

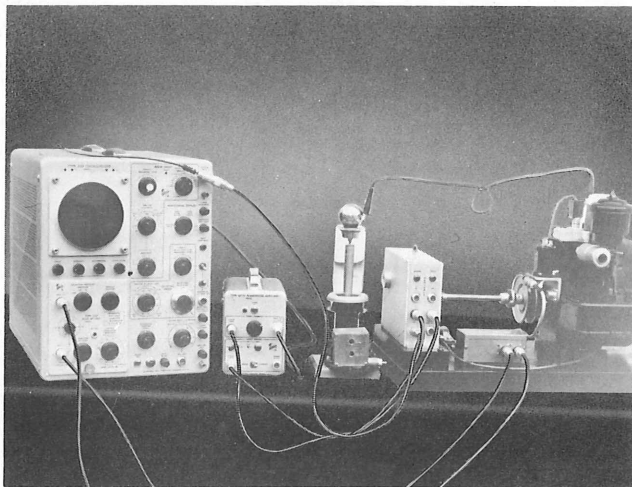
# ROTAN

A DYNAMIC ANGULAR TRANSDUCER FOR OSCILLOSCOPE DISPLAY OF ROTATION-RELATED PHENOMENA

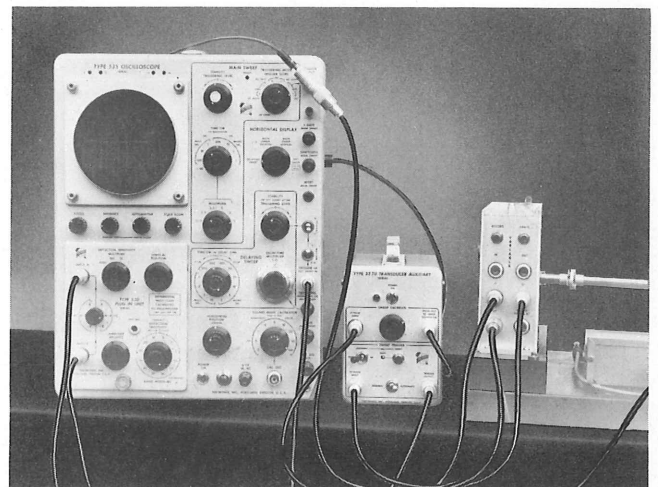
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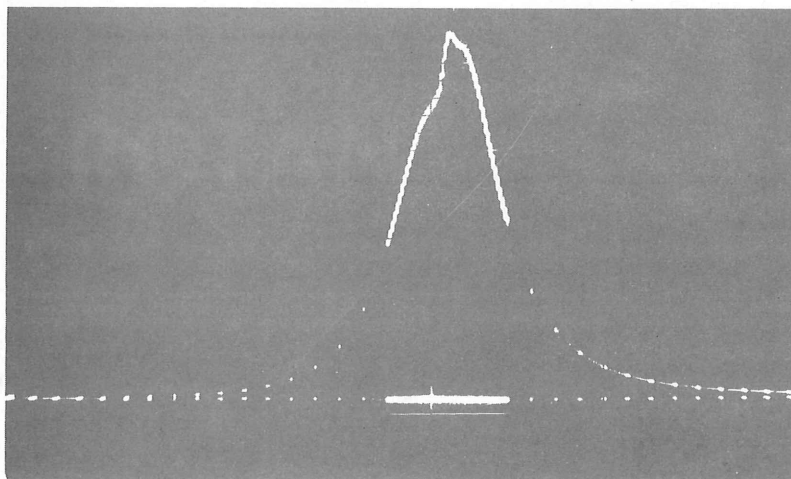
GEORGE EDENS  
CENTRAL DIVISION MANAGER  
TEKTRONIX, INC.



ROTAN and 535 Oscilloscope arranged to display 4 cycle engine data vs crank angle. Engine is instrumented for cylinder pressure, vibration, and ignition measurements.



The two units comprising the ROTAN connected to the oscilloscope. Shaft couples to machine under observation.

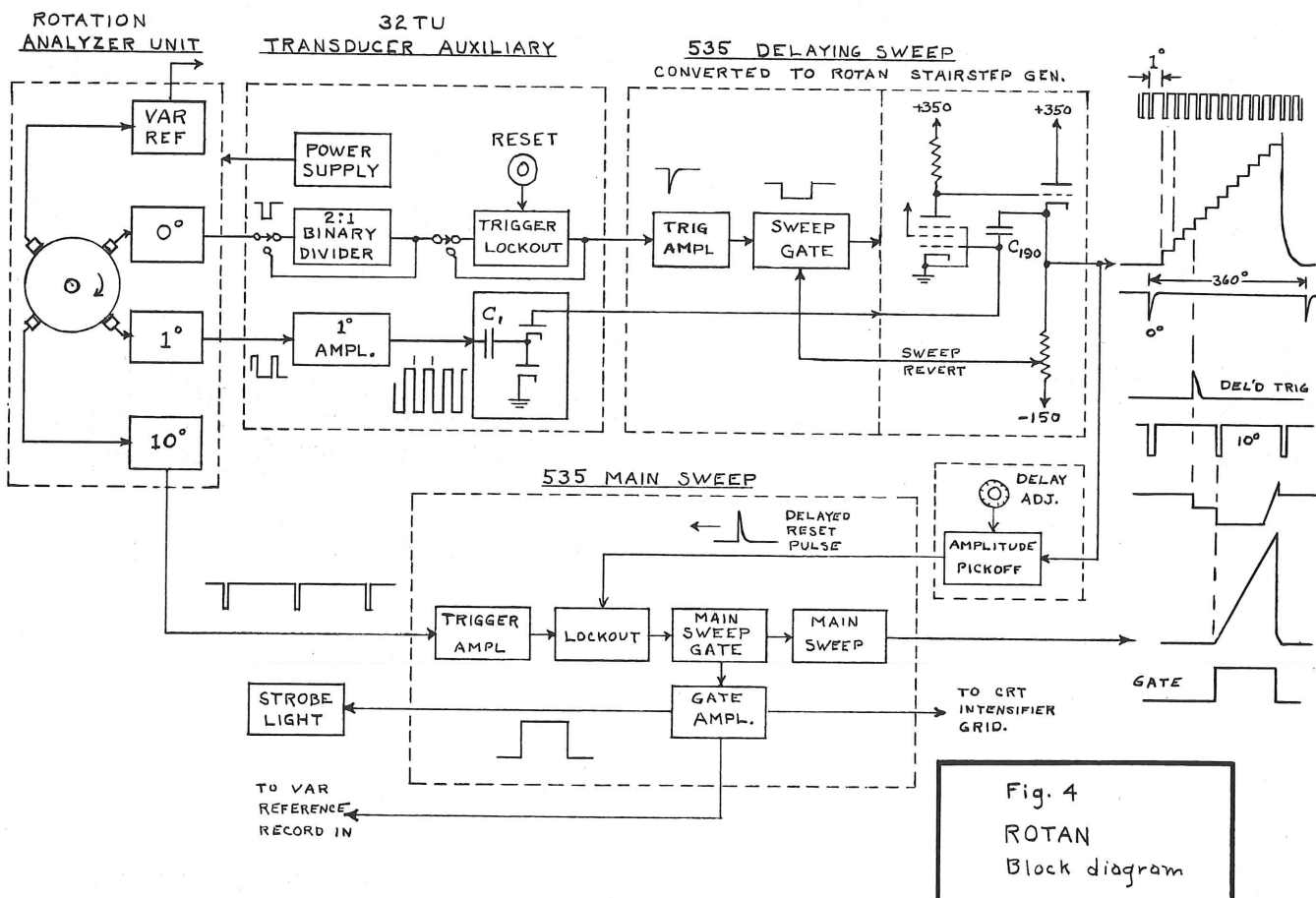


## A TYPICAL ROTAN APPLICATION

ROTAN display of diesel engine cylinder pressure vs crank angle.

ABOUT THE COVER:

The end result of a typical ROTAN application is summed up nicely in the bottom photo. Here, the cylinder pressure in a diesel engine is plotted on the Y-axis as a function of the crank rotation. The solid curve represents the cylinder pressure during a 50 degree segment of the crank rotation beginning 20 degrees before top center. The brightened spots (intensity markers) preceding and following the curve indicate 10 degree points of crank rotation.



## GENERAL

An angular transducer instrument system for studying rotation-associated phenomena in machines.

### WHAT IT IS

The Rotation Analyzer and its companion Type 32TU Transducer Auxiliary adapt an oscilloscope to create a horizontal sweep deflection which follows the angular displacement of a rotating shaft. The shaft under observation is thus made to generate a sweep concurrent with its angular motion. Speed range of 150 to about 10,000 rpm is accommodated without adjustment.

### WHAT IT DOES

A single-shot trigger feature facilitates photography of a display during one single period of revolution. Also a strobe light may be flashed in synchronism with the shaft rotation at any 1 deg. point in its revolution.

Magnetic pickup heads in the Rotation Analyzer unit detect the passage of markers recorded at 1 deg., 10 deg., and single turn intervals on the peripheral surface of a 3 inch magnetic drum. The markers are amplified by transistor circuits within the unit to form 10- and 15-volt pulses of relatively short risetime. The 0 deg. (single turn) pulses activate the oscilloscope sweep circuits to permit acceptance of the 1 deg. pulses.

### HOW IT WORKS

The 1 deg. pulses are further amplified and standardized to a 50-volt peak-to-peak amplitude. Then they are passed to the storage capacitor in the oscilloscope sweep through a capacitor and switching diode. The two capacitors and the diode are elements of a "ladle and bucket" staircase voltage generator. Circuit constants are selected to generate full CRT deflection in the desired number of 1 deg. steps, usually 360.

## SYSTEM COMPONENTS

### ROTATION ANALYZER UNIT

The unit is made up of the rotating magnetic drum assembly and transistor marker-amplifier circuitry contained within a rugged case suitable for mounting on or near machinery.

A magnifying lens and internal illumination allow viewing of a mark scribed into the rim of the drum at the 0 deg. reference point.

### MAGNETIC DRUM ASSEMBLY

The four-track magnetic drum assembly is described by the following specifications:

Drum - 3" x .0680", 2024 aluminum.  
0.060" wide x 0.010" deep slots  
are milled between 0.125" tracks.  
Surface is anodized and spray  
coated with 0.0015", 3M magnetic  
dispersion.

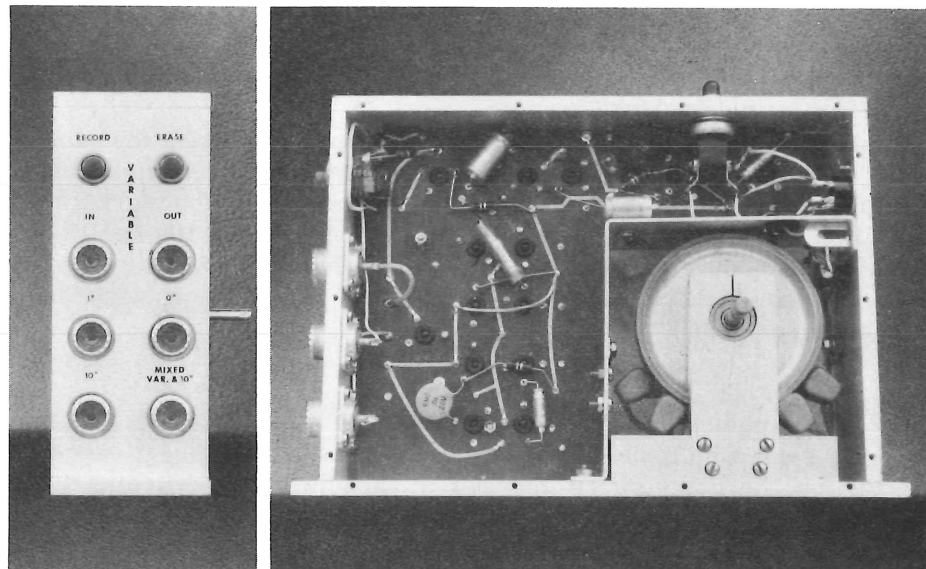


Fig. 5. Left: Panel View of ROTAN unit. Right: Magnetic drum assembly and amplifier circuit board.

Heads - Maico 8003 erase, 0.125'' track,  
0.003'' air gap, 0.001'' clearance.  
125 ohms DC resistance, 50 mh.

Bearings - New Departure 77R4A.

Shaft - 0.250'' with 0.500'' collar.

Assembly is fitted to close tolerances to maintain the  
0.001'' head clearance.

**1 DEG., 10 DEG., AND 0 DEG. REFERENCE MARKERS:** Four transistor marker amplifiers are contained within the unit. These are 1 deg., 10 deg., 0 deg., and a variable reference marker channels.

**TRANSISTOR  
MARKER AMPLIFIER**

The 10 deg. and 0 deg. markers are recorded coincident with their respective 1 deg. markers. Operating characteristics of the amplifiers are designed to maintain coincidence between these markers at all operating speeds. Output pulses from the 1 deg. channel are 10 volt positive pulses beginning at -10 volts and rising to ground potential. All other markers are 15 volt negative pulses beginning at +5 and falling to -10 volts. Transition time of the leading edge of all pulses is 1 to 2  $\mu$ s. Schematic circuit diagrams of the amplifiers are shown in Fig. 11.

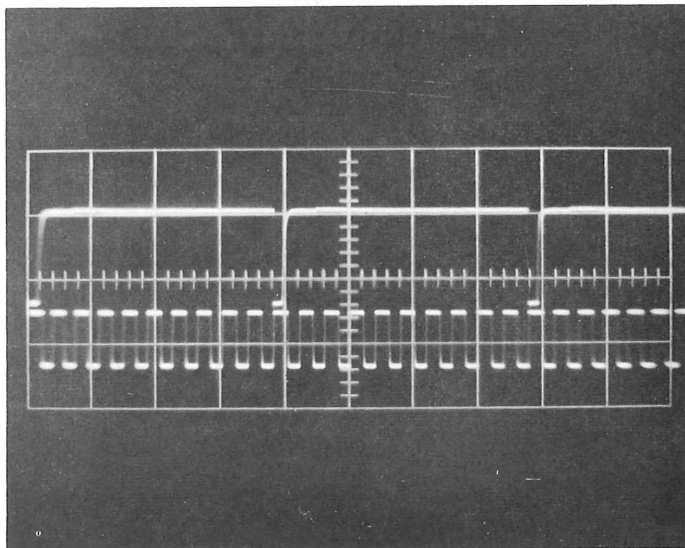


Fig. 6. 10-degree and 1-degree markers from  
ROTAN unit. Vertical calibration: 10 v/cm.  
Sweep rate: 100  $\mu$ sec/cm.

**VARIABLE REFERENCE CHANNEL:** Occasionally it will be desirable to create a reference marker at some point on the drum other than at 0 deg. This can be handled by the fourth track and its associated circuitry without stopping rotation.

Because the Main-Sweep Plus Gate on a 535 or 545 may be initiated by the Delay Pickoff at any 1 deg. point in the stairstep, it is a ready source of signal for recording the Variable reference mark.

To avoid the long delay which would result from using the negative swing of the Variable-pickup output pulse, the Variable amplifier is arranged to amplify the positive portion of the pulse.



Fig. 7. Type 32TU Transducer Auxiliary.

**TRANSDUCER  
AUXILIARY**

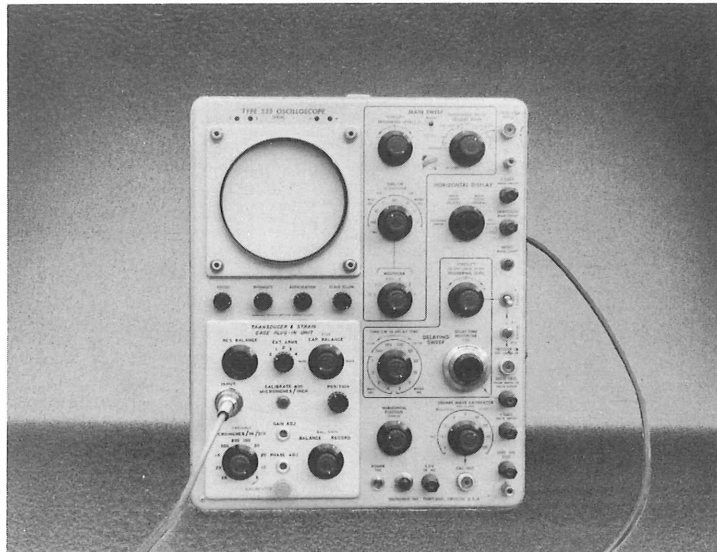
The Type 32TU performs four functions in the ROTAN system. These are:

1. Supplies power at +5 and -10 volts to the transistor marker amplifiers.
2. Amplifies and standardizes the 1 deg. markers to precisely constant amplitude pulses of about 50 volts peak-to-peak for linearly driving the stairstep sweep in the oscilloscope. Means for coarse and fine sweep calibration are provided in the Type 32TU.
3. Divides the 0 deg. (single turn) reference marker rate by two, assuring consistent display of the desired cycle of a 4 cycle engine.
4. Trigger lockout circuitry allows the operator to initiate single sweeps for photographic purposes.

The Tektronix Miller run-up sweep circuits are well suited to the purpose of stairstep-waveform generation. A minor change in the grid circuit of the sweep-generator tube adapts the oscilloscope to receive the ROTAN pulses.

For the most versatile instrumentation the Type 535 or 545 oscilloscope is recommended. Conversion of the Delaying Sweep in these oscilloscopes to generate the ROTAN sweep leaves the Main Sweep in normal operation. It is frequently convenient to use the Main Sweep for display of selected segments of the ROTAN sweep.

Installation of a closed circuit jack as shown in the Appendix allows normal operation of the oscilloscope for other purposes. Insertion of a plug into the jack instantly adapts the Delaying Sweep to the ROTAN system. Instructions for installation of the jack are given in the Appendix.



**Fig. 8.** Type 535 Oscilloscope. One type which can be used with ROTAN.

Less elaborate oscilloscopes such as the 310, 515, 532, and 533 can also be adapted readily.

The schematic diagram of the oscilloscope sweep circuitry affected by the ROTAN adaptation is shown in Fig. 14.

Mounting fixtures, anticipated vibration, and angular acceleration of the shaft to be observed determine the degree of difficulty associated with mounting the Rotation Analyzer unit and coupling it to a shaft.

Attaining alignment of the two shafts is a problem in most coupling situations. Rigid couplings should be avoided because misalignment can place large radial and thrust loads on the bearings. The Naugler Engineering couplings shown accommodate some misalignment and without appreciable angular rotation error. Other types of flexible couplings may be successfully used. Some torsional oscillations will occur under angular accelerations depending upon the flexibility and damping factor of the couplings. The couplings shown have proven satisfactory in engine testing work. Two couplings with a short extension shaft in between can accommodate rather large misalignments and relative motion between units without danger of damaging the bearings.

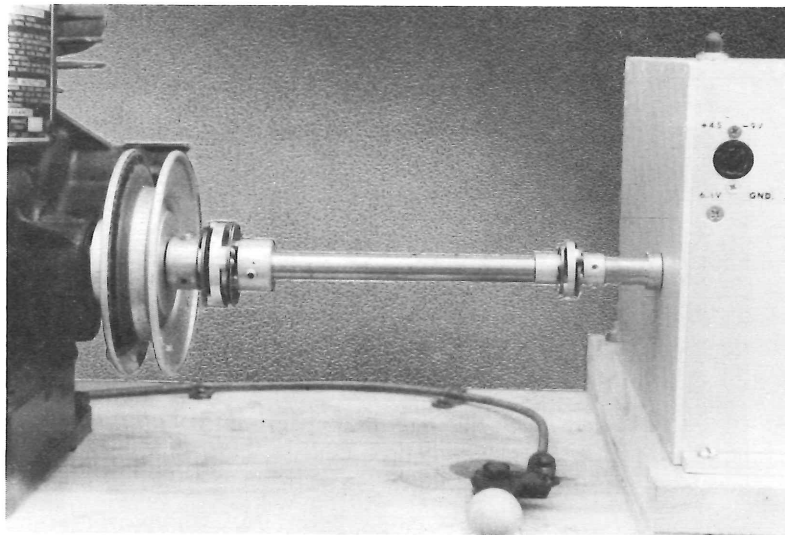


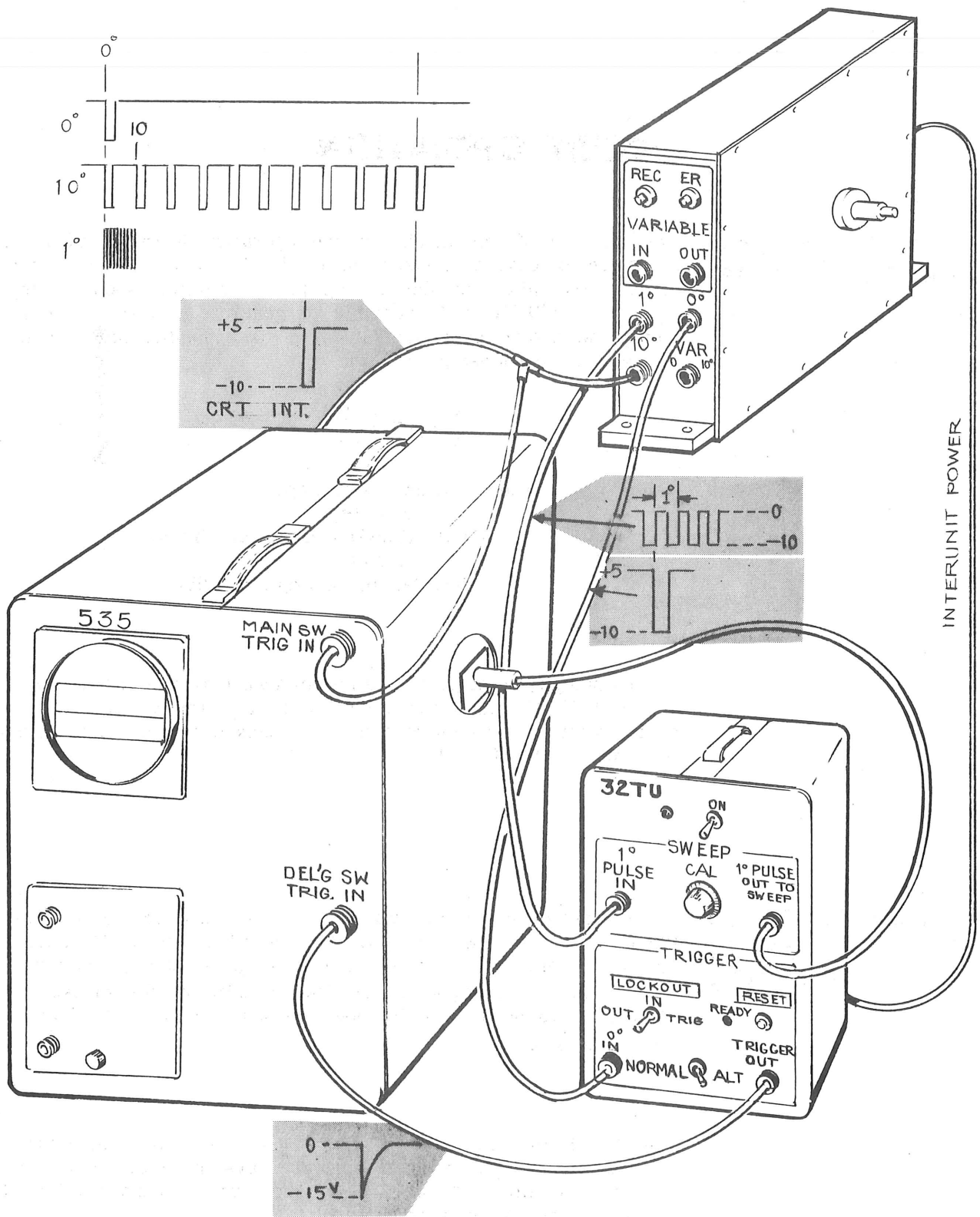
Fig. 9. Special flexible couplings used to accommodate shaft misalignment with minimum angular error.

## CABLING

Basic cabling necessary for operation of the ROTAN system is shown in the cabling sketch, Fig. 10. Connections are shown for triggering the Delaying Sweep (stairstep sweep-voltage generator) and 1 deg. driving pulses to the stairstep generator. The 10 deg. markers connected to Main Sweep trigger and to the CRT intensifier terminal are not vital to the sweep operation. However, the 10 deg. markers are extremely helpful coarse divisions from which to count 1 deg. marks. When segments of the sweep are to be displayed, reliable stability of the Main Sweep starting point can be established by triggering the Main Sweep from a 10 deg. marker. The 10 turn helipot delay control is used to select the desired 10 deg. marker.



Fig. 10 ROTAN Cabling.



## CIRCUIT OPERATION

### OSCILLOSCOPE ANGULAR SWEEP

The essence of the angular sweep operation is that a standardized increment of charge is placed upon C190 by each 1 deg. pulse applied at C1. By adjusting the 1 deg. pulse amplitude and selecting the ratio of C190/C1 it is possible to generate a stairstepping sweep voltage waveform consisting of any desired number of 1 deg. increments. The relationship is:

$$n = \frac{v}{e} = \frac{v}{E} \times \frac{C190}{C1}$$

where n=numbers of steps

e=size of step

v=total sweep voltage amplitude  
about 140 volts

E=1 deg. pulse amplitude, 55v

The stepping type integration is initiated when a 0 deg. marker triggers the SWEEP GATE. Integration ceases and the voltage falls to the origin when the sweep-reverting feedback signal is large enough to turn off the SWEEP GATE.

### ROTATION ANALYZER AND MARKER AMPLIFIERS

Pulses read out by the magnetic pickup heads range in amplitude from 20 mv at low speed to 300 mv at high speed. The transistor marker amplifiers saturate the last stage in each channel over the signal ranges mentioned. The leading edge of the marker pulses closely correspond with the negative zero crossing of the pulse at the pickup head.

Random jitter measurements of the 1 deg. output pulses made at constant drum speed indicate an overall system incremental accuracy of plus or minus 2% of 1 deg. The 2 microsecond risetime of the markers assures high marker resolution.

## **32 T U TRANSDUCER AUXILIARY**

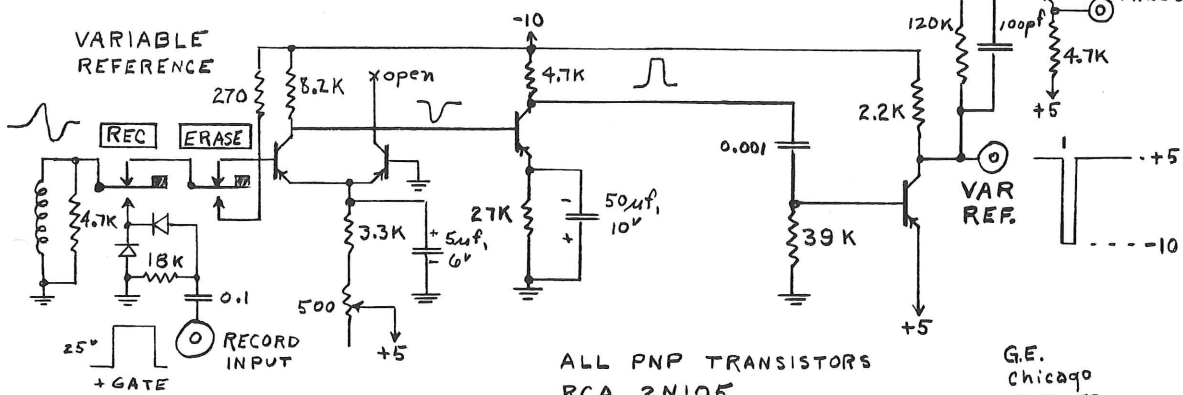
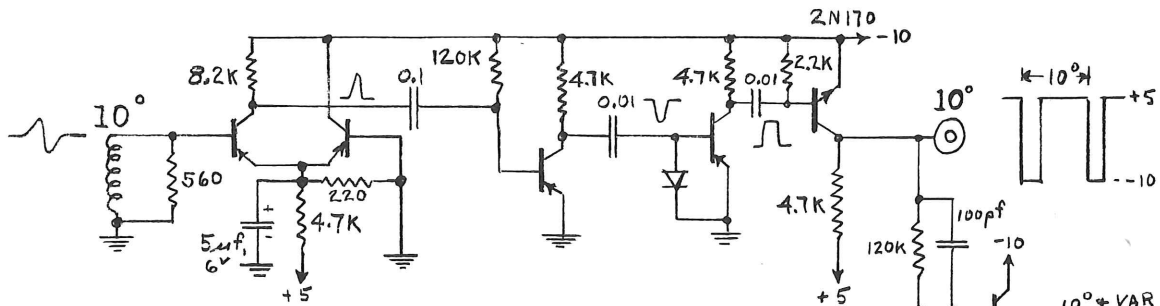
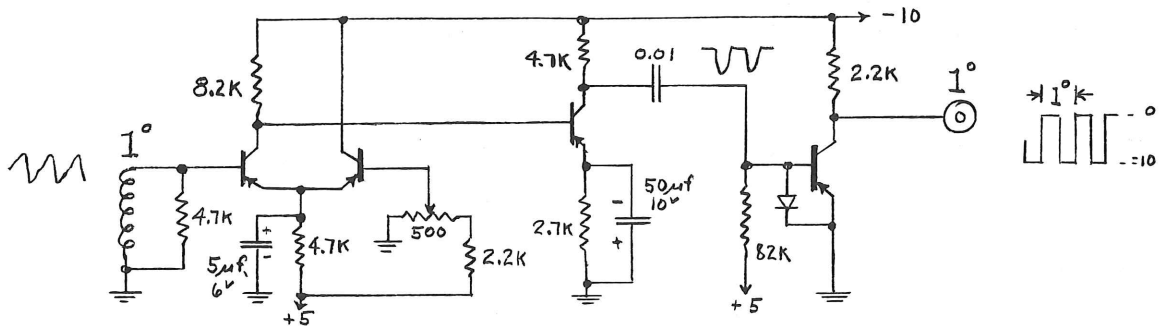
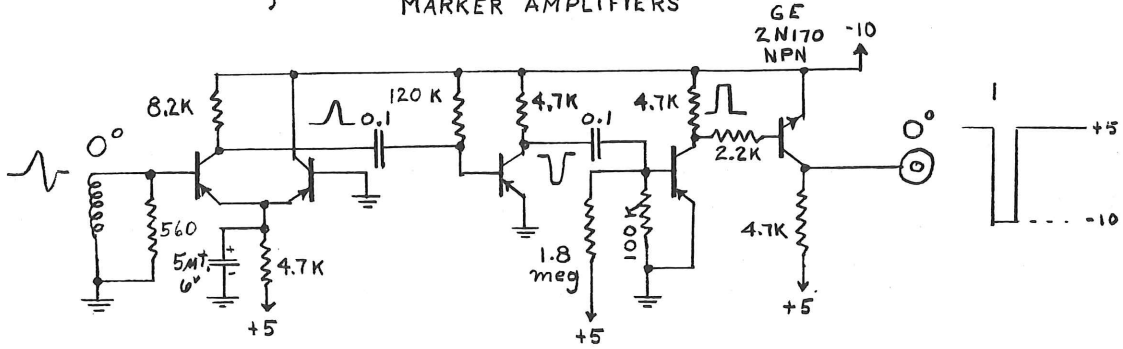
0 deg. pulses may be fed straight through the 32TU to recurrently trigger the angular sweep generator in the oscilloscope. At times it will be desirable, as in testing four-cycle engines, to accept only every other 0 deg. trigger. Once started on the compression stroke, for example, the binary trigger multivibrator will continue in the same mode, delivering an output 0 deg. pulse only on compression strokes.

Single sweeps are often needed to photograph waveforms containing random variations. When it is switched into the circuit, the 2D21 generates a lockout gate which blocks all succeeding 0 deg. pulses after the first one has entered via the momentary trigger switch.

1 deg. pulses are amplified by the 6U8 pentode and used to operate the 2N398 as a switch. Turning completely ON and OFF, the 2N398 chops the emitter supply voltage to produce uniform pulses. The 6U8 triode section accurately stabilizes the emitter supply voltage at about 55 volts.

The potentiometer and variable trimmer capacitor serve as sweep calibration controls by allowing E and C1 to be varied.

Fig. 11 ROTAN  
MARKER AMPLIFIERS

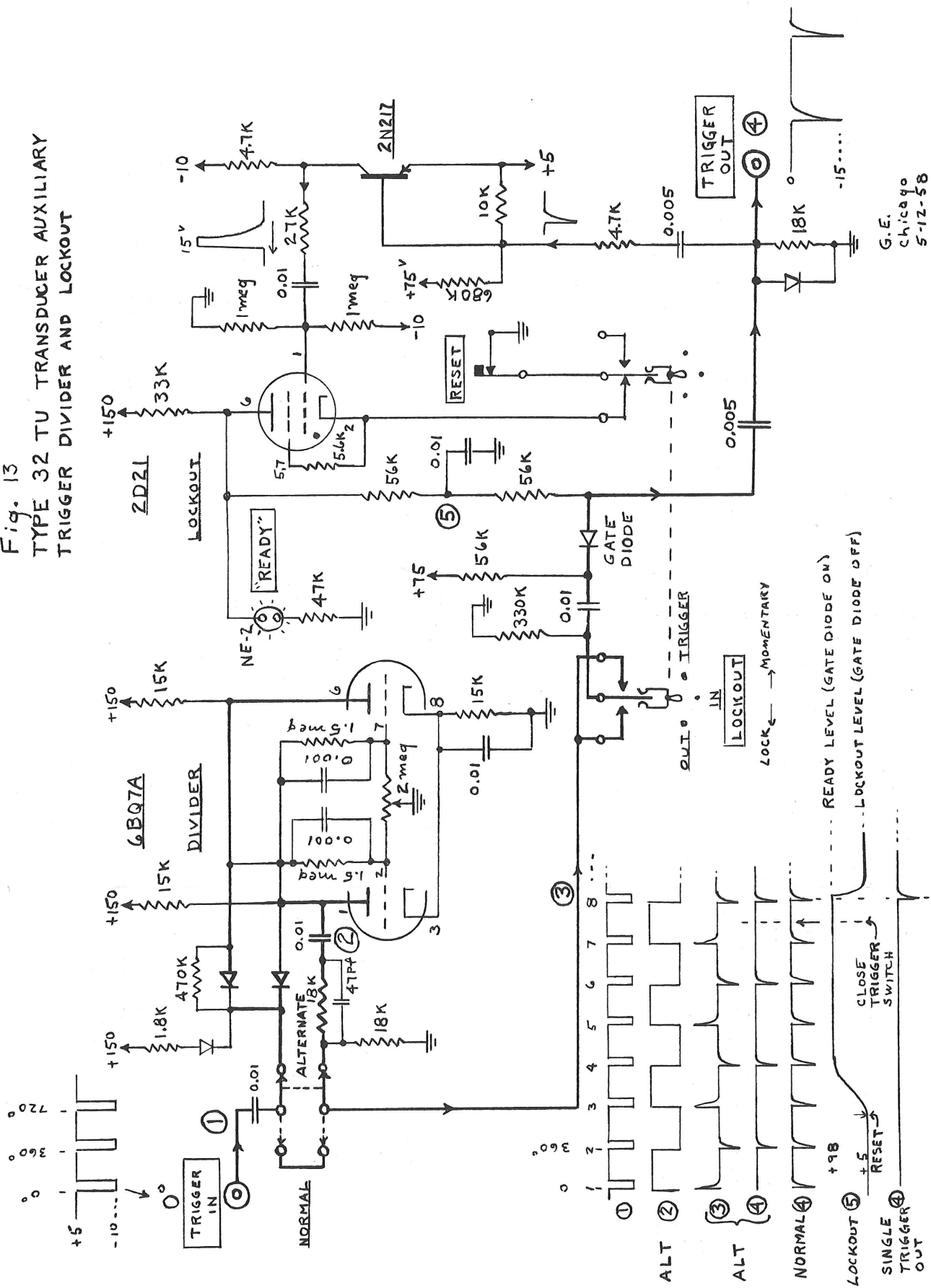


ALL PNP TRANSISTORS  
RCA 2N105

G.E.  
Chicago  
5-12-58



Fig. 13  
 TYPE 32 TU TRANSDUCER AUXILIARY  
 TRIGGER DIVIDER AND LOCKOUT



G.E.  
 Chicago  
 5-12-58

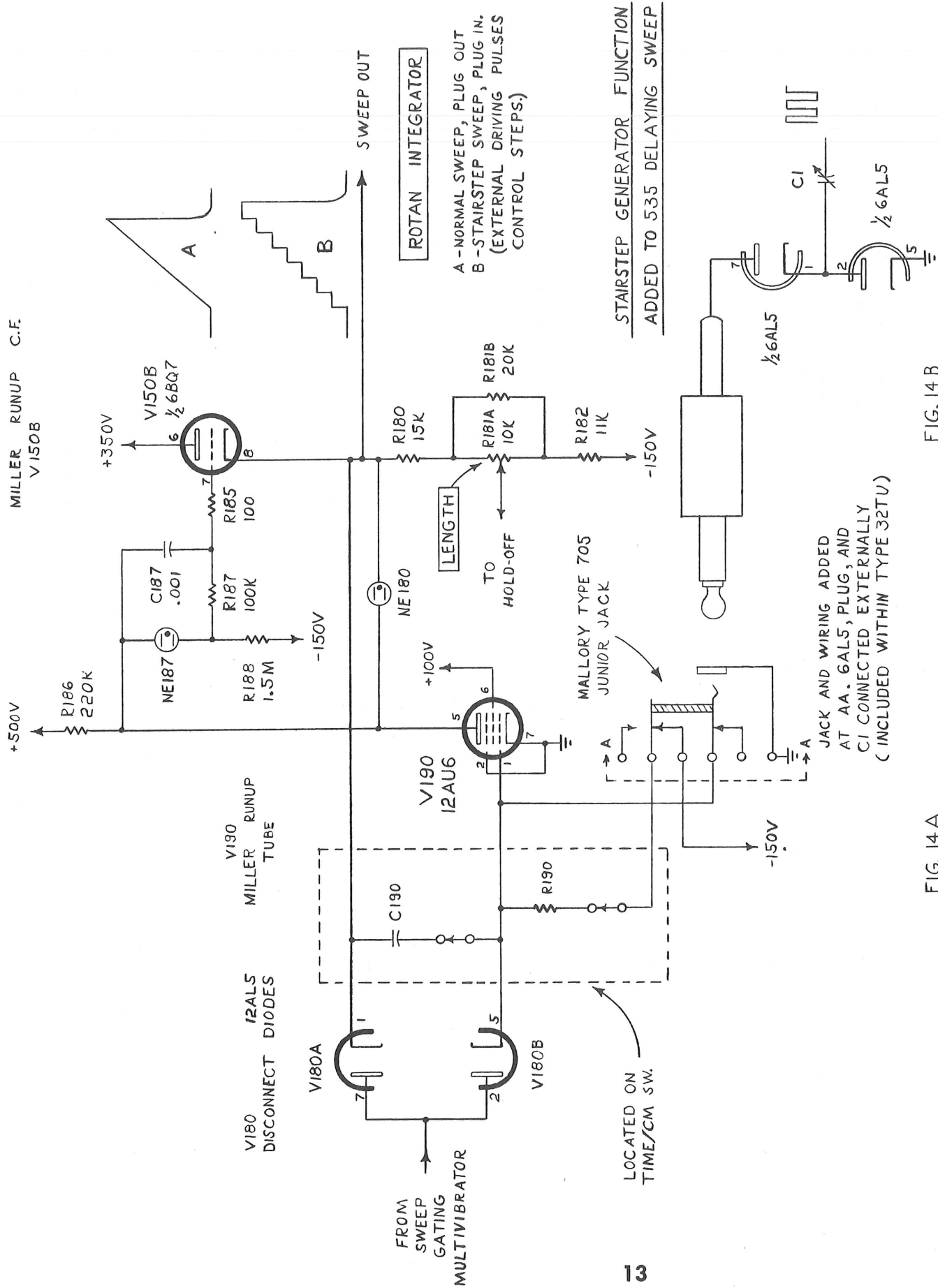


FIG. 14 B

FIG. 14 A



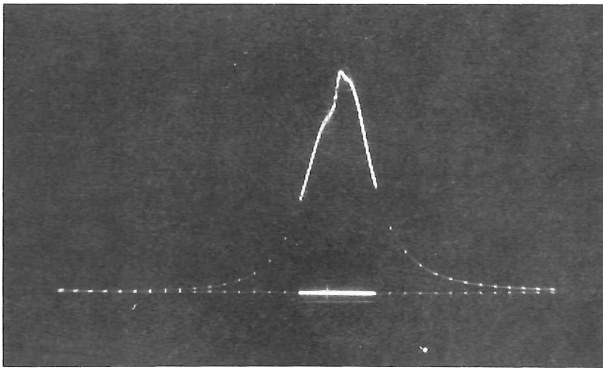


## **APPENDIX**

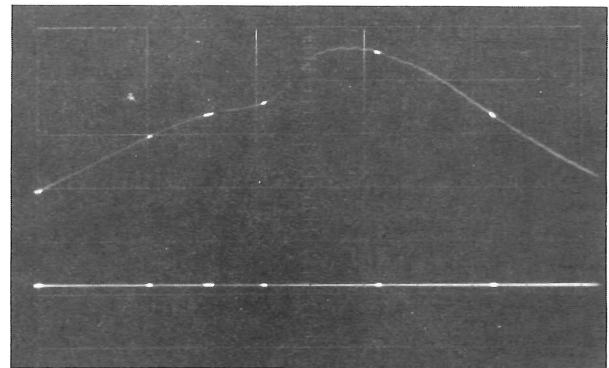
<b>TYPICAL ROTAN DISPLAYS</b>	<b>I</b>
<b>MODIFICATION OF TYPE 535/545 OSCILLOSCOPE FOR ROTAN SWEEP</b>	<b>II</b>
<b>THE GENERAL RADIO 648-A STROBOLUX</b>	<b>III</b>
<b>50KV, 10,000/1 CAPACITY DIVIDER PROBE</b>	<b>IV</b>
<b>EXPERIMENTAL TRANSDUCER AND STRAIN GAGE PLUG-IN FOR TEKTRONIX OSCILLOSCOPES</b>	<b>V</b>

I

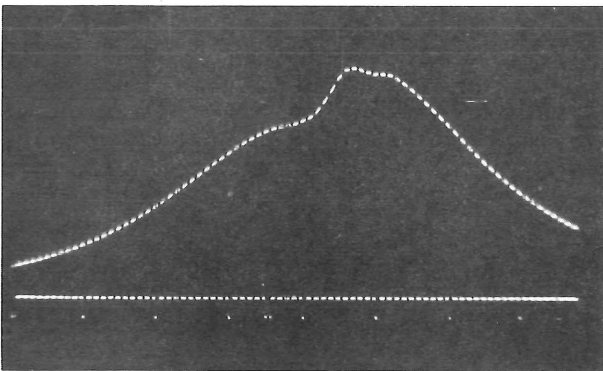
## TYPICAL ROTAN DISPLAYS



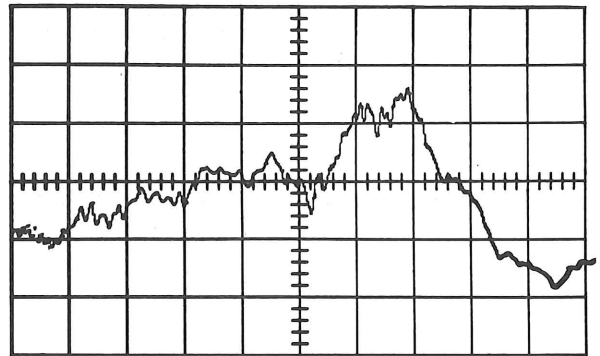
1. Diesel engine cylinder pressure vs crank angle. 360-deg. sweep, 10-deg. intensity markers. Intensified portion is 50-deg. sector covered by Main Sweep starting at 160 degrees.



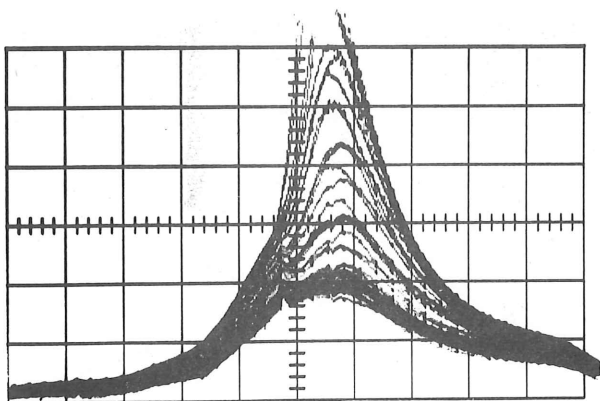
2. Diesel engine cylinder pressure vs crank angle. 50-deg. sector of #1 displayed by Main Sweep. 10-deg. intensity markers with VARIABLE intensity marker at 175 degrees.



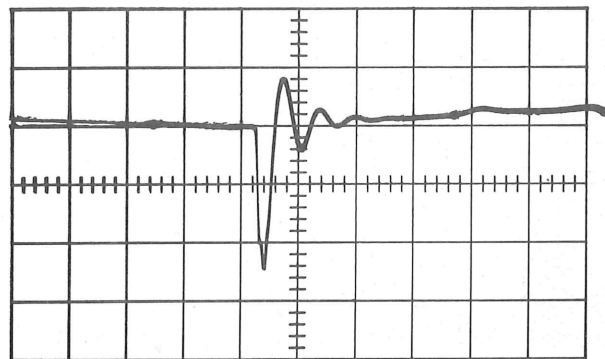
3. Diesel engine cylinder pressure vs crank angle. 78-deg. sector of #1 displayed by Main Sweep. Sector begins at 140 degrees from piston bottom center. 1-degree intensity markers. Baseline trace shows 10-deg. and VARIABLE markers.



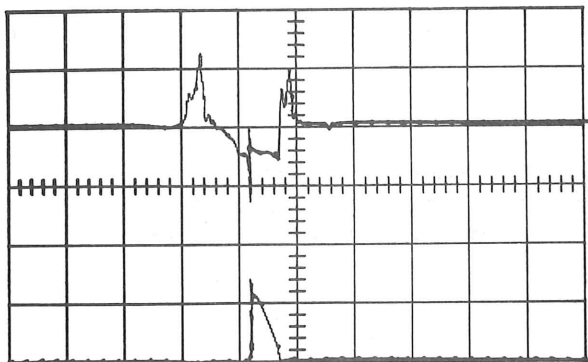
4. Vibration vs crank angle. 4-cycle, 1-cylinder, gasoline engine. 360-deg. sweep.



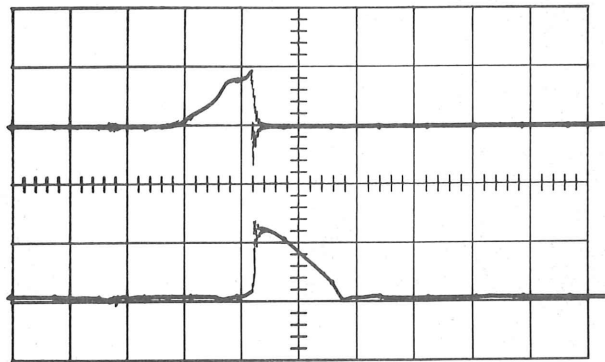
5. Cylinder pressure vs crank angle during acceleration. 360-deg. sweep. 10-deg. intensity markers. Piston TDC in center of display.



6. Open circuit magneto voltage. Vertical calibration: 5 Kv/Cm. Linear sweep. 10-deg. intensity markers. Sweep starts at 40 deg. BTC.



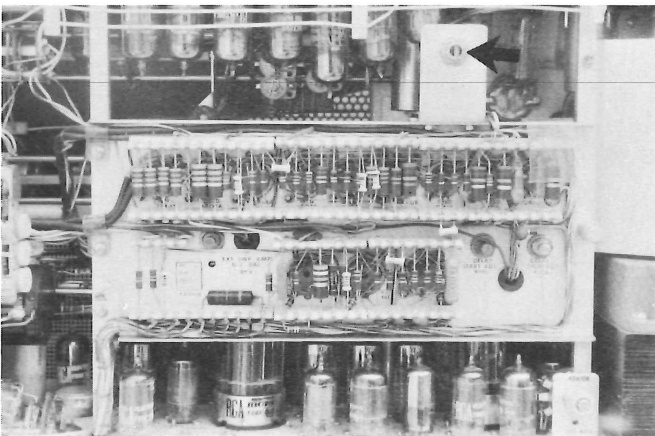
7. Ignition vs crank angle. 360-deg. display with 10-deg. intensity markers. Upper trace: Secondary voltage. Lower trace: Secondary current.



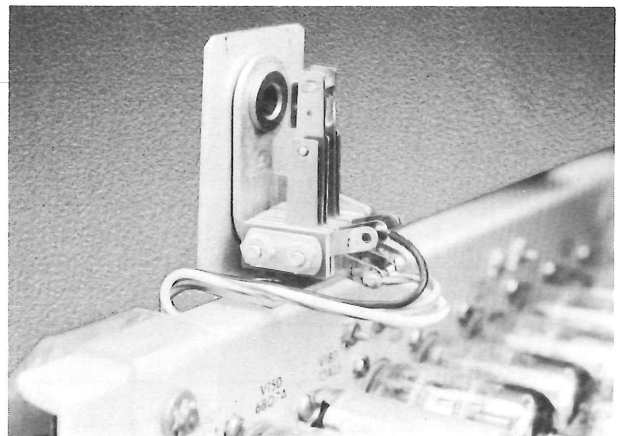
8. Upper trace: Primary current in magneto ignition coil. Lower trace: Secondary current. Linear sweep with 10-deg. intensity markers.

# II

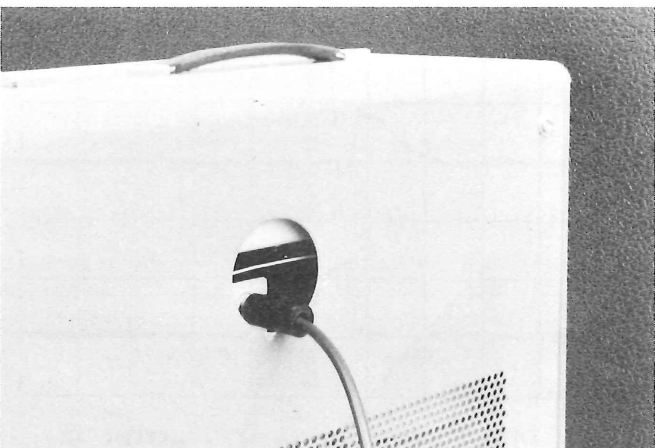
## MODIFICATION OF TYPE 535/545 OSCILLOSCOPE FOR ROTAN SWEEP



1. Mounting position of Mallory 705 jack on Delaying Sweep Chassis.



2. Mallory 705 jack.



3. Standard phone plug inserted through knockout in side panel. Removal of plug restores oscilloscope to normal operation.

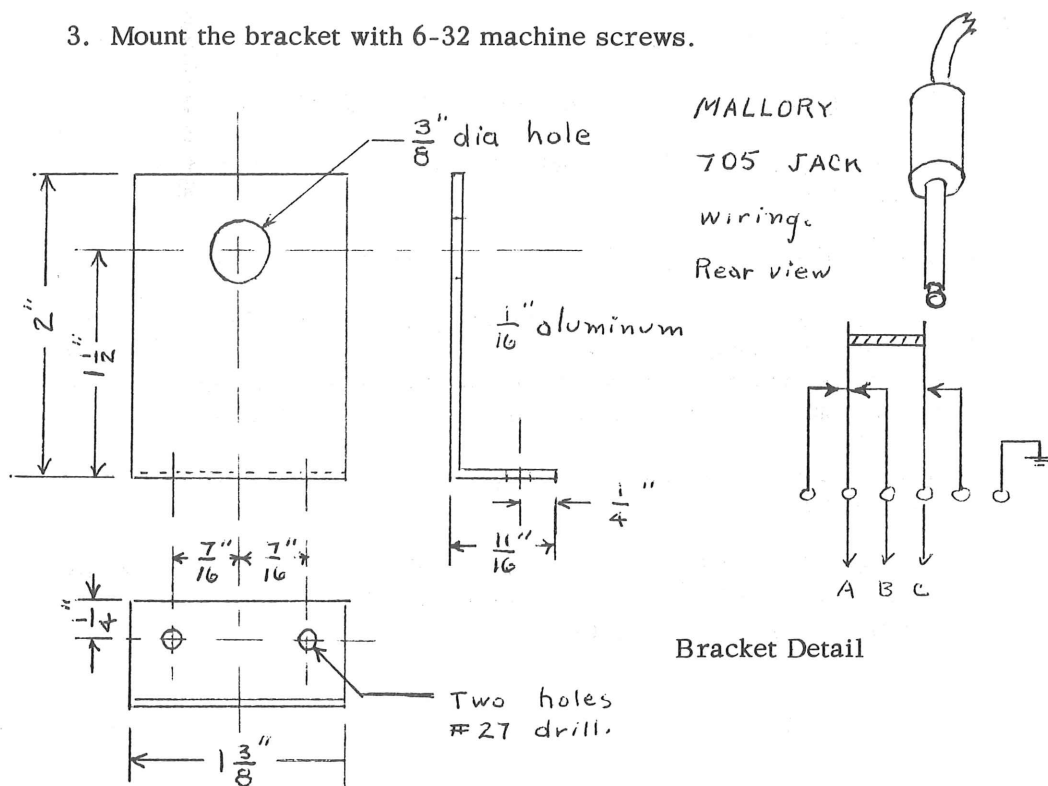
## MODIFICATION PROCEDURE

Procure a bracket as per sketch and a Mallory Type 705 jack.

11

1. On top lip of the Delaying Sweep chassis, measure and mark  $2\frac{3}{4}$ " and  $3\frac{5}{8}$ " respectively from right end. (Refer to photograph for general area of mounting.)
2. With #27 drill, drill two holes at the points marked.
3. Mount the bracket with 6-32 machine screws.

### MOUNTING THE BRACKET



(Refer to sketch, above, and Fig.14.)

1. Facing the Delaying Sweep chassis, go to left end (front of 'scope) of terminal strip. Now find the 4th notch from the front in the top row. Unsolder the brown-green-black lead from the notch.
2. Splice the lead just unsoldered and run it to terminal B (see sketch above) on the jack.
3. From the same notch from which the lead was removed (4th from front, top row), run a lead to jack terminal A.

### WIRING THE TYPE 705 JACK

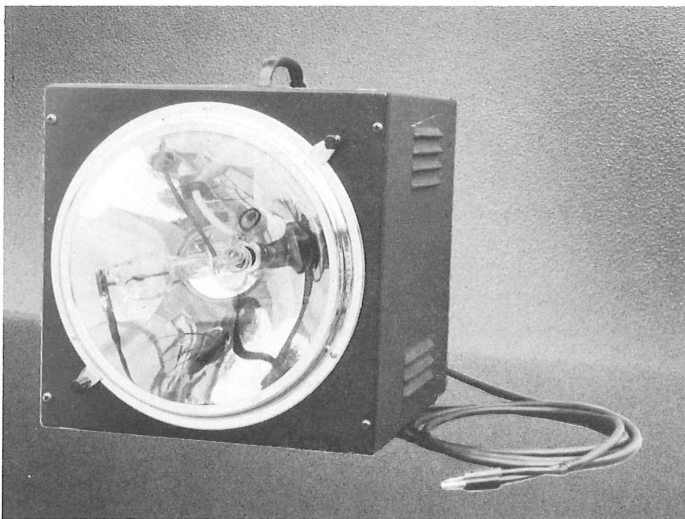
4. Connect a lead from jack terminal C to Pin 1 of V190. This completes the modification. Check Delaying Sweep for normal operation.
5. Inserting the phone plug into the jack will make all of the necessary circuit changes to convert the oscilloscope for ROTAN operation.

## CALIBRATING THE ROTAN SWEEP

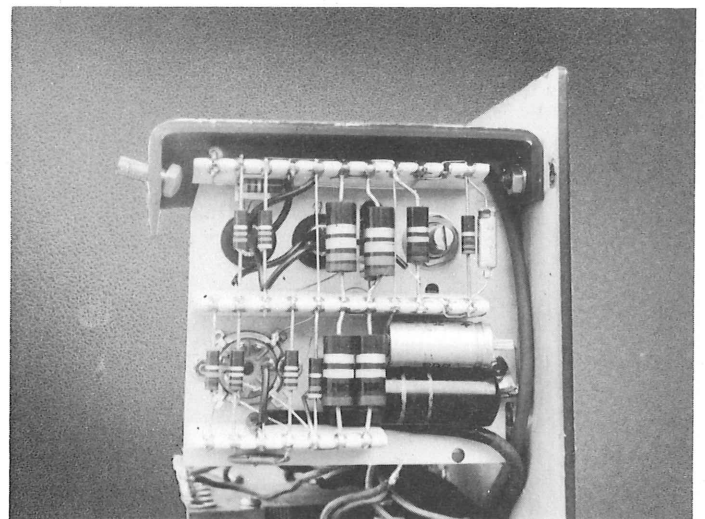
1. Make cable connections as shown in the cabling sketch, Page 7.
2. Set Del'g Sweep TIME/CM control at 1 MILLISEC/CM.
3. Set the Type 32TU FINE SWEEP CAL. (front-panel control) fully clockwise.
4. With ROTAN turning, observe 0-degree markers on the scope.
5. Adjust coarse sweep cal (7-45 pfd trimmer inside Type 32TU) until desired number of revolutions take up 10.5 to 11 cm. Coarse sweep cal has a range covering less than one revolution to 5 or 6 revolutions. Usually it will be adjusted for one revolution.
6. Trim Fine Sweep Cal until 0-deg. reference mark coincides with the 10 cm mark.
7. Number of degrees or revolutions displayed will be multiplied by 10 in 2 MILLISEC/CM position of TIME/CM control; divided by 10 in 100 MICROSEC/CM position.

# THE GENERAL RADIO 648-A STROBOLUX

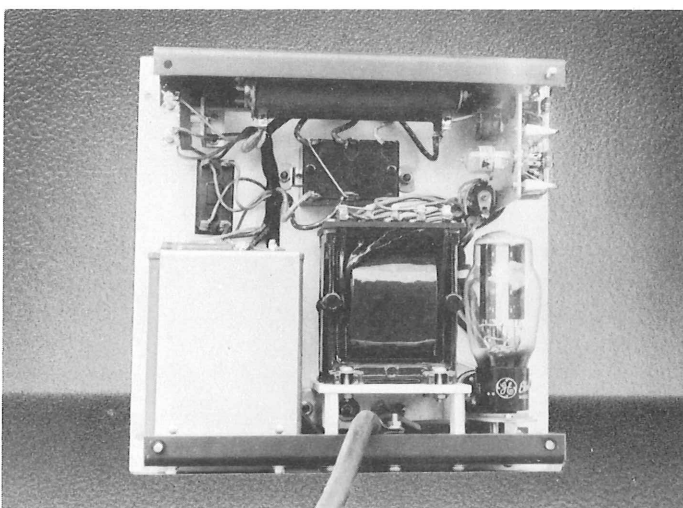
Modified for Electronic Triggering With a Positive Pulse



648-A



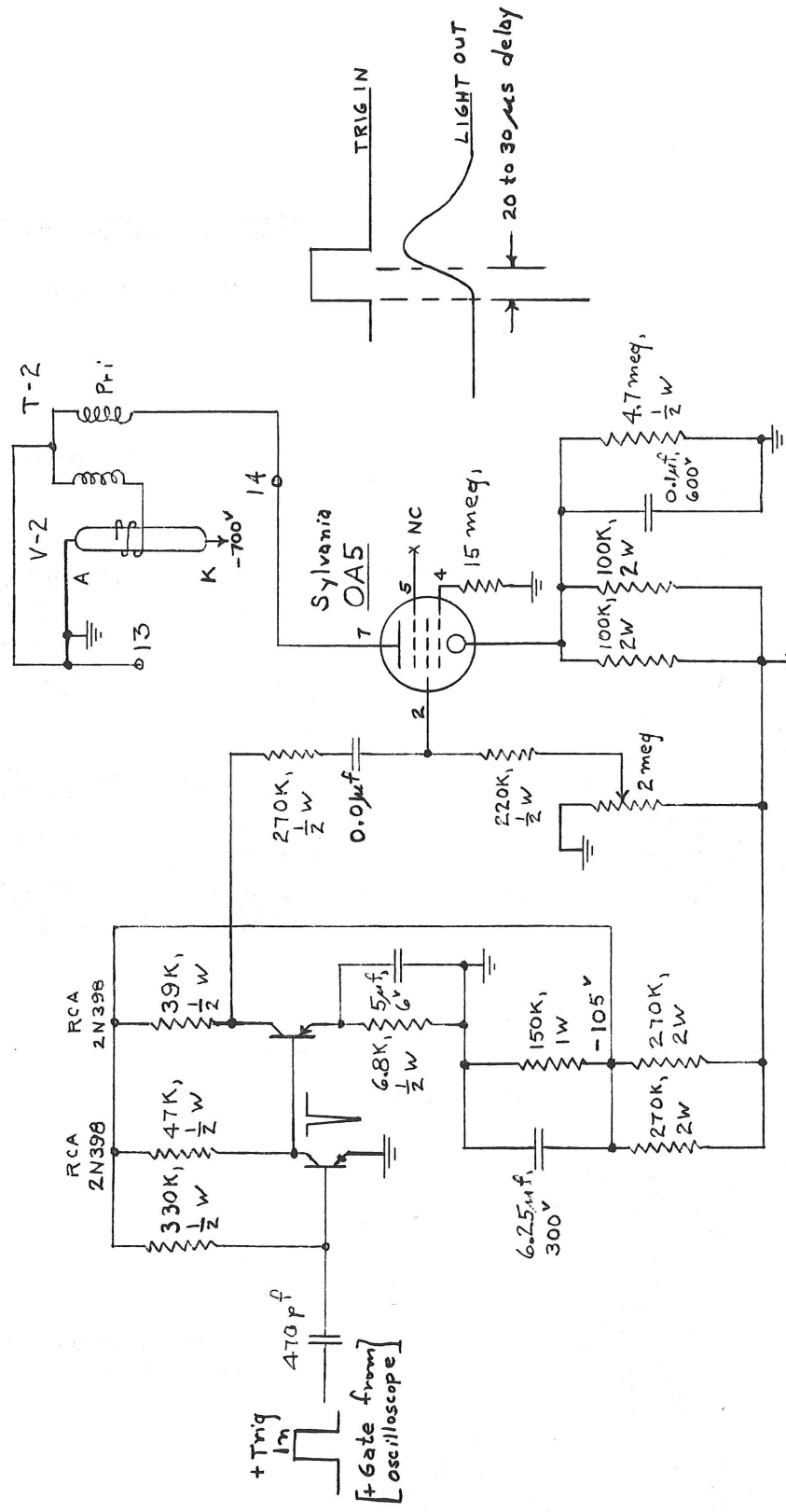
Trigger Chassis



Trigger chassis location - upper right above 5V4 rectifier.

APPENDIX 3, Page 2

TRIGGER CIRCUIT FOR GENERAL RADIO 648-A STROBOLUX



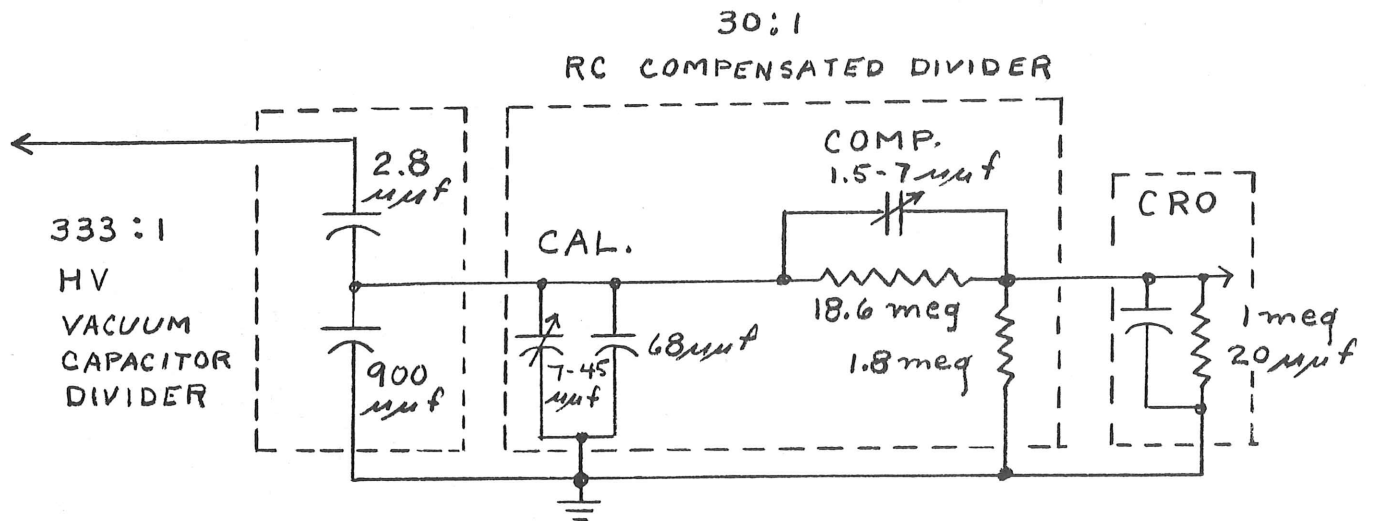
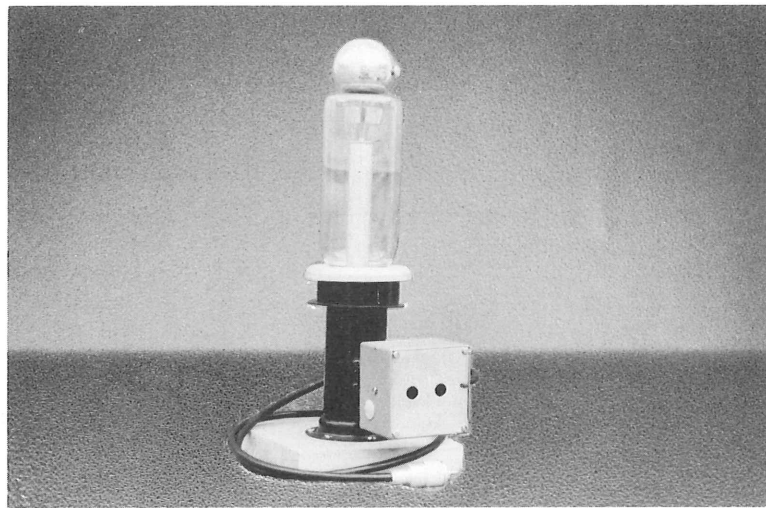
From jct of R<sub>1</sub> & C<sub>2</sub> in 648-A





IV

50KV, 10,000/1 CAPACITY DIVIDER PROBE



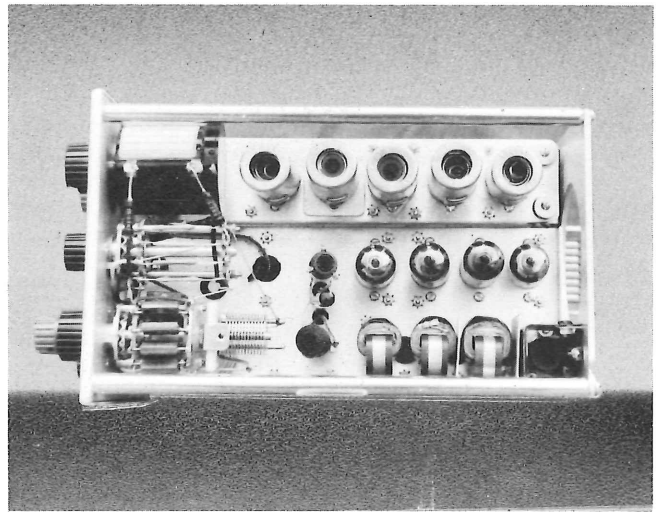
Jennings Type JP-325 High-Voltage Capacitor  
Divider, 333/1.

Frequency response (3 db or 70% voltage) 10 cps to 10 mc.  
with external shield: 10 cps to 30 mc.

**V**  
**EXPERIMENTAL TRANSDUCER AND STRAIN GAGE PLUG-IN FOR**  
**TEKTRONIX OSCILLOSCOPES**



Plug-in mounted 535.



Top view.

Bottom view.

