

# Mullard

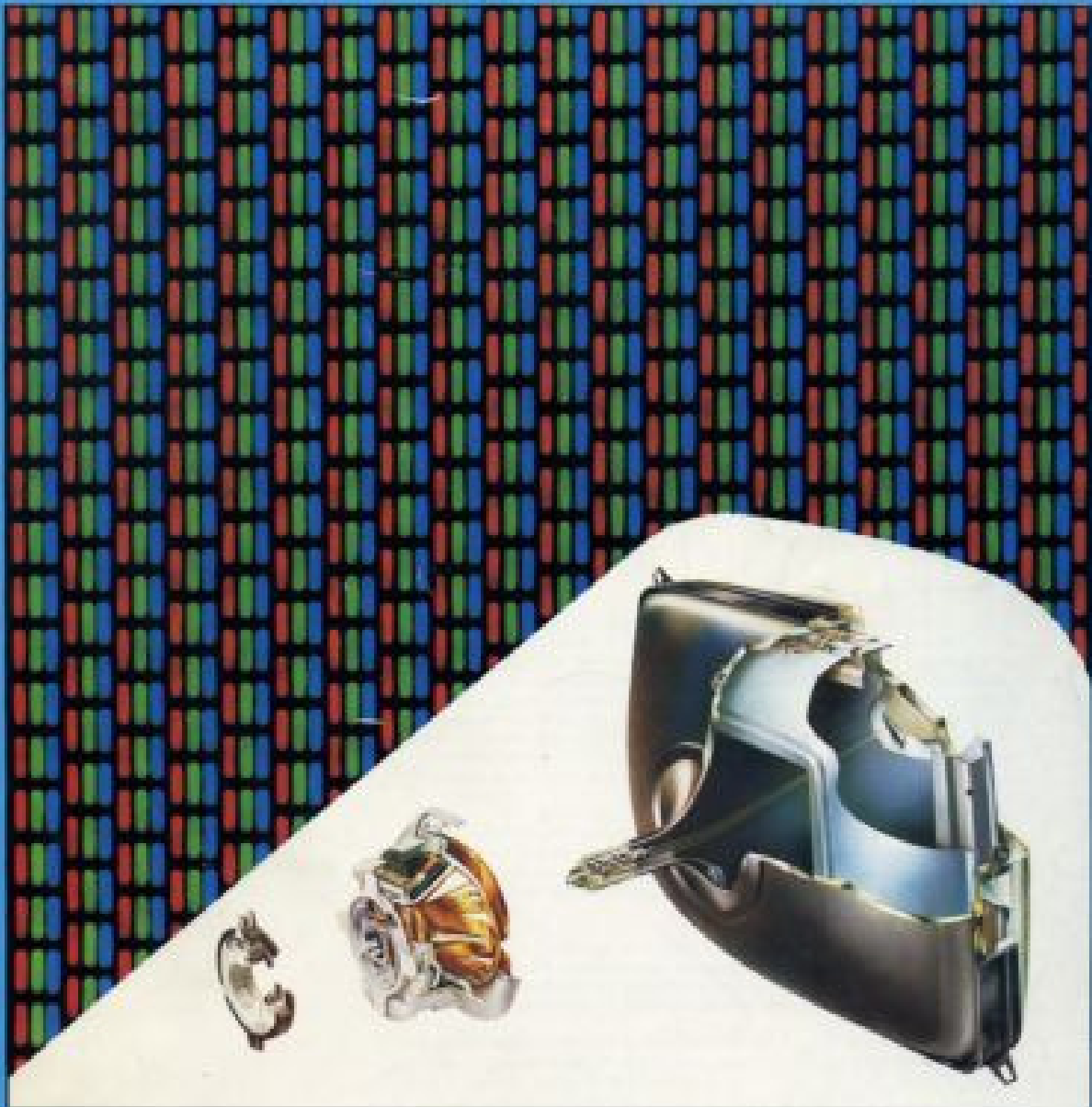


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# 20AX 110° colour television: a brief outline

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## INTRODUCTION

Since the invention of the shadowmask, picture tube development has revolved almost exclusively around the delta-gun configuration. Refinement of this technology has resulted in extremely high quality colour reproduction which has fully justified the effort expended in its perfection. In recent years, however, several manufacturers have been investigating the possibilities of simplifying the conventional receiver. In particular, a great deal of research has been carried out on picture tubes incorporating in-line gun arrays. The main advantage offered by such a gun configuration compared with the conventional delta-gun array is that dynamic convergence corrections can at least be simplified, and at best, eliminated completely.

The 20AX system adopted by Mullard and introduced early in 1974, is the first inherently self-converging 110° colour television system capable of use with screen sizes up to 26in. It incorporates a horizontal-in-line gun array with a specially designed saddle-wound deflection yoke. The complex dynamic convergence correction circuits required by delta-gun receivers are eliminated. The only dynamic corrections required in 20AX are those to compensate for small residual manufacturing tolerances. These are few, and relatively straight-forward. In fact, only 7 simple dynamic corrections expending virtually no energy are required in a

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20AX receiver compared with the 15 to 18 intricate energy-consuming corrections necessary in a comparable delta-gun set.

Colour selection is achieved by means of a vertically slotted shadowmask, the phosphors being deposited on the screen in vertical stripes. The tube has a standard 36.5mm neck, but because of modifications to the gun made possible by the elimination of pole pieces required for dynamic convergence corrections, the neck length is reduced by 20mm compared with its delta-gun equivalent.

This article describes briefly the theory behind 20AX, and gives details of the picture tube and deflection coil assembly.

## CONVERGENCE AND DEFLECTION

In any colour television picture tube, the three electron beams are deflected by a common deflection field. This field not only deflects the beams but to some extent defocuses them, hence giving rise to convergence errors. The theory behind convergence errors caused by deflection fields has been covered in detail in a previous article (Ref. 1). For completeness, however, a simplified description of the theory is given here.

Consider a conical pencil of beams which, in the absence of a deflecting field, converges at the centre of the screen (see Fig. 1). From the behaviour of such a beam pencil in a deflection field, conclusions can be drawn about the behaviour of the three beams in a delta-gun picture tube.

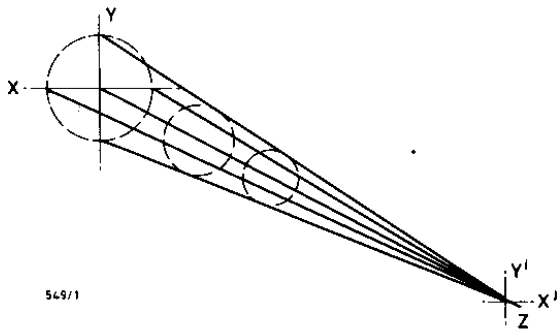


Fig. 1 — Conical pencil of beams originating in the deflection plane  $xy$ , and statically converged on the centre of the screen  $x'y'$

**Misconvergence**

The main characteristics of a deflection field that determine its convergence properties are curvature of the image field, astigmatism, and coma.

Curvature of the image field results in the radius of curvature of the surface swept by the convergence point of the beam pencil being less than that of the screen (see Fig. 2). On a flat screen, the image of the beam pencil is circular. Considering the three beams for a delta-gun as elements of a beam pencil, it is seen in Fig. 3 that the convergence point on a flat screen forms an equilateral triangle.

The second characteristic, astigmatism, causes the convergence point of the beam pencil to separate into two focal lines, one parallel to, and one perpendicular to, the direction of deflection. One of these focal lines lies in front of the original convergence point, and the other behind it. The combined result of astigmatism and curvature of field on the three beams of a delta-gun tube is shown in Fig. 4. The image spots now form isosceles triangles, instead of the equilateral triangles resulting from curvature of field only. Fig. 5 shows how curvature

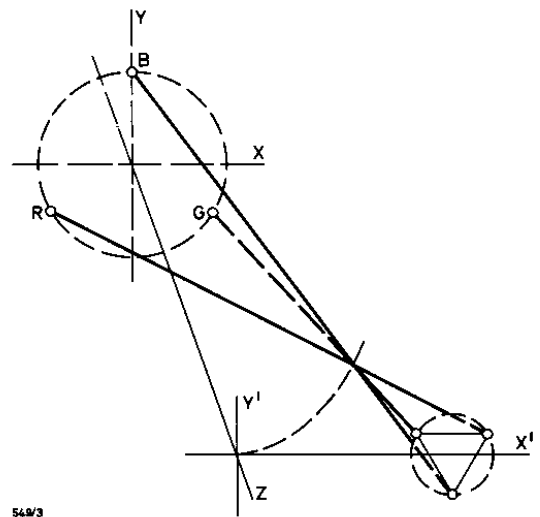


Fig. 3 — Convergence errors in a delta-gun tube caused by curvature of the image field

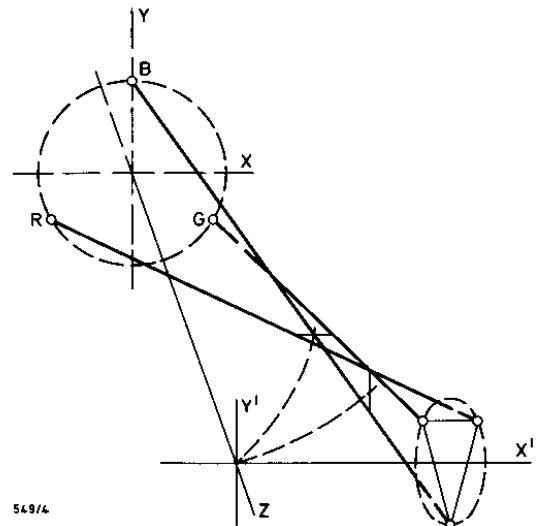


Fig. 4 — Convergence errors in a delta-gun tube caused by the combined effects of curvature of the image field and astigmatism

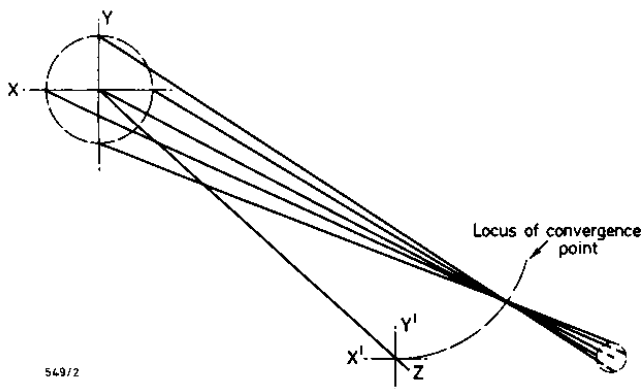


Fig. 2 — Deflected beam pencil. Locus of convergence point lies inside the plane of the screen; the image of the beam pencil on the screen is circular

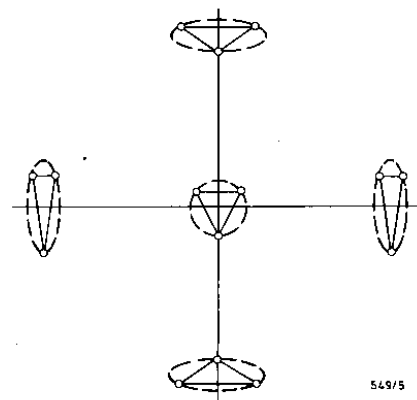


Fig. 5 — Convergence errors after vertical and horizontal deflection

of field and astigmatism affect the image spots on a flat screen after vertical and horizontal deflection.

The third source of convergence error caused by a deflection field is coma. The principal effect of coma in a delta-gun tube is to displace the blue beam relative to the red and green beams in the direction of deflection (see Fig. 6).

Of the three sources of convergence error described above, curvature of the image field is the one mainly responsible for convergence errors due to deflection. This aberration is inherent in any static deflection field; that is, in any field whose intensity is independent of its distribution. It is therefore impossible to design a static deflection field in which three statically converged beams remain converged on a flat screen through all angles of deflection. In practice, in a delta-gun tube, it is necessary to provide some means for varying the angles of the three beams according to the angle of deflection. The relative amplitudes of the required corrections depend on how much astigmatism there is in the horizontal and vertical deflection fields. (In fact, to obtain optimum convergence over the whole screen in a  $110^\circ$  system, some astigmatism is always necessary.) In a delta-gun tube, for instance, a dynamic convergence correction unit is positioned round the neck of the tube to generate correcting fields. These correct for curvature of field and astigmatism, and also for the effects of coma (the so-called blue-lateral correction). At least 12 dynamic convergence corrections and corresponding circuits are required, the complexity of the circuits increasing with increasing angle of deflection. For  $110^\circ$  deflection, 15 to 18 adjustments are normally necessary.

#### PRINCIPLE OF SELF-CONVERGENCE AND 20AX

As early as 1954, Haantjes and Lubben (Ref. 2) showed that it would be possible to eliminate convergence errors by adopting an in-line gun array in conjunction with a specially designed deflection assembly.

Their solution to the convergence problem was based on the finding that curvature of field could be compensated by increasing the astigmatism of the deflection field in such a way as to eliminate misconvergence in, say, the horizontal direction at the cost of increasing it in the vertical direction. In a delta-gun tube the effect of this would be to make the vertical focal line in Fig. 4 coincide with the flat screen over all angles of deflection. If the gun array is horizontal-in-line, however, this vertical focal line degenerates to a point, resulting in perfect convergence at all positions on the screen (see Fig. 7).

If the vertical deflection field were identical to the horizontal deflection field, but rotated through  $90^\circ$ , the horizontal focal line would coincide with the screen at all points, not the vertical one as required. The positions

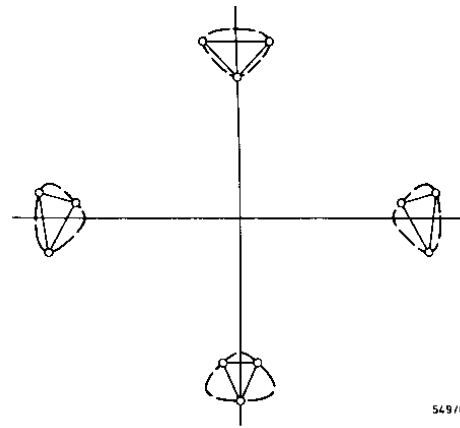


Fig. 6 — Distortion of the spot images caused by coma

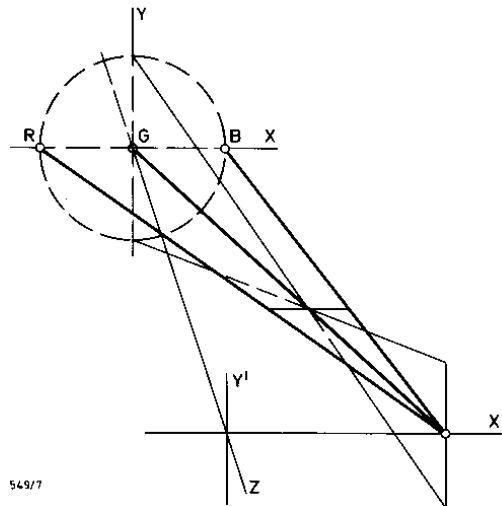


Fig. 7 — Automatic convergence in an in-line-gun tube produced by enhanced astigmatism of the deflection field

of these focal lines therefore need to be reversed. This is achieved by reversing the sign of the vertical deflection field with respect to the horizontal field. Thus, the vertical focal 'lines' (effectively points) produced by both fields will coincide with the screen at all angles of deflection, giving automatic convergence.

In a system with in-line guns, coma caused by horizontal deflection shifts the centre beam horizontally with respect to the outer beams, and coma caused by vertical deflection shifts the centre beam vertically (see Fig. 8). The field distribution must therefore be arranged in such a way as to virtually eliminate the coma errors shown in Fig. 8. This has been achieved in the 20AX system.

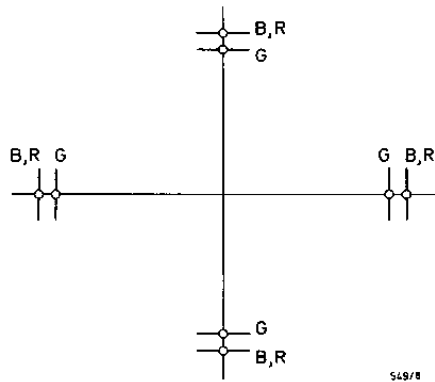


Fig. 8 — Convergence errors in an in-line-gun tube caused by coma

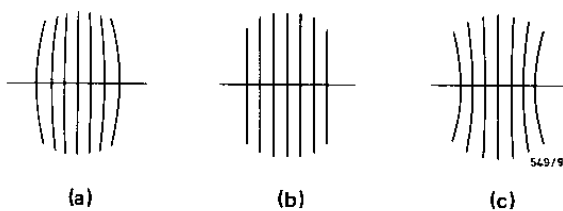


Fig. 9 — Three types of field distribution: (a) barrel (b) homogeneous (c) pincushion. The field distributions shown in (a) and (c) produce astigmatisms of opposite sign

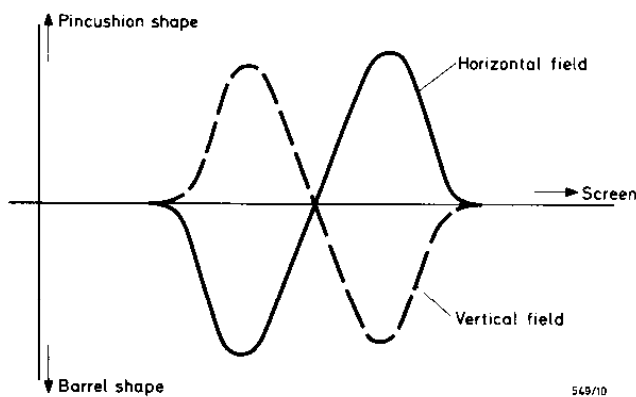


Fig. 10 — Variation of the horizontal and vertical deflection field distributions as a function of the axial coordinate in a 20AX deflection yoke (qualitative)

### Required field distribution

Astigmatism and coma both depend on the distribution of the deflection field. For a qualitative discussion of this dependence, the field can be considered in two parts, one part close to the guns, and the other close to the screen.

Astigmatism is influenced mainly by that part of the field close to the screen. If the field distribution is homogeneous (see Fig. 9), astigmatism is approximately zero. Barrel-type distribution and pincushion-type distribution

produce astigmatisms of opposite sign. To produce the automatic convergence required, the horizontal deflection field must be pincushion-shaped and the vertical deflection field must be barrel-shaped, in the parts of the field close to the screen.

Coma is affected by the distribution in both parts of the field. One way of minimising it would be to make the field homogeneous throughout, but this would conflict with the astigmatism requirement. An alternative way, the one adopted in 20AX, is to design the horizontal and vertical fields so that the coma contributions in each part cancel; that is, if the field is pincushion-shape in one part of either field, it must be barrel-shape in the other part (see Fig.10).

### COIL DESIGN

The main aspects of coil design that must be considered are:

- 1) the shape of the coil to give the required field distribution;
- 2) the provisions necessary for ensuring precise reproducibility in manufacture.

### Choice of coil geometry

For 20AX, two deflection system configurations were considered:

- 1) toroidal coils for both horizontal and vertical deflection,
- 2) saddle coils for both horizontal and vertical deflection.

At first sight, the toroidal system appears to lend itself to more precise manufacture. Fewer turns are required, and each of them can be located precisely by annular combs at both ends of the ferrite ring. The material content is low and manufacture can be easily mechanised.

However, for all its apparent simplicity, the toroidal yoke does have important limitations.

- 1) Because of the small number of turns, the impedance is low; the large stray field impairs deflection sensitivity and tends to cause interference in nearby circuitry.
- 2) Strong coupling between the horizontal and vertical deflection coils makes it difficult to use difference-current drive (see later) for tolerance compensation.
- 3) In most toroidal yokes, turns have to be layered in at least part of the winding, and this tends to degrade precision.

But the most fundamental drawback is that design freedom is severely restricted. Other than the shape of the core, the only design parameter is the angular positioning

of the turns, and since no position should be assigned to more than one turn, the horizontal and vertical deflection coils cannot be designed independently of each other.

Studies led to the conclusion that these limitations make the toroidal yoke impracticable for generating the coma-free fields required in 20AX. Additional design parameters would be necessary, thereby adding to the complexity of the yoke and increasing its final cost. A saddle-type yoke assembly was therefore adopted for 20AX.

The relationship between field distribution and saddle coil shape can be best illustrated by considering a constant diameter coil comprising two symmetrical, single-turn windings (see Fig. 11). Angle  $\alpha$  is an important design parameter (Ref. 1). If  $\alpha \approx 120^\circ$ , the field close to the axis  $z$  is homogeneous; if  $\alpha > 120^\circ$ , the field is pincushion-shape, and if  $\alpha < 120^\circ$ , the field is barrel-shaped.

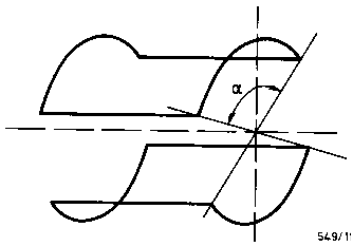


Fig. 11 – Schematic representation of a symmetrical pair of single-turn deflection coils; angle  $\alpha$  is the angle subtended by the coils

To produce the field distribution required for the 20AX self-converging system, angle  $\alpha$  must vary along the length of the deflection coil. For the horizontal deflection coil,  $\alpha$  must increase from about  $90^\circ$  at the gun end to about  $150^\circ$  at the screen end to avoid coma errors. For the vertical deflection coil, exactly the opposite variation is required; that is, from  $150^\circ$  at the gun end to  $90^\circ$  at the screen end.

This simple description considers only the lower order terms in the equations describing the field produced by a symmetrical pair of single-turn windings. However, undesirable effects due to large, higher-order terms can be minimised by adding more turns to each winding and carefully defining their positions. The final coil design for 20AX employs a relatively large number of turns accurately distributed around the inside of the ferrite core. The distribution varies along each coil in such a way as to provide the required astigmatism and absence of coma necessary to achieve optimum convergence over the whole screen.

**Coil manufacture**

The manufacture of such coils in large quantities and to the required accuracy presents certain difficulties. Coils of complex shape can be wound on specially designed

jigs, using automatic winding machinery. Even when the usual winding parameters, such as wire tension, temperature, friction, and winding speed, are very closely controlled, however, there is apt to be more variation between the coils produced than can be tolerated in a self-converging in-line system. An effective way to bring such variation within acceptable limits is the sectional winding technique that was introduced a few years ago for the manufacture of delta-gun phase II  $110^\circ$  deflection coils.

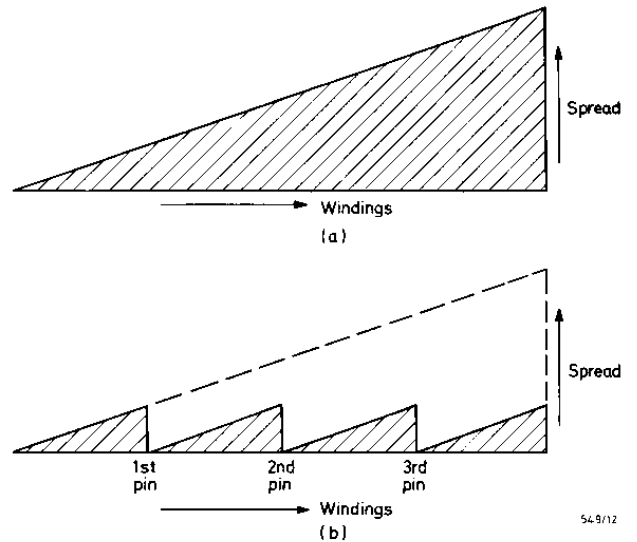


Fig. 12 – Reduction in winding precision error resulting from use of pin-indexed sectional winding

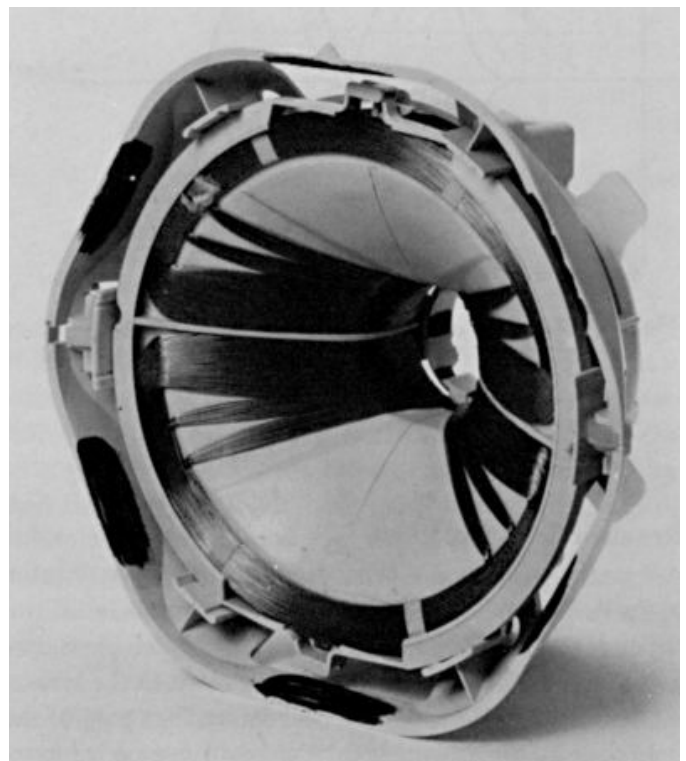


Fig. 13 – Horizontal deflection coils mounted in 20AX yoke

The principle of sectional winding is to divide the critical parts of each coil into as many sections as may be needed to ensure the requisite precision, and to make the starting point and number of turns in each section completely independent of those that have been wound before. This can be done by inserting spaced index pins into the winding jig as the coil takes shape, each pin serving to establish the starting point of a new section. The technique is of value not only in the manufacture of close-tolerance deflection coils but also in their design and development. Fig. 12 shows how the overall precision error is reduced by sectional pin indexing. Table 1 gives the electrical specifications for the horizontal and vertical deflection coils. In Fig. 13, the horizontal deflection coils are shown mounted in the deflection yoke. A cutaway view of the deflection assembly is shown in Fig. 19. More details of deflection coil design and manufacture are given in Ref. 1.

**TABLE 1**  
**20AX Deflection Coil Electrical Data**

	Horizontal deflection coil	Vertical deflection coil
Inductance	1.18 mH	35 mH
Resistance (at 25°C)	1.20 Ω	3.26 Ω
Peak-to-peak current	6.2 A	3.41 A
Energy	5.7 mJ	3.8 W

**Raster shape**

In comparison with a delta-gun system, the deflection fields required in a self-converging in-line system give greater pincushion E-W raster distortion but less N-S distortion. Because of the sign of the astigmatism, the N-S distortion is barrel-shaped. N-S raster distortion can be decreased still further by treating the shape of the ferrite ring as an additional design parameter. In the 20AX deflection unit, shaped cut-outs (Fig. 14) at the gun end of the ferrite ring are positioned so that they affect only the vertical deflection field, giving a N-S raster shape which is fully acceptable without further correction. The E-W raster distortion of 13% is corrected by means of conventional deflection current modulating circuitry.

**Mechanical assembly**

In addition to the measures taken to achieve the highest possible precision in the manufacture of the deflection coils, special attention is also paid to their assembly. The

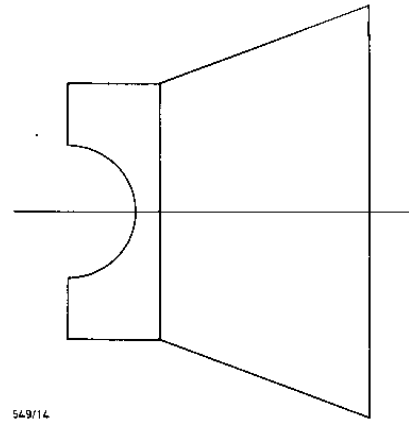


Fig. 14 – Schematic outline of ferrite core (side elevation) showing one of the field shaper cut-outs

coils are mounted in a split plastic shell which incorporates moulded-in locating pieces for each winding. This secures them in the correct position relative to the ferrite ring, regardless of small variations in turn distribution. The coils and ferrite ring are mounted as an adjustable unit in a housing (Figs. 15 and 19) that clamps to the neck of the tube and engages a centring ridge moulded into the cone. Only two adjustments are provided: a  $\pm 7^\circ$  rotation for raster alignment, and a 6mm axial shift for colour purity. Clamps on the housing lock the unit in the desired position. The axial movement is provided by an adjustable ring at the back of the housing, the coil moving in a helical slot in the circumference.

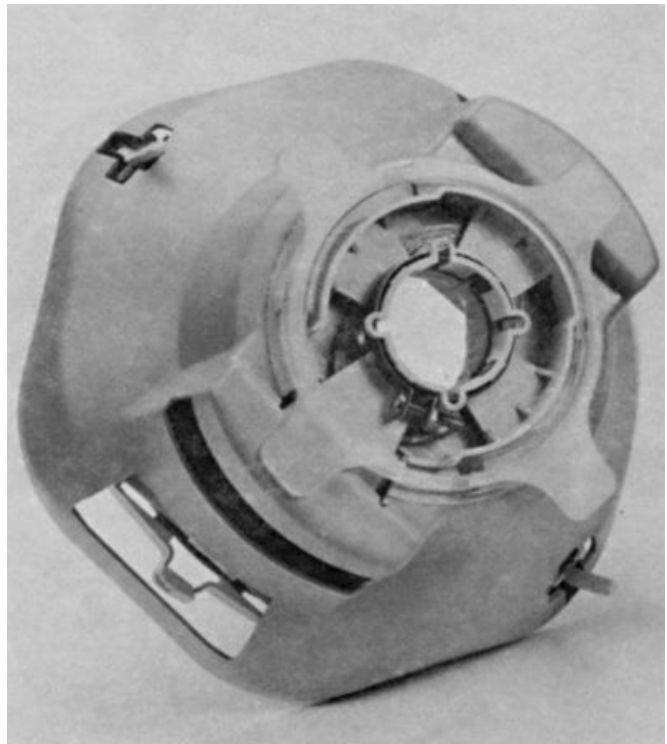


Fig. 15 – 20AX deflection yoke housing

### Static corrections

The static correction assembly (Figs. 16 and 19) consists of four ring-shaped permanent magnets; one for colour purity, one for raster symmetry, and two for static convergence adjustments. It is located on the neck of the tube between the gun and the deflection yoke. Each element of the assembly comprises a pair of magnetised plasto-ferrite rings coupled by pinion gears (Fig. 17). By rotating both rings in the same direction, the field is rotated; by rotating them equally in opposite directions the field strength is altered.

One pair of rings, magnetised as a vertical two-pole magnet, adjusts colour purity in the horizontal direction.

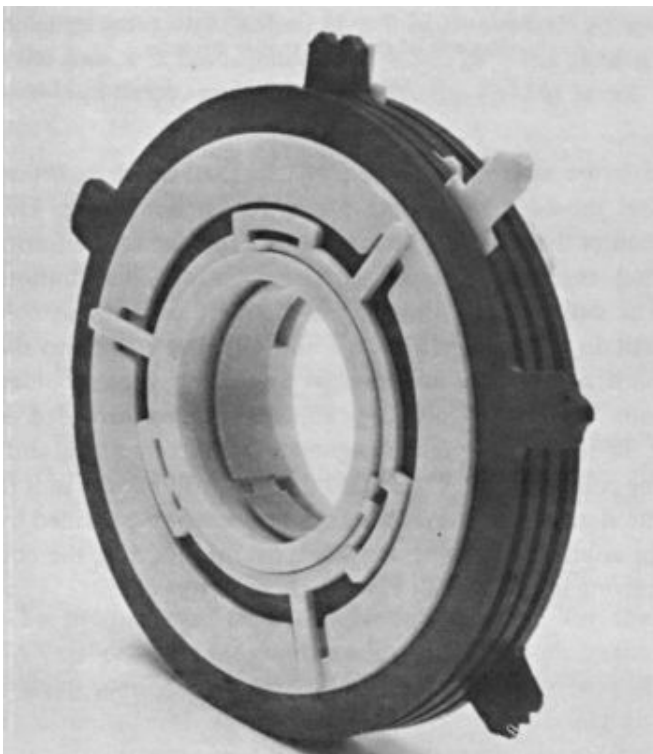


Fig. 16 – Static correction unit

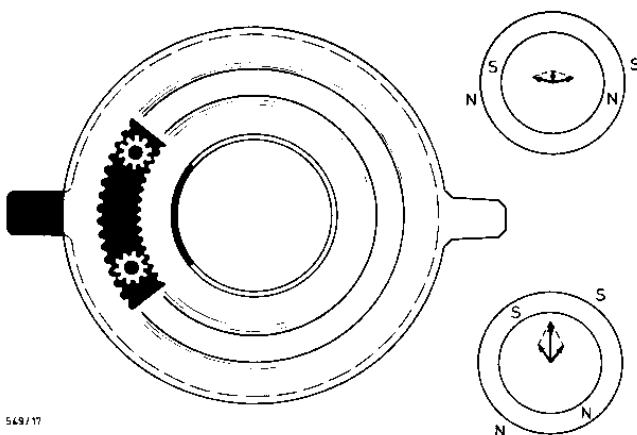


Fig. 17 – Pair of plasto-ferrite magnet rings as used in static correction assembly, showing coupling pinions

Another pair, magnetised as a horizontal two-pole magnet, corrects any vertical misalignment there may be between the beams and the axis of the tube-yoke system. Owing to the strong astigmatism of the horizontal deflection field, such misalignment would otherwise cause curvature of the horizontal axis of the raster. Two pairs of rings allow for static convergence correction, one magnetised as a four-pole magnet, and the other as a six-pole magnet. Adjustment of the four-pole pair pre-deflects the two outer beams equally in opposite directions, and adjustment of the six-pole pair pre-deflects them equally in the same direction, making it possible to bring all three beam spots into coincidence on the screen.

The complete multi-pole static correction assembly fits flush with the rear of the deflection coil housing on the neck of the tube (see Fig. 19). It is located by a key and slot in the housing, and is locked by a finger-operated clamp on the multi-pole unit.

### 20AX PICTURE TUBE

Externally there is little to distinguish a 20AX picture tube (Fig. 18) from a comparable delta-gun 110<sup>0</sup> type apart from the shorter neck and the deflection yoke centring ridge on the cone. Internally, however, there are fundamental differences. A cutaway view of a 20AX picture tube, deflection yoke, and static correction assembly is shown in Fig. 19.

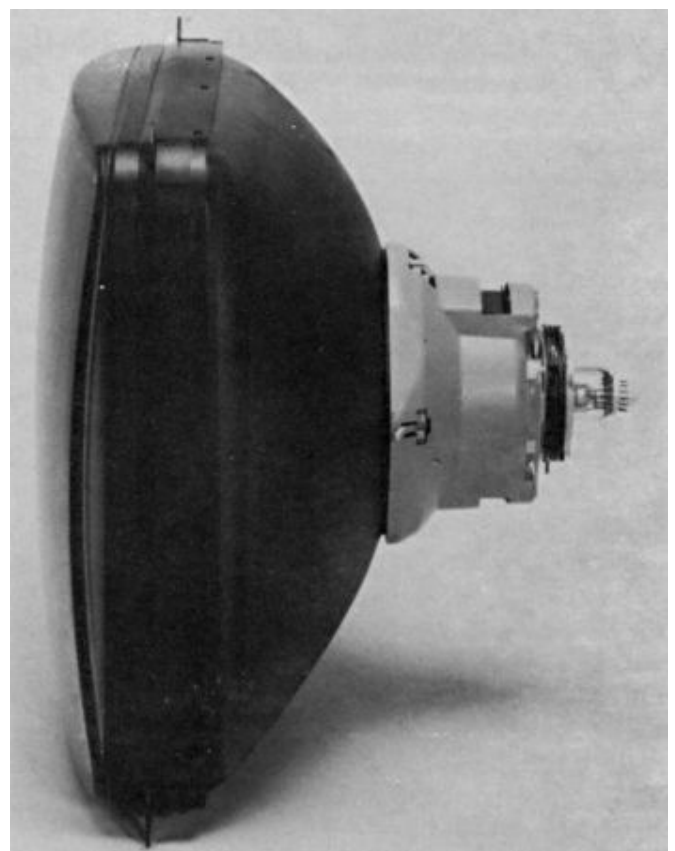


Fig. 18 – 20AX picture tube and deflection yoke.

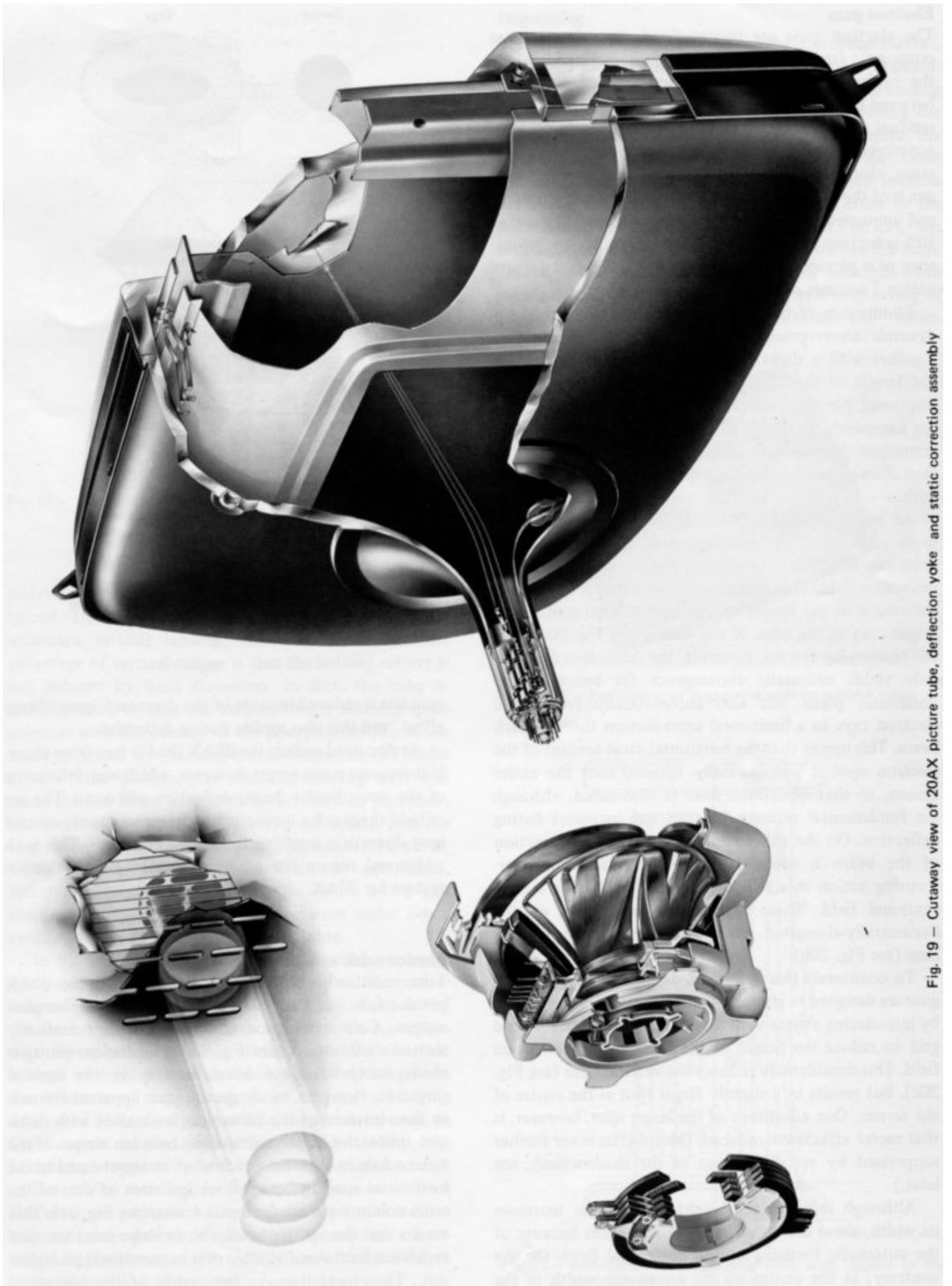


Fig. 19 — Cutaway view of 20AX picture tube, deflection yoke and static correction assembly

## Electron guns

The electron guns are mounted side by side, the two outer guns (red and blue) being slightly inclined towards the centre gun (green). The green beam is positioned between the other two to reduce the effect of small residual convergence errors. (The eye is more sensitive to convergence errors between red and green, or blue and green, than between red and blue.) The cathode of each gun is of the Quick-vision type with low thermal capacity and improved heater-to-cathode heat transfer, giving a 70% reduction in the time from switch-on to the appearance of a picture. It is thus possible to obtain a picture within 5 seconds of switch-on.

Elimination of the pole shoes (normally required for dynamic convergence) at the muzzle end of the gun, together with a slight reduction in gun length, enables the length of the tube neck to be reduced by 20mm. Improved precision in gun manufacture and assembly has narrowed the spread in the position of the statically converged beams with respect to the screen centre, thus allowing shift compensation circuits to be dispensed with.

An important aspect of the design of the electron gun is its relation to picture definition. In a conventional delta-gun tube, over-focusing of the beam occurs in the deflection field. This means that a spot that is in focus at the centre of the screen appears as a blurred spot with a bright core at the edge of the screen (see Fig. 20a). In a self-converging system, however, the deflection field not only yields automatic convergence for beams in the horizontal plane but also automatically focuses all electron rays in a horizontal cross-section through each beam. This means that the horizontal cross-section of the electron spot is automatically focused over the entire screen, so that horizontal haze is eliminated, although for fundamental reasons the spot size increases during deflection. On the other hand, the vertical cross-section of the beam is subjected to a much stronger over-focusing action in a self-converging field than in a conventional field. These two factors result in a narrow horizontally-elongated spot with pronounced vertical haze (see Fig. 20b).

To counteract this deflection defocusing, the electron guns are designed to give astigmatic beams. This is achieved by introducing a plate with a horizontal slit in the second grid to reduce the height of the beam in the deflection field. This considerably reduces the vertical haze (see Fig. 20c), but results in a slightly larger spot at the centre of the screen. One advantage of the larger spot, however, is that moiré effects are reduced. (Moiré effects are further suppressed by suitable design of the shadowmask; see later.)

Although reducing the height of the beam increases its width, there are no adverse consequences because of the automatic focusing of the horizontal field. On the contrary, at the centre of the screen the width of the

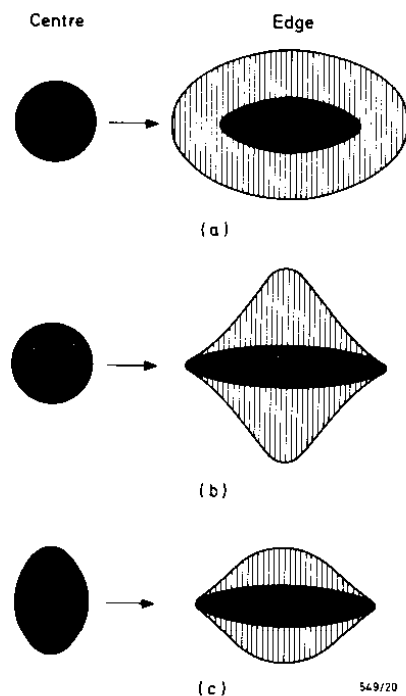


Fig. 20 — Defocusing of a round spot in:

- (a) conventional deflection field
- (b) self-converging deflection field
- (c) reduction of defocusing by use of an astigmatic gun

spot size is reduced because of the decreased space charge effect, and this also applies during deflection.

As discussed earlier, the 20AX field is free from coma. If there were coma errors, however, additional defocusing of the outer beams during deflection will occur. The use of field shapers for correcting coma errors cannot correct spot distortion resulting from the same error. This is an additional reason for adopting a coma-free deflection system for 20AX.

## Shadowmask and screen

Like most other tubes with in-line guns, the 20AX picture tube has a screen consisting of vertical phosphor stripes. Colour selection is achieved with a vertically slotted shadowmask (see Fig. 19). Thus colour purity is made independent of beam landing in the vertical direction. However, to obtain the same apparent fineness in the structure of the picture as is obtained with delta-gun tubes, the horizontal spacing between stripes of the same colour in adjacent triads must be about equal to the horizontal spacing between vertical rows of dots of the same colour on a conventional screen (see Fig. 21). This means that the width of each colour stripe must be equal to about half the diameter of a conventional phosphor dot. Therefore, the absolute value of the horizontal

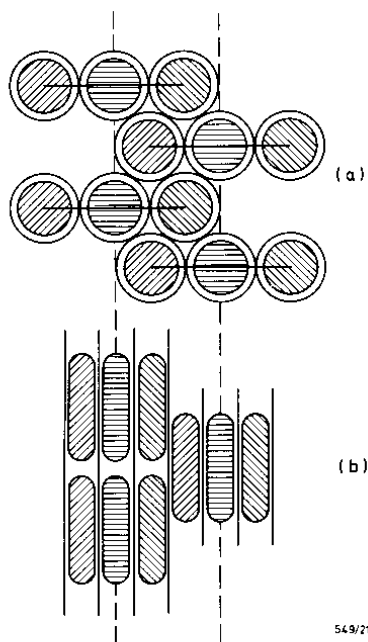


Fig. 21 — Dot-structure screen (a) compared with a stripe-structure screen (b) of equal fineness

reserve, assuming equal mask transmission, is about halved. This disadvantage must be weighed against the unlimited vertical landing reserve. However, another advantage of vertical stripes is that the landing reserve is not reduced by triad distortion. In fact, the tube is manufactured so that the centres of the electron spots coincide with the centres of the phosphor stripes. If the mask is heated by electron bombardment in the bright areas of the picture, the resulting landing shift will cause the red beam to land partly on the blue phosphor, the green beam partly on the red phosphor, and the blue beam partly on the green phosphor. However, white will still remain white. This is, of course, strictly true only for a current ratio of 1 : 1 : 1 and idealised geometrical conditions, but even under other conditions, the advantage is still noticeable.

In the 26in 20AX picture tube, the centre-to-centre spacing of the phosphor stripes is  $265\mu\text{m}$ , and the centre-to-centre spacing of adjacent triads,  $795\mu\text{m}$ . Each slot of the shadowmask corresponds to one triad. To accommodate the spherical contour of the mask, the slots are bridged at regular intervals throughout their length. In the interests of suppressing moiré effects, a bridging interval of  $810\mu\text{m}$  (as projected on the screen) is used; in the interests of maximum strength and stability, the bridges are staggered by half an interval from slot to slot.

Use of the standard 36.5mm neck diameter enables the electron guns to be spaced for optimum colour selection. Adjustment of colour purity requires a horizontal displacement of the three beams of no more than  $45\mu\text{m}$ . No vertical adjustment is required.

### Degaussing

Like most  $110^\circ$  picture tubes on the European market, the 20AX picture tube uses an internal magnetic shield. Advantage has been taken of the unlimited vertical landing reserve inherent in the 20AX system by rotating the degaussing coils through  $90^\circ$  (Fig. 22). By this means, the vertical component of residual magnetic fields that cause horizontal landing errors is completely eliminated. Because the mask material is not interrupted by holes in the direction of the degaussing field lines (see Fig. 23), the magnetomotive force can be smaller. Therefore the number of ampere-turns in the degaussing coils has been reduced from 500 to 300, resulting in a 60% saving of copper wire compared with conventional  $110^\circ$  tubes.



Fig. 22 — Positioning of degaussing coils on a 20AX tube.

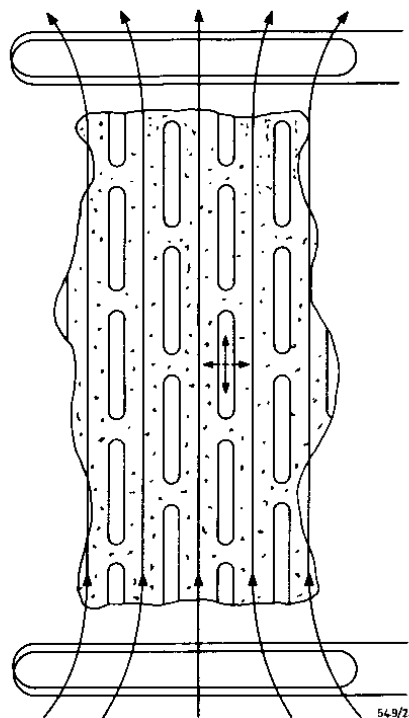


Fig. 23 — Orientation of degaussing field with respect to the shadowmask in a 20AX tube

To eliminate the risk of mis-landing caused by currents induced in the degaussing coils by the horizontal deflection field, the degaussing coils are short-circuited at horizontal deflection frequencies by a  $0.1\mu\text{F}$  capacitor. Except for this additional capacitor, the degaussing circuit (see Fig. 24) is the same as is used with a Phase II  $110^\circ$  picture tube.

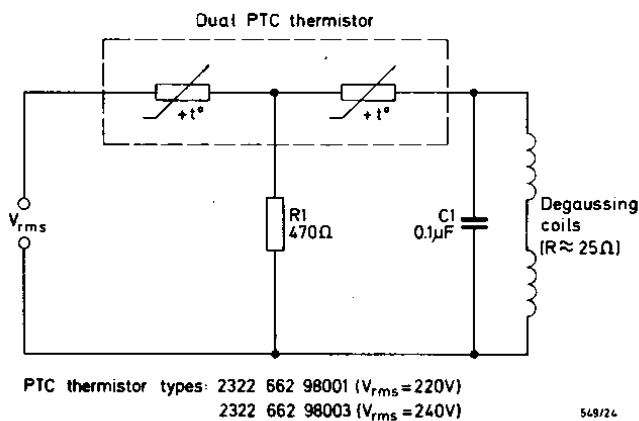


Fig. 24 — Recommended degaussing circuit with horizontal-frequency interference suppression capacitor

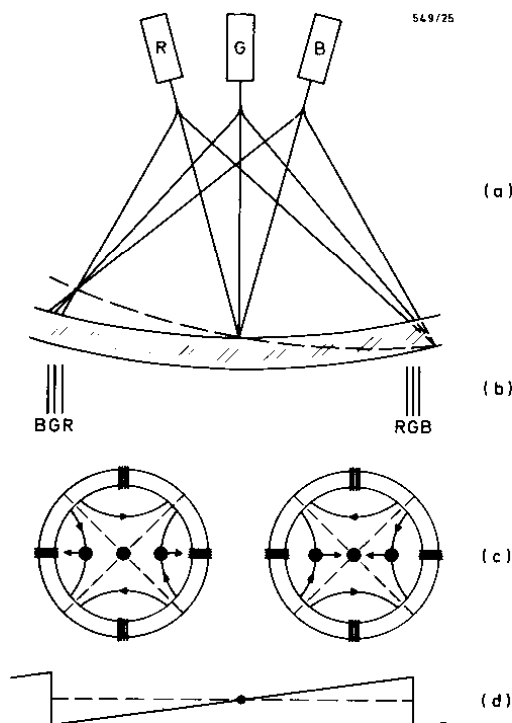


Fig. 25 — Tilting of the convergence plane (a) causes horizontal convergence errors (b) which can be corrected by four-pole windings (c) driven by a sawtooth current of line frequency (d)

## TOLERANCE COMPENSATION

Although 20AX is inherently a self-converging system, some dynamic correction may be required to compensate for small manufacturing tolerances. The system can be explained as follows.

Fig 25 shows a situation in which the plane where the beams are converged automatically is slightly tilted with respect to the screen plane because of some small left-right asymmetry in the distribution of the horizontal deflection field. As a result, horizontal convergence errors of opposite sign appear at the sides of the screen. The same type of error can be caused by a horizontal deviation of the undeflected beams from the screen centre. These errors can be corrected by a four-pole field aligned diagonally with respect to the deflection fields. This field is generated by four windings around the core of the deflection yoke. The windings must be driven by a sawtooth current which can be obtained directly from the horizontal deflection circuit.

In the same way, top-to-bottom asymmetry of the vertical deflection field, or a vertical deviation of the undeflected beams from the screen centre, causes horizontal convergence errors at the top and bottom of the screen. These errors can be corrected by passing sawtooth currents at vertical deflection frequency through the four-pole windings.

Horizontal displacement of the electron beams with respect to the deflection coil centre is not normally detrimental, because the system automatically converges all the beams which lie in a horizontal plane through the coil axis. However, vertical displacement of the plane of the beams with respect to the centre of the deflection field causes horizontal convergence errors of sawtooth character during vertical deflection (see Fig. 26). These errors can also be corrected by passing currents at vertical deflection frequency through the four-pole windings. At

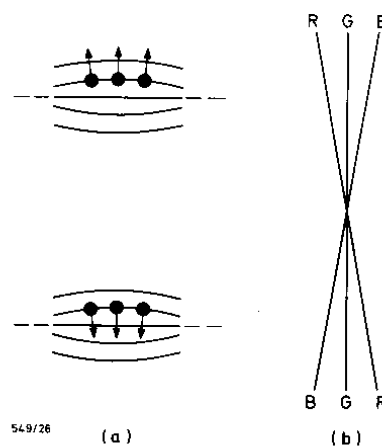


Fig. 26 — Vertical displacement of the plane of the beams with respect to the centre of the vertical deflection (a) causes red-blue crossover of vertical lines (b)

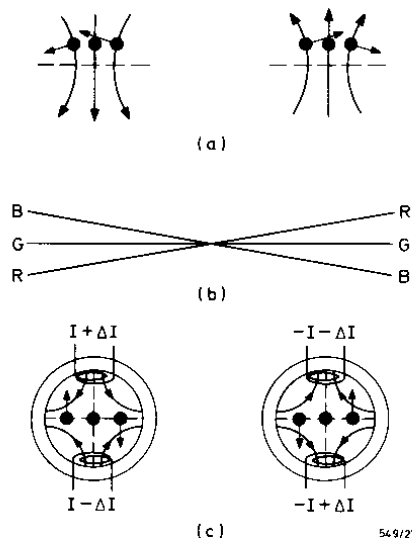


Fig. 27 – Vertical displacement of the plane of the beams with respect to the centre of the horizontal deflection field (a) causes red-blue crossover of horizontal lines (b) which can be corrected by unbalancing the horizontal deflection coil halves (c)

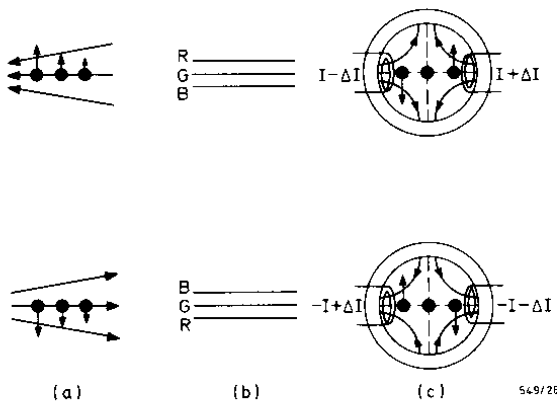


Fig. 28 – Left-right asymmetry of the vertical deflection field (a) causes vertical misconvergence at top and bottom of the picture (b) which can be corrected by unbalancing the vertical deflection coil halves (c)

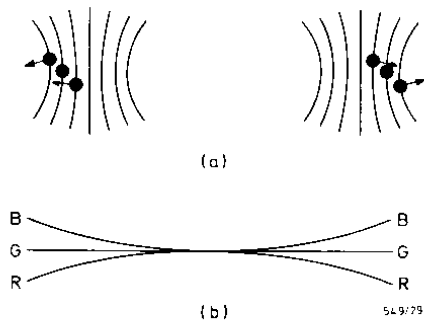


Fig. 29 – Rotation of the electron gun (a) causes vertical convergence errors of parabolic character (b)

the same time, however, vertical convergence errors will appear during horizontal deflection and will cause crossover of the horizontal red and blue lines (see Fig. 27). The same type of error can also be caused by top-to-bottom asymmetry of the horizontal deflection field.

These errors can be corrected by a four-pole field which is aligned orthogonally with respect to the deflection fields. This type of four-pole field can be generated by unbalancing the current through the halves of the horizontal deflection coil. Similarly, left-to-right asymmetry of the vertical deflection field, or horizontal deviation of the undeflected beams from the screen centre, causes vertical convergence errors during vertical deflection (see Fig. 28). These errors can be corrected by unbalancing the current through the halves of the vertical deflection coil.

If the plane of the beams is rotated with respect to the normal orientation, a parabolic vertical convergence error will occur during both horizontal and vertical deflection (see Fig. 29). This error can also be corrected by unbalancing the current through the halves of the deflection coil. In this case, however, the superimposed correction current must be parabolic.

The six corrections so far mentioned apply to 22in picture tubes; they are two horizontal sawtooth corrections, two vertical sawtooth corrections, and two vertical parabola corrections. For the 18in and 26in versions of the 20AX tube, a small systematic parabolic horizontal correction component has to be added during vertical deflection. For these screen sizes, there are therefore seven corrections.

#### Advantages of the four-pole system

The errors which require correction are very small (maximum distance between the outer beams in most cases is of the order of 2mm). The corrections therefore need not be very accurate, and simple circuits can be used. No pole shoes or separate correction units are needed. As the corrections are made in the deflection plane, they do not affect colour purity. The method of applying corrections in the 20AX system has the advantage that the number of corrections can be reduced, without changing the system, as manufacturing tolerances are reduced.

#### REFERENCES

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2. HAANTJES, J. and LUBBEN, G., U.S. Patent No. 2,866,125, filed 6th October, 1954. See also 'Errors of magnetic deflection II', *Philips Research Reports*, Vol. 14, 1959, pp 65 to 97.