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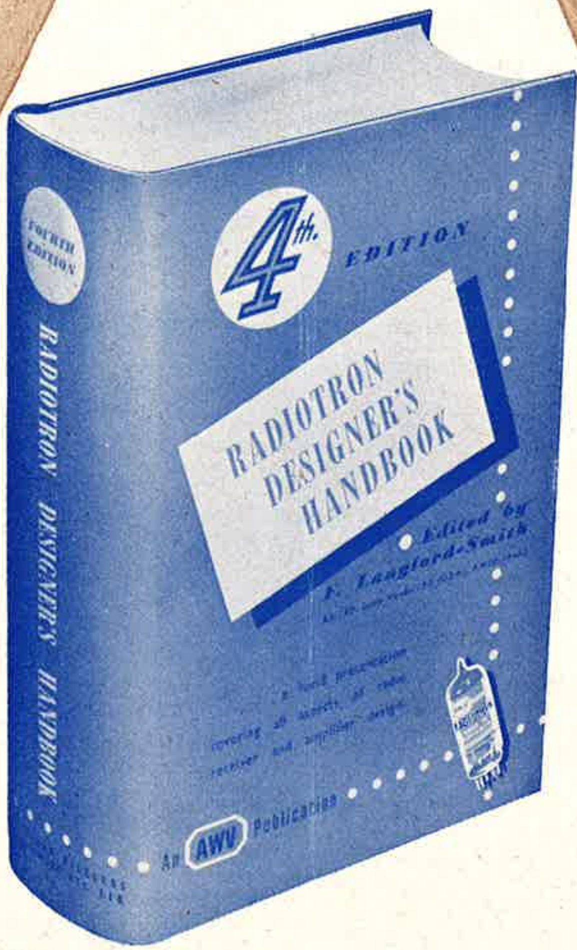

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RADIOTRONICS

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By the way —

Copies of the new fourth edition of the Radiotron Designers' Handbook are now coming to hand from the bookbinder. These are being mailed in strict rotation to all who have paid in advance. Any subscribers wishing to obtain a copy, but who have not yet placed an order, should do so immediately. It is expected that the small surplus remaining after advance orders have been distributed will be rapidly disposed of as its usefulness is more generally realised.

We continue in this issue, the television training course we commenced in October. It appears here through the courtesy of Australian General Electric and with acknowledgements to International General Electric of U.S.A.

Preparation of the second edition of the Radiotron Valve Data Book is progressing steadily. An announcement will be made in a later issue as soon as stocks become available. Orders are not being accepted at the present time for this book.

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OVERALL PERFORMANCE OF COMMERCIAL RADIO RECEIVERS

By W. B. Clark*

About three years ago an IRE convention was held in Toronto and one of the papers delivered by a good friend of mine took the form of a rather scathing denunciation of the audio performance of commercial radio receivers. During the course of the paper, demonstrations were made of the audio performance of different qualities of receivers ranging from the least expensive up to a very costly system which is typical of some of the finest custom installations. The demonstration was very effectively handled, and I, for one, left the lecture hall feeling that something should be done to improve the audio performance of commercial receivers. However, I believe that more mature thought indicates that this is a highly commendable ideal rather than a practical objective.

When the opportunity of speaking before this gathering on the subject was presented, I felt like a man who has the chance to testify on behalf of an old friend who has been charged in a court of law. I realize that friend is guilty as charged, but know of extenuating circumstances which should be brought to light. It is in that spirit that I would like to discuss some of the salient features of the audio performance of commercial radio receivers.

The receiver occupies a unique position in the overall audio chain which extends from the broadcasting studio to the receiver owner's home. In the broadcasting studio are microphones costing several hundreds of dollars each, whereas the loudspeaker at the other end of the chain is supposed to fulfill the same function in reverse while meriting an investment of only a few dollars.

The receiver is regarded by its owner subjectively. That is, his senses have to be pleased by its sound and appearance. Broadcasting equipment, on the other hand, is required to radiate a carrier, faithfully modulated by whatever happens in the studio. The broadcasting problem can be regarded objectively and can be predicated almost entirely upon analytical and experimental engineering.

The problem of the receiver engineer, however, is to participate in the creation of a saleable piece of merchandise, and to moderate his engineering ideals, having due regard for cost and cabinet styling and also the opinion of the ultimate purchaser as to how the receiver should sound.

This is a technical gathering, and the terms of reference are technical. However, in order to put our discussion of the audio performance of commercial radio receivers in its proper perspective, I must ask you to bear with me for a few minutes and consider the tremendous influence that the economics of the device, and the demands of the market, have had upon its physical form.

Fig. 1 gives an indication of the relative cost of the major elements of such receivers as are currently available in Canada. The X axis is graduated in retail price dollars and the Y axis in per cent. of retail price. The four curves show the relative value, in per cent. of total price, of the four major components of such receivers: in chassis containing the circuitry, the loudspeaker, the cabinet, and in the case of phonograph-radio combinations, the record changer.

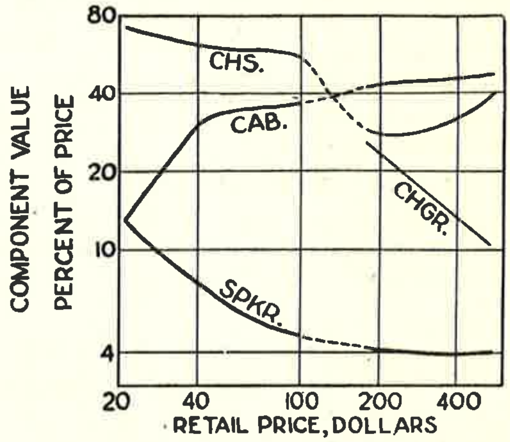

Fig. 1

To those of you who are critical minded, a question naturally arises as to the source of information upon which these curves are based. I must be frank and state that a good deal of arbitrary judgement was applied to the subjective inspection of a large number of receivers. The per cent. scale of value shown in the ordinates is, of course, based upon manufacturing cost, and does not reflect inherent functional value of components, or quality of engineering, or manufacturing efficiency.

There was naturally wide scattering of points used in the construction of the curves, particularly in the higher price bracket. Consequently I would ask the forbearance of anyone who may be acquainted with a current model of a commercial radio receiver which does not fit the data presented here.

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* Dominion Electrohome Industries, Ltd., Kitchener, Ontario, Canada.

The dotted portions of the curves lying between about $100.00 and $180.00 indicate a sparsely populated price bracket for which little data could be obtained. This region separates the table model radio receivers from console model phonograph-radio combinations.

I believe that the price of the least expensive radio receiver in Canada today is in the order of $22.00 and it is interesting to note that it provides more functional percentage value per dollar than any other. Both the speaker and the chassis curves reach their highest percentage value at this point, and the cabinet the lowest.

The percentage value of the cabinet continues to rise through the entire price range. The chassis percentage rises slightly throughout the console range, but is uniformly below the cabinet curve. Record changers as manufactured on this continent for commercial receiver use are somewhat standardized in their form and cost. This is reflected in the linearity of the curve of record changer percentage.

The fourth curve is the one in which we are interested in this symposium; it drops throughout the entire price range. One of the reasons for the use of a logarithmic distribution of the axes should be evident at this point; it was simply to keep the speaker curve off the base line in the higher price bracket.

In considering the part that the loudspeaker takes in this overall audio chain that we are discussing, we should revert from the foregoing very important "facts of life" to the somewhat purer fundamentals of acoustics.

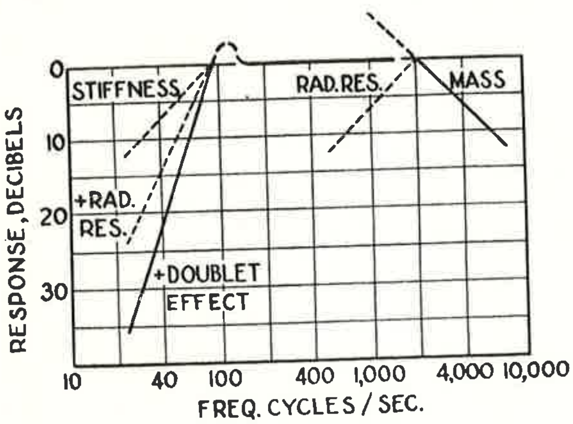

Fig. 2

Fig. 2 shows graphically the behaviour of a force driven diaphragm. For convenience, the points of slope change have been set to correspond to the physical characteristics of a typical loudspeaker such as is used in many console type receivers. The curves are purely theoretical, but they do have the validity of having been verified experimentally by authorities in the field of acoustics.

It is well known that a resonant diaphragm operating as a piston, adequately baffled, and driven by a finite force, will give an acoustic response that is flat over the frequency spectrum roughly bounded by resonance at the lower end and at the upper end by the frequency at which the acoustic wave-length is equal to the diaphragm diameter. For the typical loudspeaker referred to, these frequencies are slightly below 100 cycles and about 1,200 cycles, respectively.

Below resonance the diaphragm becomes stiffness controlled, and consequently the two effects become additive and together produce a drop in response with frequency of 12 db per octave.

Another influence that becomes manifest in this frequency range is the doublet effect due to the usual lack of complete baffling in receivers. This is due to the pumping of air around the baffle and results in a further drop in response of 6 db per octave so that total theoretical drop is 18 db per octave below resonance.

At the upper end of the spectrum where radiation resistance for piston action settles down to a constant value, the mass control of the diaphragm gives a drop of 6 db per octave as frequency is raised. However, this theoretical piston action is never achieved in practice with the type of speaker we are considering because of annular break-up of the diaphragm. The result of this fortunate phenomenon is that the relative uniformity of response is extended beyond the radiation resistance critical point for another two or three octaves.

Because of the unpredictability of the response in the neighborhood of resonance, the curve has been dotted. Another influence that sometimes exists at the point of diaphragm resonance is cavity resonance of the cabinet. If the two resonance points should be coincident, or even adjacent to one another, the acoustic response rises to many times the response at higher frequencies.

Now the purpose of introducing these fundamentals of direct radiator loudspeaker operation into this discussion is to indicate the spectrum limitation that is imposed by the single diaphragm which is characteristic of the vast majority of speakers.

The lower end of the spectrum can be extended slightly by such means as the addition of a bass reflex baffle. However, to obtain the acoustic compliance necessary for resonance in the order of 80 cycles, an air volume of 7 or 8 cubic feet is necessary. Such a volume is actually available in larger consoles but, for very good merchandising reasons, this space is invariably allocated to record storage use.

Another means of improvement which has been used in some commercial receivers is the complete enclosure of the rear of the loudspeaker. The influences of this are two-fold. The doublet effect is eliminated and the low frequency drop-off is thereby reduced. Also cabinet cavity resonance is eliminated and is replaced by stiffness only, which has the effect of slightly raising diaphragm resonance.

Now even the foregoing consideration of the low frequency end of the spectrum is to a very large degree academic. As mentioned earlier, the commercial radio receiver is completely at the mercy of subjective observation. Diaphragm resonance and cabinet cavity resonance to many people are actually desirable features. They give rise to a response over a band of a few cycles which can actually masquerade as good low frequency response. A critical observer should not, of course, be fooled by such a phenomenon. But by the very nature of the product that we are discussing, the idea of the critical observer has to be oriented to include the entire population. It has been indicated by experiments and by observation that what technical opinion determines is good is not necessarily coincident with non-technical mass opinion. I would like to refer to that point again in a few minutes.

I mentioned earlier that diaphragm break-up, or departure from piston action, is the fact upon which we are dependent for the extension of the theoretically flat part of the response upwards. Of course, other and better means of accomplishing this are the use of more than one diaphragm driven separately or even by the same voice coil as the main diaphragm. However, such speakers are rarely used in receivers of the type we are considering because of cost.

Diaphragm break-up into annular rings of alternate masses and compliances is theoretically logical for the purpose it serves, particularly when it is controlled by the introduction of annular corrugations distributed radially on the diaphragm in a systematic manner. However, the very nature of these masses and compliances is resonant, and consequently all speakers of this type manifest fairly sharp peaks and valleys of response in the upper frequency range. This becomes very apparent if the speaker is driven by means of a beat frequency oscillator through the audio spectrum and the response observed subjectively without the aid of any measuring equipment. Of course, the greater the power fed into the speaker the more pronounced are these peaks and valleys. The reason is that the departure of the diaphragm from piston operation is not gradual but is discrete; as the amplitude of the diaphragm is raised, different patterns of break-up occur and new peaks and valleys become manifest.

A different form of break-up also occurs, and this one does not have the desirable characteristics of the symmetrical annular form in extending the range. It is known to take several different geometric forms on the diaphragm such as a three-leaf or four-leaf clover node and loop formation. I believe loudspeaker manufacturers call this "oil canning"; that is, different parts of the diaphragm behave like the base of an oil can on high amplitudes of certain frequencies. Needless to say, the output, both fundamental and harmonic, and even subharmonic, rises to spectacular values at these frequencies.

We have been considering only the loudspeaker thus far. Like the speaker, the circuitry of commercial receivers differs from the circuitry of other equipment which enjoys a greater freedom from economic influence. For example, iron core audio transformers are rarely used in receivers for purposes other than the matching of output tube load impedance to voice coil impedance. On the other hand, transformers are used in broadcasting studio equipment with relatively wild abandon.

In addition, the audio transformer referred to above, which is an inseparable part of any receiver, takes a very different form from that which would be used if cost were not an influence. It is fairly obvious, for example, that the primary reactance of the output transformer should be many times the plate load impedance of the output tube at the lowest frequency to be reproduced. In actual practice, the primary reactance of the transformer in commercial receivers is usually comparable in value to the plate load impedance at diaphragm resonance. Such a practice is logical and consistent with the whole system because, as pointed out earlier, the speaker response in most cases drops 18 db per octave below resonance and there is little justification for doubling or tripling the cost of the transformer in an attempt to prevent the drop off from becoming steeper.

Also, for the upper end of the spectrum, interwinding of the transformer primary and secondary is almost standard practice on expensive transformers in order to minimize leakage reactance. Here again the omission of this refinement in commercial receivers is consistent because sideband cutting, due to selectivity on AM receivers, occurs at a frequency usually far below that at which transformer leakage reactance becomes a problem.

There are a number of factors in connection with high frequency response which should be mentioned at this point with the hope of indicating the nature of the problems that confront receiver designers.

The most provocative problem seems to be that the vast majority of users of commercial receivers simply do not like good high frequency response, or possibly they do not want to pay the price for it.

In the middle 1930's there were introduced on the market a number of medium priced receivers with manual control of selectivity to enable the overall receiver response to be extended by as much as a whole octave upwards when the signal strength and program material so warranted. I believe that this provision had only one or two years of use in commercial receivers, although it has appeared since then in custom installations. The experience of FM broadcasting with its advantages, particularly in extending the high frequency range, is an example of history repeating itself. However, that is too big a subject to be considered here.

Another point in connection with the relative acceptance or desirability of high frequency response is the almost universal provision on larger receivers of the so-called tone control. Functionally this device comprises a capacitor and series variable resistor shunted across some part of the audio circuit. The universal demand for this mechanism is, I think, amply proven by the simple experiment of turning the tone control knob of your host's radio when you are out visiting. More often than not it is set to achieve that frequency characteristic which is called "mellow".

Some light might be cast on the apparent public anathema for good high frequency response on receivers by a theory which was advanced a few years ago concerning the subjectively desirable algebraic product which should connect the two frequency limits of the audio spectrum. It has been authoritatively stated that the product of the low and high frequency limits in cps of any audio reproducing system should equal 450,000. This was based upon carefully controlled observations of audience response to program material with different audio pass bands.

If we assume the lower frequency limit of the average commercial receiver to be at about speaker diaphragm resonance of, say, 100 cycles, an upper limit of 4,500 cycles is plausible. I mention this, not as justification for the upper frequency limits that are characteristic of receivers, but rather to throw some light upon the apparent apathy of the average receiver user to what we call high fidelity response.

There is an indication here that an extension of the low frequency response is the major requirement, if for no other reason than to permit a corresponding extension at the upper end of the spectrum.

Disregarding for the moment non-linear distortion, and assuming that the audio performance of commercial receivers is capable of improvement, an obvious starting point is at the lower end of the spectrum. The first need to this end is a lower diaphragm resonance in order to extend the mass controlled frequency range. Secondly, the diaphragm will have to be coupled to the air in a manner that will prevent doublet operation of the front and rear by means of some sort of rear enclosure.

Now superficially these modifications in themselves appear to be fairly easy of accomplishment. But by going into further detail the job begins to pyramid technically and, of course, in cost.

The lower resonance diaphragm will most likely be heavier than the one we are used to and consequently a larger driving force will be required in the form of a larger voice coil and a larger magnetomotive force in the field, at least if the original efficiency is to be preserved.

The rear enclosure of the speaker diaphragm could take any one of the familiar forms, such as a box with or without an opening or the open organ pipe in the shape of a labyrinth. Any of these has to be constructed in a manner that will enable it to withstand the sound pressures involved. Also, acoustic resonance at higher frequencies must be damped by means of an absorbent material lining.

With this heavier diaphragm and voice coil we now have, the higher frequency response will be actually less than before, and some recourse must be taken to an extra small diaphragm to take over at the frequency at which the heavier diaphragm becomes immobilized through sheer overweight. This smaller diaphragm can take the form of a dome-shaped cap secured to the top of the voice coil, or, in its ultimate form, a separately driven diaphragm.

In order to maintain consistency with the improvements mentioned, the output transformer must be considered. If the lower frequency limit of the diaphragm is extended by an octave, the transformer primary inductance should be at least doubled. The transformer is therefore going to be physically larger, more susceptible to leakage reactance, and consequently the windings should be sectionalized.

All of these modifications are interdependent. If we grant the validity of the 450,000 product between the lower and upper frequency limits there is no point to extending either end without the other. I believe that the implications of the cost influence of these modifications should be clear to you. The slope of the curve that connects frequency response with the cost thereof is so steep that it would be a courageous manufacturer indeed who would attempt to mass produce and sell commercial radio receivers having a frequency response very much in excess of the average available today.

Thus far little has been said about non-linear distortion in receivers, our emphasis having been applied to frequency response. This is natural enough because non-linearities that exist within the circuitry are pretty well limited to two tubes in most receivers; one the audio voltage amplifier and the other the power amplifier. Neither one of these, as such, is a very serious offender when it is operated within the limits of its dynamic range.

Negative feedback is sometimes used in commercial receivers, but its purpose is ordinarily not to reduce non-linear or frequency distortion, but rather the opposite. One common use of negative feedback is to introduce some desired form of frequency distortion such as that needed to correct for the characteristics of phonograph records and pickups. Also, frequency selective negative feedback has been used to attenuate uniformly all frequencies above a few hundred cycles in order to give a greater relative response to the lower frequencies. Another application has been the use of selective negative feedback to provide a sharper cutoff below diaphragm resonance in order to minimize the effect of cabinet resonance upon the phonograph pickup.

I would like to suggest to you that even though commercial receivers may not measure up to the standard of performance that is achieved in some custom installations, or even amateur installations, they have occupied a place in the way of life of almost everyone in the civilized world for the past thirty odd years. I hope you agree that the performance that has been achieved, and is available to people in all walks of life, is actually a credit to the radio art in general and the receiver industry in particular.

"WIRELESS AND ELECTRICAL TRADER YEAR BOOK", 1952

23rd Edition. Published by Trader Publishing Co. Ltd., London.

Since the WIRELESS AND ELECTRICAL it has become firmly established as the retailers' invaluable reference book to the radio and electrical industries.

In the 1952 edition, data of practical use to U.K. dealers in the new English television areas and general reference and technical information have been carefully selected. Features include condensed specifications of current 1952 commercial television receivers (with such valuable facts as valves used, I.F. values, etc.), and information on valve and cathode-ray tube base connections, with over 200 valve base diagrams. These alone are invaluable to radio and TV service engineers.

A new feature, introduced in response to many requests, is a comprehensive list of the I.F. values of commercial radio receivers which have been marketed during the past five years. Other time-saving data ranges from specifications of current radio receivers, legal information and a directory of trade associations.

One of the principal aims of the Year Book is to assist traders to keep abreast of the constant changes in the names, addresses, telephone numbers and products of the firms engaged in the radio and electrical industries. These revisions have been incorporated in the directory sections, and the lists of names and addresses of firms therefore make the YEAR BOOK an invaluable and time-saving desk companion for every retailer and business man in the industry.

The WIRELESS AND ELECTRICAL TRADER YEAR BOOK will also prove of great assistance to overseas firms who are seeking contact with British suppliers.

Directory sections are printed on distinctively tinted papers for ease of reference.

Principal contents include:

Directory of principal Trade Organisations—Legal and General Information—Radio Receiver I.F. Values—Television Information and Data—Valve Base Connections—Valve Base Diagrams—Receiver Specifications of 1952 Models—Trade and Wholesalers' Addresses—Proprietary Names Directory—Classified Buyers' Guide.

Our copy received with the compliments of the publishers.

"RADIO INTERFERENCE SUPPRESSION"

by G. L. Stephens, A.M.I.E.E.
Published by Iliffe and Sons Limited.

This practical 132 page handbook, with 65 diagrams and photographs, is an up-to-date guide to the various methods of suppressing electrical interference with radio and television reception. The author, an engineer with extensive experience in this field, describes in detail the origins of interference and the whole theory of suppression technique. He then gives many practical applications. Typical interfering appliances discussed include engine ignition systems, switches, thermostats and contactors, electric motors and generators, rotary converters, lifts, neon signs, fluorescent and other types of discharge lighting, trams, trolleybuses and electric trains, radio-frequency heating apparatus, welding apparatus, oil-fired boilers, television receivers, spectrographic equipment and valve rectifiers.

Throughout the work, particular attention has been paid to the problem of interference at television frequencies. Special attention is also given to suppression arrangements on motor vehicles and on board ship. Other chapters deal with the design and choice of suppressor components, methods of locating the source of interference, and suppression at the receiver itself. Useful reference data is provided in the appendixes.

The book has been written for all who have to deal with suppression, from design engineers who must ensure that new equipment will be interference-free, to service engineers in the field who must cope with specific cases of interference.

Contents: Foreword — Introduction — Origin of Electrical Interference — Principles of Interference Suppression — Practical Applications — Marine Applications — Components for Suppression — Location of Interference Sources — Suppression at the Receiver.

Appendix 1: Measurement of Interference — Appendix 2: Wireless Telegraphy Act (Part Two) — Appendix 3: Screened Rooms — Appendix 4: Bibliography — Index.

British Standards Relating to Radio Interference.

Our copy received with the compliments of the publishers.

THE PICTURE TUBE OR KINESCOPE

1. Fundamentals of the cathode ray tube.

Cathode ray tubes are made in various sizes and types, depending upon the particular application of the tube; that is, whether the tube is going to be used in an ordinary oscilloscope, radar equipment, or in a television receiver. The exact size and type of cathode ray tube used in a television receiver depends upon a number of factors, among which are cost, size of screen, and whether the receiver is of the direct-view type or of the projection type.

Regardless of size or type, all picture tubes are fundamentally the same and every tube consists of the following basic elements.

a. A source of electrons in the form of a cathode.
b. A filament to heat the cathode so that it will emit electrons.
c. A control grid for varying the number of electrons passing it.
d. A means of focusing or concentrating the electrons emitted from the cathode into a beam.
e. A high voltage anode to accelerate the electrons emitted from the cathode.
f. A means of deflecting the beam of electrons in any desired direction.
g. A screen coated with a fluorescent material which glows upon impact of the electron beam.

2. Electrostatic type of C-R tube.

The electrostatic type of C-R tube will be considered first since it is the type used in the ordinary oscilloscope, and is probably the type that most radio technicians are more familiar with. It is called an electrostatic type of tube because the electron beam is focused and deflected by an electrostatic field.

Figure 2-1 illustrates a typical electrostatic type of cathode ray tube. The part of the tube that contains the filament or heater, the cathode, the control grid, and the beam forming anodes is called the electron gun and its action is as follows: the filament or heater causes the cathode to emit electrons which are acted upon by the control grid or electrode which is operated at some low negative potential relative to the cathode. The action of the control grid is two-fold. First, it controls the electrons emitted from the cathode as in the case of the ordinary vacuum tube; and secondly, it acts as a lens to concentrate the electrons into a small beam at the first beam defining aperture of anode #1, as shown in Figure 2-1. Since the grid is not capable of providing sufficient focusing action, additional focusing is needed and is obtained by anode #1 which is called the first or focusing anode, and anode #2 which is called the second or accelerating anode. The first and second anodes usually have beam defining apertures which prevent electrons which are divergent from the beam from getting through to the screen and, therefore, reduces the effect of scattering of the beam as shown in Figure 2-1. The main focusing action takes place in the electrostatic field set up by the potentials on the focusing anode (anode #1) and the accelerating anode (anode #2) which form an electron lens system, making the electron stream converge to a point at the fluorescent screen. The second or accelerating anode is always operated at a higher positive potential than the first or focusing anode. Focusing is usually controlled by varying the potential on the first or focusing anode while the potential on the second

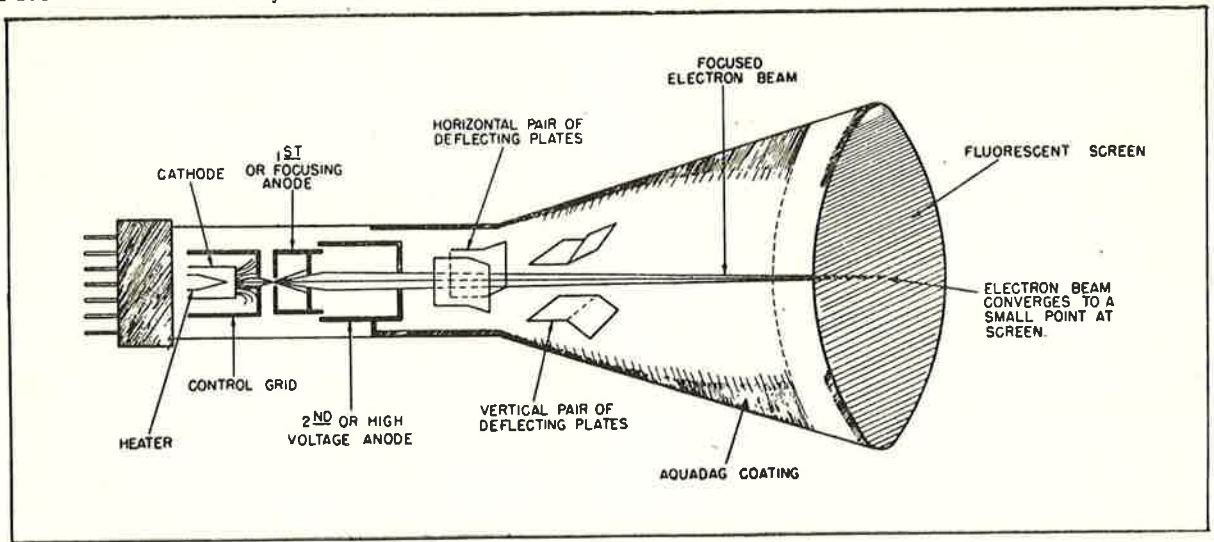

Fig. 2-1. Cathode ray tube (electrostatic type).

anode remains constant. This varies the effect that the electrostatic field has on the electron stream, and by observing the screen it is a simple matter to adjust the potential of the first anode so that the electron beam converges to a small point at the screen as indicated in Figure 2-1. In addition to their focusing action, anodes #1 and #2 accelerate the electrons so that they are moving at a high velocity when they strike the screen. Relatively high d-c potentials are used on the second or accelerating anode, since the higher the velocity of the beam the sharper will be the focusing action. The beam current is very small, varying from approximately 50 to 250 microamperes, depending on tube types and anode voltage employed.

In order to change the energy of the electron beam into light, the end or face of the tube over which the electron beam is moved is coated with phosphor which has the property of emitting light when bombarded with electrons. This property of emitting light upon impact by electrons is known as fluorescence. Various coatings have been developed which emit different colors of light. However, the phosphor used for television tubes gives off a nearly white light. Generally, it consists of a mixture of zinc sulphide and cadmium zinc sulphide or zinc beryllium silicate.

The ability of the fluorescent material to retain the image on the screen after the electron beam has passed on is called its persistence. If the image to be observed occurs at a low repetition rate, as in radar applications, the screen material should have a long persistence. In applications where the image changes rapidly, as in television, the persistence of the screen is quite short since the afterglow from a long persistence screen would cause loss of detail on the screen. A Type P4 phosphor is used for the screen of television tubes and has a medium persistence.

When the electron beam strikes the fluorescent screen, it causes secondary electrons to be emitted from the screen. If these secondary electrons are not removed, they will accumulate and form an electron cloud in front of the screen which will interfere with the normal operation of the tube.

In order to prevent this electron cloud from accumulating, the inside of the glass envelope of practically all cathode ray tubes (whether of the electrostatic or electromagnetic type) is coated with a conductive material, usually powdered graphite. This coating is called aquadag and usually extends from the neck of the funnel-shaped part of the glass envelope to within an inch or so from the fluorescent screen as shown in Figure 2-1. Since one end of the aquadag coating is connected to the second or accelerating anode, it will have a high positive potential and will attract the secondary electrons which are emitted from the fluorescent screen due to bombardment by the electron beam, This prevents a large accumulation of secondary electrons in front of the screen. In some cathode ray tubes no metallic accelerating anode is provided and the aquadag coating, in addition to collecting secondary electrons from the screen, also acts as the accelerating or high voltage anode of the tube.

Another electron gun structure used in some cathode ray tubes of the electrostatic type makes use of an extra grid which is placed between the control grid and the first or focusing anode. This second or screen grid prevents any interaction between the control grid and the focusing anode.

3. Electrostatic deflection.

Thus far we have considered how the electron beam is formed, focused, accelerated, and made to produce a spot of light on the fluorescent screen, the intensity of which can be varied by the control grid. However, in order for the cathode ray tube to be of any value, some means must be provided to deflect the electron beam, otherwise nothing but a small spot will appear in the centre of the screen.

In electrostatic deflection, two pairs of plates are placed around the beam at the end of the electron gun. For vertical deflection, a plate is placed above the beam and one an equal distance below the beam. Likewise, for horizontal deflection a plate is placed on one side of the beam and one an equal distance on the opposite side of the beam as shown in Figure 2-1.

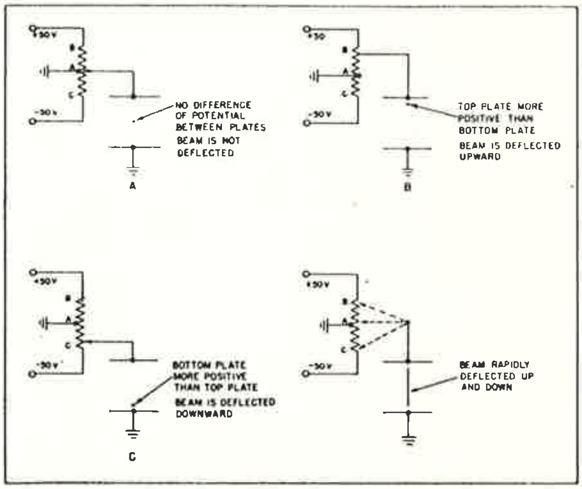

Fig. 2-2. Deflection of electron beam.

If a difference of potential is made to appear between the vertical plates, the electron beam will be deflected up or down toward the plate that is more positive, the amount of deflection on the screen being proportional to the voltage applied between the two plates. If zero potential exists between the two vertical plates, then there will be no vertical deflection of the beam. The deflection of the beam in a vertical direction for three different voltages applied between the vertical plates is illustrated in Figure 2-2. In (A) is shown the effect of zero potential between the two plates and the spot is not deflected but remains midway between the two plates. In (B) is shown the effect of making the top vertical plate more positive than the bottom vertical plate and the negative electron beam is deflected toward the positive plate. In (C) is shown the effect of making the bottom vertical plate more positive than the top plate and the electron beam is now deflected toward the bottom vertical plate. From the preceding, it is apparent that if the arm of the potentiometer is rapidly moved back-and-forth between (B) and (C), then the voltage between the vertical deflection plates will alternately change polarity and the electron beam will rapidly move up and down and trace a vertical line on the screen, as shown in (D) of Figure 2-2.

Likewise, with the horizontal plates introduced physically at 90 degrees to the vertical plates, the application of a more positive potential on one of these plates in respect to the other will cause the beam to move sideways instead of up and down as described for vertical deflection.

From the above it is apparent that if a voltage is applied to the horizontal deflecting plates and if another voltage is simultaneously applied to the vertical deflecting plates, then the position of the spot at any instant is due to the resultant force of the two voltages acting at right angles at that instant. In television, the voltage applied between the vertical deflecting plates is referred to as a vertical sweep voltage since it deflects or sweeps the electron beam in a vertical direction. The voltage applied between the horizontal deflecting plates is referred to as a horizontal sweep since it deflects the electron beam in a horizontal direction.

In television receivers,* a rapidly changing voltage or sweep is applied between the horizontal deflecting plates, which moves the beam rapidly from left to right and traces a horizontal line. At the same time that the beam is rapidly being moved horizontally, another voltage or sweep is applied to the vertical deflecting plates which changes much slower than the horizontal sweep voltage, and the beam traces horizontal lines across the face of the tube at the same time that it is gradually being moved from top to bottom by the much slower vertical sweep voltage. The result is a number of horizontal lines across the face of the tube extending from top to bottom, referred to as a raster and illustrated in Figure 2-3.

4. Electronic scanning process.

A more detailed description of how the picture is reproduced on the screen of the tube is as follows: to properly reproduce the picture it is necessary, first of all, for the electron beam or scanning spot starting at the top of the screen to travel at a uniform rate of speed across the screen of the tube from left to right. To accomplish this, a special waveform of voltage (in the case of electrostatic deflection) is applied to the horizontal deflecting plates. As the spot moves across the screen from left to right, its intensity will vary in exact accordance with the picture impulses of the video or picture signal that is applied between the control grid and cathode of the picture tube, tracing one line of the picture across the screen.

When the spot nears the right edge of the screen, the picture tube is biased beyond cut-off by means of the horizontal blanking signal. This causes the spot to be extinguished or blanked out during the time that it is very rapidly moved over to the left-hand edge of the screen, placing it in position to start tracing another line of the picture. The horizontal blanking signal is then removed and the spot again moves across the screen as before, tracing another line of the picture. This process is repeated over and over, the spot gradually moving toward the bottom of the screen by means of a much slower waveform of voltage which is applied to the vertical deflecting plates. Each horizontal line will be slightly below the previous one, slanting down slightly from left to right due to the downward pull of the much slower moving vertical sweep. When the spot reaches the bottom of the screen, the picture tube is biased beyond cut-off by means of the vertical blanking signal and the spot is extinguished or blanked out while it is rapidly moved from the bottom to the top of the screen, placing it in position to start tracing the second field. The vertical blanking signal is then removed and the spot traces the horizontal lines contained in the second field.

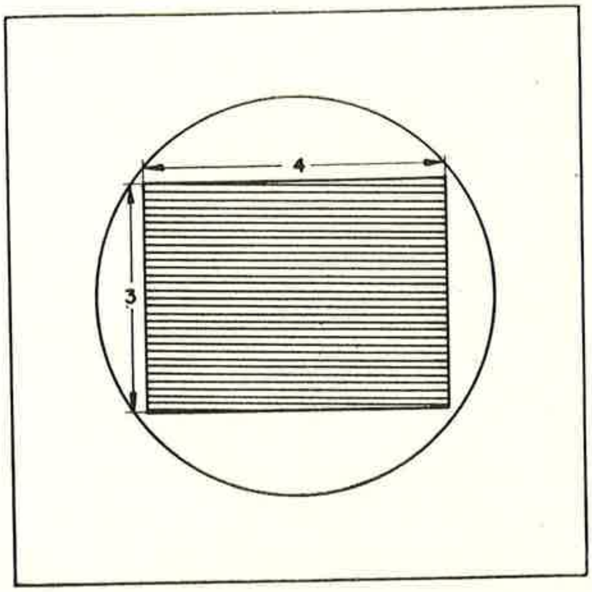

Fig. 2-3. Raster of a cathode ray tube.

The waveform of voltage that is applied to the deflecting plates must gradually increase in amplitude at a linear rate from minimum to maximum, which in the case of the horizontal deflecting plates will move the spot from left to right across the screen, and in the case of the vertical deflecting plates will move the spot from top to bottom. When this waveform has reached its maximum value, it should return to its minimum value in a very short period compared to the time required for it to go from minimum to maximum.

This rapid return to minimum of the waveform will, in the case of the horizontal sweep, move the spot back from the right-hand edge of the screen, and in the case of the vertical sweep move the spot back from the bottom to the top of the screen.

This gradual increase in the scanning voltage to a maximum value with a rapid return to its original or minimum value, requires a special voltage waveform known as a "sawtooth" waveform due to its similarity to the teeth of a saw, and appears as shown in Figure 2-4. As indicated, the increasing

* **This is not a normal application for an electrostatic tube, but it is mentioned here to illustrate the scanning principle.**

portion (that is, the portion that gradually moves the beam from left to right or from top to bottom as the case may be) is of longer duration. This is called the trace portion of the sawtooth waveform. The decreasing portion of the waveform, that is the portion that rapidly moves the beam from right to left, or from bottom to top, as the case may be, is of short duration and is called the retrace portion of the waveform.

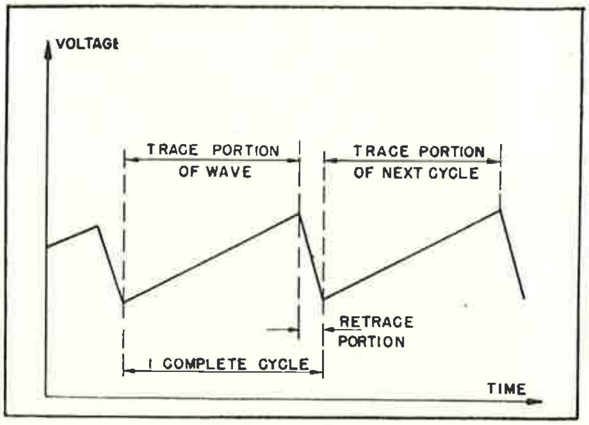

Fig. 2-4. Sawtooth waveform.

The increasing or trace portion of the sawtooth wave should be as straight as possible so that the electron beam or spot will be deflected at a uniform rate. The decreasing or retrace portion should be of short duration to reduce the time lost in moving the spot from right to left in the case of the horizontal sawtooth waveform, and from bottom to top in the case of the vertical sawtooth waveform.

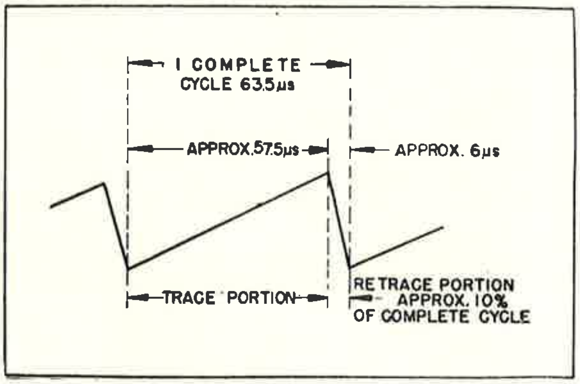

Fig. 2-5. Horizontal sawtooth waveform.

In practice, the retrace portion of the sawtooth waveform used for horizontal deflection takes up about 10% of the total time during one complete cycle, depending upon receivers as indicated in Figure 2-5. The retrace time may vary somewhat from this 10% value, but it must always be less than 16% of the complete horizontal cycle (trace and retrace) since the horizontal blanking period is only 16% of the complete cycle. If the retrace period were more than 16%, part of the horizontal retrace (that is, the movement of the spot from right to left) would be visible on the screen, which is very undesirable.

The retrace portion of the waveform used for vertical deflection consumes approximately 5% of the complete cycle, as indicated in Figure 2-6. As in the case of the horizontal retrace period, this time may vary somewhat; however it should always be less than the vertical blanking time of 8% of the complete vertical cycle. If the vertical retrace period were more than 8%, then some of the horizontal lines which occur during the vertical retrace period would be visible, which again is very undesirable.

Since one complete frame of a television picture consists of 525 horizontal lines and since 30 complete frames appear on the screen of the picture tube every second, then the scanning spot must move across the screen at the rate of 525 x 30 or 15,750 times per second. This is the frequency of the sawtooth waveform applied to the horizontal deflecting plates.

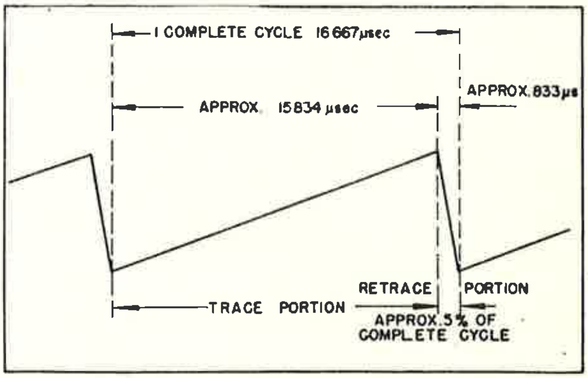

Fig. 2-6. Vertical sawtooth waveform.

The frequency of the sawtooth waveform applied to the vertical deflecting plates is much slower — being only 60 cycles per second, and is based on the fact that in interlaced scanning the picture is twice scanned from top to bottom during each frame; half of the lines being scanned the first field, the remaining lines on the second field. Since there are 30 complete frames every second, the scanning beam must move from top to bottom at the rate of 30 x 2 or 60 times per second.

There is considerably more that can be said concerning these sawtooth waveforms, as to their generation, synchronization, etc., the details of which will be covered in later sections.

5. Voltage circuit for electrostatic C-R tube.

The basic voltage circuit and schematic representation for a typical electrostatic type cathode ray tube is shown in Figure 2-7. As indicated, electrode voltages for forming, focusing and controlling the intensity of the beam are obtained from a bleeder connected across the high voltage supply. A variable voltage for the focusing anode is obtained from a potentiometer in the bleeder circuit. The potential on the 2nd or high voltage anode is usually 5 or 6 times that of the 1st or focusing anode and ranges from approximately 1500 to over 10,000 volts, depending upon the tube type. The higher anode voltages result in a smaller spot size and also produce a brighter picture.

The intensity of the beam or brightness of the picture is controlled by means of a potentiometer in the bleeder circuit which varies the bias between

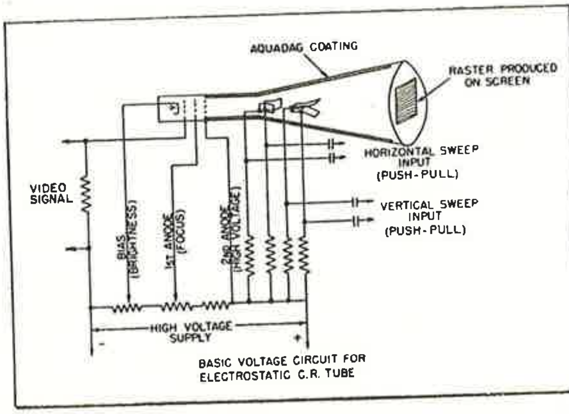

Fig. 2-7. Voltage circuit for electrostatic C-R tube.

control grid and cathode. Making the cathode more positive with respect to the grid decreases brightness, while making it less positive increases brightness. This is the equivalent of biasing the grid more-or-less negatively in respect to the cathode.

As mentioned previously, the video or picture signals are introduced in the grid-cathode circuit of the picture tube, which causes the intensity of the electron beam to vary in exact accordance with the picture signal as the electron beam is deflected across the screen by the application of suitable sweep voltages to the horizontal and vertical deflection plates.

In order to prevent the application of the sweep voltages on the deflection plates from defocusing the electron beam, the mean potential of the deflecting plates is kept at the same potential as the last or accelerating anode. It is advisable from this standpoint to use push-pull deflection circuits; that is, both sets of plates are made to vary in potential about a fixed positive potential (the last anode potential) as an operating point. This method of operation is accomplished by connecting each deflection plate to a high resistance, the centre point of which is connected to the last anode, and then coupling each pair of deflection plates to a push-pull amplifier, as indicated in Figure 2-7.

Some provision is usually made to place a variable d-c potential on each set of plates for proper centering of the beam. This small variable voltage is required to compensate for any misalignment of the electron gun and for any stray electrostatic or electromagnetic fields which would tend to move the beam off centre.

6. Electromagnetic type of C-R tube.

Figure 2-8 illustrates a cathode ray tube of the electromagnetic type and is fundamentally the same as the electrostatic type except for the fact that the electron beam is focused and deflected by an electromagnetic field instead of by an electrostatic field.

In the electromagnetic type of tube the electron gun structure is similar to that in the electrostatic tube consisting of: a heater, cathode, control grid, and two anodes as before. However, the first and second anodes do not perform any of the focusing action as before. The first anode attracts electrons from the cathode and the second or accelerating anode, which is the high voltage anode, accelerates them toward the screen. As mentioned previously, the aquadag coating is sometimes used as the second anode instead of a metallic second anode, as shown in Figure 2-8.

When electromagnetic focusing is used, the electrostatic forces considered before in connection with electrostatic focusing are replaced by magnetic forces set up by a focus coil which is placed around the neck of the tube, as shown in cross section by Figure 2-8. It will be noted that the lines of magnetic force set up inside the neck of the tube are uniformly distributed and are parallel to the axis of the tube. The focus coil is usually wound in the form of a ring as shown, with many turns of fine wire. Direct current is passed through the focusing coil to produce the desired magnetic field and the amount of current through the coil is varied to provide for fine focusing.

In order to get a clearer idea how the electrons are affected by the magnetic field, we will study their movement under various conditions. We concentrate our attention on one single electron which we shoot at right-angles into a uniform magnetic field. This is represented by a number of arrows or vectors indicating the direction and the density of the magnetic field (Figure 2-9A). The direction of the electron velocity is represented by a vector (1) which forms a rectangle A together with the field vector (2). The moving electron is affected by a force (3) which is perpendicular to the rectangle A and also perpendicular to the electron velocity

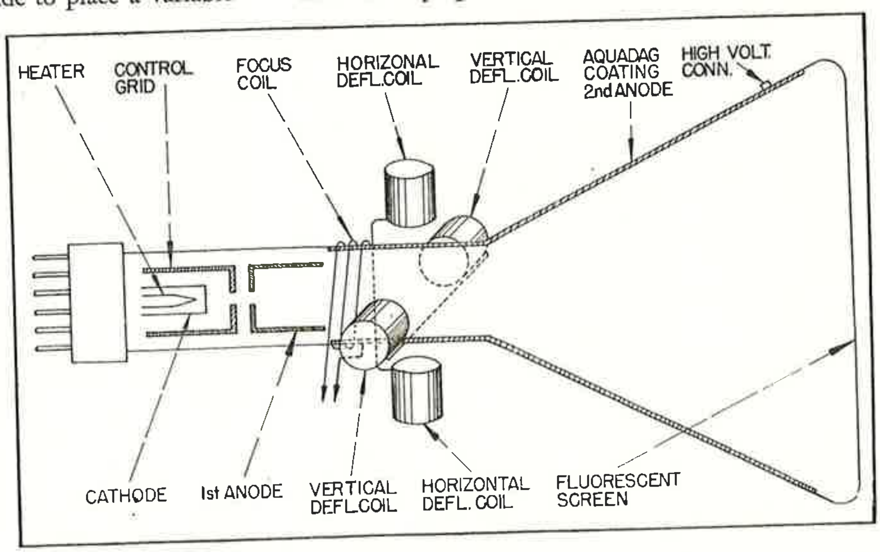

Fig. 2-8. C-R tube with magnetic focus and deflection.

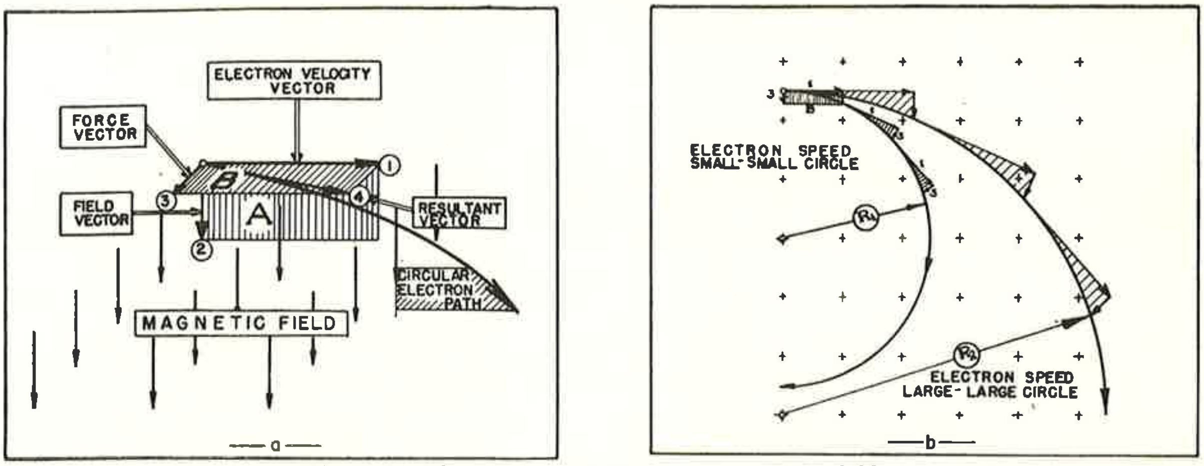

Fig. 2-9. Electron movement in a magnetic field.

vector (1). The drawing uses perspective representation in order to clarify the various directions of forces. The electron is influenced by two forces: one in the direction of the original velocity (1) and the second force in the direction (2). The resultant force is obtained by drawing the diagonal in the rectangle B with its two sides (1) and (3). The electron will follow the direction of this resultant force (4). If the magnetic field is uniform, the electron will be deflected at a uniform rate and, therefore, follows a circular path. Figure 2-9B brings this out clearly. We are above the rectangle B and looking down on the magnetic field. The arrows are shortened to a point and we see only their tails represented by crosses; the magnetic field goes perpendicular into the plane of the paper and causes a constant deviation of the electron, producing a circular path. If the electron has a larger velocity, the resultant force will be more in the direction of the electron velocity (1) and therefore the deviation will be less, producing a circular path with a larger diameter. If we consider two electrons with different speeds, they have to travel in different circular paths. However, they will complete their individual circle in the same time. The electron with the higher velocity travels along a larger circle, while the slow electron has to complete a small circle only.

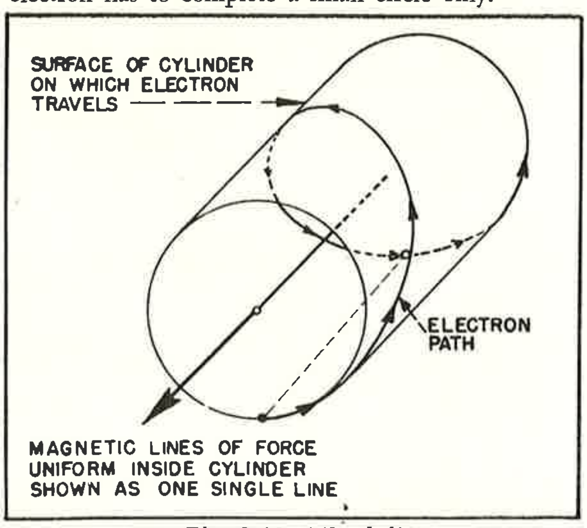

Fig. 2-10. The helix.

If the electron enters the magnetic field at an arbitrary angle to it, the electron is affected by a force which shifts the electron forward while moving on the circular path. The circle does not close any more and the electrons follow a curve similar to a normal screw thread called a helix (Figure 2-10). In spite of the change of the electron paths, the timetable for the different electrons remains unchanged. After one revolution, they all meet again on the same spot. They travel on the surface of a cylinder, as indicated in Figure 2-10.

If we look in the direction of the axis of the cylinder, the electron would seem to travel in circles because the projection of the helical path is still a circle. In our C-R tube the electrons will leave the cathode at various angles. Those which do not form an angle with the magnetic lines of force but move parallel to it will not be affected by the magnetic field and will shoot through to the screen (1). The electron with a large angle to the magnetic field (2) will travel along the surface of a cylinder with the radius R_2 (Figure 2-11). The electron

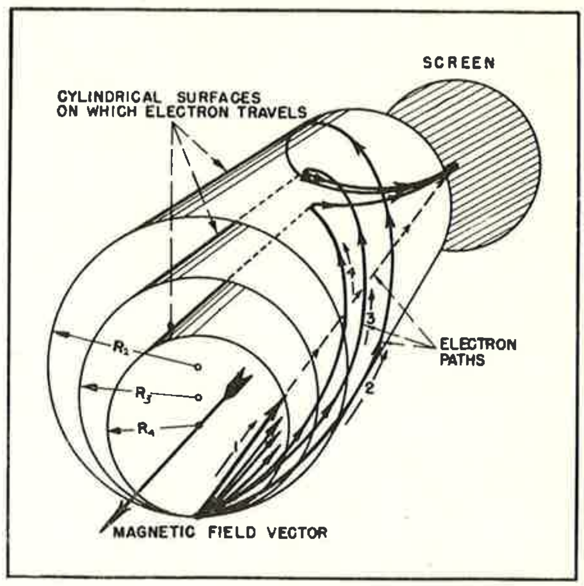

Fig. 2-11. Electrons in magnetic C-R tube.

with a smaller angle (3) will travel on the surface of a smaller cylinder R_3, and so forth. However, all the various paths will complete one revolution at the same time. By changing the magnetic field we can arrange that the electrons meet in a point on the viewing screen of the C-R tube, forming a well-defined spot. In case we do not obtain a sharp focus point, we have to change the magnetic field

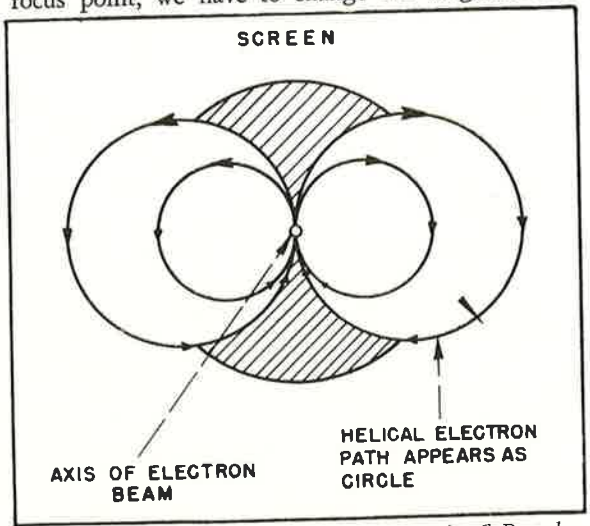

Fig. 2-12. Electron paths in magnetic C-R tube.

intensity. If we look from the cathode to the screen, the various electron paths appear as circles of different diameters (Fig. 2-12). The intensity of the field can be varied by changing the current through the coil which produces the magnetic field (Figure 2-13). Our discussions were based on the assumption that the magnetic field is uniform throughout the path of the electron. According to Figure 2-13, this is not the case. The magnetic field is uniform only within the space inside the coil, diminishing in strength on both sides of it, and simultaneously changing its configuration entirely. However, this does not change our argument principally. The projections of the path will not be circles any more, but we still retain the focusing action of the magnetic field.

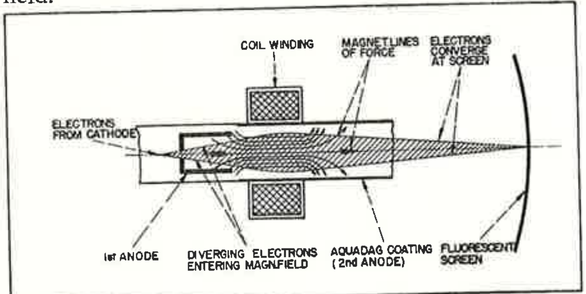

Fig. 2-13. Electromagnetic focusing.

A late refinement of the focus coil makes use of both permanent and electromagnetic fields. Instead of using a larger coil with thousands of turns of wire, a much smaller coil, shown in Figure 2-14, is used in conjunction with a circular permanent magnet. The coil is placed inside the circular permanent magnet which supplies the major portion of the magnetic field. The coil itself supplies the remaining portion of the magnetic field necessary for focusing, the current through it being variable so as to provide fine focusing.

This type of focus coil provides two advantages over the usual type of coil where all the magnetic field is due entirely to the coil itself. First of all it minimizes defocusing of the beam due to line voltage fluctuations since most of the magnetic field is fixed due to the permanent magnet ring. Also, since only a small portion of the total magnetic field necessary for focusing is produced by the coil itself, the energy supplied by the power supply for focusing is held to a minimum.

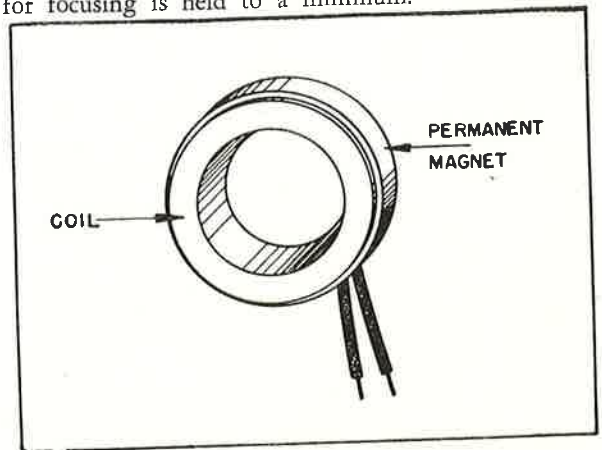

Fig. 2-14. Focusing coil.

7. Electromagnetic deflection.

With electromagnetic deflection, coils are used instead of plates and they are placed around the outside of the tube neck, as indicated in Figure 2-15. By passage of a suitable current waveform through these coils, a scanning raster can be produced on the screen of the picture tube, just as in the case of the electrostatic type of tube. The strength of the magnetic field produced by these coils is proportional to the current through them and the instantaneous deflection of the beam is proportional to the instantaneous current through the coil. In order to deflect the beam at a uniform rate, the current through deflection coils must change at a uniform rate. To accomplish this, a sawtooth waveform of the current is passed through the coils,

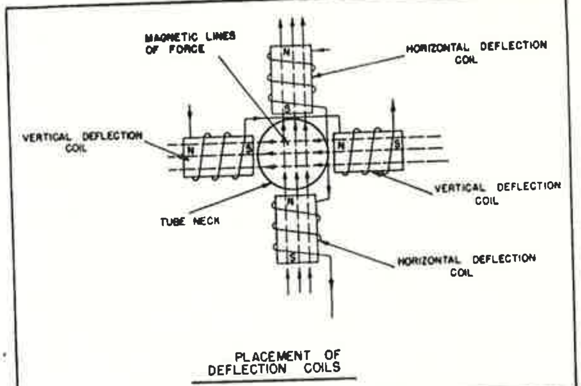

Fig. 2-15. Placement of deflection coils.

which compares to the sawtooth voltage waveform required at the deflecting plates for electrostatic deflection. It should be emphasized that when electromagnetic deflection is employed a current of sawtooth waveform is used, while for electrostatic deflection a voltage of a sawtooth waveform is used.

In order to produce a rectangular raster, it is necessary for both the horizontal and vertical deflecting forces to operate simultaneously at right-angles to each other, as in the case of electrostatic deflection. To accomplish this, two sets of coils are used which are placed around the tube neck at right-angles to each other. For horizontal deflection a coil is placed above the neck of the tube and one directly below the neck of the tube with the two coils connected in series as indicated in Figure 2-15. For vertical deflection, a coil is placed on either side of the tube neck with the two coils connected in series, as is also indicated in Figure 2-15. As will be brought out in detail in a later section, each set or pair of coils connects to its own output transformer which matches the low impedance of the coils to the plate impedance of the sweep output tubes. An important point to note is that the magnetic field produced by the vertical set of coils is exactly at right-angles to that produced by the horizontal set of coils.

Referring to Figure 2-15, it will be noted that for horizontal deflection the coils are placed in a vertical plane, while for vertical deflection the coils are placed in a horizontal plane. Both pair of coils properly mounted at right-angles to each other are combined in one assembly which slips over the neck of the tube and is referred to as a deflection yoke. The deflection yoke is always placed on the neck of the tube so that the end nearest the screen presses against the bell of the tube, as shown in Figure 2-16.

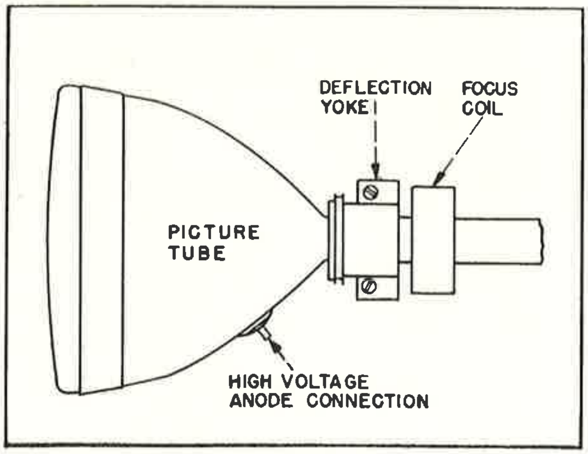

Fig. 2-16. Focusing and deflection coil assembly.

The reason for this arrangement of the deflection coils is that the electromagnetic fields of force set up by the coils deflect the electron beam in a direction which is at right-angles to both the direction of the original line of motion of the electron beam when entering the magnetic field. The deflection of a beam of electrons by means of a magnetic field may be explained by the well-known rule of motor theory where a wire carrying a current in a magnetic field experiences a force perpendicular to the direction of the electron flow in the wire and the direction of the field acting upon the wire.

This action is illustrated in Figure 2-17. The circular magnetic field existing about a wire carrying current is shown at A. Since a flow of current consists of a flow of electrons, the electron beam will also have a circular magnetic field, as in A. At B is shown the magnetic field cutting across the tube neck due to the vertical pair of deflecting coils. It should be noted that the magnetic field existing around the electron beam consists of concentric circles. Also, that the magnetic field cutting across the neck of the tube due to the vertical pair of deflecting coils is uniformly distributed.

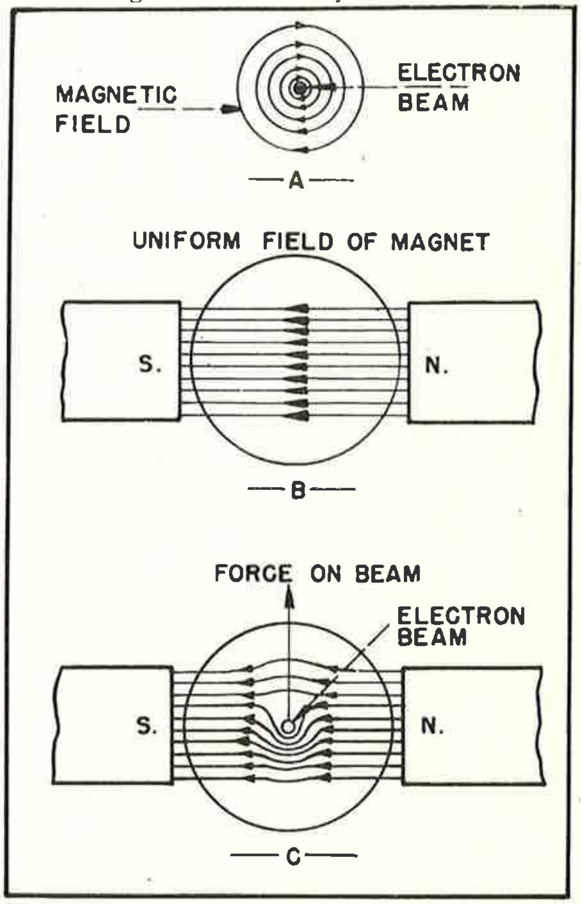

Fig. 2-17. Movement of electron beam in magnetic field.

Now when the electron beam passes through the magnetic field produced by the vertical deflection coils, the circular magnetic field around the electron beam interacts with the magnetic field of the deflection coils. This action is shown in C of Figure 2-17. As shown, the direction of the circular magnetic field below the electron beam is such that it combines with that produced by the vertical deflection coils and causes a concentration of magnetic lines below the beam. At the same time, the direction of the circular magnetic field above the beam is such that it opposes that of the deflection coils and causes a thinning out of the magnetic lines above the beam. This concentration of magnetic lines below the beam and thinning out of lines above the beam exerts an upward push on the electron beam, as indicated in C of Figure 2-17. If the magnetic field due to the deflection coils is reversed by changing the direction of the current through the coils, then there would be a concentration of magnetic lines above the beam, a thinning out of magnetic lines below the beam, and the beam would be pushed or deflected downward. It is therefore apparent that for vertical deflection of the beam, the deflection coils must be placed in a horizontal plane and, likewise, for horizontal deflection, the deflection coils must be placed in a vertical plane, as indicated in Figure 2-15. We can arrive at the same conclusions by using a vector diagram similar to Figure 2-9.

8. Voltage circuit for electromagnetic C-R tube.

The basic voltage circuit and schematic representation for a typical electromagnetic type of picture tube is shown in Figure 2-18. The high voltage is connected to the aquadag coating, which in this case acts as the second or high voltage anode. However, in some picture tubes a metallic second anode is used and the aquadag coating merely makes electrical contacts with it, as in the case of the electrostatic type of tube shown in Figure 2-1. The high voltage supply may vary from approximately 2000 to 30,000 volts, depending on the particular type of tube used. The first anode is operated at a much lower voltage than the second anode, as indicated in Figure 2-18.

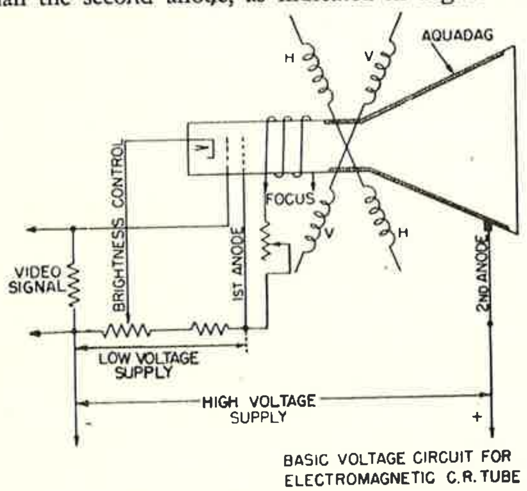

Fig. 2-18. Voltage circuit of electromagnetic C-R tube.

A potentiometer is provided to vary the bias between the control grid and cathode which controls the intensity of the electron beam and, therefore, the brightness of the picture. The focus coil is connected to a d.c. source through a potentiometer so that the current through the coil can be adjusted for proper focusing of the beam. The video signal is introduced into the grid-cathode circuit of the tube.

9. Special types of C-R tubes.

Thus far we have only considered a straightforward electrostatic type and a straightforward electromagnetic type of cathode ray tube; however, there are special types of tubes where the beam is focused by electrostatic means and deflected by electromagnetic means. A tube of this type is the type 5TP4 picture tube used in projection receivers.

This tube is specially constructed for use in projection receivers and a very high anode potential of approximately twenty-seven kilovolts is employed so as to produce a very intense image upon the face of the tube and, also, to keep the spot size as small as possible. Due to the very high anode voltage employed, special precautions are taken to reduce the possibility of voltage breakdown from high humidity. The outer surface of the tube from the high voltage anode terminal to the neck is coated with a moisture-repellent insulating material. The neck of the tube over which the deflection yoke is placed is coated with a conductive coating and grounded to prevent any possibility of arcing between the tube neck and the deflection yoke.

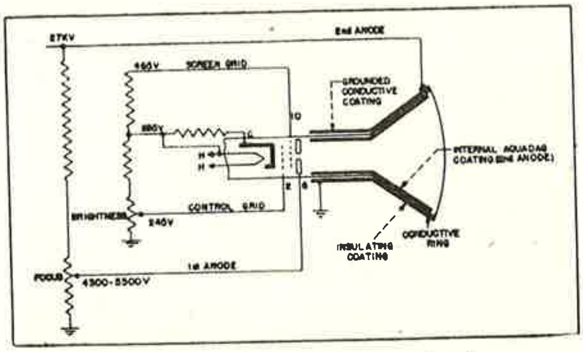

Fig. 2-19. 5TP4 C-R tube circuit.

The voltage circuit and schematic representation for this particular tube is shown in Figure 2-19. The high voltage supply connects to the aquadag coating on the inside of the tube, which acts as the second anode. The first or focusing anode connects to the focus control, which varies the first anode voltage from approximately plus 4300 to plus 5500 volts. It will be noted that this tube employs a screen grid placed between the control grid and the first anode for the reason mentioned previously to prevent any interaction between the control grid and the focusing anode. This screen grid operates at a much lower potential than the first anode, as indicated in Figure 2-19. Brightness is controlled in the usual manner by varying the bias between control grid and cathode.

10. Advantages and disadvantages of electrostatic and electromagnetic deflection.

The choice of an electrostatic or an electromagnetic type of cathode ray tube depends upon a number of factors, among which are:

a. The particular application of tube; that is, whether it is to be used for television, radar, or in an ordinary oscilloscope. Most oscilloscopes use both types, depending on other factors to be mentioned;

b. Size of equipment and size of viewing screen desired;

c. Cost of equipment;

d. Ruggedness of equipment;
e. Requirements of auxiliary circuits.

Some of the advantages of the electrostatic type over the electromagnetic type are:

a. The deflection circuits will operate over a wide range of frequencies since no coils or transformers are used in the deflection circuits, which would limit the frequency range to a narrow band. This makes the electrostatic type of tube more useful for oscilloscopes, where it is desirable for the sweep circuits to operate over a wide range of frequencies. However, in television circuits where the sweep frequencies are fixed, this feature offers no particular advantage;
b. Requires less power for proper deflection of the beam;
c. Electrostatic focusing is not affected very much by changes in line voltage;
d. No coils or sweep transformers which may break down in areas of high humidity.

On the other hand, some of the advantages of the electromagnetic type over the electrostatic type are:

a. Since the electromagnetic type has no delicate deflecting plates, it can be made at less expense;
b. Somewhat more rugged since there are no deflecting plates to be knocked out of alignment;
c. Shorter tube length for a given size screen;
d. Elimination of centering controls since centering can be accomplished by adjustment of the focus coil;
e. Somewhat sharper focusing obtainable;
f. Provides a convenient means of obtaining a special type of safe, high voltage supply;
g. Reduces the voltage requirements of the auxiliary deflecting circuits, especially in the case of the larger tubes;
h. Higher deflection sensitivity for equal anode voltages.

11. The ion spot.

One of the defects of pre-war picture tubes employing electromagnetic deflection was the formation of a dark spot in the centre of the screen. This occurred in about 80% of these tubes after approximately 30 to 40 hours' use, and obviously was very objectionable. Once this dark spot appeared on the screen nothing could be done about it except to replace the tube, which involved considerable expense.

This spot was caused by a beam of negative ions which bombarded the fluorescent coating at the centre of the screen, causing it to disintegrate, and making this area incapable of producing very much light when the electron beam strikes it, thus making this area appear dark within the bright screen.

These negative ions emitted from the cathode have a much greater mass than the electrons, being approximately two to one hundred thousand times heavier. An electrostatic field deflects these heavy ions and the lighter electrons equally well, and there is no concentration of ions at the centre of the screen and no ion spot is formed. However, an electromagnetic field has little effect on the heavy ions, deflecting the electrons only.

Therefore, when electromagnetic deflection is employed, the heavy ions will strike the centre of the screen, and in a short time will cause a dark spot to appear in the centre of the screen.

12. The ion trap.

There are several methods for preventing these heavy ions from causing a dark spot on the screen. One method is to make use of what is known as an ion trap. This ion trap actually traps the ions in the electron gun and prevents them from reaching the screen. It makes use of the fact that the electrons and ions are deflected equally well by an electrostatic field but not by an electromagnetic field.

The ion trap arrangement used in the 10BP4-A cathode ray tube consists of a special construction of the electron gun and a magnetic ring assembly placed around the neck of the tube. In A of Figure 2-20 is shown the special construction of the electron gun, and it will be noted that the adjacent ends of the first and second anodes are cut at an angle rather than straight across as in the conventional manner. Also, there is a small aperture in the end of the second anode through which the electrons must pass in order to reach the screen of the picture tube.

Anode #1 operates at approximately 250 volts, while anode #2 operates at approximately 9000 volts; therefore, a strong electrostatic field exists in the air gap between these anodes. Due to the fact that the gap between anode #1 and anode #2 is slanting, the electrostatic field set up in the gap will not follow the normal axis of the tube but will also be slanting, as shown in B of Figure 2-20. The ions, as well as the electrons, enter this slanting electrostatic field and will be deflected to one side, away from the normal axis of the tube, and will not get through the small aperture at the end of the second anode, being trapped in the second anode.

Now, since it is desired to allow the electrons to reach the screen but prevent the ions from doing so, use is made of the fact that a magnetic field will deflect electrons, but has little or no effect on the heavier ions. By placing a magnetic ring on the outside of the tube neck approximately over the gap between the two anodes, and magnetizing the ring in such a way that the magnetic flux cuts across the neck of the tube (as in the case of the deflection coils), the effect of the slanting electrostatic field on the electrons can be neutralized.

By properly adjusting the magnetic ring, the effect of the slanting electrostatic field on the electrons is just overcome by the deflecting force of the magnetic field, and the electrons will follow a straight line along the normal axis of the tube, pass through the opening in the end of the second anode and strike the fluorescent screen. However, the heavy ions will remain trapped in the second anode, since the magnetic field has practically no effect on them, and they are not deflected back to the normal axis of the tube. This action is illus-

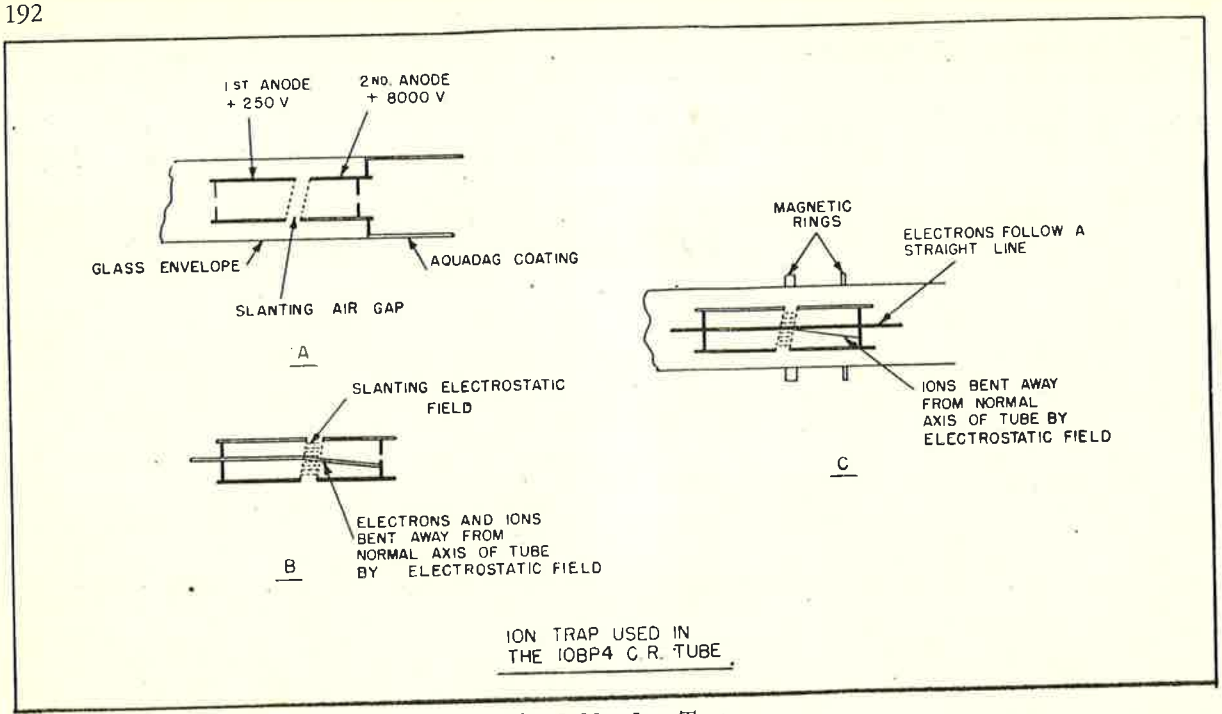

Fig. 2-20. *Ion Trap.*

trated in C of Figure 2-20. Another, but smaller ring follows the first ring, and this second magnetic ring compensates for any irregularity in the mechanical alignment of the electron gun which might prevent the electrons from following along a straight line through the opening in the second anode.

13. Aluminized screens.

Another method for preventing the formation of an ion spot is the use of an aluminized screen, such as in the type 12KP4-A cathode ray tube. This tube has a very thin coating of aluminum placed over the fluorescent material of the screen. This aluminum coating has thousands of small openings in it which are large enough to allow the electrons to pass through and strike the fluorescent screen, but at the same time are not large enough to pass the ions which have a much greater mass. The aluminized screen has another advantage in that it provides approximately 50% more brilliance on the screen for a given anode voltage (above a certain critical value) than for a tube without the aluminized screen. Due to this fact, this type of tube is sometimes referred to as a "daylight tube". The aluminized screen acts as a reflector and reflects some of the light that is normally lost inside the tube, back to the front of the tube, thereby increasing the brilliance.

14. Size of C-R tubes.

Cathode ray tubes come in various sizes—from the small two-inch tube to the large 27-inch tube used by some manufacturers in their direct-view receivers. When we refer to a 16-inch tube or a 20-inch tube, we are referring to the diameter or maximum dimension of the face or screen of the tube. A tube having a 19-inch screen, such as the type 19AP4-B, will accommodate a television picture approximately 15½ inches wide and 11¾ inches high. It will be noted that the tube diameter is somewhat larger than the dimensions of the picture reproduced on it. This is because the outside edges of the tube are masked off so as to form a rectangular form for the picture on the flat portion of the viewing screen.

15. Deflection sensitivity.

The amount that the electron beam is deflected on the screen by a given field intensity, whether electrostatic or electromagnetic, is called the deflection sensitivity.

In tubes using electrostatic deflection, the deflection sensitivity is usually expressed in millimetres per volt and expresses the distance that the electron beam is moved across the screen, due to the voltage applied to a pair of deflecting plates. The deflection sensitivity of various tubes ranges from approximately .1 to .8 millimetres per volt, depending on the size of the tube and anode voltages employed. If the voltage on the accelerating anode is increased, the deflection sensitivity is decreased since the beam will move at a faster rate and will require more energy to deflect it. Likewise, if the voltage on the accelerating anode is decreased, the deflection sensitivity is increased.

The deflection sensitivity is expressed in millimetres per ampere for tubes using electromagnetic deflection, and gives the movement of spot across the screen, due to the current passed through a pair of deflecting coils.

16. Precautions.

Due to the high evacuation of cathode ray tubes, there exists a pressure difference between the inner and outer surfaces of the glass envelope. The atmospheric pressure exerted on the glass envelope is approximately 15 pounds on every square inch of the tube's outer surface and this pressure must be borne by the glass envelope itself since there is

(Continued on page 194)

Determining Maximum Values of Grid — Circuit Resistance

Information concerning the operation of power amplifier valves usually includes a maximum value of signal grid to cathode resistance. This maximum is made necessary because of the possibility of reverse grid current flowing to the grid and reducing the effective bias.

Reverse grid current: Any current which flows externally from a valve electrode to cathode in the reverse direction to that of the current which would flow to that electrode if it were maintained at a positive voltage with respect to cathode is termed a *reverse current.*

When such a current flows through resistance in series with a signal grid, the applied signal grid to cathode negative voltage is reduced by the voltage drop developed across the resistance.

The reverse grid current may consist of one or more components, namely leakage currents between the signal grid and any other electrode, currents due to primary or secondary electron emission from the grid surface, or currents due to positive gas ions attracted to the negatively biased grid. The manufacturing specification for each valve type sets a limit to the total permissible value of reverse grid current, typical values being 1 μA or 2 μA with a specified value of resistance, e.g. 100,000 ohms, 500,000 ohms.

Reduction of bias: Since the values of reverse grid current normally occurring are not greatly affected by variations in the value of series resistance, the reduction in bias due to the current is approximately proportional to the value of series resistance.

When a valve is being operated at or near any electrode dissipation or current limit the bias change due to reverse grid current may be sufficient to cause the limit to be exceeded. Furthermore, if the current is due to "gas" in the valve, as the result of overheating an electrode, then the reduction in bias due to gas current will increase the heating of the electrode, leading to a further reduction in bias and perhaps to an uncontrolled increase in the total current drawn by the valve. Such a process is known as "running away" and it usually results in damage to the valve or to a part of the power supply.

Depending on conditions of operation, however, "running away" does not necessarily occur when reverse grid current is present, as a comparatively stable state may be reached with the valve operating at reduced bias and at a greater dissipation than that intended by the equipment designer.

Stabilizing factors: Factors which tend to stabilize the operation with a given initial value of reverse grid current are firstly a small grid resistor, secondly, series resistance between the voltage supplies and the positive voltage electrodes, since this will reduce the applied voltage as current increases, and thirdly, negative feedback such as that obtained by the use of a cathode resistor which minimizes the effects of a change in the bias voltage applied to the signal grid.

Back bias: This last factor is the reason for the increased value of grid resistor which is permissible with cathode bias as opposed to fixed bias. When back bias is used for an output valve, the bias is still dependent on the current drawn by the valve but the value of resistor is reduced because of the current drawn by the remainder of the equipment so that the compensation is reduced. For this reason, when back bias is used and any electrode dissipation or current in a valve is at or near the maximum rating, the value of grid resistor must be reduced from the value specified for cathode bias in the ratio that the cathode current of the output valve bears to the total current drawn by the equipment.

Increased values of grid resistor: Each of the possible causes of reverse grid current indicated is likely to be cumulatively increased by high temperature operation. Consequently, at reduced electrode dissipations and cathode currents, a valve can be safely operated with a higher value of signal-grid resistor than is allowable under maximum rating conditions, firstly, because the reverse grid current will normally be lower, and secondly, because larger increases in cathode current and electrode dissipations can occur before the maximum ratings are exceeded.

In the absence of specific information concerning a particular valve type the value of the grid resistor should only be increased above a specified maximum value after calculation of the possible effects on electrode dissipations and currents*.

Bias reduction due to other causes: It has been assumed above that no components other than the valve cause a reduction in effective bias. This is not always the case and it is a comparatively frequent occurrence to find that excessive current in an output valve is due to leakage in the coupling capacitor connected to its signal grid.

A typical operating plate voltage for a preceding a-f amplifier in a receiver is 60 volts, so that with a 0.5 megohm grid resistor in the output stage a leakage of 30 megohms in the coupling capacitor would cause a 1 volt reduction in bias on the output valve and thus a 10 mA increase in plate current in a valve operating under fixed-voltage conditions with a transconductance of 10 mA per volt.

Contributed by the Circuit Design Laboratory, Valve Works, Ashfield.

* **Radiotron Designers' Handbook, Fourth Edition, Chapter 3, Section 1 (iv), p. 79. (Now printing.)**

Gas current & grid emission also explained on P.8.

Other leakages may also be significant and a similar result could be caused by a leakage of 100 megohms from screen to signal-grid pins across the output valve socket or in a plate-to-grid feedback capacitor, between tags on a tag-strip or from a combination of any of these possibilities. It is thus advisable to reduce the grid resistance to the minimum usable value even when this is considerably lower than the maximum permissible.

VOLTAGE AMPLIFIER VALVES.

The considerations outlined above apply to all types of valves, but in the case of voltage amplifiers, for which a maximum permissible value of grid-circuit resistance is not often quoted, it is not unusual for the permissible maximum to be controlled by signal-grid-circuit damping due to low input impedance resulting from grid conduction in an under-biased valve.

Signal-circuit damping: To avoid operating valves under static conditions which result in low input impedance, the maximum value of grid resistance must be fixed after consideration of the maximum negative signal-grid current likely to be encountered and the difference between the bias applied to the valve and the highest value of contact potential that can be expected. For example, the contact potential of a valve having an indirectly heated cathode may be as high as −1.0 volt so that if the applied bias is −1.25 volts, signal-circuit damping may occur with as little as 0.25 μA of reverse grid current flowing in a 1 megohm grid resistor. Since 1 μA of reverse grid current is a common test-specification maximum there is thus a definite possibility of the occurrence of grid-circuit damping under the static conditions outlined.

Even when grid-circuit damping does not occur under static conditions, it is possible for the applied signal voltage to cause positive signal-grid current and thus input-circuit damping. In any application in which a signal of the order of 0.1 volt peak or more may be applied to the signal grid of a valve without a corresponding increase in bias, such as occurs in an i-f amplifier with a.v.c., then the peak value of the signal should be added to the bias requirement, as determined above.

Failure to provide sufficient margin for contact potential and gas current effects plus the i-f and a-f signals on the reflexed valve is a frequent cause of "fluttering" in reflex receivers when the volume control is turned up on a strong station.

In general, the reverse grid current of most new valves is well below the maximum value specified as permissible for a particular type and, while the practice could only be recommended when complete details of a design were known, experience has shown that, in an extreme low-bias case, a converter and i-f amplifier can be used in a broadcast-band receiver with a.v.c. applied, with a common impedance of 1.5 megohms between grid and cathode and with −1.5 volts of applied bias.

In the case of short-wave operation, the bias applied to the converter should be increased above the satisfactory minimum value used on the broadcast band. At the high-frequency end of the short-wave band, oscillator voltage will be present on the signal grid so that a larger margin is needed between applied bias and contact potential in order to avoid grid-circuit damping.

THE PICTURE TUBE OR KINESCOPE

(*Continued from page 192*)

nothing within the tube to give an outward pressure. This inward pressure on the glass amounts to a very high value for the larger tubes. For example, the pressure on the viewing end alone is approximately 1700 pounds for a twelve-inch tube, and is several times this amount for the entire tube.

With such high pressure on the tube, precautions must be taken to avoid the possibility of injury due to flying glass if the tube should explode, or rather implode, as the result of a sudden failure of the glass envelope. For this reason the viewing end of the tube is protected in the receiver by means of a non-shatterable plate glass safety window. Whenever a picture tube is handled, gloves and shatterproof goggles should be worn. It is also, of course, particularly important that the tubes be carefully handled so as to avoid striking or scratching the tube's surface.

Voltages up to 30,000 volts are used on the high voltage anode, and great care should be used to keep from getting a serious shock, especially when these voltages are obtained from a conventional high voltage supply. When these voltages are obtained from the new high frequency type of high voltage supply, the danger of a serious shock is greatly reduced. However, regardless of the type of high voltage supply used, every precaution should be taken not to come in contact with it.