DEFLECTION AND CONVERGENCE OF THE 21-INCH COLOR KINESCOPE*

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Summary*—This paper describes new deflection and convergence components and circuitry used to achieve successful operation of the 21AXP22 21-inch color kinescope. The effects of deflecting-yoke characteristics on the performance of horizontal- and vertical-deflection circuits, and circuitry required to energize the dynamic-convergence assembly, are discussed.*

Various methods of presenting information on flux distribution of deflecting yokes are reviewed, including a new method for obtaining three-dimensional flux plots. Considerations involved in the design and development of the yoke, the horizontal- and vertical-output transformers, and the converging-magnet assembly are also reviewed. Operating circuits are shown, and typical performance data given.

OPERATION of the new 21AXP22 21-inch color kinescope resulted in development of new deflection and convergence components and circuitry which are different from those included in the original 15-inch color receiver. Figure 1 shows the 21-inch kinescope with the required components in their correct relative positions. These components include the deflecting yoke, converging-magnet assembly, purifying magnet, blue-positioning magnet, and magnetic field equalizer. The new horizontal-output and high-voltage transformer and the vertical-deflection-output transformer are shown in Figure 2.

Figure 3 illustrates the basic operating principles of the kinescope which the components must satisfy to produce a good color picture. The shadow mask and faceplate are constructed to provide color changes conditional upon the direction of arrival of the impinging electron beams. After scanning, each individual beam should have maintained or regained its original relative position within the composite beam array, and the three beams should converge at the shadow mask. Since pure color fields are attained when each electron beam lands on its proper phosphor dot, corrections are made in phosphor-dot placement which effectively maintain the deflection center of the yoke and the kinescope color centers in register throughout the entire scanning cycle.

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* Decimal Classification: R583.13.

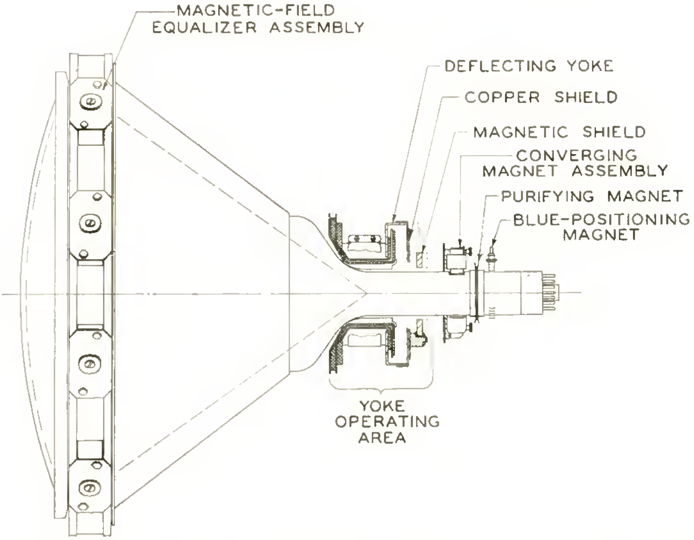

Fig. 1—Sketch showing relative placement of components on 21-inch color kinescope.

The development of 70-degree-deflection color television components has been expedited by the use of a simplified test set for which a block diagram is shown in Figure 4. An adequate signal source is the TG-2A sync and bar generator. If color pictures are required for demonstration, a flying-spot scanner may be added. Most performance tests are

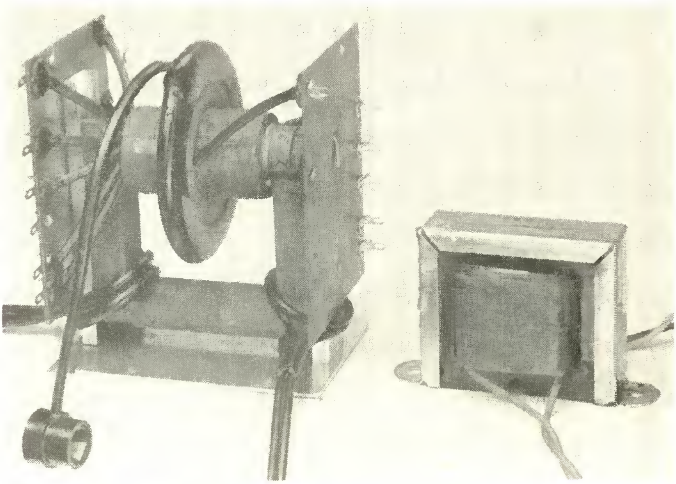

Fig. 2—Developmental horizontal-output and high-voltage transformer (left) and vertical output transformer 247FT1.

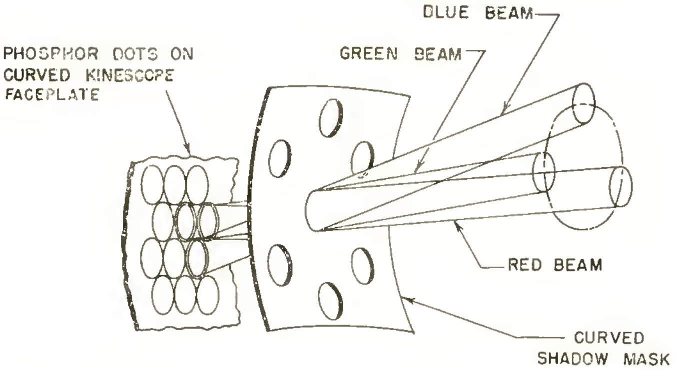

Fig. 3—Sketch illustrating basic operating principles of 21-inch shadow-mask color kinescope.

made using a white-bar test pattern, experience having proved this pattern to be superior to a dot pattern for the measurement and recording of spacing between beam centers. In addition, "ringing" effects (slight irregular vertical displacement of horizontal lines) are clearly visible when bars are used.

DEFLECTING YOKE

The 230FD1 deflecting yoke, shown in Figure 5, was designed to provide the required color purity and convergence characteristics for operating the 21-inch color kinescope, when used with associated com-

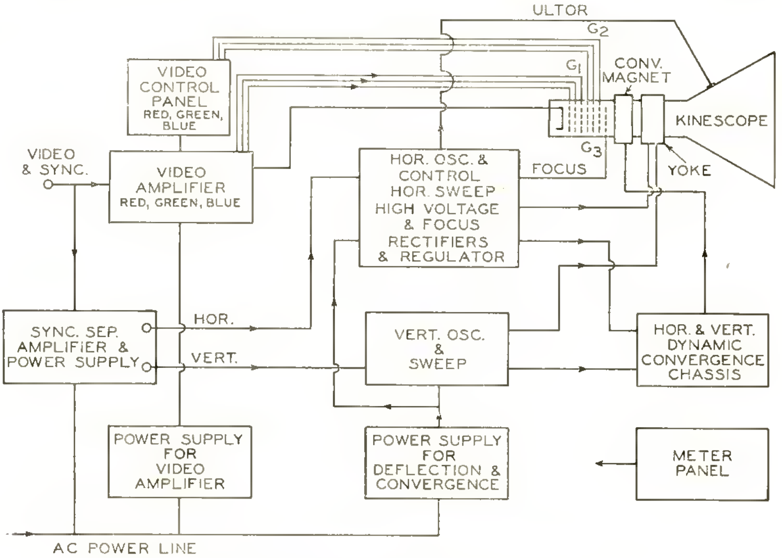

Fig. 4—Block diagram of test chassis.

ponents and circuitry. Expanded-coil and expanded-front-core construction provides shaped flux fields for full 70-degree deflection, and maintains within close tolerances red-, green-, and blue-beam convergence over the entire raster. Particular attention was given to the maintenance of red and green convergence on horizontal lines in the corners, so that the need for additional costly dynamic-convergence corner-correction circuitry was eliminated. Inductance and insulation characteristics were selected for use in auto-transformer deflection circuits of the energy-recovery type, with ultor voltages up to 25 kilovolts.

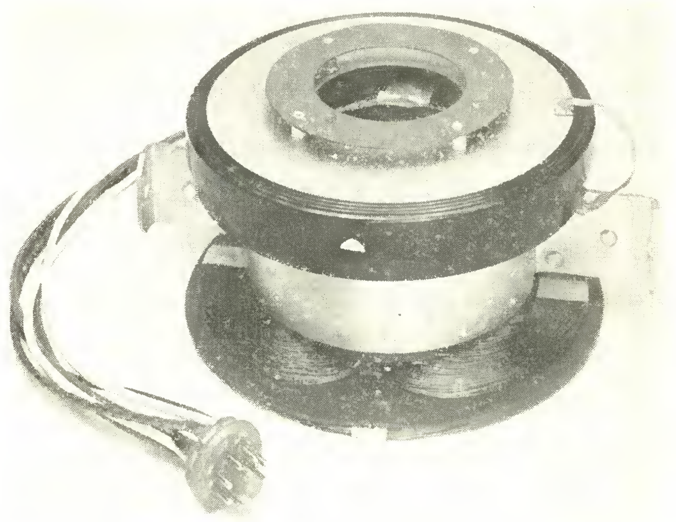

Fig. 5—Deflecting yoke 230FD1 for 21-inch color kinescope.

YOKE-FLUX PLOTTING

Although various methods may be used for the measurement of the direction and magnitude of the three-dimensional magnetic field of a yoke at any point within or about the yoke, it is difficult to depict graphically all of the data needed to define the yoke field. A rapid method of obtaining iron-filings flux plots showing equipotential magnetic lines of force uses Ozalid*-sensitized linen (activated by light and ammonia) cut to fit the yoke section being studied. The linen is reinforced with cardboard and uniformly covered with iron particles of 300-mesh size. The yoke is then energized with d-c and the assembly is vibrated by means of low-audio-frequency sound waves. After the

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*Trade mark of the General Aniline and Film Corp.

flux pattern forms, it is exposed to ultraviolet light until the color of the linen changes from yellow to white. The field and light are then cut off, the powdered iron is removed, and the paper is run through the developing section of the Ozalid machine. Sample patterns obtained are shown in Figures 6, 7, and 8; the approximate area traversed by the beam trio is marked on each pattern.

Three-dimensional flux plots have been obtained by the use of a suspension of finely divided flakes of iron in a clear casting resin. A rubber mold made to fit the inside yoke contour is used as a container for the mixture. The viscosity of the resin changes quickly after the promoter and the hardener are added. The mixture is poured into the mold about six minutes after the promoter is added. Current is then applied through the coils, and the iron flakes in the resin align themselves with the flux field.

Application of the current to the coils intermittently keeps the pattern well defined until the plastic gels, without pulling the iron particles out of position. Immediately after the mixture gels, the casting is placed in an oven at a temperature of about 85° C for ¾ hour to prevent cracking during the exothermic expansion.

After the casting has hardened, it is machined and polished so that the pattern becomes visible. Coating of the finished casting with a lacquer provides a hard, smooth finish and considerably reduces the amount of polishing needed. Ordinarily, the casting is cut axially or transversely in order to display the flux pattern distribution to best advantage. Figure 9 shows results obtained when this procedure was used.

Coil-Turns Distribution and Electron-Beam Paths

The specific turns distribution and the coil shape of the 230FD1 yoke and some of the various designs tried during development are shown in Figure 10. The relation $d = T \cos \theta$ defines the popular cosine distribution associated with conventional monochrome yoke-coil design. When a constant wire diameter is used throughout the coil, the turns distribution varies as the thickness d at the angle θ. As may be seen from the chart, neither $\cos \theta$ nor $\cos^2 \theta$ turns distribution has been used in the design of successful color yokes.

In addition to performance tests using d-c-driven multi-tapped yoke coils, flux plots of various configurations were studied and related to the actual path of an electron beam as deflected by an expanded-coil yoke. Figure 11 shows the path traced by an electron beam deflected with the 230FD1 color yoke. This data was obtained with a kinescope having a fitted, phosphor-coated, mica piece in the funnel area. The

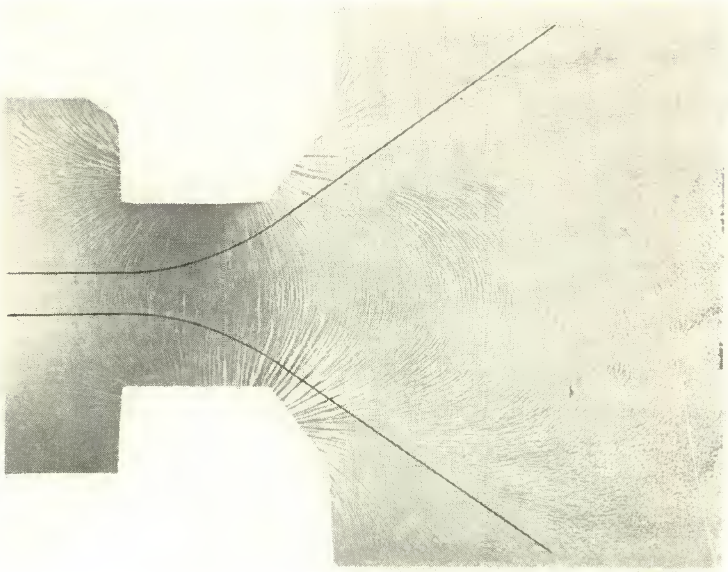


Fig. 6—Flux pattern of vertical coils of deflecting yoke 230FD1. Solid lines approximate border of area swept by beam trio.

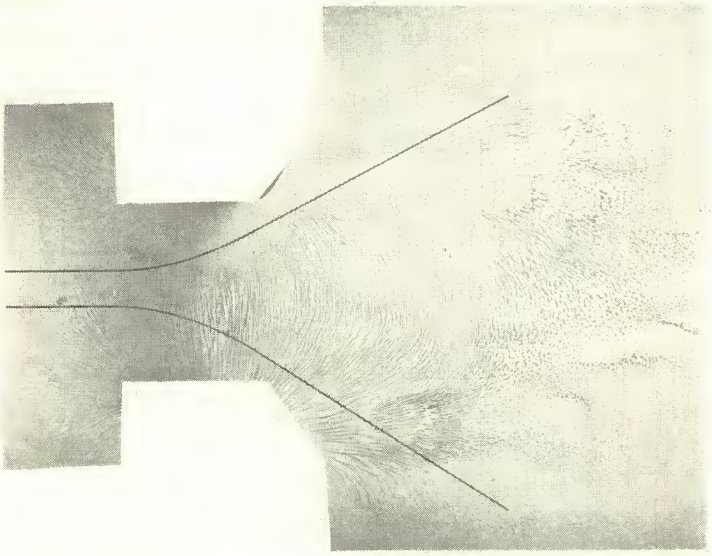


Fig. 7—Flux pattern of horizontal coils of deflecting yoke 230FD1. Solid lines approximate border of area swept by beam trio.

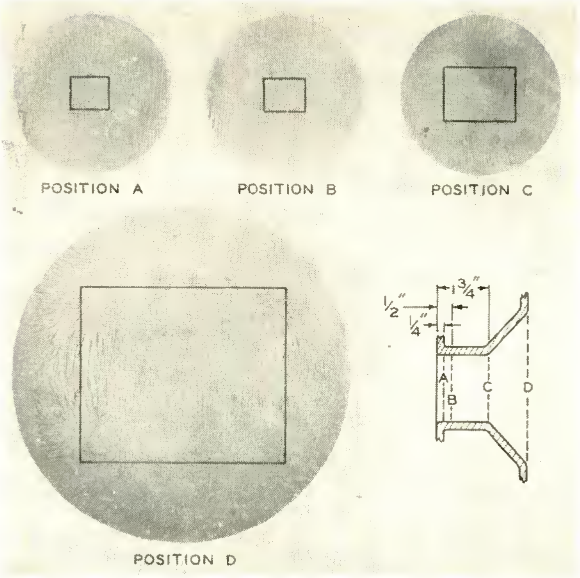


Fig. 8—Flux pattern of vertical coils of deflecting yoke 230FD1 taken in positions indicated. Solid lines approximate border of area swept by beam trio.

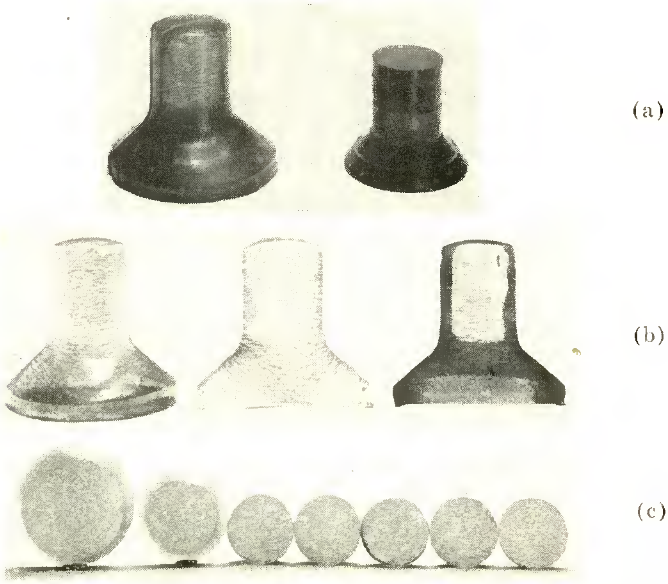
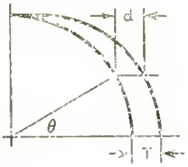


Fig. 9—Three-dimensional flux patterns of an expanded-front deflecting yoke: (a) complete casting made with iron flakes suspended in a clear resin; (b) sections of the casting cut parallel to yoke axis; (c) sections cut normal to yoke axis.



$d = T(\cos\theta)^n$

$\frac{d}{T} = (\cos\theta)^n$

d = DIMENSION OF COIL AT ANGLE θ

				DEV. 45° COLOR YOKE WITH STRAIGHT SIDES			DEV. 62° COLOR YOKE WITH STRAIGHT SIDES			EXPANDED-FRONT 70° COLOR YOKE 230FD1		
θ	cos θ	cos²θ	d (cos²θ)	d	d/t	n	d	d/t	n	d	d/t	n
0	1.000	1.000	0.125	0.125	1.000	0	0.125	1.000	0	0.125	1.000	0
15	0.966	0.933	0.121	0.127	1.016	-0.457	0.125	1.000	0	0.125	1.000	0
30	0.866	0.750	0.108	0.131	1.048	-0.326	0.125	1.000	0	0.125	1.000	0
45	0.707	0.500	0.083	0.136	1.088	-0.243	0.125	1.000	0	0.125	1.000	0
60	0.500	0.250	0.062	0.142	1.133	-0.184	0.125	1.000	0	0.136	1.088	-0.122
75	0.259	0.067	0.032	0.149	1.192	-0.130	0.125	1.000	0			
90	0											

Fig. 10—Specifications for deflecting yoke 230FD1 and for 45-degree and 62-degree developmental models.

coated mica was marked with a cross-hatched grid having known dimensions, and the beam path was observed visually.

Insulation and Core Considerations

The voltage developed across the horizontal coils during flyback is approximately 3,000 volts peak-to-peak at 15,750 cycles per second; the coils are series-connected to provide minimum voltage between turns and to permit connection of neutralizing capacitors across each coil. The vertical coils are also series-connected, with an operating voltage across the coils of approximately 200 volts peak-to-peak at 60

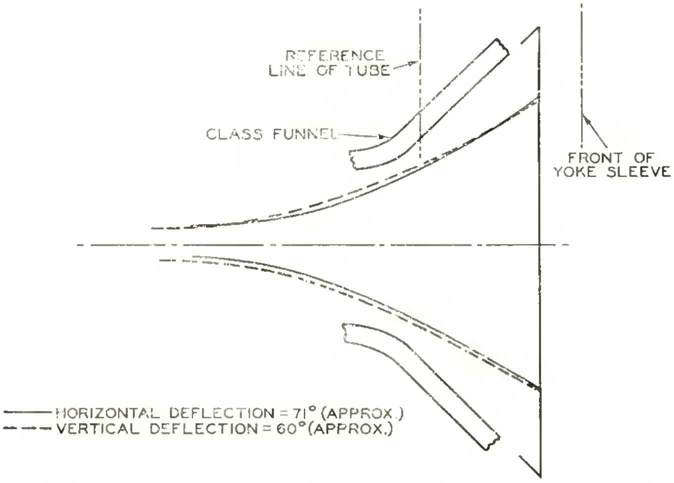


Fig. 11—Electron-beam paths in field of deflecting yoke.

cycles per second. Voltage induced by the horizontal retrace pulse of 1,250 volts peak appears between the vertical coils and ground.

Insulation between coils is provided by specially compounded molded synthetic rubber shaped to fit the coils. This insulation must withstand operating temperatures up to 85°C, at an absolute maximum voltage rating of 4,500 volts for a pulse of approximately 10 microseconds duration, and at a repetition rate of 15,750 cycles per second. Continuous life tests made at 6,000 volts peak at rated 85°C operating temperature proved the effectiveness of the insulation and the coil construction.

The ferrite cores used for the flux return path provide high permeability, high resistivity, and low losses at the operating frequencies. Permeability alone may be used in the evaluation of core materials for use at the vertical scanning frequency because losses in the ferrite at 60 cycles per second are calculated to be 5.9 milliwatts. The calculation is based on the core used in the 230FD1 yoke, which weighs 1.73 pounds and operates at an average flux density of 254 gausses. The copper loss in the vertical-deflection-coil windings, which have a total d-c resistance of 54 ohms and require an r.m.s. current of 0.145 milliampere, is 1.12 watts. This value is more than 190 times greater than the core loss, indicating the relative unimportance of core losses at the vertical-deflection frequency.

At the horizontal-scanning frequency, the core loss of the 230FD1 yoke is approximately 0.285 watt, based upon an average flux density of 230 gausses. The copper loss in the horizontal-deflection windings, which have a total d-c resistance of 7.3 ohms and require an r.m.s. current of 520 milliamperes for full scan, is 2.0 watts. The core loss is, therefore, approximately 14 per cent of the copper loss in the horizontal deflection windings.

At the low operating flux density, ferrite permeability and losses are relatively stable, and the magnetic circuit is considerably diluted by the large air cap. Careful observation of the performance of a yoke during a heat run indicated little change in performance at temperatures from 25°C to 80°C. Figure 12 shows the variation of permeability with temperature for this type of ferrite.

The ferrite core has an expanded front for flux shaping, and is designed in four 90-degree segments for better manufacturability. The volume of core material used provides optimum deflection sensitivity and good mechanical strength consistent with low cost. Because concentricity of the core and coils is required for good convergence, purity, and pattern rectangularity, the cores are ground to close tolerances.

Compressible gaskets between the core segments and the coils help maintain concentricity during assembly. A heavy cold-rolled steel band locks the core securely in position and provides means for mounting the yoke in the receiver. Figure 13 shows the disassembled yoke.

SHIELDING AND CASING

The cap-and-shield assembly includes a thin copper disc to minimize the coupling of horizontal-frequency yoke fields into the pole-piece assembly, with resulting complication of the required convergence correction. A magnetic shield provides similar action with respect to the 60-cycle-per-second vertical-deflection-frequency flux at the back of the yoke. The magnetic shield consists of a ¼-inch thick ferrite disc, or several 0.004-inch thick oriented silicon-steel discs mounted with grain structures in quadrature for symmetry.

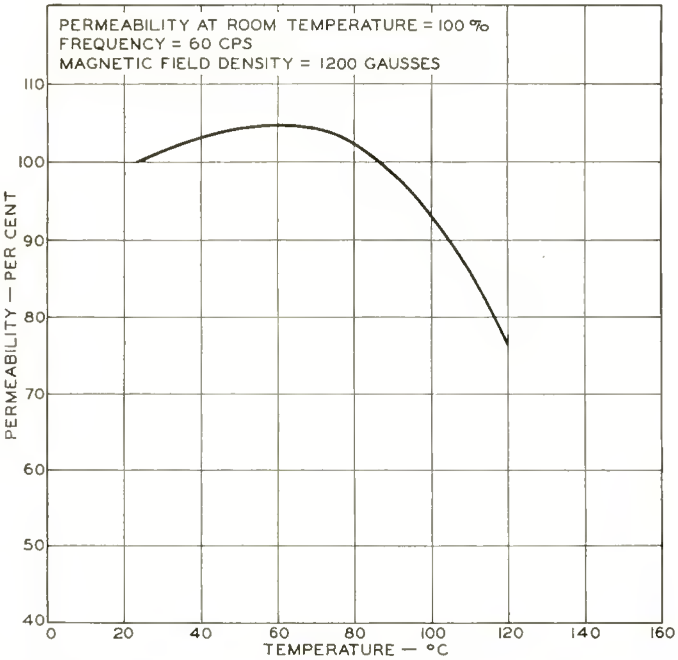


Fig. 12—Variation of permeability with temperature for ferrite mix.

The molded case-and-terminal assembly is made of thermo-setting general-purpose phenolic, and the terminals are assembled directly to the case. The characteristics of the phenolic meet the mechanical and electrical requirements of this application. This material was chosen in preference to lower-cost injection-molded thermoplastics because of its mechanical stability at elevated temperature, freedom from distortion, and mechanical strength.

COIL WINDING, ASSEMBLY, AND TEST

The coils are wound to approximately final shape with thermoplastic-coated insulated wire by means of special tension devices and arbors. After being wound, the turns are temporarily fixed in place by current passed through the coils sufficient for heating and softening the thermo-plastic coating. With the wire sizes used, #24 and #25 wound bifilar, current required for the horizontal coils is 13 amperes for 9 seconds. The wound coils are impregnated in vinyl compound, dried thoroughly, then heated, shaped, and cooled in the mold to lock the turns into their final position.

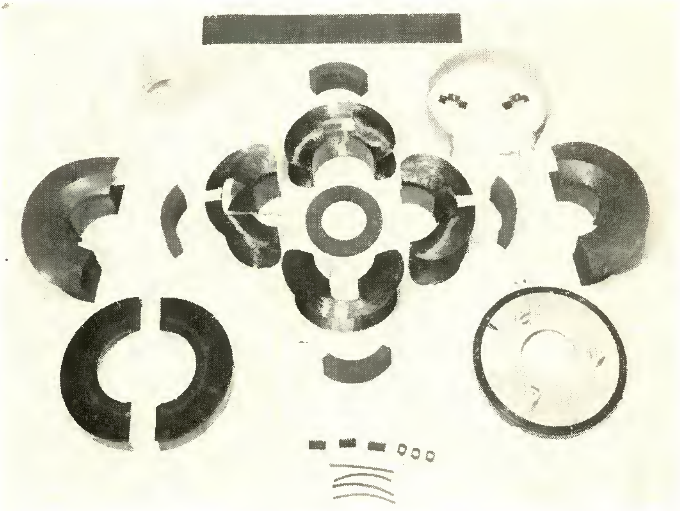


Fig. 13—Disassembled parts of deflecting yoke 230FD1.

The horizontal coil is made with 145 turns each of #24 and #25 wire bifilar wound. The vertical coil consists of 465 turns of #26 wire.

The individual coils are carefully gauged for physical size; then tested for shorted turns, number of turns, and continuity; induced-voltage-tested at 4,000 volts peak for corona; and finally calibrated for inductance and resistance. Matched pairs are assembled into complete yokes, which are then tested for interconnection of the coils, cross talk, "hipot," and induced voltage. The horizontal-deflection coils are induced in series at a peak voltage of 5,000 volts, and the vertical coils at a peak voltage of 900 volts. The performance of the completed yokes is then tested in a deflection circuit. The yokes are held to close tolerances for deflection sensitivity, ultor power output, pattern rectangularity, and convergence with color purity.

Convergence Specification

When recommended components and dynamic-convergence circuitry are used on an average 21AXP22 kinescope, the maximum distance between line centers of a rectangular-grid test pattern measured in the corners is not allowed to be greater than 1/16 inch with the center converged. In the center of the top, bottom, right, and left edges, the maximum distance between lines of the cross-hatch pattern will not exceed 1/32 inch. These measurements are made approximately 1 inch from the kinescope edge.

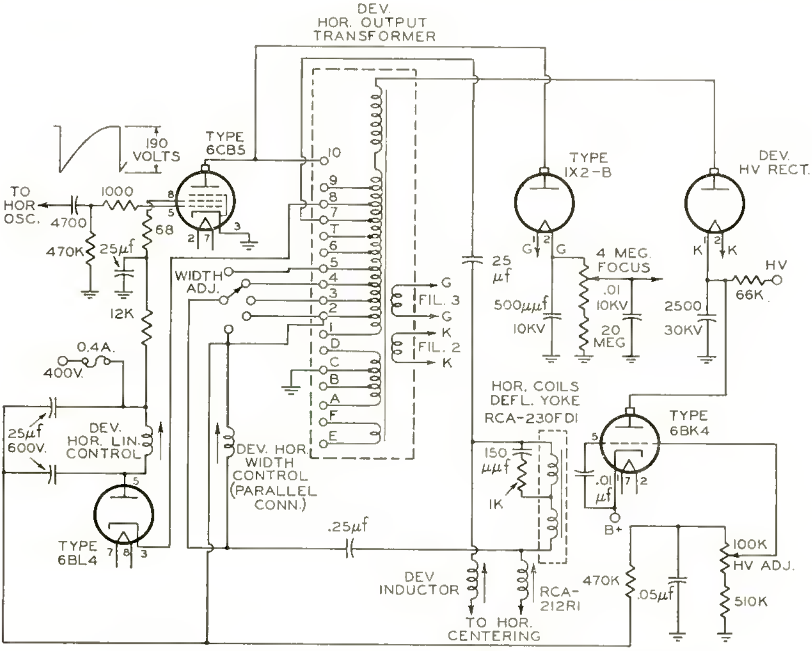


Fig. 14—Horizontal-deflection and high-voltage circuit.

Over-all performance of the 230FD1 yoke on the 21-inch color kinescope has been considered equal or superior to that previously obtained with narrow-angle color kinescopes having smaller picture area.

Horizontal-Deflection and High-Voltage Transformer

The advantages of auto-transformer flyback operation dictated the use of the circuit shown in Figure 14 for conversion of the practical value of yoke inductance of 11.8 millihenries to the required value of plate-load inductance for the driver tube. In addition to providing the required matching ratio, the transformer supplies the high-voltage ultor power and the horizontal-deflection-frequency pulse voltages needed for color-receiver operation. The new developmental transformer represents an improvement over that used in earlier circuits because the ultor and focus voltages require two rectifiers instead of three. The 1X2-B provides 5.5 kilovolts at currents up to 75 microamperes with good regulation for focusing, plus a current of approximately 150 microamperes for the bleeder. The developmental high-voltage diode rectifies the full pulse voltage of the transformer, providing the 25-kilovolt ultor voltage at a current of 800 microamperes.

ELECTRICAL REQUIREMENTS

A conventional oscillator–discharge circuit is used to provide the driving voltage for correct operation of the circuit. Other sawtooth-generating circuits such as the stabilized multivibrator may be used to provide the required voltage amplitude and waveform. Sufficient reserve driving-voltage amplitude should be available to permit adjustment for the excess-drive condition characterized by the appearance of a bright vertical line near the center of the raster. The correct driving-voltage amplitude is slightly less than the overdrive condition.

Tube type 6BK4 is used in a shunt-regulator circuit capable of maintaining the 25-kilovolt ultor voltage within ± 5 per cent from zero beam current to full 800-microampere load current. Ultor-voltage regulation is used to prevent changes in picture brightness, size, convergence, color purity, and horizontal linearity which tend to accompany large variations in beam current. The unloaded transformer is designed to deliver about 32 kilovolts. The regulator load in shunt with the kinescope draws a total current of about 800 microamperes from the rectifier at the 25-kilovolt setting, with zero kinescope current drain. Dark picture scenes, which draw little current from the kinescope, and lighter scenes requiring heavier current do not change the total load in the deflection circuit because the current through the regulator tube drops as the kinescope current increases. The regulator tube is capable of dissipating all the energy provided by the system, and does so when the kinescope is dark.

TRANSFORMER-DESIGN CONSIDERATIONS

Available literature[1] includes several excellent detailed procedures on deflection-transformer design which may be somewhat simplified in

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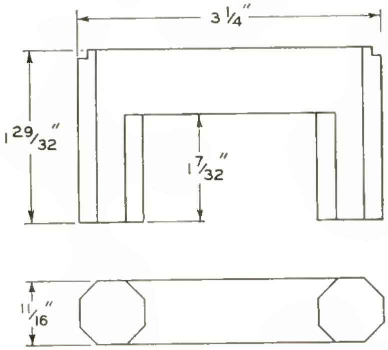
[1] O. H. Schade, "Electro-Optical Characteristics of Television Systems," *RCA Review*, Vol. IX, March, June, September, and December, 1948.

practice. When the yoke sensitivity and inductance are known, the tube complement is defined, and the supply voltage and boosted B power requirements are indicated, the following design method may be used:

1. *Core Size*—Determine the ferrite-core size, using previous designs as a guide. The ultor voltage specified will require a coil-winding structure and spacing from the grounded core which necessitate the use of an adequate window area. The core used for the developmental transformer is made of manganese ferrite and has a cross-sectional area of 2.55 square centimeters. Dimensions are given in Figure 15.



COIL DATA

ORDER OF WINDING	TURNS	TAPS	WIRE SIZE	WINDING WIDTH (CAM)	CROSSES PER TURN (X/T)
Secondary #1	68	23, 32	0.0100 SNHF	2"	1/4
Secondary #2	15	-	0.0100 SNHF	2"	1/4
Primary	810	22, 33, 50, 63, 108, 243, 477, 518, 788	2X 0.0100 SNHF	2"	1/4
Tertiary	1700	-	0.0045 DNSF	3/16"	4

Fig. 15—Core and winding data for developmental horizontal-output and high-voltage transformer.

2. *Secondary Turns*—Calculate the number of turns required for the transformer secondary. Although an inductance of 5 to 10 times the yoke inductance is usually satisfactory, the use of a yoke requiring high deflection current assures the storage of adequate energy for good regulation and permits the use of higher ratios. The core is gapped to minimize acoustic radiation and to dilute the magnetic circuit, thus reducing the variation in inductance between cores of different permeability.

The following expressions are used to determine the number of turns required for the yoke portion of the transformer secondary winding.

$$L_S = KN_y^2,$$

where N_y = number of transformer secondary turns for yoke portion of the winding,

K = proportionality factor for the core used

$= 6.8 \times 10^{-7}$,

L_S = required inductance of yoke section of transformer secondary

$= 11 \times 11.8 = 130$ millihenries

$$N_y = \sqrt{\frac{130 \times 10^{-3}}{6.8 \times 10^{-7}}} = 435 \text{ turns required.}$$ (The final optimized design included 455 turns.)

3. *Flux Density*—Calculate the flux density, $B_{\max}$, using the formula

$$B_{\max} = \frac{\hat{e} \times 10^8}{\omega N_y A}$$

where $\hat{e}$ = peak voltage across the yoke,

A = cross-sectional area of the core = 2.55 square centimeters

$\omega = 2\pi f$

f = retrace frequency

$$B_{\max} = \frac{2970 \times 10^8}{2\pi \times 50{,}000 \times 435 \times 2.55}$$

$= 855$ gausses

$$f = \frac{1}{2T}$$

T = retrace time (assume 10 microseconds)

$$f = \frac{1}{2 \times 10 \times 10^{-6}} = 50 \text{ kilocycles.}$$

This flux density, which is lower than that normally used in monochrome television transformers, minimizes core losses and resulting ultor power slump over the range from room temperature to the maximum operating temperature of 100°C.

4. *Transformer Turns Ratios*—Practical ratios between driver and damper tube are determined by losses in the system, and are usually about 1.5 or 2.0 to 1. The optimum value is best determined empirically by measurement of performance on a sample

transformer having extra taps. The sawtooth of current through the yoke results in a voltage drop, E_y, across the yoke section of the secondary which reduces the plate voltage of the driver tube.

$$E_y = L\frac{di}{dt} = \frac{11.8 \times 10^{-3} \times 0.9}{27 \times 10^{-6}} = 393 \text{ volts.}$$

The plate voltage of the driver must not become less than the voltage needed to supply the required peak plate current or low enough to cause excessive screen dissipation.

$E_{bb\,(\text{assumed})}$ = Boosted B voltage of $2(+B)$ = 800 volts

E_b = Minimum voltage on plate of driver = 100 volts

$$\frac{N_p}{N_y} = \frac{(E_{bb} - E_b)}{E_y} = \frac{(800 - 100)}{(393)}$$

where N_p = turns from a-c ground to driver plate,

$N_y = 435$,

$N_p = 435 \times \frac{700}{393} = 775$ turns (788 turns used on optimized design)

Improvement in efficiency resulted when the damper cathode was connected to a transformer tap having a voltage approximately 10 per cent higher than that of the yoke.

5. *High-Voltage Tertiary*—The exact number of turns required in the tertiary cannot readily be calculated because of resonance effects which add to or subtract from the step-up voltage based upon the yoke retrace pulse. The approximate turns, however, may be calculated as follows:

The theoretical retrace voltage developed across the yoke, $\hat{e}_y$, is given by

$$\hat{e}_y = \hat{\imath}\omega L = 0.9\ (2\pi \times 50{,}000)\ 11.8 \times 10^{-3} = 3300 \text{ volts,}$$

$$\hat{e}_t = \hat{e}_y \left(\frac{N_t}{N_y}\right)$$

where $\hat{e}_t$ = peak tertiary voltage $= \hat{e}_{\text{ultor}} - \hat{e}_y$

$\hat{e}_y$ = peak pulse voltage across yoke

N_t = number of total turns

$N_y = 435$.

Therefore, 25,000 (less boosted B voltage of 800 volts) -3300

$$= 3300 \left(\frac{N_t}{N_y} \right)$$

$$N_t = 2755 \text{ turns.}$$

A sample transformer was checked for performance as turns were removed; 2510 total turns were used on the final transformer design.

6. *Coil Configuration*—The primary and secondary coils, listed in Figure 15, are universal-wound wide coils for tight coupling and good deflection sensitivity; the high-voltage tertiary is made in a narrow coil for reduced distributed capacity to improve retrace time. The wire diameters used, which are listed in the tabulated data, are large enough to keep the winding-temperature rise within safe limits. Insulation used is adequate for the operating voltages.

7. *Power-Conversion Efficiency*—The 230FD1 yoke requires relatively high peak-to-peak current — 1.8 amperes for full 70-degree horizontal deflection. This condition is favorable for the design of a transformer which must operate at a relatively high conversion efficiency.

   Power input for horizontal scanning and high voltage $= E_B(I_p) = 400\ (0.191) = 76.5$ watts.

$$\text{Conversion efficiency} = \left[\frac{\text{Focus} + \text{Ultor} + \text{Boosted B+} \atop \text{Rectifier Filament Power Output}}{\text{Power Input}} \right]$$

$$= \left[\frac{5{,}500\,(225 \times 10^{-6}) + 25{,}000\ (800 \times 10^{-6}) \atop +\ 800\,(0.002) + 3.15\,(0.2)}{76.5} \right]$$

$$= .307 = 30.7\%.$$

This value is appreciably higher than the 10- to 15-per cent conversion efficiency provided by deflection systems presently used for 21-inch 90-degree monochrome kinescopes.

PLATE DISSIPATION ON 6CB5

A dynamic test was made to obtain temperature readings on the 6CB5 bulb at normal operating level. A static run was made, during

Table I — Typical Performance Data on Circuit Using Developmental Horizontal-Output and High-Voltage Transformer and Deflecting Yoke 230FD1

B voltage	400 volts
Ultor Power	20 watts
Boosted B Voltage	800 volts
Horizontal-Output Tube 6CB5	
Peak Positive-Pulse Plate Voltage	6200 volts
Grid-No. 2 Voltage	180 volts
Grid-No. 1 Voltage (Sawtooth)	190 volts p-p
Plate Current	193 milliamperes
Grid-No. 2 Current	18 milliamperes
Cathode Current	211 milliamperes
Grid-No. 2 Input	3.24 watts
Damper Tube 6BL4	
Peak Inverse Plate Voltage	3860 volts
Plate Current	193 milliamperes
Peak Heater–Cathode Voltage	4260 volts
Developmental Horizontal-Output and High-Voltage Transformer	
Pulse Voltage at Terminals (Measured to Ground, Terminal C)	
Terminal D	+250 volts
Terminal B	— 60 volts
Terminal A	—220 volts
Terminal E to F	100 volts
Vertical-Output Tube 6BL7-GT	
Plate Supply Voltage	400 volts
Plate Voltage	354 volts
Peak Positive-Pulse Plate Voltage	1440 volts
Grid Voltage (Referenced to cathode)	— 23 volts
Plate Current	28 milliamperes

Heat run—The final core temperature was 68°C, the transformer primary winding was 65°C, and the width-control winding was 50.5°C in a 24°C ambient temperature. Tests were made in the open, uncovered, with 10 per cent increase in $+B$ voltage and the width-control switch on terminal #4.

which screen power input was maintained unchanged from the dynamic test condition, and d-c plate power input was plotted as a function of bulb temperature. Plate dissipation was 23 watts, which is equal to the design-center value for this tube.

Table II — Deflection-Yoke 230FD1 Sensitivity

Horizontal-Deflection Coils:	
Current required for full 70-degree deflection (peak-to-peak)	1.8 amperes
Vertical-Deflection Coils:	
Current required for full 55-degree deflection (peak-to-peak)	0.5 ampere

VERTICAL-DEFLECTION TRANSFORMER

The 230FD1 yoke requires 500 milliamperes (approximately) peak-to-peak current to scan the 21-inch color kinescope vertically. The circuit shown in Figure 16 includes a vertical-blocking-oscillator transformer (208T2) used with one triode section of a 6SN7-GT to provide the driving signal for the 6BL7-GT vertical-deflection amplifier. The two triode sections of the 6BL7-GT, are connected in parallel.

Good performance was achieved with a low-cost transformer (247FT1) having a ratio of 8:1, made with a square stack of the ⅞-inch center leg 0.014 inch XXX grade lamination. The primary was 3,400 turns of 0.0063 inch diameter enamel wire; the secondary was 425 turns of 0.0113 inch diameter enamel wire. Nominal primary impedance with a 4-mil gap spacer, measured at 30 volts and 60 cycles per second with 0.025 ampere d-c is 10,000 ohms.

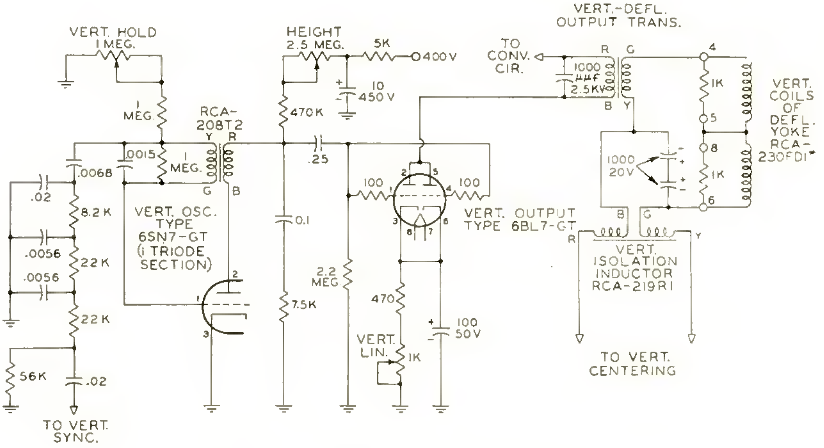


Fig. 16—Vertical-deflection-output circuit.

CONVERGENCE COMPONENTS

The deflection of a three-beam triangular array originally converged in the center of the kinescope has been shown to result in misconvergence proportional to the separation between the beams in the deflection plan and the deflection angle scanned. The 21AXP22 kinescope is designed to allow correction for this misconvergence, and has an electron gun equipped with pole pieces for static and dynamic control of each individual beam. Each pole piece supplies a magnetic field with a d-c flux component to obtain center convergence, plus dynamic components of flux to maintain convergence at full screen deflection.

The converging magnet assembly shown in Figure 17 consists of three sets of cores and coils, one to control each of the three beams. Each core assembly consists of two L-shaped pieces butted together to form a U core; the butting surfaces are slotted to accept a circular magnet. The magnet is polarized normal to its axis, and may be rotated to provide the d-c flux for center-screen convergence. Two separate bifilar wound coils on each core permit flexibility in the design of the circuit for providing the necessary horizontal- and vertical-dynamic convergence voltages.

Convergence of the three beams in the center of the screen is obtained with four separate controls. The three radial position adjustments are obtained with the converging magnet assembly. The blue-positioning magnet shown in Figure 18 permits lateral movement of the blue beam so that all three beams may be converged in the center of the screen.

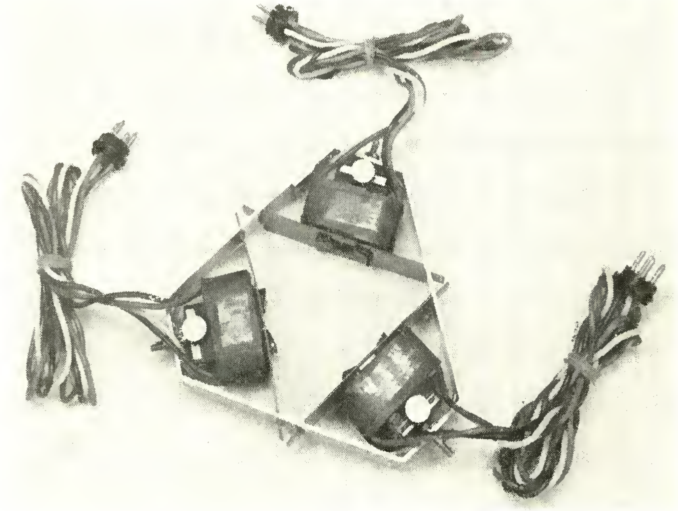


Fig. 17—Converging-magnet assembly.

The Purifying Magnet shown in Figure 18 permits adjustment of the angle of approach of the three-beam array so that it strikes the shadow mask at the correct angle to excite the phosphor dots symmetrically, and produce uniform color rendition. Rotation of the separate magnets together, or with respect to each other, provides a magnetic field adjustable in direction and intensity from 0.1 to 9 gausses.

A magnetic-field equalizer assembly positioned around the faceplate end of the 21AXP22 color kinescope provides sectionalized magnetic fields to permit compensation in localized areas for the effects of stray magnetic fields and the earth's magnetic field on color purity

The equalizer consists of eight separate magnet-and-shunt assemblies, each mounted in position over four flux-conducting pole pieces. The magnets may be adjusted to change direction and magnitude of the flux in the peripheral area of the screen adjacent to each magnet to provide beam-landing position adjustment.

The assembly is mounted between the flange and faceplate. Adequate insulation must be provided between the equalizer assembly and the metal shell of the kinescope to permit operation of the equalizer assembly at ground potential.

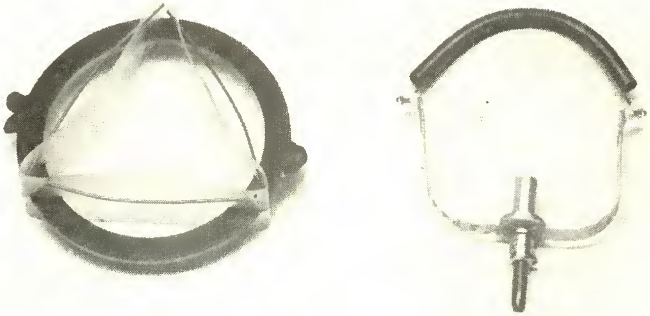


Fig. 18—Purifying magnet (left) and blue-positioning magnet.

DYNAMIC-CONVERGENCE CONSIDERATIONS

Early attempts to scan wide-angle color kinescopes were made using complex convergence circuits which had four tubes and included two special corner-correction amplifiers. Improvements made in the deflecting yoke minimized red–green separation in the corners and permitted elimination of this special type of correction, with resulting circuitry simplification and cost reduction.

CONVERGENCE CIRCUITS

The departure of a blue horizontal line from a straight line was checked, using a cross-hair telescope rigidly mounted on a calibrated rack and pinion. The curve obtained, shown in Figure 19, approximates a parabola for which the equation is $y = 2\ (0.070)\ x^2$.

Several convergence circuits have been used successfully to obtain properly shaped current waveforms at the convergence-magnet assembly. One of the circuits, shown in Figure 20, included the use of tube amplifiers to provide the basically parabolic waveforms. Provision was also made for adding positive- or negative-sloped sawtooth shaping as required for symmetry correction.

Dynamic-convergence correction in the top and bottom picture areas may be obtained by use of the shaping network in the plate circuit of the vertical-output tube. Shaping for symmetry correction is provided as required with a current sawtooth waveform developed across the 5,000-ohm center-tapped pots.

Dynamic-convergence correction at the raster sides is obtained with similarly shaped current waveforms at the horizontal-deflection rate. One triode section of the 6BL7-GT is used as a sawtooth amplifier referenced to the horizontal-output transformer. The other section of the 6BL7-GT and the two sections of a 12BH7 are used as blue-, red- and green-convergence amplifiers. A positive or negative pulse from the deflection transformer added to the sawtooth provides the required waveform.

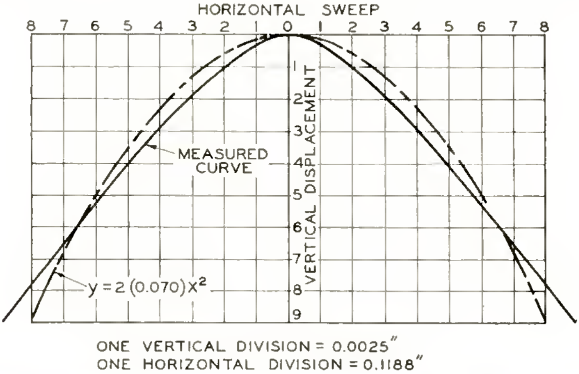


Fig. 19—Departure of a blue horizontal scanning line from a straight line.

Figure 21 shows the bar pattern completely converged.

Figure 22 shows the typical pattern obtained with an average 230FD1 yoke and 21AXP22 kinescope, with the center converged, and with no dynamic correction applied.

Figure 23 shows the horizontal stripes only, with no dynamic convergence correction. Blue is low at the sides, requiring appreciable correction, but red and green are converged within less than 0.045 inch throughout the raster. The yoke-flux pattern is designed to provide this characteristic, which makes practicable the use of low-cost horizontal dynamic-convergence correction circuitry.

Figure 24 shows the converged lines after the adjustment of horizontal and vertical dynamic-convergence amplitude.

Currently used vertical-convergence circuitry provides the required parabolic waveforms of sufficient amplitude. Figure 25 shows a vertical

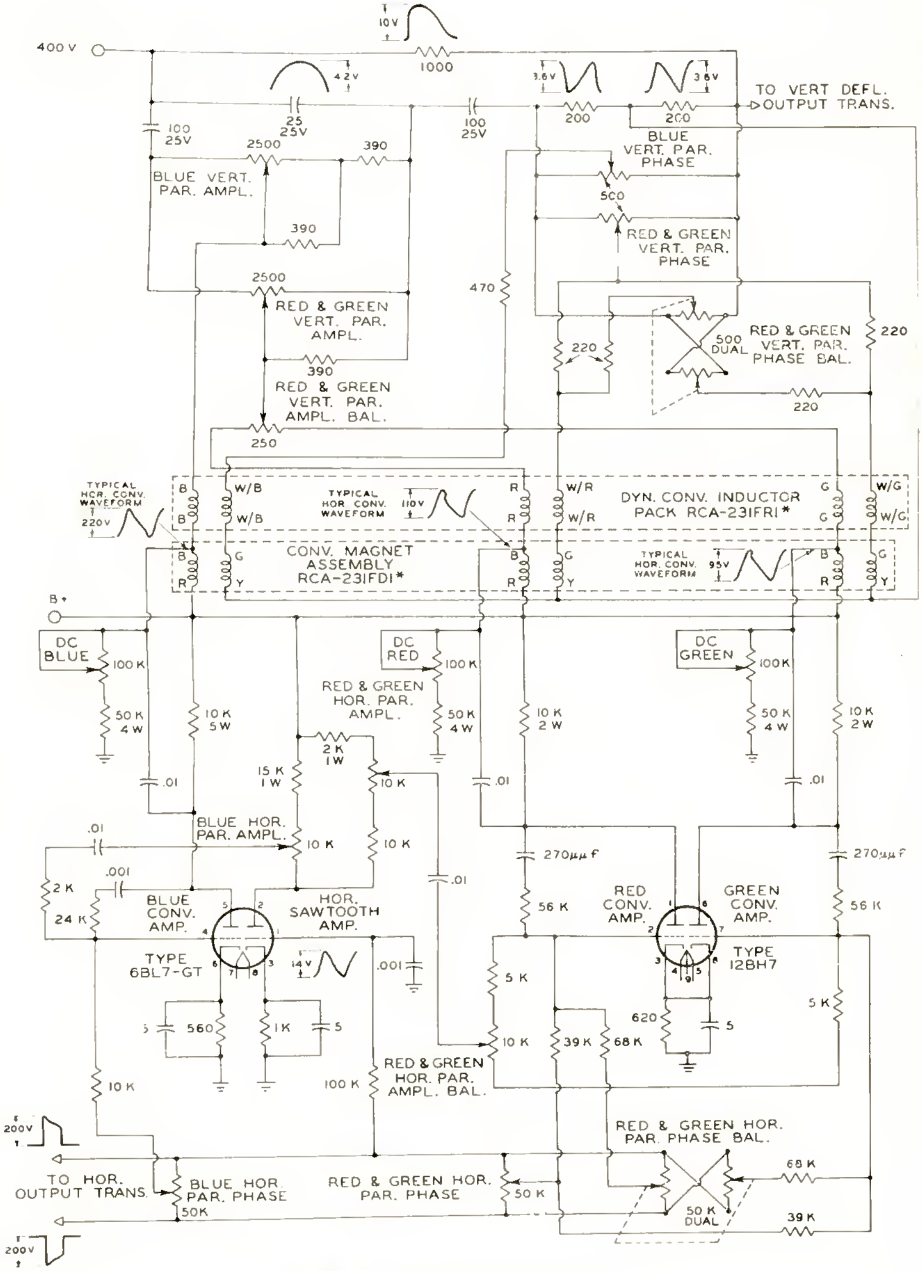


Fig. 20—Convergence circuit.

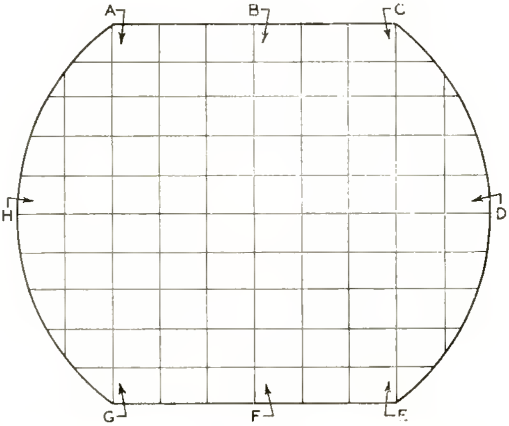


Fig. 21—Bar pattern illustrating proper convergence. The red, green, and blue horizontal and vertical bars are converged over the entire raster within 1/32 inch at B, D, F, and H, and within 1/16 inch at A, C, E, and G.

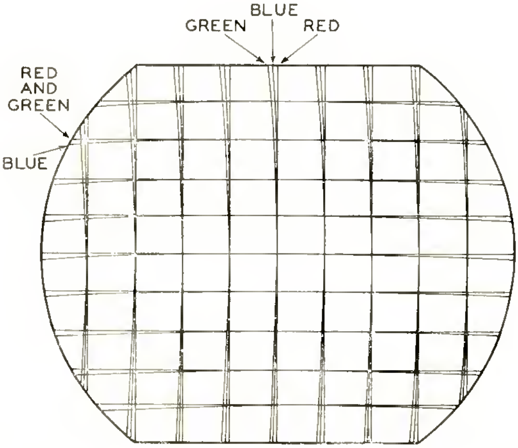


Fig. 22—Typical test pattern obtained with average yoke and kinescope. No dynamic-convergence correction. Red and green horizontal bars are converged on horizontal lines within 0.045 inch. Blue horizontal bars are low at sides of pattern, indicating need for dynamic-convergence correction. The center of the blue vertical bar at the edges of the pattern is within 1/16 inch of the center line between the red and green vertical bars.

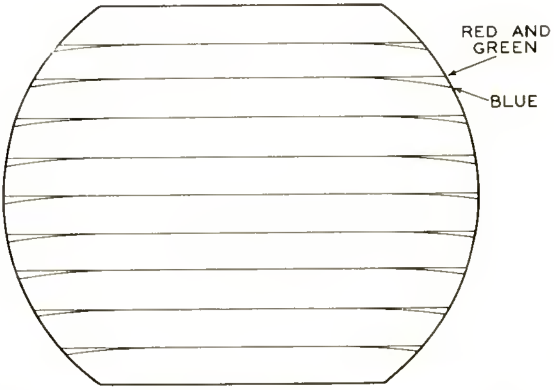


Fig. 23—Test pattern showing horizontal bars only. No dynamic-convergence correction applied. Red and green horizontal bars are converged on horizontal lines within 0.045 inch. Blue horizontal bar is low at edges of pattern, indicating need for dynamic-convergence correction.

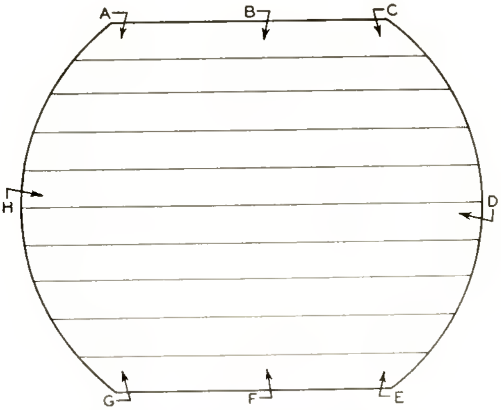


Fig. 24—Test pattern showing horizontal bars only after dynamic-convergence correction is applied by adjustment of horizontal and vertical dynamic-convergence controls. The red, green, and blue horizontal bars are converged over the entire raster within 1/32 inch at B, D, F, and H, and within 1/16 inch at A, C, E, and G.

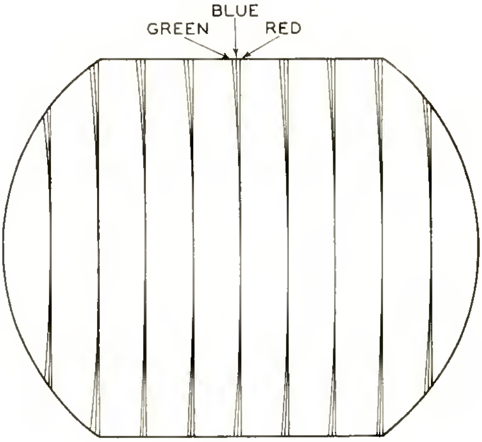


Fig. 25—Test pattern showing vertical bars only. No dynamic-convergence correction applied. The center of the blue vertical bar at the edges of the pattern is within 1/16 inch of the center line between the red and green vertical bars.

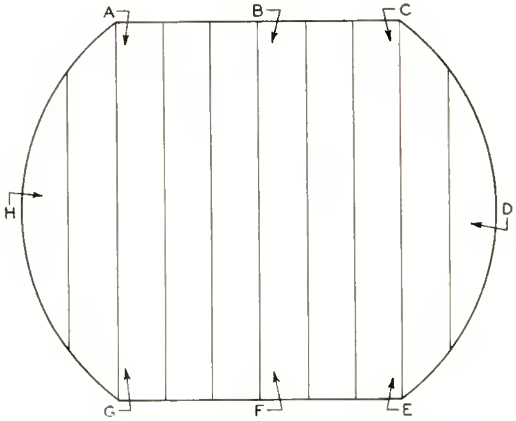


Fig. 26—Test pattern showing vertical bars only after dynamic-convergence correction is applied by adjustment of vertical dynamic-convergence controls. The red, green, and blue vertical bars are converged over the entire raster within 1/32 inch at B, D, F, and H, and within 1/16 inch at A, C, E, and G.

line pattern with the center converged, and with no dynamic correction. Red and green are bowed toward each other, almost symmetrically about the horizontal axis.

Figure 26 shows the red and green vertical lines straightened and made parallel with the vertical dynamic-convergence amplitude control. The vertical-deflection-frequency dynamic-tilt control is used to cause the maximum beam movement to occur above or below the center.

ACKNOWLEDGMENT

The horizontal-deflection transformer was developed by B. V. Vonderschmitt. The yoke development and product design was by W. H. Barkow, J. K. Kratz, and C. C. Matthews. L. E. Annus and P. E. Wiseman helped with the component testing. M. Bayer built the deflection test set, and flux patterns were made by D. J. Coyle and B. McHugh.

APPENDIX — MEASUREMENT OF LOSSES IN FERRITE CORE OF DEFLECTING YOKE 230FD1

The core loss was measured in two different ways. In the first method, a thermal meter was used to measure the voltage induced in test coils wound around the core segment, in the positions shown in Figure 27. This voltage

$$e = N \frac{d\phi}{dt} \times 10^{-8}$$

would have the waveform shown in Figure 27(a), if the flux corresponds to Figure 27(b).

With the flux variation

$$\phi_1 = K_1 \, t_1,$$

then $e_1 = K_1$

from Figure 27(b) $$e_1 = \frac{\Phi \times 10^{-8}}{26.55 \times 10^{-6}} = K_1$$

$$e_2 = \frac{\Phi \times 10^{-8}}{5.15 \times 10^{-6}} = K_2.$$

The induced voltage E_{rms} (for a single turn at horizontal frequency) $= \sqrt{\dfrac{K_1{}^2 t_1 + K_2{}^2 t_2}{T}}$

$$= \sqrt{\frac{\frac{\Phi^2 \times 10^{-4}}{(26.55)^2}(53.1 \times 10^{-6}) + \frac{\Phi^2 \times 10^{-4}}{(5.15)^2}(10.3 \times 10^{-6})}{(63.4 \times 10^{-6})}}$$

$$= 8.55 \times 10^{-4}\,\Phi$$

$$\Phi = \frac{E_{rms} \times 10^{-4}}{8.55} = 1170\,E_{rms} \text{ maxwells.}$$

With the search coil at position 1, $E_1 = 1.34$ volts for 2 turns, and 0.67 for 1 turn. Cross sectional area core $= 5.56$ cm^2, $B = \frac{\Phi}{A}$

$$B_1 = \frac{1170\ (0.67)}{5.56} = 141 \text{ gausses.}$$

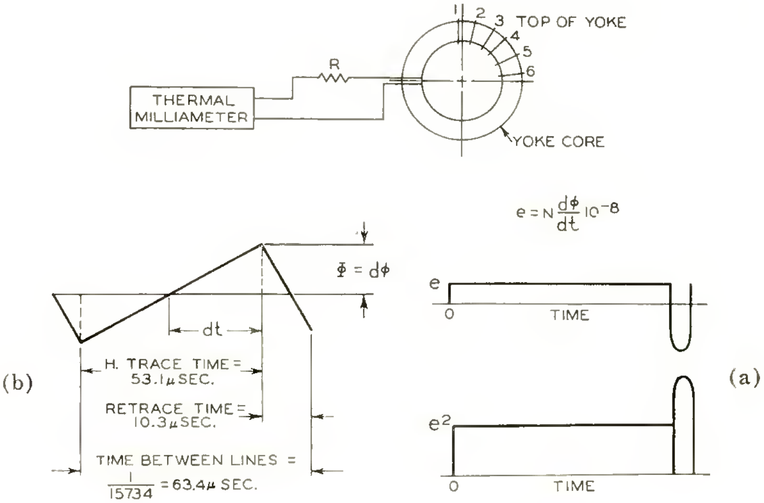


Fig. 27—Theoretical waveforms used in yoke-core flux density determination at the horizontal-deflection frequency.

At vertical-deflection frequency, trace time = 1/60 second minus return time of about 4 per cent, or .016 second. (See Figure 28.) The voltage induced in the test coils, with just the vertical coils energized is

$$e = N \frac{d\phi}{dt_1} \times 10^{-8}$$

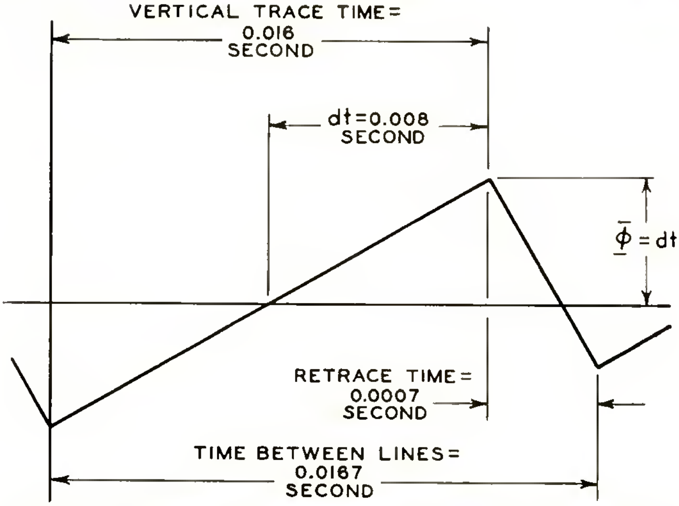


Fig. 28—Theoretical vertical-deflection frequency waveform.

Table III — Dynamic Test Method for Determining Flux Density

Horizontal Frequency

	Position	Measured Current (amperes)	Measured Resistance (ohms)	Volts	Volts per turn	Φ (maxwells)	B (gausses)
Seg. 1	1	0.042	31.97	1.34	0.67	782.	141.
Seg. 2	2	0.055	31.96	1.757	0.878	1025.	185.
Seg. 2	3	0.052	31.96	1.66	0.83	972.	175.
Seg. 2	4	0.064	31.97	2.042	1.021	1200.	216.
Seg. 2	5	0.082	31.97	2.62	1.31	1535.	276.
Seg. 2	6.	0.086	31.99	2.75	1.375	1610.	290.
					Avg.	(Seg. 2) =	228. gausses

	Vertical Frequency Position	Volts (20-turn coil)	Φ (maxwells)	B (gausses)	Total Flux Density (gausses)
Seg. 1	1	0.19	1570.	282.	423.
Seg. 2	2	0.23	1900.	342.	527.
Seg. 2	3	0.21	1737.	312.	487.
Seg. 2	4	0.18	1490.	268.	484.
Seg. 2	5	0.14	1160.	209.	485.
Seg. 2	6	0.094	777.	140.	430.
		Avg.	(Seg. 2) =	254. gausses	

$$E_{rms} = \sqrt{\frac{\dfrac{\Phi^2 \times 10^{-10}}{8^2}(16 \times 10^{-3}) + \dfrac{\Phi^2 \times 10^{-10}}{.35^2}(0.7 \times 10^{-3})}{16.7 \times 10^{-3}}}$$

$$= .600\Phi \times 10^{-5} \text{ volts per turn and, for a 20-turn coil}$$

$$\Phi = \frac{E_{rms} \times 10^5}{20 \times .600} = 8340\ E_{rms} \text{ maxwells,}$$

$$\underset{\text{(vertical coil)}}{B_{\max}} = \frac{\Phi}{A} = \frac{8340 \times 0.19}{5.56} = \underset{\text{(position 1)}}{285 \text{ gausses.}}$$

This method of determining flux density was checked with a static test, using a ballistic galvanometer, energizing the coil with d-c as required for full deflection, and then opening the circuit. Values obtained were reasonably in agreement with those determined by the first method.

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