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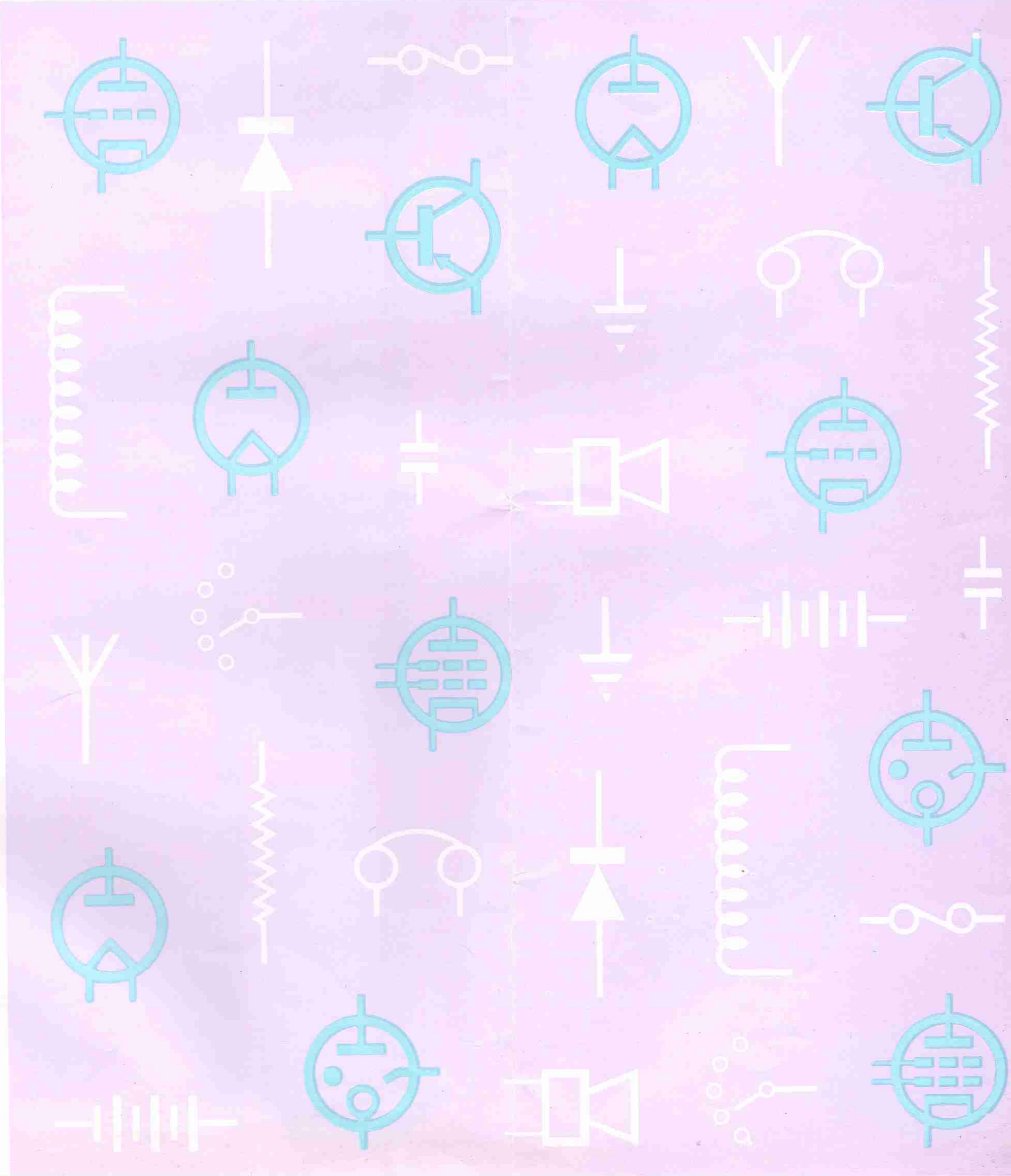

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Vol. 26, No. 8 1961

Editor, Bernard J. Simpson

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ELECTROMAGNETIC DEFLECTION YOKES

By

Ronald J. Limbert, A.S.T.C.

(AWA Component Design Laboratory)

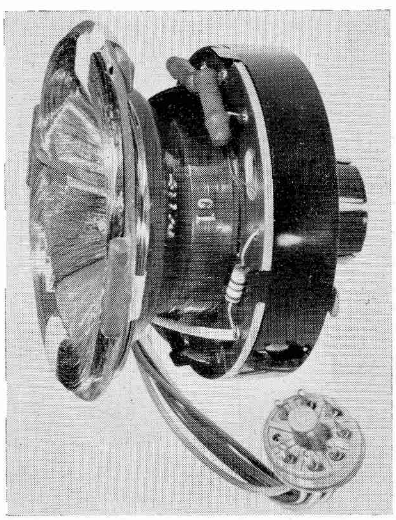
Many papers have been published on specialised aspects of electromagnetic deflection yokes, but few have been written on the general principles and applications.

This article outlines the general requirements of a good yoke, the basic principles of design and manufacture, and some of the problems encountered in the application of this type of yoke.

The aim is to help receiver designers and servicemen solve their application problems by giving them a better understanding of the basic features of this component.

Requirements

Sensitivity: The horizontal and vertical deflection sensitivities of a yoke should be such that full scan can be obtained without operating the horizontal and vertical output valves above their published ratings.



Picture Geometry: A good yoke should give a picture with a minimum of trapezoidal, pincushion or barrel distortion on the picture tube for which it is designed.

Crosstalk: The orientation of the frame coils to the line coils should be such that the crosstalk between the two sets of coils is negligible.

Pullback: The yoke design should be such that it must be pulled back at least 1/16″ along the picture tube neck before neck shadow becomes apparent.

Centring Magnets: The centring magnets should be positioned well forward of the electrodes in the picture tube gun to prevent their magnetic field from adversely affecting the picture tube focus characteristics.

Design Principles

When an electron beam traverses a magnetic field, the beam will be subjected to a force at right angles to both the field and the direction of travel of the beam. Therefore, to deflect a beam horizontally, a vertical magnetic field is required, and similarly, to deflect it vertically, a horizontal magnetic field is required.

An electromagnetic yoke may be used to set up vertical and horizontal magnetic fields in the neck of the picture tube. By varying the strength and polarity of one or both of these fields, the electron beam emanating from the picture tube gun may be deflected to produce a spot on any part of the screen.

If the horizontal and vertical fields in the picture tube neck form a perfect rectangle, then a rectangular raster will be obtained if the screen of the tube is flat. However, if these fields are barrelled, a pincushion-shaped raster will result and similarly, if the field is pincushioned, a barrel-shaped raster will result (Fig. 1), since deflection is always at right angles to the magnetic field.

In practice, the tube screen is not flat, but consists of several curves of different radii. The effect of the curved screen on picture geometry will be discussed later.

To improve astigmatism and focus around the picture edges, it is normal practice to design for a pincushioned raster and then use magnets to correct the pincushion.

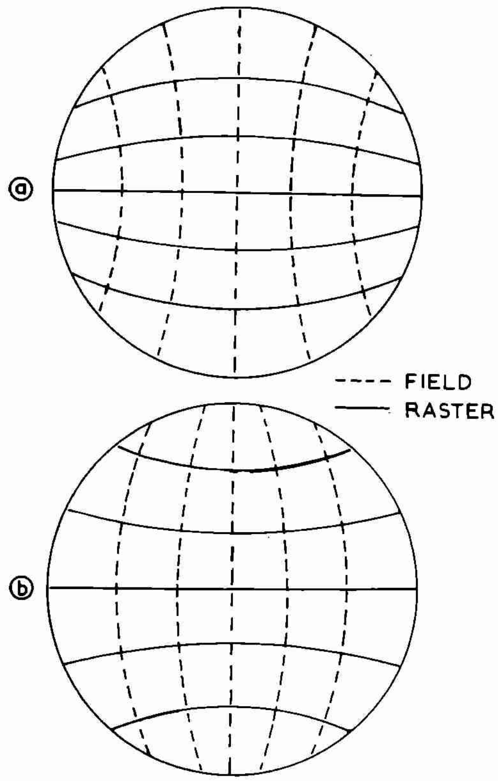


Fig. 1 — (a) Pincushion field producing a barrel raster; (b) Barrel field producing a pincushion raster.

Horizontal or Line Coils

For deflection in the horizontal plane it has been shown that a vertical magnetic field is required. This field may be obtained by passing a current through two saddle coils (Fig. 2) mounted above and below the picture tube neck.

A cross sectional view of these coils is shown in Fig. 3. If these line coils are connected so that the currents in the coil halves 1a and 2b are flowing into the paper, and the currents in coil halves 2a and 1b are flowing out of the paper, then a magnetic field will be set up as in the

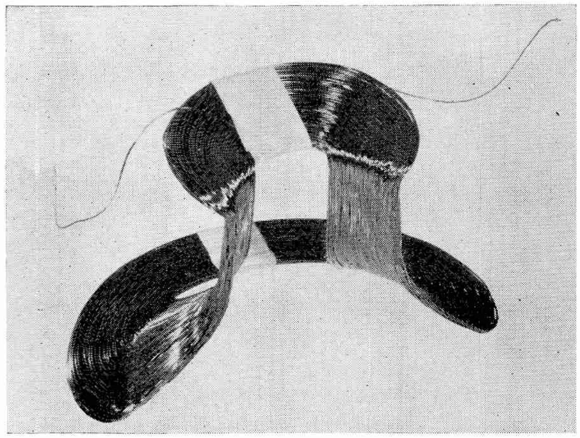


Fig. 2—Saddle line coil.

diagram. A ferrite core encircles the coils to improve efficiency by providing a low-reluctance return path for the magnetic flux. If the section of the coils adjacent to the window is reduced in thickness, then a more barrelled field, and hence a pincushion raster, will result.

In a typical application, the line coils carry a modified sawtooth current of the order of one ampere, peak to peak, and the "hot" end of the coils may reach three kilovolts during flyback. Great care must be taken, therefore, to ensure that the coils and their leads are well insulated. At the line frequency of 15,625 cycles per second, the coil inductance is the major component of line coil impedance.

Vertical or Frame Coils

For deflection in a vertical plane it has been shown that a horizontal magnetic field is required.

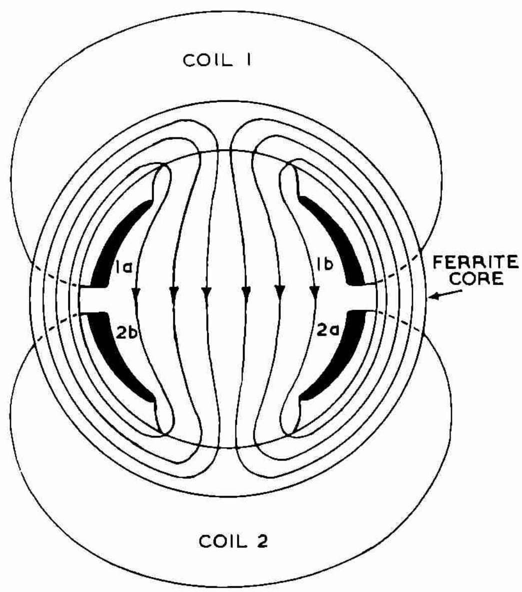


Fig. 3—Cross-section of line coils over tube neck.

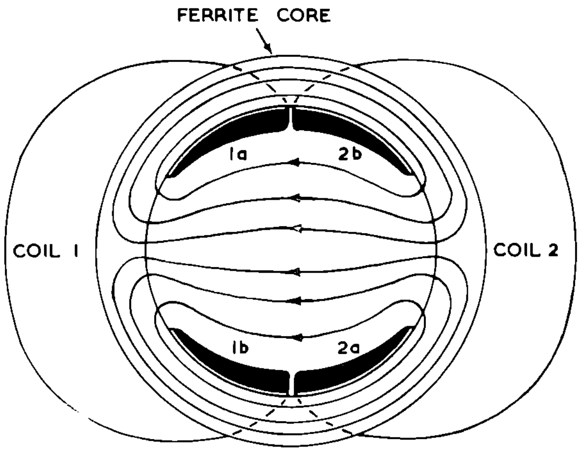


Fig. 4—Cross-section of saddle frame coils on tube neck.

This field may be produced by either saddle coils or toroidal coils.

Saddle Coils: Saddle frame coils are similar in shape to the saddle line coils and are physically mounted one on each side of the picture tube neck, thus positioning the active turns of the coils above and below the tube neck as shown in Fig. 4. If coils 1 and 2 are connected so that the currents through the coil halves 1a and 2b flow into the paper and the currents in coil halves 1b and 2a flow out of the paper, then the field shown in Fig. 4 will be set up. The ferrite core also provides a low-reluctance return path for the magnetic flux produced by the frame coils.

Toroidal Coils: In this case, the two frame coils consist of several layers of wire wound toroidally on the ferrite core. In contrast to the saddle frame coils, the toroidal coils are physically mounted above and below the tube neck. If the coils are connected series opposing, then a magnetic field will be set up in the tube neck as shown in Fig. 5.

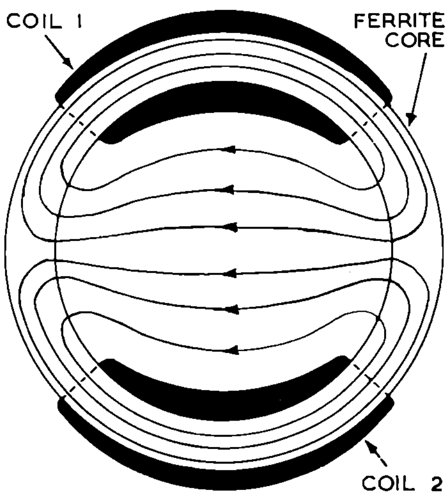


Fig. 5—Cross-section of toroidal frame coils on tube neck.

In a typical application, the frame coils carry a modified sawtooth current of the order of 1.5 amperes, and the "hot" end of the coils may be 350 volts above ground. At the operating frequency of 50 cycles per second, the resistance of the coils is the major component of coil impedance.

The flux produced in a yoke frame coil for a given power input is directly proportional to the square root of the number of turns and inversely proportional to the square root of the mean turn length. Consider a toroidal coil and a saddle coil which have the same resistance. The toroidal coil will have a shorter mean turn length than the saddle coil, and, hence, more turns are required, or finer wire is used to obtain the same resistance as the saddle coil.

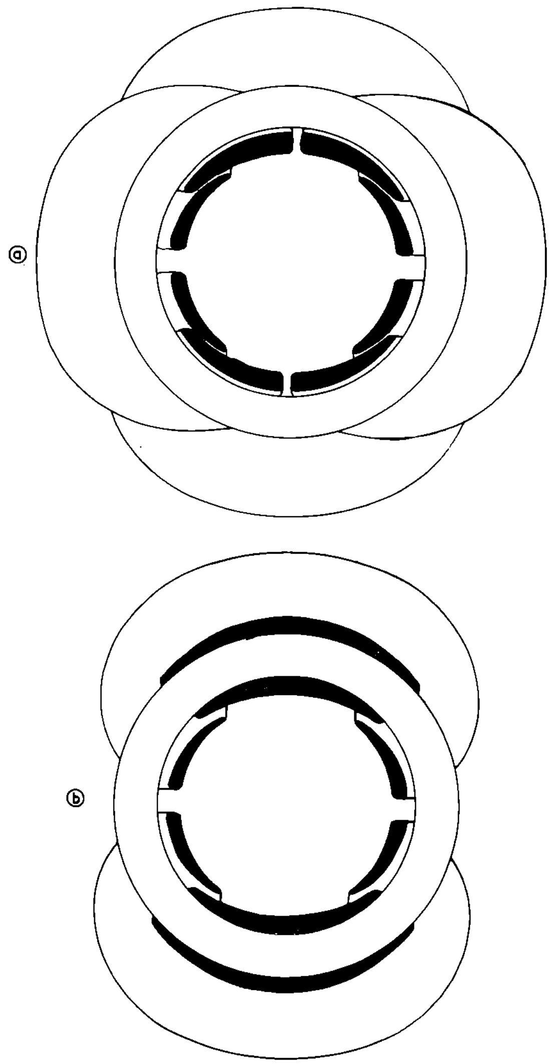


Fig. 6—(a) Relative positions of saddle line and saddle frame coils; (b) relative positions of saddle line and toroidal frame coils.

In practice, it is possible to balance the wire gauge and number of turns so that the number of turns is increased. Thus, with a shorter mean turn length and a greater number of turns, the toroid will have a higher deflection sensitivity than the saddle coil.

Yoke Assembly and Orientation

Fig. 6 shows the relative positions of line and frame coils for the two types of frame coils. Due to the close proximity of the line and frame coils, there can exist an appreciable amount of undesirable crosstalk between these two sets of coils. This is reduced during manufacture by rotating the frame coil set with respect to the line coil set until a minimum of pick-up occurs in the frame coils. This condition is fulfilled when the centre lines of the active elements of the two coil sets are 90° apart.

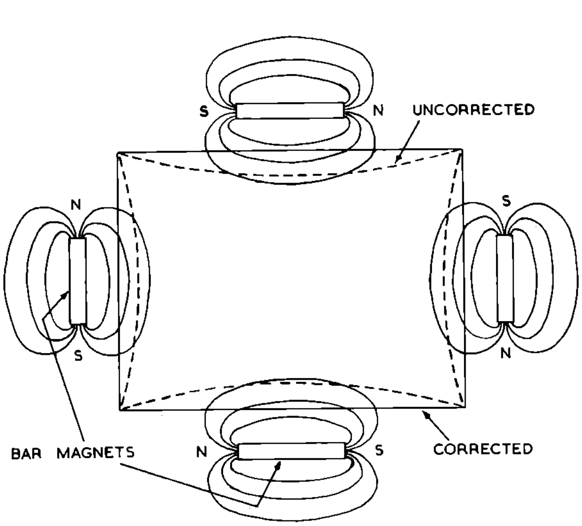


Fig. 7—Bar magnet correction.

Magnetic Correction

Since the yoke coils are usually designed to produce a pincushion-shaped raster, some method must be used to correct this distortion. This may be achieved by introducing external magnetic fields in such a way that the top, bottom and sides of the raster are "pulled out" to form straight lines.

One method frequently used is to position short bar magnets on the top, bottom and each side of the front flare of the yoke. The localised magnetic fields deflect the electron beam; by varying the strength and position of these magnets, reasonably straight picture edges may be obtained, as shown in Fig. 7.

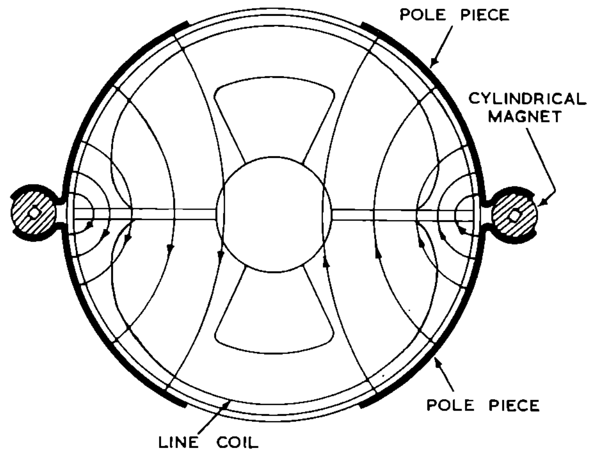


Fig. 8—Pole piece correction.

A second method of correction is shown in Fig. 8. Here, a cylindrical magnet and two associated mild steel pole pieces are positioned on each side of the front flare of the yoke. The cylindrical magnets are magnetised across a diameter and, when rotated, the strength of the field shown in Fig. 9 may be varied, and hence the correction may be increased or decreased.

Due to the shape of the field near the ends of the pole pieces, the top corners of the raster tend to be pulled down and out at right angles to the magnetic field (Fig. 9); similarly, the bottom corners tend to be pulled up and out. This has the effect of correcting top and bottom pincushion at the same time as correcting side pincushion. Frequently, however, further low-strength bar magnets are used on the top and bottom to give even more accurate correction.

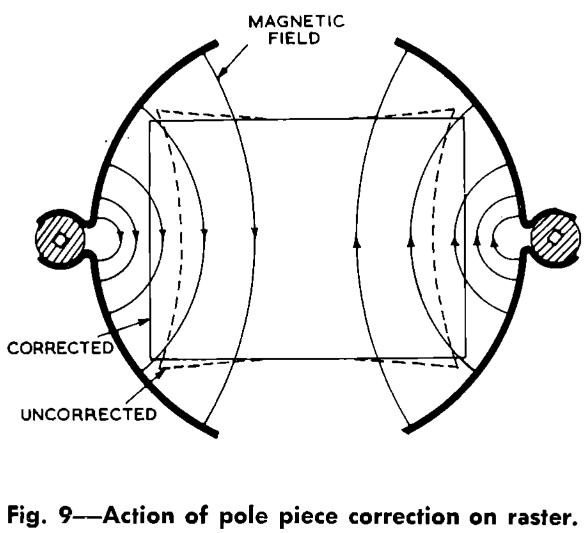


Fig. 9—Action of pole piece correction on raster.

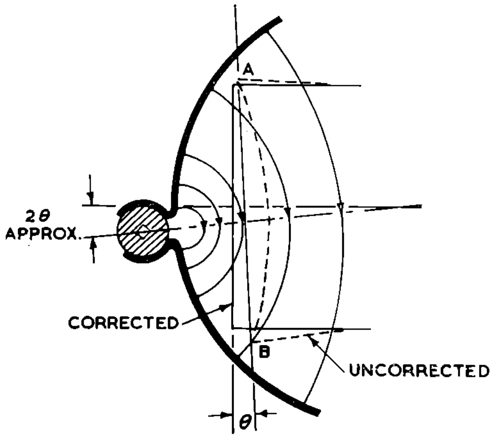


Fig. 10—Trapezoid correction by moving pole piece.

This type of correction has the advantage that it may be used to correct small deviations from the vertical at the raster sides. Fig. 10 shows how this is accomplished by moving the pole piece assembly around the periphery of the yoke insulator away from its usual position.

If the pole piece assembly is moved to the position shown in Fig. 10, then corner B will be in a stronger field than corner A. The position of the pole piece assembly can be so adjusted that corner B is directly below corner A and then the correction magnet adjusted to remove the pincushion.

Picture Geometry Limits

Pincushion and barrel distortion limits may be conveniently specified as a radius of curvature, measured ¾″ inside the picture edges on the horizontal and vertical axis. These limits are usually of the order of 125″ pincushion and 150″ barrel on the top and bottom and 100″ pincushion and 125″ barrel on the picture sides.

Parallelogram and trapezoidal distortion may be specified as the deviation from the horizontal or vertical of the lines ¾″ in from the picture edges as shown in Fig. 11.

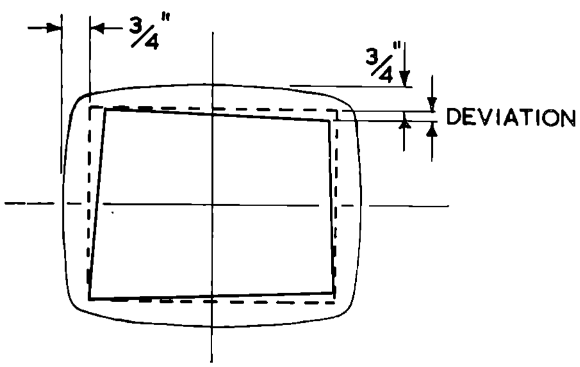


Fig. 11 — Method of specifying trapezoid distortion.

It will be shown later that it is difficult to keep parallelogram and trapezoidal distortion within ¼″ over a production batch and, consequently, the limit is usually specified as 5/16″ deviation from one end of the line to the other.

Centring Procedure

Due to the earth's magnetic field and variation in picture tube gun alignment, the centre of the raster will rarely coincide with the centre of the picture tube screen unless some external means of centring is provided. This may be achieved by mounting on the cap at the rear of the yoke two magnetised centring rings which, when rotated together or separately, move the position of the raster on the picture tube screen.

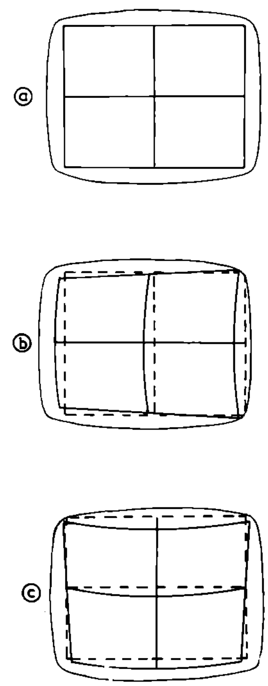


Fig. 12—Centring: (a) Raster centred on spot centred tube; (b) raster centred on tube with spot centre to right of geometric centre; (c) raster centred on tube with spot centre above geometric centre.

When testing yokes during manufacture, the centring magnets are adjusted to give straight horizontal and vertical centre lines on the raster, indicating that the electron beam passes symmetrically through the yoke field. All checks and pincushion corrections are made at this setting.

However, in a production batch of picture tubes, the position of the undeflected spot may vary up to ½″ from the geometric centre of the screen. When the centring magnets are adjusted to compensate for this, i.e., to centre raster, the edges of the raster will tend to pincushion on one side and barrel on the other, depending on which way the raster is moved. It is most important then, to ensure that both the horizontal and vertical linearities are optimised and that horizontal phasing is correct before the final setting of centring is made. This reduces any pincushion or barrel distortion to a minimum.

Another distortion introduced when compensating for variations of undeflected spot position is trapezoidal distortion as shown in Fig. 12.

Earth's Magnetic Field

In the southern hemisphere, the vertical component of the earth's magnetic field moves the raster to the right of its normal position. For a given picture tube and yoke, this movement depends on EHT voltage, and at an EHT of 16 kilovolts it is the order of 3/16″. When centring correction is applied to compensate for this, the distortion shown in Fig. 12 will be introduced. In yokes using a toroidal frame coil, this may be corrected by offsetting the frame coils, as in Fig. 13, to introduce a compensating trapezoidal distortion.

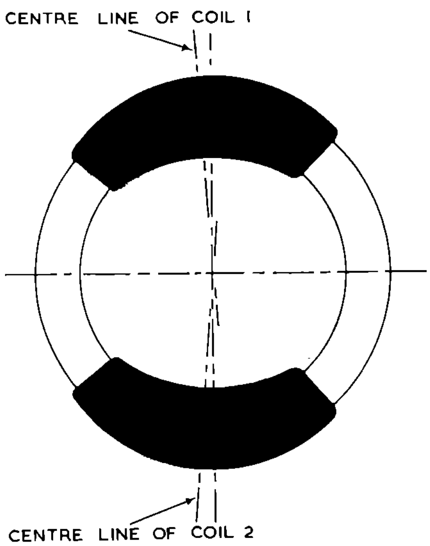


Fig. 13—Offsetting frame coils to introduce

The horizontal component of the earth's magnetic field, however, tends to twist the raster. This effect is only noticeable when the receiver is moved so that the picture tube faces in a different direction from that obtaining when the receiver was originally adjusted. Since the movement is only of the order of 1/16″ at the raster corners, this effect is usually neglected. If required, the yoke may be twisted slightly on the tube neck to straighten up the raster.

Yoke Sensitivity

Since the inductance and resistance of yokes may have a wide range of values to satisfy various applications, the most common method of comparing sensitivities is by using a figure of merit.

The figure of merit for horizontal deflection is derived from the line coil inductance and the current required to give full horizontal scan.

$$\text{Horizontal figure of merit} = \frac{\frac{1}{2}\,Li^2}{S_h^2}$$

expressed in microjoules per square centimetre (μjoules/cm^2) where:

L = total inductance of line coils (mh).
S_h = horizontal width of tube screen (cm).
i = current required to give full scan S_h (ma).

This figure is normally in the range 2.5 to 3.5 $\mu J/cm^2$, depending on the type of yoke construction. The lower the figure of merit the higher the sensitivity.

The figure of merit for vertical deflection is derived from the current required to give full vertical scan and the frame coil resistance.

$$\text{Vertical figure of merit} = \frac{Ri^2}{S_v^2}$$

expressed in milliwatts per square centimetre (mw/cm^2) where:

R = total resistance of frame coils (ohms).
S_v = vertical height of tube screen (cm).
i = current required to give full scan S_v (ma).

This figure is normally in the range 3 to 5 mw/cm^2, depending on the type of frame coil used. The lower the figure of merit the higher the sensitivity.

Picture Tubes

The radii of curvature of picture tube face plates vary from one type to another and, consequently, a yoke giving good picture geometry on one type may give objectionable picture geometry on another type. A yoke designed for a 21″ picture tube, such as a 21CEP4, will give a badly pincushioned raster on a 23″ tube.

A yoke designed for a 23MP4, which uses a conventional bulb, will give a slightly barrelled raster on a 23CP4, which uses a laminated-cap bulb. However, it is possible to adjust a yoke so that it will give quite acceptable results on either 23MP4, a 23CP4 or a 19″ tube, such as a 19XP4.

Conclusion

The requirements, design principles and application fundamentals of electromagnetic deflection yokes have been given. It is felt that this paper will give receiver designers and servicemen a better understanding of this most reliable component and thus help them when specifying a yoke to fulfil their requirements.

BOOK REVIEWS

Books reviewed in these pages (except AWV publications) are complimentary copies received direct from the publishers. All enquiries for these books should be directed to your local technical booksellers, and not to AWV.

"TV TROUBLE ANALYSIS". Harry Mileaf. Gernsback Library Inc. Size $8\frac{1}{2}$" x $5\frac{1}{2}$". 224 pages. 179 figures.

This interesting book deals with the systematic approach to trouble location in faulty TV receivers. It is significant that the very first chapter in the book deals with waveform analysis. There can be little doubt left, if any, that one of the surest and quickest approaches to trouble tracing in TV is the study and evaluation of the circuit waveforms.

The rest of the book, except for the very useful index, is devoted to two classes of failure, component failure and circuit failure. In many cases of course the two terms are effectively synonymous. The chapters on component failure are interesting in that they describe in detail some of the things that can go wrong with components. This is useful in that it broadens the horizon of the reader and alerts him to things that perhaps had not previously attracted his full attention. For a book of its size this volume is a mine of information.

"ELECTRICAL PRINCIPLES OF ELECTRONICS". A. C. Gillie. McGraw-Hill Book Co. Inc. Size $9\frac{1}{4}$" x 6". 532 pages, with copious diagrams.

This book has a rather intriguing title, in that your reviewer was unable to be quite certain from the title what to expect in the text. The text is even more interesting in that it is a good and broad treatment of the fundamental principles and laws of electricity as they apply particularly to electronics. In this respect it has much more to say than many of the books now offered to new entries to the field of electronics. In fact it could be profitably read by many already employed in the electronics industry.

This is a very thorough treatment of the characteristics of the basic building blocks of resistance, capacitance and inductance, their combination in various types of configuration, and what happens when these various circuits are energised with different types of waveform. A thorough grounding in basic concepts is invaluable, and this volume can be confidently recommended as filling a unique spot.

DATA PROCESSING IN VALVE PRODUCTION

Radio Corporation of America's Electron Tube Division put into operation at its headquarters plant in Harrison, N.J., an RCA 501 electronic data processing system capable of analyzing facts. approving shipments and preparing reports on several hundred types of receiving valves under production. This system makes possible a unique quality assurance programme that was not considered practical by other computing methods. This new system is making decisions on the quality assurance of approximately 300 different types of receiving valve manufactured in Harrison.

To handle this job by punched-card equipment is impractical, since it would have involved over two million cards. This number of cards, if placed end-to-end, would stretch more than 220 miles. Now, with the 501, volumes of test data from RCA's valve rating laboratory covering a one-year period can be condensed on only one roll of magnetic tape.

This installation of the computer is an important step in RCA's continuing effort to make electron valves with the highest standards available to the consumer. In addition to quality assurance, the RCA 501 system will be utilized by the Division for production and inventory control, order handling, billing and receivables accounting, as well as sales and cost analysis and market forecasting.

OUTER SPACE AND DOWN-TO-EARTH NEWS OF VALVES

ASTRONAUT BROADCAST FROM SPACE

The Voice of America's first astronaut—broadcast on May 5th from outer space to earth was powered by two small electron valves about the thickness of a pencil. These valves, part of the two-way radio aboard the Mercury space capsule, were made by the Radio Corporation of America. They resemble a miniature space vehicle in appearance and are slightly over two inches long.

Throughout the historic flight, Astronaut Alan B. Shepard, Jr., was in constant communication with ground stations as he travelled at a speed of 6,000 feet per second. The spacecraft's two-way radio system also helped lead the recovery team to the exact spot where the first manned Mercury vehicle plunged into the Atlantic Ocean.

These same RCA valves will be used to power the Mercury transceiver of America's first manned orbit space flight planned for later this year, according to Douglas Y. Smith, Vice President and General Manager of RCA's Electron Tube Division. In this next orbital Project Mercury mission, an astronaut will be boosted into an orbit about 120 miles above the earth's surface, circle the earth 3 times, re-enter the earth's atmosphere and then will be recovered from the ocean. The two-and-a-half pound transceiver and one-and-a-half pound power amplifier is one of several separate electronic systems which transmit human language and electrical language to and from the spacecraft.

RCA valves were selected for Project Mercury after they were painstakingly tested. The small electron devices were then built into the power amplifier which had to function efficiently in jarring shake tests. Next the valves and two-way radio were operated at torrid and then sub-freezing temperatures. The type 5876 valves are ultra-high frequency high-gain triodes.

The 5876 is a general purpose triode intended primarily for use in grounded-grid service as an rf amplifier in transmitters or receivers operating up to about 1000 megacycles per second. The valve features small size, light weight, low heater wattage and good thermal stability, and was selected for use in the two-watt power amplifier because the designers required a valve of pencil-triode configuration with low heater power (less than one watt).

Valves made by RCA are helping to tame the universe and extend the frontiers of outer space. In the Tiros satellites a TV camera tube about the size of a cigarette made several thousand photographs of the world's weather from altitudes of over 400 miles. Another tube, no longer than a spool of thread, powered radio transmissions over eight million miles from the Pioneer V information-gathering spacecraft. Other more sophisticated microwave valves are being developed for communications satellites of advanced design.

BRITISH TRADE FAIR IN MOSCOW

The English Electric Valve Co. Ltd. is one of the companies in the EEV group which participated in the British Trade Fair in Moscow from 19th May to 14th June, 1961. The Company showed air, water and vapour-cooled high power valves for use in industrial and communications equipments, together with low-power natural-cooled valves.

Other major items were image orthicon and vidicon pick-up tubes for television cameras, a selection from the wide range of mercury vapour. xenon and high-vacuum rectifiers, and cold-cathode tubes, including voltage stabilisers and trigger tubes. A travelling wave tube and its focusing solenoids, two different storage tubes and two of the recently-announced high-vacuum variable capacitors were also featured. A special publication in Russian giving details of the products of the English Electric Valve Co. was prepared especially for use by the sales engineers manning the stand.

THE DARK HEATER

Development of a new "dark heater" for all receiving valves which greatly extends their life and improves their performance, has been reported by the RCA Electron Tube Division. The "dark heater" derives its name from a specially-processed grey insulation coating which is applied to the heater wire. Heaters of conventional valves utilize a white coating. Hailing the new development as a milestone in electron valve technology, D. Y. Smith, Vice President and General Manager of the division, said:

"We regard the 'dark heater' as the key to greatly extended valve life and improved performance for all types of entertainment, industrial, and military receiving valves.

"One of the most significant advantages of the 'dark heater' is its ability to function efficiently at operating temperatures 20 per cent lower than those necessary with conventional white heaters. This feature will be a major factor in further improving the reliability and performance of receiving valves for communications, instrumentation and other critical industrial and military applications.

"The 'dark heater' operates at up to 350 degrees K below the 1500 to 1700 degrees K of the white heater. The dark surface radiates heat more efficiently and improves the transfer of heat to the cathode so that optimum cathode temperature may be attained with the heater operating at approximately 1350 degrees K.

"More than two years of research in chemistry and physics were devoted to the 'dark heater'. Our extreme confidence in the new heater has been proved by pilot production and life testing in the laboratory, as well as actual manufacturing experience.

"RCA has started incorporating the 'dark heaters' into its receiving valves. More than a quarter of a million electron valves using these heaters have been produced to date."

During the next several months, the Division will use the new heaters in a wide variety of popular valves intended for home radios, auto radios, television sets and phonographs. Use in industrial and military types will follow shortly thereafter.

Mr. Smith highlighted the following advantages of electron valves utilizing "dark heater":

- Reduced heater temperature results in lower internal stresses in the heater wire and smaller thermal change during heater cycling. These features of the "dark heater" lessen the chances of recrystallization and burnout. In addition, cooler operation minimizes changes in heater shape thus reducing the possibility of heater damage and heater shorts.

- The "dark heater" has extremely stable current characteristics throughout its life. This feature is especially important in maintaining a constant cathode temperature.

- The effects of ac leakage and hum are significantly reduced through the use of the "dark heater". This improvement is most startling because it eliminates "spike" or pulse leakage currents which are sometimes present in conventional heaters.

- The cooler operation of the "dark heater" provides a greater margin of safety in present heater-cathode voltage ratings.

TWT's INCREASE RADAR RANGE

An overall receiver noise figure of about 8db is achieved in new medium-range radar equipments recently ordered by the Ministry of Aviation for R.A.F. airfield surveillance duties. An N1042M travelling wave tube supplied by EEV makes a major contribution to the low noise figure and is used as a microwave preamplifier ahead of the signal mixer. The 8db noise figure corresponds to an effective increase in range of approximately 25% over that otherwise attainable with the same transmitter power and aerial gain.

An important feature, made possible by the use of the TWT, is that the noise figure is consistently maintained at this low level for many thousands of hours, which means that the results obtained at maximum search range will be consistent. Another factor is that it is normally impossible to damage a travelling wave tube by input overload, for during this condition the tube simply saturates. If the overload is severe, the output of the tube actually drops and this characteristic provides a measure of protection to succeeding stages of circuitry.

The English Electric N1042M TWT is housed in a metal canister, fitted with coaxial input and output connections and is focused by an N4004 lightweight aluminium foil solenoid. Under typical operating conditions the tube requires a magnetic focussing field of 525 gausses, has a gain of 25 db, a noise factor of 6.5 db and an output (saturated) of 1 mw.

MORE NUVISTORS

Two new, small, developmental nuvistor valves, which make possible use of this unique electron valve design concept in a wider variety of circuit applications, were described recently by engineers of the RCA Electron Tube Division. Design and applications of the valves were outlined in technical presentations made before members of the American Institute of Electrical Engineers at the Hotel Statler, N.Y. One paper reported on a high transconductance, general purpose, small signal nuvistor tetrode for use in rf, if, and video circuits. A small-signal nuvistor triode designed to provide low-noise amplification in the uhf spectrum also was described.

Disclosing details of the developmental nuvistor tetrode, RCA Engineers explained that this versatile valve is well suited for use in industrial and military equipment where compactness, low power drain, long life and ability to withstand mechanical shock and vibration are primary design requirements.

The valve will withstand 1000g impact acceleration, 2.5g vibrational acceleration and will operate at full ratings at any altitude. Life performance is checked at 1, 100, 500 and 1000 hours. The low heater power consumed by the nuvistor tetrode is ½ or less than that of most conventional high gain small signal tetrodes and pentodes. The valve may be operated at a chassis temperature of 75 degrees C with a 150 degree C base temperature rating.

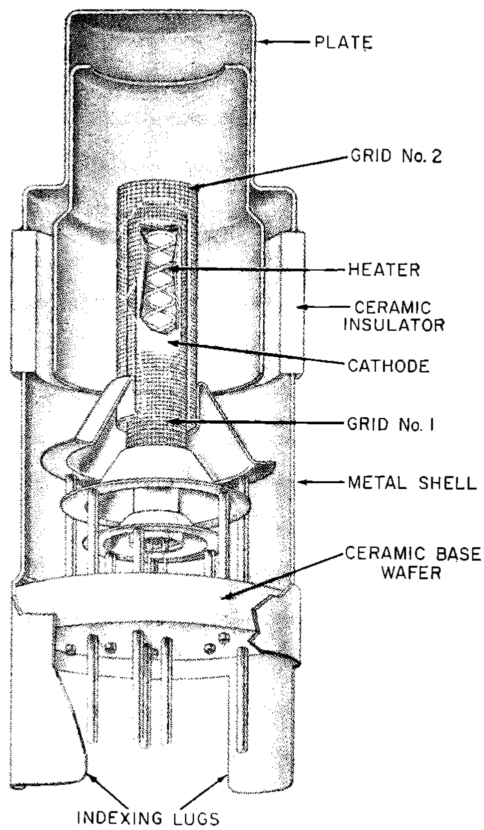
To illustrate the capabilities of the tetrode, RCA Engineers described a relatively simple 60 megacycle radar if amplifier strip having a bandwidth of 8 megacycles. The amplifier strip incorporates 5 stagger-tuned stages. The first stage consists of two 7586 nuvistor triodes in cascode arrangement followed by four developmental nuvistor tetrodes and a diode-connected 7586 as a video detector.

The over-all amplifier gain of the circuit at a fixed bias of -0.4 volt is 104,000. This measurement indicates an average stage gain in excess of 10.0. The basic amplifier chassis measures 1⅞ inches by 1¼ inches by 8¼ inches with the cascode valves inserted in one end. However, it was pointed out that it is possible to reduce further the overall size of the unit.

In a paper co-authored with W. A. Harris, R. J. Rundstedt discussed the design, performance and applications of a developmental nuvistor triode for grounded-grid rf amplifier service. In this valve, the plate is brought through a top cap, the grid is connected internally to the metal shell, and the heater and cathode connections are brought out through the base. The nuvistor socket provides the low-impedance path between grid and ground needed in grounded-grid circuits.

Mr. Rundstedt said that valves designed to provide rf amplification are needed at 450 Mc and at higher frequencies in the uhf spectrum for military, mobile and navigational equipment as well as for the rf amplifier stage in uhf TV receivers. The developmental nuvistor, he stated, enables low-noise amplification in the uhf region and is well suited to many small-signal communications applications.

The authors described several test circuits utilizing the nuvistor for frequencies from 400 to 1200 Mc. One typical example was an amplifier using lumped-constant circuits at a frequency of 450 Mc. This circuit had a noise factor of 7 decibels, a gain of 13 decibels and a bandwidth of 7 Mc.



Cut-away Drawing of a Nuvistor Tetrode

MEANDERING IN HIFI

Some thinking and remembering out-loud

I'll say at the outset that this article will probably raise doubts, questions or outright antagonism in some of its readers. There are few subjects on which decided views are held so firmly by enthusiasts as the subject of high fidelity. There are times however, when it can be profitable to stand off and take an objective look at a subject, and if we can poke a little fun in the process, then so much the better for the objective part of the exercise. Just to protect the innocent, let me say that this article is my own idea, the opinions expressed are my own, and not necessarily endorsed by anybody.

I recently had a browse around one of the new high fidelity shops that are being set up, rather timidly, in the major cities, following the overseas trend towards this type of thing. I heard some beautiful equipment, all the more beautiful to me because I can remember instruments of pre-war vintage. But in those far-off days, when the ultimate seemed to be a couple of 2A3's in push-pull, we thought the gear was pretty good. It was of course, for those days. That brings me to another thought.

This thought is that even this early in the article I must take a stand. I love music, and to me the only point in having high fidelity at all is to listen to music, reproduced at its best. You will ask what is different about this? Well, one of the things about high fidelity that amuses me, and at the same time makes me feel a little sorry and disappointed, is that there is a group of enthusiasts, we have all met them, who build or buy this lovely equipment merely to listen to the sound.

I do not decry these people's efforts, for they are entitled to find their amusement in any legal fashion that occurs to them. This is not high fidelity to me however good the sound. The contribution that these enthusiasts make towards the art is the continual striving for better things, whilst the music lover reaps the dividend. To put it perhaps a little more plainly, they are interested in the equipment itself perhaps, whereas I am more interested in the results obtained with it, not necessarily the same thing.

As far as the music lover is concerned, the subjective approach is the thing. He is prepared to throw away all the technical specifications if his equipment in his opinion is reproducing music the way it should sound. How many people today know what an orchestra playing in a good auditorium really sounds like? The continuous diet of canned music over the years, together with the limited opportunities for hearing live performances, have in my opinion, degraded the critical faculty.

I'm not talking here about what kind of music you like, but of the quality of reproduction and the ability to assess it. All this is no fault of the individual, but is an almost inevitable process under present conditions. This is proved very easily by catching a music lover who has had little exposure to modern equipment, and taking him to a demonstration of some of the top grade equipment available today. There is no doubt that he will be startled. In many cases he will also claim that whilst the demonstration is impressive, the sound is not all it should be, or worse, that it is more than it should be.

I have had this demoralising experience myself, finding myself on the defensive against someone who is very obviously not as impressed as I had hoped he would be. And this, remember, is using high grade equipment which from a scientific point of view is just about as good as it can be.

I would make two points from this. The most important, but one of the most frequently overlooked items, is that one is not qualified to judge the quality of reproduction unless one is intimately familiar with the quality of live performances. The second is that a single demonstration is no way to judge equipment. Frequent listening to different types of music over a period of time, perhaps weeks, is necessary to evaluate a system.

Talking of systems brings me to an apparent anomally, in that when any unit of a system is changed for a better (?) unit, the results are not always improved. There are several reasons for this. It is inevitable that even the highest grade components of a system fall short of the ideal, even if only by a short margin. To this extent they may add colouration of their own, they may be incapable of realising the performance capabilities of the other components of the system, or what have you?

It is possible for colouration added by one component to be cancelled in the characteristics of another component in the system. In fact it is possible for almost anything to happen. Remember also that the human ear is a very nonlinear device, and the mind, which analyses data from the senses, is conditioned to an extent by past experience. If you want to be happy with your choice, judge the system and not the individual components of it, right the way through from the tape unit or pickup, pickup arm, preamplifier and control unit, and main amplifiers to the loudspeaker system.

One thing I used to have a lot of fun with years ago, was volume expansion. It was used and abused for quite a long time, but has now just about disappeared, due to the wider dynamic range of modern records and tapes. I suppose at one time or another I made up just about every circuit published on the subject, and a few of my own which I wasn't brave enough to allow in the light of day. VE would work wonders for some of the dead old 78 records whose dynamic range appeared to be almost non-existent.

One record I was fond of using to test the ability of VE was a fine old recording of Rossini's "Overture to the Thieving Magpie". This item starts with drum rolls rising towards the crashing first statement of the orchestra. The effect of VE on this type of thing was pretty good, or so we thought in those days. I think the family got a bit tired of Gazza Laddra because I was reminded that Rossini in his day was rudely called "the master of noise" by some of his critics.

Modern Amplifiers

Some quite astonishing performance figures are quoted for modern amplifiers, and there is no doubt that most of them can be substantiated. One figure rarely quoted but quite important is the output impedance. Most amplifiers in the high fidelity bracket today boast total harmonic distortion figures of less than 0.5%. In considering this figure, remember that it is usually measured into a resistive load and at full output. Distortion will be much lower at lower outputs (normal listening levels), and some makers quote distortion figures at several power levels.

My own feeling in the matter at the present stage of the art is that once an acceptably low level of distortion has been achieved, little is gained by reducing the figure still further when viewed in the light of the effort and money involved. Amplifiers having distortion figures of in the order of 0.01% may be with us in the not too distant future, but one is entitled to ask what improvement in actual listening quality will result, and will the improvement be justified by the considerably higher cost of such units.

Always remember that the amplifier is a strong link in the system at the present stage of the art. We still have to consider the pickup/pickup arm combination and the loudspeaker system which add their own distortion before we can assess the overall system quality. Is there any point in reducing amplifier distortion and improving linearity if progress in other parts of the system is lagging?

Getting Started in Hifi

I am often asked how one should get started in high fidelity, and wend the path through the maze of competing equipment on offer today. Well it all depends on what you want and how much money you are willing to spend, either immediately or over a period into the future. It is of course possible to spend a good deal of money on this type of activity. One fine system I heard just recently was made up of components retailing at about £630. This included main amplifiers, stereo preamp and control unit, speakers, pickup and transcription turntable. Tape facilities and tuner unit would bring this up to something in the region of £800 in round figures.

Another system which I heard at about the same time and which offered the same basic facilities was priced at £350, with appropriate addition for tape and tuner. I personally liked this system better and considered it a much better buy. Both systems used a single very wide range speaker in each channel and offered just about the same facilities. The dearer system had 15 watts in each channel, the other 10. Both were beautiful systems, let there be no doubt about that, and there were factors other than listening quality which would help in justifying the difference in costs. The point is that I rated the cheaper system a better buy, both from a listening point of view alone, and partly stemming from that, the fact that I could not hear £290 worth of difference.

In the analysis I feel that the lower cost system had an apparent superiority because of the speakers used which are an excellent type rarely seen or heard in this country. Unfortunately I did not have the opportunity of making A-B tests with both speaker systems on both amplifiers, as they were at different locations. The results of this further testing may well have been different. All this points up the fact that the most expensive system will not necessarily suit YOUR ear the best, and that the system concept must be adhered to in making your selection.

Just as a matter of interest, the proportional costs of the main units of the two systems were about the same. They were main amplifiers and preamplifiers, 'A' system (dearer system), 31%, 'B' system, 28%; speakers, 'A' system, 49%, 'B' system, 47%; pickup, arm and turntable, 'A' system, 20%, 'B' system, 25%.

Reverberation

At the IRE Radio Engineering Convention in Sydney last March, I had the pleasure of hearing one of the latest additions to the range of audio components. This is the reverberation unit. At least, I didn't hear the unit itself, but a radiogram equipped with it. I have an open mind on this unit until I have had a chance to check it out more thoroughly, but the idea has been successful in the U.S.A., and provided it is not abused by the user, could make a contribution to sound realism.

The unit I saw has dual fixed reverberation times, but this is another case where the ear can be tricked. You remember how we deceive the ear with single bass source stereo? Well the ear can be deceived into translating loudness in the reverberation into reverberation time. This can only be done within limits, but quite satisfactory ones, and the total effect can be quite interesting. The most noticeable effect is on some of the older records and on broadcast items. Two fixed times are used in a unit to prevent the cancellation that would otherwise occur at the period of a single time.

Space and Building

One of the high fidelity problems that came with stereo is the question of space. Whilst we were moderately successful in persuading our families to accept one large enclosure in the living room in the interests of science and better music, in many cases there is no hope as far as a second such unit is concerned. This has led to the development of smaller speakers in smaller boxes, and to the introduction of systems employing one large speaker unit and two or more quite small satellites. This is something we have to live with. I am convinced we sacrifice something when we use less space, except perhaps in the case of certain units.

We have long seen advertised the small multiple-speaker units common in the U.S.A., and now of course they are, many of them, available in this country. Some of them have up to five units (some perhaps more, who knows what lies behind the silk) in one small cabinet which seems hardly big enough for even one decent speaker. A lot of sound (no pun) engineering has gone into these units, and it would be presumptuous of me to level much criticism at them. I will just say that I have been disappointed in every one that I have heard. Here again, of course, the question of cost arises, and whilst it does not influence the appraisal of the units in operation, it must effect the final decision on which unit to purchase. I have heard a high quality single unit speaker in a moderate sized enclosure perform better than most of these multiple units so far heard.

There is, I suppose, no doubt that the magnetic pickup in its various forms is capable of producing the highest quality, and there is consequently a tendency to discount all other types, including such comparatively crude instruments as the crystal and ceramic types. This is unjust in my estimation. It comes down in my analysis to a question of cost. The use of a crystal pickup does not usually require the provision of a preamplifier, whilst the cost of the pickup itself, usually of the integrated arm type, is a considerably smaller investment than a magnetic type.

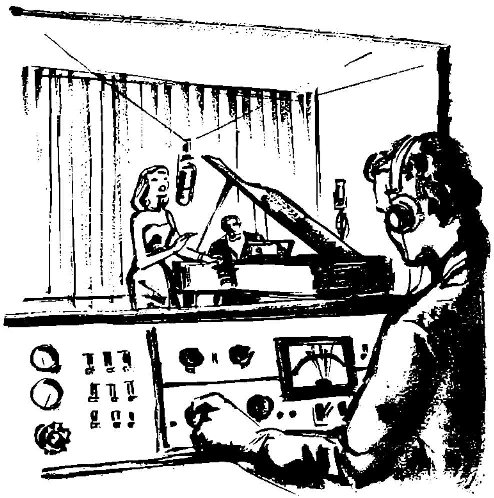
I am aware of all the disadvantages, claimed and real, of the crystal and ceramic pickup family. They are however capable of producing quite acceptable quality music, and it is a big mistake to discount them entirely. For a system to be set up on a tight budget, the use of a crystal or ceramic pickup offers very decided savings.

When it comes to home building of equipment, that is the time for critical appraisal of the type of equipment and components offering and to be built. I will say right now that someone who has never built electronic equipment before would be well advised not to undertake a large and complex unit, including magnetic pickup preamp, unless he has available to him, not only the complete list of parts, but a detailed plan of construction including the position and orientation of all parts and step by step instructions. The pitfalls are numerous, and many fall by the wayside.

Another mistake builders make is to attempt to use apparently similar components that they happen to have lying around. This is a grave mistake and false economy. If the builder is not prepared to use the exact components specified, then he should be advised to leave well alone. To the skilled builder, certain minor adjustments are possible, but even then such major components as the output transformer should not be substituted in critical high fidelity designs. In many cases the transformer has been specially designed for the amplifier, and its characteristics are intimately bound up with the performance of the amplifier.

One thing that high fidelity is doing is to displace automatic record changers. Apart from the "7's", most music today is on long play 10 and 12 inch records which hardly need such a facility. Further, it usually happens that the tracking weight is higher for auto changer pickups and the arm stiffness greater, so that the unit will operate satisfactorily under changer conditions and will successfully trip the mechanism without skidding. Both of these items affect the performance of the unit, and whilst it has undoubtedly been designed with these things in mind, there is little doubt that the lower tracking weight and improved arm characteristics associated with a separate pickup make for better performance and lower record wear.

Do not forget however, that with the high grade sensitive magnetic pickups available today, you will also need a superior type of turntable to avoid wow and flutter. The transcription type of unit is recommended as meeting the requirement, but here again, check performance before you buy. The same startling type of price differential can be met in this field as in the case of the complete systems mentioned above, and the dearest is not necessarily the best buy. Here again, the turntable should be assessed in relation to and working with the rest of the system.



A Pre-war Adventure

I remember one interesting thing I saw done some years before the war and pre-stereo. An enthusiast felt that with the equipment he had, and it was good for those days, something was lacking, specifically colour. And he meant just that. The theory behind it all was that different colours evoked different moods. They call it colour psychology these days. As I remember it, red represented anger, tension and the rest, green stood for coolness and similar ideas in the days before rock and roll terminology started to alter the meaning of our language, and yellow stood for I've forgotten. Anyway, this genius set up a series of filters to separate the audio spectrum into three bands, which were fed to three separate power amplifiers.

They were power amplifiers too, for each one fed a number of 240V coloured lamps, arranged behind a type of low screen at the end of the room. When the system was operating, in addition to the sound, the concealed groups of lights would light up in various degrees of brightness or go out, according to the frequencies in the reproduced passages. The theory was that the frequencies (notes) used and the resultant colours thrown by the concealed lights, were related to the moods expressed in the music. There is, of course, an obvious fallacy in all this, but the demonstration was still quite impressive, if you like that sort of thing. I forgot to mention that the concealed lights threw light onto a neutral coloured curtain at the end of the room and some interesting shades were produced with the mixtures of tones. The speakers were located behind the curtain.

At least it gave him something to look at if the music was a little boring. After a first stupified half hour looking and listening, I left before the enormous amplifiers feeding the lamps started to make the room uncomfortably hot. You know, although we sometimes scoff at this sort of thing, these people are the salt of the earth, because they have preserved an enquiring mind.

Looking Forward

One of the ways in which we can generate enthusiasm for the future is to take a look at what developments have been achieved in the recent past. I suppose we have all had the experience, or a similar one, where we are painting a large wall. This turns out to be quite a large job, but it is encouraging now and then to stand back and admire the amount done, and assess the appearance of the finished job whilst we take a breather.

In the same way, when we look back over the last 20 years, we can visualise some of the things to come, or the future developments of things now in the embryo stage. Pickups, for example, have come a long way since the days of the heavy (measured in ounces) moving iron types, with replaceable needles. These needles used to chatter when playing records, and it was necessary to have a well-fitting lid over the turntable and pickup to prevent this chatter ruining the listening enjoyment. One or two firms produced fibre needles in an attempt to overcome this, and one needle which was marketed was understood to be a cactus thorn in private life. These "needles" were sold complete with a sharpening tool so that the used needles could be revitalised.

Now that the magnetic pickup has achieved its present state of near-perfection, we also have the growth of the prerecorded tape as a competitor to the disc record. I'm going to fall for the temptation of becoming a self-appointed prophet and say that I feel that the pre-recorded tape will become the thing for "permanent" music, where the high quality and virtual absence of the wear problem will come into their own. What is wanted here is a more universal agreement on standards.

One last word of warning before I finish, directed to those who are just now considering taking their first step into the realm of high fidelity. It is a wonderfully interesting bug to get bitten with, but very hard to shake off afterwards. The only certain cure that has ever come to my notice is abject poverty. I hope it doesn't happen to you.

B.J.S.

AWV