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DEFLEXION YOKES FOR COLOUR CAMERAS

INTRODUCTION

Modern broadcast colour cameras form their colour pictures by superimposing three or four component images derived from photoconductive pick-up tubes. The accuracy and stability with which these multiple images are registered critically affects the basic picture quality. Registration is determined by the quality of the camera scanning circuit, photoconductive pick-up tubes, optics and deflexion yokes. This article examines basic yoke principles and design, and describes the fundamental ideas leading to the new yoke for the Mark VIII colour camera.

PHOTOCONDUCTIVE PICK-UP TUBES

To appreciate the theoretical operation of a yoke it is necessary to understand the elementary principles of a photoconductive tube. Figure 1 shows the physical relationship between the tube and the yoke.

Most photoconductive tubes used in television cameras are designed to operate with electromagnetic focusing and deflexion. The accelerating potentials do not normally exceed 1000V and, in the absence of light on the tube target, the electrons are momentarily brought to rest close to the tube target. The electrons are emitted from the cathode and accelerated towards the first anode (A_1) which is at about 300V with respect to the cathode. The control grid (G) determines the amount of current which flows from the cathode towards the anode. The electrons which pass through the 'defining aperture' form the beam which is used for scanning the target. When the electrons are under the influence of the wall anode (normally 300 to 800V) they can be regarded as travelling in a constant potential space where no electrostatic forces are applied to them. The trajectory is determined by the velocity and the effects of the magnetic focusing and deflecting fields. At the target end of the wall anode there is the mesh (typically 75V above the wall anode) which allows electrons to pass through it while maintaining a region of constant potential close to the tube target and over the whole of the target area.

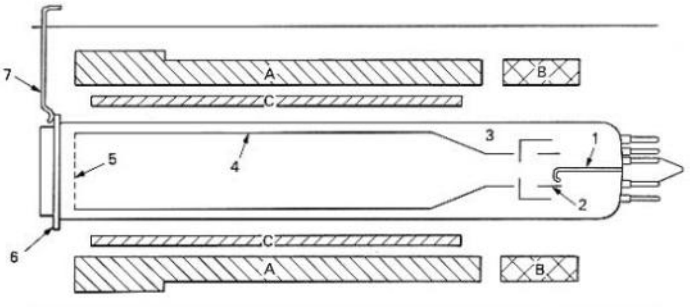

Fig.1 Physical relationship of photoconductive tube and yoke showing: (A) Focus coil (B) Alignment coil (C) Scan coil (1) Cathode (2) G_1 (3) First Anode (A_1) (4) Wall Anode (5) Mesh (6) Target (7) Target to Head Amplifier connection.

The target can be considered as a capacitor with the unscanned plate connected to a potential of normally 45V with respect to the cathode. In the absence of light on the target the electrons leaving the mesh are decelerated from 750 to 45V and still land on the target. These electrons form a current which charges the target capacitance causing the potential of the scanned side of the target to drop so low that the electrons are decelerated to a standstill. The only electrons which land thereafter are those required to make up for leakage conduction through the target. The scanned plate or the target is now stabilized to a potential only different from the cathode potential by a value corresponding to the emission velocity of the electrons. When light falls on the target conduction takes place causing the potential of the scanned surface of the target to rise. A large number of electrons are required to restore the charge on the illuminated parts of the target and these constitute the signal current flowing in the external target circuit.

DEFLEXION AND FOCUSING

Magnetic deflexion is usually achieved by a pair of saddle coils which produce a magnetic field perpendicular to the axis of the photoconductive tube. A schematic representation is shown in figure 2a. The motion of the electrons along the axis is deflected in a direction perpendicular to both axis and magnetic field. While the electrons are in the deflecting field they move along a circular segment.

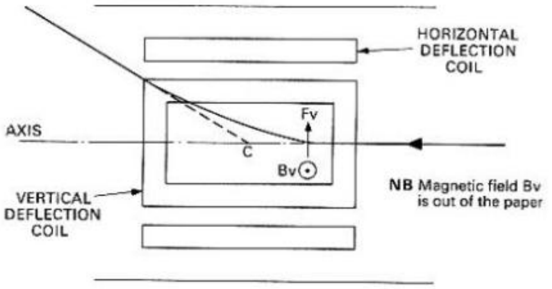

Fig.2(a) Magnetic deflexion of the electron beam in a photoconductive tube.

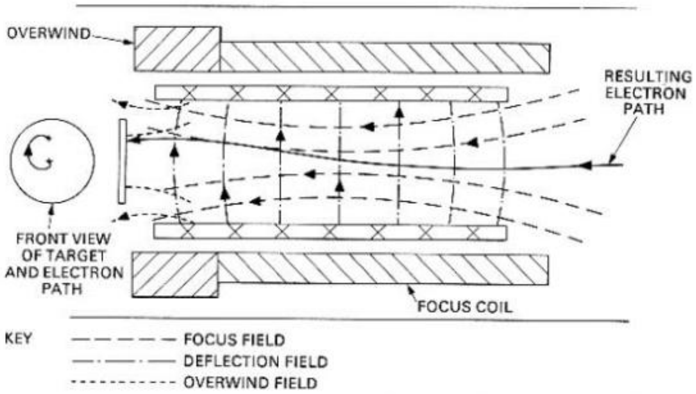

Fig.2(b) An electron path line resulting from the addition of the focusing and deflecting fields.

The centre of deflexion (c) is the point from which all electrons appear to emanate.

When magnetic deflexion and magnetic focusing fields are combined, the two fields add vectorially, a condition that is represented in figure 2b. The electrons then move along in a path approximating to a single turn helix.

Because of its helical motion the beam has a radial and tangential component of velocity as well as the axial component, thus producing a flare of electrons at the edges of the target. By correct positioning of the deflexion coils in the main focus coil, and with the aid of a focus field boost (overwind) near the target region, the beam can be made to land orthogonally on the target.

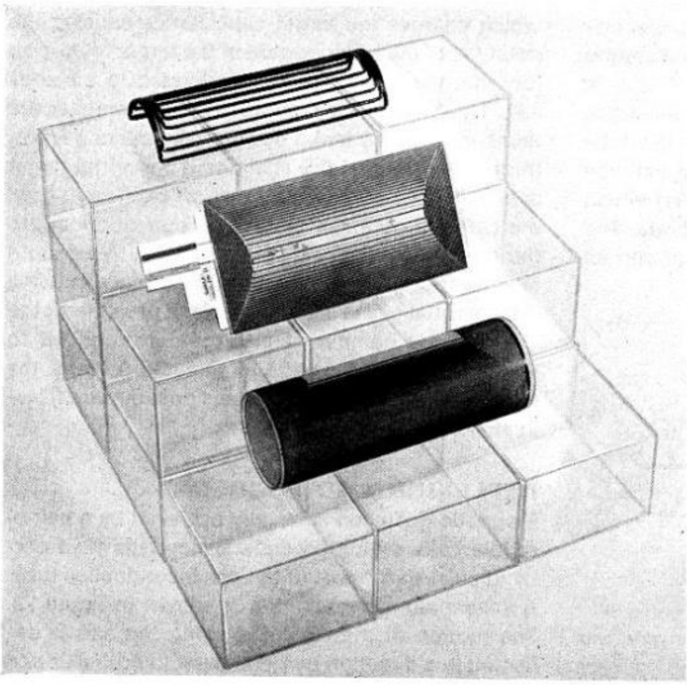

Fig.3 Three types of scan coil – conventional wirewound, flat double-sided flexible and (bottom) glass tubular.

For optimum deflexion the beam is initially assumed to travel along the axis. In practice, however, owing to mechanical tolerances in the tube, correct axial trajectory is seldom obtained. To overcome this a set of alignment coils, situated near the cathode of the tube, supply a d.c magnetic field in the x and y directions so that correct trajectory of the beam can be ensured.

SCAN COIL DESIGN

The most important part of any yoke is usually considered to be the scan coil assembly. Early yoke designers produced coils wound by hand and machine, involving intricate assembly procedure, and producing yokes with individual flaws. Typical errors could be as follows:

(a) Skew distortion – (rhombic faults) cross-coupling between the two scanning fields due to the scan coils not being perpendicular to each other.
(b) Trapezium, pin cushion, barrel distortions – deflexion fields not homogeneous.
(c) 'D' distortion – unwanted coupling between fields due to non-symmetrical scan saddles.
(d) Linearity errors – inefficient magnetic return path for the scanning fields and non-symmetrical mechanical design.

The above errors are not only different in each yoke, but vary according to temperature, vibration and age, and would result in frequent misregistration of the colour camera.

Later developments in yoke design were awakened when forms of printed scan coils were introduced. Although many of the defects of wirewound coils were overcome, only partial success was achieved. Owing to the still intricate means of assembly and manufacture some of the above mentioned faults were still apparent.

With the introduction of automatic registration and beam alignment during the early stages of development of the Marconi Mark VIII colour camera, it was decided that a new deflexion yoke was required. Early development of the yoke was concentrated on a new type of printed scan coil. The first printed coils were similar in design to the conventional wirewound saddle coils and, being etched while flat, needed a bending and sticking process to be carried out in order to form the scan coil assembly. Several yokes were made with variations of flat printed coils giving results which proved a good foundation for further design and development work. At this stage it was decided that printed coils of the flat construction were superior to their wirewound equivalent, but that the ultimate scan coil must be of tubular construction needing no extra bending, wrapping or forming. Figure 3 shows the three forms of coil including a Mark VIII tubular coil.

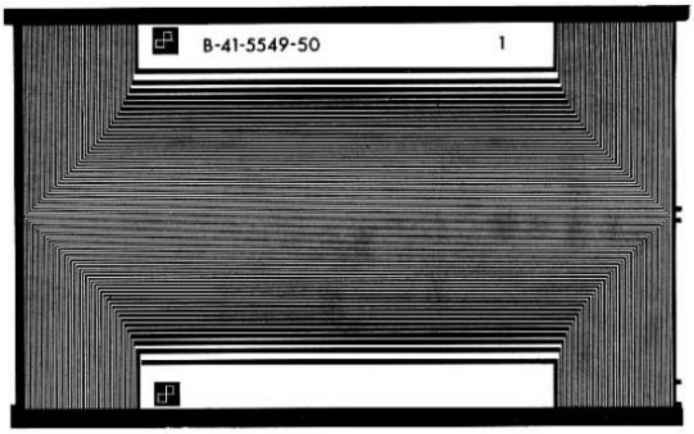

Fig.4 Photo-master of the glass tubular coil showing the conductor pattern.

THE TUBULAR GLASS COIL

To make printed coils in their tubular form needs a new chemical etching expertise far in advance of average printed circuit board etching. For good efficiency as many turns as possible are required on the coil. This means that in the space available some turns are no greater than 0·18mm apart and run for the complete length of the coil. With the skill achieved from making the flat coils sufficient experience had been obtained to undertake this venture.

It was decided that a tubular coil was not a satisfactory proposition unless a rigid and stable material could be used for the tube. Glass was chosen because of its good thermal and aging characteristics. It also meant that, with modern glass grinding techniques, the glass tube could be produced to a very high accuracy, thus ensuring a tube of reliable dimensions on which the printed coil could be etched.

Using a printed coil technique means that, once a suitable photographic master has been obtained many identical coils can be etched. Theoretically it can be shown that the ideal distribution of turns for a uniform magnetic field follows a cosine law.[1] As theoretically an ideal situation is being approached, the turn positional layout for the photographic master can be determined accurately by computer. This ensures that each turn is positioned to better than 0·05mm.

In manufacture the glass tubes are first plated with an even thickness of copper to a close tolerance and then coated with photo-resist. By using suitable jigs the tube is then exposed to a photo-master as a contact print, the photo-master consisting of one half of the scan coil, as shown in figure 4 Both halves of the tube are exposed in turn to the same photo-master, the join between the two halves being at a position of minimum field on the coil where there are only ends and no longitudinal conductors. This means that many of the asymmetrical errors found in previous coils are eliminated. Due to the fineness of pattern, the etching has to be relatively deep, and a special spray-type bath has been developed for this purpose.

Both line and field deflexion coils are made in the glass tube form and are accurately assembled using concentric end rings. The position of minimum cross-coupling of the two coils (very nearly perpendicular to each other) is determined by a simple electrical test.

ALIGNMENT AND FOCUS COIL DESIGN

As already mentioned, the axis of the cathode is very seldom coincident with, or parallel to, the axis of the tube. This means that an electron leaving the cathode in a direction parallel to the axis of the cathode will make a small angle with the axis of the tube and the magnetic field, and will not land perpendicularly on the target. This will cause most of the geometrical errors already mentioned.

Because of this, the role of the alignment coil can be as important as that of the scan coil assembly. Figure 5 shows the Mark VIII yoke with alignment and scan coils shown separately. The alignment coil consists of four coils which have been toroidally wound onto a coated mu-metal ring. As well as providing a magnetic return path, the mu-metal provides a very rigid support for the coils.

Focusing of the electrons onto the tube target in modern photoconductive tubes is usually by means of a solenoid. Theoretically the magnetic field produced by a long solenoid is ideal and gives good resolution capability. Unfortunately, the magnetic focusing system can only be analysed approximately by theoretical methods because of its intermediate length, it being neither very long nor very short compared to its radius. The focus field is contained by magnetic shielding material to minimize the focus coil current and is combined with the deflexion fields and often with an accelerating electrostatic field on the focus element of the photoconductive tube itself. As a result, an empirical as well as a theoretical approach has to be applied.

The Mark VIII focus coil is designed to provide an adequate focusing field with a minimum power input. The tube is focused by adjusting the voltage on the focus electrode of the tube, the focus coil current remaining constant, so that the electrons revolve through one loop to cross the axis at the target.

With modern winding and bonding techniques a wound focus coil assembly can be made repeatable and stable. The assembly of the focus coil to the scan coil assembly has to be to the highest accuracy to ensure that there is no undesired influence of the focus coil on the scan coil. This may occur if the

Fig.5 The Mark VIII toroidally-wound alignment coil, yoke assembly and scan coil assembly.

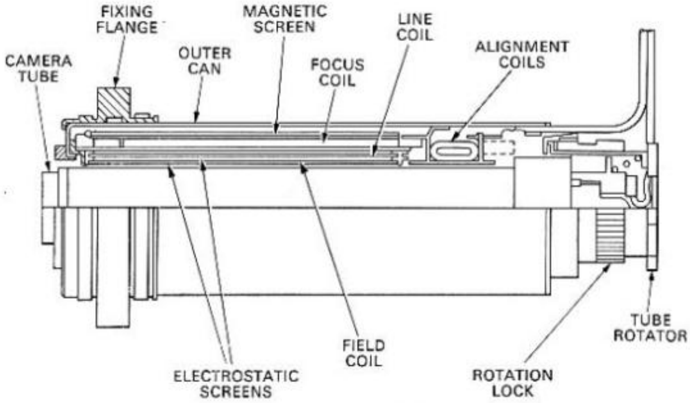

Fig.6 Part-sectioned view of deflexion yoke.

focus coil is not completely parallel to the scan coils.

MECHANICAL DESIGN

The success of any electrical component in a yoke is dependent on its mechanical design. In the Mark VIII yoke design, illustrated in figure 6, the main aim has been to achieve in production and maintain in service a high dimensional accuracy. For desired performance a concentricity tolerance of 0·038mm is thought necessary for the scan coil and focus coil assembly, which means tolerances on some diameters of the order of 0·02mm. The front of the yoke has a substantial metal mounting flange to give a precise and stable fixing to the camera optical housing. The concentric tubes carrying the scan coils are held firmly at the front by a stout metal ring. This ring is fixed to the outer mu-metal can, the can being seamless and forming the main structural member.

The tube can be removed from the yoke by unscrewing the rotation lock thus permitting the tube to be withdrawn. The electrostatic screens take the form of Faraday shields, made by printed wiring methods of flexible base material attached to the inside and outer surfaces of the inner scan coil. The inner magnetic screen provides a return path for the deflexion field and must be uniform in magnetic properties to maintain the deflexion geometry. Particular attention has been paid in the design to avoid asymmetrical metal parts, and to increase where possible rigidity and reliability since these all add towards a good over-all performance. In production the yoke is assembled precisely to exact specifications in a clean area where the particle size is no greater than 20μ.

CONCLUSIONS

It is believed that the present state of yoke design is probably in advance of photoconductive tube design. However, with the introduction of automatic registration and alignment a good consistent yoke is a fundamental requirement. The introduction of the tubular glass scan coil has made the Mark VIII yoke a precision component and has enabled the high degree of registration required for broadcast quality pictures obtainable at the press of a button.

ACKNOWLEDGMENTS

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REFERENCE

1 Tsakerman: *Electron Optics in Television;* Pergamon Press