LINEAR CORRECTION FOR CATHODE RAY OSCILLOGRAPH

By Frederick Bedell and Jackson Kuhn
Cornell University, Ithaca

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Abstract

The deflection of the cathode beam in a cathode-ray oscillograph tube, while substantially proportional to the voltage applied to the deflecting plates within the tube, is not proportional for small voltages in tubes commonly used. This non-linearity is due to the heavy cloud of ions between the plates. In the practical use of such a tube error due to this non-linearity is avoided by applying a bias to the plates so as to work on the straight part of the curve.

In a cathode-ray oscillograph the deflection of the cathode beam is proportional to the electromagnetic field through which it passes. While in an ideal case the deflection is likewise proportional to the electrostatic field through which the beam passes, there are certain disturbing elements in cathode-ray tubes, as usually constructed, which need to be taken into consideration, particularly when the deflection is small.

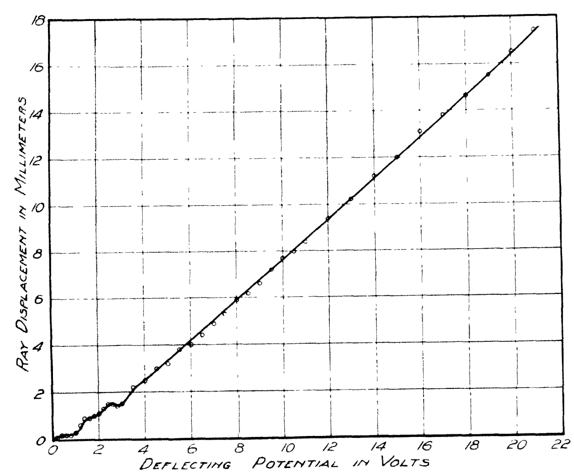


Fig. 1. Relation between deflection and applied e.m.f.

Fig. 1 shows the relation between the deflection and applied e. m. f. in a W. E. 224-B cathode-ray oscillograph tube, in which the electrostatic field is obtained by applying the e.m.f.s., which are to be measured or compared, to two pairs of deflecting plates, located inside the tube, between which the beam passes. It is seen that when the applied e.m.f. exceeds 3 volts, giving an observed deflection of 2.5 mm, or more, the curve is practically a straight line, while for smaller values the proportionality does not hold.

This is further shown in Fig. 2, obtained by applying a periodic e.m.f. to one pair of deflecting plates and a constant e.m.f., varied by steps of 10 volts, to the other. The second set of more or less parallel lines was obtained by

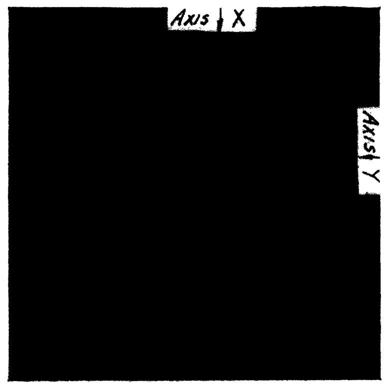


Fig. 2. Displacement of X and Y axes, vertically and horizontally, by 10-volt steps. Distance of camera from screen: 18 inches.

repeating, with the connections to the plates reversed. The vertical line marked "Y-axis" corresponds to zero e.m.f. on the X plate; the lines on the left and right corresponding to negative and positive e.m.f. s of 10, 20, 30

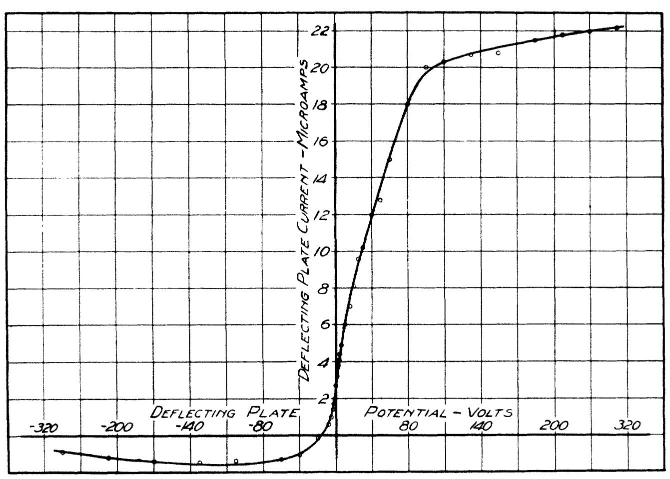


Fig. 3. Plate current for different plate voltages, using deflecting plate Y; anode potential 400 volts.

volts, etc. Similarly the horizontal line marked "X-axis" corresponds to zero e.m.f. on the Y plate. Negative and positive refers to the potential of the free plate with respect to anode.

Under ideal conditions, we should have in Fig. 2 a system of square coordinates made by two systems of equidistant parallel lines. Departure from this condition is caused by the non-linear calibration, as shown in Fig. 1, and other causes which will not be analyzed here, as the curvature of the screen, location of the camera, etc.

The non-linearity of the relation between plate potential and the resulting beam deflection, as shown in Fig. 1, is due to the heavy cloud of ions between the deflecting plates. An idea of the number of ions can be obtained from the curve in Fig. 3, which shows the plate current corresponding to different plate voltages. The presence of these ions between the plates masks the effect of the applied potential, so that the potential gradient at the beam is not proportional to the applied potential. This masking effect is, of course, more marked at the lower potentials. At high potential this effect is negligible as the ions are swept away. The relation between deflection and deflecting potential is now linear within the limits of observation, although there are probably slight departures due to critical potentials.

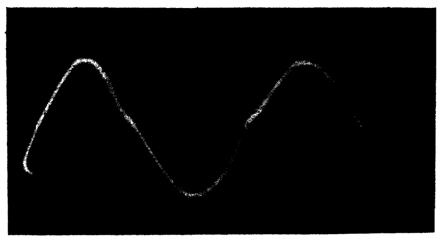


Fig. 4. Effect of non-linearity shown by bump in what should be smooth curve.

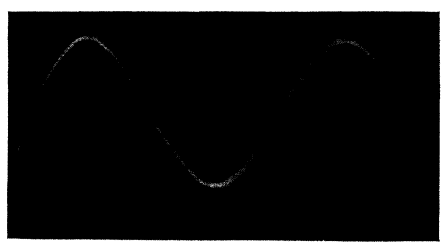
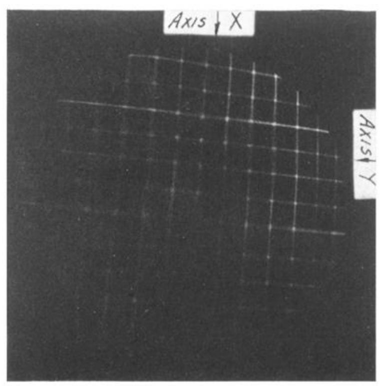


Fig. 5. True curve, without bump, obtained with stabilized oscilloscope with linear scale.

So far as the practical applications of the tube are concerned, the cure for the non-linearity of the calibration curve in Fig. 1 is obvious: to shift the zero by applying a plus or minus bias to the deflecting plates so as to work on the straight part of the curve. For the plate current to be a minimum the biasing potential should be negative, as shown in Fig. 3. A biasing potential of about 50 volts applied to both plates will displace the spot diagonally to the periphery of the screen, outside the area in which observations are made. The spot may be restored to an artificial zero position near the center of the screen by a constant magnetic field, so that the curve as observed will never pass through the real zero, now displaced to the periphery of the screen, with its non-linear error. In other words, the observed deflections, both horizontal and vertical, will always be on the straight part of the calibration curve shown in Fig. 1.

As ordinarily used, without a corrective device, a cathode-ray oscillograph, when connected to a smooth nearly sinusoidal e.m.f., does not show a smooth curve but shows a curve with a little bump, as in Fig. 4. On the stabilized oscilloscope[1] used by the authors, equipped with linear correction as here described, the true curve without this bump is shown as in Fig. 5. The horizontal and vertical scales are both truly linear. The authors were assisted by G. B. Engelhardt in the experimental work. The investigation was carried on under a grant from the Heckscher Research Council.

[1] F. Bedell and J. G. Kuhn, Rev. Sci. Insts. **1**, 227 (1930).



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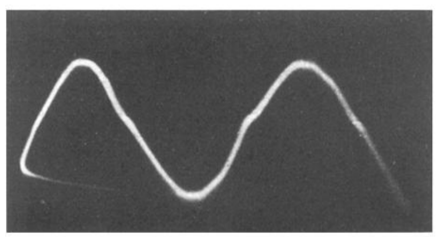

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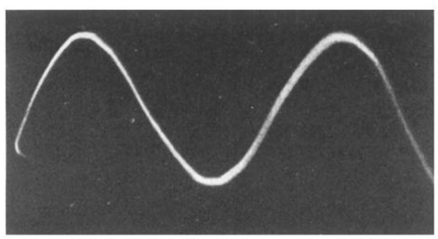

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