

Internal Electrostatic Deflection Yokes

Equal horizontal and vertical deflection sensitivities result from simultaneous deflection. Confinement of fringe fields provides greater freedom from scan distortion and defocusing and permits wider angles of deflection

WHEN COMPARING conventional electrostatic and magnetic deflections in their present forms, it is found that the former is basically sequential and the latter simultaneous in operation. The crossed-pair system of deflector plates delivers first one component of deflection and then the other, whereas the modern magnetic yoke handles both components at once. Undoubtedly, it is desirable to do the same with electric fields.

The resemblance between the physical laws for static electricity and magnetism holds a clue for the construction of an electrostatic yoke. Assuming cylindrical geometry, that analogy demands that we should provide two crossed sets of boundary potentials, each of them with a cosine distribution around either axis of deflection. On the basis of these considerations, the present form of deflection electrode was developed. Since this is a separate unit, structurally and functionally, within the tube, the designation Deflectron was coined for it.

Early Efforts

There have been earlier attempts to solve the problem of simultaneous electrostatic deflection in two dimensions. For instance R. R. Law suggested resistive material to obtain the correct boundary potentials;¹ H. Salinger used, for the same purpose, a 12-wire cage connected to a mixing network outside of the tube;² and F. Gray applied V.

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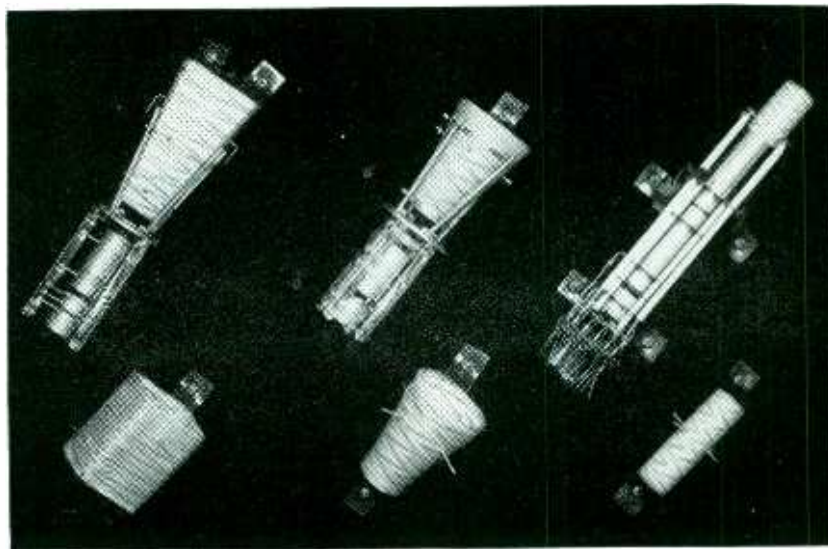
Ardenne's principle of distributed shielding,³ to perform various electronic functions, including deflection.⁴

However, none of these earlier efforts seems to have resulted in a practical device suitable for use in modern cathode-ray tubes. To be useful, such a unit should have no more than four terminals, high sensitivity, low admittance, a rigid, lightweight structure and it should be easy to produce and to reproduce. The Deflectron meets all of these requirements.

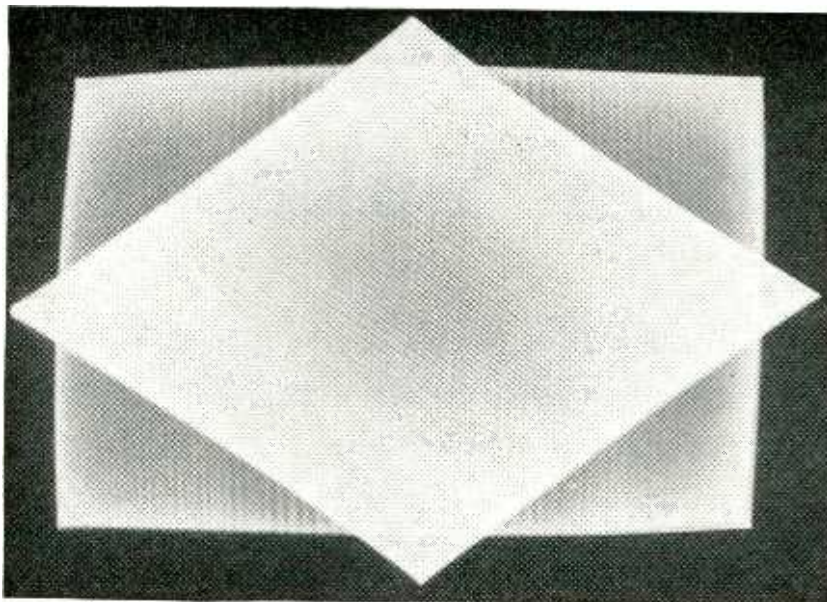
Figure 1 explains the principle of composite electrodes, which are the basic elements of the Deflectron. In Fig. 1A metallic areas of different width are connected, alternately, to separate voltages V_1 and V_2 . An electron flying in the Z direction across the strips at an altitude d , will see a resultant potential V as described by

$$V = \left[V_1 \frac{l_1}{\lambda} + V_2 \frac{l_2}{\lambda} \right] + 0.64 (V_1 - V_2) \sin \left(\frac{\pi l_1}{\lambda} \right) e^{-2\pi \frac{d}{\lambda}} \cos \left(2\pi \frac{z}{\lambda} \right)$$

This effective potential consists essentially of a constant term and an



Typical electrostatic deflection units for tv (left) circular (center) and 30-degree pencil (right) yokes



Sweep patterns from rectangular unit with and without matrix network. Matrix provides almost double scanning area

alternating term. The constant term indicates an average potential which is the sum of the two bias voltages, each weighed by the effective length of the strip, to which they are applied. This term does not change with distance.

The alternating term on the other hand is proportional to the bias-difference between strips, and it is found to decrease rapidly with distance from the electrode. Figures 1B and 1C show the potential-functions at the surface and approximately $\frac{1}{2}$ wavelength away, respectively. An observer who is more than one-half a wavelength away will therefore see less than 4 percent of the alternating component, but all of the average potential.

$$V_{av} = V_1 l_1/\lambda + V_2 l_2/\lambda$$

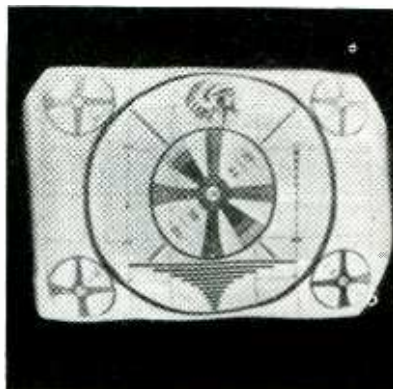
Since the relative strip width may be varied, across the surface by design, we are in a position to realize many desirable potential distributions including the case of a constant gradient parallel to the surface of the electrode. This is illustrated in Fig. 2.

Rectangular Deflectron

Figure 2A shows the conventional sequential type of electrostatic deflection using two crossed pairs of plates as contrasted to an equivalent Deflectron which performs biaxial deflection, simultane-

ously. The deflection box is only half as long as the crossed-plate structure. The sides of the box are formed by composite electrodes with triangular boundaries. Each coating is continuous along an edge so that there are four terminals.

Center of deflection R is the same for all rays. In the conventional structure, there are two separate deflection centers R_v and R_h and two different sensitivities for the two axes. In the crossed-plate arrangement, the fringe field between pairs has to be traversed by the beam thus giving rise to defocusing and keystone distortion. In the box system, these fringe fields are confined to the vicinity of the composite surfaces. The beam passes through the central region where the field is uni-



Television test pattern scanned with circular electrostatic deflection unit

form. This provides greater freedom from scan distortion and defocusing so that wider angles of deflection become practical.

Figure 3A shows what happens if the corner terminals are directly connected to two balanced sweep generators V and H . If the box is cut for an aspect ratio of 4×3 , the figure of scanning becomes a rhombus, standing on one point and including an angle of 74 degrees.

Figure 3B shows how to obtain a rectangular television scan parallel to the sides of the box. A matrix R-C network is inserted between the generators and the tube. Two arms of this matrix are reactances and the other two are resistances. If designed for a crossover frequency of 1,000 cps, the network will behave at the line and field frequency as if R or C , respectively, did not exist. As shown in the crt face by the use of the matrix the scanning area is almost doubled.

Deflection Sensitivity

A box in matrix connection is the equivalent of a matched pair, that is, a set of parallel plates cut for the same exit angle. The ultimate deflection sensitivity of such plates depends only on their aperture and the beam voltage as indicated by

$$e_d = 4E_A \tan^2 (\frac{1}{2} \alpha)$$

where E_A is the beam voltage at the point of deflection, e_d the peak-to-peak voltage between plates and α the total deflection angle.

This expression shows that at 52 degrees, deflection requires as much voltage as acceleration and, at 72 degrees, twice as much.

Fortunately, only one-half of this total has to be supplied to each plate, if push-pull operation is used. This high voltage demand, rather than functional deficiencies, seems to draw a line beyond which the use of electrostatic deflection becomes increasingly difficult. The practical limit appears to be reached at 50 degrees total deflection angle.

Figure 4 gives a general idea of the sweep circuit techniques for television. The system, when sealed into a bulb type 16LP4 run at 15,000 volts, requires 4,500 volts

for vertical and 7,900 for horizontal deflection, if no use is made of post acceleration. The vertical sweep voltage may be readily derived from two small triodes type 6SF5, running in push-pull off a plate supply of 2,700 volts and drawing 600 microamperes apiece.

The line sweep comes from a pulse amplifier with reactive load. It uses a power pentode type 6AU5 and a step-up transformer, whose secondary is tuned to approximately one-sixth of the line frequency (2,500 cps.). An early model of this sweep unit consumed 10 watts which is only a fraction of the power input used for conventional magnetic sweep circuits.

The need for a matrix network

with its attending frequency restrictions is obviated by the use of Deflectrons with rotational sym-

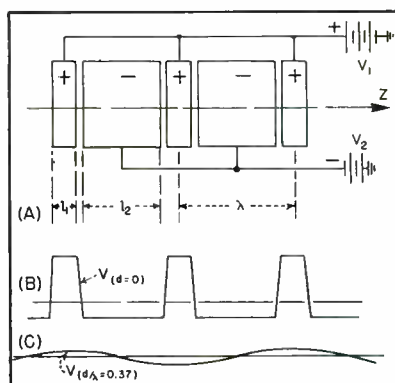


FIG. 1—Typical composite electrode configuration (A) and theoretical potential functions at (B) and at a distance d (C) from electrode surface

metry. The circular unit may be used with or without matrix, in a great variety of applications including tv picture tubes, radar indicators and oscilloscopes. The cylindrical form has the advantage of providing greater spacing between beam and electrode surface for most of the scan, thus minimizing deleterious wall effects. This advantage is largely maintained but the sensitivity is increased, if the cylinder is tapered off to a cone.

Circular Analysis

Figure 5 illustrates the basic conditions under which a uniform field with an inclination of φ degrees is properly reproduced in a

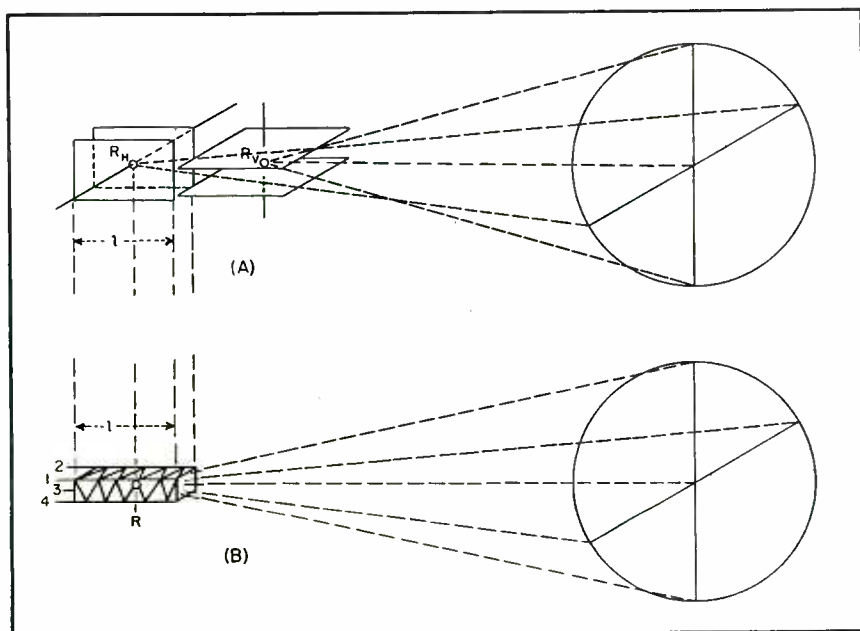


FIG. 2—Biaxial electrostatic deflection system (B) has advantage over conventional sequential type (A) of equal deflection sensitivities and common center of deflection

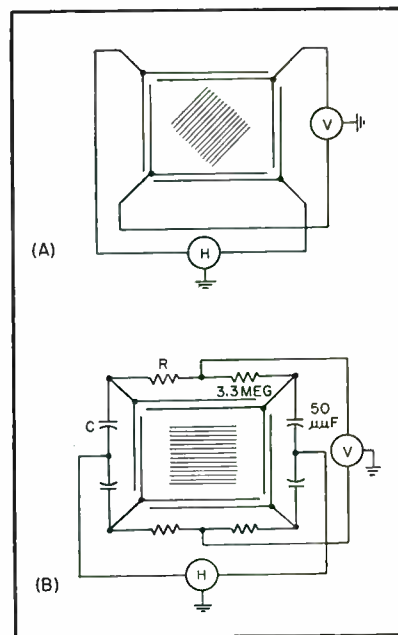


FIG. 3—Matrix connection (B) corrects for rhombic geometry

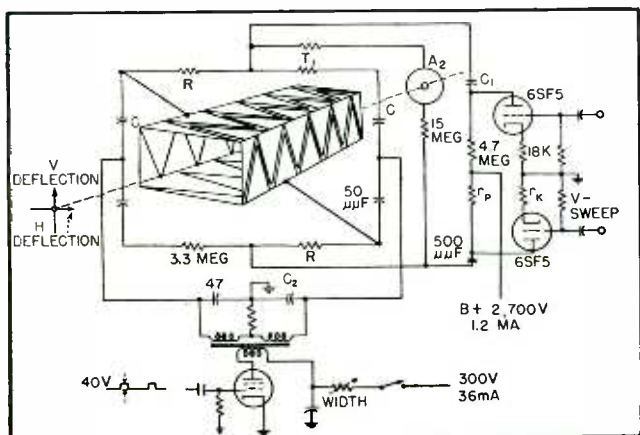


FIG. 4—Rectangular deflection box with matrix and sweep circuits

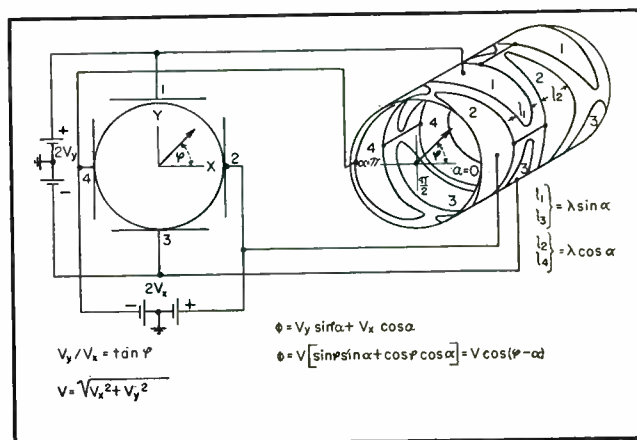


FIG. 5—Circular deflection unit offers production advantages

circular deflection. Suppose two voltages V_x and V_y are applied to the plates of a conventional oscilloscope in ratio of

$$V_y/V_x = \tan \varphi$$

To reproduce that angle correctly, with the same voltages, a circular deflectron has to be printed in such a way that the active length of the pattern is a sine and/or cosine function of the angle. In Fig. 5 this is accomplished by metallic areas which are bounded by half waves of sine and cosine, respectively. The boundary potential then is the sum of the applied voltages weighed by their respective lengths

$$\Phi = V_y \sin \alpha + V_x \cos \alpha$$

From the voltage ratio equation we find this to be the equivalent of a new cosine distribution.

$$\Phi = V \cos (\varphi - \alpha)$$

where $V^2 = V_x^2 + V_y^2$. The potential described by this equation generates, within the cylinder, a uniform field of the desired inclination. This reveals, moreover, that it is mandatory to keep the deflection voltages balanced at all times, including any d-c shift and positioning voltages. In this respect, the Deflectron is more touchy than its counterpart, the plate deflector, which may be operated from single-ended sources without too much trouble, at least at small angles.

There is apparently more than

one way to meet the required cosine distribution of potential in circular configurations. Figure 6 shows three geometries which are equivalent at least to a first approximation. Figure 6A shows the sinusoidal area distribution just mentioned. This pattern has the disadvantage of requiring conducting bridges which spoil the potential distribution and introduce points of high voltage gradient involving insulation difficulties.

The pattern of Fig. 6B shows the offset sine, which has inherent continuity thus avoiding one of the above defects. Figure 6C, or the arrow pattern, offers both continuity as well as good voltage stability. It consists of four groups

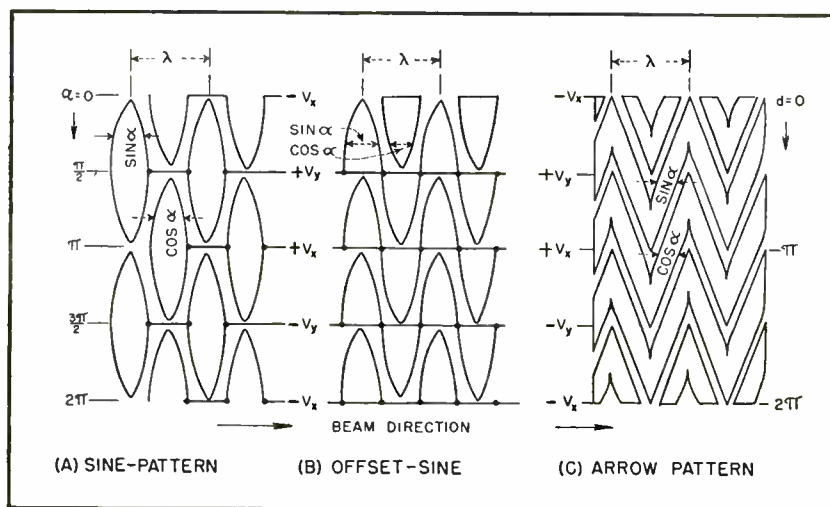
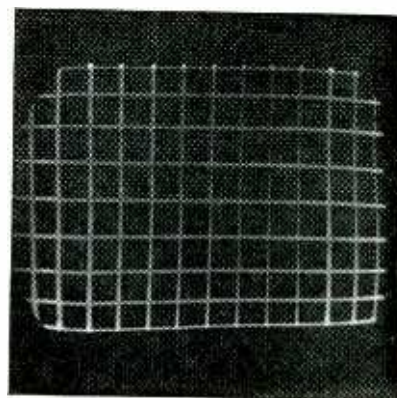


FIG. 6—Pattern geometries for circular Deflectrons



Bar pattern obtained with conical deflection unit

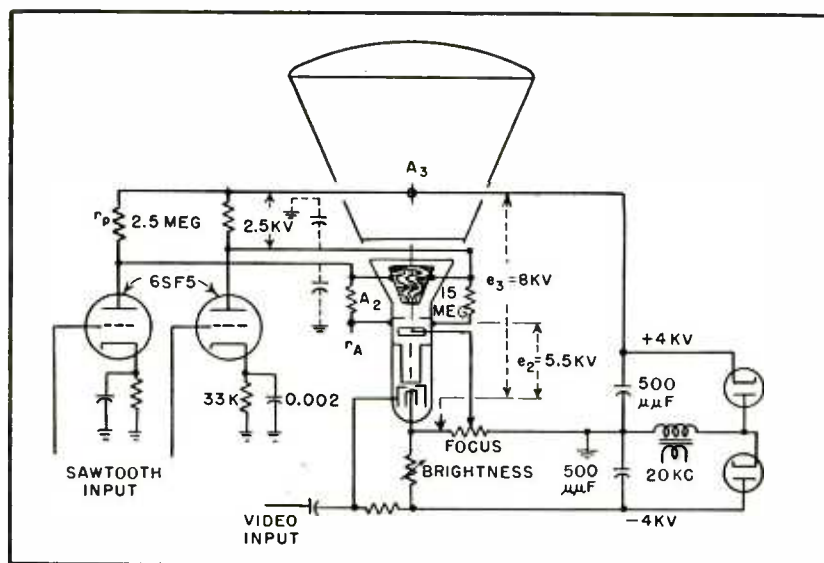


FIG. 7—Circuit illustrates extreme simplicity of conical deflection unit for ppi radar displays. Two 6SF5's generate 7,200-volt deflection signals

of metallic ribbons, whose width in axial direction varies as a sine-function of the angle. Each ribbon covers one-half of the perimeter.

The center of the photograph of various configurations shows a conical Deflectron of the offset-sine variety. Below it is a conical electrode with arrow pattern. These cones are cut for a 60-degree opening and have a 2 to 1 taper, which results in a sensitivity increase of 30 percent. The positive lens effect caused by the taper is negligible.

The gun used in all these Deflectron tubes is short and straight since no ion trap is required. Focus is done electrostatically at voltages between zero and 300 volts.

The conical unit has been successfully employed for radar applications. Figure 7 shows the extremely simple circuitry required

for ppi displays. Two pairs of 6SF5 triodes generate the required 7,200 volts of clipped sawtooth wave in push-pull out of a B-supply of 4 kv. With an input of 45 volts per phase, we obtained 50-degree deflection of an 8,000-volt beam using a moderate amount of post-acceleration (1.4 to 1).

The combined power supply for preamplifiers and tube employs a pulse-operated voltage doubler at a repetition rate of 20 kc. Since balanced d-c deflection is provided for, the spot may be shifted permanently toward the perimeter without defocusing. The small Deflectron capacitance ($25 \mu\mu\text{f}$ per phase) permits fast sweeps with negligible plate power.

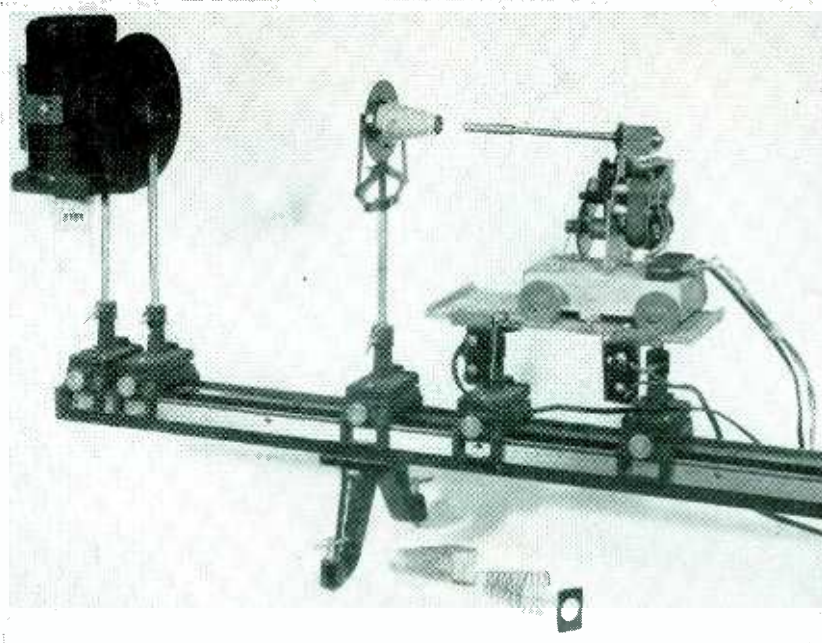


Radar ppi obtained using conical deflection circuit shown in Fig. 7

To illustrate an oscilloscope application, a 30-degree pencil unit was developed and mounted on top of a standard electron gun type 5CP1-A.

The pencil-Deflectron electrode shown at right in the composite of different types is a glass-cylinder two inches long and $\frac{1}{2}$ inch wide with an arrow pattern. Similar pencil units may also be produced inside of a 1-inch cylinder with $\frac{1}{4}$ inch diameter.

In its present form, the deflection factor of this tube is about twice as high as that of a conventional 5CP1, but both axes have identical characteristics. The mechanical ruggedness, simplicity of mounting and alignment, and the ease of reproduction may outweigh the loss of sensitivity for many applications.



Flying-spot illuminator for photoengraving electrostatic deflection yokes

One of the advantages of the Deflectron over the conventional crossed-pair system is the ease by which it may be reproduced with high accuracy. The Deflectron uses a glass base with narrow inside, but with wide outside, tolerances. Such a body may be readily produced by pressing glass around a precision graphite filler in a mold. The accurate reproduction of the metallic pattern is assured by using methods of photo-engraving. With this technique, all units are printed from a single master negative which is, itself, a photographic copy from an enlarged pattern design drawing.

Production Techniques

In production, a film carrying the master pattern is inserted on the inside of the glass envelope and illuminated by a concentrated arc lamp. The small size of this light source insures sharp contours, in spite of the fact that contact between glass and film may be as far off as 20 mils.

To obtain constant and uniform exposure all along the inside of the electrode, it was found necessary to use a flying-spot method of illumination, rather than a stationary lighthouse setup. A small motor rotates a surface-silvered 45-degree mirror around the axis of the elec-

trode, so that the reflected light hits the film glass surface under almost normal incidence. At the same time, the motor carriage rolls slowly back and forth, so that the inside is scanned in a helix. The rest of the procedure follows the established methods of photo engraving. The etched silver base is built up by electro-plating of copper.

When placed inside the evacuated envelope, the units are able to withstand the high sweep voltages without arc-over. On a glass base, the phase to ground capacitance averages $20 \mu\mu\text{f}$, while the surface insulation after processing regularly exceeds 100 megohms, thus permitting the use of high-impedance sweep circuits with low power consumption.

The project has been supported by D. E. Noble, vice-president of Motorola, Inc. and Director of Research, and benefitted from the assistance of Gerald C. Hoffman, V. Graziano and James H. Grigg.

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