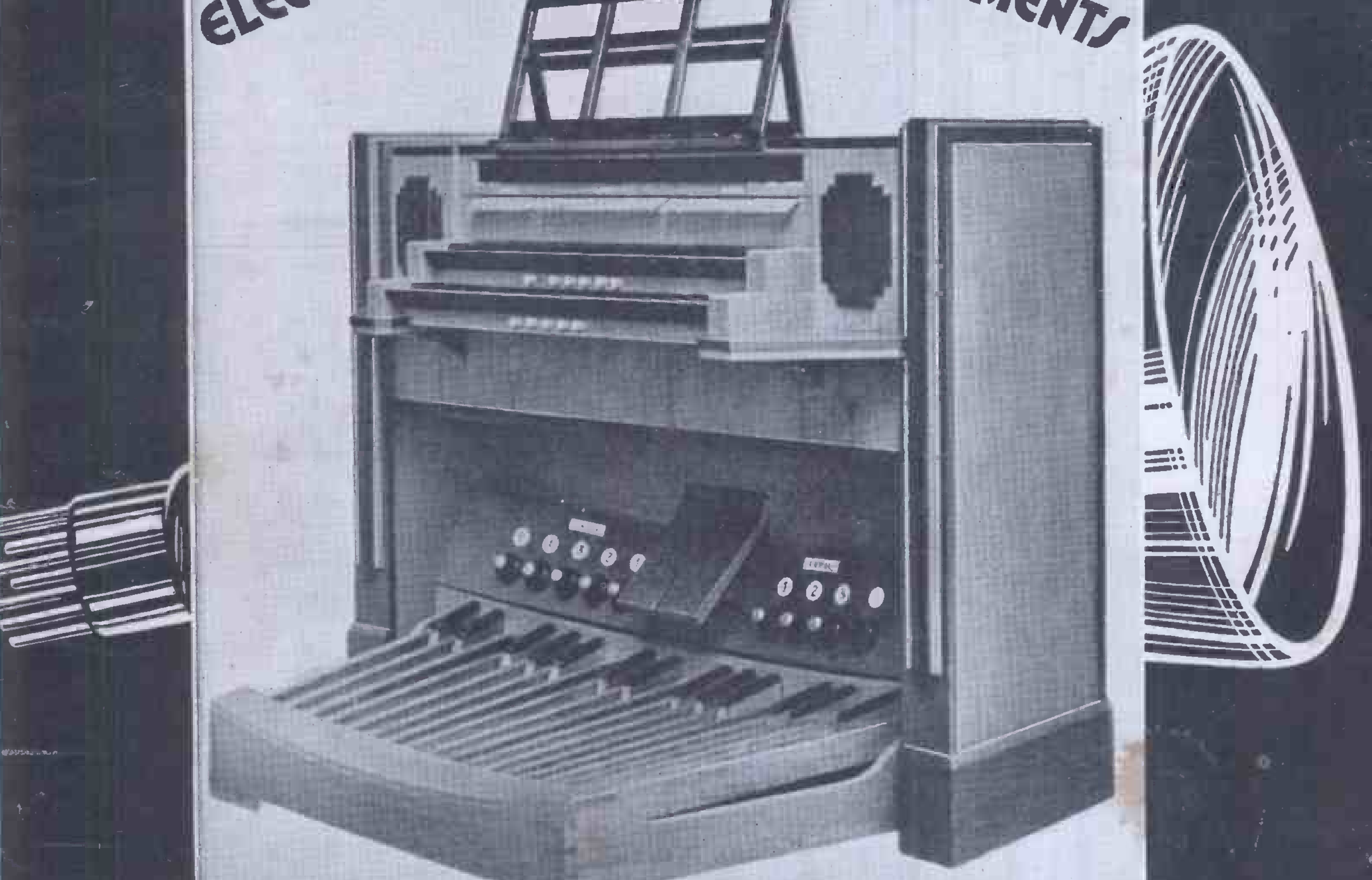
ELECTRONICS AND TELEVISION & SHORT-WAVE WORLD

1/6

AUGUST, 1940

ELECTRONIC MUSICAL INSTRUMENTS



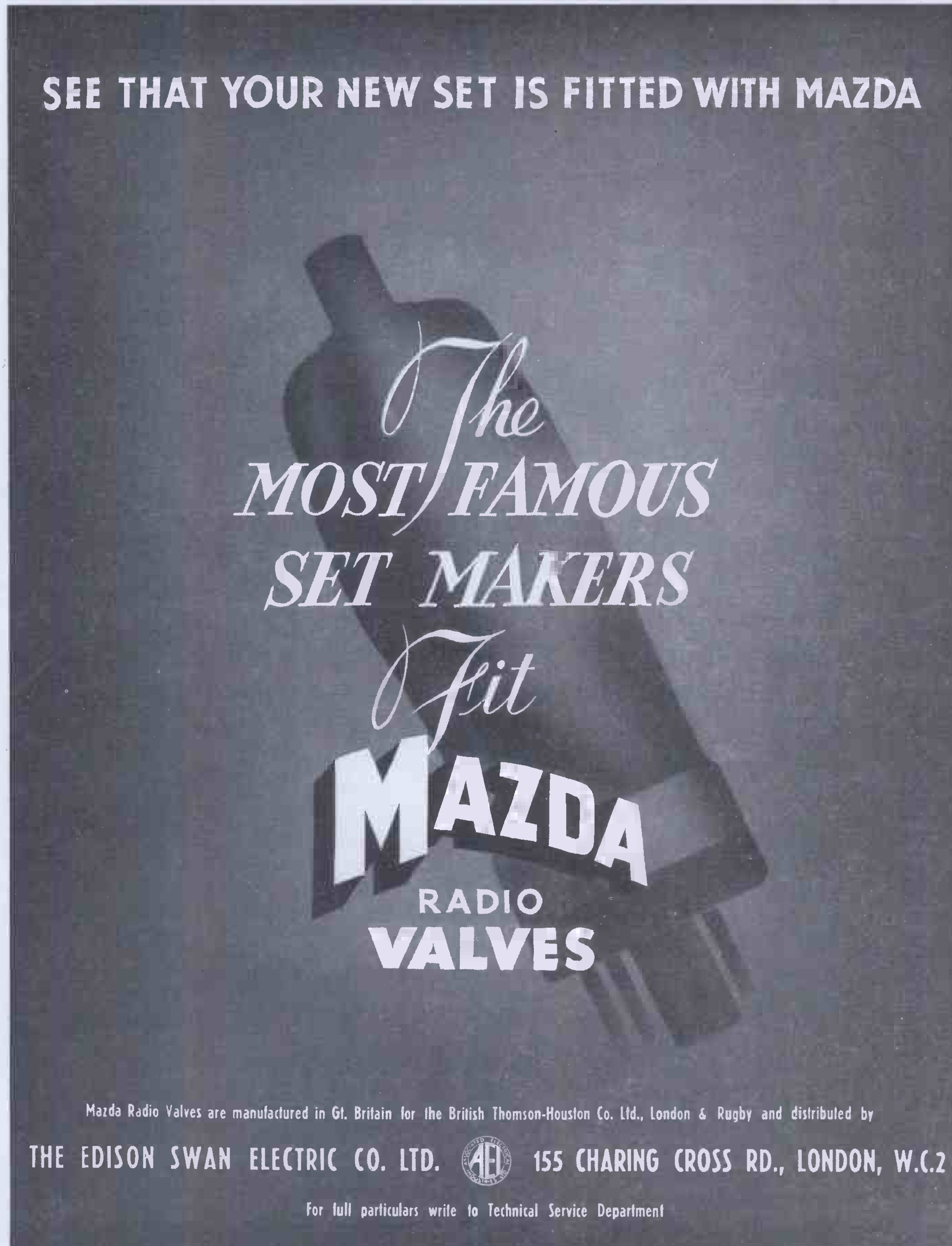
THE FIRST TELEVISION JOURNAL IN THE WORLD

HULTON PRESS LTD., 43, SHOE LANE, LONDON, E.C.4

PRINCIPAL CONTENTS

AUGUST, 1940

Contributions will be promptly considered: they should be accompanied by a stamped addressed envelope for return in case of non-acceptance.


SEE THAT YOUR NEW SET IS FITTED WITH MAZDA
The
MOST FAMOUS
SET MAKERS
Fit
MAZDA
RADIO
VALVES
Mazda Radio Valves are manufactured in Gt. Britain for the British Thomson-Houston Co. Ltd., London & Rugby and distributed by
THE EDISON SWAN ELECTRIC CO. LTD.
AEI
155 CHARING CROSS RD., LONDON, W.C.2
For full particulars write to Technical Service Department

No. 150. Vol. XIII. AUGUST, 1940

Electronics and Television and Short-Wave World

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES
43, SHOE LANE, LONDON, E.C.4

Editor : H. CORBISHLEY

Telephone : CENTRAL 7400

Subscription Rates; Post Paid to any part of the world—3 months, 5/- ; 6 months, 10/- ; 12 months, 20/-. Monthly (published 25th of preceding month) 1/6 net, Registered for Transmission by Canadian Magazine Post.

News and Views

ON other pages of this issue we present an important paper on the development and present possibilities of electronic musical instruments. Investigation of these devices has not received the attention in this country commensurate with their probable future importance, but it is evident that a field is open which will well repay attention; it is a line of investigation that directly concerns the electronic engineer.

A considerable amount of prejudice against the introduction of new types of musical instruments is bound to exist, particularly if they are intended to rival those which have taken centuries to develop, but even if we admit that in some respects the new types possibly fall short of those they are intended to simulate, few will deny that under certain conditions they are likely to prove most valuable. As the authors said in reply to some criticisms of the production of music by electronic methods, although in the present stage of development of electronic organs it may appear that they could not be built to compete with very large pipe organs, it must be remembered that electronic forms of organ have only been contemplated since the beginning of this century and that large scale development only commenced about ten years ago. In view of the fact that the pipe organ is the product of many centuries development, a similar degree of finality and perfection is hardly to be expected in what must therefore be considered to be the comparatively early stages of the development of electronic organs.

One surprising fact which emerges from a study of the review presented is the large variety of methods that may be employed for the production of electronic music and the authors make it clear that the possibilities of both methods and principles are by no means exhausted.

From time to time discussions have taken place in the Press regarding the apparently unnecessarily stringent specifications for Service apparatus, and the delays and increased costs which result therefrom. The increasing use of radio communication in modern warfare has caused receiver manufacturers to view their production from a different viewpoint, and no doubt many are surprised to note how far their opinion on what constitutes reliability and workmanship differs from that of the Service authorities.

While it is not proposed to enter into a discussion on what constitutes reliability from Service considerations, it is to be hoped that Mr. Morrison's advice on omitting the "spit and polish" from certain components and thereby increasing production is being followed in the radio industry as well as in the armament trade. Some time ago a well-known manufacturer abandoned the usual cobalt plating in favour of sprayed finish—a small point which did not affect the performance of the receiver, but which saved an appreciable amount in production costs.

In an American broadcast talk in June, Ray Giles said that "thinking wild" solved many problems after systematic thinking had failed. He quoted the case of Singer, the sewing machine inventor, who was obsessed with the idea of a needle with an eye in the blunt end, as had been the practice for centuries. As soon as his imagination suggested the apparent absurdity of an eye in the point the problem of the sewing machine was solved.

In a paper presented to the Institution of Electrical Engineers, Mr. W. T. O'Dea puts forward an argument for the revision of standards at present drawn up for performance of electrical apparatus and components. He claims that it is impossible to discriminate between batches of a manufactured product by applying a criterion in the form of a "factor of safety," and states that it is quite possible that a batch with poorer characteristics has a better chance of being accepted under such circumstances. It is suggested that the existing factors of safety be replaced by a new set of empirical standards based on a guaranteed minimum performance.

It is also pointed out that in some cases the present test samples are inadequate in size and number, and it is recommended that samples of 50 items in some products should be accepted as reasonable. While Mr. O'Dea's arguments are intended to apply in the main to electrical materials they may well be taken as a basis on which to revise the acceptance tests for components such as condensers and other items in radio construction.

Impulse Testing

By W. A. Flint

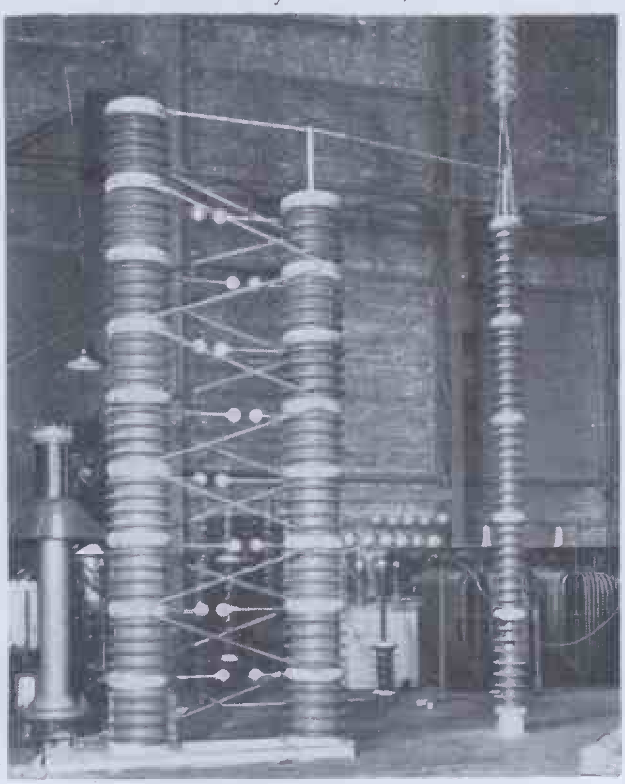
Numerous classes of high-voltage apparatus, each having its particular application and field of use, are now available for testing and research purposes. There are, however, four varieties which cover most of the requirements, viz. :—

1. Sustained low-frequency.
2. Constant direct current
3. High-frequency.
4. Surge or impulse.

Particulars of the Surge or Impulse type are given in this article.

THE demand for the impulse generator has increased greatly within the last few years because the experimental investigation of transient disturbances on transmission lines, due to lightning, switching and other causes, has shown that the most frequent and dangerous type of disturbance is a travelling wave of steep waveform, usually non-oscillatory, but alternatively heavily damped. When a surge of this type enters a transformer at the end of a line, the voltage, instead of distributing evenly across the transformer winding, builds up at one end and causes stresses out of all proportion to the initial amplitude of the surge; and these excess surges may ultimately cause the breakdown of the transformer.

The impulse generator has been devised in order to produce these high voltage surge effects artificially in research laboratories; and its fundamental operation is the charging up of a condenser to a certain voltage, and then discharging it through a circuit having the required electrical constants to give the type of surge required for the test. It will be noted that, with this circuit, the condenser will have to be charged up to at least the voltage required for testing, so that the cost of the condenser and rectifying apparatus is somewhat high.



Impulse generator manufactured by Metropolitan-Vickers Electrical Co., Ltd., showing loading condenser and resistance voltmeter, with the 150 kV. rectifier in the background.

These difficulties have been overcome, however, by a simple arrangement invented by Dr. Marx, of Brunswick. The circuit is shown in its simplest form in Fig. 1 and operates by charging a number of condensers in parallel through resistances, and then, when a predetermined voltage is reached, automatically discharging them in series through spark gaps.

The condensers are all charged up to approximately the same potential by means of the transformer and rectifier. The time taken to charge the condensers will depend upon their capacity and also the maximum current-carrying capacity of the rectifier. When the potential of the condensers reaches a predetermined value corresponding to the setting of the sphere gaps, g, the gaps break down and instantly connect the condensers in series through the sparks, so that the full series voltage of all the condensers appears across the output terminals O and E.

In this way, the applied voltis built up across each condenser in turn and then, when the condensers are discharged in series, the voltage across them adds up for each stage so that the total discharge voltage is many times that of the applied D.C. voltage depending on the number of stages in use. With a 3-stage generator as shown in Fig. 1 and a rectified output of 50 kV, each condenser would charge up to approximately 50 kV and the total discharge voltage through the spark would be of the order of 150 kV.

The purpose of the resistance R_1 is to limit the current flowing and protect the rectifier, and of the resistances R_2, R_3, R_4 and R_5 to isolate the condensers from one another so that they may be discharged in series through the spark gaps.

There is, of course, a large difference in potential between each condenser, but, as the duration of the surge discharge is so very short, the loss of energy in the resistances is negligible.

This circuit can be used with any number of stages, but it must be appre-

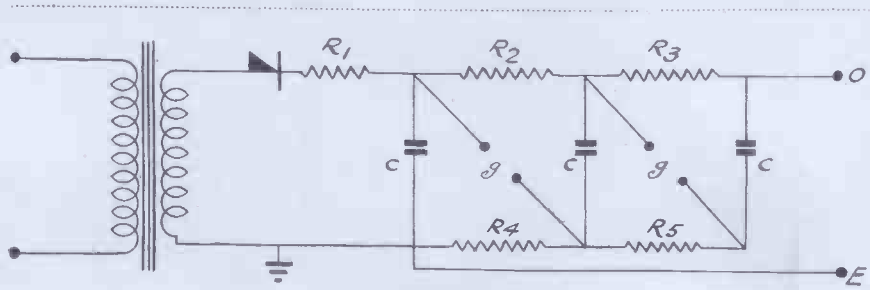


Fig. 1. Half-wave circuit.

ciated that, as the number of stages increases, the condensers that are situated at the high voltage output end may not become fully charged owing to the high resistance between them and the D.C. supply.

The strength of a dielectric to withstand voltage surges depends upon the steepness of the waveform and the amplitude of the surge. The waveform of the generator can be adjusted for any surge up to the maximum by means of a combination of resistances and inductances connected between the generator and the material under test. It is possible to calculate the waveform, but, if very accurate results are required, it is better to employ a cathode-ray oscillograph.

It will be noted that it is possible to apply a surge of constant amplitude and varying waveform, or one of varying amplitude and constant waveform, to the apparatus under test.

The D.C. supply for charging the impulse tester proper is naturally very important, as the reliable working and cost of upkeep will depend upon an efficient rectifier. There are two alternatives that can be used, viz. (a) a valve, and (b) an oil-cooled metal rectifier. The metal rectifier, although only slightly more expensive initially, has an almost continuous life, whereas the valve has a limited life and must be replaced from time to time.

The chief advantages of the metal rectifier for this purpose, however, are that the circuit is simple as there are no filament transformers nor filament adjustments for different output voltages; also considerable overloads are permissible on account of the high thermal capacity of the rectifier.

Two types of feed circuit may be employed for charging the condensers of the impulse generator, viz:—

The half-wave circuit as shown in Fig. 1.

The modified voltage-doubler circuit as shown in Fig. 2.

When designing a rectifier for supplying an impulse generator, the generator as a whole is assumed to be one large capacity and a series resistance, in the case of the half-wave circuit, decides the frequency of the impulse. The higher the frequency, the greater the mean current and consequently the larger the rectifier that is required. The transformer voltage for the half-wave circuit is approximately the mean D.C. output voltage divided by $\sqrt{2}$, plus about 10 per cent. to allow for the asymptotic part of the charging curve.

120 kV. Impulse testing rectifier for National Physical Laboratory.

The most popular feed circuit, however, is the modified voltage-doubler circuit shown in Fig. 2. In this case, the transformer voltage is only the mean D.C. output divided by $2\sqrt{2}$ plus about 10 per cent., and this makes the transformer very much cheaper. The frequency of firing of the generator is now decided by the impedance value of the feed condenser C_1 and the waveform of the generator is dependent only upon the associated resistance, and is entirely independent of the circuit constants of the feed circuit.

With this type of circuit, too, it is far simpler to calculate beforehand exactly what will happen in the circuit.

1,200 *kV* *Impulse Generator*

The accompanying photographs show an 8-stage 1,200 kV impulse generator built by the Metropolitan-Vickers Electrical Co., Ltd., and the oil-immersed metal rectifier equipment, built by Westinghouse Brake & Signal Co., Ltd., which feeds the generator. The modified voltage-doubler feed circuit is employed with a feed condenser of 0.003 mfd., and the D.C. output of the rectifier is 150 kV with a mean current of 10 mA. The input voltage to the rectifier is 63.5 kV r.m.s. 50 cycles, and the effective capacity of the surge generator is 0.4 mfd. with a firing frequency of 6 seconds.

The rectifier has been designed for a 24-hour day continuous rating, but, owing to the large thermal mass of the oil-immersed rectifier, the equipment can be operated at a higher frequency, e.g., every 3 seconds, for considerable periods of time, provided a check is kept on the oil temperature rise.

The relative cheapness of the surge generator designed and built upon the Marx principle, combined with the important part played by surges in the life of electrical apparatus, make it essential that such equipment forms part of every high-voltage testing laboratory.

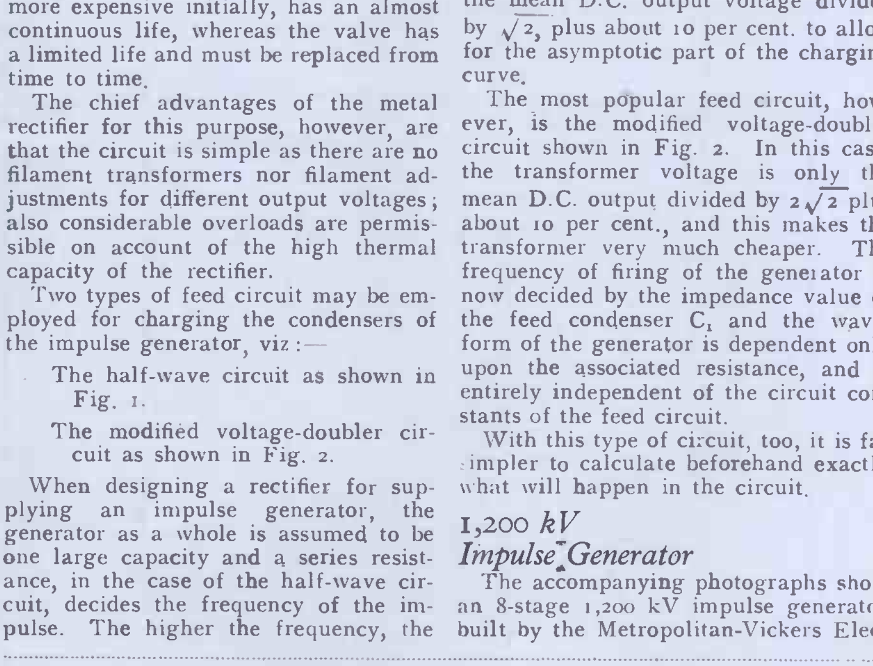


Fig. 2. Modified voltage-doubler circuit.

Book Review

Radio at Ultra High Frequencies. R.C.A. Technical Press. 430 pp. Not for public sale.

According to their previous practice, the R.C.A. Technical Press have issued this book gratis to subscribers to the "R.C.A. Review." It contains a collection of various papers on U.H.F. which have been published by R.C.A. engineers over the past two or three years together with a selection of abstracts from papers which have appeared in the I.R.E. Proceedings on the same subject.

The book is divided into two sections covering frequencies below 300 mc. and above 300 mc. Of particular interest to television engineers is the article on Simple Television Antennas and the Empire State Building antenna. Measurements in U.H.F. are covered by a survey by L. S. Nergaard, and the receiving aerial and input circuit are also dealt with by Holmes and Turner.

As stated above, the book is not obtainable through the ordinary channels, but by becoming a subscriber to the "R.C.A. Review." It is strongly recommended that readers write to the publishers, R.C.A. Institutes Press, for particulars of the special subscription rate. The address is: 75 Varick Street, New York City, N.Y., U.S.A.

The Sales and Administrative Offices of Messrs. Marconi-Ekco Instruments, Ltd., have been moved to more convenient premises, and their new address is: "Elmhurst," Hatfield Road, St. Albans, Herts.

ELECTRONIC MUSICAL INSTRUMENTS

The Development of the Pipeless Organ

By

G. T. WINCH & H. M. MIDGLEY

Electronic organ with case removed.

GREAT skill and ingenuity have contributed to the present standard of perfection of the traditional forms of musical instruments. However, it must not be overlooked that such instruments are dependent on the limitations of mechanical resonators, and this automatically determines their size, loudness, cost, degree of flexibility of control and the tone colours which they can produce

Possibilities of Electronic Methods

The attraction of electronic methods of producing (as apart from reproducing) music is that, at least theoretically, it should be possible to generate electric current of any desired fundamental frequency and harmonic content. Such currents when amplified and converted

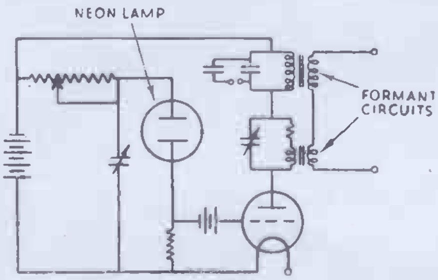
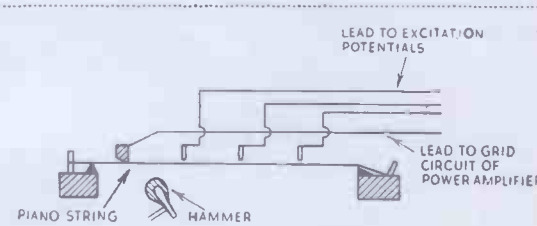


Fig. 1 (left). Neon lamp oscillator circuit.

Fig. 2 (right). Struck string as generator, with electrostatic pick-up.



to sound-pressure waves by means of loudspeakers should enable sound waves to be generated of any frequency and harmonic form, over an almost infinite loudness range. The flexibility of control of such methods of sound production should exceed that of any of the traditional forms of musical instrument, and there seems every reason to expect that the bulk and cost should be only a fraction of that of large and elaborate instruments such as pipe organs.

Very many systems have been proposed for producing musical tones of different timbre by electronic methods. The table indicates the various branches of electronic musical instrument

This article is an abstract from a paper read before The Institution of Electrical Engineers (Tees-side sub-centre) and is published here by kind permission of the Institution. This portion is a survey of the practical design of electronic instruments which simulate the pipe organ and reviews very comprehensively the several types developed.

development. It will be noted that these developments may be considered in three main groups, namely, melodic or single-note instruments, harmonic or multi-note instruments of the percussion type essentially developed from the piano, and harmonic instruments simulating the pipe organ both in playing technique and musical effect.

Melodic or Single-note Instruments

The Duddell singing arc was probably the first melodic electronic musical instrument, although obviously its form and potentialities were not such as to attract interest in it as a serious musical instrument. In fact, only one serious attempt was made to construct an electronic form of musical instrument prior to the advent of the thermionic valve, namely, that by Cahill in 1897.

In 1915 Lee de Forest lodged the first patent application for a musical instrument utilising thermionic valves for producing musical tones. His instrument consisted of a valve oscillator, the frequency of which was controlled by adjustable capacitance. The amplified audio frequency was then fed to a loudspeaker which produced the musical notes.

This was followed at a later date by a number of inventions in which various forms of oscillatory circuits were proposed, with the object of facilitating playing technique, and to some extent controlling the harmonic content or timbre of the notes produced by the super-position of formant frequencies.

By separately generating these formant frequencies and superposing them on the note frequencies, the electronic instrument is made to produce a limited range of tone colours. In another variation of the circuit for producing these effects, neon lamps are incorporated in conjunction with condensers and discharging resistances to produce audio-frequency oscillations. One example of the form of circuit used in this type of instrument is shown diagrammatically in Fig. 1.

Classification of Electronic Musical Instruments

Two instruments of this melodic type have attracted considerable attention as solo instruments and may be quoted as examples. In the instrument invented by Theremin, two supersonic valve oscillators produce beat frequencies in the audio range, the desired frequency or pitch of the note being controlled by the hand capacitance of the player. This is accomplished by moving the hand to different positions in space with respect to an electrode in the form of a vertical rod projecting from the oscillator

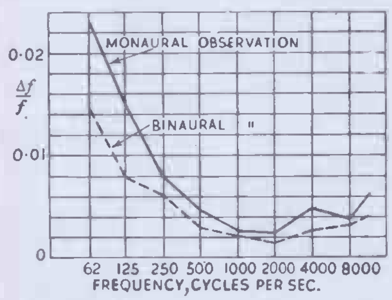


Fig. 3. Relation between pitch discrimination and frequency of pure note at sensation level 40 db. above threshhold.

cabinet. Starting and stopping of the notes is accomplished by means of a switch held in the other hand of the performer.

The Trautonium, invented by Trautwein, has a measure of timbre control which is realised by superposing formant frequencies on those generated by means of neon tubes. The pitch of the notes is in this case controlled by means of a variable resistance in the form of a spun-wire cord stretched over a steel band, the wire being pressed on to the band at the desired point by the performer.

TABLE

Group. (1)	Sub-group. (2)	Division. (3)
(A) Single-note form	(a) Electric arc	—
	(b) Oscillating valve circuits	—
	(c) Oscillating neon-lamp circuits	—
(B) Multi-note key-board percussion form	(a) Struck string or tuned rod as generator	(i) Electromagnetic pick-up (ii) Electrostatic pick-up
(C) Multi-note key-board organ form	(a) Maintained tuning form or vibrator as generator	—
	(b) Maintained strings as generators	(i) Electromagnetic pick-up (ii) Electrostatic pick-up
	(c) Cathode-ray generator	—
	(d) Multiple oscillator circuits utilising valves and neon lamps	(i) Thermionic-valve oscillator circuits (ii) Neon-tube osc. circuits
	(e) Wind - maintained reeds as generators	(i) Electrostatic pick-up (ii) Electromagnetic pick-up
	(f) Rotary forms of generator	(i) Photo-electric (ii) Electromagnetic (iii) Electrostatic

Note:—There are two distinct methods which may be adopted with any of the above forms of instruments :—

(*a*) To generate directly complex waveforms of the requried shape to produce the various tone colours.

(*b*) To generate series of sinusoidal waveforms of the required fundamental and harmonic frequencies, and by mixing circuits combine these to form the required complex waveforms and tone colours by synthesis.

Multi-note Instruments

A type of instrument which has been developed mainly by Vierling and Miessner consists essentially of piano-type action and strings mounted on a frame in the conventional manner, but with no soundboard The general form of arrangement adopted in such instruments is shown diagrammatically in Fig. 2, from which it is clear that if different excitation voltages are applied to the respective pick-up bars and the strings connected to the grid circuit of an amplifier, when the strings are vibrated by the hammer blow, the resulting variations in capacitance at the respective audio frequencies can be used to produce musical notes. The harmonic content of the notes will depend on the proportionate excitation of the various pick-up bars and their positions along the strings.

Various methods have been proposed for controlling the extent to which the

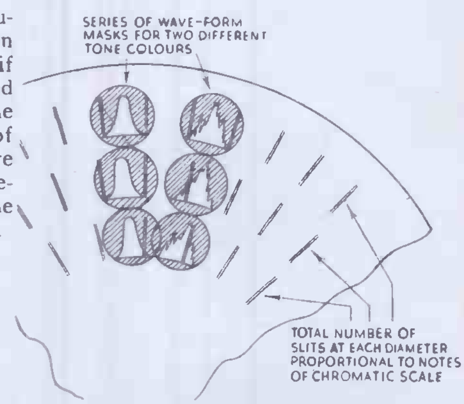


Fig. 5. Sketch showing arrangement of stationary waveform masks and slits on portion of rotating scanning disc of photo-electric organ.

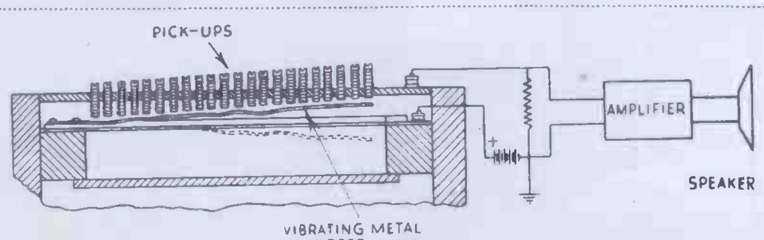


Fig. 4. Wind-maintained reed generator.

Frequency Generators

starting transients are included in the component fed to the amplifiers for production by loudspeakers, and for controlling the harmonic content of the steady tone produced. Such instruments have a much greater dynamic range than normal pianos, this being made possible, of course, by the valve amplification and loudspeakers used. Also, greater variations in tone colour and waveform envelope shape are at the command of the performer.

Simple forms of such instruments have recently appeared on the market, in which, by means of electrostatic pick-up and amplifier arrangements, quite a small instrument is made to produce tone more nearly approaching that of a grand piano. The volume can be set to suit the particular requirements, and in some examples, while playing, the performer has limited control over tone or volume in addition to that normally available to the pianist by keyboard technique.

Problems of the Pipeless Organ

It would appear that with electronic methods it should be possible to construct an instrument comparable with a pipe organ at a greatly reduced cost and of considerably smaller dimensions. This, it must be admitted, is one of the prime considerations behind the development of all commercially available instruments.

The range of pitch of the fundamentals of all the notes of a pipe organ is from the lowest note of the 32 ft. pedal stops with a frequency of approximately 16 c./s., to at least the top note of the 2 ft. manual stops with a frequency of the order of 8,000 c./s. Actually, in larger instruments some of the mutation stops may extend to higher fundamental frequencies. Also, the harmonics of notes of some of the tone colours it is desired to produce may extend to the limit of the audio-frequency range.

As far as accuracy of pitch is concerned, it is important that all the octaves be perfect because when sustained notes are sounded in octaves, beats are immediately apparent if there is the slightest error in tuning. With regard to the intervals within the octave, a small departure from the theoretical equal temperament intervals is allowable.

From the point of view of the design of an electronic organ it is important to know in terms of frequency what errors are tolerable in the case of these intervals within the octave.

Observations of the least perceptible difference in pitch of notes played successively have shown that the ear is most sensitive between 1,000 and 2,000 c./s. Shower and Biddulph investigated this effect by means of a heterodyne oscillator which could be adjusted to produce notes of pure sinusoidal form at any desired frequency throughout the audio range. These results are summarised in Fig. 3, from which it will be seen that monaural hearing is less critical than binaural hearing, the latter being susceptible to changes of 0.1 per cent. in frequency in the most sensitive range.

In order to imitate the many tone colours by electronic means, a knowledge of their respective sound-pressure wave-forms or the harmonic composition of the tones produced is necessary.

The problem of the starting and stopping characteristics is, however, a much more difficult one, and although very considerable inventive genius has been shown in the many proposals which have been made for accomplishing this, usually a compromise has to be adopted.

In the design of an electronic organ provision should be made, if possible, for the easy control by the performer of the harmonic content of the steady tone of at least one stop in addition to the means of tone control provided by stops imitating existing instrumental tone colours. Some provision must also be made for the control of the envelope of the complex sound-pressure waveforms produced, if it is not possible to imitate exactly the required starting and stopping transient conditions.

The electrical problems involved in the various generator systems which have been proposed and used in the construction of full-compass organs will now be dealt with in the order in which they are classified in the sub-groups of group (C) in the table. As has been previously pointed out, sub-groups (C) (*a*), (*b*) and (*c*) have not been developed past the experimental stage.

Of the three remaining systems, valve and neon-lamp generators are the ones in which no moving parts are required. In the case of reed generators, compressed air is needed to vibrate the reed, whereas the rotary-generator systems require synchronous electric motor drive.

Multiple Oscillator Circuits

The choice of oscillatory circuits for use in electronic musical instruments depends on many factors, the foremost of these being the stability of the frequency, as upon this depends the constancy of tuning of the instrument.

Many circuit arrangements have been suggested, each of which has its own peculiar limitations and advantages. For example, the use of one valve for each fundamental and each harmonic naturally involves a large number of valves with their appropriate resonant circuits, cathode heater, and anode supplies, and the arguments in favour of the use of tempered harmonics would in this case materially assist in reducing the number of valves required. In order to reduce the number of cathode heater circuits, proposals have been made to use special valves in which one cathode functions for a number of independent oscillatory circuits.

In 1930, Coupleux demonstrated in France an organ having two manuals of three octaves' compass and pedals of normal compass, in which valve oscillatory circuits were used to generate complex waveforms and filter circuits arranged to select the particular frequencies as required. Subsequently he built a three-manual and pedal organ of 76 stops incorporating 400 valves, which was installed in the studio of the Poste Parisien broadcasting station. In these instruments each note-frequency oscillator circuit was provided with means for adjusting the frequency so that the tuning could be carried out, the constancy of pitch depending on the constancy of the valve characteristics and associated circuit components. The stop keys brought into action banks of filters for modifying the generated waveforms to produce the necessarily limited and somewhat arbitrary range of tone colours.

An experimental two-maual and pedal organ was built by Kock, employing as generators neon lamps in oscillatory circuits; this was claimed to be very stable. Here again special filter circuits brought into action by the stop-key mechanism provided a limited range of tone colours.

Quite recently, an instrument of American origin, developed by Williams and Hammond, made its appearance in this country. This can hardly be classed as an organ, although it can be used to produce sustained tones in addition to the many percussion and specialised effects. Like a piano, it has only one 6 to 7-octave keyboard and no pedals other than for controlling expression.

In this instrument frequencies of the 12 notes of the top octave are generated by beat-frequency oscillators. The output from these 12 oscillators is connected respectively to frequency-halving circuits of special design which thus provide the note frequencies for the next lower octave of 12 semitones. This process is repeated for each octave down to the lowest note on the keyboard. The output from these divider circuits is then taken through control valves operated by the note keys to the amplifier, filter, and loudspeaker circuits.

Electromagnetic Generators

Three filter circuits controlling the top, middle and bottom registers, give a measure of tone control, whilst special filter networks enable the envelope of the waveform of the note to be modified. Volume and tremolo effects are also provided.

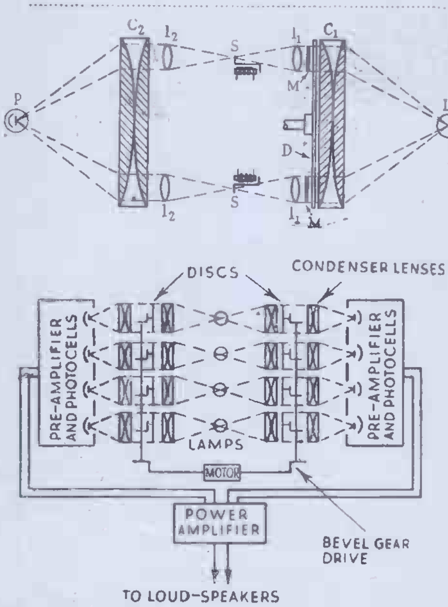


Fig. 6. Details of Toulon's assembly of scanning units; one unit per octave.

The reed-type generator is seldom used for generating sinusoidal waveforms for synthesising tone colours, as the complex nature of the vibrations of free reeds makes this extremely difficult.

The reed-type generator depends for its action upon the change in electrostatic capacitance between the metal tongue and small insulated electrodes placed above it. The reeds used for this purpose are similar to those employed in harmoniums, etc., and are vibrated by low-pressure wind.

By arranging a number of small screws immediately above the vibrating reed to act as pick-up electrodes, and connecting them in a circuit of the form shown in Fig. 4, a musical note of fundamental frequency of that of the reed will be obtained.

There are, of course, other ways of controlling the tone produced by reed generators; some depend upon electrical considerations, but most of these are based on practice common to reed-organ builders, such as shaping of the ends of the reeds. The electrical output from this type of generator is very low, being in the region of −70 to −80 db. (zero level = 0.006 watt) and consequently high-gain amplifiers, of the order of 100 db. gain, are required.

Rotary Forms of Generator

Photo-electric Scanning.

Photo-electric methods of scanning used in electronic musical instruments may be divided into two main groups, namely, those in which the light from an illuminated stationary slit is modulated by the passage in front of the slit of a variable-density or variable-area form of mask after the manner of the sound track of a talking film, and those in which the illuminated mask of the waveform is stationary and is traversed by a series of slits one fundamental wavelength apart, in the manner shown in Fig. 5. In both these forms the resultant modulated beam or beams of light are concentrated on to one or a small group of photo-electric cells, the output from which is fed to a power amplifier and loudspeakers.

Toulon was probably the first to construct a full-compass photo-electric organ, and his instrument utilises stationary waveforms arranged radially, one row per tone colour, immediately in front of a rotating disc carrying slits in concentric rows at diameters corresponding to those at which the wave forms are placed, as shown in Fig. 5. The slits are spaced one fundamental wavelength apart so that the wave-masks are scanned at the appropriate speeds. The rows of slits are arranged at the different diameters so that the numbers of slits in each successive concentric ring are approximately proportional to the frequencies of the tempered scale. The tuning inaccuracies are, however, greater than 0.1 per cent. in frequency, the normally acceptable limit. In this particular arrangement one rotating disc carrying slits, together with its associated waveforms, is required for each octave.

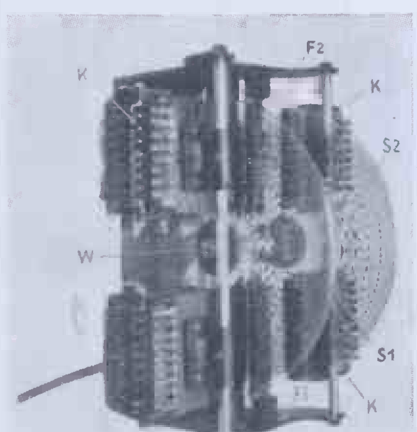


Fig. 7. Welte photo-electric organ scanning unit.
W—**spindle.**
K—**mechanism containing exciter lamps and shutter.**
F1 and F2—**photocells.**
S1 and S2—**discs carrying sound tracks.**

The optical arrangements utilised in this instrument are very compact and are indicated diagrammatically in Fig. 6. It will be seen that all the modulated light beams from all the notes of different tone colours of one octave are concentrated by the condenser lens on to one photo-cell, and the shuttering of the modulated beams of light associated with the individual notes is achieved by small electromagnetically operated shutters which operate at the focal point of the individual beams, so that the amount of movement required is extremely small. Eight such units are employed, one for each octave so that eight photo-cells are required. The number of light sources used in this case is only four, because of the symmetrical disposition of the units on either side of the tungsten filament lamps.

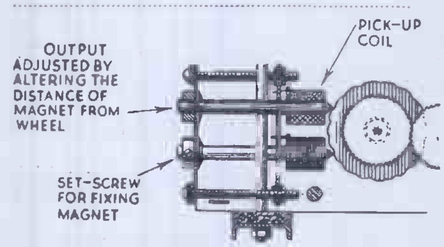


Fig. 8. Electromagnetic generator, one disc per note, simple waveform type.

The photo-electric organ constructed by Welte employs a series of variable-area sound tracks arranged concentrically on discs rotated synchronously at appropriate speeds. Small lamps illuminate the stationary scanning slits, and the resultant modulated light is concentrated on the photo-electric cells. The form of one scanning unit used in this instrument is shown in Fig. 7.

The electromagnetic system of generation was used by Cahill in 1897. At that time the thermionic valve was not invented and he used large generators in order to obtain the requisite power.

It was not until after the invention of the thermionic valve and the development of amplifiers and loudspeakers that further proposals were made for developing this principle. By means of valve amplification the use of very small generators was made practicable, the simplest form consisting of a small iron disc with suitably shaped periphery mounted on a shaft and arranged to rotate in front of an electromagnetic pick-up. In early forms the pick-up was polarised electromagnetically, but in later designs, the core is a permanent magnet.

Generator Output

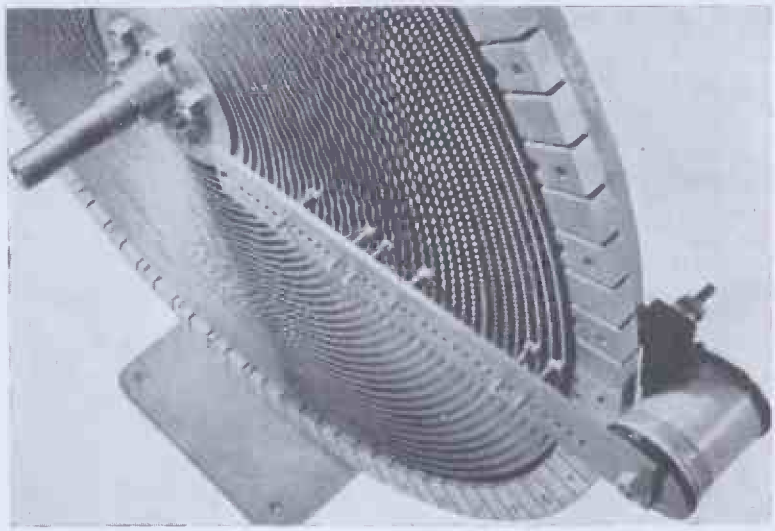


Fig. 9. Partly assembled multi-frequency electromagnetic generator, showing portion of disc, and pick-ups on one radial arm.

A unit of such a generator incorporated in a contemporary electronic organ developed by Hammond is shown in Fig. 8. Rotation of the wheel produces an alternating current in the pick-up coil, corresponding approximately in waveform to the shape of the indentations on the wheel, and in frequency to the number of waveforms and speed of rotation. It will thus be seen that if a series of such generators are used, producing the fundamental and harmonic frequencies required, it should be possible to combine these currents of various frequencies in any desired proportions to produce various complex waveforms. This form of generator is not only the simplest, but in practice it has proved the most economical, to construct. The electrical output from it is high as compared with that from electrostatic and photo-electric generators, and in consequence, less amplification is required.

In addition, the background noise level is low. A difficulty associated with this, and in fact all electromagnetic systems, is the elimination of fringing effects. This is of particular importance if sinusoidal waveforms are being generated, as spurious frequencies are introduced.

In another form of generator which has been constructed experimentally, a number of concentric ridges are cut on one face of a rotatable iron disc. On the face of each ridge, at right angles to the plane of the disc, sinusoidal waveforms are cut. The size and number of waveforms is so arranged that, progressing from the inner ring, each successively larger ring has twice the number of waveforms of the inner adjacent ring. Series of magnetic pick-ups consisting of radially arranged iron strips with pole-pieces in the form of grub screws opposite each of the concentric rings, are set radially facing the side of the disc on which the waveforms are engraved, as shown in Fig. 9.

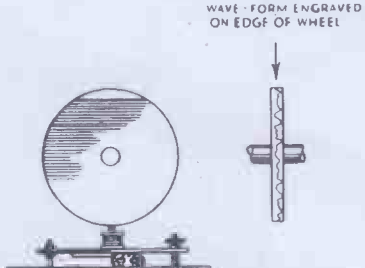


Fig. 10. Electromagnetic generator. One disc per note—complex waveform type.

It will be seen that by altering the relative distance of the screws in the pick-ups, chosen proportions of the frequencies generated when the disc is rotated may be obtained. Also the magnitude of the current of complex waveform so generated may be controlled in each radial pick-up bar by varying the electromagnetic excitation.

A further example of an electromagnetic generator developed by Robb is indicated in Fig. 10. Here complex waveforms are engraved on the edge of the discs, the idea being to use one disc per note per tone colour, each disc generating, in its associated pick-up, current of the appropriate complex. This system also suffers from fringing effects, and the construction has proved very costly.

Electrostratic Generators

One early form of electrostatic generator, due to Bourn, is shown diagrammatically in Fig 11. This comprises a stationary disc of insulating material on which are arranged concentrically a series of metallic rings, one edge of which is of sinusoidal form. A flat metal arm mounted at right angles to the plane of the disc, with one edge about 1/64 in. away from it, rotates over the disc about its own centre. The rotating arm and the sinusoidally shaped rings form a capacitance varying cyclically in a manner depending on the speed of rotation and the number and shape of the waveforms on the metal rings. By connecting these elements in the circuit as shown in the figure, small voltages of sinusoidal waveform are generated when any one ring is keyed into the excitation circuit. If more than one ring is keyed into circuit at the same time, a voltage will be generated having two or more component frequencies superposed in proportions depending on the values of the excitation potentials. By suitable choice of these excitation potentials, a chosen complex voltage waveform may be generated.

The output of such a generator is very small and is liable to be uneven due to mechanical difficulties in maintaining accurately the distance between the rotating metal arm and the stator. Very small mechanical errors may in consequence introduce very objectionable cyclic modulation of the output. Also, fringing troubles will arise from this form of construction, and the generation of sinusoidal waveforms will only be approximate.

These difficulties are overcome by making the rotor of the web form shown in Fig. 12 and the stator as in Fig. 13. Here, the number of radial lines or scanning elements has been increased so that they are spaced one-half wavelength from one another. This results in an appropriate increase in output and also provides a compensation effect, should the scanning disc run out of truth owing to small mechanical inaccuracies of mounting. By forming the rings from metal, sputtered on to an insulating base, and afterwards engraving the concentric sinusoidal contours, an island is left between each ring. If this island is connected to earth, fringing is prevented by reason of the resulting focusing effect of the lines of force. The circuit arrangements in Fig. 11 entail the use of a brush-type contact between the rotating collecting arm or multiple scanning elements and the grid circuit of the first amplifying valve.

Mixing Circuits

In the circuit arrangement in Fig. 14 the brush connection is in the earthed side to overcome the possibility of noise being generated owing to this moving contact. In systems where the rotor and stator are placed close together, stray leakage currents, giving rise to

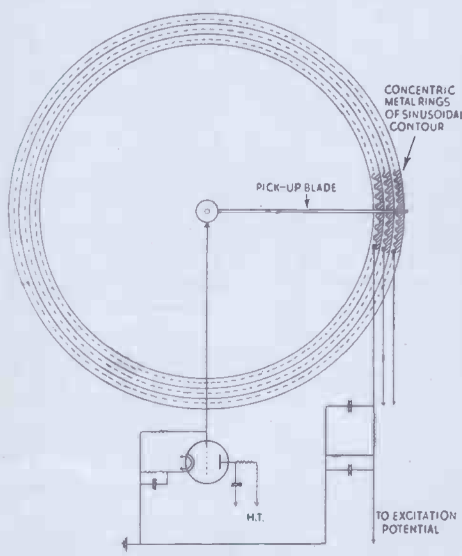


Fig. 11. Electrostatic simple waveform generator.

noise, which may be generated as the result of the presence of small particles of dust or moisture.

The above effects are minimised in a later form of generator construction, shown in Fig. 15. This avoids the need for moving contacts, and allows of the use of larger spacing between the elec-

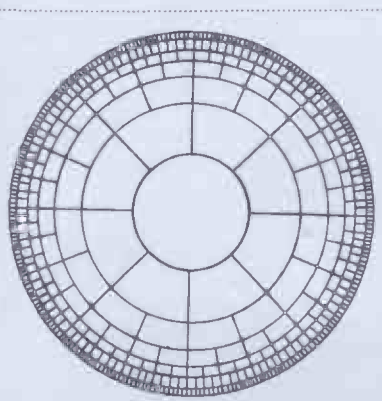


Fig. 12. Web form of rotor with multiple scanning elements.

trodes, thus reducing the mechanical and electrical difficulties. In this arrangement the bakelite rotors are of the form shown at C and D, respectively, Fig. 13, whilst the plane disc form of stator E fits on the opposite side of the rotors in both generators. In this construction the bakelite rotors produce sinusoidal variations in the dielectric between the corresponding concentric conducting rings of sinusoidal contour on the stators, and the stator discs. For example, a generator for providing two low frequencies consists of a rotor such as A, revolving between a stator C and a disc E. By connecting the conducting rings on one stator C to the appropriate excitation potentials through suitable resistances and switching circuits, and the other stator disc E to the grid circuit of the amplifier, voltages of sinusoidal waveform may be generated.

Systems have also been proposed by Curtis, Estell Scott and Biggs involving the use of electrostatic generators to modulate the high-frequency currents produced by valve oscillators. Subsequently, the modulated high frequency is passed through a detector stage, and the audio-frequency component amplified. The advantages claimed for this system are that the construction of the rotary generator is extremely simple, the signal/noise ratio practically infinite, and amplification problems simplified. As keying and mixing of high frequencies can be accomplished through small condensers, it is proposed to use such methods to avoid key contacts and mixing circuits. By using different high-frequency carriers, the frequencies for several manuals could be supplied from the one rotary generator, via suitable filter circuits.

Frequency Generators—Mechanical Considerations

In the case of rotary forms of generator there are many mechanical problems to be surmounted. In all rotary systems, whether photo-electric, electromagnetic, or electrostatic, the accuracy of pitch depends on the accuracy of rotation of the generator rotor. According to the particular system employed, one of two general forms of drive will be necessary.

Where all the 12 semitones within the octave are derived from one disc, cylinder, or group of generator rotors on one shaft, each successive shaft will need to be driven at twice the speed of that providing the frequencies for the octave below, so that the gear ratios in this case are simple ones. The accuracy of the musical pitch will obviously depend on the number of scanning elements or generator poles provided for generating each semitone, and on the constancy and actual speed of the rotational drive. For example, to take the case of a photo-electric scanning disc provided with slits radially engraved one fundamental wavelength apart in concentric rings, clearly if the intervals are to be those of the tempered scale to within 0.1 per cent. it will not be possible to use less than a predetermined number of slits in each ring. This will

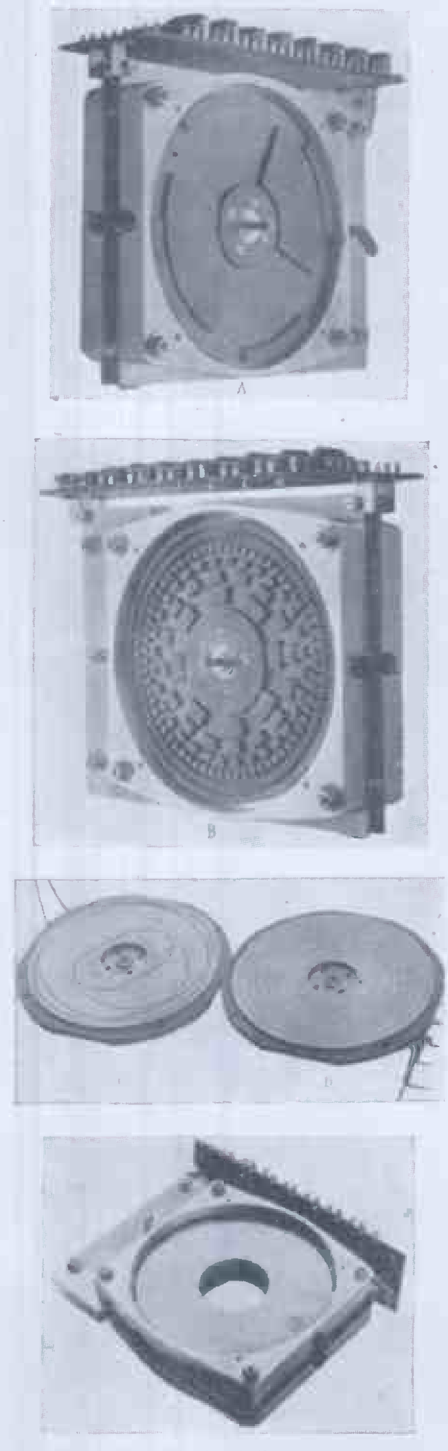


Fig. 13. Electrostatic generator—partially assembled components.
A and B—**Bakelite rotors exposed.**
C and D—**Stators with sinusoidal contours.**
E—**Disc stator.**

Practical Construction

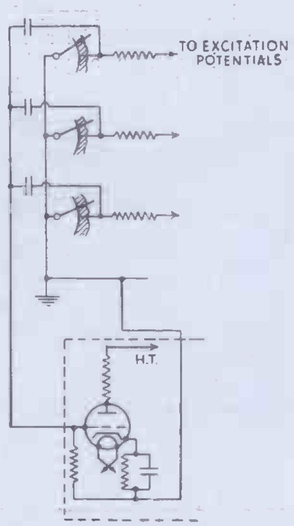


Fig. 14. Circuit arrangement for electrostatic generator with brush connection in earthed lead.

automatically determine the actual speed of rotation of the disc for a given musical pitch.

In the alternative form, the fundamental frequency and all its harmonics are derived from one disc, cylinder, or group of separate note generators all carried on one shaft. The semitones are provided by driving 12 such generators, or sets of generators, at speeds progressively increasing in the ratio $1 : \sqrt[12]{2}$. The accuracy of the pitch of the semitone intervals will therefore be governed by the gear ratio employed.

Even if precision-made clock gears are used in the drive from the synchronous motor, irregularities in speed will occur. However, it has been found that by the use of carefully designed mechanical filters these speed variations can be damped out.

One example of a 96-note electromagnetic generator is shown in Fig. 15. The picture shows the synchronous-motor drive with its mechanical filters on the left. On the top of the generator housing are the components of the electrical filter circuits which are necessary in order to eliminate the unwanted harmonics in the generated currents, the waveform of which is only approximately sinusoidal. The mechanical filter in the drive will be seen adjacent to the synchronous motor. This comprises a spring-driven flywheel to reduce hunting, followed by a spring drive to the first counter shaft on which is mounted the driving gears for the first set of rotors. The drive to the rotors is then taken via a small hair-spring so that any non-uniformity due to backlash or imperfections in the gears is damped.

Mixing Circuits

In the various generating systems, methods must be devised for combining the many frequencies generated, and in this connection it is necessary to take into account the relation between the sensation of loudness at different frequencies and the radiation intensity.

In considering the circuit arrangements for producing equal steps in loudness of the tones produced, the energy steps must be in geometrical ratio in accordance with Weber's law which states that " Equal increments in intensity of sound as interpreted by the ear are increments which bear a definite relationship to the intensity of sound before the increment."

In addition it may be well to bear in mind that when considering the circuit arrangements for producing a given

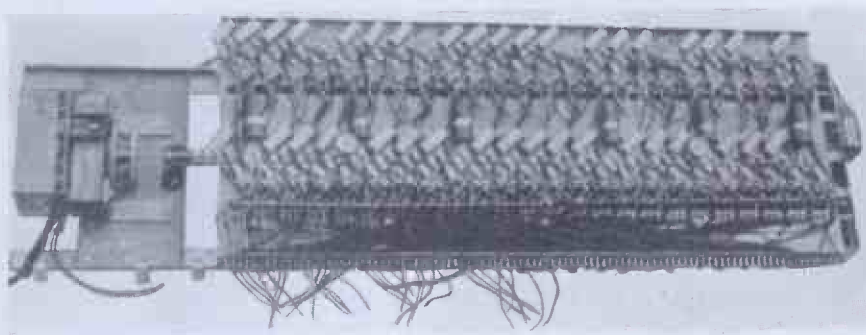


Fig. 15. Assembly of 96-note electromagnetic generator. Mechanically damped synchronous drive (on left) ; components of filter circuit (on right).

summation of energies, the voltages or currents involved must be proportional to the summation of the square root of the energies.

The methods of mixing fall into three general groups. In the light scanning methods used in photo-electric types of organ, the problem of mixing is an optical one. The components of the many individual scanning elements must be so arranged that the modulated light beams are all collected on to one photo-cell, or a small group of photo-cells. Many methods have been proposed, and Fig. 6, which has already been referred to, is an arrangement used by Toulon, requiring one photo-cell per octave, i.e., 8 photo-cells in all. These photo-cells are connected in a parallel network and thence to the input circuit of a power amplifier and loud-speakers. In general, in the generator, systems classified under (C) (a), (b), (d), (e) and (f) (ii) in the table in which either complex or sinusoidal waveform audio frequencies are generated and

(*Continued on page* 380)

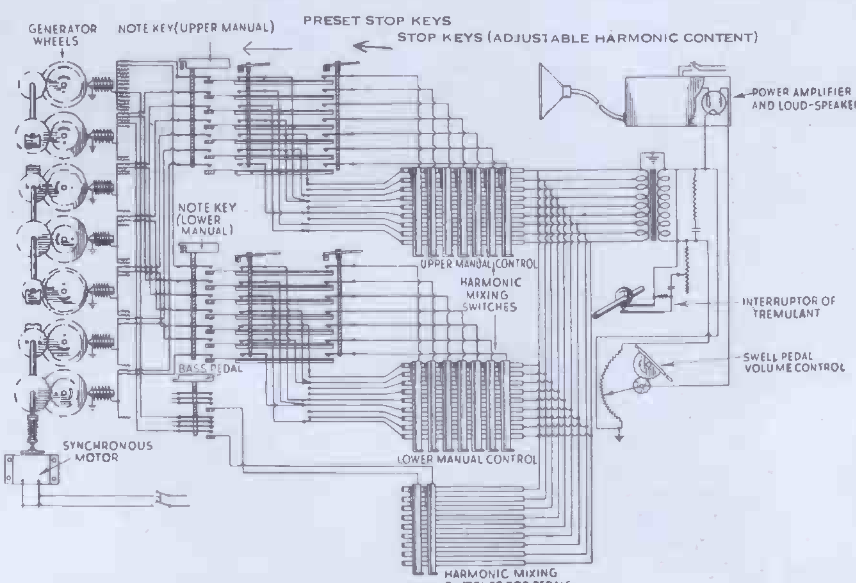
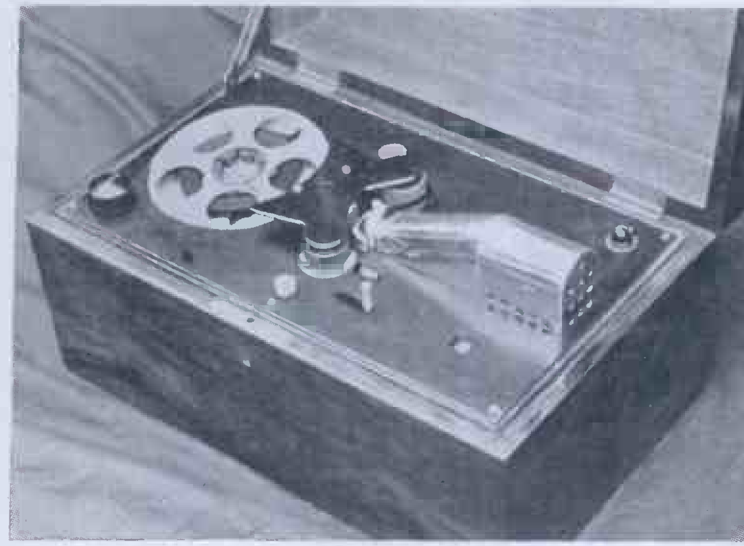


Fig. 16. Form of circuit of an electronic organ utilising electromagnetic generators of the type shown in Fig. 8.

A NEW FILM GRAMOPHONE

One-and-a-half hours' playing from one film



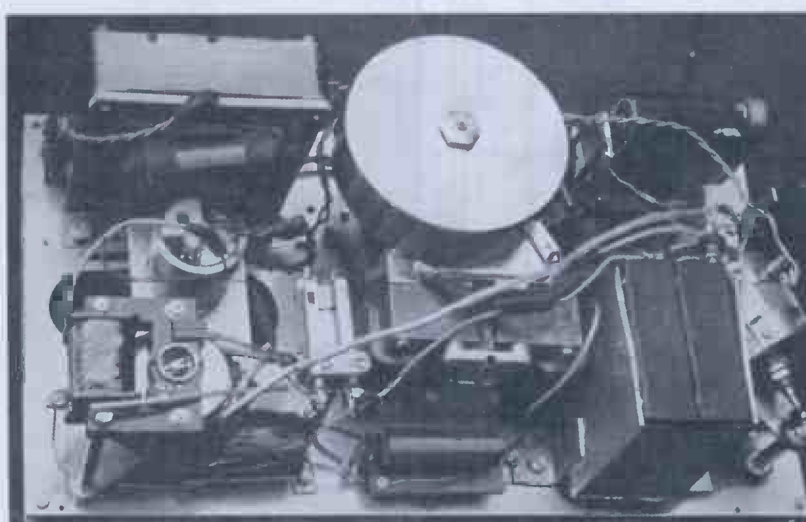
THE demand for complete and uninterrupted reproduction of music and speech is undoubtedly great and technicians have therefore devoted a considerable amount of attention to the problem. Present-day gramophone records do not meet this demand because the playing-time is only three minutes or so, and even with an automatic record-changer the continuity is broken. Gramophone records are also subject to considerable wear, particularly when needles of the semi-permanent type are used as is essential with the automatic type of machine.

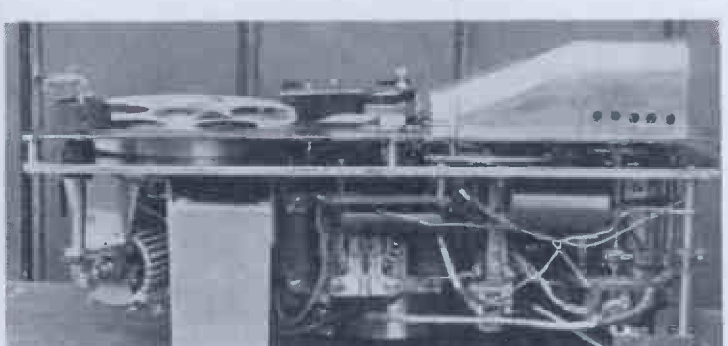
One solution of the problem of a long-playing gramophone is by the use of film. A new type of apparatus, shown by the photographs, has been developed which uses a continuous band of film carrying four sound tracks. The playing time of each spool is, therefore, about one and a half hours. One track after another is utilised automatically in rotation or any track can be selected at will by the touch of a press button.

The entire apparatus consisting of driving and track changing mechanism and photo-cell and lamp can be built into a box 14 in. by 9 in. by 7 in. This, therefore, is a complete unit and a plug point is provided to couple the output to any existing radio set or amplifier.

The apparatus obviously has many applications besides amusement in the home, as for instance, at public gatherings and for educational purposes. The principles utilised in the film gramophone are not new although many improvements in this apparatus are novel, notably the manner in which the film in the form of an endless strip feeds from its centre and re-winds round the periphery of the roll simultaneously, so that the film always remains in a rolled up state except for a few inches of free film passing through the cell mechanism. With this ingenious arrangement there is no winding of the film necessary after playing.

Another ingenious scheme is the transfer from one sound track to another which, as stated before, can be effected at any instant by pressing of a button. When all four sound tracks have been played, that is to say, when the film in its entirety has passed through the cell mechanism four times, the whole process repeats itself automatically until the apparatus is switched off. This is secured by the use of four photo-cells which are of the small barrier-layer type, one being used for each sound track. The change-over, therefore, is entirely electrical and does not involve any change in the positions of either film or cells, a matter of considerable importance owing to the very fine limits necessary.





These two photographs show the underside of the film gramophone. The large white disc in the upper picture is the motor flywheel.

The film with which the apparatus was demonstrated had been recorded from a standard gramophone record with the aid of an ordinary pick-up and even under these circumstances the results were excellent. The film had also been run well over a thousand times and yet there were no signs that any detrimental wear had taken place.

The inventor is Wender, of the Electro Physical Laboratories, and the light cells used are the barrier-layer type manufactured by that company.

Design Considerations of

The Augetron Secondary-emission Multiplier

By the Technical Staff of Vacuum Science Products, Ltd.

In recent articles in this journal, the Augetron characteristics have been published, giving readers an accurate idea of Vacuum Science Products thermionic electron multiplier. This article explains how a particular type of construction was arrived at.

IN secondary emission tubes, the primary electron stream emitted by a thermionic cathode may be directed on its successive targets by magnetic or even by correctly adjusted electrostatic fields.

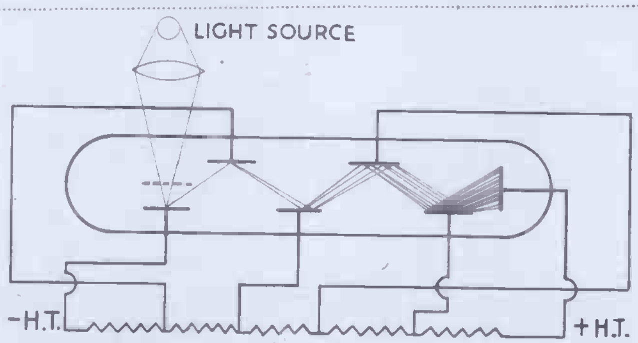


Fig. 1. The Slepian type secondary-emission multiplier.

In designing commercial electron multipliers, which have to be made to a fixed standard with definite characteristics, all the problems of alternative construction of secondary emitting cathodes have been studied including investigation of the Slepian type and the Zworykin type, of which schematic representations are given in Figs. 1 and 2, in which electron paths are shown. Several variations of either type have been evolved with relative claims to higher efficiency.

The electron beams have to be guided and directed by magnetic fields, and although improvements have been made in designs of magnets to create these magnetic fields, it constitutes, nevertheless, a serious handicap, and we have, therefore, to abandon a higher possible efficiency with a high specific secondary emission co-efficient, for a more simple and reliable, but slightly less efficient method. It should be borne in mind that for commercial purposes, replacement should be made easy, while it should at the same time, offer to the user the greatest possible simplicity, and the use of magnetic fields is definitely a handicap in this direction.

Three other methods are possible :—

(1) The electrostatic direction of the electron stream, such as is applied by Philips and Mullard in their single-stage secondary emission valve.

(2) The concentric arrangement of secondary emitters round the central cathode, as adopted by Zeiss in Germany.

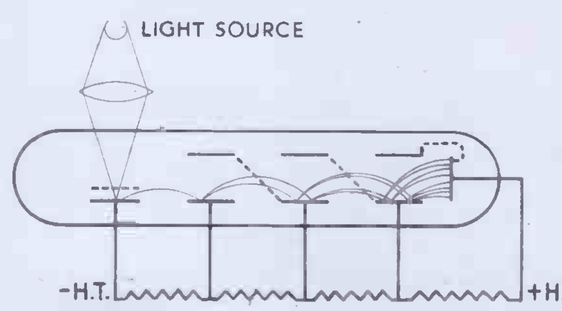
(3) The disposition of the secondary cathodes behind each other and made pervious to the electron stream, as adopted by Weiss, and Baird Television in this country.

(1) In this case, the complication of the electrostatic fields required, limit the number of stages, besides which, extra care has to be taken to prevent poisoning of the secondary emitter by the primary cathode. In the case discussed here, the electrostatic direction of the primary electron stream was arrived at after it was found that, experimentally, a secondary emission cathode, built concentrically round the cathode could be covered entirely with a monomolecular layer of barium oxide in forty hours, thus making it impossible from the commercial aspect, where a much longer life is anticipated from a thermionic valve. It is not proposed to discuss the merits of secondary-emission co-efficients, input impedance, slope, etc., of this particular valve as they are outside the scope of this present article.

(2) Various people have been working on the idea of putting the secondary cathodes concentrically round the cathode and making the secondary cathodes out of grids, thus pervious to the electron stream. The Germans first applied for patents for this form, which has many disadvantages, such as evaporation of the coating material of the primary cathode. In the case of barium oxide coated cathodes, the secondary emitters are poisoned. In the case of other oxides, such as caesium oxide, the life of the cathode is very short. Recently, however, the Germans improved this construction and placed a double series of louvres between the control grid and the first secondary emitter. This has the advantage of shielding the primary cathode from the secondary emitter and of allowing electrons to pass which have a definite velocity. However, the first series of louvres lose their efficiency rather quickly because here again they get coated and the efficiency of the tube drops rather abruptly when the first louvres become secondary emitters. Also there are other limitations such as frequency response, etc., which make research in that direction not worth while.

(3) The disposition of the secondary cathodes behind each other, such as in the Weiss and Baird types, we found to be the most practicable, because it allowed us to build a secondary emitter structure which was independent of the primary emitter, and we could thus concentrate on building thermionic guns with a high slope, which, with the addition of the secondary emitter, results in the output slope, given in preceding articles. Many details, such as frequency response in relation to structure have been discussed in the past

Fig. 2. The Zworykin-type multiplier.



One advantage claimed for Vacuum Science secondary emitters over the grid system adopted by Weiss is that the anode current can be of the order of 10 milliamperes without injuring in the slightest either the secondary emitters,

(*Continued in 1st col. of next page*)

News Brevities—

Commercial and Technical

A STATEMENT has now been issued by the Post Office regarding the use of radio equipment in dealers' vans. This is as follows:—

"Apparatus which can be used only for the purpose of amplifying speech and music and comprises a microphone, low-frequency amplifier, record player and loudspeaker(s) is not considered to be 'wireless receiving apparatus.' Consequently, the Postmaster-General, as at present advised, would not regard such public address apparatus as covered by the provisions of the Defence Regulation provided that the vehicle carrying it does not, at the same time, carry apparatus which could be readily used to convert it into wireless receiving apparatus.

"The use of a wireless receiving set in a road vehicle in association with public address apparatus for the purpose of amplifying broadcast programmes would clearly contravene the regulation."

Another order requires that any person who had high frequency apparatus in his possession on June 28 that generates or uses a maximum output exceeding 10W at a frequency exceeding 10,000 C/S, or who acquires any after that date, must notify the police. The types of apparatus covered are:—Diathermy and electro-therapy apparatus using either valves or spark coils (frequently known as ultra-short wave, or short or long wave diathermy, surgical diathermy or therapy apparatus); high frequency furnaces; eddy current heating apparatus such as is used by valve and electric lamp manufacturers; testing oscillators with a high frequency output exceeding 10W.

* * *

The Electric Construction Co., Ltd., have recently issued a catalogue which gives comprehensive details of their range of metal rectifiers.

The E.C.C. metal rectifier is made in three distinct types, each with its own applications. The first group comprises metal rectifier battery-chargers for electric vehicles, the second battery-chargers for A.C. mains operation only, and the third oil-immersed rectifiers for plating and electrolytic work of all kinds.

The catalogue gives much valuable information, and readers who are interested should get in touch with The Electric Construction Co., Ltd., at their temporary address: Lamport Hall, Northampton.

* * *

Georg Wilhelm Alexander Hans Count von Arco, who founded the well-known German radio corporation Telefunken Gesellschaft in 1903, has died at the age of 71.

Count von Arco originated the idea for the German radio station at Nauen, near Berlin, and the credit for popularising radio broadcasting in Germany is largely due to him. Subsequently, his work resulted in the establishment of radio telephonic transmission between Germany and the rest of the world.

* * *

The Federal Communications Commission recently announced that in future frequency modulation stations will be licensed on the basis of coverage, rather than power; stations serving the same centre of population will be licensed to cover the same area, their power being adjusted to give the desired coverage.

* * *

When the National Republican Convention at Philadelphia was televised last month, American television entered the political arena for the first time. Two complete mobile television units were used for the transmission, which were described as the most elaborate television coverage ever given to a single event, and the programmes were relayed by coaxial cable to New York for broadcast over the N.B.C. transmitter in Manhattan.

It is estimated that a maximum audience of nearly 40,000 persons saw the transmissions, based on the belief that there were eight to ten persons to every television receiver.

* * *

Details of a direct-reading photo-electric densitometer appeared in a recent issue of the Journal of the Society of Motion Picture Engineers. The film to be measured is placed between the photo-cell and a circular neutral wedge rotated at 20 c.p.s. to which a scale is attached. The photo-cell output is fed to an amplifier which distorts it into a square wave, in which the times of current or voltage change mark, one, the change from maximum to minimum transmission of the wedge; and the second the time in the cycle when the light received by the cell equals a fixed value. At the moment of this second change a stroboscopic lamp is flashed, illuminating a reading on the rotating scale corresponding to the density of the test strip.

* * *

The applications of the photo-cell in the foodstuffs industries was the subject of a paper by A. Seymour in a recent issue of the *Electrical Times*.

In commerce the difference between one quality of rice and another consists mainly in the proportion of discoloured grains present, but as Mr. Seymour points out, since hand-sorting has never been commercially practicable, the mechanical and electrical method of sifting out the discoloured grains by a machine may have far-reading effects.

The machine described utilises the properties of a photo-cell and by an ingenious mechanical method, the grains emerge from the feeder in a single line at a speed of 5 ft. per second, and pass under the electric "eye." The perfect grains shoot straight forward into a tube leading downwards to a sack. Discoloured grains cause an electrical impulse which brings into action a jet of compressed air, sending them into another receptacle.

Examination of granulated sugars is more elaborate, as it includes a classification of the finished sugars for general appearance and an evaluation of the colour and turbidity of the sugar solutions.

Experiments with photo-electric apparatus have shown that good correlation exists between the appearance of a sample of granulated sugar and its reflectance relative to magnesium oxide. A specially designed optical system in the photo-electric apparatus permits measurements of the transmittancy of sugar solutions as well as of the reflectance of the sugar in granulated form, and numbers obtained from these data enable the expert to compare the relative merits of the samples.

* * *

Successful two-way radio contacts with the West base and WGEO in Schenectady, of the U.S. antarctic expedition, have now been established. Relatives and friends of expedition members are being invited to visit the

---

"The Augetron Secondary-emission Multiplier"

(*Continued from preceding page*)

the performance, or the life of the tube. The thermionic cathode operating at a maximum current of 10 microamperes, there is little danger of cathode evaporation with the consequent poisoning of the secondary emitters. This has also the advantage of a high signal-to-noise ratio, and coupled with a very low input impedance and low input and output capacity and the high possible anode current, without injury to the secondary emitters, definitely establishes the Augetron as a commercial thermionic secondary emission tube, presenting an advanced technique.

One objection which many users point out is the high voltage employed. This, however, is due to the fact that the tube is run at its maximum efficiency of secondary emission. If the use of a lower voltage was advocated there would result a drop in secondary emission co-efficient and a consequent drop in overall efficiency. We claim to have developed a thermionic electron multiplier commercially available, built to a definite performance and definite characteristics.

studio and actually talk with expedition members. Conversations, of course, depend upon reception of signals from the West base, but the first two have been entirely successful.

* * *

American television programmes have been successfully received 234 miles from New York. The receiver was installed in a liner travelling between New York and Bermuda, and according to N.B.C. engineers who were on board, images were held for a full hour without fading or distortion, in spite of the great distance.

Another record reception is also reported from America. An engineer living in Chicago, nearly a thousand miles from the television transmitter, managed to tune in both vision and sound programmes. Although the images faded after a few minutes, the sound was received for 16 minutes.

* * *

The capabilities of frequency modulation for purposes other than regular broadcasting are being steadily recognised in America, and this is borne out by the fact that two-way frequency modulation communication for emergency service is soon to be put into operation in Douglas County, Nebraska.

The new equipment will make it possible for officials to maintain constant, interference-free communication with mobile units patrolling different sections of the county.

Radio transmission of photographs via frequency modulation has also been successfully achieved in America. The photographs were received on a General Electric frequency-modulation home broadcast receiver after travelling 87 miles from Boston to Paxton and back again, and were almost duplicate reproductions of the originals. Largely eliminating static, frequency modulation cuts out the static distortion that has hitherto attended radio photo transmission.

An Essential for Long-distance Reception

WE are frequently asked what type of headphones we can thoroughly recommend for really good long-distance reception, and yet which are, at the same time, comfortable in wear and very pure in tone.

As is generally known, reception of long-distance short-wave stations is often inconsistent and many stations require very careful tuning before they can be heard with clarity. An efficient receiver is, of course, an important factor, but really sensitive phones are essential, and we have no hesitation in recommending Ericsson Supersensitive Headphones. Our experience with these has shown that they are very reliable and extremely efficient.

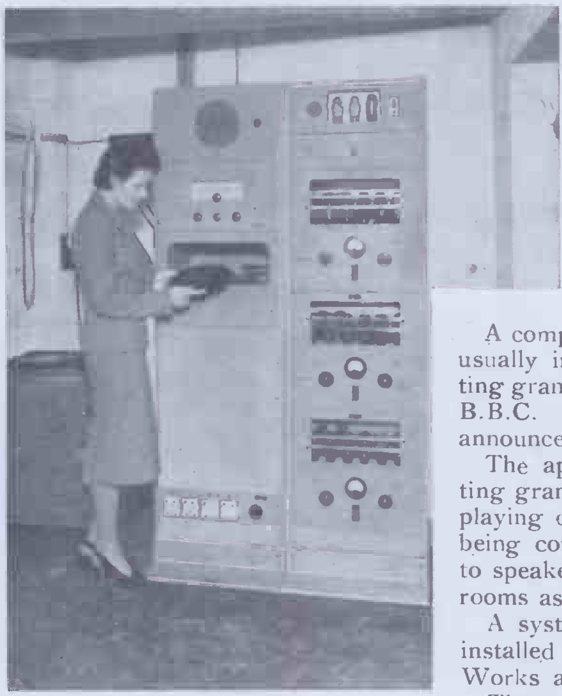
Apart from one small increase at the beginning of the war, the price remains unaltered. They are made in three resistances, 120, 2,000 and 4,000 ohms, the price being the same for each type.

* * *

Mr. F. Lewin, of 97 Bryant Road, Kettering, Northants, informs us that he has available back numbers of TELEVISION right from the first issue, which he is prepared to dispose of at a low figure.

Broadcast Music To Speed-up Production

Details of a Complete Installation



Radio, gramophone, amplifying and control equipment for a factory installation.

MANY tests have been made as to the percentage increase in production obtained in works when music is broadcast. According to Report No. 77 entitled "Fatigue and Boredom in Repetitive Work" made by the Medical Research Council Industrial Health Board, the average rise in production is usually not less than 6 per cent.

A complete installation of this kind usually includes provision for radiating gramophone music, broadcasting B.B.C. programmes, and general announcement facilities.

The apparatus required for radiating gramophone music consists of a playing desk and an amplifier, these being connected via a control panel to speakers placed in shops or workrooms as required.

A system of this nature has been installed at the Osram-G.E.C. Lamp Works at Hammersmith.

The processes in the majority of the production departments of this factory are concerned with the manufacture of radio valves and lamps of several categories. They are of the most pronouncedly repetitive nature, and are typical of the kind encountered in small part mass production.

The installation, besides providing gramophone music, comprises equipment that enables it to be used both for the diffusion of radio broadcasts, and for A.R.P. and other "announcement" purposes. Two microphones, two hundred and twenty speakers, amplifying apparatus, record-playing desk, radio and control panels are included.

Apparatus Used

The amplifying and associated equipment which comprises the system is situated in a control room which is deep in the heart of an underground part of the factory chosen for its invulnerability. At one end of this room, as can be seen from the photograph, the apparatus is mounted in convenient racks.

The amplifier has three 100-watt channels, taking the microphone, gramophone and radio inputs through a remotely controlled relay panel.

The remotely controlled relay panel allows appropriate switching from the telephone exchange or con-

(Continued on 3rd page of cover)

THE PHOTO-ELECTRIC CELL IN INDUSTRY

Photo-electric Control of Paper Registration

IN THE PRINTING INDUSTRY

By E. W. Forster, B.Sc., A.M.I.E.E.
British Thomson-Houston Research Laboratory

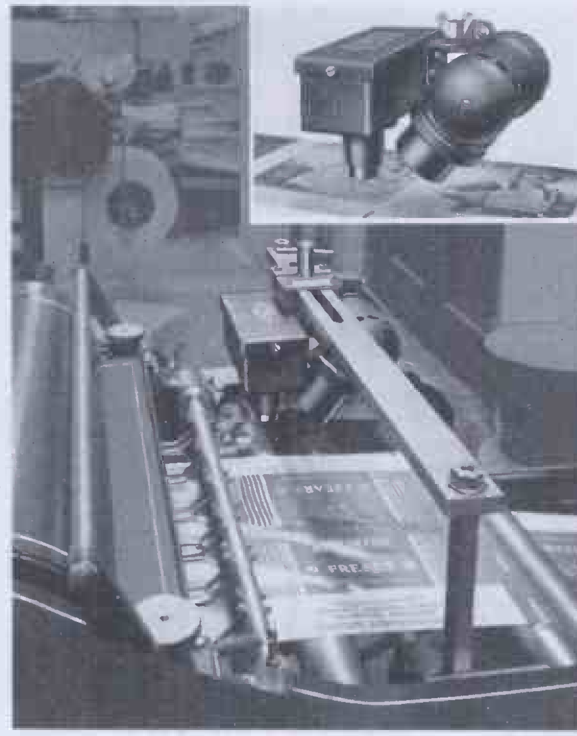


Fig. 1. Biscuit wrapping machine with (insert) photo-electric scanning head.

PHOTO-ELECTRIC equipment may be used to control the rate of feed and the position of a pre-printed web of material with respect to the operating cycle of a machine, using, or working on, this material. Typical applications are provided by packing machines, wrapping machines, paper bag making machines, and web insetters for printing presses.

In most cases draw rolls are used to pull the paper from the pre-printed roll and feed it into the machine where a knife or cutter or some other device performs the necessary operation on the paper web. It is necessary to maintain register between the design on the paper web and the operation being performed by the machine. For instance, on a wrapping machine each wrapper must be cut off in the same position (within limits) with respect to the design on the wrapper.

When the machine is started, the design on the web may be in register with the cutter, but any discrepancies in the gearing, diameter of draw rolls, slip at draw rolls, or stretch in paper will result in an accumulation of errors which will soon throw the web out of register after a few operations of the machine. An error of only 0.01 in. in the cut-off length becomes a total of 1 in. in 100 operations of the machine unless some means are employed to correct the position of the web, when the error amounts to the maximum which can be tolerated; usually something of the order of $\pm\frac{1}{8}$ in.

Detection of Error and Correction

On high-speed machines it is obviously quite impossible for an operator to make this correction by observation of the web and even at slow speeds it becomes a very tiring business. However, the detection of error and subsequent correction of web can be done automatically by photo-electric register control.

At the time that the design is printed on the webb a small register mark about $\frac{1}{4}$ in. by $\frac{1}{8}$ in. is also printed, usually in the margin where it is clear of other printed matter.

When the paper is subsequently passed through the machine which performs the necessary operation on it, the register mark passes through an area scanned by a photo-cell, and by illuminating this area, a change in photo-cell current is produced every time the mark passes the photo-cell. The photo-cell impulse is amplified by a valve amplifier which impresses a voltage impulse on the grid of one thyratron tube when the mark arrives late with respect to the cut, and on another thyratron when the mark arrives early. The

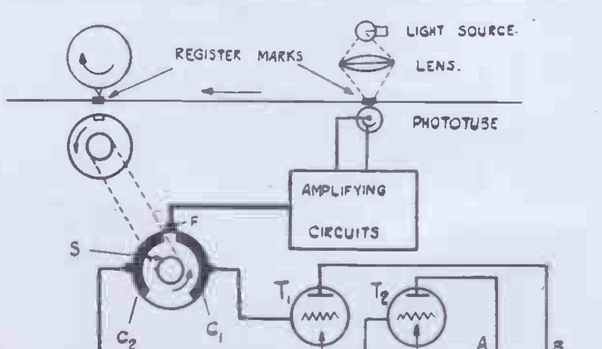


Fig. 2. Web in register. Photo tube impulse occurs when control circuits are broken; neither control circuit is energised.

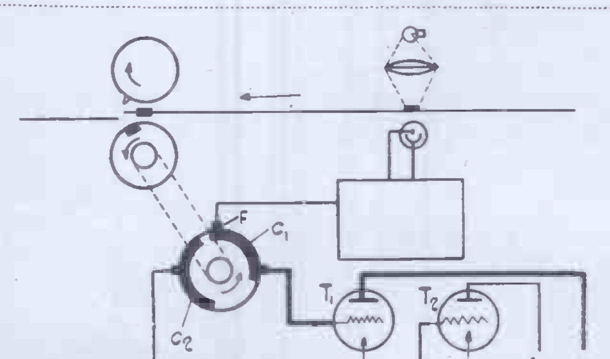


Fig. 3. Web running behind mean register position. Photo tube impulse is transmitted to T1 and circuit B is energised to advance web.

How the System Functions

thyratron is a gas-discharge valve in which an arc can be made to strike when its grid receives a positive voltage impulse even though the duration of this impulse is as short as 0.0001-second. Once the arc has struck the thyratron will remain conducting for any desired time interval.

Obviously, some means must be employed to differentiate between a web too far advanced and one too far retarded. By driving a two-circuit rotary switch from the cutter shaft, this differentiation may be achieved and Figs. 2, 3 and 4 illustrate diagrammatically the three conditions when the web is in register and out of register in a positive or negative sense. In the diagrams, S represents the rotary selector switch and T1 and T2 are two thyratrons; T1 energises circuit B to advance the web, and T2 energises circuit A to retard it.

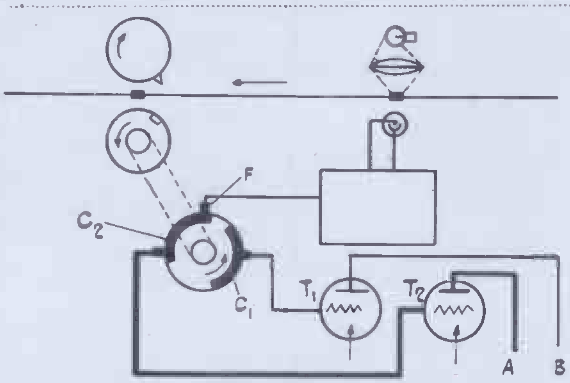


Fig. 4. Web running in front of mean register position. Photo tube impulse is transmitted to T2 and circuit A is energised to retard.

This two-way control is essential for high paper speeds; theoretical consideration and practical experience have shown that it is very necessary at high paper speeds, to give not only a space change to the web to bring it back immediately into register, but also a small permanent speed change. If a space change only is made it is conceivable that the rate of a accumulation of error may be greater than the rate at which corrections may be made since there is a definite limit not only to the amount of space change per correction, but also the permissible number of corrections per minute.

If a speed change only is made then the web will never settle down to a steady speed. When an error is detected the speed will be changed until the web is brought back into register. By this time, however, the speed will be incorrect, and before long speed changes in the opposite sense will be required. The web will, therefore, "hunt" continuously with an amplitude of the original error. For paper speeds up to approximately 50 ft. per minute as in the majority of wrapping and packing machines, it is permissible to arrange the amount of draw so that the requisite length of paper plus or minus a small fraction is drawn per operation. The respective systems are termed "overfeed" or "underfeed."

One-way control only is necessary for these systems. A single circuit rotary selector switch is required which connects the amplifier to the thyratron. The switch is driven off the cutter shaft in exactly the same manner as shown diagrammatically in Figs. 2 and 4, and it may be considered as switch S with only one segment C2, for instance. The thyratron may be considered as T2.

To take the case of a machine using the overfeed system, when the web is in register the photo-cell impulse occurs when segment C2 has passed brush F. Due to the overfeed, however, the mark will gain on the switch S and after a certain number of operations the impulse occurs when F makes contact with C2. Thyratron T2 conducts and the web is drawn back. This cycle repeats itself and another correction becomes necessary after approximately the same number of operations. To reduce the number of operations to a minimum the amount of overfeed should be made as small as possible.

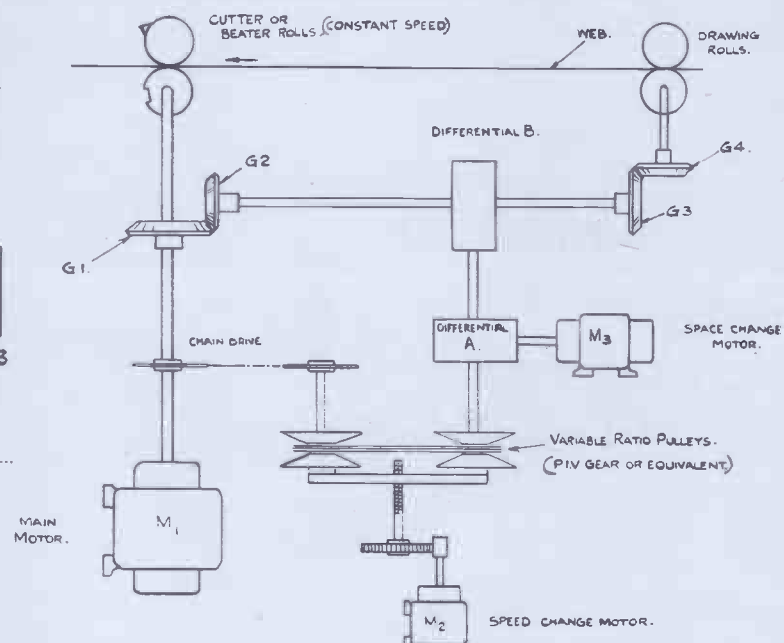


Fig. 5 Double differential system of paper register control.

Mechanical Equipment

The mechanical equipment required on the machine to effect the necessary speed and space change can be of various types, but it will suffice to describe briefly one or two arrangements.

In nearly every case a differential gearbox is required in the train of gears to the draw rolls. The gear ratio is chosen so that at least 98 per cent. of the power necessary to drive the draw rolls is supplied from the main drive. The remaining 2 per cent. is supplied by the drive to the third member of the differential gearbox.

Fig. 5 illustrates one arrangement. M1 is the main driving motor, and differential B is interposed in the drive to the draw rolls. Neglecting differential A for the moment, the third member of B is driven from the main drive. The variable ratio gearbox, however, is only required to supply about 2 per cent. of the total power delivered to the draw rolls.

When a correction is made the permanent speed change is effected by running motor M2 for the correcting period. This alters the ratio of the gearbox and the draw rolls are given a small increase or decrease in speed.

The space change is produced by differential A, the third member of which is coupled to motor M3. M3 is also run for the correcting period and by so doing the draw rolls are given a temporary speed change in one direction or the other. Thus, the web is advanced or retarded slightly. The motors, M2 and M3, are, of course, quite small. This arrangement may involve the addition of differentials A and B, variable ratio gearbox, and motors M2 and M3.

Mechanical Equipment

Fig. 6. Photo-electric relay for single-way register control.

Another arrangement which does not require the addition of as much mechanical gear, but involves the use of more electrical equipment, is one in which differential B is retained, but a D.C. motor takes the place of differential A and the variable ratio gearbox. In addition to this motor a D.C. generator is employed which must be driven off some part of the main drive, and also a small 3-unit motor-generator set which can be placed in any suitable position. The D.C. motor normally obtains its supply from the generator, and the permanent speed change is brought about by varying the generator voltage. The space change is produced by boosting or bucking the generator voltage momentarily. This has the same effect as differential A in Fig. 5. Each case has to be considered on its own merits in order to decide which system will be the best.

The mechanical equipment required for wrapping machines, etc., where only a space change is given to the paper (i.e., one way control) is, of course, simpler. For instance, a differential gear as B in Fig. 5, may be used with the difference that the third member would normally be stationary and only rotated momentarily in one direction when a correction is made.

A motor or a pawl and ratchet wheel could be used for this purpose. The pawl, which would be power driven by the machine, would be allowed to engage with the ratchet wheel whenever a correction was necessary. A solenoid can be used for this purpose.

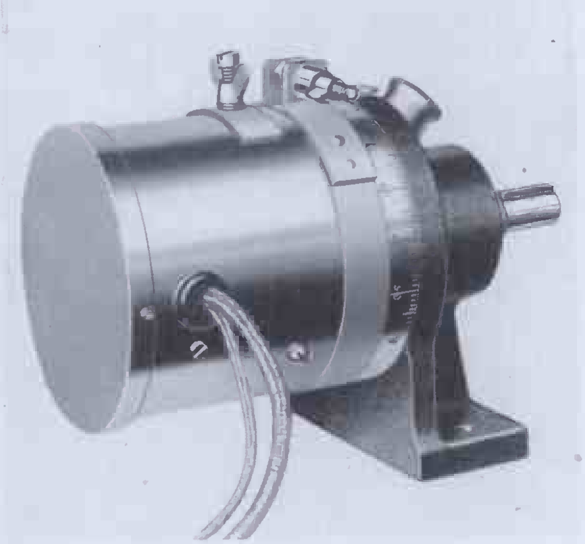


Fig. 7. Rotary selector switch for photo-electric paper register control.

Register Control Equipment

Fig. 6 shows a photo-electric relay. The photographs Figs. 6-9 show register control equipment made by The British Thomson-Houston Co., Ltd., suitable for applications where a one-way correction only is required. The contactor may be used for controlling an external solenoid for the purpose of making a correction, or if desired the thyratron may be used to energise this solenoid direct. For this purpose it should be noted that the maximum pressure and current available is 180 volts, 0.06 amp. This limitation is determined by the rectifier.

The scanning head houses the photo-cell and when reflected light is used, the projector lamp is mounted on the side of the head. For thin waxed papers and cellophane, transmitted light is preferable, in which case the lamp may be mounted on the opposite side of the web. The photo-cell and lamp heads are connected to the thyratron panel.

A single circuit rotary selector switch, Fig. 7, is necessary, and this is connected between the amplifier and the thyratron. It is also necessary to open the anode circuit of the thyratron after the latter has become conducting in

(Continued in third column of page 357)

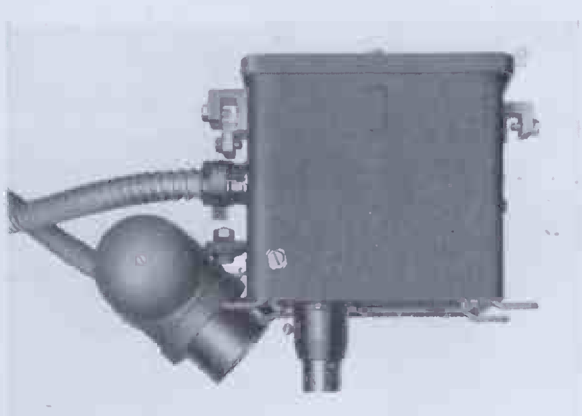


Fig. 8. Scanning head for photo-electric control equipment.

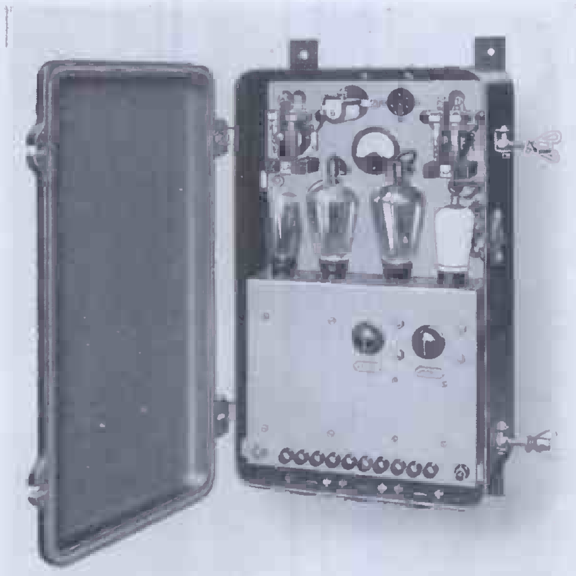
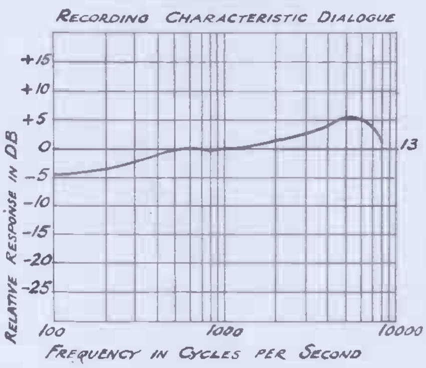


Fig. 9. Thyratron panel for two-way register control.

Frequency Characteristics of Film-recorded Sound—Part II (Conclusion)

This is the concluding instalment of the article by R. Howard Cricks, F.R.P.S., discussing the factors which affect the frequency characteristics of film-recorded sound.

In considering the requirements of the recording frequency curve, many factors have to be taken into account. A number have been already considered, and the net effect is to fix a virtual limitation of the response curve to the range from 50 to 8,000 c.p.s.



[Courtesy S.M.P.E. Journal.

Fig. 10. Subjective recording curve.

The recording amplifier therefore embodies a network system whereby the over-all frequency curve may be adjusted to the particular theories of the recordist. Separate high-pass and low-pass filters are provided with individual adjustments, so that independent control can be obtained of the high- and low-frequency portions of the curve, and a bump or a dip can be added at any point. Great importance is placed on the numerous types of networks used, and in fact a recently published American textbook on recording devotes about half its space to the subject.[7]

Starting with the microphone, the most popular types give a peak round about 3,000 or 4,000 c.p.s., which is generally retained or only slightly varied, to improve speech intelligibility. One factor that has recently been realised is that all these networks, containing inductive and capacitative elements, introduce a certain phase distortion, and excessive "doctoring" of the microphone characteristics is to be avoided.

Dialogue Equaliser

The so-called "dialogue equaliser" serves the purpose of attenuating the low frequencies for speech recording only. Two reasons given for the use of such an equaliser are that studio sets are generally more reverberant at the lower frequencies, and that microphones are generally more directional at the higher frequencies, and thus pick up excessive reverberation at the lower frequencies.

Other factors which have to be considered are the high-frequency losses due to the various causes already discussed; any special characteristics necessitated by reason of the fact that many tracks have subsequently to be re-recorded for the purpose of adding music or background noises; the limitations of printing and processing; and finally the reproduction characteristics, in particular average auditorium acoustics.

Notwithstanding the recent attempt by the American Academy of Motion Picture Arts and Sciences to standardise reproducer frequency characteristics, recordists have all their pet theories as to the type of curve that is desirable. In particular, they are apt to favour a curve which complements the customary characteristics of the reproducer system installed in their own preview theatre (generally of the same make as their recorders); thus it can often be noticed that R.C.A. recordings have more bass than Western Electric, because Western Electric speakers tend to give more bass than R.C.A. (This statement, incidentally, is denied by manufacturers and recordists, but I have proved it by listening tests over a number of years).[8]

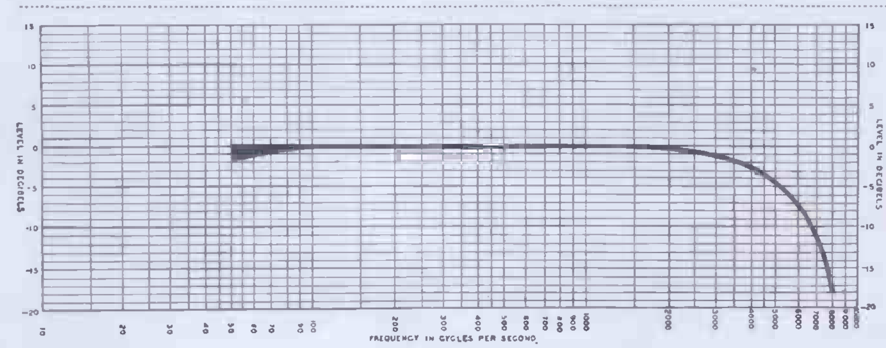
Averaging out the wide divergencies that exist between the preferences of various recordists, the tendency is towards a curve rising from 50 to 300 cycles, having a slight hump at about 2,000 or 3,000 cycles of perhaps 3 db., and tailing off to about −18 db. at 8,000 cycles.

Physiological Factors

A study has recently been made at the Bell Laboratories of an aspect of sound reproduction which, while applicable in many spheres, is of particular interest in the kinema—the physiological and psychological reactions of an auditor towards reproduction. As a result, certain modifications have been suggested in the customary recording characteristic, which are illustrated by the curve of Fig. 10. This curve is described as "subjectively flat," since it represents the requirements for apparently level response in the ear of the listener.[9]

A physiological phenomenon of some importance is that the frequency sensitivity of the ear varies appreciably according to the loudness of the sound. It is common observation that as a sound increases in intensity, it becomes more "boomy," and, in general, the louder the sound, the more accentuated the bass appears.

Research has been carried out on this subject at the Case School of Science in America, and has resulted in the production of an automatic frequency-discriminating volume control system which serves to adjust the frequency characteristic of the reproducer to suit the varying characteristic of the ear at different loudness levels.[10]



[Courtesy A.M.P.A.S. Bulletin.

Fig. 11. Typical reproducer response curve.

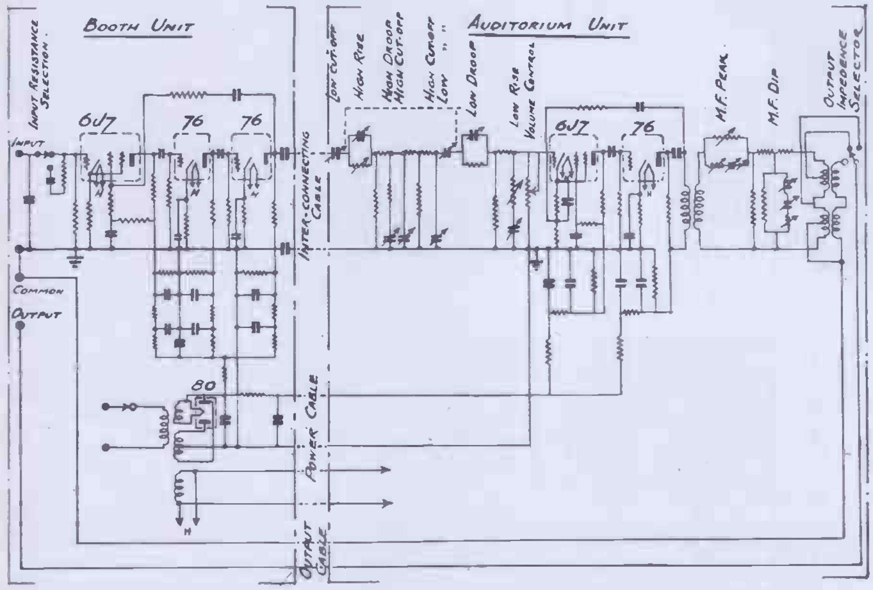
Mention should also be made in this connection of some valuable physiological data recently recorded by Dr. A. F. Rawdon-Smith, of Cambridge University, in which he suggested that an extension of the now possible frequency range was of less importance than other factors, notably improved transient response, improvements in acoustics, and—an advance which he predicted would prove outstanding—stereophonic reproduction. One suggestion of some importance was that reproducer distortion not exceeding 2 per cent. or 3 per cent. second and third harmonics at maximum output will, provided this maximum output corresponds to a loudness level of not less than 80 phons to the listener, be completely masked by the 10 per cent. or more second and third harmonic distortion for which the ear is responsible.[11]

Reproduction Frequency Characteristics

To a very large extent, all the operations in the production of a finished sound track, up to the point where it reaches the kinema, are capable of more or less accurate control by qualified technicians. Studio acoustics, the characteristics of the various electrical components, the results of laboratory processing, all can be brought and maintained within suitable tolerances to ensure the production of a satisfactory sound track. The number of studio productions to-day which contain really poor sound is very small.

But the last and most vital link in our chain is the one most susceptible to variation : the kinema auditorium. From the small show, converted from a chapel or public-hall, to the old-time theatre—from the modern news-theatre to an up-to-date super-kinema—every conceivable acoustic characteristic is encountered. Consequently, reproducing systems need to be capable of a wide variety of frequency response characteristics.

The Academy of Motion Picture Arts and Sciences some time back prepared a series of curves for various types of installations of which Fig. 11 is an example. The recommendations specify : "These characteristics are valid for measurements made at the output of the power amplifier, including the low-pass filter, with a resistance equivalent to the speaker load, using the Academy Research Council Standard Multi-frequency Test Reel (corrected), and are subject to modifications to fit special acoustic conditions which exist in many theatres, due to the fact that the reverberation time or other acoustic characeristics are not optimum."



[Courtesy S.M.P.E. Journal.

Fig. 12. Circuit of adjustable equaliser.

A tolerance of ±1 db. up to 3,000 cycles, increasing progressively with frequency to ±2 db. at 7,000 cycles is the maximum permitted. "Wherever such conditions exist that the particular characteristic recommended does not give satisfactory results it is recommended that the acoustic characteristics of the auditorium be corrected."[12]

The latter is, of course, a counsel of perfection. While an acoustic correction of an auditorium may be quite an expensive matter, a modification of the frequency curve of the reproducer, which in many cases is a fairly satisfactory expedient, can be made when the equipment is installed, or subsequently in the ordinary course of the service engineer's duties. Actually, innumerable small theatres have no acoustic treatment other than perhaps the use of curtains to stop reflections from the back wall, and it follows that the installation engineer is required to do his best to compensate for the poor acoustics by adjustment of the reproducer.

As a result, specimen curves of reproducers as finally adjusted vary enormously. What happens in practice is that a reproducer set, pre-adjusted to correspond approximately with the Academy recommendations, is installed in a kinema, and its characteristics modified as the installation engineer may think fit.

He may find that, while with a full house speech comes over well, with a small audience it is too reverberant, and consequently he has to cut the bass.

In order to overcome these practical difficulties, an American servicing company has designed an "adjustable equaliser," by means of which nine adjustable equaliser sections can be controlled actually from the auditorium. The sections are designated as low-frequency rise, low-frequency droop, low-frequency cut-off, mid-frequency peak, mid-frequency dip, high-frequency rise, high-frequency droop, high-frequency cut-off No. 1, high-frequency cut-off No. 2. The various sections can be switched in and out by dials in the auditorium, and when the best of the many millions of possible combinations has been selected, it can be set permanently on the reproducer.[13]

REFERENCES.

7. *Motion Picture Sound Engineering* (Chapman and Hall)
8. *Ideal Kinema*, Dec. 1936, p. 43 : Feb. 1937, p. 48.
9. *J.Soc.Mot.Pic.Eng.*, June 1939, p. 631.
10. ,, ,, ,, Jan. 1940, p. 59.
11. *J.Brit.Kine.Soc.*, July 1940, p. 109.
12. *A.M.P.A.S.Bull.*, Oct. 10, 1938.
13. *J.Soc.Mot.Pic.Eng.*, April 1940, p. 351.

"Photo-electric Control of Paper Registration"

(*Continued from page 355*)

order to render the tube non-conducting in preparation for the next impulse. Some form of switch driven by the machine is necessary for this purpose.

Equipment suitable for high paper speeds where two-way corrections are necessary is shown by Figs. 8 and 9. The scanning head (Fig. 8) in this case houses not only the photo-cell but also the amplifier. This arrangement permits of short leads between the photo-cell and the amplifier, which is essential as at high paper speeds the photo-cell impulse may be as short as 0.0005 second.

The thyratron panel (Fig. 9) houses the thyratrons, rectifier, time delay relay and contactors. In this case a time delay relay determines the duration of the correcting period by automatically opening the thyratron anode circuits after the latter have become conductive. The duration of the correcting period is adjustable. The rotary selector switch may be driven by a gear train or chain, but it is necessary to reduce backlash to a minimum in whatever drive is used.

If reversing contactors for two-phase or three-phase motors are required, a separate contactor panel is connected to the thyratron panel.

THE REDUCTION OF LOSSES IN SHORT-WAVE RECEIVERS

By O. J. Russell

THE harmful effects of electron transit time upon valve performance were discussed in the June issue. This effect sets a limit to the effective input impedance of the valve. Thus at 60 megacycles the input impedance of a typical valve is of the order of 5,000 ohms.

As there is no difficulty in constructing conventional tuned circuits having far greater dynamic impedance than this (and with the use of concentric line and other systems extreme values of dynamic impedance may be obtained) the damping introduced by the low input impedance of normal valves is extremely serious from the point of view of both amplification and selectivity. Even at a frequency of 15 megacycles the effect of finite transit time is already becoming noticeable with normal valves.

A partial solution of the problem is obtained by tapping the grid of the R.F. amplifier valve down on the tuned circuit. This may be regarded as matching the input impedance of the valve to the dynamic impedance of the tuned circuit. Thus to take a simple case, with a valve of input impedance of 5,000 ohms, and a tuned circuit of 20,000 ohms dynamic impedance, an appreciable gain in both selectivity and sensitivity would be obtained by connecting the grid half-way down the tuning coil. Connection of the grid to a lower tapping point than this would increase selectivity, but decrease amplification.

Inductance Effects

Serious as the effect of low input impedance is, it is still not generally realised that the effects of inductance are equally serious. The inductance of leads is serious in the case of by-pass circuits, as the inductance increases the impedance of the R.F. path to earth. Furthermore, the by-passing capacitor may have an appreciable inductance itself. The ceramic type of capacitor is in general to be recommended for by passing functions upon the shortest wave bands.

It should be noted that the inductance of the by-pass leads together with the inductance of the condenser, form with the by-pass capacity, a series tuned circuit. When the capacity of the condenser is such that the series circuit is resonant at the frequency operation, the impedance to earth is at a minimum, and consequently the by-passing action is most effective. No more effective by-passing will be obtained by increasing the capacity of the by-pass condenser.

If it is assumed that the inductance of the by-pass path is equivalent to an inch of wire, the by-pass capacity at 10 metres works out at .001 mfd. For the normal short wave bands this value is quite satisfactory. It is important to remember however that if two equal inductances are parallel connected, the effective inductance is halved, the law for paralleled inductances being similar to that for paralleled resistances. This offers a possibility of decreasing inductive effects by using multiple by-pass connections. Moreover if by-passing action is required over a wide waverange, the large by-pass condensers for the higher wavelengths may be shunted by the smaller capacities appropriate for the lower wavebands. A further application is seen in a new type of valve provided with multiple cathode connections, for the purpose of decreasing the effective inductance of the cathode lead.

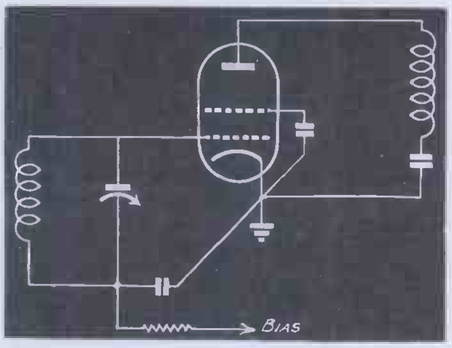


Fig. 2. A more effective arrangement with the earth returns taken to the cathode pin.

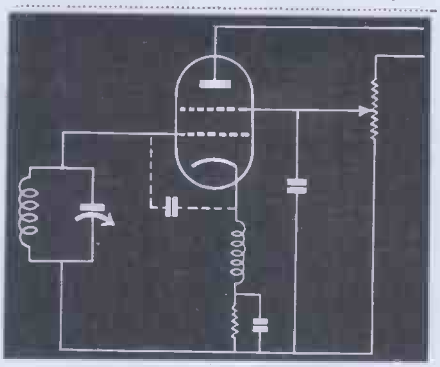


Fig. 3. A regeneration circuit providing increased H.F. gain.

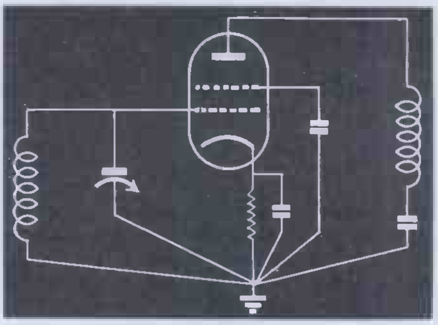


Fig. 1. Central earthing arrangement.

Cathode Lead Inductance

The inductance of the cathode lead reduces the input impedance and gain of the valve due to the degenerative feedback introduced. The loss of amplification due to this cause may be even more serious than the effects due to the electron transit time. It is essential that the cathode-to-earth path should be of the lowest possible inductance.

In the more recent types of valve construction the length of the leads from electrodes to the valve pins has been reduced substantially. In order that the effects of cathode lead inductance be reduced to the minimum it is desirable that the cathode be directly connected to earth, and bias obtained by battery, or by tapping the grid at a point of suitable negative potential. The inductance of a resistor and condenser for auto bias may be too high for efficient operation upon the lowest bands.

The inductance of the cathode-to-earth path is reduced to the utmost minimum when the cathode pin is made the common earthing point for the stage in which the valve is being used. It should be pointed out that the superior results given by the later types of valves is due not to any important reduction in the transit time of the electron stream, but rather to the considerable reduction in the length, and hence in the inductance of the leads from the electrode system of the valve to the contacts in the base. It is interesting to note that the old top cap grid construcion has been largely dropped, in the interests of shortening leads, and compactness of the electrode structure.

The modern type of valve base, such as the Loctal, and E series side-contact base, together with the older octal base, are especially suitable for compact arrangement of the by-pass components, more especially if the cathode pin is adopted for the common earthing point. In Fig. 1 is reproduced the cen-

(*Continued on page 360*)

The Gasfilled Tetrode

By G. Windred, A.M.I.E.E.

This article deals with the operating characteristics of the particular type of grid-controlled rectifier having a second grid. The addition of this grid imparts several valuable properties to the device, which must be regarded as an important member of the family of electron tubes.

THE application of grid control to gasfilled rectifiers created a very wide sphere of use for these tubes, variously known as thyratrons, grid-glow tubes, gasfilled relays, grid-controlled rectifier tubes, gas triodes or gasfilled triodes, according to origin.

Although it may be said that the full possibilities of application have by no means been fully realised, there are many cases in which the use of the grid-controlled rectifier has permitted the development of highly efficient control systems and even rendered possible the solution of problems which could not have been solved otherwise in a practicable manner. The advent of the double-grid rectifier or gasfilled tetrode, which is a comparatively recent development, has still further increased these advantages and widened the scope of practical application.

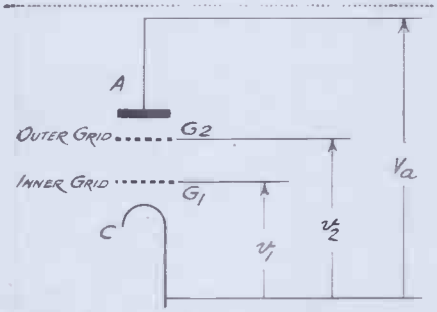


Fig. 1. Electrode arrangement and voltage designation for gasfilled tetrode.

The electrode arrangement of the gasfilled tetrode is similar to that of the vacuum tetrode, and is shown diagrammatically in Fig. 1, where the various electrode potentials are also designated.

The electrode potentials in a double-grid rectifier combine as in the case of a multiple-grid vacuum valve to give a resultant potential in the plane of the grid lying nearest the cathode. The magnitude and direction of this potential determine the magnitude of the electron current from cathode to anode and thereby control the striking of the arc across this path. Striking occurs when the resultant potential exceeds a definite critical value in the positive direction with reference to the cathode for a given value of anode voltage.

The outer grid, or shield grid, protects the inner or control grid from the effects of the electrode material sputtered or evaporated from the cathode. The discharge through the tube is also protected from extraneous charges which may collect on the tube walls. The grid system closes all cathode-to-anode paths except for electrode clearances, so that close control is exercised upon the arc and the arc path.

The presence of two grids offers the possibility of changing the grid control ratio of the tube, representing the slope of anode striking voltage to critical control grid voltage. For the so-called trigger applications, where the tube discharge is either on or off and control of the average anode current is not required, this feature is not very important, but in the case of anode current control by phase-shift of the applied grid voltage it is very often desirable to be able to change the grid control characteristic. This is particularly the case when there is little or no control over the available amplitude of applied grid voltage.

The curves in Fig. 2 represent typical alternative characteristics obtained from the same tube by connecting either the inner or outer grid to the cathode, so that v_1 or $v_2 = 0$, and using the other as the control grid. It will be seen that with the inner grid to cathode the control characteristic is moved so as to require less instantaneous anode voltage for striking with a given grid voltage, which means that a higher negative grid potential is required to prevent conduction with a given anode voltage. From the curves it will be seen that in this case the grid-control ratio is about 42, whereas with the inner grid controlled and the outer connected to cathode the ratio is about 130.

If required, different potentials may be applied simultaneously to the respective grids, in which case the control characteristic is determined by the resultant grid potential and is therefore a function of both these voltages. Fig. 3 shows a typical static grid control characteristic, measured with D.C. on both grids and the anode, for two values of anode voltage. A limit to the magnitude of the positive grid volttage which may be applied is formed by the possibility of a grid-to-cathode discharge, which would disturb the normal functioning of the tube.

Important Possibilities

Interesting and important possibilities are offered when separate alternating voltages are applied to the respective grids. In the typical case represented in Fig. 4 the voltage v_1 on the control grid is 180° out of phase with the anode voltage, V_a, whereas for v_2 the phase angle is 90°. If V_a and v_2 are kept constant while v_1 is varied in amplitude with constant phase position it is possible to vary the striking point through practically the entire range of the positive half-cycles of anode voltage. Further possibilities are introduced by independent variation of the magnitude and phase of the respective grid voltages. The point of striking, and hence the average value of anode current, may thus be made to depend upon the relationship between two controlling voltages. A still further alternative is represented by one grid supplied with D.C. and the other with A.C.; either or both voltages being variable with respect to magnitude, and the latter also with respect to phase position if desired.

An important function of the second grid when used as a shield grid is to protect the control grid from the effects of transients in the anode circuit. Such transients can be very troublesome in the case of the conventional single-grid tube, and may necessitate the use of special smoothing arrangements. In the double-grid tube the shield grid also protects the control grid to some extent from the effects of heat radiated from the anode, cathode and arc stream. This has the effect of reducing disturbances due to secondary emission.

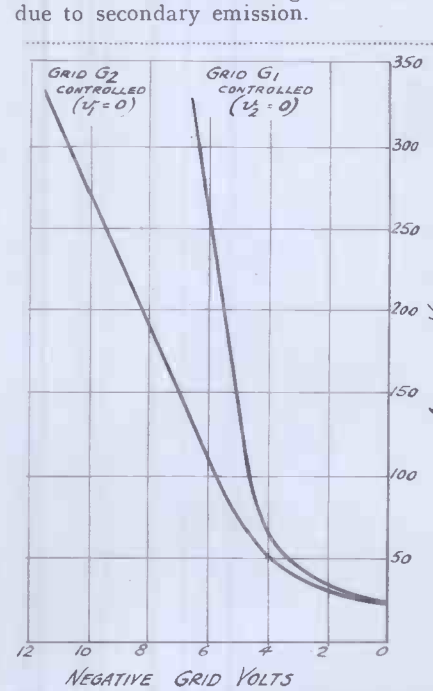


Fig. 2. Characteristics corresponding to alternative connection of inner or outer grid to cathode.

Gasfilled Tetrode Uses

Advantages

The advantages of the gasfilled tetrode in comparison with the conventional grid-controlled rectifier may be summed up as follows:

1. Much less grid current is required for striking the tube, so that high impedance control circuits may be employed.
2. The grid control characteristic of a given tube may be changed to suit specific requirements by the use of appropriate shield-grid potentials.
3. Alternative grid control characteristics may be obtained in a given tube by using one or other grid as the control grid.
4. By using independent control voltages on the respective grids it is possible to make the point of conduction, and hence the anode current, a function of two independent signals. This control may be obtained by varying the phase or amplitude of the control voltages.
5. The action of anode circuit transients upon the control grid are reduced by the presence of the shield grid.
6. Secondary emission from the control grid is reduced by the heat-shielding effect of the shield grid.

It is evident that the double-grid tube has very important advantages for many applications, and it is probable that when its capabilities become more widely known it will become a valuable addition to the range of electronic devices available for the use of engineers

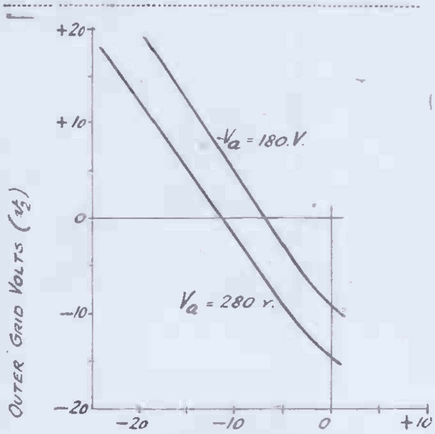


Fig. 3. Critical grid voltage characteristic with D.C. on both grids and anode.

concerned with the development of special methods of electrical control. It will be realised, of course, that for the great majority of applications the single-grid rectifier offers all that is necessary. It is for the more unconventional applications that the double-grid tube is more suited.

The new type of tube does not appear to have received a great deal of attention in this country, although the principle has been incorporated in rectifiers of fairly large size. With regard to small tubes the R.C.A. gas tetrodes 2050 and 2051 are of interest, and brief particulars are given in the accompany-

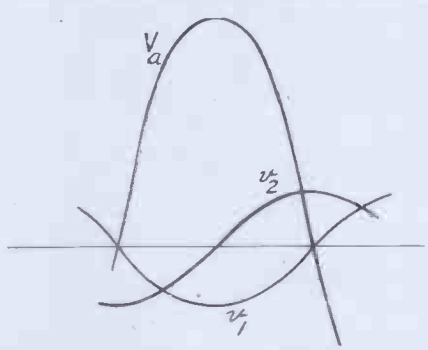


Fig. 4. Typical phase relationships between independent alternating grid voltages and anode voltages.

ing data. As an example of the sensitivity of these tubes arising from the high permissible grid circuit resistance it may be mentioned that they may be operated directly from a photo-electric cell without the use of an amplifying valve.

RCA GAS TETRODES
2050 and 2051

Hot cathode type Heater ..	Coated unipotential cathode.
Voltage	6.3 (A.C. or D.C.).
Current	0.6 amp.
Direct interelectrode capacitance Grid to anode ..	0.2 mmf.
Preheating time	10 seconds (minimum).
Overall length	4⅛" (max.)
Diameter	1 9/16" (max.).
Bulb	ST-12.
Base	Small shell octal 8-pin.

GRID-CONTROLLED RECTIFIER SERVICE

	Type 2050	Type 2051
Peak forward anode volts	650 max.	350 max.
Peak inverse anode volts	1300 max.	700 max.
Shield grid (No. 2) volts ..	0	0
Peak anode current (mA.)	500 max.	375 max.
Average anode current (mA.)	100 max.	75 max.
Arc drop volts, approx. ..	8	14
Grid resistor (megohms) ..	0.01 min. 10 max.	0.01 min. 10 max.
Grid control ratio (negative grid region) approx. ..	230	230

"Reduction of Losses in Short-Wave Receivers"

(*Continued from page* 358)

tral earthing scheme shown last month, while Fig. 2 illustrates the even more effective arrangement, in which the cathode pin becomes the point to which the earth returns are taken.

As already stated the inductance of several leads in parallel is reduced as with resistances in parallel. It should be noted also that the inductance of a large diameter wire is less than a smaller wire. While the use of large wire is impracticable, thin strip copper may be conveniently employed for the wiring of H.F. stages for low waveband operation. In multi-stage assemblies, it should be remembered that while each stage may be earthed to a single point for stability, the connection from one earthing point to the other, may have appreciable inductance, which may introduce difficulties. It has in general been recommended that each stage be earthed separately, with a single connection between the stages, each stage being mounted upon a sheet of copper. For minimum inductance of the lead joining the two or more stages a connecting busbar of strip metal has been recommended. The most satisfactory solution would seem to be the mounting of stages back to back upon sheet metal, with a single wire joining the stages.

By the correct use of a large inductance in the cathode lead, the feedback becomes positive, and regeneration results. Fig. 3 shows a type of circuit employing regeneration for the purpose of increasing H.F. gain. The choke is a normal S.W. type, for operation upon the normal S.W. bands. The screen voltage is applied via a potentiometer to provide a control of regeneration. In some cases smoothness of control is aided by increasing the grid-to-cathode capacity by connecting a small ceramic condenser of from 2 to 10 micro-micro-farads from grid to cathode.

Although regeneration in the H.F. stage enables losses due to insulation and other reasons to be overcome, it is essential that the insulation materials should be of the best possible types such as the new synthetic polystyrene class. The insulation resistance of inferior insulators under the influence of H.F. actually fluctuates, presumably due to electron bombardment effects, with the result that spurious noise effects are introduced and deterioration of the signal-to-noise ratio. This factor does not seem to be so generally recognised as it should be. It is frequently alleged that the use of regeneration results in a deterioration of the signal-to-noise ratio. Actually, the use of regeneration results in an improved signal-to-noise ratio, as the selectivity of the tuned circuit is vastly increased. It need not be stressed that the use of the very best insulating materials is essential in all radio-frequency equipment, whether regeneration is employed or not. Regeneration is unfortunately not able to overcome the deleterious effects of cheap and faulty insulation, at least as far as spurious noise is concerned.

A RECORD OF PATENTS AND PROGRESS

RECENT DEVELOPMENTS

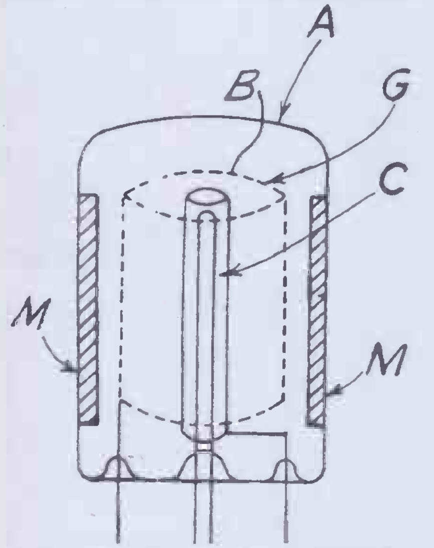
PATENTEES

Telefunken Ges für Drahtlose Telegraphie m.b.h. :: M. von Ardenne and Siemens and Halske Akt. :: A. F. Burgess :: Marconi's Wireless Telegraph Co., Ltd. :: Kolster-Brandes Ltd., and C. N. Smyth :: Belling and Lee Limited and F. R. W. Strafford (Drawing) :: Automatic Signal Corporation.

Short-wave Generators

(Patent No. 517,526.)

Very short waves, extending into and beyond the infra-red part of the spectrum, are generated by bombarding selected materials by high-speed electrons. The action is similar to the known process of producing visible waves from a fluorescent screen by electronic bombardment, as in a cathode-ray television receiver, except that, in the present case, the waves generated are considerably longer.



Short-wave generator, Patent No. 517,526.

As shown in the Figure, the electrons liberated from an indirectly-heated cathode C are accelerated by a grid G towards an anode A which is coated with a special layer M capable of liberating waves of the desired frequency. The layer M is made of a selenide or telluride of zinc, cadmium, or mercury mixed with metallic copper, silver, or cadmium, according to the particular wavelength required. The oscillations so produced may be modulated by inserting a second grid between the cathode and anode. The indirectly-heated cathode C may be replaced by a spark-discharge electrode, in which case the containing tube is gas-filled.—*Telefunken Ges für drahtlose Telegraphie m.b.h.*

Electron Microscopes

(Patent No. 518,951.)

The object to be examined is placed in the track of a scanning beam of electrons having a diameter of less than the thousandth of a millimetre. The electrons passing through the object, or those diffracted, diffused, or reflected by it, are then re-focused upon a photographic film, so as to form a magnified image of the object, or of its crystalline or other structure.

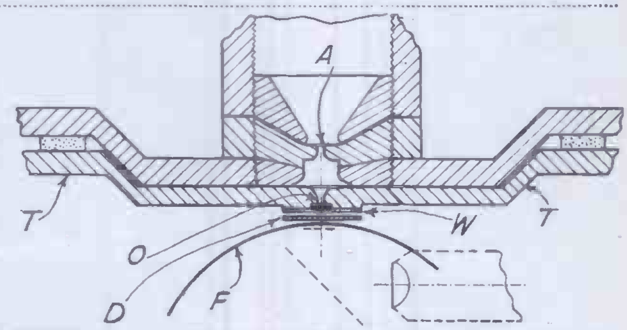


Diagram of magnetic lens for electron microscope. Patent No. 518,951.

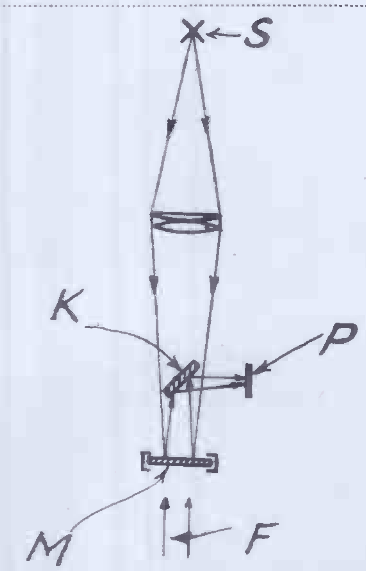
The drawing shows the construction of the magnetic lens inside the cathode-ray tube which forms the electron microscope, together with the aperture A through which the scanning stream of electrons passes on to the object O. The latter is placed on a thin plate W of collodion, which is cemented to the outer wall T of the cathode-ray tube, and forms a "Lenard window" to allow the passage of the scanning electrons on to a photographic film R, where the image is recorded. A diaphragm D, with an adjustable aperture, is placed between the colloidion "window" and the film F. The object O can be mounted on the outside surface of the colloidion plate, if it is desired to examine it in free air.—*M. von Ardenne and Siemens and Halske Akt.*

Photo-electric meters

(Patent No. 519,417.)

Purely mechanical forces, such as stresses and strains, are measured by using them to cause a change in the brightness of a reflecting surface. The resulting change is indicated by a photo-sensitive cell, so that no undesirable inertia effects are involved at any stage in the process.

In the drawing, the force to be measured is indicated by the arrows F, which are applied to bend or "arch" a small membrane M. A ray of light from a source S is focused upon the diaphragm, so that any change in its effective surface due to the arching causes a corresponding change in its surface brightness. This change in brightness is measured by diverting the reflected rays by a mirror K on to a photo-electric cell P.—*A. F. Burgess.*



Method of measuring electric strains by means of photo-cell. Patent No. 519,417.

Electron Multipliers

(Patent No. 520,117.)

The secondary-emission electrodes of a multiplier tube are made substantially L-shaped in cross-section, and are arranged in two rows, one above and the other below the main axis of the tube. The limbs of the electrodes overlap each other in such a way that the secondary electrons (emitted when a ray of light strikes against the photo-electric cathode) are " shepherded " between them, and so made to follow a zig-zag path through the tube. In this way, they strike each target electrode in succession, until the amplified stream is collected by the output electrode.

Owing to the shape of the electrodes, this path is followed without the necessity of having to use any auxiliary focusing means. Another advantage is that any positive ions which may be liberated, when the main stream strikes against the targets, are collected by the longer limbs of the L-shaped electrodes, and are so prevented from " choking-up " the tube, or affecting the straight-line response required between input and output.—*Marconi's Wireless Telegraph Co., Ltd.*

Scanning Control

(Patent No. 520,235.)

Provision is made in a television receiver (a) for simultaneously adjusting the horizontal and vertical sweep of the scanning voltages, so that any desired part of the picture can be enlarged, or shown as a close-up, on the screen, and (b) for centring different parts of the picture on the screen.

For magnifying the image, the output from the " framing " amplifier is controlled by a potentiometer in its grid circuit, whilst that from the line amplifier is controlled by a reverse feed-back resistance in its cathode circuit; both these controls are ganged together for simultaneous operation.

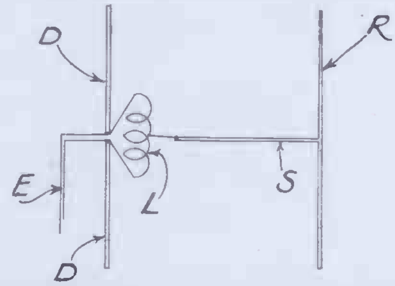
For centring any required part of the picture, two auxiliary deflecting-coils are provided. These are connected in a bridge circuit so that they carry no current during the normal operation of the set. When desired, they can be independently energised, through a single control, for bringing any selected part of the picture to the centre of the fluorescent screen. —*Kolster-Brandes, Ltd.*, and *C. N. Smyth.*

Television Aerials

(Patent No. 520,628.)

An aerial, of the dipole-and-reflector type, is arranged so that it can be used for receiving either television signals, or the medium and long-wave broadcast programmes, at will. In the latter case, the spacing-rod between the dipole and reflector, as well as the reflector itself, both serve as capacity loading, and separate down-leads are used for the two types of signal.

Alternatively, as shown in the Figure, the dipole D, D1 and reflector R are coupled together through a coil L having a low impedance to medium and long wavelengths, so that the whole unit, including the spacing rod S and reflector R, serves to pick up the ordinary broadcast programmes and feed them to the set through the down-lead L.



Dipole aerial for reception of television and broadcast programmes. Patent No. 520,628.

For television frequencies, however, the coil L acts as an effective choke, and the signal pick-up is confined to the dipole D, assisted only by the re-radiation effect of the reflector R. In this arrangement, the same down-lead E is used in both cases.—*Belling and Lee, Ltd.*, and *F. R. W. Strafford.*

Traffic Detectors

(Patent No. 521,339.)

It is well known that when a body containing iron or steel passes through a magnetic field, it provides a better passage for the flux than ordinary air. The field is therefore momentarily strengthened and an electromotive force is generated. This principle is used to detect the passage, say, of a motor-car along a road, and to cause it to operate traffic lights automatically.

A pair of magnetised iron bars are laid down, just below the surface of the roadway, and spaced a few inches apart. The magnetic field spreads above the surface and is momentarily strengthened by the iron in the wheels and chassis of a passing car, thus producing a voltage " kick." This is used to operate a relay and so record the passage of the vehicle, and, if necessary, to operate signalling lights. By arranging the windings of the magnetised detector unit in series opposition, the device can be arranged to respond only to vehicles travelling in one direction and not in the other. If necessary a thermionic amplifier is used to amplify the initial voltage impulse, induced by the passage of the car.—*Automatic Signal Corporation.*

Summary of Other Electronic Patents

(Patent No. 513,776.)

Cathode-ray dispersion screen made of alkali-halide crystals for projecting a televised picture on to a viewing screen located outside the C.R. tube.—*Scophony, Ltd.*, and *A. H. Rosenthal.*

(Patent No. 513,810.)

Volume control for adjusting the gain of the radio and intermediate-frequency amplifiers in a television receiver.—*The General Electric Co., Ltd.*, and *D. C. Espley.*

(Patent No. 513,984.)

Method of scanning and synchronising in which the line and the frame impulses are distinguished by differences in the " slope " of each leading edge.—*Hazeltine Corp.*

(Patent No. 514,304.)

Four-terminal network for coupling the valves in a wide frequency-band amplifier, suitable for television.—*Marconi's Wireless Telegraph Co., Ltd.*, and *N. M. Rust.*

Rotary Convertors

There is at the present time a steadily increasing demand for small power rotary convertors both of the D.C./A.C. and D.C./D.C. types. The uses of this class of machine are many, particularly for radio, amplifiers and public address systems. A very complete range is manufactured by Chas. F. Ward, of 46 Farringdon Street, with outputs from 60 to 250 watts.

The machines are of particularly sturdy construction and embody modern scientific principles of design. Commutators and slip-ring assemblies are of unusually heavy build, giving long life, and trouble-free commutation.

Both double wound and single wound armatures are available, the former being most suitable for radio applications.

Prices range from £9 to £15 according to output and type, and designs are available for a very full range of input and output voltages.

Separating Sync. Pulses and Picture Signals in Television Receivers

Details of a New Scheme

IN present-day television systems, it is the practice to transmit a composite signal consisting of picture signals and synchronising pulses of different amplitudes. At the receiver it is necessary that the synchronising pulses be separated from the picture signals and that these pulses only be applied to the horizontal and vertical deflecting circuits. Various circuits for obtaining this separation have been devised but good separation is difficult because of variations in amplitude of the incoming signals. This difficulty could be overcome by utilising an automatic volume control circuit having a sufficiently flat characteristic, but the use of such a circuit would be unduly expensive.

An alternative solution to this problem is the use of two synchronising impulse-separating circuits connected in cascade through an amplifier, the design being such that the first separating circuit functions only as an amplifier for signals of low amplitude, while complete separation is effected by the second separating circuit. For signals of comparatively high amplitude, however, the first separating circuit effects partial separation and prevents overloading or saturation of the amplifier connecting the two separating circuits whereby the synchronising pulses are not removed from the signal reaching the second separating circuit.

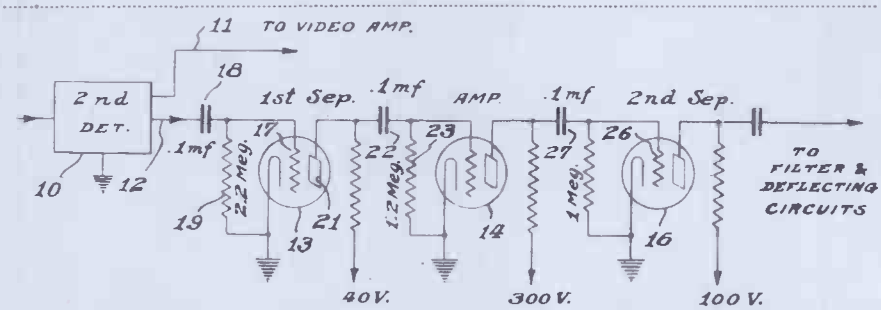


Fig. 1. Part of television receiver circuit employing two sync. pulse separating circuits in cascade

Fig. 1 shows a portion of a television receiver circuit embodying a form of this type of separating circuit. The video signal, comprising picture signals and synchronising pulses, appears in the output circuit of a second detector indicated at 10 and is supplied via a conductor 11 to the video amplifier and cathode-ray tube and via a conductor 12 to the separating circuit.

The separating circuit comprises a first separating valve 13, an amplifying valve 14 and a second separating valve 16. In this particular arrangement, the two separating circuits are of the same known type, each one having synchronising impulses of positive polarity impressed thereon and being biased by means of the flow of grid current.

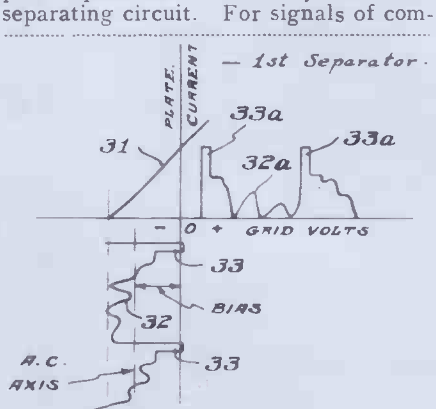


Fig. 2. Grid voltage-current characteristic of first separator valve.

The separating valve 13 may be a triode as illustrated or it may be of a type including more grids, such as a pentode. The signal is applied to the grid 17 of the valve through a grid condenser 18. A grid leak resistor 19 is provided having sufficient resistance to prevent the grid condenser from discharging a very substantial amount between the occurrence of successive frame-frequency synchronising pulses.

A lower anode voltage than normal is applied to the anode of the valve to cause anode current cut-off to occur at a less negative grid voltage than otherwise would be the case.

The output of the valve 13 is applied to the amplifying valve 14 through a coupling condenser 22. A grid leak resistor 23 is provided which preferably has such resistance that the time constant of the circuit including it and the condenser 22 is less than the time constant of the preceding circuit comprising grid condenser 18 and resistor 19 for a reason which will be explained later.

Normal anode voltage is applied to the anode of valve 14 and though this valve is shown with zero bias, actually there is a negative bias on the grid during operation due to a grid leak biasing action. The amplifying valve 14 need not be of a type which will take a wide grid voltage swing without distortion.

The second separating circuit is of the same type as that described above. The synchronising pulses appear in the anode circuit of the amplifier 14 with a positive polarity and are impressed upon the grid 26 of valve 16 through a grid condenser 27. A grid leak resistor is given sufficient resistance to make the grid condenser hold over most of its charge between successive frame synchronising pulses. At the same time, its resistance is such that the time constant of the circuit including it and the condenser 27 is less than the time constant of the corresponding circuit for the preceding valve. Thus, from the input to the output of the complete separating circuit the time constant of the grid condenser-grid leak resistor circuit is decreasing in value.

The voltage applied to the anode of valve 16 is preferably below rated voltage, but may be higher than the voltage applied to the anode of the first separator valve.

The operation of the circuit will be apparent from the following discussion of the circuit action under two conditions, first, for an incoming signal of small amplitude, and, second, for an incoming signal of large amplitude.

Referring to Fig. 2, the grid voltage-path current characteristic of the valve 13 is shown at 31. An incoming signal of comparatively small amplitude is shown at 32-33, the picture signal portion being indicated at 32 and the line synchronising pulses being indicated at 33. It will be apparent that under these

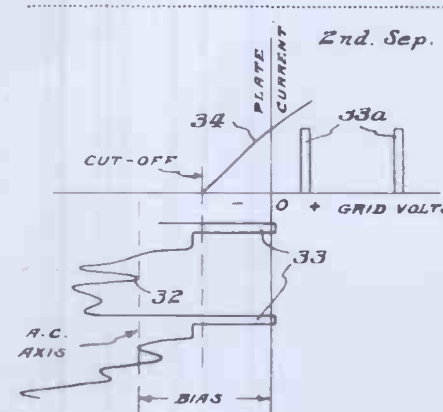


Fig. 3. Grid characteristic of second separator valve.

conditions the valve 13 is acting as an amplifier, its output being indicated at 32a-33a. Its output is further amplified by the valve 14 whereby a signal of sufficiently large amplitude for good separation appears on the grid of the second separator valve 16 as shown in Fig. 3.

In Fig. 3 the grid voltage-anode current characteristic of the valve 16 is shown at 34. The input signal 32-33 has sufficient amplitude to cause only the synchronising pulses to appear in the anode circuit of the valve as indicated at 33a.

From an inspection of Figs. 2 and 3,

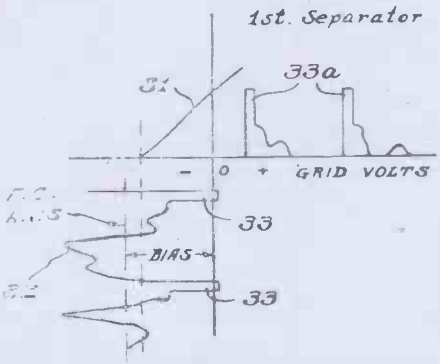


Fig. 4. Curve showing increased bias on first separator valve.

it will be seen that the grid bias of a separating valve increases with an increase in the amplitude of the applied signal, although there is either little or no separation at the first separating valve under the condition assumed.

Now considering the second condition of operation where the amplitude of the incoming signal is large, it will be seen from Fig. 4 that the signal 32-33 of increased amplitude has caused the bias on the grid of separator valve 13 to increase. Partial separation of synchronising pulses and picture signals

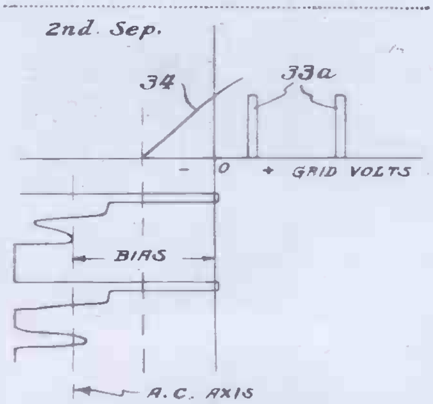


Fig. 5. Diagram showing how complete separation is obtained.

occurs, the signal appearing in the anode circuit of the valve 13 being as shown at 32a-33a.

The output of valve 13 is amplified by valve 14 and applied to the separator valve as shown in Fig. 5. Complete separation is provided by this second separating circuit as shown at 33a-33a.

From the foregoing, the importance of applying signals of substantial amplitude to a separating circuit for obtaining good separation will be appreciated. It might appear at first glance that satisfactory separation would be obtained by employing an ordinary amplifier in place of the first separating circuit. This is not the case, as will be evident from an inspection of Fig. 6, where the grid voltage-anode current characteristic of the amplifier valve 14 is shown at 36. It is assumed that an incoming signal 32-33 of large amplitude has been applied to the grid of valve 14 without any separating action in a preceding valve. Obviously, some or all of the synchronising pulses will be clipped or wiped off and the resulting signal 32a appearing in the anode circuit of the valve will be worthless for synchronisng purposes.

On the other hand the signal applied to the valve 14 under the conditions just assumed is the signal 32a-33a. It is apparent that this signal may readily be amplified by a valve such as the valve 14 without distortion or clipping of the synchronising pulses.

The difficulty illustrated by Fig. 6 could be avoided by employing a valve designed to give an undistorted output with a wide voltage swing on its grid. This, however, would be attained with lower amplification and thus insufficient signal would be available on weak input signals.

As previously mentioned, the grid condenser-grid resistor circuits of the several valves should preferably have time constants of decreasing values. It has been found that this feature gives the overall circuit a better low-frequency response.

An alternative arrangement illustrated in Fig. 7 comprises a first separating valve 41 having a cathode resistor

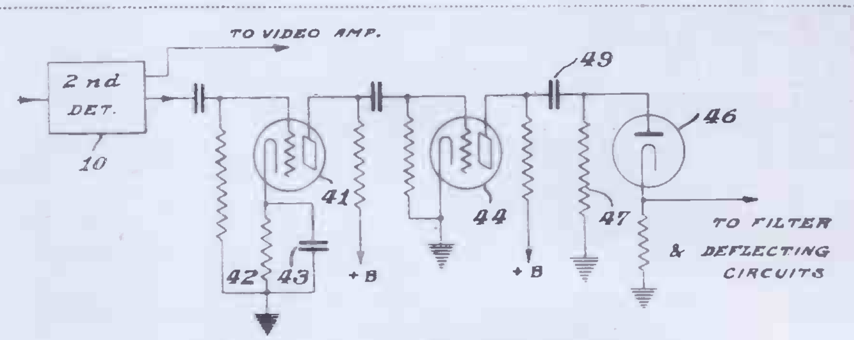


Fig. 7. An alternative circuit arrangement.

42 shunted by a condenser 43 for providing a variable grid bias due to anode current flow. The time constant of the biasing circuit 42-43 is such that most of the charge on condenser 43 holds over between successive frame synchronising pulses. The synchronising pulses are, of course, applied to the grid of the valve 41 with positive polarity.

The amplifier 44 may be the same as the amplifier 14 of Fig. 1. It will be understood, however, that in some instances it may be preferable to apply a fixed bias to the grid of either one of these amplifier valves. It may be noted that the valve 44 (also the valve 14) acts as an amplifier rather than as a separator even though there is no fixed bias since substantially full anode voltage is applied.

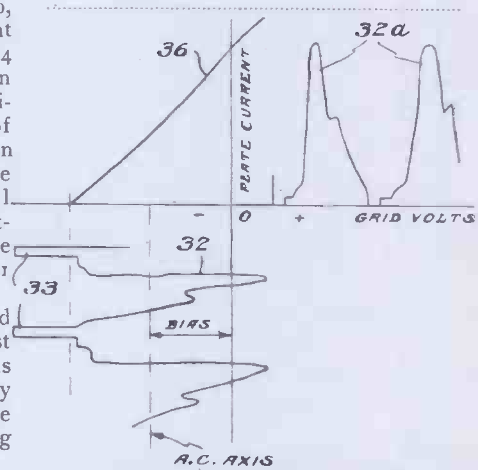


Fig. 6. Grid voltage-anode current characteristic of amplifier.

The second separating circuit may be of the diode type comprising, for example, a diode 46 having a comparatively high resistance resistor 47 across which the signal is applied and a comparatively low impedance resistor across which the synchronising pulses only appear. The input signal is applied through a grid condenser 49 which is charged by the periodically recurring flow of diode current caused by the synchronising pulses.

The discharge circuit for condenser 49 includes the resistor 47 which has a sufficiently high value to prevent the condenser 49 from discharging to any considerable extent between the occurrence of successive line synchronising pulses.

This development is reported from the laboratories of The Radio Corporation of America.

Gain Control of Radio-frequency Amplifiers—

Its Effect on the Input Admittance

By C. Lockhart

IN many applications, such as, for example, short-wave broadcast and communication receivers, television amplifiers, etc., it is often required to be able to vary the gain of the R.F. amplifiers without appreciably altering the tuning and response of the receiver.

The overall response of the receiver may be affected by the gain of the R.F. amplifiers in the following ways :—

(1) Regeneration either in individual stages or overall, which increases with gain.

(2) Change of input resistance (due to lead loss and transit time) with variation of gain.

(3) Change of input capacity due to space charge variation with change of gain.

(4) Change of input admittance due to Miller effect.

(1) This variation in overall response can be suitably dealt with by sufficient screening and decoupling of the individual stages, and therefore will not be further considered here.

(2) At high frequencies the input resistance of the valve falls, due to two reasons—finite transit time of the electrons, and loss introduced by the inductance of the cathode lead.

Both these losses in a given valve are proportional to $\frac{1}{\omega^2 gt}$ where $\omega = 2\pi \times$ frequency and gt = mutual conductance expressed as the change of *total* cathode current per volt change at the grid.

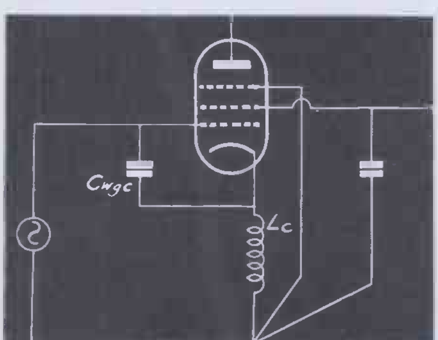


Fig. 1. Illustrating the factors affecting cathode load loss.

In practice, with the majority of valves the loss introduced by cathode lead inductance Lc is appreciably higher than that due to transit time effects. The input resistance due to the cathode inductance effect is equal to

$$Ri = \frac{1}{gt\,\omega^2 LcCwgc} \text{ ohms} \quad \ldots\ldots\ldots \quad (1)$$

From the above expression it will be seen that as the frequency is increased a stage will be reached when the input resistance begins to control the response curve of the receiver. When this condition is present, special methods have to be employed to reduce the variation of input resistance with gain, if appreciable gain changes are required. Some of these methods are discussed in more detail later.

This article describes the effect of variation in gain of R.F. stages on the overall response of the receiver.

(3) The input capacity of a valve consists of the following components :—

(a) Co the cold static input capacity which may be subdivided into Cgc, the control grid to cathode component, plus all the other static components such as Cgs, the control grid to screen capacity, Cgm, the control grid to metalising capacity, etc.

(b) ΔCo the increase in the input capacity when the heater is switched on, but no cathode current is flowing.

(c) Cs the increase in input capacity due to space charge effects, when cathode current is flowing. The extent of this increase will in any given valve depend on the magnitude of the cathode current.

The total operating capacity for any given set of conditions will be a summation of all the above effects and is designated by Cw and the grid cathode component of this operating capacity by Cwgc.

When we change the gain of a receiver by altering the mutual conductance of the R.F. amplifiers by changes in either the control grid bias, suppressor grid bias or screen volts, the capacity Cs will change in magnitude, and so detune the input grid circuit of the stage in question. In the case of medium-slope R.F. pentodes with mutual conductances of the order of 2 mA./V., the value of Cs is comparatively small, of the order of 1 to 1.5$\mu\mu$f. With high-slope pentodes such as those designed for television receivers, the value of Cs will range between about 2½ and 4½ $\mu\mu$f., depending on the valve type. The higher the maximum slope of a valve, the higher usually the maximum value Cs, though by the use of very small gaps between the electrodes it is possible to improve matters.

It should be realised that the values of Cs quoted above is the total change in input capacity that would be produced by biasing a valve from its normal recommended operating point to the point of zero gain. The change in the value of Cw with bias on the control grid, is shown for the Mullard EF50, Mazda SP41 and RCA1852 in Figs. 3, 8 and 10 respectively. Curves are also given showing the variation of the input resistance at frequencies of 50, 45 and 40 megacycles respectively. While, as stated above, the input resistance Ri is inversely proportional to the frequency squared, the input capacity is sensibly independent of frequency. The change of Cw and Ri with gain control by applying bias to the suppressor grid is shown for the EF50 in Fig. 4.

From these curves it will be seen that controlling gain by biasing the control grid has the effect of reducing Cw and increasing Ri, the latter change being very appreciable. Controlling gain by biasing back the suppressor grid has the opposite effect and is less efficient as Cw rises to higher values and Ri falls to very low values.

One of the first attempts to reduce the variation in the input capacity and resistance of an R.F. valve was made by the Philips Laboratories in 1937. The circuit employed is shown in Fig. 2 where a resistance Rc by-passed by a condenser Cc is included in the cathode lead, the condenser Cc consisting of stray cathode to chassis capacities (such as cathode-heater, cathode-screen, cathode-suppressor capacities) or of an intentional added condenser. It can be shown that under these conditions that :

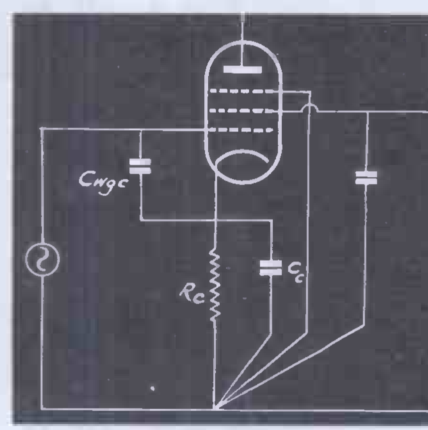


Fig. 2. Circuit for neutralising input loss of valve.

$$Cw = Cwgc + \frac{Cwgc}{1 + gt\,Rc} \quad \ldots \quad (2)$$

$$\frac{1}{Ri'} \approx \frac{1}{Ri(1+gtRc)} - \frac{\omega^2 RcCwgc(CcRcgt - Cwgc)}{(1 + gtRc)^2} \quad (3)$$

$$ga' \approx ga\left(\frac{1}{1 + gt\,Rc}\right) \quad \ldots \quad (4)$$

where Cwge is the working input capacity excluding capacities to cathode; Ri is the input resistance with Rc = O and Ri′ is the input resistance for a finite value of Rc. Similarly, ga′ is the mutual conductance of the anode current/grid volts characteristic for a finite value of Rc, while ga is that for Rc = O.

Examining first the expression (2) for the input capacity Cw in the case of the fraction term it will be seen that as the numerator diminishes with a reduction in gt, so the denominator also drops in value. By a suitable choice of Rc it is thus possible to reduce the variation of Cw with bias. This is shown for three values of Rc in Fig. 10, which illustrates this effect with an 1852; a similar curve for the EF50 is shown in Fig. 6.

In the case of the mutual conductance this is reduced in the ratio one would expect from the usual negative feedback considerations. Actually, the expression given by (4) is only approximate as a quadrature term introduced by Cc, has been neglected for simplicity. This term introduces a phase angle to the mutual conductance.

Lastly, we come to the expression for the input resistance Ri. To simplify the interpretation of performance the equation (3) has been given in the form of a conductance. The first term indicates that Ri has been increased in the same proportion as the gain is reduced by negative feedback effect, i.e., by the factor (1 + gt Rc) or alternatively that the first term of the conductance has been reduced by this factor. The second term of the conductance equation (3) is, however, of far greater interest. If we can arrange for the (Cc Rs gt − Cwgc) part of the numerator to be positive, then the second term of expression (3) will subtract from the first, giving in effect a lower resultant input conductance, and therefore a higher input resistance. As we bias the control grid and reduce gt, Ri will increase rapidly, so that the term $\frac{1}{Ri\,(1 + gt\ Rc)}$ will drop rapidly; at the same time, however, the factor (CcRc gt − Cwge) will decrease in value and then go through zero when

$$gt = \frac{Cwgc}{CcRc}$$

after which this factor will become negative for any further reduction in gt.

For low values of gt, the second term of expression (3) therefore adds to the first term and thus reduces the possible rise in Ri.

From the foregoing it will be seen that by a suitable choice of values for the components Rc and Cc, it is possible to make the input resistance Ri either rise, remain reasonably constant, or fall with the application of bias. This effect is well illustrated for the case of the 1852 in Fig. 10. A value for Rc of about 40 ohms would have given the most constant input resistance, this being of the order of 7,000 ohms.

The mutual conductance for this value of Rc is reduced to 70 per cent. of its normal value. This loss of mutual conductance can, to some extent, be reduced by using a larger value of Cc and lower value of Rc, as will be seen from equation (3).

The frequency dependance of the above method of compensating for changes of input resistance with bias may be easily estimated if we make the simplifying assumption that the input loss is mainly due to cathode lead inductance, as given by equation (1) and that the capacity Cc is mainly external (that is, that it does not shunt the cathode lead inductance). With these assumptions the input conductance becomes

$$\frac{1}{Ri'} \approx \frac{\omega^2 Cwgc}{1 + gtRc}\left\{gtLc\,\frac{Rc(RcCcgt - Cwgc)}{1 + gtRc}\right\} \quad (5)$$

from which the input resistance is seen to be still inversely proportional to the frequency squared, and the compensating action independent of frequency. In practice we would therefore expect that the compensating action will not be greatly affected by reasonable changes in frequency.

In the arrangement described above, we therefore have a method of reducing the variation of input capacity and resistance, while at the same time increasing the input resistance. This, however, is accomplished at some loss in mutual conductance, and possible coupling between the anode and grid circuits in the cathode circuit. The net result as far as overall amplfication is concerned depends entirely on the class of receiver considered. For example, in the case of the H.F. stage of a broadcast or communication receiver where the maximum amount of selectivity is desired, the input resistance of the valve will be, most likely, small compared with the attainable dynamic resistance of the aerial tuning circuit. The gain under such conditions will be approximately proportional to $(g_a\sqrt{Ri})$, and the loss in amplification, if any, produced by the use of the circuit shown in Fig. 2, will be small while the improvement in selectivity will be marked.

On the other hand, in the case of H.F. and I.F. amplifiers used in television systems requiring bandwidths of

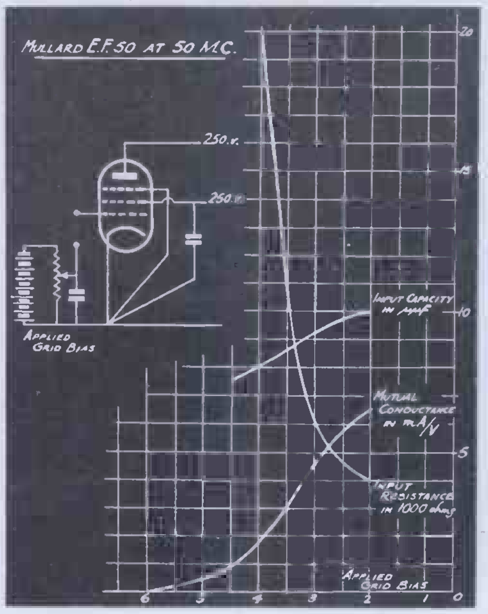


Fig. 3 (left). Variation of Input Admittance with control grid bias for one type of H.F. pentode.

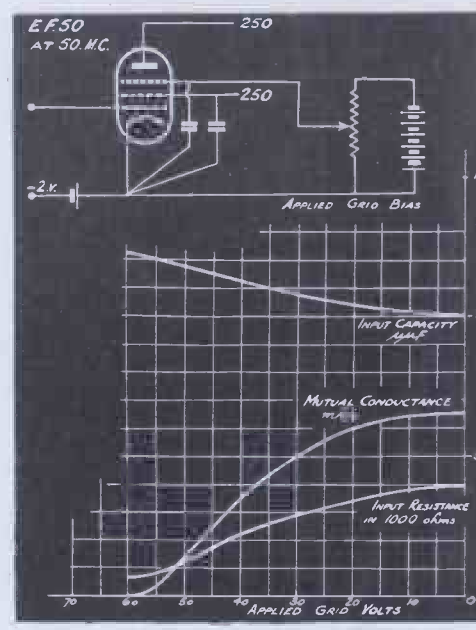


Fig. 4 (right). Variation of input admittance with suppressor grid bias for the same valve.

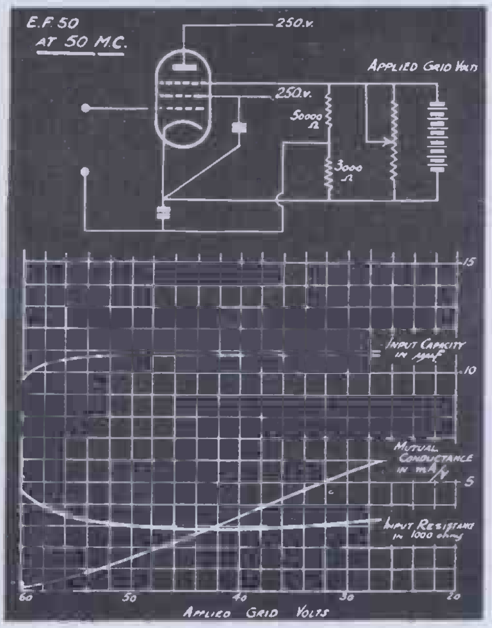


Fig. 5 (left). Variation of input admittance with simultaneous alteration of suppressor and control grid bias.

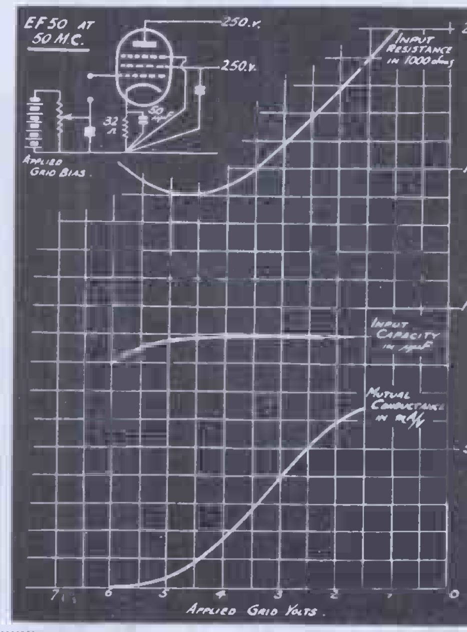


Fig. 6 (right). The effect of a loss compensating circuit on the input admittance-control grid bias only.

4 Mc. or more, the input resistance of the valve may already be too high and extra loading may have to be added to the coupling circuits. Under such conditions, it is required to be able to control the gain of the valves without appreciably changing their input admittance, and without sacrificing any mutual conductance in the process.

A circuit arrangement which satisfies these requirements has been used in British television receivers and is shown in Fig. 9. The principle of the arrangement is easily understood by inspecting the input capacity and resistance curves in Figs. 3 and 4. It will be seen that while in Fig. 3 the input capacity falls and the input resistance rises with increase of control grid bias, in Fig. 4 with suppressor grid control, the opposite effect is present. It is therefore possible by applying the controlling bias in a suitable proportion to the two grids to balance the opposing effects and keep the admittance reasonably constant. This is achieved without loss of mutual conductance at the minimum bias which is provided by the self-bias resistance. Curves illustrating the performance of this circuit in the case of the Mazda SP41 are shown in Fig. 9.

The performance of the Mullard EF50 in a slightly modified version of the above circuit is shown in Fig. 5. This modification, however, will entail a deterioration in performance over the circuit shown in Fig. 9, due to the large bias present on the suppressor grid at the condition of maximum gain. This large bias reduces the mutial conductance available for a given cathode current by increasing the screen-current-to-anode-current ratio, and the latter effect also entails a reduction in the signal-to-noise ratio.

The circuit arrangements shown in Figs. 2 and 5 can be combined and the performance of an EF50 in such a circuit is shown in Fig. 7. The change in the input resistance could be reduced at the expense of a greater change in the input capacity by reducing the value of the resistance Rc.

(4) Due to feedback through the anode-to-grid capacity Cga the input admittance of a valve depends upon the stage gain and type of anode load employed.

This admittance can be considered as an extra capacity and conductance, in parallel with the ones already discussed, and is usually known as the Miller effect.

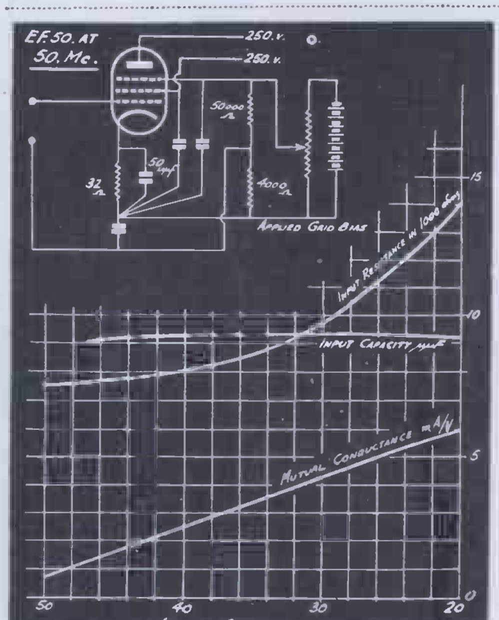


Fig. 7 (left). The effect of a loss compensating circuit on the input admittance-simultaneous variation of suppressor and control grid bias.

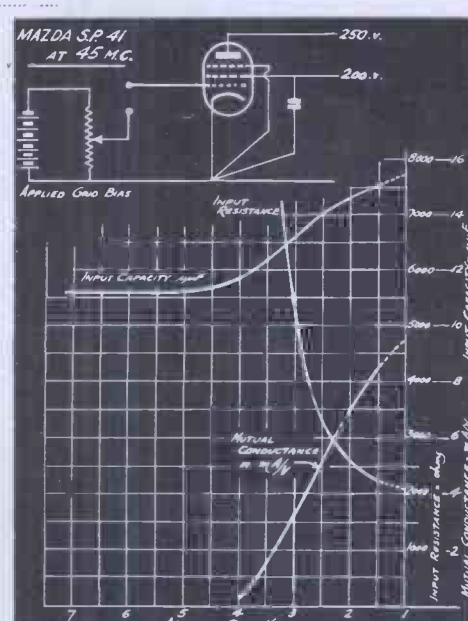


Fig. 8 (right). Curves of Fig. 3 drawn for another type of H.F. pentode.

The input capacity component of this admittance is

$$C_M \approx C_{ga}\,(1 + g_a' \,|Z_a|\, \cos\Theta) \quad \ldots \quad (6)$$

and the input conductance component

$$\frac{1}{R_M} \approx -\omega C_{ga}\, g_a' \,|Z_a|\, \sin\Theta \quad \ldots \quad (7)$$

where $g_a' |Z_a|$ = stage gain, (Za) is the absolute value of the anode load impedance, and (Θ + 180°) is the angle by which the voltage across the anode load leads the applied grid voltage. (Θ is positive for an inductive anode load.)

The above equations assume that the internal A.C. resistance of the valve is very large compared with Za, as is usually the case with pentodes.

$$C_{ag} = (A - W^2 B) \quad \ldots\ldots\ldots\ldots \quad (8)$$

where A is the static grid-to-anode capacity measured at a low frequency, while B is a factor depending on the extent of the mutual couplings in the valve.

At high frequencies the value of Cga therefore becomes negative, and the absolute value of A has usually little effect.

The user can do little to compensate the deleterious effects of the " Miller " admittances, except to make certain that the valves employed have been designed for operation at high frequencies. Most television type pentodes have been designed with the object of reducing the above effects.

is divided into three sections, the first dealing with the fundamental physical phenomena involved in television : electron emission, electron optics, fluorescence, and the principles of vacuum practice.

In Part II the problems of transmission of pictures are dealt with in general and a brief historical summary of the various pick-up devices leading up to the Iconoscope is given.

Part III contains the important features of the work done in the R.C.A. laboratories : the Iconoscope and Kinescope and their associated circuits, the arrangements for scanning and synchronising, transmission at U.H.F. and finally, the receiver.

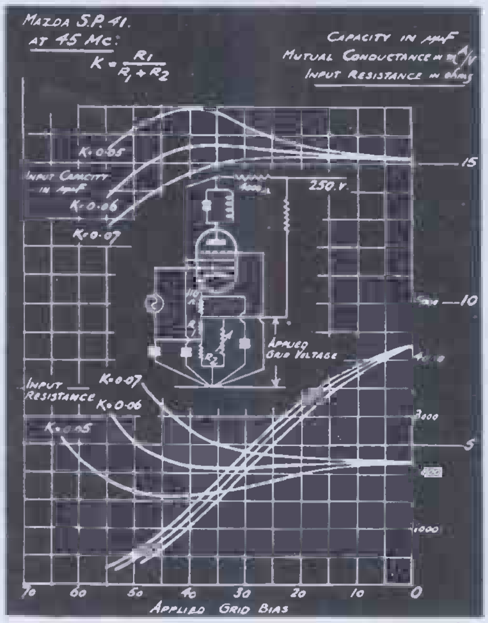
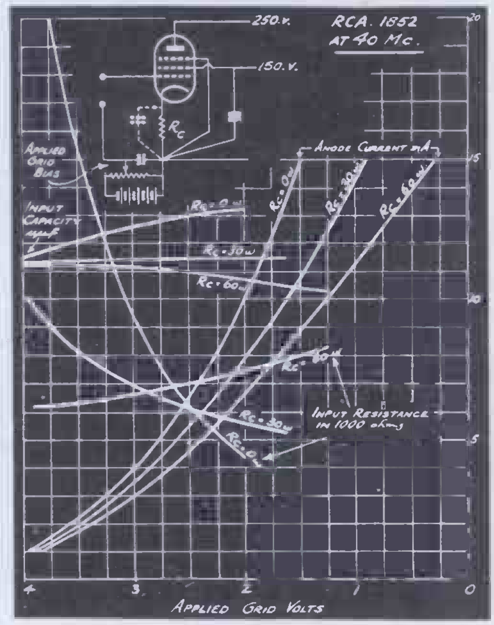


Fig. 9 (left). Variation of input admittance with simultaneous alteration of suppressor and control grid bias—another type of valve.

Fig. 10 (right). Similar curves to those of Fig. 6 for another type of H.F. pentode.



When the anode circuit consists of a parallel-tuned circuit, then :—

(a) At resonance Za is a pure resistance equal to the dynamic resistance of this circuit Θ = O.
 $C_M = C_{ga}\,(1 + g_a' R_{dyn})$
 $R_M = \infty$

(b) At frequencies higher than resonance, the angle Θ is negative and therefore the input resistance will be positive in sign, while the input capacity will be reduced below its value at resonance.

(c) At frequencies lower than resonance, the angle Θ is positive, and therefore the input capacity is again reduced, but the input resistance becomes negative.

The net result of these variations is to produce an asymmetrical resonance curve which is shifted towards the lower frequencies. The extent of this asymmetry is reduced as the stage gain is decreased.

Due to the presence of mutual couplings between the electrodes in the valve, the grid to anode capacity of a valve is not constant, but may be expressed in the form

Book Review

Television. Zworykin and Morton. John Wiley (Chapman & Hall), 36s. net. 631 pp.

This may fairly be called the first comprehensive textbook on television practice to be written, and the fact that it deals with American standards and methods does not in any way detract from its value to the engineer or student.

Dr. Zworykin's work in television is so well known that a concise account of his work on electron optics and the iconoscope will be read with interest and profit, and, as might be expected, it occupies nearly half the book.

As outlined in the preface, the book

The last part of the book covers the R.C.A.-N.B.C. television system and the Empire State transmitter. An interesting chapter on the problems of television programmes, engineering, servicing and various other aspects is given in conclusion.

In the section on television receivers a complete circuit for an experimental receiver is given embodying the special details which have been discussed by R.C.A. engineers from time to time in the technical Press. The subject of separating the line and frame impulses in the receiver is clearly explained—a point which has not received much attention in technical literature in Britain. Each chapter has a bibliography of the main references to the subject and the book is plentifully illustrated with circuit diagrams and illustrations.

Every television engineer in this country will want to possess a copy of this treatise, which apart from its instructive contents is a valuable record of American progress up to the present day.

THE SHORT-WAVE RADIO WORLD

A Review of the Most Important Features of the World's Short-wave Developments

A 20-watt Parallel-rod 224-Mc. Oscillator

THE unusual push-pull parallel-rod oscillator shown by Fig. 1 has proved a satisfactory source of power for experiments in the $1\frac{1}{4}$-metre band. A parallel-rod line is used as the frequency controlling element and a small self-tuned coil is used in the anode circuit. The resonant line is made up of two $\frac{7}{8}$ in. thin-wall copper pipes spaced $\frac{7}{8}$ in. $9\frac{1}{2}$ in. long overall, and connected together both at the top and bottom to act as a half-wave line instead of the more common quarter-wave arrangement. The base for the line is a piece of 20-gauge sheet copper $1\frac{3}{4}$ in. by 4 in. which is mounted above the $9\frac{1}{2}$ in. by 5 in. by $1\frac{1}{2}$ in. chassis by means of stand-off insulators.

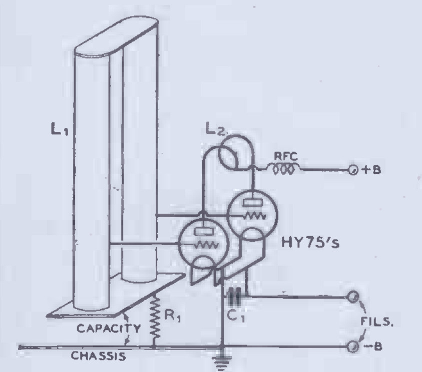
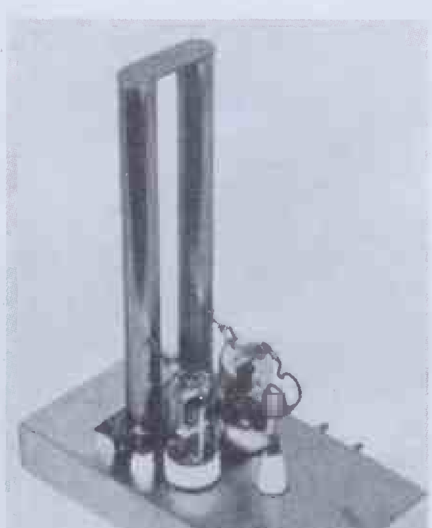


Fig 4. Circuit of the 20 to 25 watt 224-Mc. oscillator.

C_1—.003-μfd. midget mica. R_1—5,000 ohms, 10 watts. L_1—Half-wave parallel-rod line. L_2—2 turns $\frac{5}{8}$ in. dia., 1 in. long. RFC—6 turns hookup wire, $\frac{1}{4}$ in. dia.

The capacity to chassis of the copper base plate acts as a by-pass for the centre of the parallel-rod line. The copper plate can be proved to be acting normally as a by-pass since its centre will be quite cold to R.F. One of the stand-offs which supports the copper plate is of the feed-through type and has the grid leak connected between its lower end and the earthed side of the filaments of the valves.

The power output of the oscillator as shown is 20 to 25 watts with 450 volts on the anodes of the valves. The anode efficiency is approximately 40 per cent. with the half-wave line in the grid circuit as shown. The anode efficiency was somewhat less than this until the original quarter-wave grid line was replaced with the capacity-shortened half-wave line.—Q.S.T.



The 224-Mc. oscillator using the new HY75's.

Say It With Words

In the June issue of QST the Managing Secretary of the A.R.R.L., K. B. Warner, gave his views on a subject which has been discussed many times in this country when amateur transmitting was active—the abuse of recognised abbreviations in ordinary speech between operators. Many non-transmitting radio amateurs have ridiculed the jargon which the so-called "ham" employs in the simplest and most ordinary conversation. As Mr. Warner says: "It is difficult to understand why phone operators drag in by the heels a bunch of C.W. abbreviations designed for the 'brasspounder,' but which have no place in the medium where voice can be used." Many listeners on the amateur bands will endorse this query. A transmitter concluding his message with the words "Best 73's, O.M.," as so many do, is in effect saying "Best best regardses," which is about as nonsensical as some of the commercial English phrases in use in this country.

Mr. Warner is to be congratulated on airing a defect in the otherwise high technical standard of the amateur transmitting fraternity.

Additional frequency bands have been made available for amateurs in U.S.A., and in particular the upper $\frac{1}{2}$ mC. of the 5-metre band has been opened for frequency-modulated voice transmission. The revised regulations are as follows:—

12.113. *Individual frequency not specified.* Transmissions by an amateur station may be on any frequency within the bands assigned. Sideband frequencies resulting from keying or modulating a transmitter shall be confined within the frequency band used.

12.114. *Types of emission.* All bands of frequencies allocated to the amateur service may be used without modulation (Type A-1 emission).

12.115. *Additional bands for types of emission using amplitude modulation.* The following bands of frequencies are allocated for use by amateur stations using additional types of emission as shown:

1,715 to 2,000 kc.	—	—	A-4	—
1,800 to 2,000 kc.	—	A-3	—	—
28,500 to 30,000 kc.	—	A-3	—	—
56,000 to 60,000 kc.	A-2	A-3	A-4	—
112,000 to 116,000 kc.	A-2	A-3	A-4	A-5
224,000 to 230,000 kc.	A-2	A-3	A-4	A-5
400,000 to 401,000 kc.	A-2	A-3	A-4	A-5

12.116. *Additional bands for radiotelephony.* Amateur stations may use radiotelephony with amplitude modulation (Type A-3 emission) in the frequency bands 3,900 to 4,000 kc. and 14,150 to 14,250 kc. provided the station is licensed to a person who holds an amateur operator licence endorsed with Class A privileges, and actually is operated by an amateur operator holding Class A privileges.

12.117. *Frequency modulation.* The following bands of frequencies are allocated for use by amateur stations for radiotelephone frequency modulation transmission:

58,500 to 60,000 kc.
112,000 to 116,000 kc.
224,000 to 230,000 kc.
400,000 to 401,000 kc.

Type A-1 emission, for which all the bands are open, is pure c.w. telegraphy. A-2 is tone-modulated telegraphy. A-3 is *amplitude*-modulated telephony; it does *not* include frequency modulation. A-4 is facsimile and A-5 is television.

A Reactance Valve Circuit for Frequency Modulation

There are numerous methods of obtaining frequency modulation. These vary in complexity from the Armstrong phase modulation system at one extreme to the simple loop-modulation process at the other. For amateur purposes it is essential that the frequency modulator be simplified as much as possible—as long as the simplification does not cause non-linearity or amplitude modulation. Almost any of the simpler systems will give linear frequency modulation over a small range of swing and still be essentially free from amplitude modulation. Unfortunately the linear range of the simpler systems is usually not great enough to permit a 50 kc.

swing at 2½ metres. A hypothetical example of a typical frequency modulation voltage characteristic of an average simple system is shown in Fig. 2. This characteristic is not necessarily that of any one of the simpler systems in particular, it is merely representative of the average observed voltage-frequency characteristic of some of them. While amplitude modulation to a certain degree in a positive direction can be tolerated in a frequency modulated transmitter which has several stages between the oscillator and the aerial, its presence in a negative direction to any great extent will necessarily result in negative amplitude modulation of the output and must be avoided.

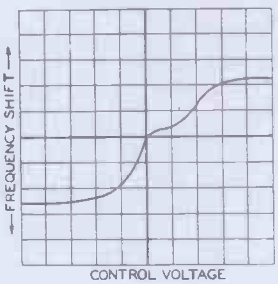


Fig. 2. A typical frequency-voltage characteristic of some of the simpler forms of modulator. The linear portions of the curve are too short to give any promise of successful use as frequency modulators.

It is quite possible that some of the frequency modulation systems which have been tried and rejected may respond to compensating factors introduced into them. Some of the possibilities include the use of a vacuum valve as a variable resistance in a series with a reactance, either inductive or capacitive, coupled to the oscillator tank, the use of the No. 4 grid in a pentagrid converter valve (such as a 6A8) as a frequency varying element, and the use of anode voltage variable at audio frequencies on an E.C.O., the screen voltage being fixed and the output being taken from the grid tank. Another possibility is the use of a short length of line to transform a variable resistance such as a vacuum valve to a variable reactance in series with the oscillator tank.

The best of the frequency modulators tried by the writer proved to be the conventional reactance valve. The reactance valve modulator is conventional as far as the appearance of the circuit goes; the correct values of the components are rather critical in some parts of the circuit.

The reactance valve was originally intended to be used as a frequency-varying element in broadcast receivers using A.F.C. There are numerous variations of the basic circuit but the essential requirement is that the grid be supplied with an R.F. voltage of such a phase that the anode draws a lagging current, the anode-cathode circuit of the reactance valve being connected across the oscillator tank. The effect of the lagging current drawn by the valve is to make it appear as an inductance to the oscillator tank. Thus the oscillator tank circuit has two inductances in parallel, the oscillator coil and the reactance valve. The effect of two inductances in parallel is a resultant inductance less than either of them. Hence the frequency of the oscillator is raised by the application of the reactance valve. Since the effective inductance presented by the valve may be varied by varying its mutual conductance, a convenient method of varying the resultant oscillator tank inductance, and consequently the oscillator frequency, is provided. When this inductance is varied at an audio frequency we have frequency modulation at an audio rate.

There are probably a dozen different configurations of the basic reactance-valve circuit. The difference in the various arrangements is principally in the method used to obtain the required phase difference between the R.F. voltages on the anode and grid of the reactance valve. The simplest of these arrangements is the one shown in the diagram, Fig. 3. Here a 90-degree shift is obtained by the use of a resistance-capacity network across the oscillator tank. In this case R_6 is the resistance in question and the capacitance is provided by the grid-to-cathode capacity of the 6SJ7 and the distributed capacity of the R.F. choke. Condensers C_6 and C_7 serve merely as coupling condensers to isolate the D.C. voltages in the circuit. Resistor R_7 improves the linearity of the frequency modulator; when it is omitted from the circuit the voltage-frequency characteristic of the circuit falls off rapidly on the positive grid voltage side. The use of a series screen resistor and a rather high value of semi-fixed bias on the reactance valve are other factors which aid in giving linearity to the frequency modulator.—Norton *Radio,* April, 1940.

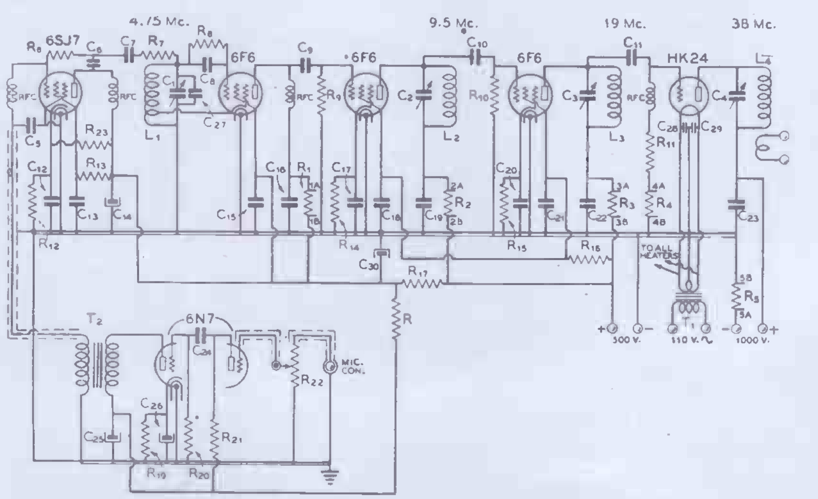


Fig. 3. Reactance valve circuit for frequency modulation.

C_1—75-μμfd. variable.
C_2—35-μμfd. variable.
C_3—25-μμfd. variable.
C_4—20-μμfd. variable.
C_5, C_6, C_7—.003 μfd. mica.
C_8—.0001-μfd. mica.
C_9—.0001-μfd. mica.
C_{10}, C_{11}—.00005-μfd. mica.
C_{12}—.01-μfd. 400 volt tubular.
C_{13}—.003-μfd. mica.
C_{14}—8-μfd. 450 volt electrolytic.
C_{15}, C_{16}, C_{17}, C_{18}, C_{19}, C_{20}, C_{21}, C_{22}—.003-μfd. mica.
C_{23}—.002-μfd. 2,500 volt mica.
C_{24}—.02-μfd. 400 volt tubular.
C_{25}—8-μfd. 450 volt electrolytic.
C_{26}—10-μfd. 25 volt electrolytic.
C_{27}—100-μμfd. ceramic.
C_{28}, C_{29}—.003-μfd. mica.
R_1, R_2, R_3, R_4, R_5—50 ohms, 1 watt.
R_6—100,000 ohms, ½ watt.
R_7—2,500 ohms, 1 watt.
R_8—60,000 ohms, 1 watt.
R_9—100,000 ohms, 1 watt.
R_{10}—150,000 ohms, 2 watts.
R_{11}—25,000 ohms, 10 watts.
R_{12}—1,000 ohms, 1 watt.
R_{12}—50,000 ohms, 1 watt.
R_{14}, R_{15}—500 ohms, 10 watts.
R_{16}—15,000 ohms, 10 watts.
R_{17}—5,000 ohms, 20 watts.
R_{18}—10,000 ohms, 1 watt.
R_{19}—2,000 ohms, ½ watt.
R_{20}, R_{21}—50,000 ohms, ½ watt.
R_{22}—1 megohm potentiometer.
R_{23}—50,000 ohms, ½ watt.
T_1—6.3 volts, 10 amps.
RFC—2½ mh.
M—0-150 ma.
L_1—17 turns of no. 22 d.c.c. wound to a length of ⅞ in. on 1¼ in. dia. form. Cathode tap 6 turns from earth end.
L_2—20 turns no. 14 enam. 1 in. dia., 1⅝ in. long.
L_3—15 turns no. 14, ¾ in. dia., 1⅝ in. long.
L_4—10 turns no. 10 enam. 1 in. dia., 2½ in. long.

A Simple Coupling Transformer Unit for Television Receivers

COUPLING transformers are often required in television receivers, for example, for coupling the aerial feeder to the tuned input circuit of the first amplifying valve and a very convenient construction has recently been disclosed by the Radio Corporation of America.

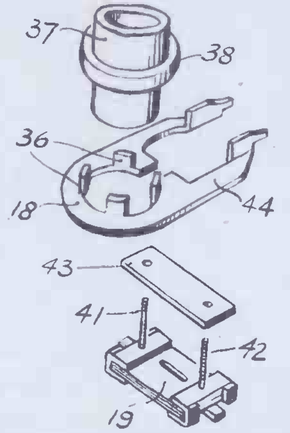


Fig. 1. Perspective sketch of assembly of primary strap.

The transformer is shown in the accompanying drawings, Figs. 1-4. As will be seen from Figs. 1 and 2 each primary is a metal strap forming a fraction of one turn and having lugs 36 thereon. These lugs secure the primary strap firmly to a supporting tube which preferably is of styrol. The primary strap 18, for example, is slipped over the end of a styrol tube 37 and the strap

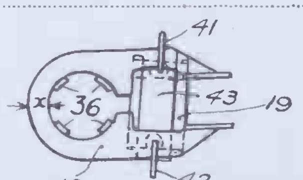


Fig. 2. Plan of primary strap with condenser.

18 heated sufficiently to permit embedding the lugs 36 in a ring 38 which is an integral part of the tube 37. Thus, the primary strap is rigidly supported a fixed distance from the secondary winding which is wound in grooves on the supporting tube surface, as shown at 21 in Fig. 3.

It will be seen that the primary strap extends beyond its supporting tube sufficiently to provide space for connecting a condenser across the legs of the U. This is shown clearly in Figs. 2 and 4. Considering the primary 18, a small fixed condenser 19 having terminal wires 41 and 42 is positioned across the legs of the U, preferably with an insulating strip 43 between the condenser 19 and the strap 18.

In the example shown, the terminal wire 42 is passed through a hole 44 in one leg of the strap 18, bent over, and soldered to the strap. The terminal wire 41 falls inside the U and is bent over the other leg of the U. By swinging the condenser about the hole 44 as a pivot, the amount of inductance in the primary circuit may be varied to tune the primary to the proper frequency. After the condenser has been moved to the position giving the proper tuning, the terminal wire 41 is soldered to the strap 18. The finally adjusted position of the condenser may be as shown in Fig. 2.

Of course, a condenser may be connected across the primary strap and adjusted in other ways to obtain proper tuning.

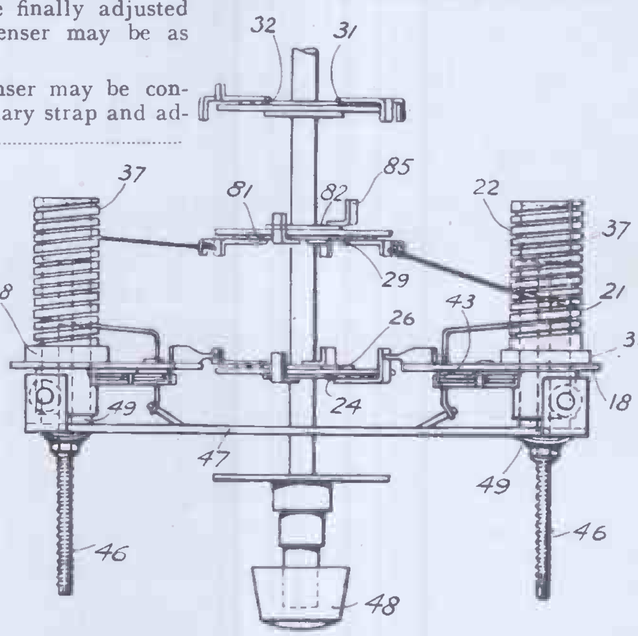


Fig. 3. Sketch of complete assembly of transformer unit.

The secondary windings are tuned by means of magnetic cores. Thus, the tuning of the secondary 21 may be adjusted to the desired frequency by moving the core 22 axially inside the tube 37 by means of a rod 46 (Fig. 3) to which the core 22 is attached.

The supporting tubes of styrol or the like for the tuned selecting circuits are supported on the plate 47 by pressing them over short cylindrical plugs secured to the plate (Fig. 3). The supporting tube 37 is held in position by a plug 49 over which it fits. The magnetic core 22 may be moved coaxially along the tube 37 by rotating the rod 46 which is threaded into the plug 49.

The primary inductance may be adjusted if desired, for example, for matching impedances, by varying the width of the strap, i.e., the dimension x (Fig. 2) and, of course, by varying either the actual or effective length of the U.

Resistances can be employed in shunt to some of the primaries to obtain the desired pass band width for the selecting circuits.

Where signals at frequencies above 90 megacycles/sec. are to be received, it may be desirable to employ the primary coil design shown in Fig. 4. With one exception, it is the same U-shaped strap as previously described and is mounted in the same way on a styrol tube carrying a secondary winding. The exception is that the portion immediately adjacent to the styrol tube is completely closed by a transverse portion 53, whereas, in Fig. 2, for example, this portion has been cut away. The primary is tuned by a condenser 54 in the manner described above.

The manner in which coupling is obtained between a secondary winding and a primary winding such as shown in Fig. 4 will be understood by referring to Fig. 5. The primary proper comprises the transverse portion 53 and the portion of the strap to the right. Thus, the primary circuit is through condenser 54, and portion 53, the greater part of the current circulating as indicated by the right-hand arrow. A portion of the current, however, circulates through the condenser 54 and the end portion 56 of the strap as indicated by the left-hand arrow. This latter portion which may be one-third of the total primary current provides the coupling between primary and secondary.

If desired the tuned U shaped member may be utilised as a trap circuit to reject an undesired frequency. For example, two units such as shown in Fig. 2 may be connected in the trans-

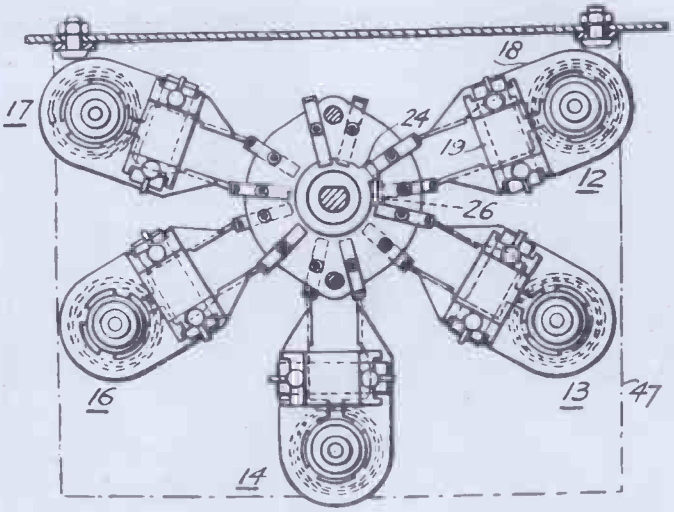
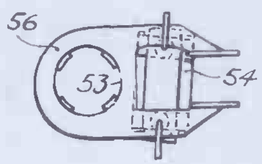


Fig. 3a. Plan of unit.



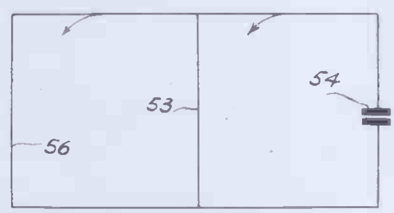


Fig. 4 (left). Primary coil design for use with high frequencies.
Fig. 5 (right). Method of coupling primary and secondary windings.

mission line, one in each conductor of the line, for the purpose of rejecting the sound signal of an adjacent television channel. In this case the condenser is adjusted along the legs of the U and soldered at a point where the unit is tuned to the undesired sound signal.

A New Projection System for Large-screen Television Receivers

TELEVISION receivers of the projection type are usually provided with a lens which projects on to a suitable screen a magnified image of the picture reproduced on, for example, the fluorescent screen of a small cathode-ray tube. In such receivers a compromise is usually made in the focus of the lens between providing good illumination of the image as seen from an axial point conjugate with the aperture of the projecting lens, and average illumination, as seen over a wider angle, by providing that the light emerging from the lens is approximately parallel.

The use of the special lens system about to be described enables optimum light distribution to an audience to be achieved and this result is obtained by a lens the components of which are aspherical, as in the case of two cylindrical lenses arranged at right angles. The two lenses are made to be of unequal power, thus resulting in a spherical cylindrical combination having two foci consisting of line images at right angles to one another.

Such a lens combination provides two images, a primary image near the lens and a secondary image further away, and the primary image is used to satisfy the illumination conditions required by observers placed near the screen, the secondary image being used to satisfy observers further away from the screen.

A lens of the type required to produce the effect referred to may be manufactured by pressing a sheet of plastic transparent material with a wax matrix in which ruled parallel grooves are formed. The angle of the grooves is progressively increased from the central axis in the plane of the lens so as to produce the required configuration of the surface of the sheet and the lens rulings may be formed either both on the same side of the sheet or one on each side.

The lens so formed may be used in conjunction with a diffusing screen of the ground glass or transparent type, or the lens elements or ribs on the surface may be formed to give the required diffusing action. Such a diffusing action of the lens ribs may be produced by cutting the grooves in the wax blank or blanks forming the prototype of the two component cylindrical lenses with a cutter having a curved edge so that the optically active face of each groove, besides having the appropriate angle required due to the cylindrical lens formation of which it constitutes a part, has such a curvature that it is in fact an elongated cylindrical lens itself.

As the rulings constituting the two cylindrical lenses intersect at right angles, the combined field lens and diffusing screen will consist of a mosaic of elementary sphero-cylindrical lenses, as well as constituting as a whole the main lens, or lens system, with sphero-cylindrical properties. The curvature of each groove is chosen to suit the vertical and horizontal distribution of light demanded by the viewing angle it is desired to preserve or set up.

The action of the screen may be explained as follows :—

A narrow ray of light from the projection lens falls upon the screen and its direction is changed both in horizontal and vertical planes due to the main sphero-cylindrical properties of the screen, so that the light travels towards the audience. In addition, the ray on emerging from the lens will no longer be a narrow pencil, but will be in the form of a divergent cone of somewhat elongated cross-section, the angles of divergence being determined by the required viewing angles.

It is obvious that if the cylindrical components have equal curvature the combination will, in fact, be a spherical lens, but the method described retains the advantage of making it possible to produce the diffusing screen integral with the lens rulings. Also, in the case of a spherical Fresnel lens, the side of the viewing screen is limited by the difficulties in providing suitable presses and engraving apparatus. An additional advantage accrues, therefore, to the type of cylindrical lens combination described, in that it is possible to rule each of the lenses in sections and fit them together, subsequently to form a large field lens such as would be required for demonstration of television in a theatre.

"Magnetostatic Focusing of Electron Beams"

Correction.—In the article with the above title which appeared in the July issue, on pages 297-301 there are two typographical errors which possibly have puzzled readers. These are as follows :—

A few lines below Eq. (14p)—

$z = v = \sqrt{2qE/m}$ should read

$$\frac{dz}{dt} = v = \sqrt{2qE/m}\ ,$$

and in Eq. (22p)—

$(H_z . \sqrt{q/8mE. z + B})$ should read

$$(H_z . \sqrt{q/8mE}\ .z + B).$$


PX4

R.C.A. Tube Data

A Review of American Handbook Information

THE last few years have seen remarkable progress in the development of electronic tubes and other apparatus, as well as their applications to various branches of practice. This development has been so rapid and far reaching that it would be difficult indeed to predict the future trend of events in this sphere. It can safely be assumed, however, that progress will continue, and that we may expect radical future changes resulting from the extending uses of electronic equipment.

A large proportion of contemporary development in this direction has taken place in America, where the use of electronic appliances of all kinds is already extensive, and still increasing rapidly. Evidence of this progress is to be found not only in the numerous items of electronic research which are reported from time to time in America, but also in the vast literature on the subject which has made its appearance there. The number of American textbooks dealing with the industrial applications of electronics provides in itself an indication of the amount of attention devoted to the subject.

In the radio field and related spheres of activity, the Radio Corporation of America, known universally as the R.C.A., occupies a prominent place and has brought to industry the advantages resulting from standardisation and coordination on a large scale. R.C.A. publications have supplied a definite need in this direction by giving essential data for a wide range of tubes of different types.

Complete R.C.A. tube data has recently been issued in the form of handbooks with loose-leaf data sheets so as to facilitate the introduction of new or revised material. The sheets are classified under three headings, representing respectively receiving types, transmitting types and miscellaneous types. The data given for each type include the price, intended uses, ratings, physical dimensions, terminal connections and characteristics in the form of curves plotted to scales large enough for the solving of design problems. The loose-leaf binders are of black fabricoid, imprinted in gold, and are made in three forms covering respectively all types (Handbook Series HB-3) with prong or ring binders, and the Receiving-Tube Handbook (HB-1). The foreign subscription prices for these volumes are respectively \$5.25, \$5.75 and \$3.75. These prices include the first year's service of sheets giving new or revised information, subsequent issues of which cost \$2.00 annually for volumes including all types of tubes and \$1.50 for receiving types only.

Service sheets are sent during the subscription period to the subscriber whose name appears in the R.C.A. records against the serial number of the handbook. In case the handbook is re-sold or transferred within any subscription period, service sheets are sent to the new owner if the change is notified. The sheets measure $6\frac{3}{4}$ in. by $3\frac{3}{4}$ in. and are photolithographed.

The preface to the handbook of all types states that it is the outgrowth of the increasing demand for a one-volume reference to the characteristics of all R.C.A. tubes. Some idea of the scope covered may be obtained from the fact that the general tube list contains designations of no less than 332 types. This total is made up of 200 receiving types, 78 transmitting types and 54 miscellaneous types.

Basic Information

The prefatory information includes some useful definitions of a basic nature, such as amplification factor, input capacitance, etc., and there are also definitions of the various forms of amplifier: Class A, AB, B, BC and C. Information is given concerning the alternative types of cathodes used in different tubes. In connection with the thoriated-filament type, a procedure is specified for reactivating the filament in the event of reduced emission due to the accidental application of too high filament or plate voltage, provided that the over-voltage has not persisted too long. In some cases it is possible to secure a few hundred extra hours of life in this way, although filaments occasionally burn out during the process, which includes flashing at three times normal voltage for periods up to one minute.

A particularly interesting and useful feature is the index of receiving types according to use and cathode voltage. The index relates to 36 tube types which are shown by experience to meet the needs of design engineers for practically all types of radio sets and the majority of applications where receiving types are used. The advantages of standardising upon a limited number of types in this way may be summarised as follows:

1. Lower initial cost of tubes.
2. Advantage from improved deliveries.
3. Improved quality, resulting from increased skill of operatives working on one type of tube.
4. Reduction in number of stock parts required, such as condensers, resistors, etc., for variety of tube types.

Some of the data sheets bear a star near the index corner, indicating that the maximum rating of the corresponding tube is to be interpreted in accordance with R.M.A. Standard M8-210, which defines operating conditions. The design of the cathode in receiving tubes must be such as to ensure that emission will not fall off unduly with a small drop in voltage and that the life will not be excessively shortened with a small rise in voltage. The tolerance of voltage allowed is usually 5 per cent. above and below the nominal figure.

A note of warning is sounded here against the measurement of cathode voltages at points other than the corresponding socket terminals. It is also pointed out that a high-resistance voltmeter is necessary in order to avoid inaccuracy, especially when the current is small. Practical hints and reminders of this kind are of the greatest help in many cases where operating conditions require investigation.

It is a little difficult to know why the so-called gas triode OA4-G should be included under the classification of receiving types. This tube is described as a cold-cathode starter-anode type, and the starter-anode requires so little energy to initiate the main anode-to-cathode discharge that it becomes possible to obtain remote control of relays, for example, by means of electrical impulses at radio frequencies superimposed on the same power line. Although this application may justify the inclusion of the tube in the receiving section, it would appear more at home under the heading of miscellaneous types along with the conventional gas triodes. In fact it seems rather unfortunate that the term gas triode should be used at all for the OA4-G, especially in view of the fact that the same name is used for the hot-cathode control-grid types 884 and 885, whose operation and principles are essentially different from the OA4-G.

The data given concerning receiving tubes includes in most cases some typical operating curves, such as anode current versus anode volts and anode current versus grid volts for ordinary types. In the case of combined valves, such as double-diode triodes, particulars are given for both units, or alternatively reference is made to curves given under another type designation with the same characteristics. A useful feature of the data is a specification of the mounting

(*Continued on page* 376)

PREMIER RADIO

NEW PREMIER S.W. A.C. RECEIVER KIT

In response to many requests we have now produced an A.C. version of the popular Premier Short Wave SG3 Kit.
Circuit : Pentode H.F. Stage, Pentode Detector, Beam Power Output, and F.W. Rectifier. 200-250 v. A.C. Operation.
Built in Power Pack. Hum-free operation. For use in Phones or P.M. Speaker.
Complete Kit of Parts with drilled chassis, all components. Plug-in Coils covering 13-170 metres, 4 valves and full instructions and circuits £4-10-0. Completely wired and tested £5-10-0. ***Send for full details.***

"LEARNING MORSE"

Premier Morse Practice Key on Bakelite Base and Brass Movement	3/3
General Purpose Morse Key ...	5/10
Heavy Duty TX Key on Cast Base ...	10/-
Bakelite Buzzers	1/9
Complete Kit of Parts for Valve Oscillator as described in W.W. "Learning Morse"	25/-

SHORT-WAVE GEAR

Short-Wave Coils, 4- and 6-pin types, 13-26, 22-47, 41-94, 78-170 metres, 2/- each, with circuit. Premier 3-Band S.W. Coil, 11-25, 19-43, 38-86 metres. Suitable any type circuit, 2/11.

4-pin or 6-pin Coil Formers. Plain or Threaded, 1/2 each.

Utility Micro Cursor Dials, Direct and 100 : 1 Ratios, 4/3.

New Premier 2-Gang S.W. Condenser. 2 x .00015 mf. with integral slow motion, 5/9.

Bakelite Dielectric Variable Condensers. .0003 and .0005 mf. Suitable Tuning or Reaction, 1/6 each.

Short-Wave H.F. Chokes. 10-100 m., 10½d. each. High grade Pie Wound U.S.A. type, 1/9 each.

Lissen Dual Range Screened Coils. Medium and Long Waves, 2/9 each.

PREMIER 1940 HIGH FIDELITY AMPLIFIER KITS

Each Kit is complete with ready drilled chassis, selected components, specially matched valves and full diagrams and instructions.

	Kit of Parts with Valves	Completely Wired and Tested
3-watt A.C. Amplifier	£2 6 6	£3 4 0
3-watt A.C./D.C. ,,	£2 6 6	£3 4 0
6-watt A.C. ,,	£6 2 6	£7 0 0
8-10-watt A.C./D.C. ,,	£5 5 0	£6 2 6
15-watt A.C. ,,	£6 14 0	£8 2 6

Black Crackle Steel Cabinet 15/- extra.

SHORT-WAVE CONDENSERS

Trolitul insulation. Certified superior to ceramic. All-brass construction. Easily ganged

15 m.mfd. ...	1/9	100 m.mfd. ...	2/3
25 m.mfd. ...	2/-	160 m.mfd. ...	2/6
40 m.mfd. ...	2/-	250 m.mfd. ...	2/11

MOVING COIL SPEAKERS

All complete with transformer. Rola 8 in. P.M.s, 16/6 ; 10 in. P.M.s, 22/6 ; G.12 P.M.s, 66/-.

ENERGISED MODELS

Plessy 8 in., 175 ohm field, 7/6 ; G.12 energised, 59/6. 10 in. B.T.H. 1,600 ohm field, less transformer, 11/6.

PREMIER SHORT-WAVE KITS for OVERSEAS NEWS

Incorporating the Premier 3-Band S.W. Coil. 11-86 Metres without coil changing. Each Kit is complete with all components, diagrams and 2-volt valves. 3-Band S.W. 1 Valve Kit, 14/9. 3-Band S.W. 2-Valve Kit, 22/6.

DE LUXE S.W. KITS

Complete to the last detail, including all Valves and coils, wiring diagrams and lucid instructions for building and working. Each Kit is supplied with a steel Chassis and Panel and uses plug-in coils to tune from 13 to 170 metres.

1 Valve Short-Wave Receiver or Adaptor Kit	20/-
1 Valve Short-Wave Superhet Converter Kit	23/-
1 Valve Short-Wave A.C. Superhet Converter Kit	26/3
2 Valve Short-Wave Receiver Kit ...	29/-
3 Valve Short-Wave Screen Grid and Pentode Kit	68/-

PREMIER 1940 "5v.5" COMMUNICATIONS RECEIVER

A 5-valve Superhet, covering 12-2,000 metres in 5 wave bands.

- Beat Frequency Oscillator.
- 2-Spread Band-Spread Control
- A.V.C. Switch
- Illuminated Band-Spread Dial
- Send-Receive Switch
- Iron-Cored IF.s
- Phone Jack
- Over 4-Watts Output

Built into Black Crackle Steel case providing complete screening. 10½ in. Moving Coil Speaker in separate steel cabinet to match.

Receiver, complete with all tubes and Speaker ... **£9 . 9 . 0**

Auto Transformers. Step up or down. 100-125 v. to 200, 230 or 250 v. A.C., 60 watts, 9/11 ; 125 watts, 13/6 ; 250 watts, 18/6.

L.T. Transformers, all C.T.

4 v. 2-3 a. ...	9/11	6.3 v. 2-3 a. ...	9/11
2.5 v. 5 a. ...	9/11	7.5 v. 3 a. ...	9/11
5 v. 2-3 a. ...	9/11	12 v. 3-4 a. ...	15/-

Lissen Hypernik QPP Driver Transformers. Ratio 8 : 1. 4/3.

Push-Pull Driver Transformers 6/6

Universal Output Transformers. 11 Ratios. Single or Push-Pull 6/6

MAINS TRANSFORMERS

Wire-ends. All L.T. Windings Centre-Tapped

SP. 301	300-300 v. 150 m.a. 4 v. 2-3a, 4 v. 2-3a, 4 v. 1a, 4 v. 1a ...	15/-
SP. 350A	350-350 v. 100 m.a. 5 v. 2a (not C.T.), 6.3 v. 2-3a	14/-
SP. 350B	350-350 v. 100 m.a. 4 v. 2-3a, 4 v. 2-3a, 4 v. 2-3a...	14/-
SP. 351	350-350 v. 150 m.a. 4 v. 1-2a, 4 v. 2-3a, 4 v. 3-4a...	15/-
SP. 352	350-350 v. 150 m.a. 5 v. 2a, 6.3 v. 2a, 6.3 v. 2a...	15/9

MATCHMAKER UNIVERSAL OUTPUT TRANSFORMERS

Will match any output valves to any speaker impedance.

11 ratios from 13 : 1 to 80 : 1, 5-7 watts, 15/9. 10-15 watts, 20/6. 20-30 watts, 35/-.

REPLACEMENT VALVES FOR ALL SETS

Europa Mains Valves. 4 v. A.C. Types A C/H.L., A.C./L., A.C./S.G., A.C./V.M.S.G., A.C./H.P., A.C./V.H.P., A.C.P., all 5/3 each. A.C./H.P., A.C./V.H.P., 7-pin, 7/6. A.C./Pens, I.H., 7/6 ; A.C./P.X.4, 7/3 ; Oct. Freq. Changers, 8/6 ; Double Diode Triodes, 7/6 ; 3½-watt D.H. Triode, 9/9. 350 v. F.W. Rect., 5/6 ; 500 v., 6/6. 13 v. .2 amp. Gen. Purpose Triodes, 5/6 ; H.F. Pens. and Var.-Mu. H.F. Pen., Double Diode Triodes, Oct. Freq. Changers, 8/6 each. Full and Half-wave Rectifiers, 6/6 each.

Triad U.S.A. Valves

We hold the largest stocks of U.S.A. tubes in this country and are sole British Distributors for **TRIAD** High-grade American Valves. All types in stock. Standard types, 5/6 each. All the new Octal Base tubes, at 6/6 each.

Clearance Line U.S.A. Valves

U.S.A Types, 24, 30, 35/51, 55, 56, 57, 71, 85, 2A5, 2A6, 2A7, 2B7, 6A7, 210, 250, all 2 for 3/-.

Premier Pick-up Heads.

Will fit any tone-arm 5/3

ANOTHER SPECIAL OFFER.
Rothermel Brush Piezo Crystal Pick-ups.
New Junior P.U. with arm, 19/6. Standard, S.8 Model with arm, 29/6. P.U. head only, De Luxe Model, 19/6.

PREMIER BATTERY CHARGERS for A.C. Mains

Westinghouse Rectification complete and ready for use

To Charge :			
2 volts at ½ amp.	11/9	6 volts at 1 amp.	22/6
6 volts at ½ amp.	19/-	12 volts at 1 amp.	24/6
		6 volts at 2 amps.	37/6

PREMIER MICROPHONES

Transverse Current Mike. High grade large output unit. Response 45-7,500 cycles. Low hiss level, 23/-.

Moving Coil Mike. Permanent magnet model requiring no energising. Response 90-5,200 cycles. Output .25 volt average. Excellent reproduction of speech and music. 48/-.

Microphone Transformers. Suitable for all mikes. Tapped secondaries. A, 20 and 40 : 1 ; B, 30 and 60 : 1. 6/6 each.

Microphone Stands. Bakelite table stand, 9 in. ring, 7/6 each. **Adjustable Floor Stand.** 8 in. ring. Chrome finish. 26/6.

ALL ENQUIRIES MUST BE ACCOMPANIED BY 2½d. STAMP.

PREMIER RADIO CO.

ALL POST ORDERS to : JUBILEE WORKS, 167, LOWER CLAPTON ROAD, LONDON, E.5 (*Amherst* 4723).
CALLERS to : Jubilee Works, or 169, Fleet Street, E.C.4 (*Central* 2833); or 50, High Street, Clapham, S.W.4 (*Macaulay* 2381).

"R.C.A. Tube Data"

(*Continued from page* 374)

position, with supplementary instructions on horizontal mounting where this is permissible.

Transmitter Tubes

The transmitter tube section contains information of a similar kind relating to tubes mainly employed in transmitters and associated equipment. In this case an index has been arranged so as to classify the tubes by (1) use, and (2) power output. This, incidentally, is a feature which would have been very useful in the receiving tube section. As it is, there is a rather imposing array of different types, listed in order of designation, through which one must search patiently in order to discover a tube likely to fulfil the requirements. It would seem quite possible, and very helpful, to include an index guide to specific types.

In the transmitting tube guide the types are listed in relation to plate input, plate volts, plate dissipation and filament volts for the different classes of amplifier. The range in size is from type 841, for example, with an overall length of 8⅛ in. and a maximum plate dissipation of 12 watts, to the type 898, over 60 in. long and with a maximum plate dissipation of 100 kilowatts. Tables are given showing the relationship between operating frequency and permissible tube ratings for transmitter types. These show the limiting frequency in megacycles for 100, 75 and 50 per cent. of the maximum rated plate volts and plate input, as well as the resonant frequency of the individual tubes The data sheets for specific types give electrical particulars, maximum ratings for typical operating conditions, dimensions, bulb particulars and average characteristics.

The miscellaneous tube section is of particular interest from the viewpoint of engineering electronics, as distinct from the radio field. Some idea of the range of apparatus dealt with may be gained from the following list :—

Cathode-ray tubes.
Gas triodes and tetrodes.
Iconoscopes.
Kinescopes.
Monoscopes.
Photocells (gas and vacuum).
Rectifiers.
Video beam tubes.
Voltage and current regulator tubes.

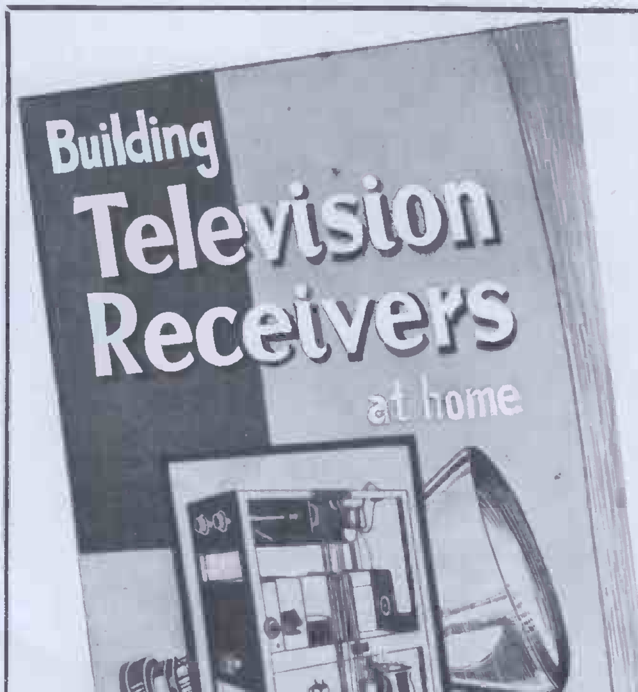
Some of the types seem out of place in this section; for example, types 840 (R.F. pentode) and 954 (detector amplifier pentode).

An interesting item is the type 920 gasfilled twin phototube, having two caesium-coated cathodes, each with a window area of 0.31 sq. in. The reduction of sensitivity with increase of frequency is approximately 20 per cent. between 100 and 10,000 cycles, or from 75 to 60 microamperes per lumen. A figure of not more than 10 is given for the gas amplification factor, defined as the ratio of sensitivity at maximum anode voltage (90 volts D.C. or peak A.C.) to sensitivity at a voltage sufficiently low to eliminate the effects of gas ionisation. This is at about 25 volts.

In many cases the information is amplified by means of typical circuit diagrams, which are very helpful. In fact, one might wish to see more of these, although it would be necessary in most cases to delete other information or reduce the size of the characteristic curves if extra pages were to be avoided.

It is inevitable that in the assemblage of such a vast amount of information, a few errors should occur. Thus under types 2050 2051 (gas tetrodes) the tube voltage drop is given as 8 and 14 *milliamperes* respectively. Slips of this kind, however, detract but little from the value of the information as a whole, which is of the greatest interest and service to all concerned with applied electronics in its various branches.

G. WINDRED.



Adjacent Channel Rejection

A Means of Securing Extreme Selectivity

ALTHOUGH very great selectivity can now be obtained with superhet receivers, it is sometimes desirable to obtain even greater selectivity than can be provided by the usual multi-stage tuned I.F. amplifiers.

This can be done by providing special coupling circuits in the I.F. amplifier which are so arranged that two opposing couplings cancel out at frequencies separated by a given amount from the desired I.F. frequency. An interesting example of a receiver of this type recently disclosed by the Radio Corporation of America is described below.

The circuit diagram of this receiver is shown by Fig. 1, which will be recognised as that of a conventional superhet receiver having in addition to the normal I.F. amplifier stages two additional stages comprising the valves 30 and 40, to which A.F.C. is applied.

Between the I.F. output circuit 11 and the input electrodes of amplifier 12 there is connected the tuned circuit 14 and the latter is resonated to the operating I.F. The input circuit 11 comprises coil 16 and the shunt tuning condenser 15; tuned circuit 14 comprises coil 17 and the link coupling coil 18, coils 17 and 18 having connected in shunt with them the resonating condenser 19. The capacity C connects the high alternating potential sides of the circuits 11 and 14, and provides a capacity coupling path between the cascaded tuned circuits.

Inductive coupling is provided between circuits 11 and 14 by the coupling between coils 16 and 18, and this inductive coupling is denoted by the symbol M. The circuit details of amplifier 12 are not shown, but it will be understood that the cathode circuit of this, as shown in connection with amplifier 12′, includes the usual signal grid biasing network. The I.F. output circuit 21 is connected to the anode of the amplifier 12.

The coupling capacity C is denoted in dotted lines, because it is provided by the capacity between the grid and cathode of the valve 30. The control grid of this valve is connected to the high alternating potential side of circuit 11 by a direct current blocking condenser 31, whereas the cathode is connected to the high potential side of circuit 14. The anode is connected to a source of positive potential through a resistor 32. The magnitude of capacity C is controlled by varying the bias of the grid of valve 30.

The inductive coupling M is so poled that the voltage induced through M is opposite in sign to the voltage induced through the capacity coupling C. Furthermore, these voltages are made to cancel at an adjacent channel frequency which is spaced from the I.F. value by a predetermined frequency magnitude.

In Fig. 2 there is shown the type of selectivity characteristic secured with the circuit disposed between the network 1 and amplifier 12′. It will be understood that the curve in Fig. 2 to one side of the vertical dotted centre line represents the rejection characteristic of the coupling network between 1 and 12. The resistor R, connected across the link coupling coil 18, functions to correct for all factors in the circuit.

In other words, the function of the resistor R is to provide accurate cancellation of the opposed voltages due to C and M; correct values of M, C and R provide infinite rejection of the undesired adjacent channel frequency.

The resistor 33, connected between resistor R and earth, is shunted by the by-pass condenser 34 and functions as the grid biasing network for the grid of valve 30. An examination of Fig. 2, and particularly one-half the curve on either side of the centre vertical line, shows the infinite rejection characteristics secured. This type of rejection characteristic is secured when the capacity C is adjusted to reject an adjacent channel frequency which is 10 kc. off resonance.

It may be pointed out that while the capacity coupling C increases with frequency, impressed voltages transmitted through the coupling M are subjected to a decreasing coupling with frequency increase. Accordingly, while no coupling exists between circuits 11 and 14 at the channel 10 kc. off resonance, coupling does exist at the I.F.

The network between amplifier 12 and amplifier 12′, on the other hand, is constructed to produce a rejection characteristic as shown in the opposite half of the curve in Fig. 2. In other words, the coupling circuit between networks 1 and 12 has the characteristic shown on one side of the vertical dotted line in Fig. 2, while the coupling circuit between amplifiers 12 and 12′ has the characteristic curve shown in the opposite half of the curve in Fig. 2. It will be seen that the coupling network between amplifiers 12 and 12′ rejects the adjacent channel frequency on the opposite side of the I.F.

The coupling network between amplifier 12 and amplifier 12′ comprises the output circuit 21 and the input circuit 22 of amplifier 12′. The circuit 21 is tuned to the I.F., and the coil 23 of this is magnetically coupled, as at M_1, to the link coupling coil 24 of the I.F. input circuit 22.

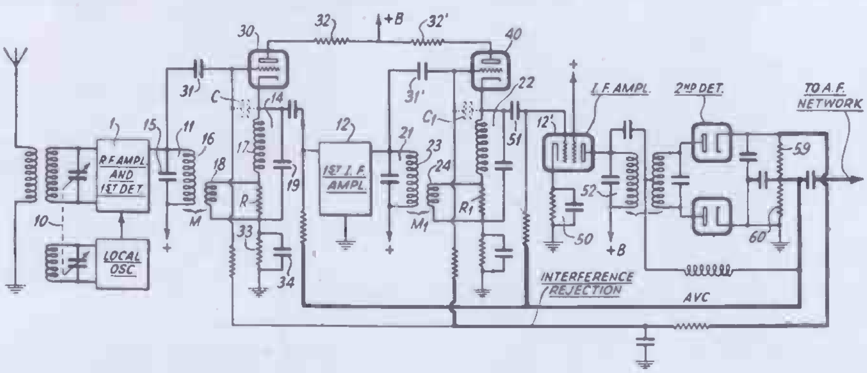


Fig. 1. Circuit diagram of superhet with two additional stages for obtaining great selectivity.

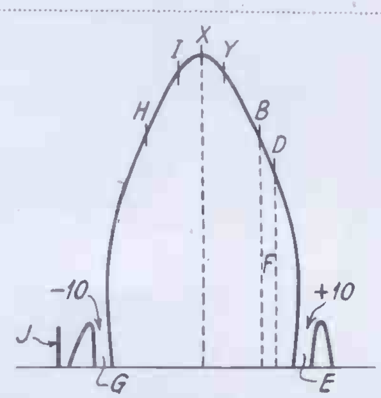


Fig. 2. Curve showing selectivity characteristics.

The capacity C_1, shown in dotted lines, provides the coupling capacity between the high alternating potential points of circuits 21 and 22, and is provided by the capacity existing between the grid and cathode of valve 40. It will be noted that the construction of the selector network between amplifiers 12 and 12′ is substantially similar to that preceding amplifier 12.

The control grid of valve 40 is connected to the high-potential end of coil 23 by a direct-current blocking condenser 31′, and the anode of this valve is connected to the positive potential source of valve 30 through a resistor 32′. The cathode of valve 40 is connected to the high-potential side of circuit 22. The resistor R_1 is connected in shunt with coupling coil 24, and functions in the same manner as described in connection with resistor of valve 40. Circuits 21 and 22 are each resonated to the operating I.F. value.

The I.F. amplifier 12′ includes in its earthed cathode circuit at signal grid biasing network 50, and its control grid is connected by the direct-current blocking condenser 51 to the high potential side of input circuit 22. The anode circuit of valve 12′ includes an output circuit 52 which is resonated to the operating I.F. value.

The second detector arrangement is of the well-known kind in which audio frequency and A.V.C. voltages are developed across the load resistance 60, while A.F.C. voltages are developed across the resistances 59 and 60 in series. The latter voltages are applied to the control grids of the valves 30 and 40.

To explain the operation of the receiving system shown in Fig. 1, let it be assumed that the selectivity curve shown in Fig. 2 is that of the receiving system with an incoming signal properly tuned; in that case no direct current voltage is developed across resistors 59-60. The desired signal carrier may then be represented as being located at the point X which is at the central dotted line of the curve.

Assuming further now that an interfering signal occurs at a point B, the natural tendency of the operator would be to adjust the tuning device 10 so as to retune the receiver to attempt to reduce the magnitude of the interfering signal. If the desired carrier were shifted to a point corresponding to point Y, the undesired signal would be shifted a corresponding amount to point D. However, upon adjusting the tuning mechanism 10 so as to shift the desired signal carrier frequency to point Y, there would be developed sufficient discriminator voltage across 59-60 to move the rejection notch E to the position F located between the vertical dotted lines B and D. The effect of this shift of the rejection notch E to the poition F would be entirely to remove the interfering carrier.

In the same way if an interfering signal should appear at point H, it could be removed by adjusting the tuning mechanism 10 until the desired carrier is shifted to the point I. In other words, upon adjusting the tuning mechanism 10 in a sense to tune out the interfering carrier H, the rejection notch G is shifted towards the position of the interfering carrier H, as was described in connection with the rejection notch E.

While shifting of either of the rejection notches, say, E, towards the centre line X results in a simultaneous shift of the rejection notch G to the point J, the proper operation of the system will not be affected. The essential advantage of the present arrangement is that the discriminator functions automatically to adjust the magnitude of either of the capacities C or C_1 when the tuning device 10 is adjusted to detune the receiver on either side of a desired carrier frequency.

The effect of the detuning is to develop discriminator voltage; the latter is utilised for automatically adjusting the appropriate one of the rejection networks in a sense to eliminate the interfering carrier. Minimum interference occurs when rejection notch E and the interfering carrier coincide in frequency. This would occur when the desired carrier is tuned to Y. The interfering carrier has been moved to point D.

By detuning the desired signal to Y a positive voltage is developed by the discriminator circuit; this increases the electronic capacities of valves 30 and 40. In turn, this moves notch E to D which eliminates the interfering carrier. At the same time notch G would have moved to J but this effect in this case is unimportant.

If, however, the interfering carrier had appeared at H the desired signal would have been tuned to I; and the discriminator output would have been negative and notch G would have moved in to take out the interference.

As a matter of fact the receiver operator, upon tuning to a desired carrier frequency and hearing an interfering carrier, will adjust the tuning device 10 until the interfering carrier response is a minimum. This means that he has detuned the receiver sufficiently to one side of the desired carrier frequency to develop enough discriminator voltage thereby to shift a rejection notch to the position occupied by the interfering carrier frequency.

In *Progesso Foto*, recently, an account was given of experiments in producing copies of sound tracks upon narrow steel tape, to be reproduced magnetically. The author states that the best results were obtained by covering one face of the tape with a dilute solution of bichromated gelatin, and making a copy by methods used in enamelling processes: the layer is tinted after printing, washed in warm water, heated, and then etched by a solution of ferric chloride at 38 degrees Baume. In order to limit the etching to the one face of the tape, it is wound in a helix on a rubber roller.

Number four of the *Television Journal* has just been published and has been circulated to members on the active list. The Editor asks us to point out that those members who have not yet received their copies have probably omitted to notify him of any change of address, and they are recommended to write immediately to W. G. W. Mitchell, "Lynton," Newbury, Berks. The following is a list of the chief contents of the Journal:—

Twelfth Annual Report.
Twelfth Annual General Meeting.
A New Method for Television Image Transmission.
The Implosion of Cathode-day Tubes.
In Search of a Technique for Television.

"Electronic Musical Instruments"

(*Continued from page* 348)

subsequently combined, some form of mixing circuit must be provided.

In complex waveform systems this is accomplished by arranging for the outputs of the various generators to be fed to multi-ratio transformers, the feeds from the generators for each particular tone colour being provided with limiting impedances in order to keep the primary loading on the transformer as constant as possible. If this is not done, frequency distortion will occur according to the number of notes being played. A similar circuit arrangement is required for combining the various note frequencies associated with their respective stops.

As one example of a *simple* waveform generator, Fig. 16 indicates the complete circuit of an organ incorporating the 96-note, simple waveform tempered-harmonic generator of the single-note-per-disc, magnetic type.

By means of the multi-contact key switches the current from the note-frequency generators is fed via a limiting resistance to the stop switches, which are adjustable over the busbars connected to the 8 tappings on the primary of the output transformer, which feeds the power amplifier. The tappings of the transformer primary are such that the successive tappings provide voltages in geometrical progression. This is in order that adjustment of the harmonic mixing switches which make contact on these busbars shall provide successive equal increments in loudness, in accordance with Weber's law. Each of the harmonics of one note is obtained via a limiting resistance from the appropriate generator through one of the contacts of the key switch to the appropriate harmonic mixing switches.

It will be clear that the depression of a key switch will connect to the transformer the generators supplying frequency whch have been selected by the harmonic mixing switches, the intensity of the particular harmonics being regulated by the extent to which the mixing switch is drawn and the particular busbar which has been connected in this manner.

Additional multi-contact stop switches are provided so that any harmonic content which has been found pleasing can be connected to the appropriate tappings of the output transformer.

Mixing circuits are used in conjunction with electrostatic rotary generators and in modified forms in other types of electrostatic generator. In such generators the A.C. output, and therefore, the voltage impressed on the grid of the first amplifier valve, will be proportional to the D.C. excitation voltage applied to the generator electrodes. The generation of sinusoidal or complex voltage waveforms of the required magnitudes is therefore most readily performed by applying the appropriate D.C. voltages to the generators.

Sound Producing Equipment

Considerable progress has been made in the design of amplifiers and loudspeakers in recent years, particularly in connection with sound-film developments.

The main difficulties arise in the extension of the frequency range down to the limit of approximately 16 c./s., and the uniform radiation of the sound, as high directional intensities are very undesirable, except perhaps in exceptional circumstances.

A loudspeaker system which has been specially developed for use in conjunction with electronic organs incorporates an amplifier having a suitably extended frequency response, and high- and low-frequency range loudspeakers of special design. These speakers have stretched aluminium foil diaphragms mounted on circular rings. The diaphragm has a moving-coil drive and at low frequencies operates approximately as a piston in the surrounding baffle. The polar distribution of the sound radiated from this form of loudspeaker is extremely uniform so that there are no undesirable focusing effects.

A view of the complete console, the overall dimensions of which, without the pedal board, are 49 in. high, 62 in. wide, and 29 in. deep, is shown by the photograph on page 342. The loudspeaker cabinets, which also house the power amplifier, the size and number of which will depend on the building in which the organ is to be installed, are separate components.

No one will deny, of course, that electronic organs are still in their infancy, as compared with traditional forms of musical instruments. Nevertheless, a stage has now been reached when the designers of electronic organs may be proud of their achievements, having in mind the hundreds of years of development which have contributed to the present high standard of excellence of the modern pipe organ. Obviously, immediate attention will be directed towards the perfection of details of design of instruments operating on the principles already referred to in some detail, and it is certain that surprising improvements will follow from the increased range of tone colours and effects which will become possible.

Other principles may be anticipated; for example, the use of a cathode-ray method of waveform generation has been proposed. The attraction of such a method would seem to be the absence of moving parts, although it is difficult to say at this stage whether or not this advantage would be outweighed by the more elaborate nature of the components.

The July issues of the American Short-wave Press announce the cancellation of the 1940 DX contest, consequent on the ban on amateur radio communication between America and all foreign stations. This ruling does not, of course, apply to amateur communication between licensed stations in U.S.A. and its possessions. It is pointed out that this restriction will not be extended to a total prohibition of amateur radio in America.

New Valves

U.H.F. Push-pull Transmitting Pentode

The latest trend in transmitting valves seems to be toward the multiple-unit type. The R.C.A. announce the introduction of the Type 829, the envelope of this valve, which is designed for U.H.F. performance, contains two beam tetrodes. The cathodes are connected together inside the bulb, while the heaters are connected in series with the centre tap brought out to a separate terminal so that they may be operated in series from a 12.6-volt supply or in parallel from a 6.3-volt supply. The valve is designed particularly for push-pull operation.

Maximum CCS ratings in Class-C telegraph service are: D.C. anode voltage, 500; total anode current, 240 mA.; total anode dissipation, 40 watts; maximum anode input, 120 watts. Typical power output is approximately 83 watts. The valve may be operated at full ratings at frequencies up to 200 Mc. and at reduced input to 250 Mc.

The Columbia Broadcasting System has filed an application with the Federal Communications Commission for permits to construct two new 50,000-watt international short-wave broadcast stations.

One of these permits would grant an increase in power and provide for removal of the present short-wave station, WCBX, from Wayne, New Jersey, to the location chosen for the new transmitters—a 1,200-acre site on Long Island, New York.

The equipment would operate with full power on each of the six bands between 6,000 and 22,000 kilocycles now allocated for this type of service.

Both would also be capable of delivering full power to several directional aerials with which they are to be employed. The aerials would have an effective gain of at least ten to one in the direction of maximum signal; thus signals would have a strength equivalent to 500,000 watts.

* * *

Oscillograms of speech sounds made by a number of speakers show considerable variations in the rate of building up to full amplitude. Contrary to expectation, state Messrs. R. O. Drew and E. W. Kellog in an article in the Journal of the Society of Motion Picture Engineers, sounds commencing with an explosive consonant build up less rapidly than those with an open vowel. An increase of modulation from zero to 100 per cent. in 0.05 second was frequently found, but the majority of syllables start more gradually than this. The point is of considerable importance in connection with noise-reduction systems.

HOME INSTRUCTIONAL COURSE

THE PURPOSE OF THIS SERIES

With the object of filling the gap which has been temporarily caused in the education of the radio student, we are providing a series of articles on various theoretical aspects of radio engineering.

The present position has led to the suspension of evening classes in many of the Technical Institutes and added to the difficulties in attending those that are available. Some thousands of students of radio will miss the opportunity of increasing their knowledge of the theoretical side of the subject. Practice is not always enough to keep abreast of the subject, and the radio engineer or serviceman must understand fully the theory underlying the practice in order to cope with the frequent "out of the ordinary" jobs that come his way.

The articles are not intended to compete with or in any way displace the "correspondence course" in which the subject is dealt with fully from beginning to end, but are aimed to give concise information on certain fundamental theories which will be of direct use to the student in his work.

Each article will be complete in itself and in order to give mental exercise, examples will be given at the end. While we cannot enter into correspondence with readers on the subject matter of the articles, it will be found that the examples given are answered in the succeeding article and numerous explanatory foot-notes should make the discussion as clear as possible.

Suggestions are invited from students for special aspects of the subject to be dealt with in later articles.

THE VALVE AS AN AMPLIFIER

IN an article which appeared earlier in this series (April, 1940), the principal constants of the valve were discussed —the magnification slope and A.C. resistance.

The magnification of the valve is an indication of its usefulness as an amplifier of voltage variations—a valve with a high magnification will give a large change in anode voltage for a small change in grid voltage. The magnification should not be confused with the "stage gain" which is a measure of the amplifying properties of the valve and its associated components. In the case of a resistance-coupled amplifier the stage gain depends on the value of anode resistance besides the constants of the valve.

The formulæ for calculating the stage gain of a valve and resistance depends on the type of valve used since the characteristics of a triode are entirely different from those of a pentode.

The characteristics of a triode have already been shown in the article referred to, and are reproduced again in Fig. 1 for the sake of convenience.

Before dealing with the calculation of gain, a point may be mentioned which is sometimes overlooked by the student. The curves show the relation of the anode current and grid voltage at given values of anode voltage. This voltage is not the same as that of the H.T. battery unless the coupling device in the anode circuit has negligible resistance. If the valve is coupled by means of a transformer, the primary winding has a resistance of a few thousand ohms which may be neglected in some cases, but if the valve is resistance coupled the current flowing through the resistance will produce a voltage drop which will reduce the potential actually applied to the anode. Taking an example, a resistance of 50,000 ohms with 3 mA. flowing through it produces a voltage drop of 150 volts.

To give an anode voltage of 100 we therefore require an overall H.T. voltage of 250. A more common case is where the voltage of the battery is fixed at, say, 150 and the anode voltage is then found by deducting the drop in potential across the anode resistance.

The importance of this is in calculating the exact operating point of the valve from the characteristic curve. Referring to Fig. 1, a grid bias of −1 volt with 75 volts on the anode gives 2 mA.

With an anode resistance of 50,000 ohms and an H.T. battery voltage of 150, the voltage available at the anode would be 150-100 or 50 only. Thus the valve would not operate at the point on the characteristic shown, but the anode current would be reduced slightly till the drop in the resistance and the anode voltage added up to give the overall H.T. voltage. The operating point would be at a slightly lower value than the 75 volts curve shown—about 1.6 mA., giving 80 volts dropped and 70 volts available at the anode.

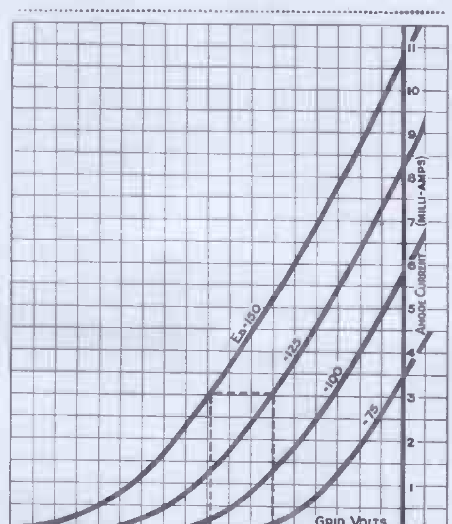


Fig. 1. Typical triode characteristic used for finding operating point.

Gain of a Triode

In calculating the stage gain of a triode with resistance coupling, two factors have to be taken into account: the load resistance (that in series with the anode) and the internal resistance of the valve. The valve can, in fact, be considered as an alternating current generator driving a current through the two resistances in series. If the voltage applied to the grid is e, the voltage change in the anode circuit is μe according to the definition of magnification, μ being the magnification factor of the valve. This alternating voltage μe is applied to the internal resistance and the anode load resistance in series, producing an anode current I_a which is given by the formula:

$$I_a = \frac{\mu . e}{R + R_a}$$ where R is the load resistance and R_a is the A.C. resistance of the valve.

To find the stage gain, we are concerned with that portion of the voltage which is developed across the anode load R so multiplying the current by R, we obtain:

$$RI_a = \frac{\mu . e . R}{R + R_a},$$ RI_a being the voltage across the load.

This formula can then be used to find the stage gain of a valve of which the magnification factor and the circuit constants are known.

Taking the case of an average high-magnification triode of the AC/HL type, the published data show that the magnification factor is 36 and the A.C. resistance 10,000 ohms. With an anode load of 50,000 ohms, the stage gain will be $\frac{36 \times 50{,}000}{50{,}000 + 10{,}000}$ or $\frac{36 \times 5}{6}$ which is 30. The maker's published figure is 27, which is in close agreement as the value of A.C. resistance is approximate. The term e in the formula is taken as 1, i.e., the answer gives the amplification of the stage per volt input.

On examining the formula it will be seen that the higher the anode load, within reason, the greater the stage gain. With 100,000 ohms the gain would be $\frac{36 \times 100}{110}$ or 33 approximately. The limit is reached when the value of anode load is so high that there is negligible voltage at the anode itself and the valve is consequently incapable of operating at a point on the straight portion of the characteristic. If the H.T. voltage is raised to compensate for the voltage dropped in the resistance there is a possibility that the safe working voltage of the anode may be exceeded when the signal is applied.

The overall gain of two or more valve stages in cascade is found by multiplying the gains together. Thus, two stages of 30 per stage would have an overall gain of 900, and three stages, 27,000. The practical limit is set by the stability of the amplifier, and for high-gain amplifiers it is customary to use pentode valves on account of the greater stage gain obtainable.

Gain of a Pentode

Inspection of the characteristic curves of the pentode given in Fig. 2 shows that its performance is different fundamentally from that of a triode. The characteristic used in determining the performance is the anode current-anode volts characteristic and not the anode current-grid volts curve of Fig. 1.

In calculating the power output obtainable from a pentode or triode the anode current curves are required and for this reason the anode current-grid volts curves are seldom given for a power pentode.

The most important point in the study of the curves is to note that the current remains practically constant over a wide range of anode voltage, under given conditions of grid bias and screen voltage. The calculations of magnification and slope as done on the triode characteristic of Fig. 1 have therefore no significance in the pentode. For example, we could attempt to find the magnification by noting the change in anode current on the curve produced by a change of 2 volts grid bias. This may be from -10 to -12, the change being 5 mA. In order to compensate for this change in anode current the anode voltage would have to be raised from 240, its initial value to approximately 600 volts (found by extending the 12 volts bias curve along until it intersects the 30 mA. line).

Such a value of magnification (180) would not be accurate and would have no practical meaning. The slope, on the other hand, may be obtained from either the curve of Fig. 2 or the anode-current-grid volts curve at a given screen voltage. From the curve shown it is equal to 5 mA. change per 2 volts change on the grid, or $2\frac{1}{2}$ mA. per volt.

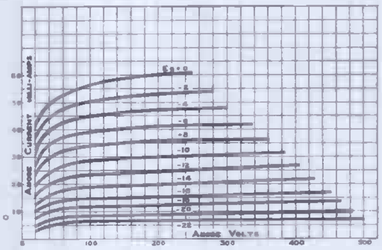


Fig. 2. Pentode characteristic showing "constant current" property of pentode.

For calculating the gain obtainable, it is most convenient to consider the pentode as a generator of constant current which is flowing through the load resistance in the anode circuit. The signal applied to the grid causes a change in anode current which is equal to g, the slope of the valve, and this change in current flowing through the anode resistance produces a voltage change equal to $g.R_t$ where R_t is the total equivalent resistance in the anode circuit. This is actually made up of the anode resistance R and the grid leak resistance of the next stage R_g in parallel, together with the A.C. resistance of the valve also in parallel.

The formula then becomes:

$$\text{Gain} = g.\frac{R}{1 + \frac{R}{R_g} + \frac{R}{R_i}}$$

R_i being the internal resistance of the valve. This formula neglects the effect of the coupling condenser and does ot allow for any shunting effects at high frequencies, but is accurate for audio frequencies.

Operating Point

When the valve is used as a voltage amplifier, the grid bias and anode voltage are adjusted so that the normal operating condition gives a value of anode current on the straight portion of the characteristic. As the applied signal changes the grid voltage by a given amount on either side of the fixed bias value, the change in anode current will follow the change in grid voltage according to a linear law, i.e., the variations in the grid voltage will be faithfully copied in variations in anode current and hence in voltage change across the anode load.

This is the essential requirement for distortionless amplification and if the valve is not operating on the straight portion of its characteristic the output voltage in the anode circuit will contain unwanted components which will distort the output waveform. Similar distortion will arise if the signal applied to the grid is so large that the anode current changes bring the current momentarily on to the curved portion of the characteristic—the valve will be "overswinging." In choosing the operating conditions for a given amplifier it is therefore necessary to make sure that the input can be handled by the valve without overload and the value of H.T. and grid bias must be chosen accordingly. With low values of input it is possible to select an operating point which is well down on the curve, as the change in grid voltage and anode current will be so small that the curvature of the characteristic will not introduce appreciable distortion. The operating point, particularly with battery valves is chosen with regard to economy in anode current, too low a bias resulting in a large "standing" anode current which will waste the H.T. battery.

Some years ago the problem of waste in anode current received a great deal of attention and methods were devised to operate the valve at a point on the characteristic which would ensure a minimum anode current when no signal was being received, rising in value when the valve was delivering power.

Class A and Class B

In Class A operation, the grid bias of the valve is adjusted so that the anode current value is about the mid-point of the straight portion of the characteristic. This is the operating point which has been assumed in the discussion in this article. The change in anode current then follows exactly the changes in grid voltage. While this results in distortionless amplification, the valve is not operating economically in anode current consumption.

In Class B operation, the grid is deliberately biased so that the operating point is down on the lower part of the curve towards the "tail." This means that the anode current change will be greater when the grid is made less negative than when the bias is increased. The resulting anode current wave will be asymmetrical if a symmetrical waveform is applied to the grid, but this apparent distortion can be overcome by using two valves arranged in push-pull, each valve handling half of the input wave.

An extreme case of Class B operation uses the valve with the grid biased to the cut-off point, so that no anode current is flowing until the signal is applied to the grid. Then alternate halves of the input wave will produce a half-wave of anode current. This method of operation is known as "Class C."

OPPORTUNITIES SECTION

BUSINESS :: EQUIPMENT :: EMPLOYMENT :: MISCELLANEOUS

The charge for miscellaneous advertisements on this page is 12 words or less 2/-, and 2d. for every additional word. Singe-column inch rate displayed, 12/6. All advertisements must be accompanied by remittance. Cheques and Postal Orders should be made payable to Hulton Press, Ltd. and crossed, and should reach this office, 43, Shoe Lane, London, E.C.4, not later than the 15th of the month previous to date of issue.

"Broadcast Music to Speed-up Production"

(*Continued from page 352*)

trol room according to which centre is being used for microphone announcements, it being possible to cut either of the microphones into the gramophone or radio programmes at will. A very flexible system is thus provided.

There are 220 speakers fed from this equipment situated in all parts of the factory, the type of speaker used depending on its situation. In the machine rooms for instance, where the noise level is rather high, wide angle projection speakers of the horn type have been fitted.

These successfully overcome all extraneous sound and counteract the absorption of broadcast music or speech by lathe belting.

For general purposes where relatively quiet operations such as hand assembly of valve parts are conducted, the standard industrial pattern speaker is installed. This type is also utilised for the air raid shelters. In shops having approximately unity aspect ratio, i.e., square, concentric diffuser speakers are employed. These are designed to spread the sound in all directions at once, and are thus suitable for central mounting. Standard pattern domestic loud speakers are fitted in the executive and general offices. These speakers, together with those operating in the laboratories and in other situations where it is not desired to radiate music, are not connected with the radio or gramophone circuit.

It has been discovered that persistent noises of not too obtrusive a character affect enjoyment of programmes less than intermittent sounds, especially if the periods between the intrusions are irregular. By the careful placing and choice of speakers, however, this difficulty has been overcome.

A system such as the above can be applied to a wide range of situations. Where managers are seeking to increase output and ensure the safety and welfare of their employees, it is greatly to be advocated. By tending to provide increased output it is likely to pay a high dividend which will be found quickly to cancel original costs.

INDEX TO ADVERTISERS

Printed in Great Britain for the Proprietors, Hulton Press, Ltd., 43-44 Shoe Lane, London, E.C.4, by The Press at Coombelands Ltd., Addlestone Surrey.
Sole Agents for Australia and New Zealand: Gordon and Gotch (A/sia), Ltd. South Africa: Central News Agency, Ltd.