...ma is dropped to 250 volts ...section. The second stage of the two-stage *LC*-filter is shunt-tuned to approximately 120 cps.

18·5. Oscilloscope TS100/AP.[1] *Function.*—Test oscilloscope TS100/AP has been designed to perform two general functions. It is a precision range calibrator which uses a circular sweep to measure the time intervals normally encountered in radar practice with an accuracy of about 0.02 per cent. It is also used with linear-type "A" sweeps as a general-purpose portable test oscilloscope for radar equipments.

Characteristics.—A type 3DP1 *cathode-ray tube* operating at an accelerating potential of 1800 volts is used. This gives a vertical deflection factor of about 150 volts/in. Two *sweep generators* are included in this instrument, providing gated or continuous circular sweeps and triggered linear sweeps. The length of each revolution of the circular sweep is 12.361 μsec (1 nautical mile), accurate to 0.02 per cent. This sweep is generated continuously. All revolutions or the first 1, 30, or 350 revolutions immediately following the synchronizing trigger may be intensity-gated. Triggered linear-sweep lengths of approximately 10,370, and 4300 μsec (0.8, 30, and 350 nautical miles) are provided. Either the intensifying gate of the circular sweeps or any of the linear sweeps may be delayed by a continuously variable period to a maximum of 620 μsec (50 nautical miles) with respect to the synchronizing trigger.

[1] Developed by the Radiation Laboratory and manufactured by the United Cinephone Corporation, Torrington, Conn. Procured by the Signal Corps, Dayton Procurement Office; and Radiation Laboratory. The *Manuscript of Handbook of Maintenance Instructions for Test Oscilloscope TS100/AP* is an instruction manual printed by the manufacturer. Also available is the technical order TO-08-TS100/AP-2, published by the Signal Corps, Dayton Procurement Office. The sections on maintenance and the waveforms shown in this latter publication are inaccurate and do not apply to this instrument. This unit is used with the AN/APS-15 and other airborne radar systems. The Model 5 type AJ test oscilloscope (60ACZ) which is described briefly at the end of the present section is of similar mechanical and electrical design.

The sweep circuits may be synchronized either by the internal trigger or by an externally generated trigger of either polarity having an amplitude of 15 to 50 volts and a minimum rate of rise of 100 volts/μsec.

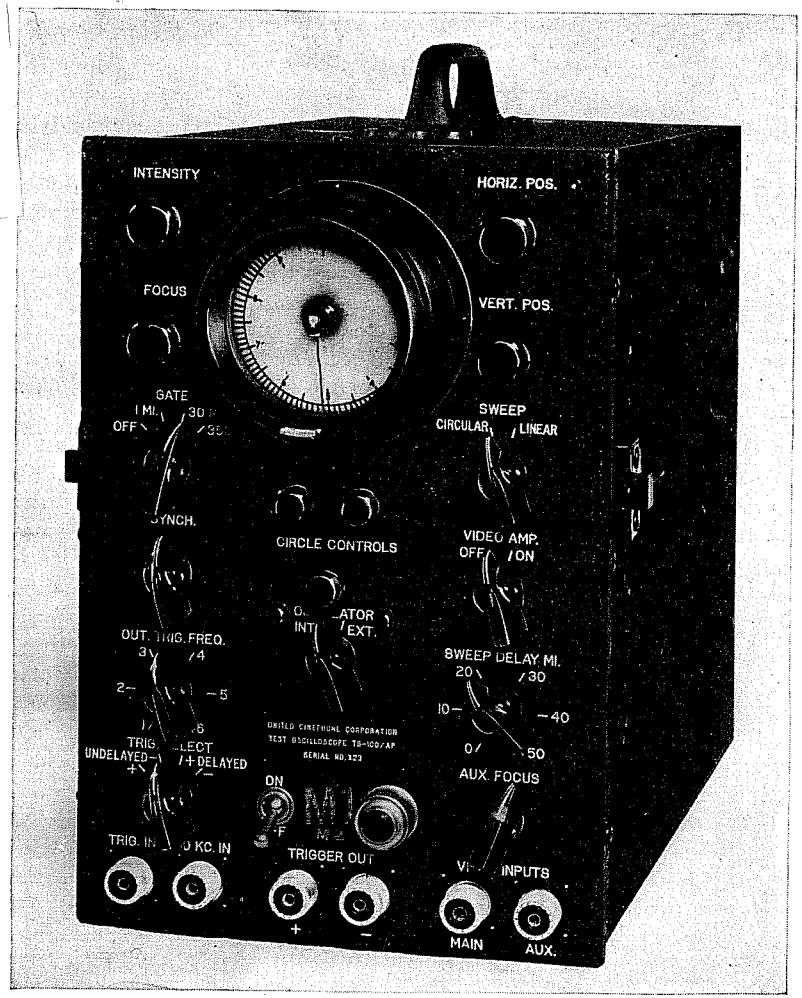

FIG. 18·27.—Oscilloscope TS100/AP.

Satisfactory triggering may be obtained up to 5000 cps when the sweeps are triggered directly or to 1200 cps when the variable delay is used. A positive linear-sweep voltage of 225 volts amplitude may be obtained from a connector on the back of the instrument. This circuit has an

internal impedance of 100,000 ohms. An input is also provided on the panel for an externally generated sinusoidal voltage having an amplitude of 35 to 100 volts rms and a frequency between 78 and 84 kc/sec to generate a circular sweep.

The circular sweep, which is generated by quadrature voltages from a crystal oscillator, provides a *precision time base* for the measurement of short time intervals. The period of each cycle, which corresponds to the time for one revolution of the sweep, is accurate to better than 0.02 per cent. The position of a signal on the circle can normally be read to $\pm.05$ μsec (± 8 yd). Marker pips generated by the crystal oscillator can also be made available by adding a panel connector and one wire to the instrument.

A 100-volt positive trigger and a 70-volt negative trigger having a pulse width of 0.6 μsec are supplied by the *trigger generator* for synchronizing external equipment. These triggers are accurately locked in phase with the circular sweep by frequency division. The repetition rate is variable from 300 to 1500 EM/SEC in integral submultiples of 80.86 kc/sec. A low-impedance output is provided.

A direct *signal channel* to either or both vertical deflecting plates is provided when the linear sweep is used or to the center electrode for the circular sweep. The input impedance is 1 megohm paralleled by 55 $\mu\mu$f for the upper vertical deflecting plate and 45 $\mu\mu$f for the center electrode. The *video amplifier* has a voltage gain of about 12 which is constant to ± 3 db between 250 cps and 2.8 Mc/sec. Overloading occurs with an input signal amplitude greater than 2 volts. The input impedance is 1 megohm paralleled by 32 $\mu\mu$f, and the stage gain is fixed with no control provided. Only one signal input is provided for the circular sweep. Signals can be mixed on the linear sweeps, however, as inputs to both vertical deflecting plates are provided. One input is connected directly and the other either connected directly or through the video amplifier.

The over-all dimensions of this oscilloscope are 9 by 14 by $16\frac{1}{2}$ in., and the weight including the cover is 42 lb. Test cables weighing a total of 2 lb are also supplied. Power requirements are 115 ± 10 volts (the transformer may be reconnected for operation on 230 volts), 50 to 1200 cps, 110 watts at 60 cps. Ambient temperature limits are $-22°$ to $+122°$F. The tube complement is 1-3DP1, 1-2X2, 1-5Y3GT/G, 1-6AG7, and 7-6SN7GT. Space is provided in a removable panel cover for the variety of test leads and cables supplied.

Circuit Description.—The *cathode-ray tube control circuits* use a conventional high-voltage bleeder containing the focus and intensity potentiometers. Dual potentiometers provide balanced centering voltages for deflecting the beam. An

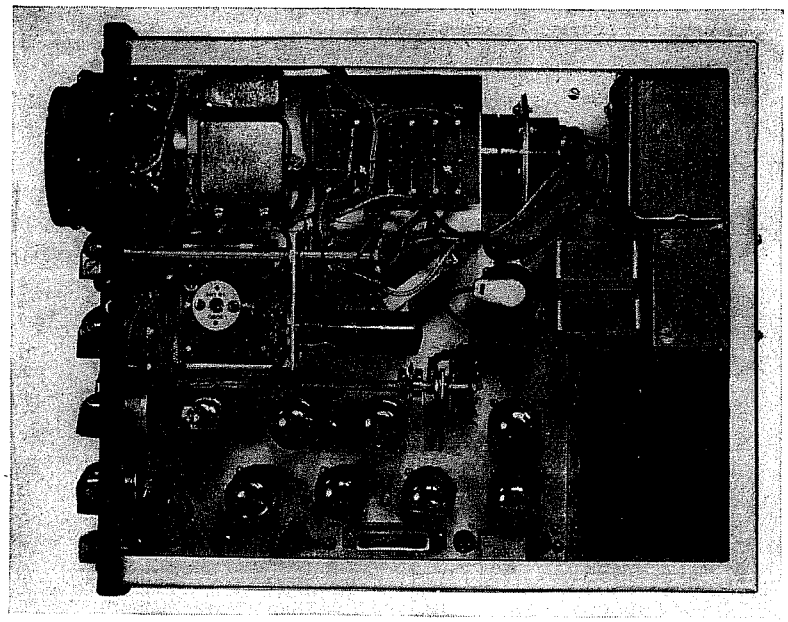

FIG. 18·28.—Right interior view of the TS100/AP.

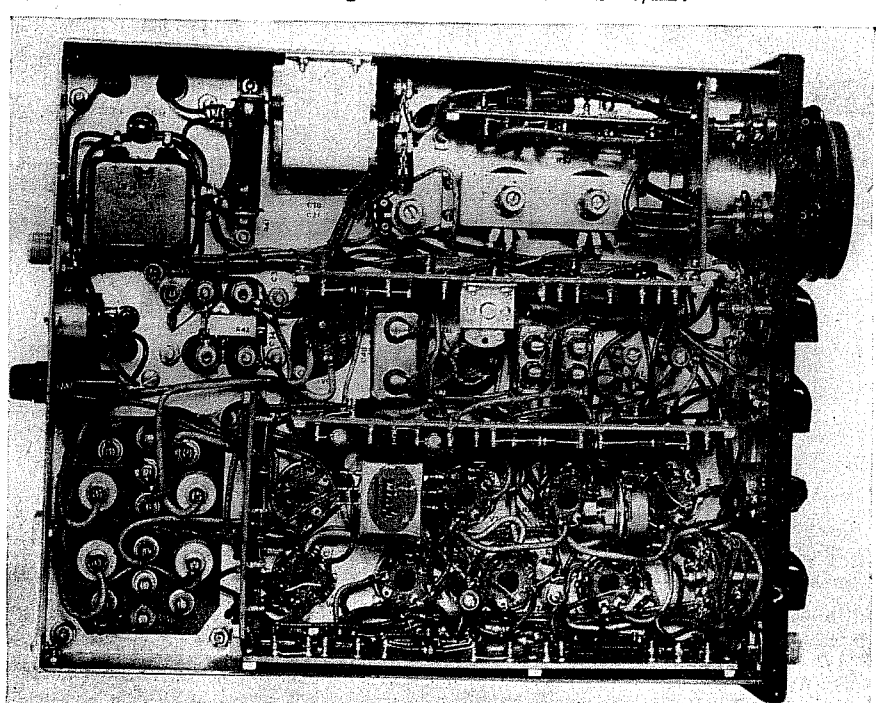

FIG. 18·29.—Left interior view of the TS100/AP.

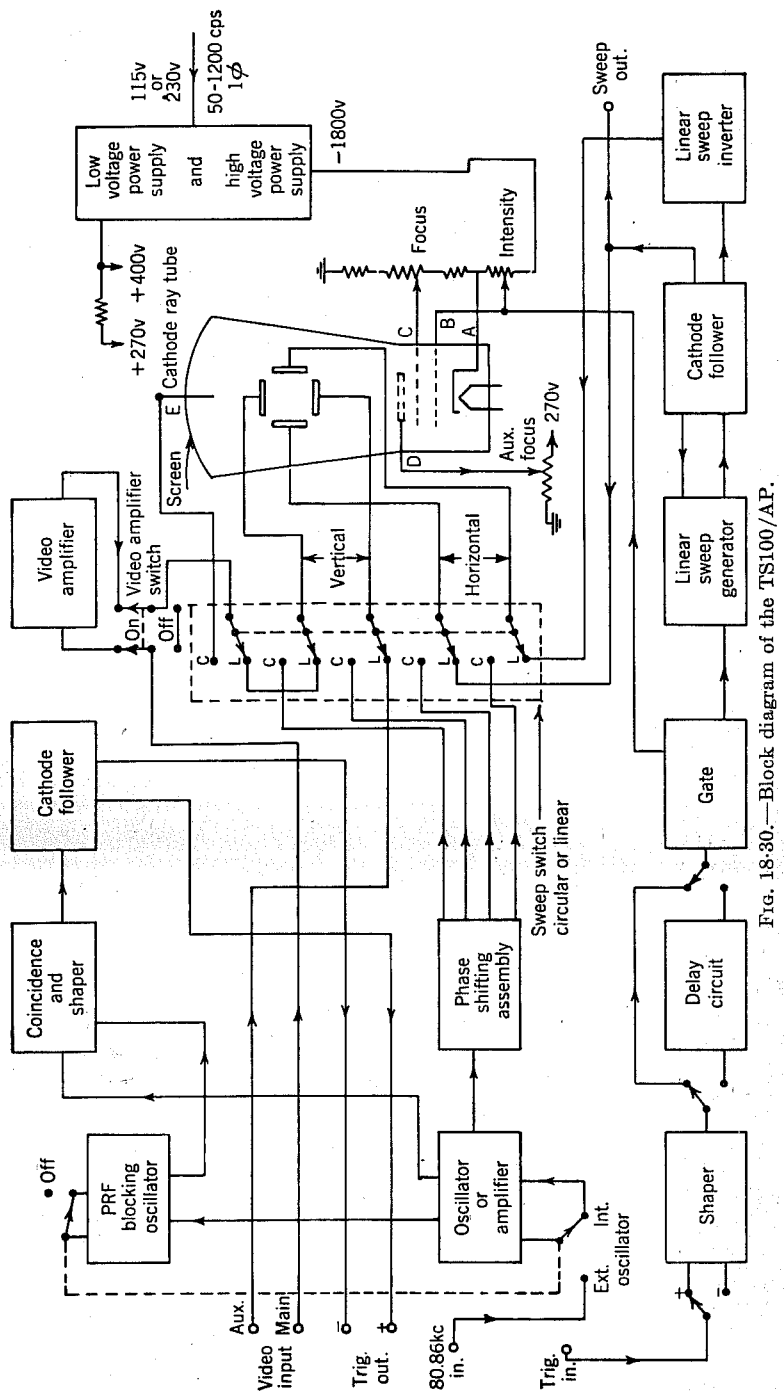

FIG. 18·30.—Block diagram of the TS100/AP.

astigmatism control, which sets the voltage on the center electrode and the second anode, is mounted on the panel, since it must normally be adjusted to obtain good focus when changing from a circular to a linear display.

The *circular sweep* is generated by a triode crystal oscillator V_{7B}. The crystal is ground to a frequency of 80.86 kc/sec giving a period that is equivalent to one radar nautical mile. The oscillator may also be used with an 81.94-kc/sec crystal for a 2000-yd period. Several circuit changes are necessary to modify this instrument for use with a 100-kc/sec crystal (giving a 10-μsec period).

The tuned transformer in the oscillator plate circuit (Sickles RE10001) has two sets of secondary windings which are tuned by panel-mounted air trimmer condensers paralleled by temperature-compensating fixed capacitors. These windings are each coupled to a pair of cathode-ray tube deflecting plates and are tuned on opposite sides of the resonant frequency to give a 90° phase difference between the voltages across them. When the horizontal and vertical deflection amplitudes are also equal, a circular trace is obtained. The circle diameter is controlled by a trimmer condenser across the primary. It may also be adjusted by the screw-driver-controlled potentiometer in the oscillator plate circuit to compensate for variation in the deflection sensitivity when the cathode-ray tube is replaced.

When the oscillator switch S_2 is in the EXT. position, the crystal is shorted out and the oscillator stage functions as a low-gain amplifier. A sinusoidal voltage from an external oscillator having either of the frequencies mentioned above may then be connected to the 80-kc IN connector to generate the circular sweep.

The circuits generating the *linear sweep* include a trigger shaper, a sweep delay multivibrator, a sweep gate multivibrator, a "bootstrap" sweep generator, and an inverter to provide push-pull deflection. The trigger shaper consists of the triode tube sections V_{1A} and V_{1B}. The first tube receives either a positive trigger on the grid or a negative trigger on the cathode and amplifies it to fire the biased-off blocking oscillator V_{1B}. The waveform of the pulse produced by this stage is essentially independent of the input trigger characteristics and provides the optimum trigger for the multivibrator following.

The two triode sections of V_2 are used in a cathode-coupled delay multivibrator whose pulse length is set by the SWEEP DELAY grid-voltage control. When the TRIG SELECT switch S_1 is in the + or − DELAYED position, this multivibrator is triggered by the blocking oscillator pulse. The fall of the positive rectangular pulse that is generated at the plate of V_{2B} is differentiated to provide a delayed trigger for the sweep gate multivibrator. With switch S_1 in the + or − UNDELAYED position, the delay multivibrator is not used and the sweep gate multivibrator is triggered directly by the trigger shaper. The + and − positions of the switch S_1 refer to the input trigger polarity. The SWEEP DELAY control has a roughly calibrated dial to indicate the time delay in terms of nautical miles. Slope and zero adjustments can be made with the screw-driver-adjusted potentiometers in the control voltage bleeder to make the actual delay agree with the dial reading. This delay is normally used with the 1-mile circular or linear sweep to expand a portion of the viewed signal.

Tube sections V_{5B} and V_{5A} make up the sweep gate multivibrator which is

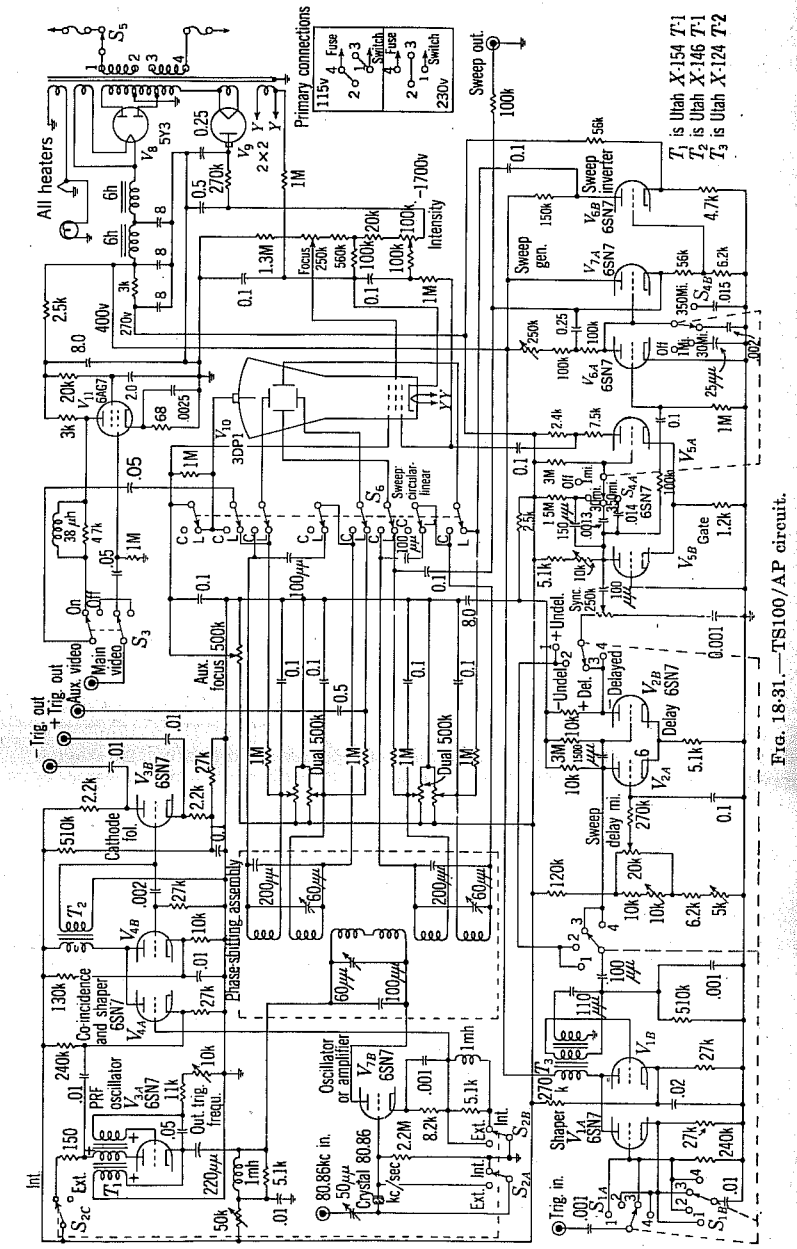

FIG. 18·31.—TS100/AP circuit.

also of the cathode-coupled type. The length of the pulse produced by this circuit is controlled by changing the feedback capacity with the GATE switch S_{4A}. The positive pulse developed at the tap in the plate-load resistor of V_{5A} is coupled to the grid of the cathode-ray tube to turn on the beam when the sweep voltage is generated. The negative pulse from the plate of V_{5B} is coupled to the grid of the clamp tube V_{6A}. Simultaneous control of the three pulse lengths selected by switch S_{4A} is provided by the screw-driver-adjusted potentiometer in the plate circuit of V_{5B}. This makes it possible to compensate for the variation of pulse length with tube and component changes. The SYNC potentiometer is used to adjust the trigger amplitude when the time interval between trigger pulses is less than the multivibrator gate length. Stable operation at these high repetition rates may be obtained when the trigger amplitude is just sufficient to cause the multivibrator to fire.

The linear-sweep voltage is generated by the clamp tube V_{6A} and the cathode follower V_{7A}, which are used in a bootstrap-type circuit. Since the sweep duration is set by the length of the gating pulse, the capacity of the sweep condenser must be changed for each gating pulse length if the sweep amplitude is to be constant. The GATE switch S_{4B} performs this function. Simultaneous adjustment of all sweep amplitudes can be made with the screw-driver-adjusted potentiometer in the plate circuit of V_{6A} to compensate for tube and component variation. The positive sweep voltage is coupled to one horizontal deflecting plate from the cathode follower. An attenuated voltage of similar waveform is developed at the tap in the cathode-load resistor of this stage and is coupled to the grid of the inverter amplifier V_{6B}. The negative sweep voltage at the plate of this tube is approximately equal in amplitude to the positive sweep voltage and is coupled to the opposite horizontal deflecting plate.

A single-stage *video amplifier* is connected into the main video signal input circuit when the VIDEO AMP switch S_3 is in the ON position. Series peaking and cathode peaking are used to extend the bandwidth. No gain control or attenuator is necessary, since the gain is quite low ($G = 12$). The amplifier is connected to either the top vertical deflecting plate or the radial deflecting center electrode by the SWEEP switch S_6, which selects either linear or circular sweep operation. Direct connection to both vertical deflecting plates or to the center electrode may be made through the MAIN VIDEO and AUX VIDEO inputs when the video amplifier switch S_3 is in the OFF position.

The *trigger generator* is designed to provide positive and negative output triggers which are accurately locked in phase with the sinusoidal voltage generating the circular sweep. Any phase shift, or "jitter," in this relationship would cause a broadening of the signal trace or an actual shift in its position on the circular sweep. Since time measurements are made by direct comparison with a scale on the face of the cathode-ray tube, the accuracy of the instrument would be materially reduced.

By inserting small resistance-damped inductances in the plate and cathode circuits of the crystal oscillator, relatively short voltage pulses (or pips) are produced by the pulses of plate current in the Class C oscillator. The pips produced in the plate circuit are used to synchronize an otherwise free-running block-

ing oscillator V_{3A}. This circuit oscillates at a rate determined by the discharge time constant of its grid circuit which is varied by the OUT. TRIG. FREQ. potentiometer. The circuit constants of this blocking oscillator have been so chosen that a relatively square negative current pulse of about 15 volts amplitude and 18-μsec duration is generated across the resistor in the plate circuit. This pulse and the positive 15-volt pips generated in the cathode circuit of the crystal oscillator are coupled to the cathode and grid respectively of the coincidence amplifier V_{4A}. The fixed bias level of this tube is set to give conduction when these pulses occur simultaneously. Since the crystal generated pips have a 12-μsec period, this will occur for the pip immediately following the one that causes the blocking oscillator to fire. When coincidence occurs, the amplified pip appears as a negative trigger at the plate. Since V_{4A} has a common plate circuit with the blocking oscillator V_{4B}, this stage is fired. The 0.6-μsec positive

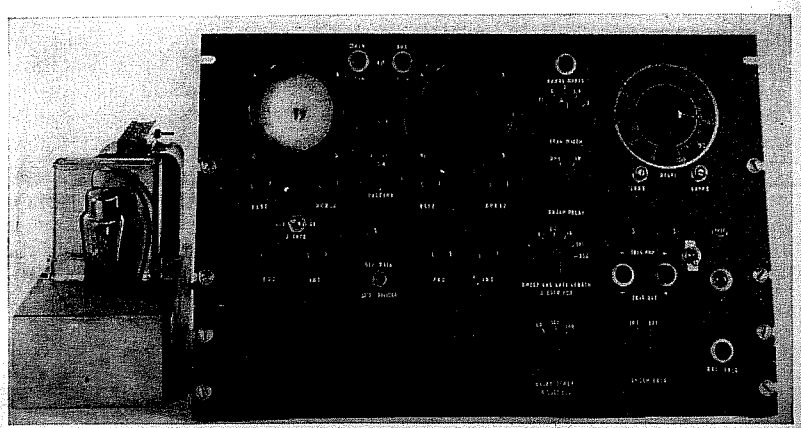

FIG. 18·32.—Laboratory type A and J oscilloscope.

trigger generated is coupled to the cathode follower inverter V_{3B} which supplies low-impedance positive and negative output triggers.

A *power supply* of conventional design is used. The low-voltage supply gives 400 volts at 40 ma and 270 volts at 45 ma. A −1700-volt, 2-ma supply is provided for the cathode-ray tube. The power transformer has a two-section primary winding which may be connected for operation on either 115 or 230 volts.

Similar Equipments.—The Model 5 type AJ test oscilloscope manufactured by the Technical Apparatus Company of Boston, Mass., is almost identical with the TS100/AP in electrical and mechanical design. The circuits have been modified, however, to provide a 6.1-μsec (1000-yd) circular sweep and linear-sweep lengths of approximately 5-, 370-, and 2500-μsec duration. The repetition rate range of the trigger generator has been changed to 250 to 1000 cps. Other characteristics of the two instruments are essentially the same.

Only component value changes were necessary in the oscillator, sweep gate multivibrator, and sweep generating circuits. The Sickles transformer No. RE13386 was developed to supply the quadrature voltages for the circular sweep.

A redesign of the blocking oscillator frequency divider V_{3A} was necessary to generate the rectangular 8-μsec current pulse required for selection of one of the pips generated in the 163.88-kc/sec crystal oscillator. The same pulse transformer is used, however. No changes were required in the other circuits.

While the redesign was made for a specific application, this unit has some advantages over the TS100/AP. The most important of these are higher reading

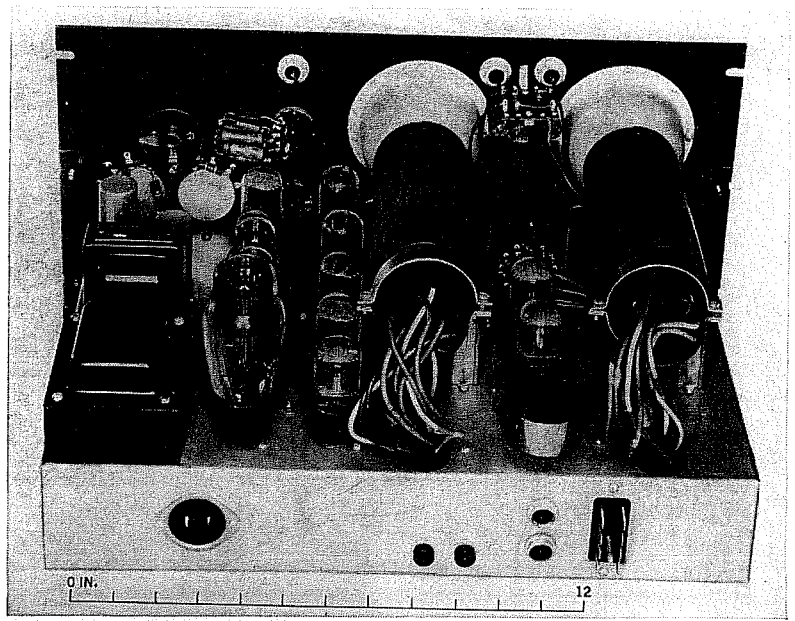

FIG. 18·33.—Top view of the laboratory model.

accuracy obtained with the 1000-yd circular sweep and the faster linear sweep for viewing portions of waveforms.

Figures 18·32 and 18·33 show a laboratory instrument that used the same circuits as the TS100/AP. Somewhat greater flexibility was obtained by using separate cathode-ray tubes for the linear and circular sweeps, eliminating switch S_6. Signal inputs go to both tubes simultaneously, removing some of the ambiguity encountered in the use of the circular sweep alone.

18·6. Model III Range Calibrator.[1] *Function.*—The Model III range calibrator is a relatively specialized device for accurately measuring small time intervals in the laboratory. It uses a circular sweep generated by

[1] Developed by the Radiation Laboratory and the F. W. Sickles Co. and manufactured by the latter company. Procured by the Radiation Laboratory and others. "Operating Data for the Model III Calibrator" is an instruction report published by the F. W. Sickles Co. The Models I and II Sickles Calibrators (RL Report No. 333) are earlier models of this unit which have similar functions.