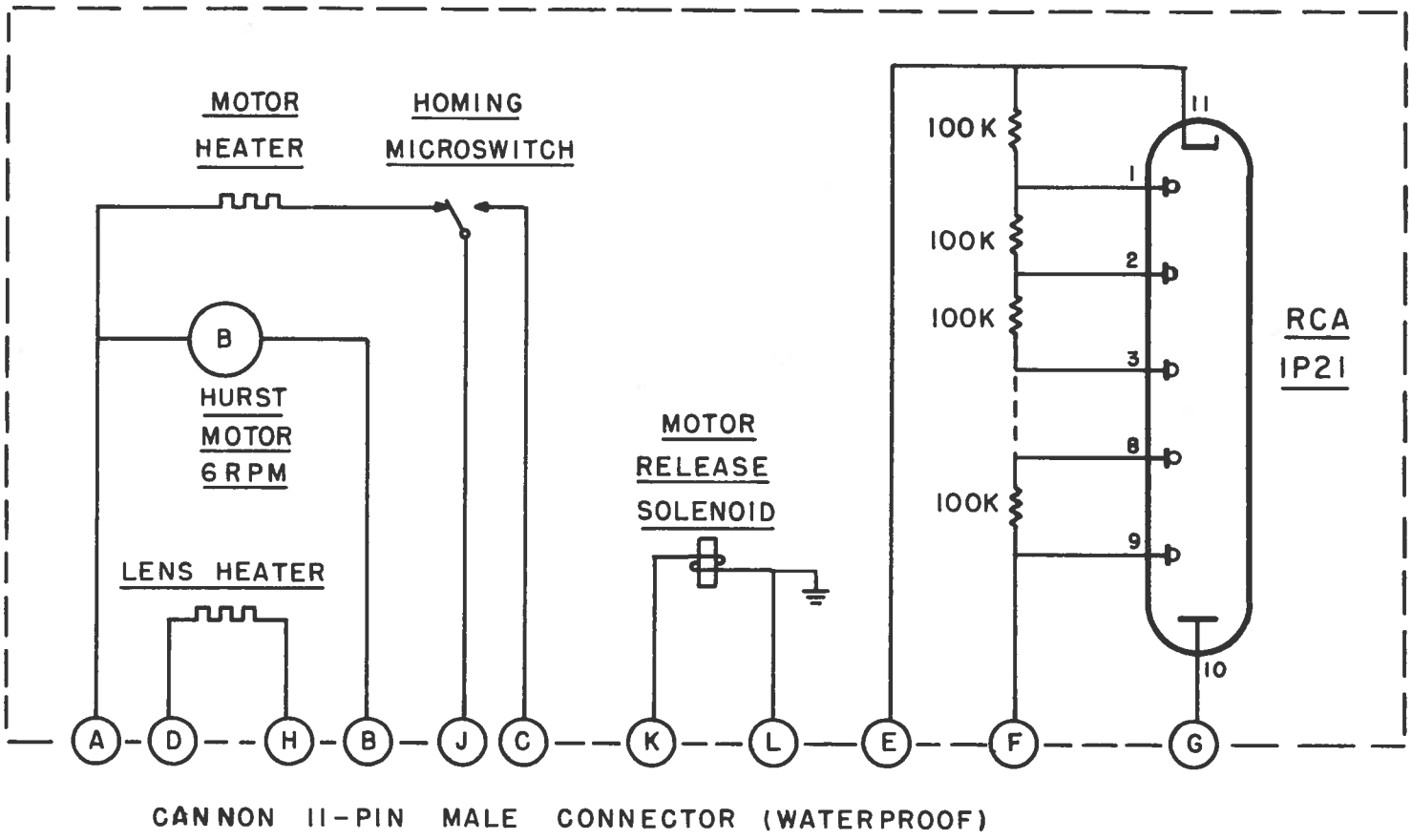

Fig. 2 Wiring diagram of Photometer Head

3. ELECTRONICS

The electronic circuit (Fig. 3) is of the type described by Bell and Graham [3], in which the over-all voltage applied to the photomultiplier dynode chain is controlled by a negative feedback circuit so that the anode current is held constant. This circuit has come into wide use for auroral photometry (for example, see References 4 and 5). The amplification factor of a photomultiplier tube varies nearly exponentially with dynode voltage, so that, for constant anode current, the dynode voltage is nearly proportional to the logarithm of the incident light intensity. This logarithmic characteristic has been found very useful in auroral work where intensities vary over wide ranges; in addition, the negative feedback provides a valuable safety feature for unattended equipment which may be accidentally exposed to bright light. A small fraction of the over-all dynode voltage is recorded on an Esterline-Angus graphic milliammeter (Fig. 4).

4. CONTROL CIRCUITS

Since the photometer is intended to operate without continuous supervision, the control system is fairly complex.

The photometer is operated from an independent timer (Fig. 5). This consists of a tuning-fork-stabilized 400 c/s supply (Fig. 6) (powered by 60 c/s mains or by a 12-volt d-c standby storage battery) which drives a mechanical clock. When stabilized by a selected fork, the clock has an accumulated error of less than 0.5 seconds per day. Suitable magnetic reed switches and microswitches mounted within the clock provide short pulses at 1 minute, 1 hour, and 1 day intervals. These pulses are used to energize a margin pen on the recorder according to a pre-programmed code. This is necessary in order to obtain time information on the chart record, since the recorder is turned on only during hours of darkness.

The entire system is switched on at dusk, and off at dawn, by means of a small cadmium sulphide photoresistor (Clairex CL605-L). When the equipment is shut off at dawn, the filter turret is made to continue stepping around until the opaque blank is in front of the photomultiplier tube, as indicated by a microswitch and cam (see Section 2, above). This "homing" technique prevents sunlight from falling upon the photomultiplier tube during the day, which would seriously fatigue the cathode.

The Amplifier/Control chassis is mounted above the Supply/Timer chassis in a combination rack/transit case. The chassis are connected to the Photometer Head by a length of multiconductor, armoured cable which has been found suitable for arctic use (Royal Canadian Navy Type MSCA-14 or MHFA-14).

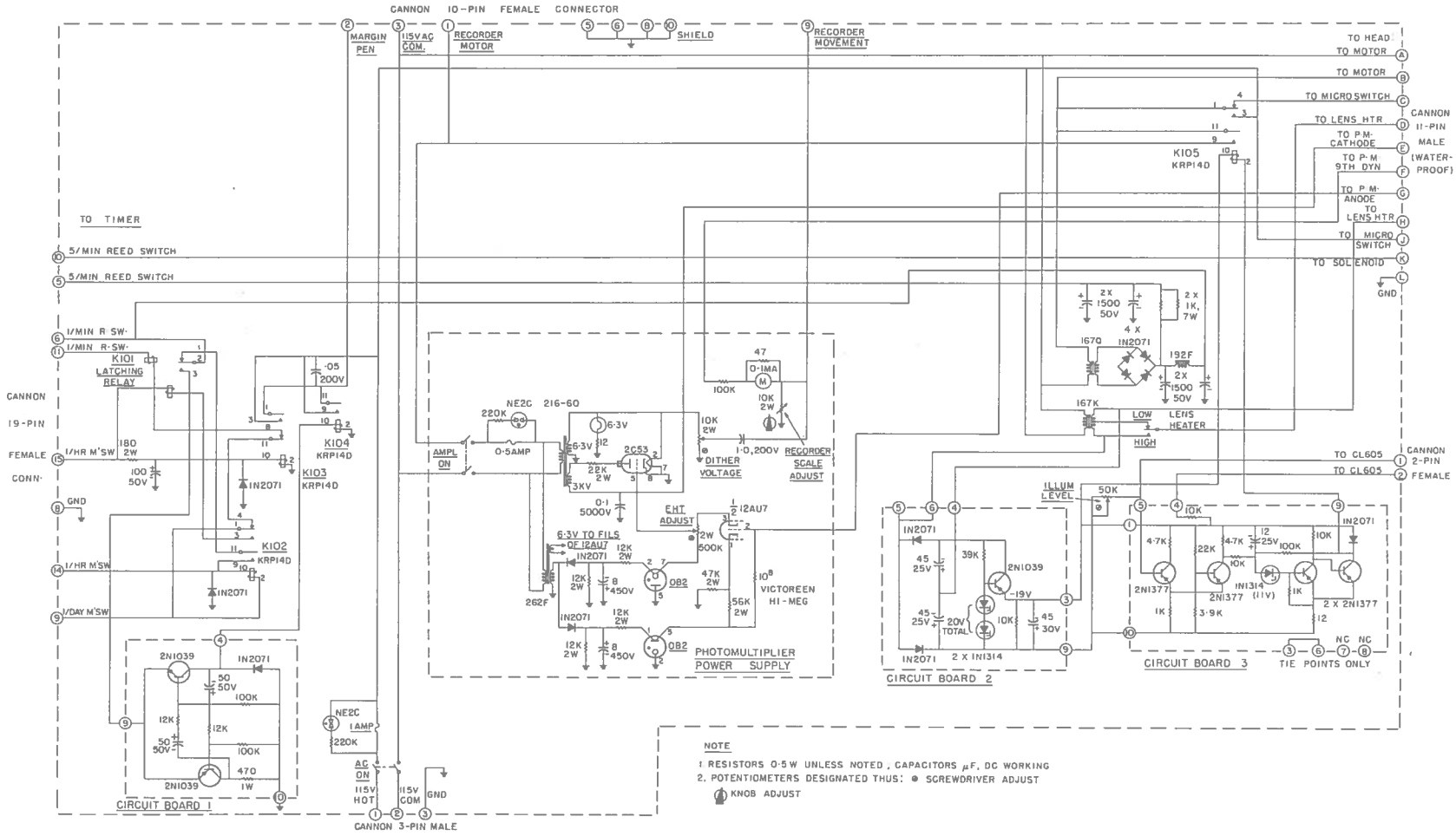

Fig. 3 Wiring diagram of Amplifier/Control chassis

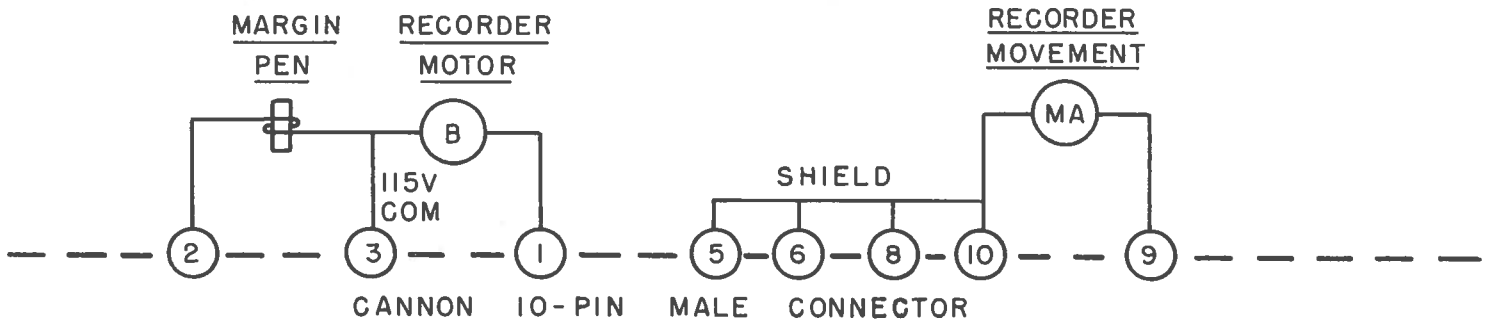

Fig. 4 Wiring diagram of Recorder

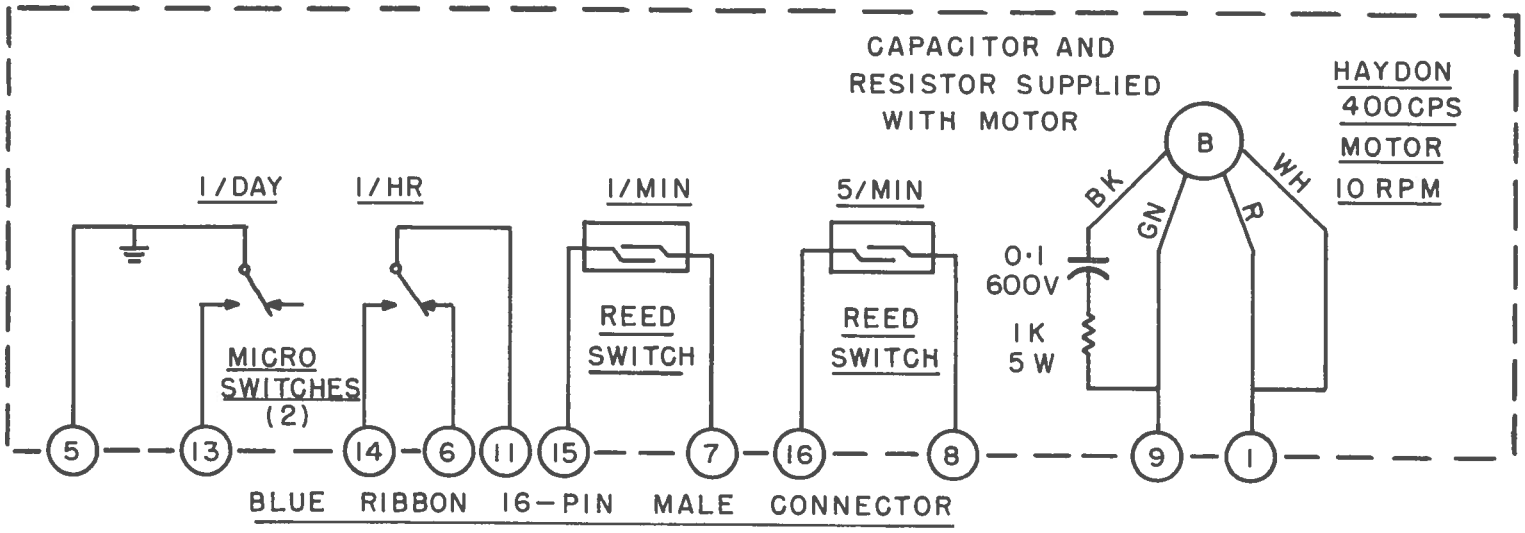

Fig. 5 Wiring diagram of Timer

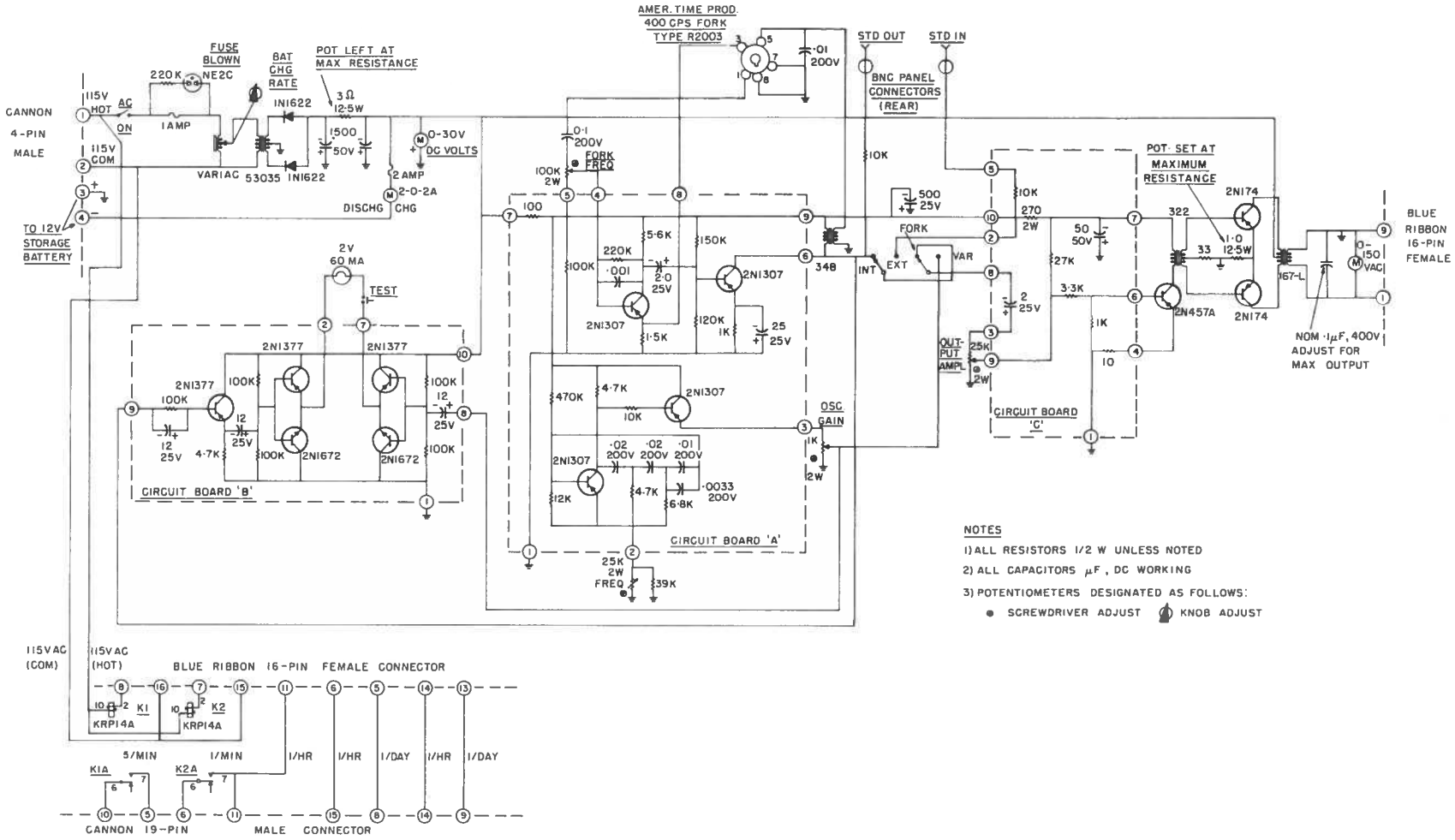

Fig. 6 Wiring diagram of Supply/Timer chassis

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2. Shepherd, G.G. (1954) Scientific Report No. AR-16, USAF Contract AF19(122)-152, University of Saskatchewan

3. Bell, R.E., and Graham, R.L. (1952) Rev. Sci. Instr., 23, 301

4. Hunten, D.M. (1956) J. Opt. Soc. Am., 46, 578

5. Hunten, D.M., Vallance Jones, A., Ellyett, C.D., and McLauchlan, E.C. (1964) J. Atmosph. Terr. Phys., 26, 67

III. INSTALLATION AND OPERATION

a) HEAD

The Head is packed and shipped completely assembled, except that the filter turret and type-1P21 photomultiplier tube are removed, separately packed, and shipped in the same crate with the Photometer Head.

The photomultiplier tube and filter turret must be installed in the Head before it is mounted. Be sure the two centre-punch marks on the end of the shaft and the filter turret mounting flange are aligned. The filter turret is held on the shaft by a taper pin (lightly smeared with DC-4 compound) and by a locking setscrew (four-pointed spline socket). The top lid for the Head casing should be lightly smeared with DC-4 compound around the inside of the lip before being fitted and screwed on.

Be sure all exposed screw heads are tightened down, and the snorkel end cap is snugged up against the window gasket (which should be smeared lightly with DC-4 compound).

The Photometer Head is weatherproof, and is intended to be mounted upon the roof of the IQSY tower. The mounting yoke is fastened down with a single half-inch-diameter bolt (two bolt assemblies are taped to the mounting yoke). The azimuth of the line of sight should be set before tightening the bolt. The elevation may then be adjusted by loosening the two large slotted hex-head screws which act as horizontal axles, tilting the Head to the desired elevation, and tightening the screws. The proper azimuth and elevation for the photometer line of sight, for this station, are:

_____: azimuth _____

elevation _____

The Head is connected to the rest of the equipment by multiconductor cables. A length of custom-made 11-conductor cable runs from the Head to a junction box inside the tower hut. The "Head" end of this cable terminates in a special Cannon weatherproof connector. DC-4 silicone compound should be used generously to fill the Cannon receptacle on the Photometer Head before the plug is mated with it (thus excluding moisture from the contacts). The other end of the 11-conductor cable terminates in the junction box in the tower hut. The colour-coding for the conductors is given on page 7.

A length of armoured cable (RCN type MSCA-14 or MHFA-14) runs from the junction box in the tower hut to a similar one inside the laboratory building. The three extra conductors are used to carry intercom signals. The conductor colour-coding and barrier-strip terminal numbering are given on page 7. The coding is the same for both the barrier strip in the tower hut and the one in the laboratory building.

A 20-foot length of made-up cable is provided to connect the junction box inside the laboratory building to the A/C chassis. The colour coding is identical with that given on page 7. It is unnecessary to use DC-4 compound in the special Cannon connectors inside the building.

b) INDOOR COMPONENTS

These consist of Units 2, 3, 4, 5, and 6 listed in Section I of this manual.

Units 2 and 3 are shipped in an aluminum transit case which also serves as a relay rack when opened. The Amplifier/Control chassis and 400 c/s Supply/Timer chassis are to be left in the case permanently.

Units 4 and 5 are packed and shipped along with the Photometer Head (Unit 1), except for the long armoured cable which is shipped separately. The Recorder may be placed in any convenient location, preferably on top of the transit case containing Units 2 and 3. The connecting cables can be connected only in the proper way, since each of the plugs is unique. In addition to the cables necessary to operate the equipment (Figs. 7, 8, 9, 10), two test cables are provided for checking purposes. One is a short length of cable (with Cannon waterproof connectors on both ends) (Fig. 11) to connect the Head to the rest of the equipment (so that the Head may be operated indoors); the other (Fig. 12) has modified Blue Ribbon connectors on each end and is a "cheater" cord which allows the 400 c/s Timer to be operated out of its housing in the Timer chassis. The storage battery and electrolyte are separately packed.

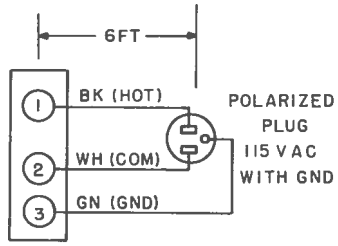

Fig. 7 Wiring diagram of Amplifier/ Control chassis power cable

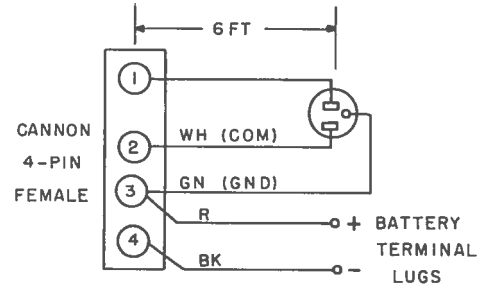

Fig. 8 Wiring diagram of Supply/Timer chassis power cable

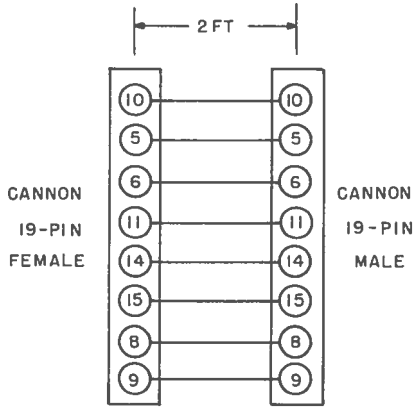

Fig. 9 Wiring diagram of cable connecting Amplifier/Control chassis and Supply/Timer chassis

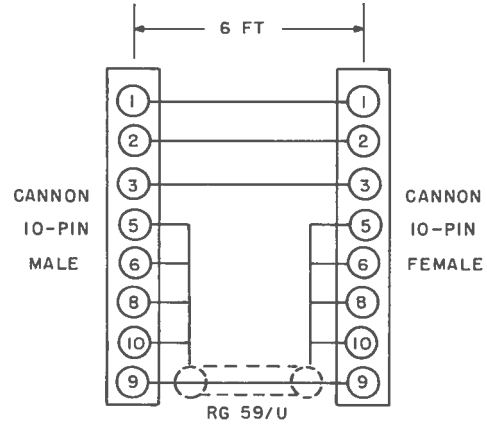

Fig. 10 Wiring diagram of cable connecting Amplifier/Control chassis and Recorder

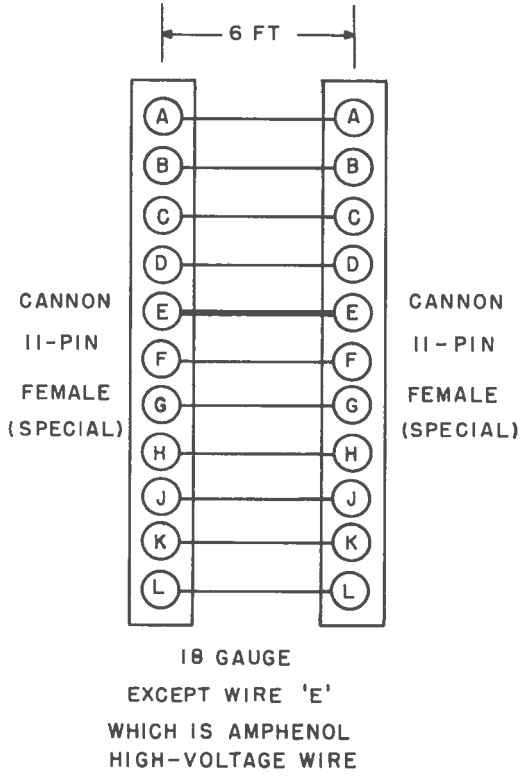

Fig. 11 Wiring diagram of Head "cheater" cable

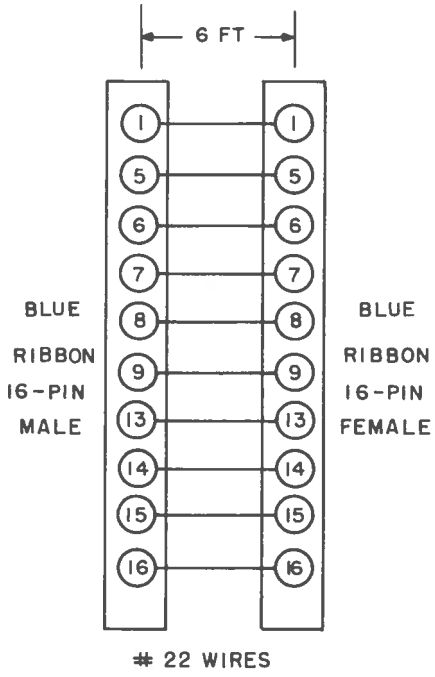

Fig. 12 Wiring diagram of Timer "cheater" cable

HEAD CABLE COLOUR CODING

BARRIER STRIP TERMINAL NO.	CONDUCTOR COLOUR
1	Brown
2	Red
3	Orange
4	Yellow
5	H.V. Red
6	Green
7	Blue
8	Purple
9	Grey
10	White
11	Black

MSCA-14 (MHFA-14) COLOUR CODING

BARRIER STRIP TERMINAL NO.	CONDUCTOR COLOUR
1	Black
2	White
3	Red
4	Green
5	Orange
6	Blue
7	White/Black
8	Red/Black
9	Green/Black
10	Orange/Black
11	Blue/Black
12	(Black/White
13 INTERCOM	(Red/White
14	(Green/White

Installation should follow these steps:

1. Open front and back of aluminum transit case and remove any accumulated debris, moisture, etc.
2. Unpack Photometer Head (see part (a) of this section for installation), Recorder, and short connecting cables. Place Recorder upon transit case or in other convenient location.
3. Unpack 12-volt storage battery and electrolyte, and prepare battery for service as per instructions given below. (A set of these instructions is also packed with each battery.)

    a) Fill each cell $\frac{1}{8}$" below the indicated level with acid supplied. Temperature of battery and acid should be not less than 60°F and not higher than 100°F.

    b) Immediately put on charge at 2 amp. till battery is fully charged. This will probably take 10-15 hours, and can be judged by the levelling-off of the specific gravity at its maximum value (1.240 to 1.260).

    c) Top up each cell to the full mark with acid.

4. Interconnect Supply/Timer chassis and Amplifier/Control chassis with appropriate cables (all connections at rear). There are <u>two (2)</u> 115-volt a-c plugs to connect to the 60 c/s supply. The red and black wires with lugs go to storage battery (red to positive terminal).
5. Connect the cable from the wall-mounted junction box to the Cannon weatherproof connector on the A/C chassis.(It is not necessary to use DC-4 compound on this connector.)

This completes the installation of the indoor components.

The equipment is placed in operation as follows:

1. Check that all fuses are installed and operative.

On S/T chassis:

2. Set toggle switches to INT and FORK.
3. Turn AC switch ON.
4. Adjust CHG RATE control so meter reads slightly CHARGE.
5. Adjust AMP GAIN so AC VOLTS meter reads 90 volts. (DC VOLTS should be between 10 and 15 volts.)

6. Wait several minutes for Timer to come up to speed, then adjust Timer to correct time. Use CHU as standard, but set Timer to UT (Z).

To adjust Timer:

7. Determine whether time is fast or slow.

8a. If Timer is fast: Turn FREQ control counterclockwise from 400 c/s setting, set toggle switch to VAR, wait until timer has slowed to correct time, reset toggle switch to STD, check time, and repeat if necessary.

8b. If Timer is slow: Turn FREQ control clockwise from 400 c/s setting, set toggle switch to VAR, wait until Timer has speeded up to correct time, reset toggle switch to STD, check time, and repeat if necessary.

NOTE:

The TEST pushbutton and pilot light are provided as a convenience for finding the 400 c/s setting of the FREQ control. To use, depress the pushbutton and observe the rate of flicker of the lamp. The 400 c/s setting of the FREQ control is at about the middle of its range and is indicated by a zero rate of flicker of the pilot light. DO NOT CONFUSE this with the extremely rapid rate of flicker found at the ends of the FREQ control range. It is quite easy to adjust the Timer to an accuracy of $\pm\frac{1}{4}$ second, which is adequate for operation of the photometer.

9. Readjust the CHG RATE and AMP GAIN controls as necessary to maintain the proper readings on the meters:

DISCH - CHARGE	=	slightly CHARGE
AC VOLTS	=	90 V
DC VOLTS	=	10-15 V.

On A/C chassis:

10. Turn AC switch ON.

11. Turn AMPLIFIER switch ON.

12. During dusk (either post-sunset or pre-dawn) at Civil Twilight (solar depression 6°), rotate the ILLUM CONTROL clockwise (starting from full counterclockwise) until the control circuit switches on. This is indicated by the clear pilot light over the AMPLIFIER switch.

13. Adjust the EHT ADJUST control to give a maximum meter deflection of 0.50 (measured over a period of at least one minute).

14. Adjust the RECORDER SCALE ADJUST control so that as much as

possible of the Recorder's dynamic range is utilised. Leave a space of at least $\frac{1}{2}$ inch on both sides of the trace, however, to allow for possible drift.

15. Set the DITHER VOLTAGE control so that the inked trace is slightly wider than it was with no dither voltage applied.

16. The LENS HEATER switch should be set to LOW or HIGH, depending on the weather at any given time. (Experience is the best teacher. The object is to keep the Head window free from obstruction due to snow and ice, without dissipating so much power that the rest of the Head becomes heated as well.)

c) CALIBRATION

Each station is equipped with a Calibrator consisting of a light source and a control unit (Fig. 13). The Calibrator is powered by two mercury cells which should last several months under normal service. Replacement batteries will be supplied promptly when they are required.

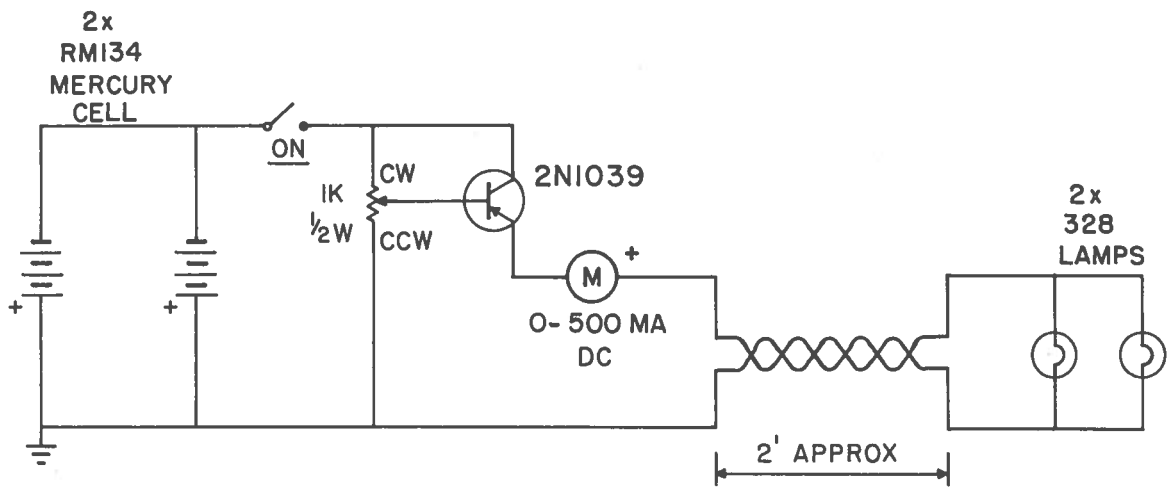

Fig. 13 Wiring diagram of Calibrator

The following steps are used in calibration:

1. Take the Calibrator up to the roof of the tower hut.

2. Place light source on snorkel of Head, taking care to have the side labelled "THIS SIDE UP" facing upward, and to have the light source

pushed all the way onto the snorkel.

3. Note time at beginning of calibration. (There is a column for this in the logbook.)

4. Switch control unit ON and adjust lamp current to the first value given in the table below. Leave for two minutes.

5. Adjust lamp current, in turn, to the other values given in the table, leaving the current fixed for two minutes in each case.

6. Switch control unit OFF, note time at end of calibration (column provided in logbook) and remove light source from snorkel of Head.

CALIBRATION	
STEP	LAMP CURRENT (ma)
1	250
2	275
3	300

IV. MAINTENANCE AND REPAIR

a) PREVENTIVE MAINTENANCE

1. Photometer Head

The various components of the optical system (flat glass window, interference filters, and 1P21 envelope) should be removed periodically, checked for possible damage, and gently cleaned with Kodak lens cleaner and lens cleaning paper.

The mechanical components of the Head should not require any preventive maintenance other than an occasional cleaning and checking for obvious wear or damage.

The frequency with which these cleanings and checkings are done will depend on local conditions and is left to the discretion of the technician in charge. It is

suggested that once per month might be suitable. The outside surface of the window should be cleaned daily, if possible, to prevent the accumulation of condensation nuclei.

2. S/T Chassis

Dust and/or grit should not be allowed to accumulate on the chassis or components. In particular the Timer should be kept clean since it contains precision mechanical parts. A good quality paintbrush is a useful cleaning tool.

3. A/C Chassis

Dust and/or grit should not be allowed to accumulate on the chassis or components. In particular the Hi-Meg resistor mounted beneath the chassis (Plate IV) should be kept scrupulously clean to avoid surface leakage. DO NOT TOUCH THE GLASS ENVELOPE WITH THE FINGERS.

4. Recorder

The ink reservoirs should be kept filled to guard against the chance of drying up. Periodically (once per month) the pens and reservoirs should be removed, cleaned with water, re-filled, and replaced. Use only the black ink supplied.

5. Storage Battery

The battery electrolyte should be checked periodically in accordance with the instructions given on the battery check sheet.

6. Connecting Cables

The short cables used to interconnect the chassis, Recorder, battery, and wall-mounted junction box should require no maintenance other than periodic checks to assure they have not been damaged through mechanical abrasion by heavy objects, etc. The long armoured cable running from the laboratory building to the instrument tower at Resolute Bay lies on top of the ground and is subject to possible damage by traffic (treads of vehicles, dog-sled runners, etc.). It should be inspected for cuts, nicks, or fraying at least once per week, where possible. If it is evident that no damage has been done to the black "filler" layer inside the braid, the nick should be daubed with tar and kept under watch for further deterioration. If the filler layer or the conductors themselves are damaged, the cable should be cut and the conductors spliced together inside a junction box. The box should be filled with tar after the splicing.

The cable running from the tower junction box to the Head should be checked

weekly for possible wear due to flexing in the wind, abrasion against the tower hut, or other causes. The special Cannon connector should be kept filled with DC-4 silicone compound.

b) TROUBLESHOOTING AND REPAIRS

Since the IQSY is the first period of prolonged use for the auroral photometers, only a minimum of experience is available concerning troubleshooting.

The Recorder indicates essentially the magnitude of the high voltage applied to the 1P21 dynodes. Therefore a Recorder deflection near or at zero indicates no EHT, while a steady deflection up-scale indicates continual EHT. In the former case, voltage readings in the amplifier-power supply part of the circuit should be taken. Note that the grid of the 12AU7 tube is a high impedance point, and that therefore readings taken with an ordinary multimeter will be in error.

The second condition (continual EHT) indicates either that no light is reaching the 1P21 or a failure of the 1P21 itself. The first cause can be easily checked by looking at the various components in the optical system. The second possibility may be tested by replacing the 1P21 with a spare.

The Photometer Head may be dismantled by following these steps:

1. Remove top cap (three screws).
2. Remove 6/0 taper pin through filter turret hub and shaft.
3. Loosen setscrew in filter turret hub.
4. Lift out filter turret, being careful not to touch filters.
5. Remove 1P21. Handle by base, not envelope (Plate V).
6. Unsolder snorkel heater lead wires from feedthrough terminals.
7. Remove bottom cap ring (three screws).
8. Remove three screws passing through outer case and into lower bulkhead, while holding Cannon connector to support inner assembly.
9. Carefully withdraw inner assembly through bottom of outer case.

Three types of spare parts are furnished for the mechanical timer (Plates VI to X) on the S/T Chassis. These are: (a) spare hex-socket "No-Mar" set screws, compression springs, and nylon plungers for the ratchet assembly on the 1 RPH drum; (b) a spare Haydon 10 RPM 400 c/s synchronous motor complete with drive gear, capacitor, and resistor; (c) spare dry-reed switches and 1SM11 micro-switches.

To change the motor, unsolder the leads at the Blue Ribbon connector, remove the two motor-mounting screws, and withdraw the entire motor assembly with the drive-gear pinned to the shaft. Replace with the spare motor (and capacitor and resistor, if found necessary). Mail the faulty motor (along with covering letter) immediately to M.D. Watson at NRC (address below).

A fairly complete set of spare parts is supplied to each station, and it is expected that repairs will be limited to the replacement of parts which have failed. In cases where this is insufficient to return the instrument to a serviceable condition, or where a troubleshooting problem cannot be solved, the operator is requested to communicate within 24 hours with the undersigned:

M. D. Watson

Radio and E.E. Division

National Research Council

Ottawa, Ontario

The means of communication will vary with each station; the following is suggested for this station:

Station _____

Telephone:

Telex:

Radiotelephone:

Other: Mail

V. SPARE PARTS LIST

1 — 1P21 photomultiplier tube

1 — 2C53 tube

2 — 12AU7 tubes

2 — OB2 tubes

1 — 10^8 ohm resistor

1 — glass window

3 — lens cleaner

15 — lens tissue

1 — 10 RPM Hurst motor

1 — 10 RPM Haydon motor with gear, capacitor, and resistor

1 — Ledex Solenoid

3 — dry reed switches

2 — microswitches type 1SM11

1 — microswitch type V3-701

6 — taper pins size 6/0

3 — sets of ratchet parts for timers

6 — circuit boards (A, B, C, 1, 2, 3)

3 — boxes fuses ($\frac{1}{2}$A, 1A, 2A)

5 — pilot lights assorted

1 — latching relay GL-1024 modified

4 — relays KRP 14D

2 — relays KRP 14A

6 — pot shaft covers

1 — camel hair brush (optics)

1 — paint brush (electronics)

VI. ADDITIONAL NOTES

Plate I — External view of Photometer Head

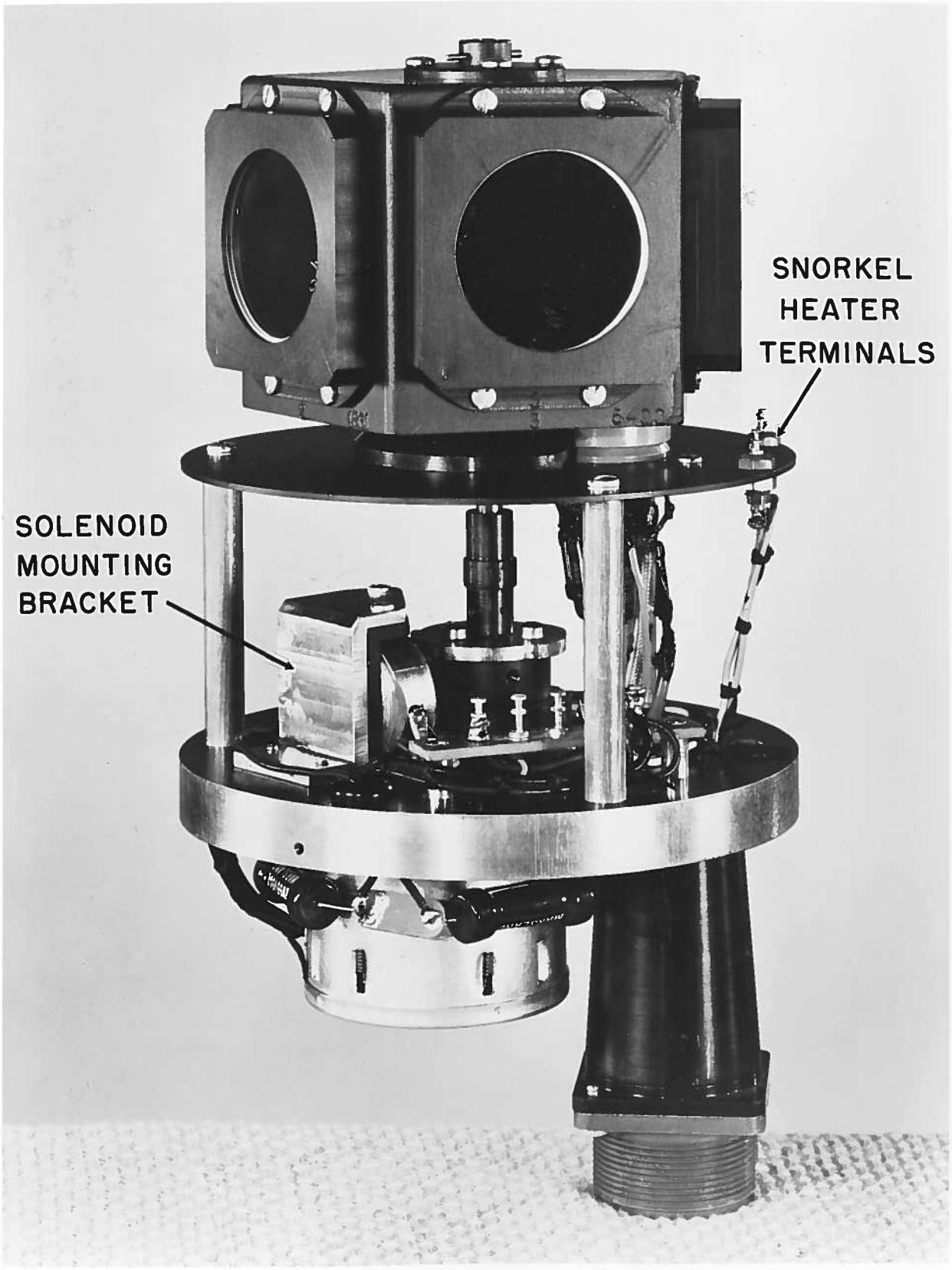

Plate II — Internal mechanism of Photometer Head (side view)

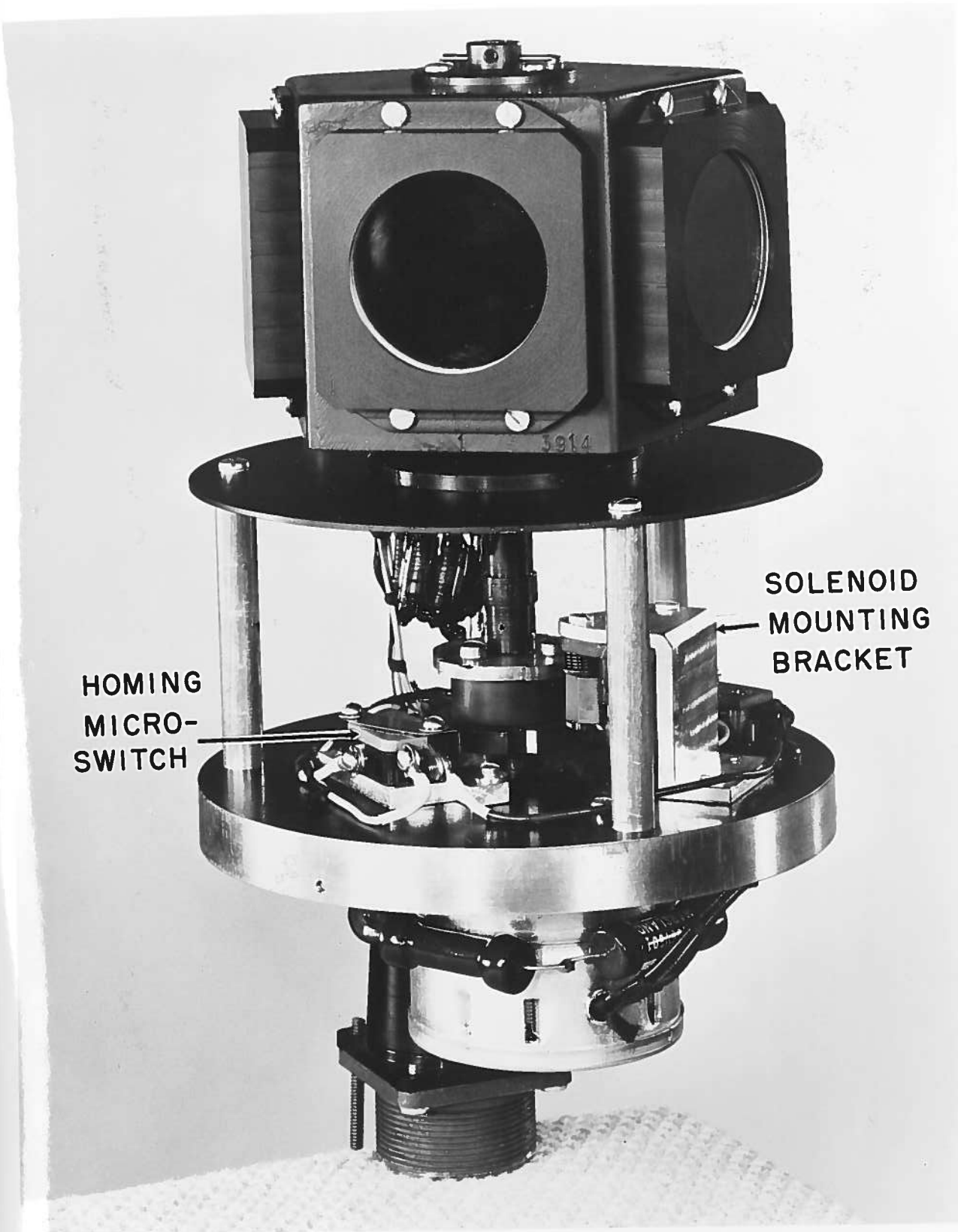

Plate III — Internal mechanism of Photometer Head (back view)

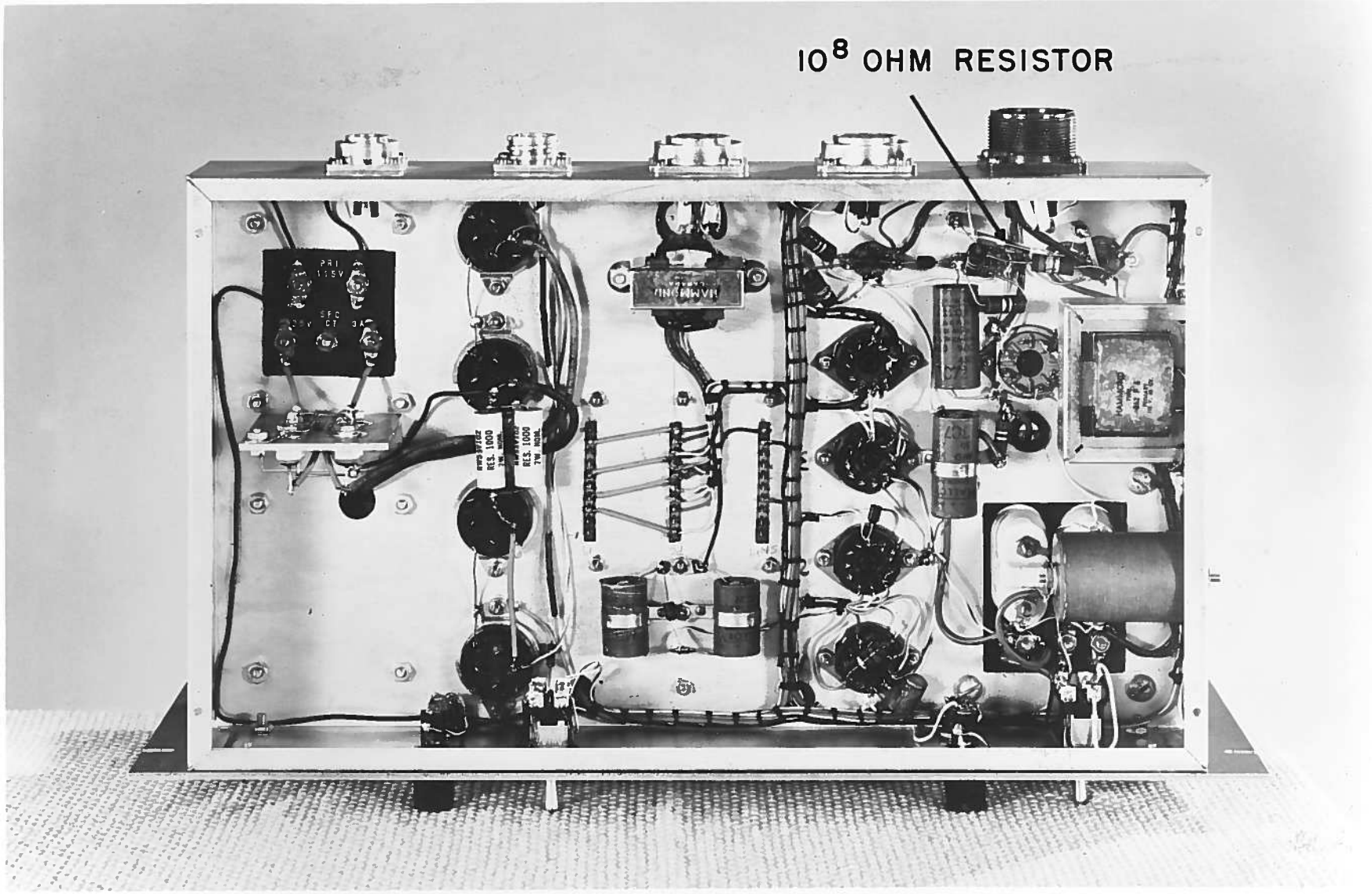

Plate IV — Bottom view of electronics chassis

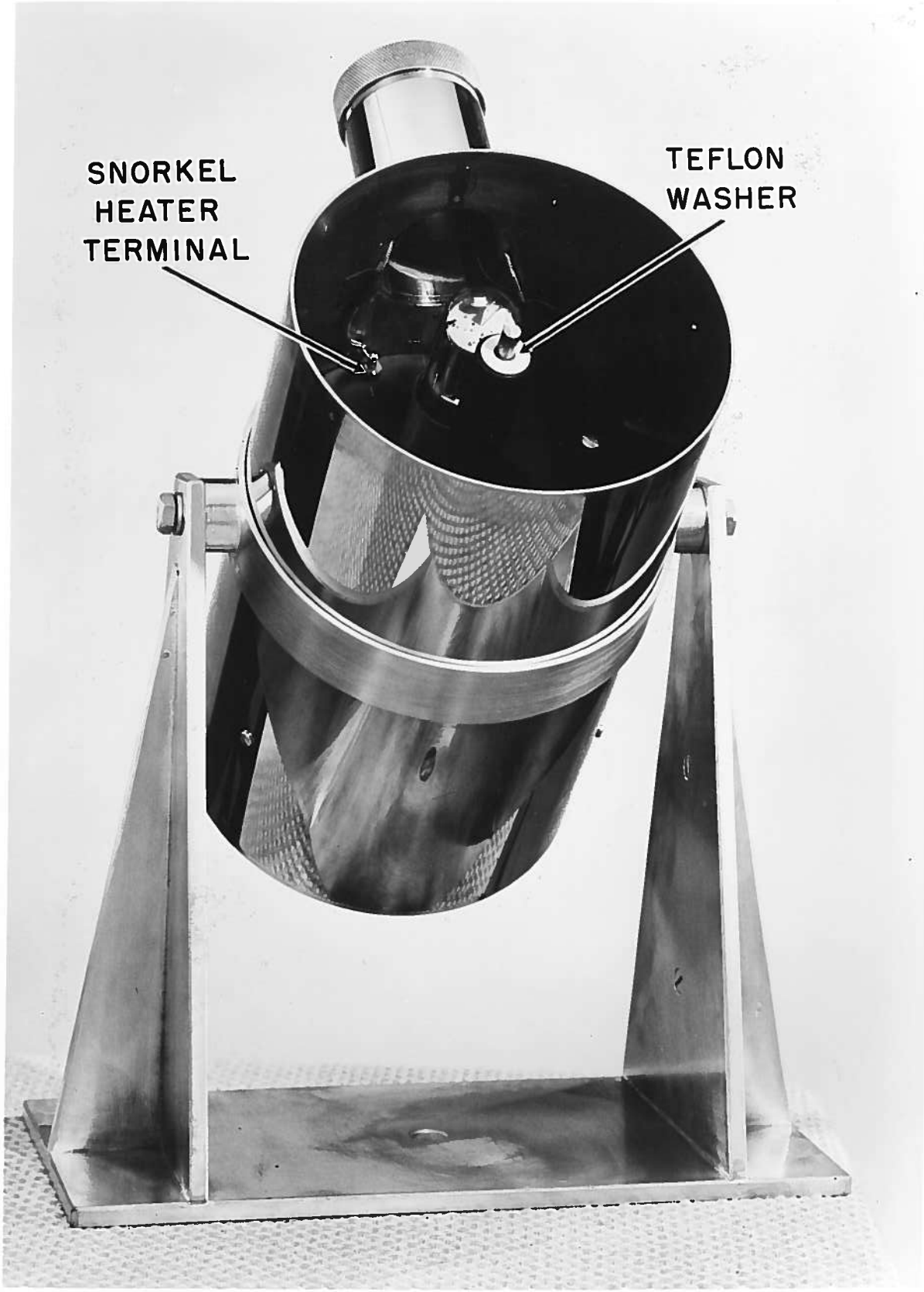

Plate V — Top view of Head, with cap and turret removed

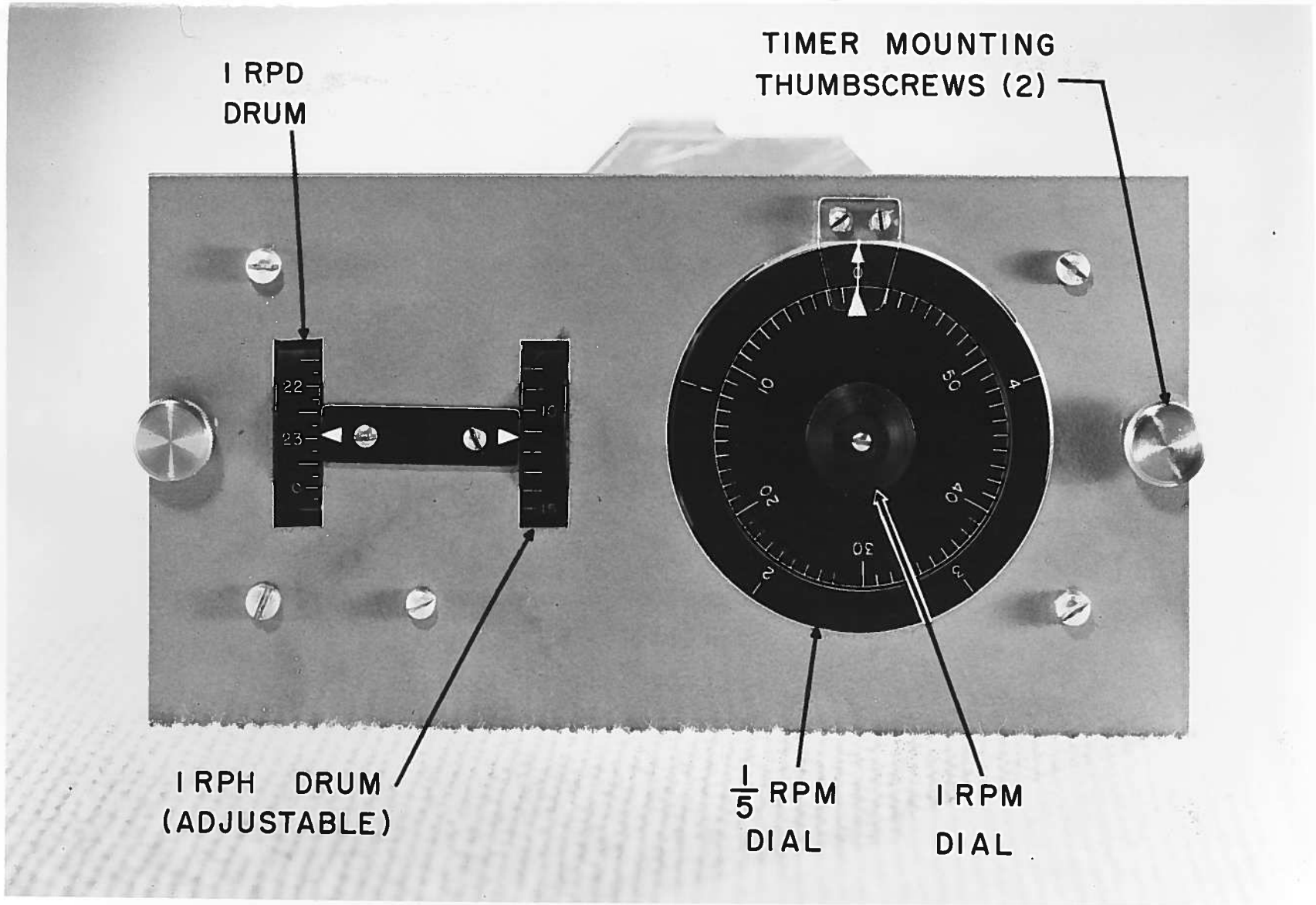

Plate VI — Front view of Timer

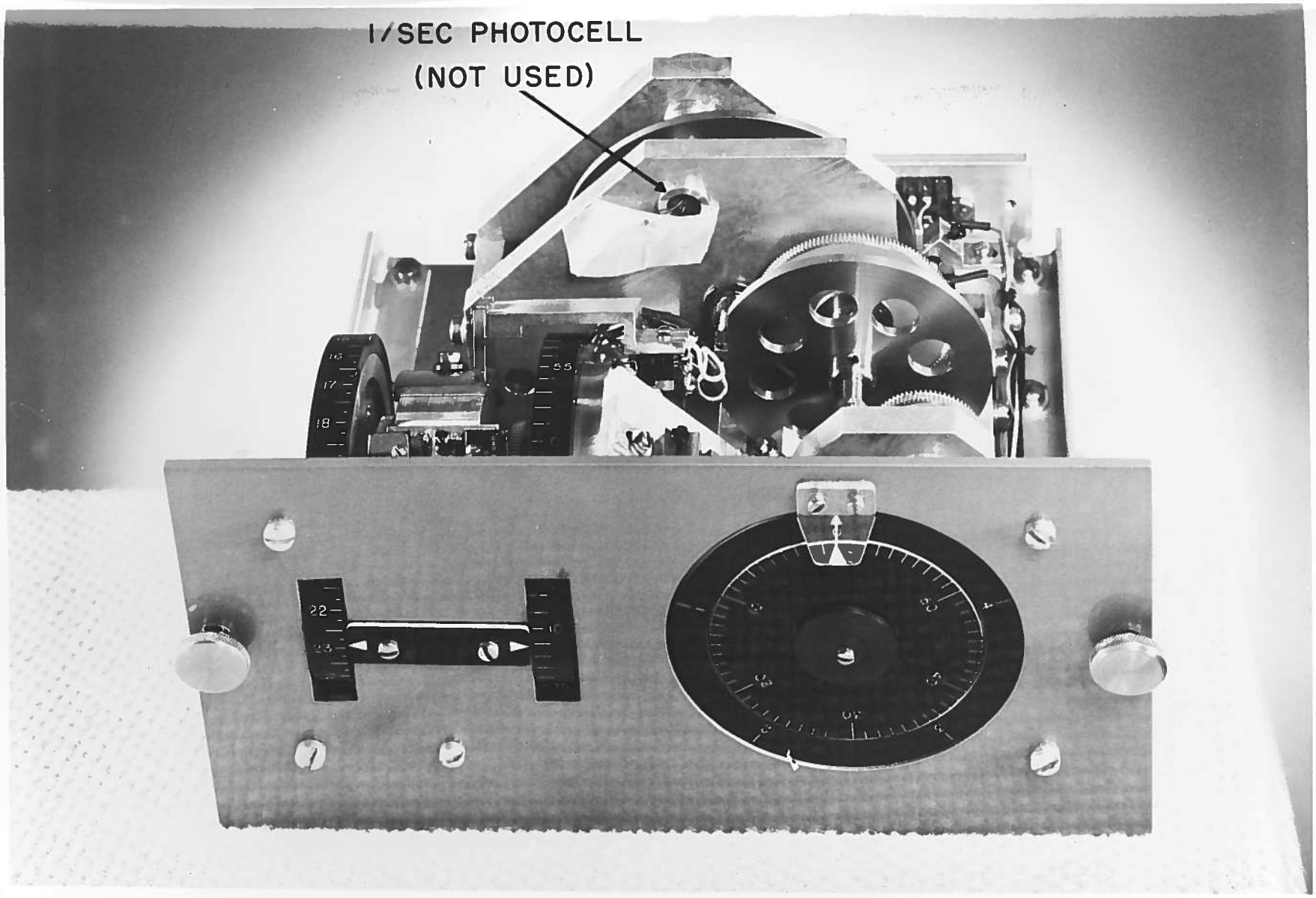

Plate VII — Front three-quarter view of Timer

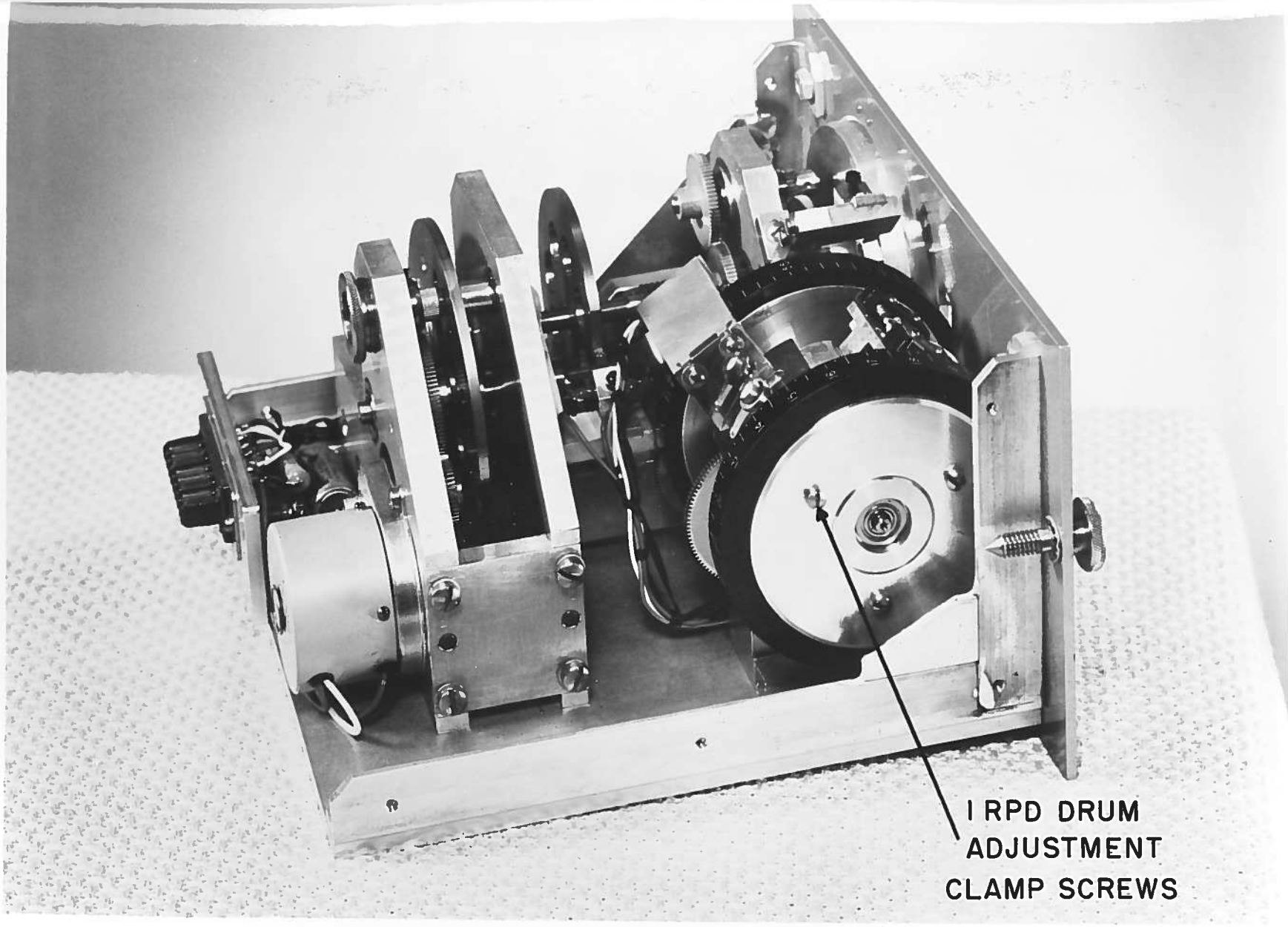

Plate VIII — Left three-quarter view of Timer

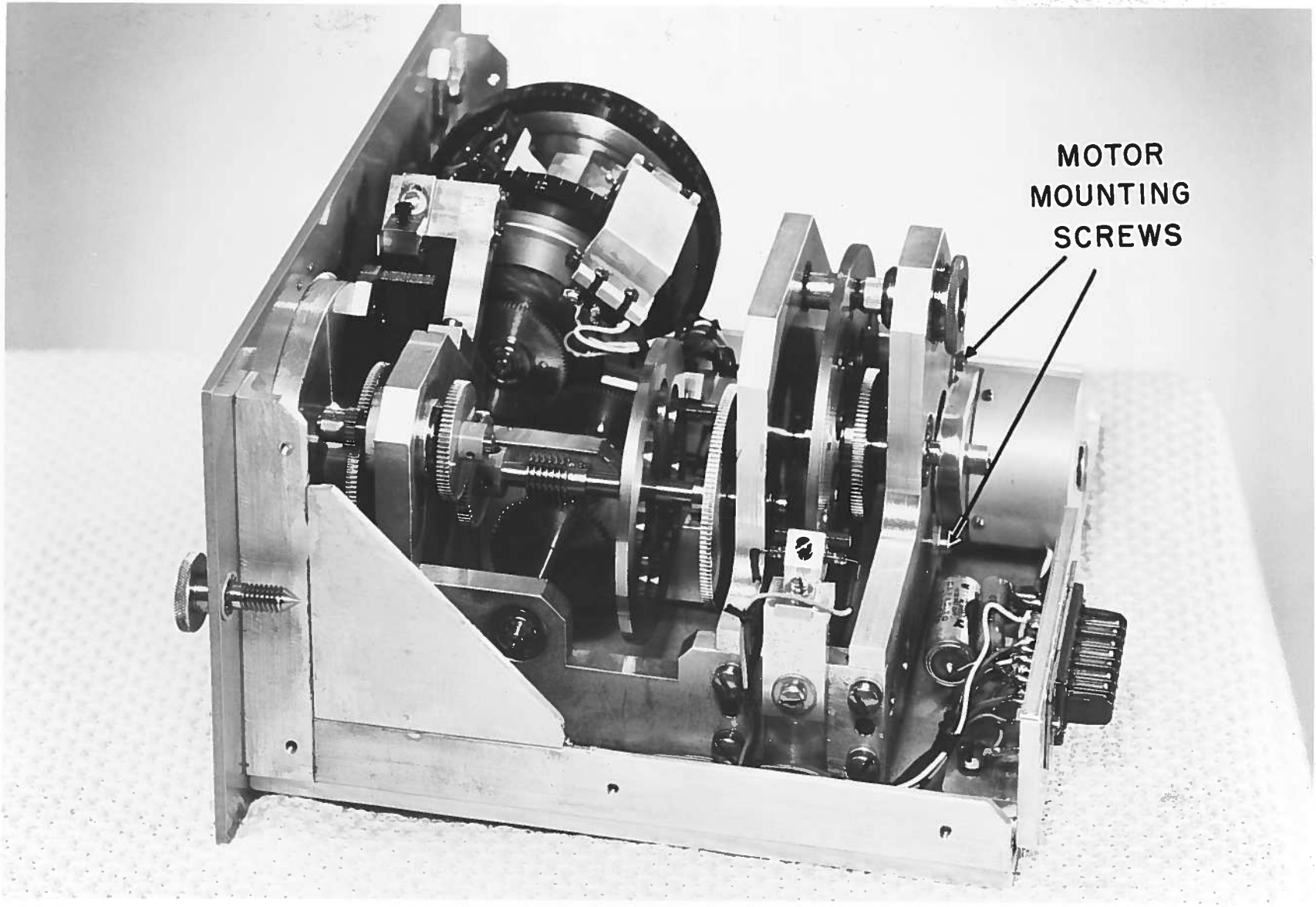

Plate IX — Right three-quarter view of Timer

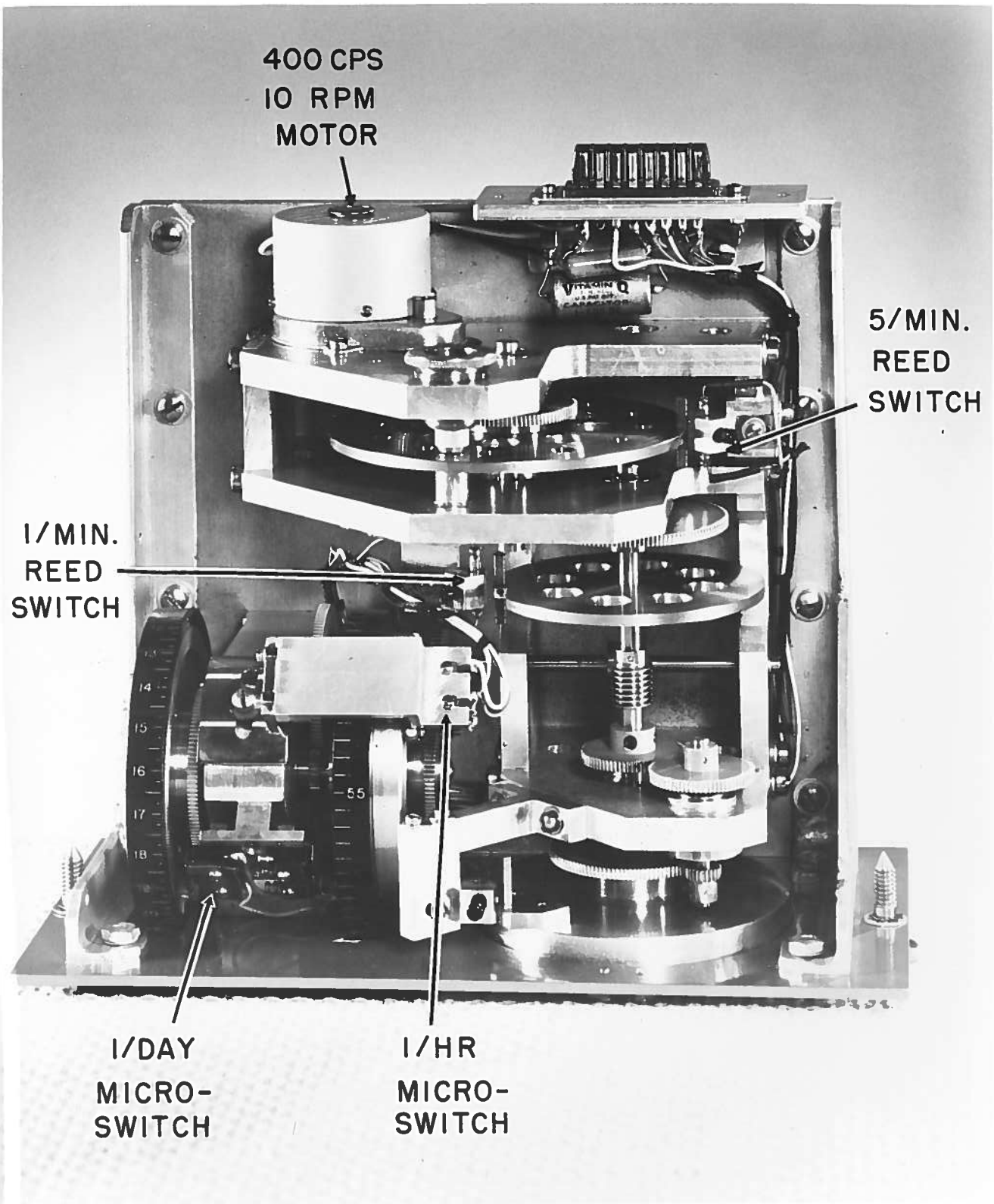

Plate X — Top view of Timer