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LONG-LIFE MECHANICAL CLOCK WITH MULTIPLE OUTPUTS

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OTTAWA

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ABSTRACT

A mechanical clock is described, which operates reed relays, microswitches, silicon controlled rectifiers, and Schmitt trigger circuits to provide output pulses at intervals ranging from 1 second to 24 hours. All outputs are gated back to the 1-second timing pulses and therefore have the same basic accuracy. The mechanical accuracy is better than ± 0.1 second; long-term accuracy is dependent entirely upon the accuracy of the ac power source for the drive motor.

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LONG-LIFE MECHANICAL CLOCK WITH MULTIPLE OUTPUTS

- L.R. McNarry -

INTRODUCTION

The clock described in this paper was designed to provide reliable, accurate pulses to operate timing devices for film-recorded meteor radar data(1), auroral photometers, and solar radiometers. The range of timing pulses required is from seconds, through minutes and hours, to one per day; the pulses are needed to provide timing marks on film and paper-chart records at both attended and unattended remote sites.

The relative accuracy of the timing pulses is determined by the mechanical accuracy of the clock. The absolute accuracy is determined by the ac voltage supplied to the drive motor. Where drifts of a few seconds per day can be tolerated, and independence of ac power sources is required, a battery-operated 400-Hz fork drive may be used. Where accuracy of the order of ± 1 second in 6 months is required, the ac can be derived from a secondary frequency standard. All timing pulses are gated by the 1-second pulses and so have the same absolute accuracy.

In summary, the requirements are that the clock will provide:

1) Timing pulses accurate to ± 0.1 second for all outputs

2) Pulses suitable for operating existing devices such as paper-chart marker pens

3) Pulses suitable for operating electronic marking devices such as brilliance markers on cathode-ray tubes

4) Mechanical reliability and long life without loss of accuracy

DESCRIPTION

The visual readout arrangement is shown in Plate I, the mechanical arrangement in Plate II. In Plate I the left hand drum rotates once per day, the right hand drum once per hour, the outer ring under the plastic indicator once every 5 minutes, and the inner dial once per minute. Controls for the electronic pulse generators are grouped to the right of the clock.

The mechanical gear train is shown in Fig. 1. The gear ratios are listed in the appendix. One-second pulses are generated by the sequential illumination of a photoconductive cell through ten holes in the 6 rpm disc. The 1-second pulses are then gated through the reed switches to the appropriate Schmitt trigger circuits, shown in Fig. 2.

Precision gears and sealed ball bearings are used throughout; the switches are magnetically controlled reed relays operating at essentially zero load for timing intervals of minutes or less, and microswitches for the hour and day functions. The life expectancy of the reed relays is greater than 10 years continuous operation. The timer outputs are listed in Table I.

TABLE I

Available Outputs from Mechanical Clock

OUTPUT	TYPE	SOURCE
1 per second	Pulse (±)	Photocell
1 every 10 seconds	Pulse (±)	Photocell via reed relay
1 per minute	Closed contact	Reed relays (8)
1 per minute (59th eliminated)	Closed contact	Heavy duty reed relays
1 every 5 minutes	Closed contact	Reed relays (4)
1 per hour	Closed contact	Microswitch
1 every 24 hours	Closed contact	Microswitch
Miscellaneous to operate lamps and counters	Capacitor discharge	Silicon-controlled rectifier

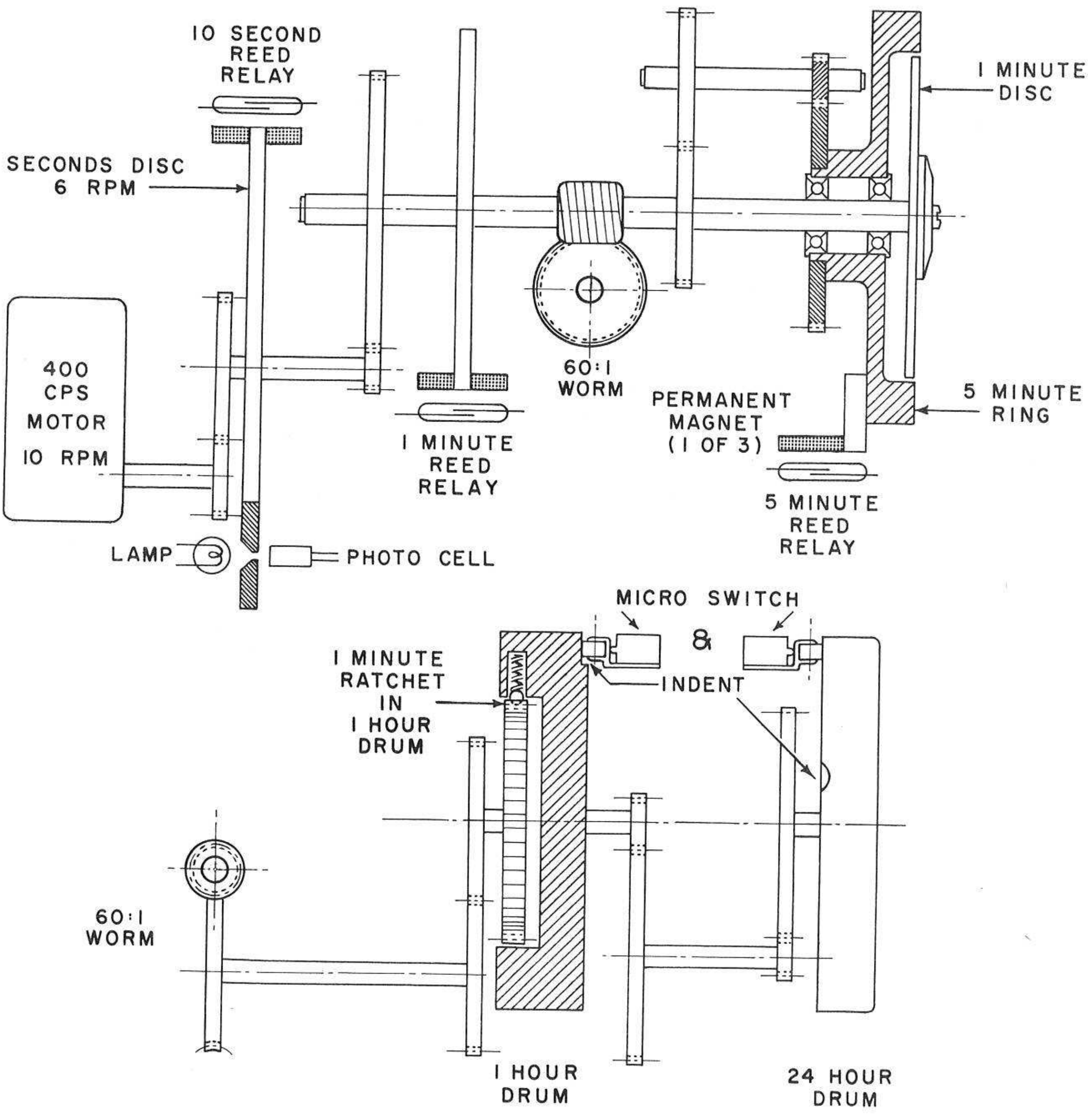

Fig. 1 Simplified mechanical diagram of gear train

In addition, all closed-contact outputs listed in Table I are available from a bank of controlled three-pole, double-contact plug-in relays having a current rating of 5 amperes for other users of the timing information. These relays are operated by capacitor discharge through reed relays in the circuits of the timer proper. Thus the accidental abuse of a timer output by one user does not affect any of the outputs to other users. The controlling reed relays open at very low voltage and current.

The 5-minute mechanically derived output can be easily modified for other time intervals such as 1.44 minutes, which is equal to one milliday. (Such a count enabled the entire IGY period to be tabulated by one 6-digit mechanical counter.)

The clock can be set at 5-minute intervals only. The 1-hour drum may be rotated in either direction against a mechanical ratchet in 1-minute steps. It must agree with the minute dials and if the clock is out by several minutes it must be set for the next 5-minute interval and then be started at the appropriate time. For fine adjustment of the time, a variable-frequency oscillator is used to feed the power amplifier and to drive the clock motor either fast or slow until the correct time is indicated. In the radio-astronomy application of this clock, the power amplifier is fed from a 400-Hz source derived from a crystal-controlled 100-kHz secondary frequency standard with an accuracy of one part in 10^{10}. When power interruptions occur, the clock drive circuits only are automatically connected to a 24-volt storage battery by a drop-out relay. The frequency standard has its own internal battery. Thus power failures of several hours duration do not result in any loss of primary time information.

PULSE GATING CIRCUITS

The pulse gating circuits are shown in Fig. 2. By gating backwards from the microswitches and/or reed relays having the longest closed times to the 1-second pips produced by the photocell circuit, it is possible to set up each timing interval so that the appropriate relay can be operated only when the entire chain of contacts is closed back to the 1-second Schmitt trigger. This is so up to and including the 24-hour relay.

For convenience in identifying hours, one set of heavy duty minute contacts has the 59th minute closing eliminated

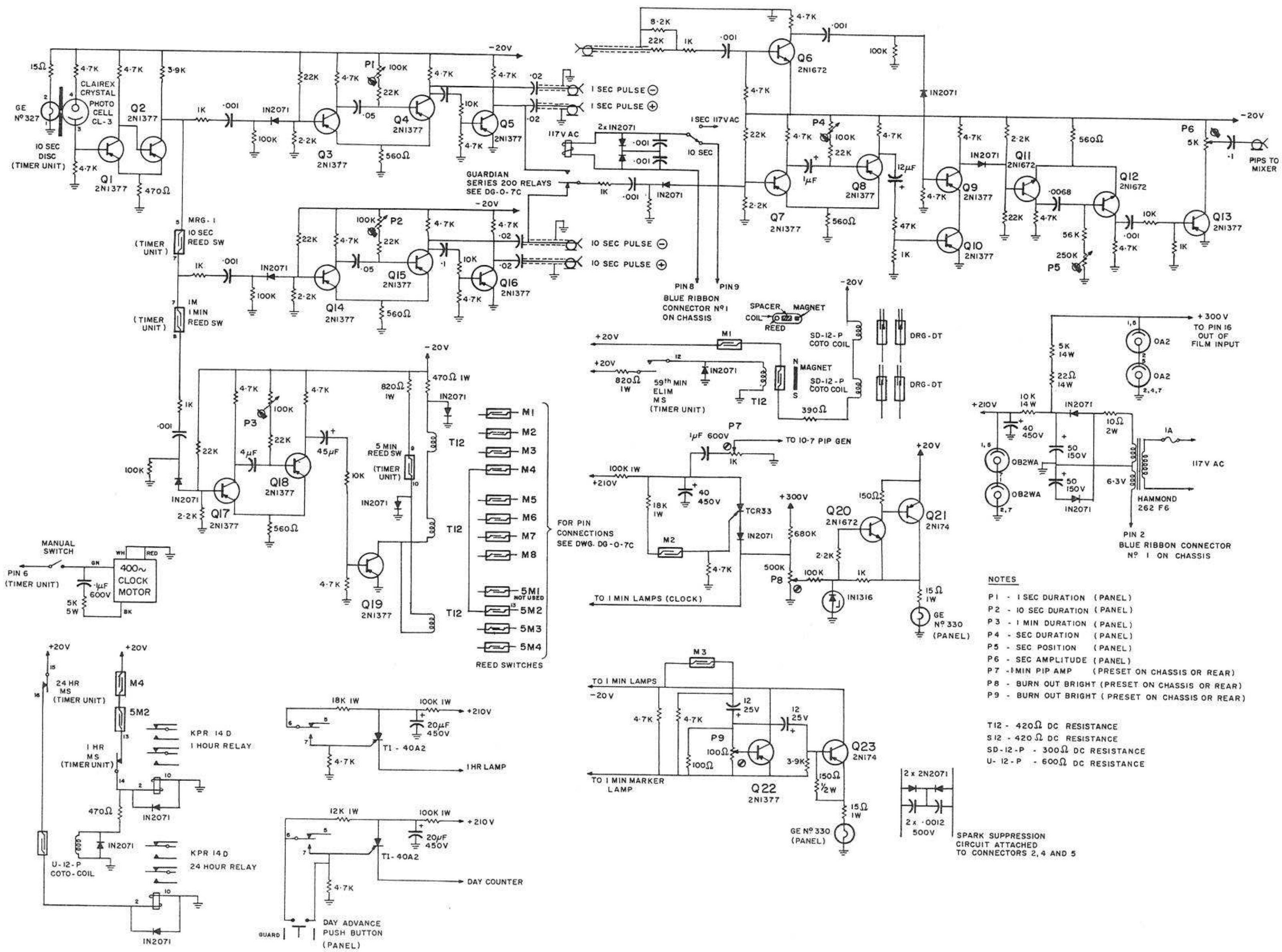

Fig. 2 Associated trigger and relay circuits

through the operation of an auxiliary microswitch actuated by the 1-hour drum.

The duration of the Schmitt trigger pulses is variable. In general, the duration used is 1 millisecond. The durations of both the 1- and 5-minute pulses are controlled by P_3 in the 1-minute trigger circuit.

It should be noted that the lamp illuminating the photocell to produce the 1-second pulses is a 28-volt lamp operated from a 20-volt supply through a 15-ohm resistor, thus ensuring very long life for this lamp.

Several of the circuit details in Fig. 2 are applicable to a particular requirement of the timer application and are not directly related to the function of the timer.

DRIVE CIRCUITS

While a 400-Hz source is used to power the timer, any other suitable combination of power frequency and drive motor may be substituted. If possible power failure is not a problem and extreme precision is not required, then the most simple drive circuit is the 60-cycle mains supply.

A simple 400-Hz fork drive circuit and variable frequency oscillator were used for several years to drive this timer unit. Recently, a precision divider using integrated circuit elements has been built to derive 400-Hz from a 100-kHz secondary frequency standard. This circuit and the 400-Hz fork (now used as a back-up) are shown in Fig. 3. It has not been necessary to reset the clock since this circuit was installed.

PERFORMANCE

The mechanical portion of the clock has now been in continuous use for four years. The only failure has been one reed relay which had a tendency to remain stuck in the closed position. The drive motor and the seconds illuminating lamp have each been replaced once. Otherwise the unit has given no trouble of any kind. Initially, some of the gears were secured by set screws in the gear hubs. It was found that these had a tendency to loosen slightly so all gears were pinned to the shafts to permanently fix the mechanical synchronizing of the timer.

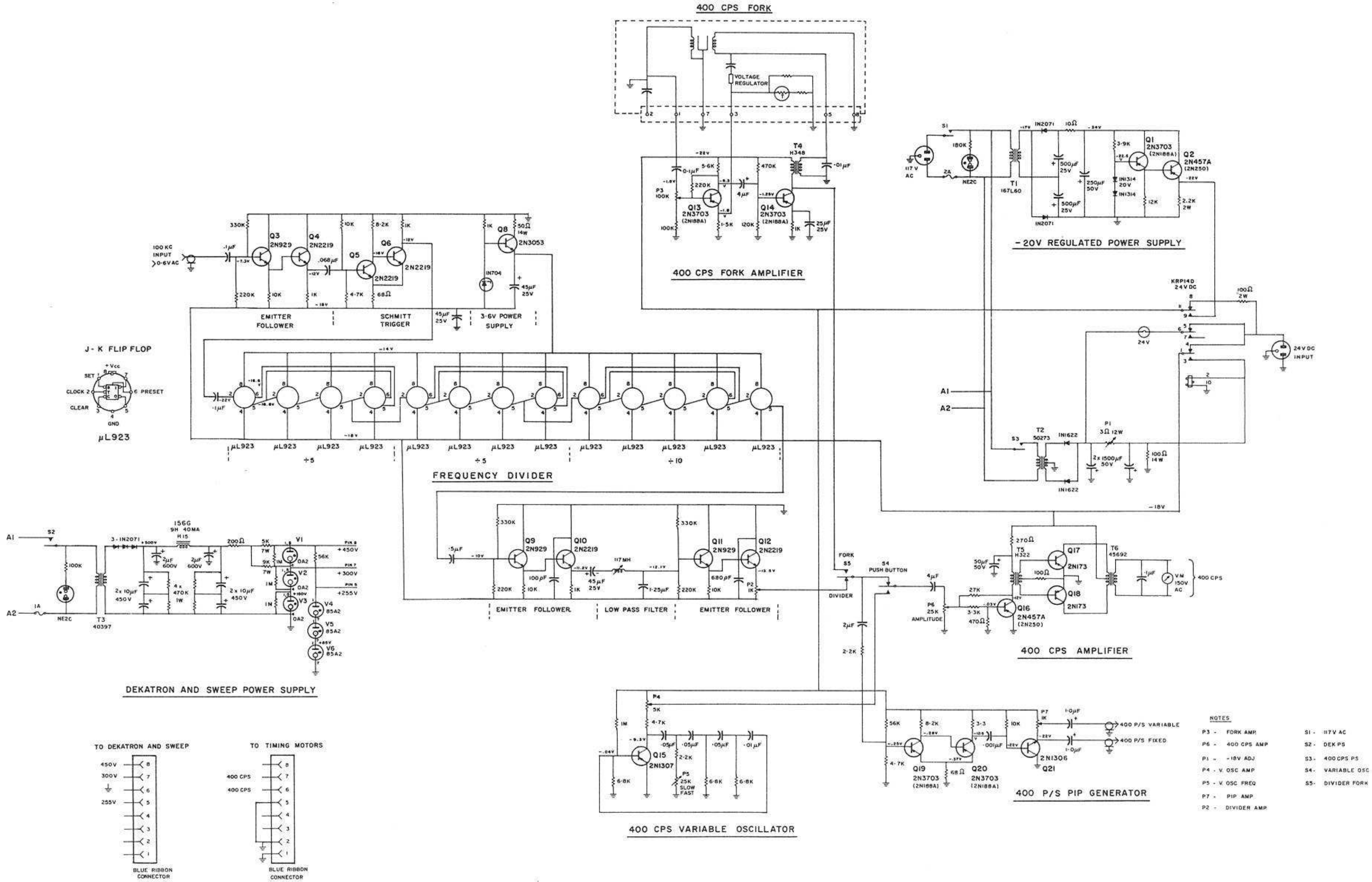

Fig. 3 400-Hz divider from 100-kHz secondary-standard oscillator, variable-frequency oscillator, and power amplifier

Other units are in service in the Canadian Arctic, and at Byrd Station in the Antarctic as well as at other research field stations in Canada. All are giving essentially trouble-free service.

ACKNOWLEDGMENTS

Particular thanks are due to Mr. M.J. Neale for many hints based upon his long experience with timing problems as well as to Mr. Z. Mordasewicz and Mr. D. Hoey for the excellence of the mechanical design. Thanks are also due to Mr. B.E. Bourne and Mr. W.P. Gilchrist for design of the associated electronic circuits.

REFERENCE

1. M.J. Neale Radar equipment for continuous meteor observations. Can. J. Phys. 44: 1021; 1966

APPENDIX

GEAR RATIOS (given in teeth per gear)

FROM		TO		
10-seconds shaft	24T	minute shaft	144T	
minute shaft	60:1 worm	hour shaft		
hour shaft	84T	hour drum	84T	
hour drum	28T	idler shaft	112T	
idler shaft	20T	24-hour drum	120T	
(auxiliary ring dial for 5, 2, or 1.44 minutes per revolution)				
minute shaft	72T	idler shaft	72T	5 minutes per revolution
idler shaft	24T	5-minute ring	120T	
minute shaft	72T	idler shaft	72T	2 minutes per revolution
idler shaft	48T	2-minute ring	96T	
minute shaft	60T	idler shaft	72T	1.44 minutes per revolution
idler shaft	60T	1.44-minute ring	72T	

NOTE: The motor drive ratio depends upon selection of motor.
All gears are 64 pitch, 20° pressure angle.

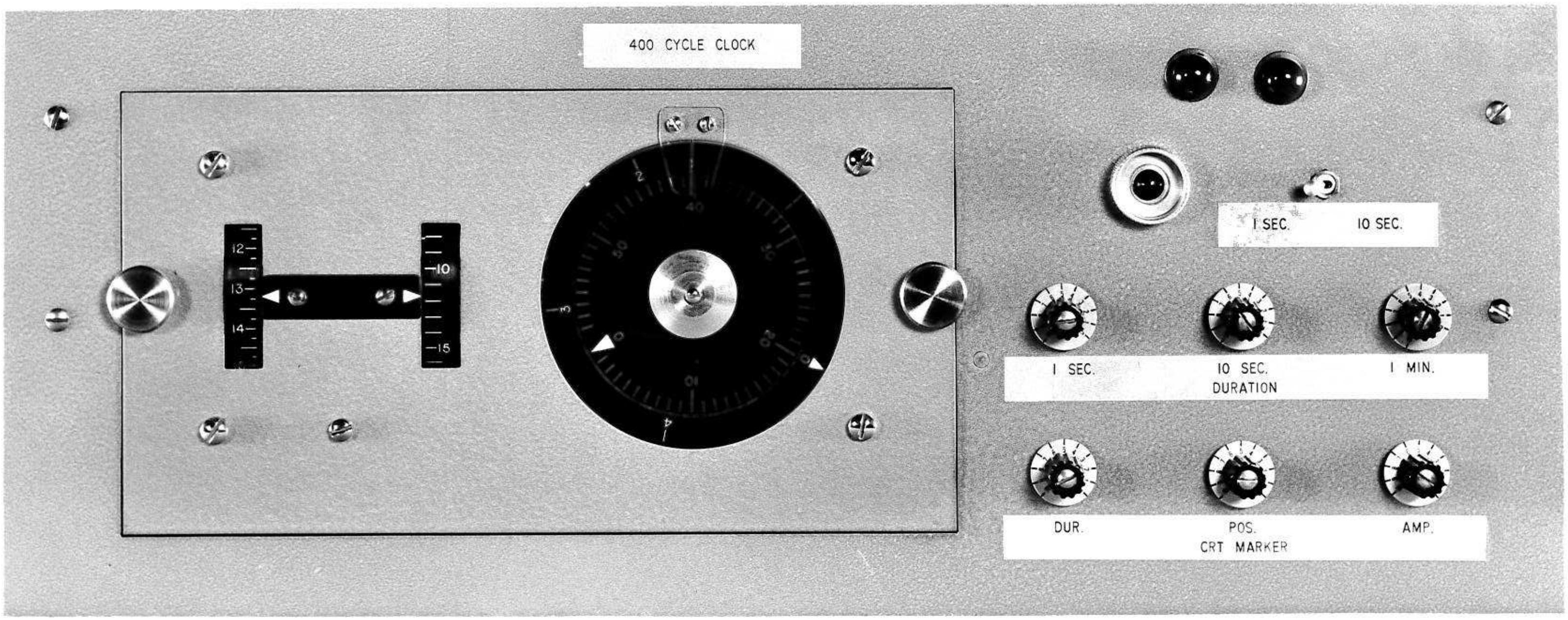

Plate I   Front panel of clock

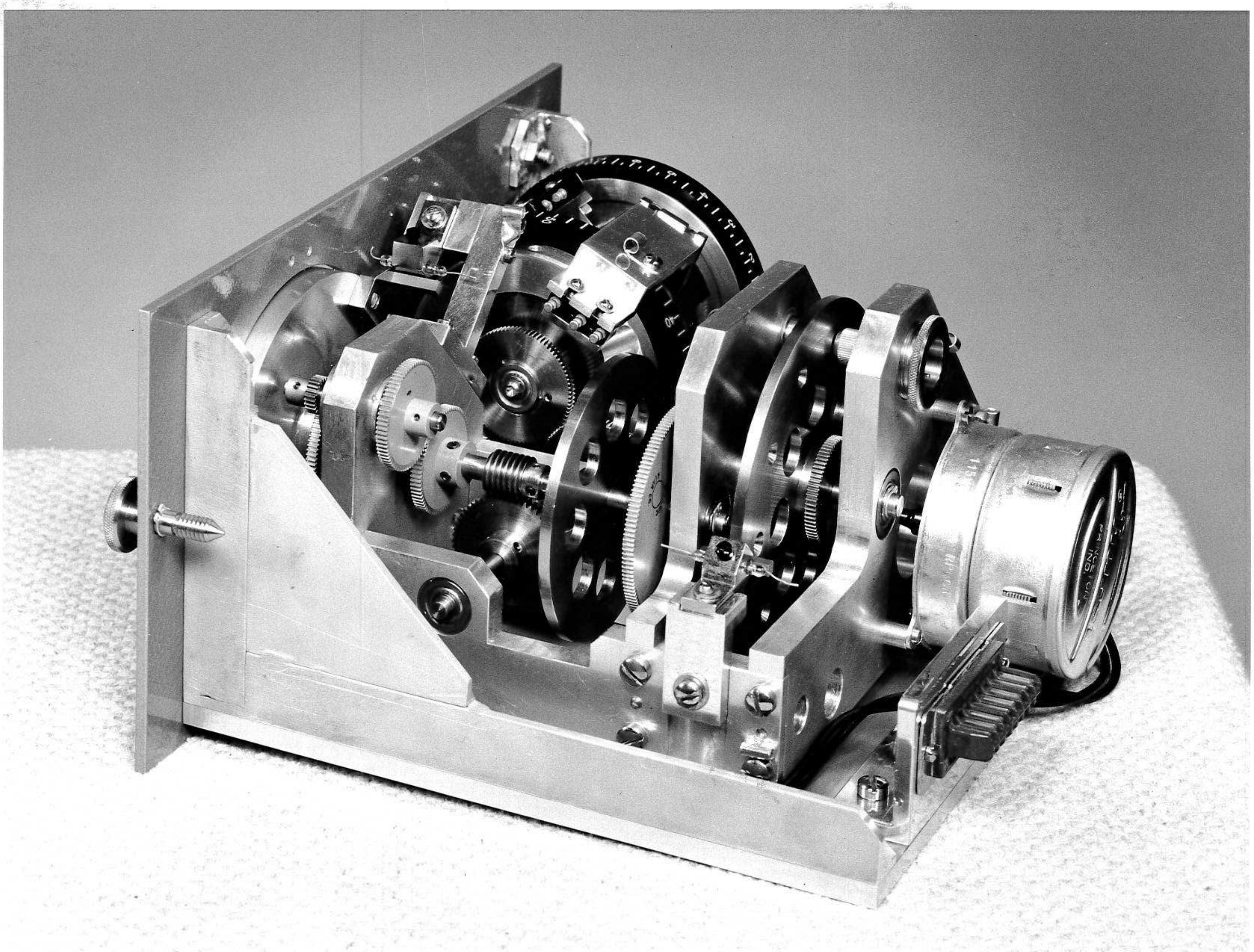

Plate II   Three-quarter view of clock mechanism