The Strobotron

A new cold-cathode gas-filled control tube capable of carrying large peak currents. The tube is ready for instant operation without time delay for cathode heating

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IN THIS paper a tube, named the Strobotron, is described which has been developed primarily for producing stroboscopic light. Its unique characteristic is a cold cathode which under certain conditions is capable of carrying very large peak currents with a low tube drop, and with a life sufficient for its uses.

The Strobotron has applications other than that of a stroboscope, such as its use as a relay, or trigger tube, for various purposes. Its particular value in such cases is the lack of power and time delay required for cathode heating, and the effectiveness with which the tube operates.

Circuits for the proper use of the Strobotron are quite unusual, since they are designed to put very large peak currents through the tube to start the arc discharge.

The Strobotron Tube

Figure 1 is a photograph and diagram of the Strobotron No. 631-P1 as used in the "Strobotac," an adjustable-frequency stroboscope manufactured by the General Radio Company. This particular instrument has been designed to be used as a tachometer and has a dial reading directly in speed with a fundamental range of 600-14,500 r.p.m.

The Strobotron is shown with two grids, although this is not necessary in the usual circuit application. Both grids are needed in the Strobotac because of the peculiar output waveform of the oscillator that is used. The grids may be tied together and used as a common element, or the inner grid may be connected to the cathode through a resistor.

The cathode consists of a caesium compound which breaks down under the action of the cathode spot and liberates free caesium. Caesium was chosen because of the ease with which it permits spot formation, and to facilitate further the formation of the cathode spot the surface of the cathode is made rough and irregular. Surrounding the cathode is a ceramic insulator which concentrates the discharge on the active portion of the cathode, and also serves as a support for the inner grid. During the treatment of the tube some caesium metal is sputtered on the inner grid, located just above the cathode, and this materially reduces the breakdown voltage between it and other elements of the tube. This is an advantage, since it makes the tube

easier to start; that is, it requires a lower starting voltage on this grid to initiate the main discharge. The inner grid may also be treated in other ways to reduce the breakdown voltage and thus assist in starting the tube. The outer grid in the tube shown is of graphite, and it effectively shields the cathode and inner grid from the anode. Graphite has been used, since the breakdown voltage between it and the anode is not seriously reduced by condensed or

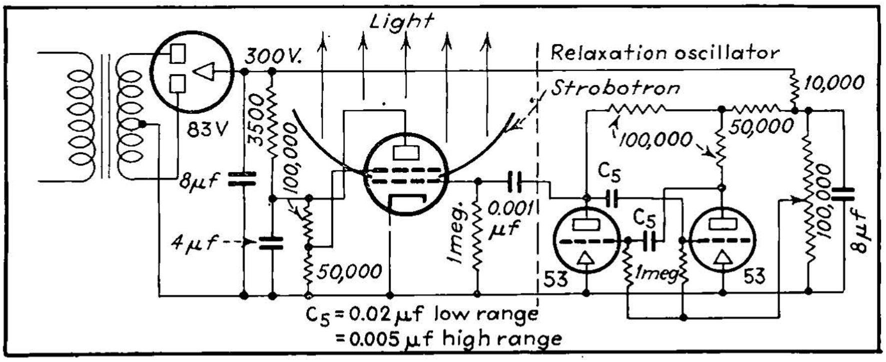


Fig. 2 *Wiring diagram of an adjustable-frequency stroboscope using a Strobotron tube as employed in General Radio "Strobotac"*

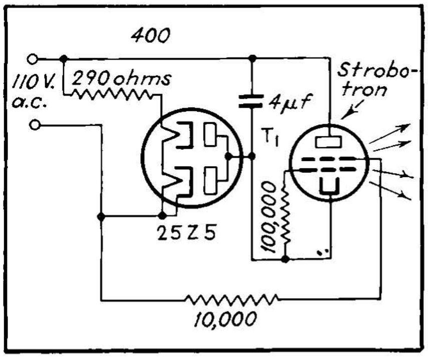


Fig. 3 *Diagram of a 60-cycle stroboscope used at M.I.T.*

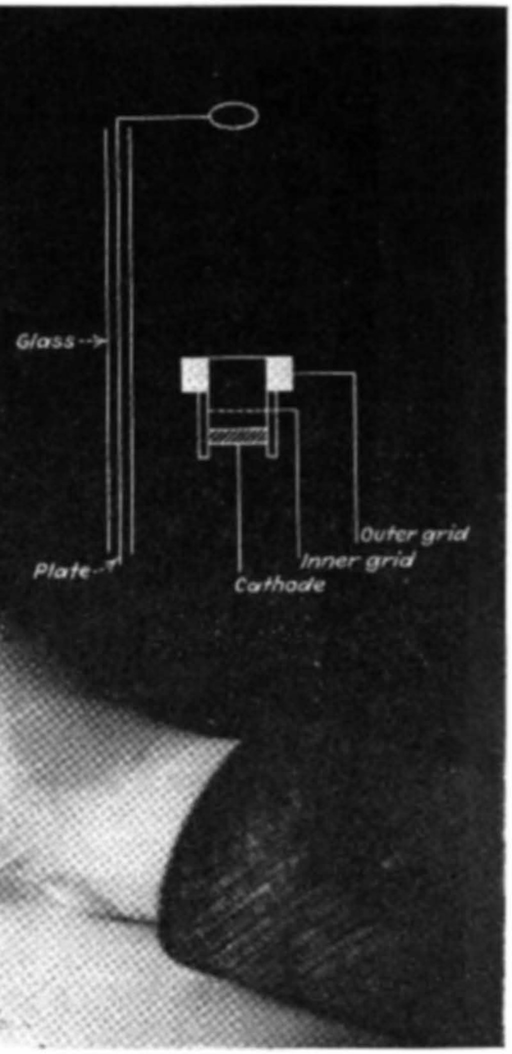


Fig. 1 *Photograph and drawing of Strobotron showing arrangement of the elements*

sputtered caesium from the cathode during the life of the tube.

Above the grid-cathode structure is located the plate upon a vertical glass-insulated support. The discharge of a condenser through the tube produces a luminous column of light about three-eighths of an inch in diameter from anode to cathode.

Neon gas at a pressure of 1.5 cm. is used in the tube illustrated. Argon gas has also been used, and operates very satisfactorily, but does not produce as much visual effect as neon.

A companion paper, with Professor W. B. Nottingham and Mr. A. B. White as co-authors, is to follow, which describes in detail the electrical characteristics of the Strobotron. In particular the conditions for starting are discussed, from the standpoint of applied voltage and required grid current, for different circuit conditions. A brief discussion of the characteristics of the Strobotron and a few circuit applications have been given in a paper by the present authors.[1]

As mentioned before, the Strobotron is useful as a source of stroboscopic light. The essential diagram of the circuit in the General Radio Company's "Strobotac" is shown in Fig. 2. A flash of light is produced from the Strobotron each time that the 4 μf condenser is discharged through the Strobotron. Control of the flashing rate is effected by impulses from the relaxation oscillator[2] whose circuit is shown at the right of the diagram. A negative potential is suddenly impressed on the inner grid when the left tube in the oscillator begins to conduct current in the course of the oscillation cycle. The potential difference between the inner grid and the outer grid at this moment exceeds the starting potential, and the Strobotron flashes. The frequency of oscillation is controlled by the potentiometer instead of the usual method of varying grid R or C_5 with the grid resistors connected to the cathode. Changes of scale are effected by changing the circuit constants in the grid circuits of the oscillator. (With C_5 as 0.02 μf the range of frequency is approximately 10-60 cycles per second; with C_5 as 0.005 μf, 40-240 cycles.)

A simple stroboscope that produces one flash per cycle of the supply voltage is conveniently arranged according to Figure 3. During the half-cycle that the rectifier charges the condenser the grid-bias voltages on the Strobotron are such as to prevent starting. On the other half of the cycle, however, the inverse voltage across the rectifier is applied to the outer grid and reaches the critical starting potential at a given part of the a-c voltage wave. Several small stroboscopes of this type are in use in the Electrical Machinery Laboratories at the Massachusetts Institute of Technology for measuring the slip of induction motors and the power angle of synchronous motors.

A counting circuit that has proved useful for recording the pulses from Geiger-Muller tubes is shown as Fig. 4. The counter, Western Electric message-register type No. 5T, is actuated when the condenser is charged from the

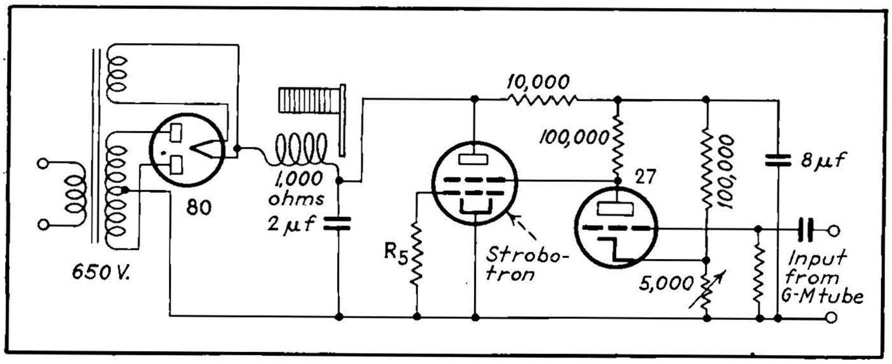
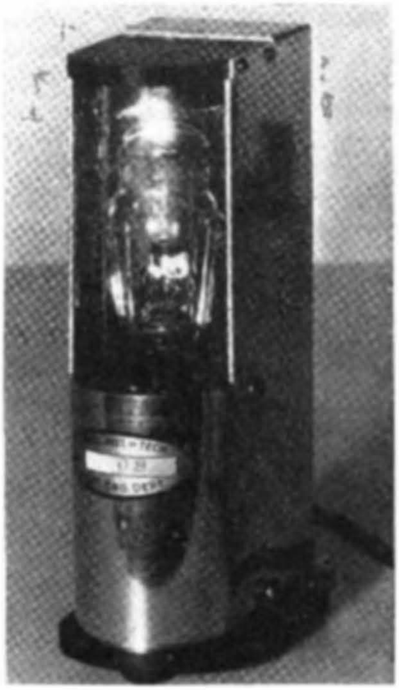


Fig. 4 *Circuit diagram for a circuit to operate a message counter register for recording cosmic rays by a Geiger-Muller tube*



Completely assembled 60-cycle stroboscope in use at M.I.T.

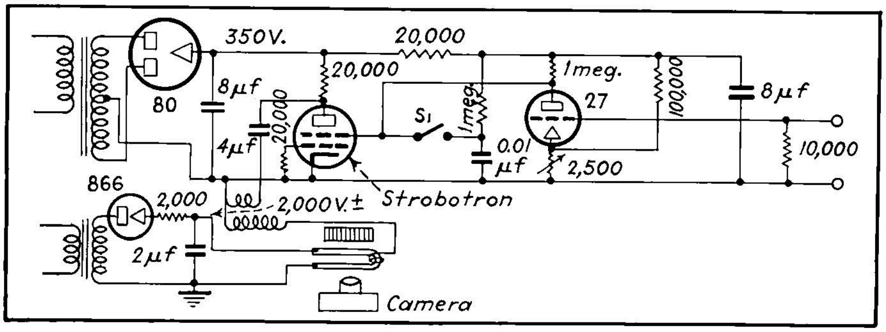


Fig. 5 *Circuit diagram of a light-flashing apparatus for the photographic recording of spectral data*

transformer through the 80 tube. Tests show that the condenser is fully charged in 1½ or 2 cycles of the 60-cycle supply, and the ballistic effect of the force resulting from this charging-current surge in the recorder causes it to register. The steady current to the amplifier is not enough to hold the counter in a closed position.

A negative surge on the grid of the amplifier tube causes the plate voltage, and thereby the outer-grid voltage, of the Strobotron to increase to the critical value at which the Strobotron starts. Once a glow is started, it immediately transfers into an arc and discharges the 2 μf condenser to almost zero voltage. A count is recorded when the condenser is again charged from the rectifier and transformer.

Sensitivity control is effected by the adjustable resistance. This resistor is increased to as large a value as can be used without the self-operation of the Strobotron. The drop across the amplifier tube is used as a positive bias for the Strobotron, and the larger it is, the smaller will need to be the surge to reach the critical potential at which the tube starts.

The counting speed of the above circuit is determined by the counter, that is, about ten a second with the Western Electric Type 5T. With higher-speed counters the same type of circuit can be used, utilizing if necessary a direct-current source instead of the rectified alternating-current supply.

A Strobotron is used in an apparatus for recording data in the automatic wave-length comparator[3], a new model of which is now being constructed by Professor G. R. Harrison, of the Physics Department at the Massachusetts Institute of Technology. The function of the Strobotron is to turn on an intense light source which photographs a high-speed rotating counter that shows the wave-length of the spectral line. A quick flash is needed, since the counter wheel rotates 1000 times a minute. Figure 5 is a circuit diagram of the Strobotron circuit and the amplifier with it for timing the flash. A negative surge to the grid of the type 27 amplifier tube increases the positive bias on the outer grid of the Strobotron, and turns it on at the instant a spectral line centers on a slit as the plate moves along. The resulting surge of current in the Strobotron circuit passes through the primary of a spark coil and produces a high voltage on the secondary, which in turn starts the argon stroboscope lamp. Either the voltage or the pressure of gas in the argon lamp is adjusted until the lamp does not flash by itself but is always flashed by the spark coil.

The Strobotron has been used in the Aberdeen chronograph spark-recording apparatus. A circuit of the type shown in Figure 5 is used, except that the output from the spark coil is connected directly to the marking electrodes that direct the spark through the moving waxed paper. Instantaneous control of the starting of the spark is thereby obtained without requiring an appreciable amount of electrical power in the control circuit.

As a final example of typical uses of the Strobotron Figure 6 shows a satisfactory method for starting mercury-arc rectifier tubes. The function of the Strobotron in this example is the same as in the one described in connection with Figure 5, that is, to impress (momentarily) a very high potential to start the main discharge. A condenser (3 μf) is quickly discharged into the spark coil V_1 at the instant the potential on the tube inner grid reaches the critical potential. The high voltage from the spark coil when connected to the external starting band of the mercury tube starts a cathode spot at the junction of the mercury and glass. At the end of the half-cycle the tube goes completely out, but is restarted at the desired portion of the next cycle by another surge of voltage from the Strobotron circuit. The phase-shift method of controlling the output is effected by varying the phase of the tripping voltage with respect to the applied plate voltage on the mercury-arc tube. This same type of circuit has also been used for starting ignitrons.

Professors Gray and Nottingham at the Massachusetts Institute of Technology have used a circuit of the type shown in Figure 6 to operate a spot welder for half-cycle welding. A paper describing the circuit arrangement will be published by them in the *Review of Scientific Instruments*.

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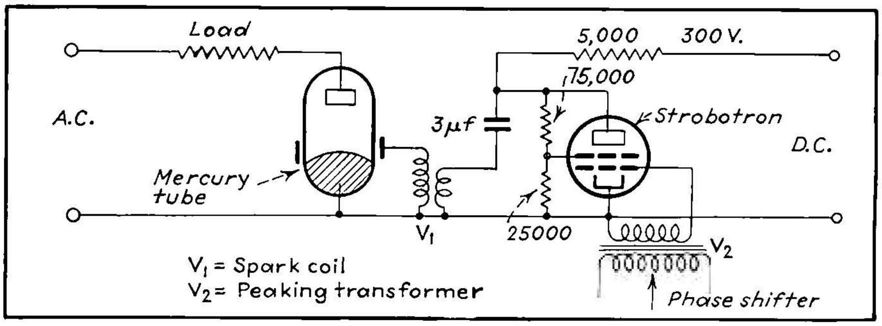

Fig. 6 *Circuit showing the use of a Strobotron for starting a mercury pool rectifier used in a half-cycle welding circuit*