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THE CATHODE RAY TUBE IN TELEVISION RECEPTION

BY

I. G. MALOFF*

Delivered before the Radio Club of America
September 18, 1935

The discoveries of the electron and of electron emission and the development of means of controlling the electron emission, opened a wide way which led to the present day radio broadcasting, sound recording and communication systems in general. In exactly the same way the gradual development of means for concentrating electron beams and especially the development of means for controlling these beams in intensity and direction, are directly responsible for the present day television systems of high definition.

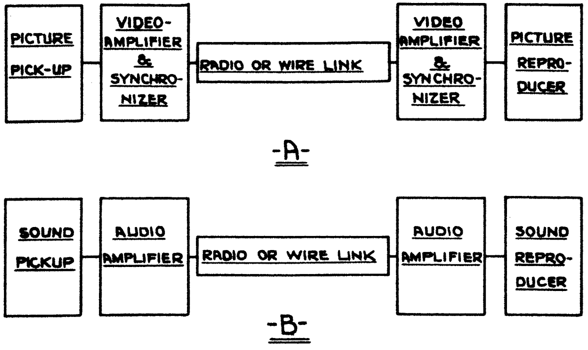
An electron beam is a narrow pencil of negatively charged particles moving with great velocities of the order of 30,000 miles per second. While electron beams were discovered and used as early as the end of the last century, it is only in the last decade that their properties were understood, and means for their generation and control were developed.

A television system of high definition, just as any television system, must have several component parts.

Fig. 1a shows a block diagram of a practical television system.

It has been shown time after time that in order to transmit a picture over wires or radio it is necessary to split the picture having two dimensions, namely, height and width, into one dimension of length. In other words, we have to scan a picture in order to transmit it, and moreover we have to scan synchronously the picture at the receiver and to vary the intensity of the spot at the receiver in synchronism with the variation of brightness under the scanning spot at the transmitter.

FIG. 1.



The only difference between television systems of high and of low definition is in the degree of detail transmitted and received. The old mechanical systems are satisfactory for televizing pictures having definitions up to 100 lines and reach their limit of definition somewhere between 100 and 200 lines. High definition systems employing electron beams have hardly a limit to their capability of definition. The limitations on these are imposed chiefly by the associated communication apparatus.

On Fig. 1b a block diagram of a complete sound communication system is shown. The only essential difference between the two systems is the fact that a television system requires synchronizing arrangements while a sound system does not. Outside of that, the similarity is striking.

True, the amplifiers have to pass frequency bands of differing widths, but in all essentials the systems are alike. Both systems pick up forces affecting our senses and translate these forces into electrical intensity vs. time variations; both systems pick them up at low levels and have to use vacuum tube amplifiers in order to bring them to levels suitable for transmission over distance; both systems may or may not use carriers to transmit the intelligence over the distance by means of either the air or cable. On the receiving end, both systems have to demodulate and amplify the received signals to bring them to the required power levels and then, by means of suitable transducers, reproduce the forces similar to those which were originally picked up.

The microphone in the sound system corresponds to the "Iconoscope" in television, and the power output stage and the loud speaker similarly correspond to the cathode ray tube with its electron gun and fluorescent screen.

While both the "Iconoscope" and the cathode ray receiving tube, or the "Kinescope" employ electron beams, the structure, operation and characteristics of the two are widely different. In this discussion we will deal with the "Kinescope" or the

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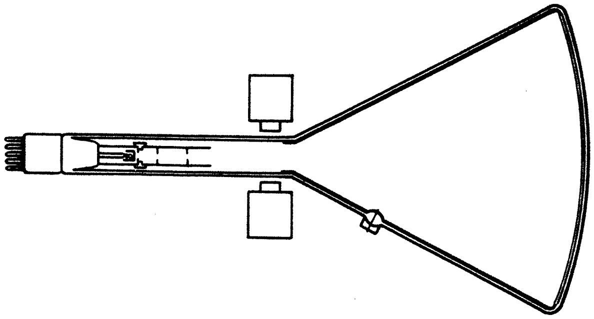
*Research Division, R. C. A. Mfg. Co., Inc., Camden, N. J.

FIG. 2



cathode ray television receiving tube, with its construction, characteristics and operation.

THE "KINESCOPE"

A typical "Kinescope" is shown on Fig. 2.

It consists essentially of five component parts: first, a glass envelope, sealed for maintenance of high vacuum; second, a cathode from which the cathode rays or, utilizing the modern term, the electrons are emitted; third, a device for concentrating, controlling and focusing of the electron beam; fourth, an arrangement (either internal or external) for deflecting the beam; and fifth, a fluorescent screen on which the received image is reproduced.

The envelope is usually made of glass, strong electrically and mechanically, and is designed to withstand atmospheric pressure with a large margin of safety. The tube during its processing is painstakingly baked and outgassed to maintain a very high vacuum of the order of 10^{-7} cm. of mercury. The early tubes were partially gas filled and utilized for beam concentration the space charge resulting from collisions of electrons with gas molecules. This so-called gas focusing is rather uncertain, since the gas pressure in any tube varies with life. If in a tube the focusing of the beam is critically dependent on pressure, the useful life of such a tube is short. Most of the modern cathode ray receiving tubes are of the high vacuum type where the concentration of the electron beam is accomplished by means of electric or magnetic fields produced between electrodes and poles. The vacuum treatment of the modern tubes is such that even at the end of the tube's life, that is, when the cathode emission has fallen off, the vacuum is still sufficiently high so that collisions between electrons and molecules of the residual gas seldom occur.

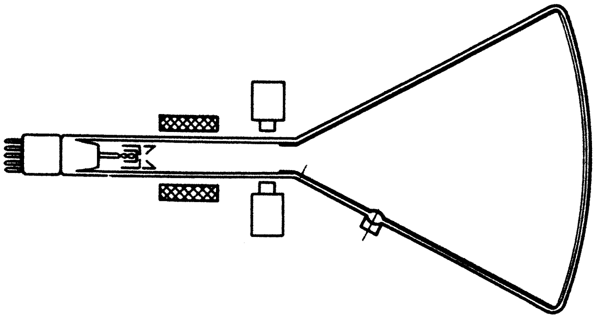
The cathode is of a tubular form with a flat emitting surface covered with a preparation of barium oxide. Only the flat end, facing the fluorescent screen, is covered with the electron emitting material. A tungsten heater, non-inductively wound and insulated with a heat resisting material, is located inside of the tubular cathode.

The electron gun, or the device for concentrating, controlling and focusing of the electron beam, consists of a grid sleeve, and a first anode. Sometimes it includes another electrode, usually called screen grid, not essential for operation and not shown on the figure. The grid sleeve is of a tubular form with a disc parallel to the flat emitting surface of the cathode. A circular hole in the center of the disc is coaxial with the cathode sleeve. The first anode cylinder coaxial with the rest of the system is usually mounted by means of insulators on the grid sleeve. It carries diaphragms or aperture discs on the inside for stopping or limiting the beam angle and for limiting the penetration of electrostatic fields. The glass envelope of the "Kinescope" carries a black conductive coating on its inner side and has a sealed-in conductor leading to this coating. The conductive coating forms the last or the second anode.

The final electron accelerating potential is applied between the cathode and the second anode.

The purpose of the first anode is to stop the beam similarly to an optical stop in a lens and to create an axially symmetric electrostatic field which would start the initially divergent electrons of the beams towards the axis. By adjusting the voltage on the first anode the fluorescent spot on the screen can be brought to a minimum diameter. The voltage on the first anode for best focus is usually about 1/4 or 1/5 of that on the second anode.

FIG. 3.



An electromagnetic system of focusing is shown on Fig. 3. A short first anode and the second anode are connected together to the source of the final accelerating potential and the concentrating field is produced by a multilayer solenoid coaxial with the tube and the gun.

The fluorescent screen is placed on the inner side of the front face of the tube. This face is usually as flat as mechanical strength permits. The material is usually either a sulphide or a silicate of zinc and is deposited in a very thin translucent layer.

OPERATION OF THE "KINESCOPE"

The operation of the tube is as follows: The electrostatic field created by the potential applied to the first anode penetrates the grid opening and draws the emitted electrons into a well defined beam. The grid is usually at a somewhat lower potential than the cathode and in this way limits the beam intensity. By applying a more negative potential to the grid the beam can be completely cut off. After entering the first anode, the beam passes through a masking diaphragm which cuts off some of the irregular peripheral portion of the beam. Then the beam enters the region of the field produced by the difference of potentials between the first and second anodes. In this field a strong focusing action takes place, which gives the electrons a radial component of velocity directed toward the axis of symmetry of the beam. The radial momentum acquired by the electrons is sufficient to bring them, after a flight through the equipotential space of the main body of the tube, to a focus at the screen.

Some of the electrons originally drawn from the cathode are cut off by the masking aperture. They return to the emf source through the first anode lead. The rest of the electrons strike the fluorescent screen. They excite the screen and dissipate most of their kinetic energy there. This kinetic energy has been acquired by the electrons through acceleration from the very small velocities of emission to that corresponding to the second anode voltage.

Some of the energy of the beam is transformed into light, some goes into heat raising the temperature of the glass, while the rest is spent in knocking out secondary electrons from the screen material. These low velocity secondaries flow in a steady stream to the conductive coating of the second anode. An equilibrium condition is quickly established, the conductive coating acquiring the highest possible potential with respect to the cathode while the fluorescent screen slides a few score of volts below the potential of the coating. The difference of potentials between the fluorescent screen and the conductive coating is such that it draws the secondaries to the coating at exactly the same rate as the primaries are arriving to the screen.

Just as soon as the beam leaves the first anode it is subjected to the action of either magnetic or electric fields for the purpose of deflecting the beam in a predetermined manner. This deflection is scanning in television.

There are three ways of scanning, namely: first, by means of two electrostatic fields at right angles to each other; second, with two electromagnetic fields also at right angles to each other; and third, with an electrostatic and an electromagnetic field parallel to each other. It may be remembered at this point that the electrostatic field deflects electrons along the lines of force and that an electromagnetic field deflects them perpendicular to the lines of force.

The electrostatic deflecting plates are usually placed inside of the glass envelope while the electromagnetic deflecting coils are invariably outside the envelope.

SCANNING REQUIREMENTS

Since most of the tube characteristics can be observed and measured only while actually scanning, we will take up the scanning means first. The purpose and principle of scanning have been treated at great length by many writers, so we will limit ourselves to the recollection of scanning requirements in a high definition television system.

In our organization we have made a thorough study of this subject and the following are some of the conclusions reached.*

If we qualify and limit the ability to tell a desired story to specific conditions, the experience we have had with television allows us to make some interesting approximate generalizations. If we take as a standard the information and entertainment capabilities of sixteen-millimeter home movie film and equipment, we may estimate the television images in comparison.

60	scanning	lines	entirely inadequate
120	"	"	hardly passable
180	"	"	minimum acceptable
240	"	"	satisfactory
360	"	"	excellent
480	"	"	equivalent for practical conditions.

This comparison assumes advanced stages of development for each of the line structures.

We may say therefore that a number of scanning lines in the immediate vicinity of 360, say 340, will give a very good performance comparable with 16 mm home movie film.

In motion pictures the taking, or the camera frame frequency determines how well the system will reproduce objects in motion. This has been standardized at 24 frames per second. In television it is assumed that we shall use a frame frequency of 24 per second or greater. Since this is satisfactory for motion pictures, it is also satisfactory for television and this characteristic of frame frequency will, therefore, not be considered further.

In the reproduced image there is another effect of frame frequency. This is the effect of frame frequency on flicker. Motion picture projectors commonly used are of the intermittent type. The usual cycle of such a projector is that, at the end of each projection period, the projection light is cut off by a "light cutter", the film is then moved and stopped so that the succeeding frame registers with the picture aperture; the light cutter then opens, starting the next projection period. This is repeated for each frame - 24 per second. Since projection at 24 light stoppages per second with illumination levels used in motion pictures causes too great a flicker effect, the light is also cut off at the middle of the projection period for each frame for a time equivalent to the period that it is cut off while the film is moved from one frame to the next. This results in projection at 24 frames per second with 48 equal and equally spaced light impulses. Such an arrangement provides a satisfactory condition as regards flicker. In television we also may have a reproduced image at 24 frames per second, but because of the manner in which the image is reconstructed, a continuous scanning process, it is not practicable further to break up the light impulses by means of a light chopper in a manner similar to that used in the projection of motion pictures. We, therefore, have for the usual systems of television a flicker frequency which corresponds with the actual frame frequency (24 per second, for example). This is satisfactory at very low levels of illumination but becomes increasingly objectionable as the illumination is increased.

It has been concluded that, in a television system, satisfactory flicker conditions exist if each frame consists of two groups of alternate lines and that there should be 24 or above of the complete double frames. This so-called interlaced scanning is equivalent to 48 or above frames per second as far as flicker is concerned.

At 48 equivalent frames and with 60 cycles power system, the effects of hum or ripple travel across the reproduced image. The choice of 60 equivalent frames or 30 interlaced frames per second provides a complete solution to the visual requirements, i.e., motion, flicker and ripple.

ACCESSORY CIRCUITS

If we have to lay out a circuit to receive the television picture we have to provide: first, a suitable "Kinescope" with suitable power supply; second, a deflecting yoke for deflecting the beam vertically and horizontally at, say, the just-mentioned frame and line frequencies; third, for driving this yoke synchronously with the incoming signal, and fourth, an electric circuit to drive the grid of the "Kinescope" to provide the gradations of brightness on the screen.

The last item, of course, includes circuits for demodulating, amplifying, etc. of the incoming signal.

So far we have been discussing elementary generalities. Let us now consider somewhat in detail the question of the accessory circuits and of the arrangements required by the output device of a television receiver.

The first item is: a suitable "Kinescope" with a suitable power supply.

A typical set of characteristic curves of a "Kinescope" are given on Figure 4. It is very similar to that of a four-electrode tube. The second anode current I_{p2} is shown as a function of grid bias; the current on the first or the auxiliary anode is also shown. But there are two quantities on the characteristic which do not appear on that of an ordinary vacuum tube. They are line width vs. grid voltage and total light vs. grid voltage.

The line width is measured by means of a microscope with a scale focused on an isolated scanning line, when a pattern is scanned at normal scanning rates. The vertical deflection is increased until the adjacent lines separate by a centimeter or so. The total light is measured by means of a suitable illuminometer. The brightness units are rather con-

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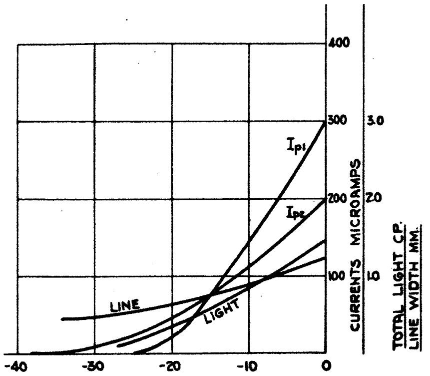
***See papers by E. W. Engstrom, IRE Proc. Vol. 22, page 1241, Nov. 1934, and IRE Proc. Vol. 23, page 295, April, 1935.**

FIG. 4.



fusing, just as all the light units. It is not hard to remember, however, that a perfectly diffusing area of 1 square foot and having brightness of one foot candle emits 1 lumen of luminous flux. One lumen of luminous flux from a flat surface is generated by a source whose intensity is $1/\pi$ candle power.

The total light in most of the modern tubes is approximately proportional to the beam wattage or beam current at a constant beam voltage, the coefficient of proportionality being between 1 and 2 c.p. per watt. The tube, the characteristics of which are shown on Fig. 4, has a screen efficiency of 1.5 c.p. per watt.

Now let us see what kind of picture we can produce on this "Kinescope". Suppose it has a screen large enough to accommodate a 6" x 8" picture. For 340 lines it should have a line width of 6/340 = .018", or roughly .5 mm.

Experience, however, has taught us that the lines can be somewhat larger than this theoretical value because the intensity of the luminous spot falls rather rapidly as we go away from the center of it. A reasonable correction factor is about 1.6 times the theoretical value. This means that we may tolerate a line width up to .8 mm. From the characteristic curve we take the corresponding value of beam current: 86 microamperes at -14 volts on the grid. The cutoff we find to be -40 volts. This means that a grid swing of 26 volts peak to peak will drive this tube from black to maximum permissible high light.

From the same set of curves we find that the total light for this high light will be about .75 c.p. Now if the picture is 6" x 8" and we have an entirely white picture, we will get .75 c.p. of total light from 48 square inches. This amounts to 2.36 lumens from 1/3 of a square foot, equivalent to 7.1 foot candles. So the maximum brightness of the high lights in the received picture will be 7.1 foot candles. Now, remembering that the brightness of a picture in home movies is of the order of 10 to 20 foot candles, we may conclude that we will have a picture of a brightness comparable with that of home motion pictures.

The useful information which we obtained from the characteristic curve can be summarized as follows:

The "Kinescope" under consideration will produce a picture of detail corresponding to 340 scanning lines and 30 interlaced frames with approximately 7 foot candles in high light and a grid swing of 26 volts peak to peak. The power supply will have to provide 6000 and 1200 volts and have a sufficient regulation for 80 microamperes. The adjustable or automatic bias supply should go down to -40 volts.

DEFLECTING SYSTEM REQUIREMENTS

Four factors are important when considering a particular arrangement for deflecting or scanning. First, the system must require not more than a reasonable amount of power for a full size pattern; second, the luminous spot must maintain its size and shape when deflected to the edges of the pattern; third, the pattern must not deviate from its normal rectangular shape; and fourth, the system must be capable of giving a high enough ratio of the picture to return sweep. The properties corresponding to these requirements are:

Deflection sensitivity.
Freedom from defocusing of the luminous spot.
Freedom from distortion of the pattern.
High enough overall frequency response.

The above requirements apply to any system of deflection, but the mechanics of magnetic and electrostatic deflection differ greatly. Let us consider magnetic deflection.

The magnetic field for deflecting electron beams is produced by combinations of coils and poles which are often called the magnetic deflecting circuit. Since to supply power to such a combination an electrical network or circuit is required, the latter also has been called the magnetic deflecting circuit. It sounds reasonable to call the whole combination "magnetic deflecting system and its component parts; magnetic driving circuit and magnetic deflecting yoke".

While the magnetic field in which we are interested is formed in air or vacuum rather, the magnetic deflecting yoke often contains iron for the purpose of confining the field and reducing reluctances of return paths, thereby reducing the total energy stored in the field for a given deflecting effect.

A magnetic field gives an electron an acceleration at right angles to the direction in which it travels. Since it is always at right angles the electron cannot change its speed and can change only the direction in which it travels. The kinetic energy of an electron moving in a magnetic field is a constant quantity and therefore the radius of curvature "R" of the orbit can be calculated from the law of conservation of energy. It comes out as

$$R = \frac{mv}{eH}$$

where e, m, v and H are charge, mass and velocity of the electron and H is the intensity of the magnetic field. Reduced to practical units this expression becomes:

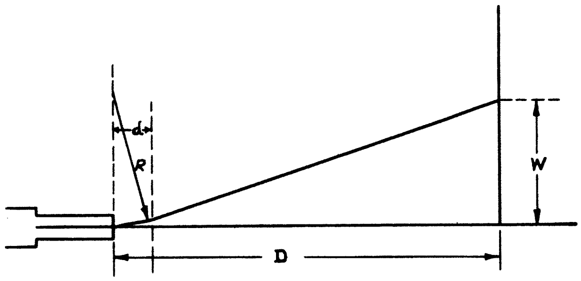
$$R = 3.36 \frac{\sqrt{V}}{H}$$

where R is in cm., V is in practical volts, and H is in Gauss or in Gilberts per cm. Referring to Fig. 5, let D be the gun screen distance, d be the length of the magnetic field. The magnitude of the deflection W comes out as follows:

$$W = R + \frac{Dd - R^2}{\sqrt{R^2 - d^2}}$$

If d is small compared to D we get: $W \cong Dd/R$

FIG. 5



For a magnetic yoke of increasing length (d), with the inductance kept at a constant value by corresponding reduction in the number of turns, the current required for a given deflection is proportional to the square root of the reciprocal of the length of the magnetic yoke. The power required for a given deflection and also the energy stored in the magnetic field comes out inversely proportional to the length of the deflecting yoke. This means that if we can deflect a given beam by means of two power tubes, doubling the length of the deflecting yoke will require the use of only one tube to accomplish the same result.

A measure of the sensitivity of a particular magnetic deflecting system is the amount of total energy Σ stored in the magnetic field for a given full deflection, from one edge of the tube to the opposite edge.

$$\Sigma = \frac{L_o I^2}{2}$$

Here Σ is in joules, L_o is in henries and I is in amperes. If the picture is repeated n times per second and after each picture sweep this energy is dissipated, then the output tube should be capable of delivering $n\Sigma$ watts to the yoke. This value, however, is not as important as the product in voltamperes of the voltage across the yoke during picture sweep by the maximum current amplitude thru the yoke.

The ability of the power tube to supply a deflecting yoke has been treated in detail in one of the earlier papers (1932) by the author, and will not be repeated here.

DEFECTS OF THE SCANNING PATTERN

There are two main forms of defects of the scanning pattern on the screen of cathode ray tubes. The first is defocusing of the luminous spot, and the second is the distortion of the scanning pattern. By defocusing of the luminous spot is meant the change of the size of the spot when deflected. By distortion of the scanning pattern is meant the deviation of the pattern from its normal rectangular shape.

The degree to which the above defects may be present in a particular deflecting system is determined primarily by the shapes and types of the deflecting fields. There are two more common defects caused more or less by the deflecting circuit as a whole. They are: non-uniform distribution of the scanning pattern or non-linearity of the sweep, and the crosstalk between the vertical and horizontal circuits. For the first of these, the wave shape of the magnetic driving circuit and the frequency response of the yoke are responsible. For the second, either the coupling between corresponding driving circuits or the coupling between the fields of the yoke may be the cause.

Both the static and the magnetic deflecting systems are subject to the defects enumerated above, and the work on improving both types has been in progress for several years. The early high definition systems in this country employed magnetic deflection both ways, early foreign systems showed preference for the electrostatic both ways. At present most of the systems used in this country utilize either a combination of static magnetic deflection or the all-magnetic systems.

The combined system provided only a partial solution, however. The main source of trouble in such a combination is the defocusing of the spot by the electrostatic field. A certain small amount of similar defocusing shows itself even in the best modern magnetic deflecting systems. The old magnetic systems had an exceedingly large amount of defocusing. All-magnetic systems seem best from the viewpoint of defocusing difficulties. Most of what follows refers to all-magnetic deflecting system.

DEFOCUSING OF THE LUMINOUS SPOT

Magnetic defocusing is caused by two factors: first, for a given non-uniform magnetic field it is a function of the diameter of the beam while it is under the action of the field, and second, for a given cathode ray tube it is a function of the non-uniformity of the field in the direction of deflection. The mechanism of defocusing will be better understood by considering Fig. 6. Take an electron beam of a circular cross-section with electrons moving parallel to each other. Such a beam before it is deflected will produce a luminous spot B on the screen. This spot will be of a circular shape. Now let us deflect the beam to one side of the screen by means of a magnetic field produced by electromagnets: C and C_1. Following the right-handed screw rule the beam will be so deflected that the spot will shift to D. The magnetic field produced by the two coaxial bar magnets will be of a barrel shape form and will be the densest in the middle. The cylindrical electron beam had initial direction toward the center of this field, but when deflected it will miss the axis. The side of the beam which is closest to the axis will be deflected more. The side directly opposite will be deflected less. The spot will be compressed along the direction of deflection. It can be shown mathematically that any non-uniform magnetic field possesses a certain curvature, which is a function of the non-uniformity.

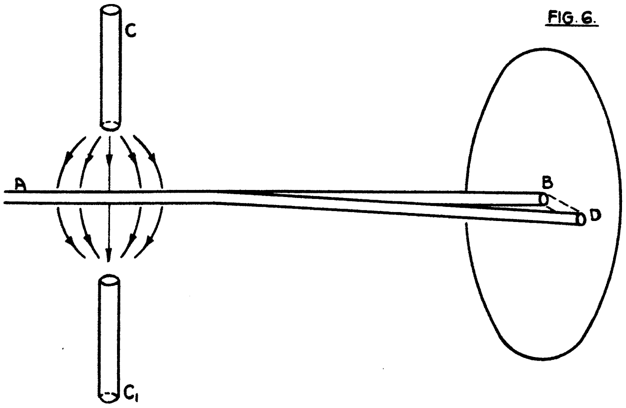


FIG. 6.

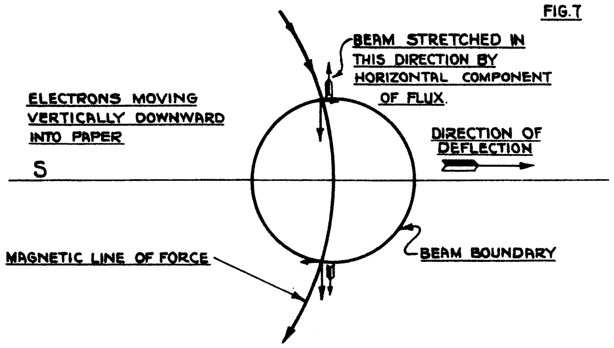


FIG. 7

Fig. 7 shows a beam of cylindrical shape being deflected away from the center of a barrel shape field. Away from the plane of symmetry of the field, the curvature of the field results in a component of the field parallel to the plane of symmetry. These components, however, have opposite directions on the opposite sides of the plane of symmetry. In the case shown the upper and the lower parts of the beam will be stretched away from the plane of symmetry in opposite directions. This will change the shape of the spot from a circle to that of an ellipse with a major axis perpendicular to the direction of deflection. Therefore we may conclude that the non-uniformity of the field and the curvature of it both act to change the luminous spot into an ellipse with its major axis perpendicular to the direction of deflection. But this will hold only if the direction of deflection is away from the region of the field where it is most concentrated.

When a cylindrical beam is pulled into a field towards the region where it is more concentrated, the beam is stretched into an ellipse with its major axis parallel to the direction of deflection. We may look at the effects of non-uniform fields from another angle. A non-uniform field affects a cylindrical beam as a divergent cylindrical lens.

For deflection towards weaker regions of the field, the axis of this lens is parallel to the plane in which the direction of the deflection lies. For deflection toward stronger regions of the field, the axis is perpendicular to this plane, and the larger the beam diameter the larger the effect of a given field.

So far we considered only the cylindrical beams. In practice we always have converging beams, which are either focused, or underfocused, or overfocused. It can be shown by reasoning similar to that just given that if a field stretches an overfocused beam in a particular direction, a readjusting of the focusing field to give an underfocused condition will stretch the spot in a direction perpendicular to the former.

DISTORTION OF THE SCANNING PATTERN

By distortion of the scanning pattern is meant the deviation of the pattern from its normal rectangular shape. When all the four corners are pulled away farther than they should be, we get a pincushioned pattern and when these corners are not pulled far enough we get a barrel pattern.

Distortion as well as defocusing is caused by the non-uniformity and the curvature of deflecting fields. A combination of two magnetic deflecting fields, each of which is of barrel shape distribution, causes a pincushion pattern. A combination of two pincushion fields produces a barrel shape pattern. The reason for these effects can be better understood by considering Fig. 8.

FIG. 8.

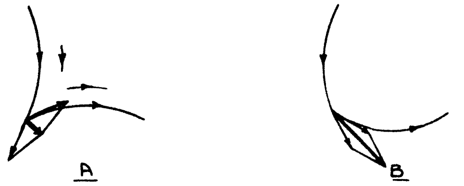


Fig. 8A shows how the components of two pincushion fields add together and give a comparatively small resultant for corner deflection and a barrel shape pattern. Similarly the components of two barrel shape fields add together as shown on Fig. 8B and give a comparatively large resultant and a pincushion pattern.

OVERALL FREQUENCY RESPONSE

To reproduce a saw tooth wave shape the magnetic deflecting yoke should be capable of responding to many harmonics of the saw tooth frequency. Other ways of obtaining the same result have been suggested but so far have not proven sufficiently advantageous to warrant a treatment here. For an infinite ratio of picture to return sweep the coefficients of successive harmonics are inversely proportional to the order of the harmonic. If the amplitude of the fundamental is 1, the second harmonic comes out as a half, and the third harmonic as a third, and the tenth as a tenth. Meaning that the tenth harmonic is of an amplitude equal to ten per cent of the fundamental. Now this is sort of high. Let us figure it out: 340 lines and thirty frames - this makes 10,200 lines or sweeps or cycles of the fundamental per second. This means that the tenth harmonic has a frequency of 102 kilocycles and contributes ten per cent to the wave. Fortunately we synchronize the picture every frame and every line. For positive synchronizing we have to take about 10 per cent of the time. This permits us to have, say, a ten to one ratio. Now for a nine to one ratio (which is easier to compute than the 10:1 case) of the saw tooth wave, if the amplitude of the fundamental is 1, the amplitude of the second harmonic comes out as .495, the third .300, the fourth .187, the fifth .131, and the tenth comes out negligible. So we may add to the requirements of a deflecting system that it must be capable of responding to a frequency band extending from the fundamental of the saw tooth frequency to its tenth harmonic.

CROSS TALK

Frequently in a deflecting system, a serious cross talk takes place between the horizontal and vertical circuits. Usually it is the horizontal impulse which finds its way into the vertical deflecting circuit and produces wavy zigzag scanning lines instead of straight lines. It may be caused by coupling of some sort between the driving circuits. This kind of cross talk is usually eliminated by electrically isolating and shielding the respective circuits. Often, however, it takes place because of either electrostatic or magnetic coupling between the coils of the deflecting yoke. The type and degree of coupling is usually definitely connected with electric, magnetic and physical arrangements peculiar to this particular type. It cannot be treated, therefore, in general, and has to be studied individually with every particular type of deflecting system.

As a rule, however, the cross talk can be eliminated by so arranging the coils on the yoke that the undesired induced voltages and currents buck each other out. Sometimes it calls for connecting horizontal coils in parallel and vertical in series. In other cases, both should be connected in parallel, while in some, no cross talk is produced under any conditions.

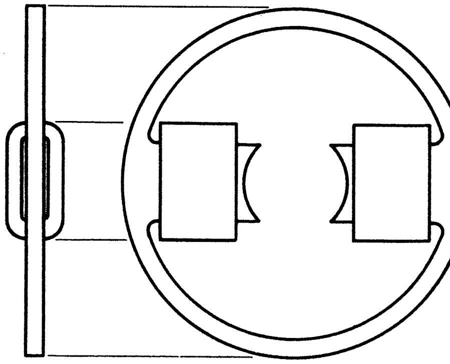
IRREGULAR DEFECTS

In our discussion of defects of the scanning pattern, we considered so far only the perfectly symmetrical yoke and a centrally located electron beam. If, however, for any reason either the beam is not centrally located with respect to the yoke, or the magnetic return legs of the yoke are not symmetrical, or the coils are not symmetrically located, the irregular defects of the scanning pattern result. If the deflecting field is sufficiently uniform, the position of the beam with respect to the yoke is not as critical as in the case of a non-uniform field.

Any non-symmetry in the yoke, however, ruins the uniformity of the field and immediately shows itself by producing defocusing in a part of the picture, stretching a corner or a side of the pattern and usually producing serious cross talk. The symptoms of the irregular defects are such that they are easily located and eliminated by tracing defective coils and by checking the geometry of the yoke and the cathode ray tube.

In conclusion let us consider a deflecting yoke of the type shown in Fig. 9. Two such yokes sufficiently spaced give a very good pattern for a 340-line 30 interlaced frame picture. It is balanced to give a very uniform field along the directions of deflection. Along the beam it naturally gives a wall of flux, so to speak, and a wall of uniform height.

FIG. 9.



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