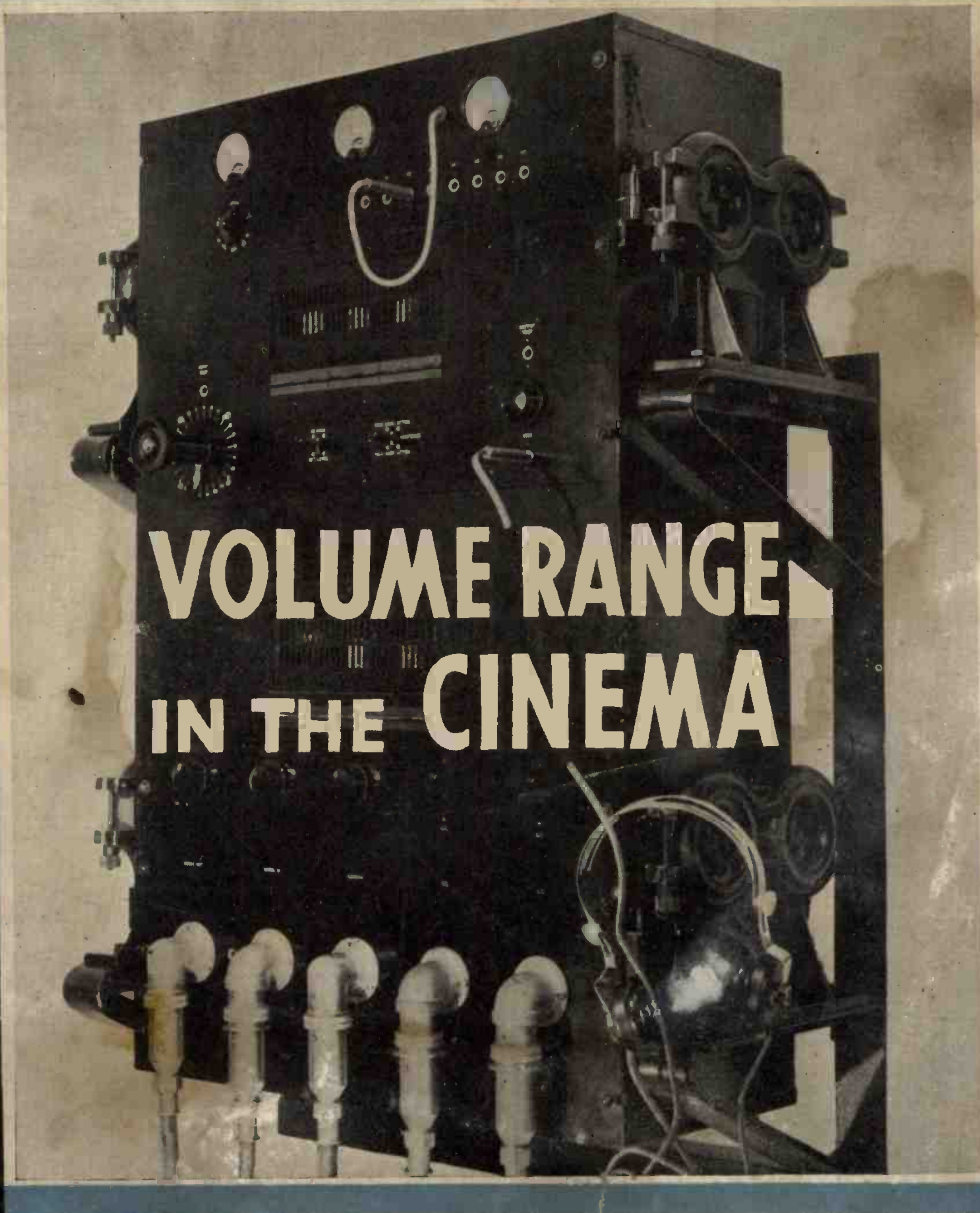
ELECTRONICS AND TELEVISION

& SHORT-WAVE WORLD

1/6

JUNE, 1940



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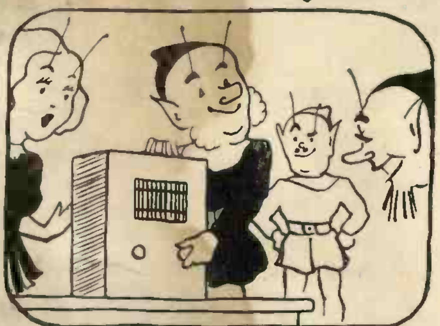

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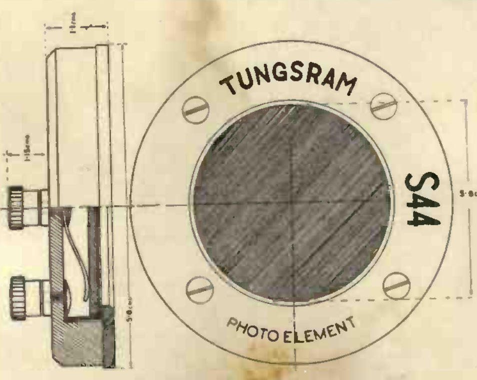

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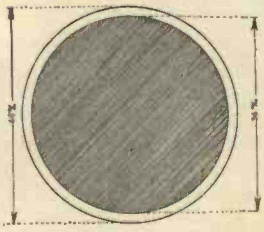

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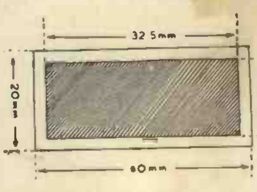

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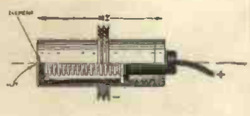

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A Hulton Publication

IN 1928, an off-shot of the company that had been formed to develop the television inventions of Mr. John Logie Baird produced the first issue of this journal. Its title was "Television," the first journal of its kind in the world. The fact that such a journal could be published was in itself remarkable at that date. Two or three years later, "Television" passed into the ownership of Benn Bros, Ltd., a notable house associated with the publishing of trade and technical papers, and in December, 1933, it was sold to Bernard Jones Publications, Ltd., in whose hands it was enlarged and strengthened, so much so, that during the years immediately preceding the public television service it did its part manfully in influencing those in authority and in educating the trade and the public to the need of regular television transmissions.

Now, with this issue, ELECTRONICS AND TELEVISION (as this journal has been known since October last) goes over to Hulton Press, Ltd., already famous as the proprietors of five journals, each entirely distinctive: *Picture Post*, the world-famous picture weekly; *Lilliput*, a clever pocket monthly; *Farmers' Weekly*, a well-produced weekly covering all the interests of the agricultural community; *Nursing Illustrated*, a bright and authoritative weekly for the nursing profession; and lastly, *Housewife*, a pocket monthly of a new order appealing to every woman who is running a house and home. Into the hands of this up-to-date and enterprising house ELECTRONICS AND TELEVISION now passes. For the time being it will be maintained more or less in its present form, but with the resumption of peace, whenever that should come, its new owners hope to develop it on outstanding and generous lines and in so doing to evince the complete confidence which they have in its future possibilities.

CONTENTS FOR JUNE

A Recent Improvement in Filamentary Cathodes

FILAMENTARY type thermionic cathodes have been made of pure tungsten, activated thoriated tungsten and oxide coated nickel. The pure tungsten cathode is a very stable emitter and is efficient, but must be operated at very high temperatures to obtain ample emission.

The activated thoriated tungsten cathode may be operated at lower temperatures than a pure tungsten filament and is more efficient, but is easily poisoned by oxygen and other gases which adversely affect the emission, is not very stable when operated at high voltages, and requires special processing and seasoning.

Effect of High Frequencies

It has been noticed that when operated at ultra-high frequencies, for example, above 15 or 16 megacycles, emission becomes erratic and there is sometimes a total loss of emission. In addition, the activated thoriated filament is apt to be brittle, and if operated at too high a temperature quickly de-activates and loses its ability to emit a sufficient number of electrons to be useful.

The oxide coated nickel filamentary cathodes and oxide coated indirectly heated cathode operate at a much lower temperature than either kind of tungsten cathode and are efficient, but cannot be satisfactorily operated in tubes in which very high plate voltages, such as 1,000 volts, are used, and they require considerable processing and seasoning.

Thoriated molybdenum has also been thoroughly investigated, but rejected commercially as a filament cathode, because it is unstable, sensitive to poisoning by gas within the tube, and must be operated at fairly high temperatures, between 1,400° and 1,600° C. to provide satisfactory emission.

Thermionic cathodes which are efficient at desirable operating temperatures, and which can be satisfactorily used at high frequencies and high voltages have recently been developed in the laboratories of the Radio Corporation of America. Broadly, this new cathode consists of a refractory metal having a high melting point, preferably 2,400° C., or higher, combined with thoria or its equivalents and cathodically treated in an electrolytic bath. Of the refractory metals tungsten and molybdenum are preferred.

The preparation of these new cathodes is as follows :—

A thoriated molybdenum or thoriated tungsten base may be prepared as a ductile metal in well known manner, or by squirting the finely divided material admixed with a binder. For example, if molybdenum is used powdered nitrate or thoria may be added to the powdered oxide of molybdenum before the reduction of the oxide of molybdenum, or thoria may be added to the oxide of molybdenum after reduction, but before consolidation of the metal powder by sintering or mechanical working to the solid state. The amount of thoria may vary from about ½ of 1 per cent. by weight of the metal to about 10 per cent. of the metal.

Tungsten containing more than 2 per cent. or 3 per cent. of thoria is extremely brittle and hard to work, but in general it is desirable for best results to add as much thoria as may be tolerated in the refractory metal without interfering with the subsequent swaging and drawing of the metal. This has been found in practice to be up to 1-½ per cent. for tungsten and up to 3 per cent. for molybdenum. A filament of this thoriated metal may be used.

Preparation

In general the larger the percentages of thoria the better the emitter. While thoria is preferred, equivalents of thoria, for example, one of the group of metals consisting of zirconium, uranium, cerium, titanium, vanadium, yttrium and lanthanum may be used with tungsten and molybdenum to form a base and the base then cathodically treated in an electrolyte, preferably dilute sulphuric acid which may be ½ per cent. solution of H_2SO_4. Other acids such as chromic acid (H_2CrO_4), acetic acid $H(C_2H_3O_2)$ and hydrochloric acid (HCl) also provides suitable baths.

While the current density for electrolysing the thoriated metal base may vary between wide limits, for example, from a few hundredths of an ampere to over 1 ampere per square centimetre, a current density of about 1 ampere per square centimetre for a period of one minute seems to produce the most satisfactory results. The resulting thoriated wire may be used for a thermionic electron emitter without further treatment, but in the case of the thoriated tungsten base it is preferable to flash the electrolysed filament in vacuum at over voltage; for example, to heat the filament to a temperature of approximately from 1,500° to 2,000° K for short periods up to ten minutes, and thereby facilitate the activation of the filament.

It is also desirable, though not necessary, to insure stability of emission to season the filament whether of tungsten or molybdenum by operating the electron discharge device containing the filament with normal voltages applied for approximately fifteen minutes in an oscillating circuit.

It is believed that the new cathodes are superior to known cathodes partly for the following reasons :—

When the thoriated tungsten or thoriated molybdenum filament is cathodically electrolysed, the tremendous electrostatic field acting at the electrode during electrolysis causes hydrogen ions to be absorbed into the crystal lattice of the metal. When subsequently the hydrogen is suddenly released by heating, the crystal structure of the surface of the filament is shattered, causing the metal surface to become semi-liquid for an instant of time. During this instant of semi-liquid state the surface tension becomes effective to cause the metal surface to pass to the amorphous state and subsequently freeze in this state so that it does not recrystallise. This results in a greater surface energy of the filament and makes it capable of adsorbing more thorium with greater energy.

In a modification, a pure molybdenum or tungsten filament which has been previously electrolysed as described above is brushed with powdered thoria suspended in an acetone solution to provide a coating which results in an efficient electron emitter. No binder is necessary and if the cathode is handled carefully the coating will not come off during assembly in a tube. When the cathode is heated during operation the coating is sintered on the cathode filament.

Although the thickness of the coating is not critical it should not be so thick as to materially increase the surface area of the cathode and thus lower the temperature of the cathode to such an extent as to affect emission when the cathode is operated at what are considered normal currents and voltages. The filament so prepared may be activated as described above.

Thoriated tungsten filaments treated according to this description indicate emission currents of 6.0 amperes per cm^2 when operated at 25 watts per cm^2 in comparison with 2.89 amperes/cm^2 with untreated thoriated tungsten, burning at the same temperatures. Pure tungsten electrolysed and coated with pure thoria also indicates emission currents of substantially the same magnitude. When such a filament is operated at 30 watts per cm^2 which gives a temperature well below 2,000°K, a value of 7.0 amperes per cm^2 is indicated.

Making a comparison in another man-

(*Continued on page* 249).

Please ask your bookstall or newsagent to reserve a copy of ELECTRONICS AND TELEVISION & Short-Wave World each month and avoid disappointment.

VOLUME RANGE OF SOUND-ON-FILM RECORDING

By

R. Howard Cricks, F.R.P.S.

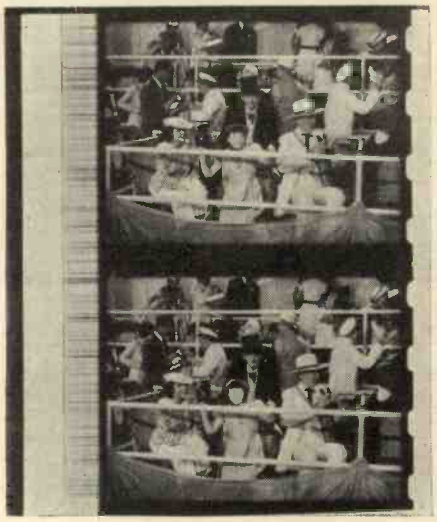


Fig. 1a. Variable-density track.

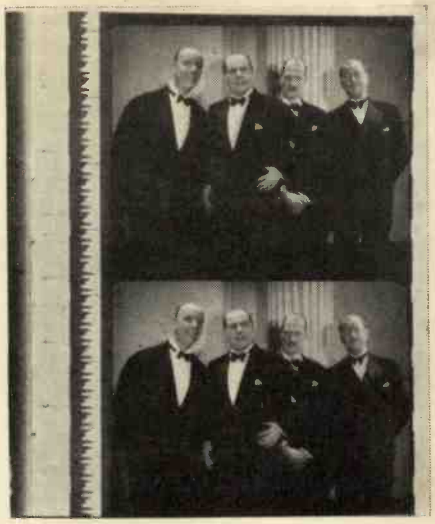


Fig. 1b. Variable-area track.

Enormous progress has been made in sound-on-film recording and in this article, Mr. R. Howard Cricks, who is technical editor of "Ideal Kinema" and editor of the "Journal of the British Kinematograph Society," discusses one of the most important technical advances —the range of volume.

EVERY transmission system has a maximum permissible volume range, which may be defined as the ratio between the maximum undistorted signal modulation and the ground noise. Sound-on-film recording and reproduction differs from other transmission systems only in having so many more points at which limitation of volume range may occur, either by the gradual accumulation of ground noise, or less frequently by the gradual attenuation of signal strength.

The latter is almost entirely confined to the higher frequencies, and need not concern us at the moment. But ground noise is a serious factor in many of the stages from the recording of the negative to the reproduction of the positive.

First let us consider the basic principles of sound-on-film recording.

Principles of Film Recording

The 16 in. discs upon which, more than eleven years ago, the world heard Al Jolson's voice singing "Sonny Boy" have of course long vanished. To-day the sound is recorded on a track on the film, between the picture and the perforations, and 0.1 in. in over-all width (this figure includes the opaque margins). The sound waves are recorded either in a series of graduated densities perpendicular to the length of the track (variable density) or by a series of peaks dividing the track into opaque and transparent areas (variable width or variable area). The German terms are probably the most explanatory: *Sprossenschrift*, or graduated recording, and *Zackenschrift*, or comb-tooth recording.

The former track was originally recorded by means of a glow-lamp which flickered in accordance with the sound currents received from the microphone; but this is now almost entirely superseded by the light valve, in which two minute duralumin ribbons, separated by a distance of about 1 mil. are stretched in the field of a powerful magnet, and carry the sound currents, as a result of which they vibrate in opposite directions, so varying the effective width of the slit between them; this slit being imaged with a reduction of one-half upon the continuously running film, the duration of exposure on the track is continually varying, so that we get a series of ladder-like lines of varying density.

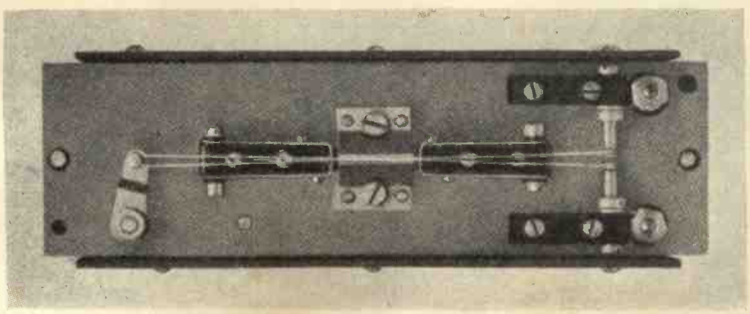


Fig. 2. Recording light-valve (Western Electric).

The variable area track is recorded by some modification of the ordinary mirror oscillograph, a mirror, perhaps 1 mm. square, being affixed to wires strained in the field of a magnet. In the original form of unilateral track (Fig. 5a) the mirror vibrates in a horizontal plane; to produce bilateral or multiple tracks, which have certain advantages, the mirror vibrates vertically, moving the image of a V, W, or similarly shaped mask, over a horizontal slit.

Either type of track is reproduced in the sound head by imaging a narrow slit of light, 1 mil. or less in width, upon the track, and thence upon a photo-cell. Obviously it is immaterial whether the light beam falling upon the cell is modulated as to over-all intensity or effective width.

As a matter of interest, the running speed of the film is 24 frames, or 18 in. per second, or 90 ft. per minute. Thus a 1,000 c.p.s. frequency has a wavelength on the track of 0.018 in., and an 8,000 c.p.s. tone—the limit of present-day recording—just over 0.002 in. The latter figure suggests some of the difficulties, mechanical, optical, and photographic, encountered in the recording and reproduction of high quality sound.

Maximum Signal Strength

Quite obviously, in the case of the variable area track the maximum signal strength is fixed primarily by the width of the track, and secondarily by the contrast of the track—the density of the opaque portion as compared with the transparency of the clear part. In prac-

Effect of Film Grain

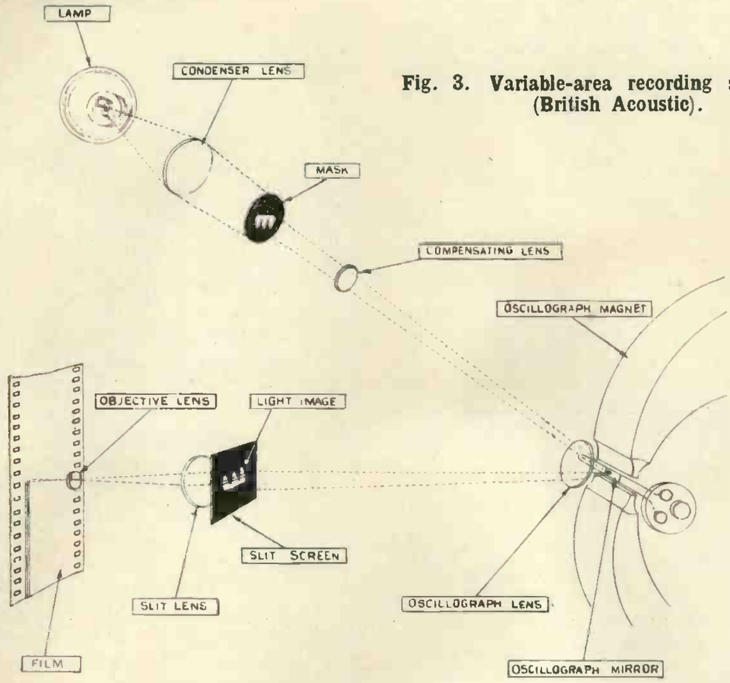


Fig. 3. Variable-area recording system (British Acoustic).

tice, the density of the opaque portion is so high as to have no adverse effect upon the contrast of the track.

In the case of the variable density track, the maximum signal is determined by the maximum contrast obtainable with a given recording lamp, the maximum contrast inherent in the emulsion as a result of the processing operations both of negative and positive films, and other factors about which we need not now concern ourselves. All these factors are mathematically linked, and in order to get a quantitative view of the density process, a brief incursion into photographic theory is necessary.

Theory of Photographic Tone Reproduction

The *transmission* of a photographic image is defined as the proportion of transmitted to incident light. The *opacity* is the reciprocal of the transmission, and the *density* is the logarithm of the opacity. Thus a density of 1.0 is equal to an opacity of 10, or a transmission of 0.1, so that only one-tenth of the incident light is transmitted through the silver deposit.

The characteristic or Hurter & Driffield (H. & D.) curve is plotted as density against log. exposure. The resultant curve consists of the toe, which contains the fog densities; the straight-line portion, in which there is a linear relation between density and log. exposure; and the shoulder, or region of over-exposure. The tangent of the angle formed by producing the straight-line portion to the log E axis is known as the *gamma,* which is thus a measure of image contrast in the correctly exposed portion of the image. Gamma is varied by varying the time of development, or the concentration or temperature of the developing solution.

It will be apparent from the curve that as far as the region of correct exposure is concerned, the density resulting from a given exposure will be shown by the expression :

$$D = \gamma \log E.$$

A similar curve can, of course, be drawn for both negative and positive. The fundamental requirement for correct tone reproduction is that product gamma shall be equal to unity :

$$\gamma n . \gamma p = 1.$$

In a photograph we are concerned in reproducing faithfully the tones of the original subject; on the sound track, we are concerned with a faithful reproduction of the amplitudes of sound pressures by corresponding sound-track modulations. In either case, the last requirement applies except that in practice other factors have to be applied to allow for the difference between diffuse and specular density, printer gamma, and other matters.[1]

Obviously the sound-track gamma in the print must be fixed by the requirements of the picture; on the other hand, separate negatives are almost invariably used for picture and sound, and our requirement of unity product-gamma can therefore be met by adjustment of the sound negative gamma. In practice, a gamma of from 2.0 to 2.4 is usual for the print; to obtain an over-all gamma of from 1 to 1.2 leads (taking into account the other factors mentioned) to a negative gamma of from 0.45 to 0.55, and such figures are commonly used for a variable-density negative. Obviously a slight increase of product-gamma will give an increased volume output.

In the variable area track we are concerned with obtaining a maximum contrast rather than with correct tone reproduction, and considerably higher gammas are usual, of about 0.65.

Although the H. & D. (logarithmic) curve is universally employed in sensitometric work, it is the transmission, or linear curve, which is of chief interest in variable-density recording, since in the ideal system the transmission of the track, and hence the voltage in the photo-cell, must be linearly related to the deflection of the light-valve ribbons. Obviously the relation between the track modulation and the signal output in decibels involves a quadratic expression, since the decibel is a power unit.

The film industry owes one very great advance to the sound film : the introduction into the film laboratory of sensitometric methods, in place of the rule-of-thumb working formerly universal.

The Causes of Ground Noise

When we come to consider the second term of our signal-to-noise ratio, we are confronted with a factor which has no precise equivalent in telephonic systems : ground noise due to the film itself. Although analogous to the ground noise of gramophone records, it has many different properties.

One cause of film noise is inherent in the process : the granularity of the emulsion structure, since the emulsion consists of silver grains varying in size from 0.2 to 2.5μ. But this is insignificant compared with other factors which are encountered in practice, chief of which is dirt.

When a film print has been run through the projector a number of times it acquires a considerable amount of dirt, oil and scratching. On the clear area of the sound track these naturally produce an unwanted modulation of the reproducing light falling upon the photo-cell, and give rise to very considerable ground-noise. On the other hand, dirt and oil can have no effect on the opaque areas of the track, and scratches rarely penetrate the image (on the transparent area they show up because they quickly pick up dirt).

Noise Reduction System

In early types of recordings, the density of the variable-density track varied evenly around a mean of about 0.5, while in the variable area track the unmodulated portion was half the available width of the track, leaving the other half clear film. In either case,

Volume Compression and Expansion

ground noise becomes quite a serious matter.

Therefore noiseless tracks were introduced; this means in the case of the density track that the light valve is biased so that in silent passages, or during low amplitudes of sound, the ribbons remain nearly closed, reducing the unmodulated density of the negative track

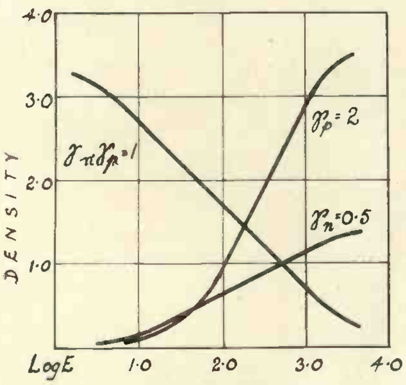


Fig. 4. H and D curves.

to, say, 0.35 (and so increasing print density correspondingly), while when a louder sound comes along, they open to their normal spacing to accommodate the full modulation. Similarly, in the case of the area track, either the oscillograph is biased to reduce the clear width of the positive track, or a shutter is introduced, cutting off the unwanted portion of the track. In either case, the mean transmission of the positive track is materially reduced in periods of low modulation,, and consequently the factors giving rise to ground noise can have less effect.

Biasing

The biasing of the light-valve, oscillograph, or shutter is effected by a current derived from the envelope of the speech current. Furthermore, a time constant is necessary, so that when a sudden sound comes along, the track may open up to its full extent as rapidly as possible to avoid chopping commencing peaks, while equally avoiding the generation of audible frequencies; after the sound has died away, the silent conditions are restored gradually, to avoid that unpleasant effect known as "breathing.'

The biasing voltage is produced by a supplementary amplifier associated with the main recording amplifier. It is fed with a portion of the amplified speech current, which it rectifies and smooths, and, *via* a time-constant circuit, controls the bias or the shutter. The delay effect is, of course, obtained by charging and discharging a condenser.

Opinions differ as to the volume range practically attainable with different types of track. German workers claim a range of 40 db. for density, and 50 db. for a bilateral track, in both cases without noise reduction;[2] but we have recently had other reasons to realise the optimism of the German mind. Other estimates suggest a volume range not exceeding 25 db. for new prints without noise reduction, which may soon be reduced, as a result of wear and tear, to as little as 15 db. Noise reduction will add 6 db. in the case of a density track, and at least 10 db. in the case of area; even more is claimed for recent tracks in which a bias line of as little as 1 mil. in width is obtained.

The value of the noiseless track is so self-evident that one would imagine it would be universally employed. Unfortunately it is tied up by very strong patents, which are pooled by the leading firms, leaving the free-lance manufacturers to retain an open track. Thus one can still hear atrocious ground-noise in many recordings.

Reproducer Output

The wide adoption of noiseless systems has led to one important development: the use of amplifiers and speakers of increased power in theatres. Whereas for the average small-to-medium kinema an amplifier of 6 to 8 speech watts would have been considered adequate years ago, to-day outputs of 20 and 25 watts are customary.

The limit has probably been reached at the Empire, Leicester Square, where the RCA equipment has an undistorted speech output of 150 watts. Needless to say, the whole output is practically never used; but the fact of its being available ensures a greater freedom from distortion at lower reproducing levels.

As in other types of equipment, the increased volume of reproducers has been secured by the use of push-pull output stages, negative feed-back, and other well-known means of reducing distortion.

Volume Compression and Expansion

There is another method by which the available volume range of the sound track can be increased: by the use of volume compression in recording, associated with volume expansion in reproduction. The former is being increasingly employed, but the latter, although perfectly feasible, is for commercial reasons rarely found in practice; the latest B.T.H. reproducer equipment embodies a variable expansion control.[3]

The object of volume compression systems may vary from the mere avoidance of peak-chopping, in which case they operate without any time-lag; but more often they serve actually to compress the recorded volume into the smaller compass of the track; and to prevent the resultant volume distortion becoming evident, they operate with a time-lag. Similar circuits are commonly used in radio reception, and hardly call for a description here. In one system, for instance, a compression of from 30 db. to 15 db. is available to the recordist.

It has, however, been suggested that volume compression should play a more active rôle than merely enabling an extensive volume range to be compressed into a smaller range—that it should additionally improve the intelligibility of speech. One type recently introduced provides a frequency-dependent logarithmic compression, in which those frequencies representing the voiced fundamental tones of speech are compressed by as much as 20 db. at 100 per cent. amplitude, and correspondingly less at lower amplitudes, while the higher frequencies which represent the consonantal sounds, and are chiefly necessary for intelligibility, are practically uncompressed.

As shown in the circuit reproduced (Fig. 7), part of the output voltage from a transmission amplifier is fed back to

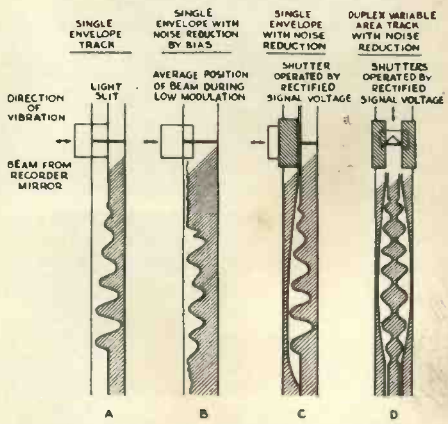


Fig. 5. Types of variable-area tracks: *A* single or unilateral open track; *B* and *C* with noise reduction; *D* bilateral or duplex track with noise reduction. (*Courtesy S.M.P.E. Journal*).

the duo-diode-triode V_3, where it is rectified and fed to the control grids of two variable-*mu* valves V_1, V_2, which carry the main signal, and which operate in Class *A* push-pull, to avoid distortion. The components C_6 and R_{24} provide the time constant which brings the full compression into operation within 2 milliseconds, but needs 80 milliseconds for its release.

Volume Control

Fig. 6. RCA amplifiers, undistorted output 150 watts. *(Courtesy RCA Photophone.)*

The control effected by this system is given by the expression:

$$E_o = \frac{Z}{Z_r} . C \log E_i + K$$

where E_i and E_o are respectively the input and output voltages of the transmission amplifier (whose gain is normally unity), Z is the impedance at the recorded frequency of the resonant circuit formed by the primary of the transformer T_4 and the adjacent condenser, r is the resonant frequency (arbitrarily fixed at about 700 c.p.s.), C is the arbitrarily chosen compression ratio (at maximum compression from 35 db. to 15 db.) and K is a constant, which permits of increasing the level of low sounds rather than reducing higher levels.[4]

Finally, how can the recordist be sure that he is keeping his recorded volume within the limits of the track?

The characteristic curve of the variable-density track corresponds, of course, to the ordinary photographic characteristic and has a marked toe and shoulder. In practice over-modulation and noise-reduction bias are commonly permitted to extend into the toe of the negative curve, so providing a form of volume compression without noticeable distortion.

But in the variable area track, any over-shooting results in immediate chopping of the peaks and violent distortion. This over-shooting may be sometimes permissible, or even desirable, as in the case of shouted speech or gunfire. But, in general, over-modulation must be avoided.

In the studio, the output from the microphone or microphones (sometimes, although less frequently than formerly, three or four microphones may be used to cover a large set) is controlled by the mixer and passed to the recordist. The mixer may be either on the studio floor, listening to the sound through high-grade earphones, or he may be in a separate sound-proofed booth or mixer room, overlooking the floor, and listening to the sound through a loudspeaker.

Whichever system is preferred, the mixer will need volume indicators to supplement his oral judgment. He has to decide when to keep his peaks within the limits of the track, or by how much they shall be allowed to over-shoot. Thus, although r.m.s. meters are commonly included in recording systems, the more important types of volume indicators are of the peak-reading type. The simplest type is an ordinary undamped peak-reading meter, while cathode-ray tubes are also used.

A particularly ingenious and convenient type is used by RCA; this consists of a row of neon lamps, connected in such a way that they glow at different sound levels. The third tube from the right is marked O, indicating 100 per cent. modulation; those to the right of it are respectively marked +3 and +6 db. above 100 per cent., and those to the left are spaced at intervals down to 45 db. below full modulation. As the sound is recorded, the mixer can watch the flickering lights and see exactly the instantaneous amplitude of the peaks on his track.

I have dealt at some length with the existing limitations of volume range, without stressing the vital need for an increase in the possible range. As far as dialogue is concerned, the present

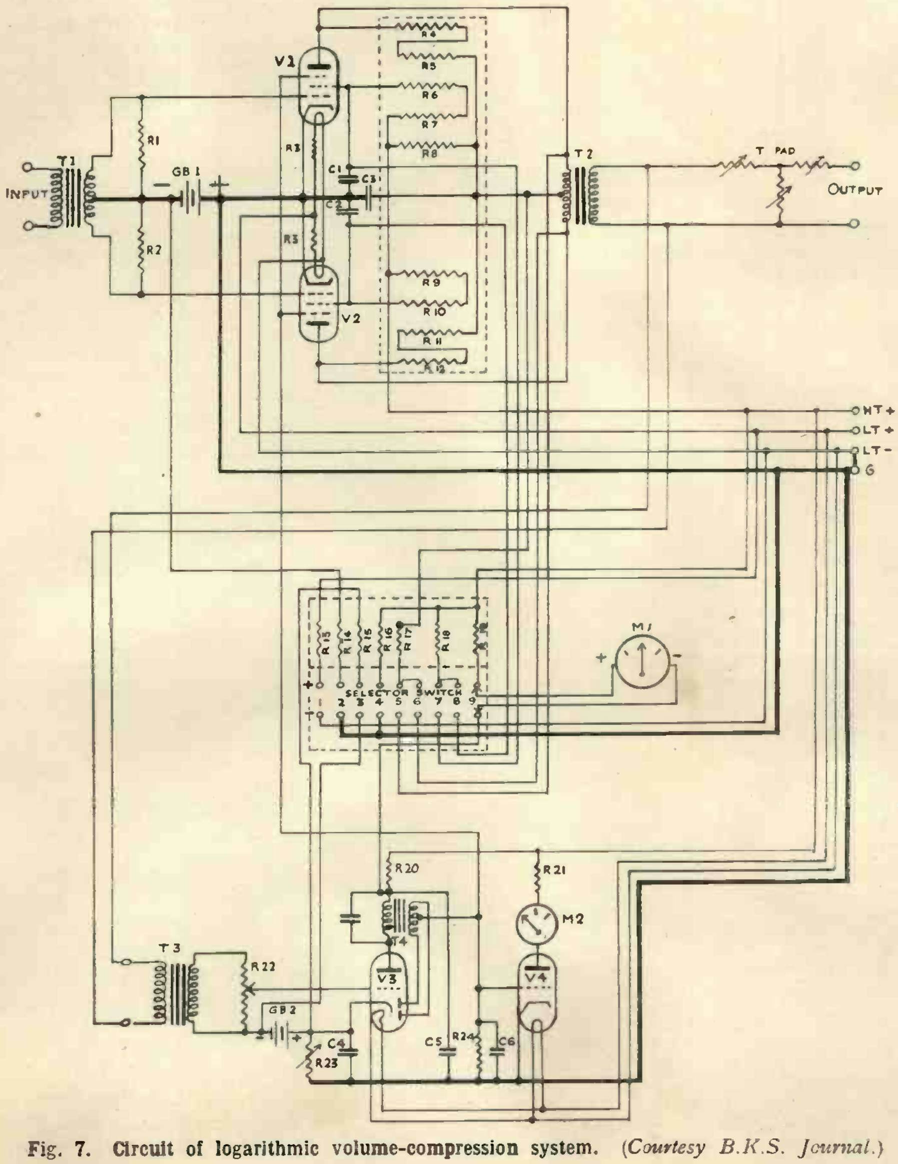


Fig. 7. Circuit of logarithmic volume-compression system. *(Courtesy B.K.S. Journal.)*

Increasing Volume Range

range is ample, given a fairly clean print and reproducing equipment with a reasonably low ground noise level. But the position is totally different in the case of music.

On the advice of a musical friend, I recently tried to compare the volume range of a symphony orchestra at the Queen's Hall (which is estimated at 120 db.) with that which would have been possible with a film recording of the same music. I came to the conclusion that, even after allowing for an increase of 20 db. in the noise level of a kinema audience, as compared with that of a concert audience, there was a gap of 50 or 60 db. which would have to be filled.

As far as one can see at present, the prospects of filling even a small fraction of this gap are remote. Experiments have recently been made in the Bell Laboratories, in America, whereby a volume compression is employed in recording, the compression control current is recorded in the form of a separate track on the film, and in reproduction this track serves to operate a volume expansion system.[5] Another method is the use of a Class *B* push-pull track.

It must be confessed, however, that neither these nor other expedients are beyond the laboratory stage, while any system that necessitates modification of the many thousands of reproducing equipments—surely a necessary preliminary—must be considered as remote.

What is perfectly practicable, and very much overdue, is an improvement in the volume range of reproduction in the average kinema. As I have indicated, cleaner prints (in the physical sense) are the first essential; improvements in film stocks, in printing and processing methods will play their part. Finally, there is still room for a reduction of ground noise in reproducer amplifiers.

Fig. 8. RCA neon volume indicator with four microphone channels. Neons are in upper panel. (*Courtesy RCA Photophone.*)

References.

1 B. C. Sewell, *Phot. Journal*, Mar. 1936, p. 127.
2 A. Narath, *J. Brit. Kine. Scy.*, II, No. 1, Jan. 1939, p. 38.
3 J. Moir, *J. Brit. Kine. Scy.*, I, No. 3, Oct. 1938, p. 175.
4 M. F. Cooper, *J. Brit. Kine. Scy.*, III, No. 1, Jan. 1940, p.3.
5 *Kine Weekly*, Apr. 25, 1940, p. 33.

Preservation of Film

FROM the earliest days of the kinema, efforts have been made to eliminate scratches or "rain" on used films. Projectionists have used carbon tetrachloride or other non-inflammable solvents; such processes are not very thorough, and have only a temporary effect.

The more satisfactory methods of film treatment are of two kinds: after-treatment of the already damaged film, and the preserving process, which treats both surfaces before the film is run, so that scratching on either side will be minimised.

In the first place, scratches were removed mechanically, by brushing or polishing. Quite a number of processes and devices have been described.

In another method, which operates chemically, the celluloid side of the film is treated with a solvent, which is applied in a thin layer, for instance, by spraying. Thus the sharp edges of the scratches are removed, and after the solvent has evaporated, the surface is no longer ridged. In order to fill in the grooves completely, the use of cellulose lacquer has recently been suggested, so providing an even surface. The film is run through a solution of nitro-cellulose or the like, and the surplus is squeegeed off.

More numerous are processes for preventive treatment, which mostly consist in applying a special layer to one or both sides of the film. Practically all materials known to form an emulsion have been tried. The oldest coating process was that used by Gaumont in 1908, employing a mixture of collodion and non-volatile oils. Subsequently gelatine, shellac, cellulose esters, wax, synthetic resins, etc., have been used. These materials were as a rule applied as a solution, or suspended in water. Particular care must be taken to keep the sprocket holes open by compressed air jets.

Finally, instead of applying solutions, thin foils have been cemented on to the film. Some experimenters have applied these protective foils on one or the other side, others on both sides; some applied the protective layer on the newly manufactured stock, others on the developed picture.—*Kinotechnik.*

"Recent Improvement in Filamentary Cathodes"

(*Continued from page* 244)

ner, at 20 watts per cm² the emission efficiency of thoriated tungsten made as above is 150 Ma. per watt. For the usual carburised thoriated tungsten, the emission between 110 and 115 Ma. per watt at 30 watts per cm² input. From these data it is seen that the electrolysed thoriated tungsten is a more efficient emitter than the conventional thoriated tungsten filaments.

This new cathode is a very stable emitter and will operate at a comparatively low temperature, is not easily poisoned by gas, and the cathode readily recovers its emitting characteristics even if accidentally operated temporarily at too high temperatures.

(This development is reported from from the Laboratories of the Radio Corporation of America).

Electron Microscope Using an Electron Mirror

ELECTRON microscopes cannot generally be made of sufficiently high magnifying power if only one stage is used. It is therefore usual to include two or more stages. In this case the final magnification is the product of the magnifications of each stage. Such an arrangement will include one electrostatic or magnetic electron lens per stage and the length of the evacuated envelope required increases as the number of lenses increases.

With the use of an electron mirror it is possible to reduce the length of the evacuated envelope by causing the electron beam to traverse the distance twice and at the same time to reduce the number of lenses per stage to less than one, i.e., to use some of the stages twice.

Two alternative schemes are suggested, one using an electromagnetic lens and one an electrostatic lens, but in both arrangements the application of the electron mirror is the same.

Fig. 1 shows the electrostatic arrangement. Electrons are accelerated from a cathode arrangement (not shown) into the cylinder (1) maintained at potential V_1. The electrons strike the microscopic object on the gauze 8 and then pass through the lens between cylinders 1 and 2 to form an enlarged image 9 in cylinder 2 at potential V_2 which is considerably higher than potential V_1. This enlarged image 9 serves as the object for the decelerating electrostatic lens between cylinders 2 and 3 which will produce a further enlarged image 10 in the final cylinder 4.

This final cylinder is maintained at potential V_4 which is negative with respect to the cathode. A zero equipotential is thus set up between cylinders 3 and 4 which reflects the electrons back towards the source. The twice enlarged image 10 now serves as object for the electron mirror and a further enlargement is produced by it giving the image 11. This is now finally enlarged by the accelerating lens between cylinders 3 and 2 and produces an enlarged image 12 on the fluorescent screen 13. Apertures 5, 6 and 7 are inserted with the object of reducing aberration by limiting the beam width.

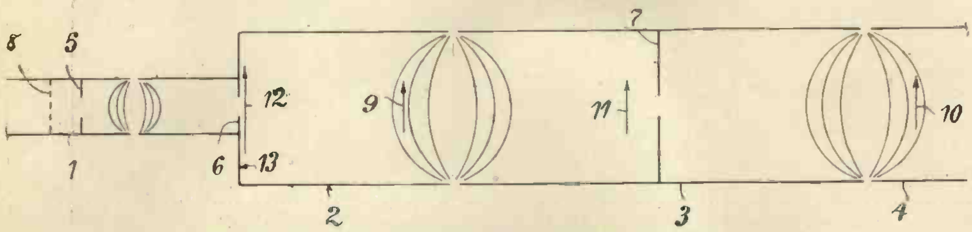


Diagram of electron microscope incorporating an electron mirror.

It will be observed that the lens between cylinders 2 and 3 is used twice, once as a decelerating lens and once as an accelerating lens. Also by the use of the electron mirror the length of evacuated envelope is reduced by half.

In place of the elcetrostatic lens between cylinders 2 and 3 a magnetic lens can be used. In this case cylinders 2 and 3 would be connected together at potential V_2 and the magnetic focusing coil would be arranged coaxial with the cylinders and midway between them.

It is clear that the above arrangement could be extended to include two or more lenses between the first lens and the mirror, both of which could be used twice.

This development is reported from the Laboratories Electric and Musical Industries Limited.

Book Review

Photo-Electric and Selenium Cells. T. J. Fielding. Chapman and Hall. 7s. 6d. net. 160 pp. 82 figs.

This is a second edition of Mr. Fielding's book, which was first published in 1935, and serves as an excellent introduction to the many uses and varieties of photo-cells.

It is gratifying to note that a chapter on the making of selenium cells is added after the introductory matter. In many quarters it is considered that selenium cells became obsolete with the passing of early television, but their usefulness to the experimenter as a simple light relay is not often appreciated.

As the author says. "In its great response to low illumination lies one of the greatest advantages of selenium. No other cell is comparable with it in this respect, and were it not for the disadvantages outlined the selenium cell would doubtless have ousted the photo-electric cell."

Various circuit diagrams for cell amplifiers are given, often with practical details, and a new chapter has been added on time delay circuits. The use of the photo-electric effect in television and talking pictures is described with a review of the various typical industrial applications—counting, safety devices, advertising, etc. The photo-electric organ and the talking book are two of the lesser-known applications described under "Miscellaneous Applications," with a note on the talking clock, which so far as is known, has not appeared elsewhere than in the original technical paper.

In spite of its size, the book covers the field of photo-electricity in a remarkably thorough manner and can be recommended to the radio amateur who is not familiar with this branch of physics. Industrial engineers will also find the book of interest in its suggestions for the use of photo-cells in engineering safety devices. It is written in a very readable manner and at 7s. 6d. represents excellent value for money in these days of rising prices.

G.P.

Messrs. Universal Electric, of Clerkenwell Road, carry a comprehensive stock of photo-electric cells, mercury relay valves, Weston milliammeters and ammeters, Ferranti line transformers and Foster double-wound transformers. They also supply all types of rotary converters. For further details we refer readers to the advertisement of this company on page 283 of this issue.

WELDING PERIOD TIMING BY MEANS OF STEEL IGNITRONS

By B. G. Higgins, B.Sc., A.M.I.E.E.
of The British Thomson-Houston Industrial Engineering Department

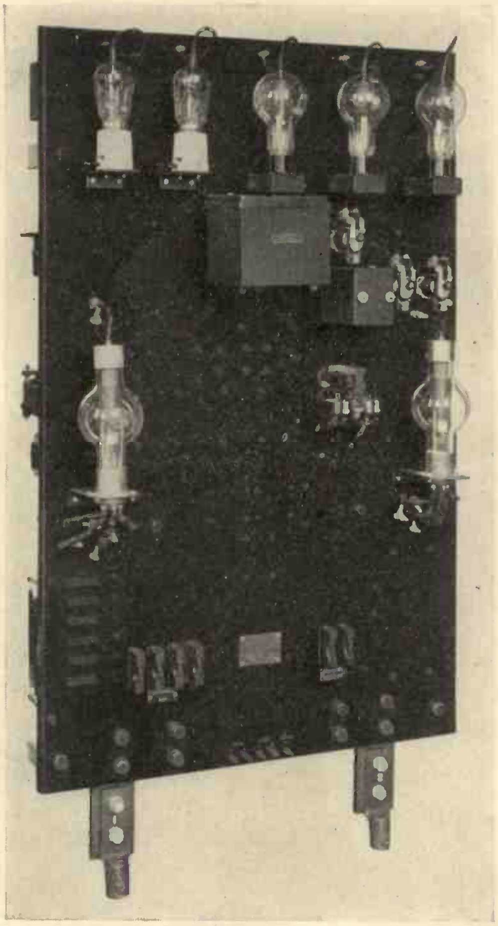


Fig. 1. Front view of B.T.H. welder control panel.

FOR accurate timing of the welding period when resistance welds of extremely short duration are to be made, electron tube control is absolutely essential.

Ignitron Control

Nearly three years ago the B.T.-H. Company introduced ignitron control which has found a very considerable field of application in the control of spot welders. This equipment uses glass ignitrons, and adjustment of the welding time is again effected in increments of one cycle, although welds of half-cycle duration are also possible with this control.

With seam welding, however, duty cycles as high as 60 per cent. are quite common, and a duty cycle of 80 per cent. (e.g., 8 cycles on, 2 cycles off) is not unknown. It will be appreciated that two ignitrons, capable of only 60 amperes (mean) between them, offer far too low a rating to be of practical use as far as high power seam welders are concerned.

Steel Ignitrons

The solution of this problem lies in the use of the steel ignitron. This consists of a permanently sealed evacuated steel cylinder, at the bottom of which is the cathode lug, integral with the cylinder end. The anode is carried on an insulating glass seal at the top of the tube, and the igniter is supported from a glass insert in the bottom of the tube, the necessary amount of mercury being included. Around the tube proper is a steel waterjacket, which provides very effective cooling.

In this way, the rating of the tube is so considerably increased that two of these tubes, known as the Type BK 24 ignitron, can handle 130 kVA. at 440 volts continuously, i.e., at 100 per cent. duty cycle. At a duty cycle of 60 per cent., the rating is increased to 230 kVA. Nevertheless, this steel tube of 150 amperes mean rating is physically much smaller than a glass ignitron of lower mean rating. Even larger steel ignitrons are available, known as Type BK 34, two of which can handle 200 kVA. continuously, or 350 kVA. at 60 per cent. duty cycle.

When steel ignitrons are used with spot welders, which operate on low duty cycles, the rating is again considerably higher. Thus, two Type BK 24 ignitrons can handle 1,000 kVA. at 10 per cent. duty cycle, with a maximum of 1,230 kVA. at 6 per cent. duty cycle. The large Type B 34 tubes can handle 1,500 kVA. at 10 per cent. duty cycle, with a maximum of 2,400 kVA. at 4 per cent. duty cycle.

Ignitron control lends itself readily to varying the value of the welding current, in addition to controlling the duration of the current flow, i.e., number of cycles.

Accurate control of welding pressure and welding current is necessary if good welds are to be maintained consistently. Although a welding machine may be equipped with as many as 16 taps or heat settings, it is frequently found that the correct heat cannot be obtained, as one setting may be too hot and the next one not hot enough. Some attempt may be made to get an intermediate value of heat by adjusting the welding time. The amount of variation in heat by this method that can be tolerated, however, is limited by the damaging effect of too long a welding time, and the even more dangerous result of insufficient welding time.

It is obviously impracticable to equip the welding machine with still more heat steps, and the addition of some auto-transformer device raises fresh problems apart from commercial considerations.

If, however, instead of firing one tube immediately the other tube has ceased to pass current, the firing of each tube is delayed and one tube made to fire, say, 30 degrees after the other tube has ceased to pass current, then the duration of each current loop will be less, and the average current value will be reduced. The current will not now be a complete sine wave, but each loop will be a wave of 150 degrees duration, followed by zero current for a period of 30 degrees.

If the firing point is still further delayed so that current flow is initiated

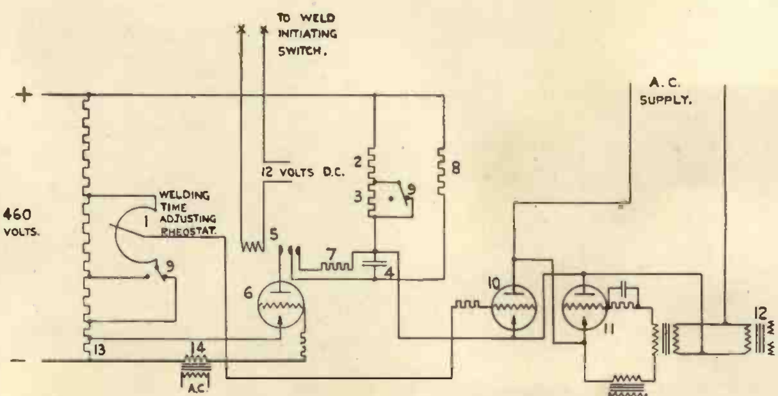


Fig. 2. Simplified circuit diagram for ignitron spot welder control.

Spot Welder Control

in one tube, say, 70 degrees after current has ceased to flow in the previously conducting tube, then the average value of current (and hence the heat) will be still further reduced. In this case, each current loop will be of 110 degrees duration, followed by zero current for a period of 70 degrees.

In practice, the tubes are fired by a peaked voltage which is obtained from a transformer supplied from a phase shifting bridge. The peaked voltage is capable of being shifted in phase over some 100 degrees; the amount of phase shift possible will depend on the power factor of the welding machine. The phase shift provided will allow phase advance to give a continuous sine wave of current with a welder whose power factor is as high as 70 per cent.

Taking the voltage wave as a reference, this means that the peak will occur 45 degrees from the start of the voltage wave to give maximum heat. It can be retarded in phase to a point 145 degrees from the start of the voltage wave to give minimum heat.

As the means of shifting the phase is a rotary rheostat of the stepless type, an infinite number of heat settings are available between the limits of phase shift specified. By this means, therefore, extremely fine adjustments of heat are possible, without the necessity for altering the "cycles on" in order to change the heat. This arrangement gives such an excellent adjustment of the heat that it is possible to reduce the number of taps on the welder transformer, or even to do without them altogether, if desired.

Fractional half-cycle welds can be arranged very readily. It is only necessary to cut out on ignitron, set the control for "1 cycle on," and the equipment will then deliver a fraction of a half-cycle current, dependent on the heat control setting.

The function of the equipment is to control accurately the duration of the welding time of spot welds, and of the welding time and non-welding time of seam welds; and also to effect variation in the heat of the weld by means of a heat control phase shifting circuit, operating on the ignitrons.

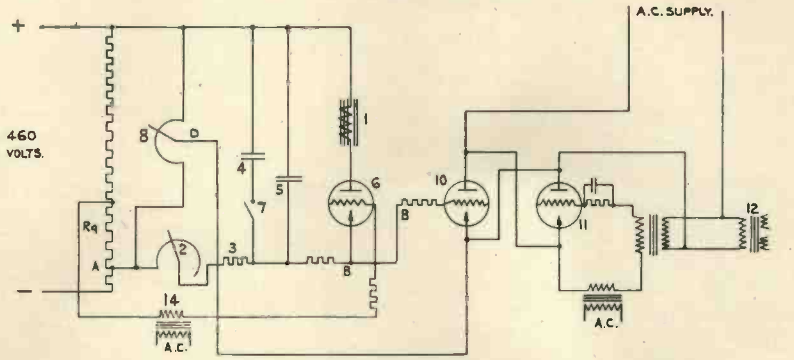


Fig. 3. Basic circuit diagram of ignitron seam welder control.

Synchronous thyratron timing ensures that all welds are of exactly the same duration, control of the welding current being carried out by two ignitrons connected in reverse parallel in one supply line to the primary of the welder transformer.

Two time ranges are arranged both for seam and spot welder control, and two heat control ranges are also provided. The equipment will handle up to a maximum of 1,200 kVA. at 440 volts, 50 cycles, single-phase, when fitted with two Type BK.24 ignitrons, or 2,400 kVA. at 440 volts when fitted with two Type BK.34 ignitrons. Either tube can readily be used in the equipment, which is supplied with a control auto-transformer for operation on a wide range of voltages between 200 and 550.

The two steel ignitrons are mounted on the back of a panel housed in a sheet steel cubicle (see Fig. 1, page 251). The ignitrons are water cooled, and are under the control of two firing thyratrons mounted on the front of the panel. Here also are accommodated the synchronous timing thyratron, its associated rectifier tubes, and the duty cycle control thyratrons; also the spot weld initiating relay, and the time delay relay that ensures that a weld cannot be made until the cathodes of the control thyratrons have reached their operating temperature.

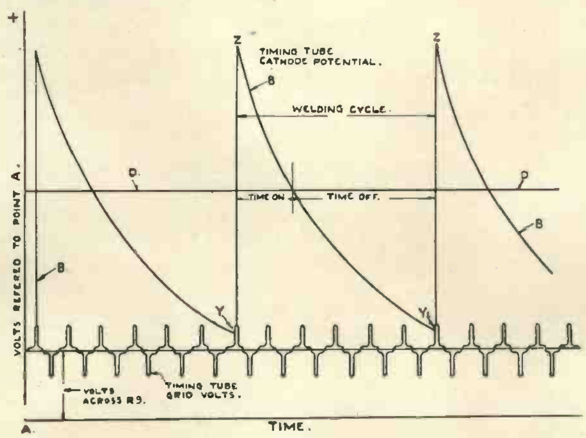


Fig. 4. Timing tube circuit voltage conditions.

The Circuit

Spot Welder Control.—When the control is operating in conjunction with a spot welder, the circuit is as shown in Fig. 2.

The 460-volt D.C. supply, derived from a rectifier incorporated in the equipment, serves to energise the potential divider for the welding time adjusting rheostat (1). The charging circuit comprises the charging resistances (2) and (3) and the capacitor (4), the relay contacts (5), and the timing tube (6). Resistance (7) is the discharging resistance for capacitor (4), which is discharged through the normally closed contacts of relay (5). Resistance (8) is a by-pass resistance which serves to maintain the arc in tube (6) when the capacitor (4) is fully charged. The range switch (9) gives two ranges of welding times for the rheostat (1).

The "leading" control thyratron (10) is under the control of the charging circuit of capacitor (4), while the follower control tube (11) is arranged to pass current on each half-cycle following that during which the leading control tube (10) passes current. Tubes (10) and (11) serve to energise the main tubes firing transformer (12), the operation of which will be described later.

The control circuit operates as follows:—

When it is desired to make a weld, the weld initiating switch is closed, and relay (5) is energised. This applies anode volts to tube (6), which is held

Seam Welder Control

non-conducting by the negative voltage across resistance (13), until a firing peak from the peaking transformer (14) overcomes the negative voltage and fires tube (6).

At this instant, the anode voltage of tube (10) is at its negative peak. Since capacitor (4) is discharged when tube (6) fires, the cathode potential of tube (10) is raised so that it is substantially the same as that of the D.C. positive bus-bar, and tube (10) will therefore fire as soon as its anode voltage becomes sufficiently positive. Tube (11) will fire on subsequent half-cycles. When the voltage across capacitor (4) has risen to such a value that the cathode of tube (10) is once more positive with respect to its grid, then tubes (10) and (11) will become non-conducting again.

The time taken for this to occur will depend on the position of the slider of rheostat (1) and the range switch (9). When the weld is completed, the relay (5) is de-energised and capacitor (4) is immediately discharged.

It will be seen then that the rheostat (1) and the range switch (9) determine the number of cycles transformer (12) is energised during each welding period.

Seam Welder Control.—When the control is operating in conjunction with a seam welder, the control circuit is re-arranged by means of change-over links so that it is as shown in Fig. 3. The timing tube (6) is now connected in a simple inverter circuit, in which the capacitors (4) and (5) are allowed to charge through resistances (2) and (3), and are discharged by the firing of tube (6), the inductance (1) serving to extinguish the arc in tube (6) when the discharge is complete. The frequency of the conducting impulses of tube (6) is set by the value of resistance (2) and by the amount of capacity in the circuit as set by the range switch (7).

Resistance (2) therefore sets the number of welds per minute, its dial being calibrated in cycles to show the duration of the "welding cycle." The leading and following control tubes (10) and (11) control the supply to the firing transformer (12) in precisely the same way as when spot welding.

The grid of the leading control tube (10) is connected to the inverter circuit in such a way that when tube (6) is fired, the grid of tube (10) is carried positive with respect to its cathode, and tube (10) will fire as soon as its anode voltage becomes sufficiently positive.

The timing tube circuit voltage conditions are shown in Fig. 4, and the operation of the circuit is as follows:—

It should be assumed that the timing tube (6) is just fired by the peaked voltage from transformer (14), at point Y in Fig. 4. The timing tube cathode potential B—which is the same as the grid potential of tube (10)—will then rise positive, and when B becomes positive with respect to D, as set by the slider of rheostat (8), tube (10) will fire. When the capacitors (4) and (5) have been discharged, tube (6) will be extinguished at Z, and the capacitors will then start to charge through resistances (2) and (3). B will thus gradually become more negative and a point will be reached when B is once more negative with respect to D, and tubes (10) and (11) will then cease conducting. The potential of B will continue to become more negative until the peaked voltage from transformer (14) is once again enabled to carry the grid tube (6) positive with respect to B, when tube (6) will fire once again, at Y_1. The cycle of operations will then be repeated.

It will thus be seen that while rheostat (2) and switch (7) set the number of cycles for each complete "welding cycle," rheostat (8) sets the number of cycles that tubes (10) and (11) conduct in each "welding cycle," and rheostat (8) is therefore known as the "ratio" control and is calibrated in percentages of the "welding cycle" setting of rheostat (2).

The Power Circuit.—The elementary circuit diagram for the power circuit is shown in Fig. 5. The two steel ignitrons (1) and (2) are connected in reverse parallel in series with the power supply and the welder transformer primary. Each ignitron has its igniter energised by a thyratron connected virtually in parallel with the ignitron. These two thyratrons are known as the firing tubes (3) and (4).

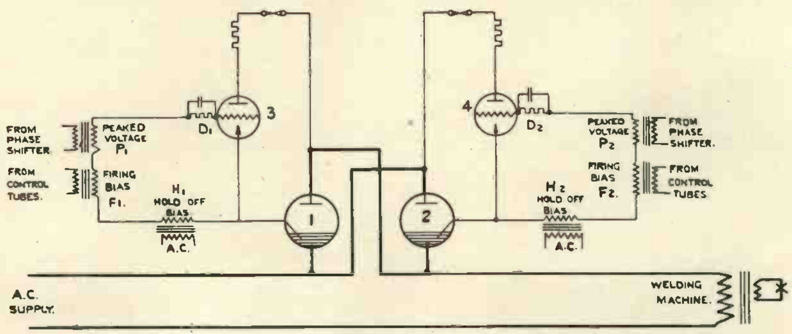


Fig. 5. Simplified circuit diagram of power circuit for ignitron welder control.

Each firing tube grid circuit voltage consists of four voltages in series:—

(1) An A.C. hold-off bias, H_1 and H_2.
(2) A D.C. hold-off bias, D_1 and D_2.
(3) An A.C. firing bias, F_1 and F_2.
(4) A peaked voltage P_1 and P_2.

The A.C. hold-off bias H_1 and H_2, in conjunction with D.C. hold-off bias D_1 and D_2, serves to hold the firing tubes non-conducting, since the peaking voltages P_1 and P_2 are insufficient to overcome the hold-off bias voltages.

When the control tubes energise the firing transformer, the firing bias F_1 and F_2 appears, tending partially to overcome the hold-off bias, and so enable the peaked voltage to cause the tubes to conduct.

The peaked voltage is derived from a transformer which is fed from a phase shifting network, thus enabling the peak to be shifted in phase over approximately 100 degrees. The firing tubes may therefore be fired at a point in the voltage wave corresponding to a power factor angle of 45 degrees (maximum heat); or the phase may be retarded to cause the firing tubes to conduct at a point in the voltage wave of 145 degrees (minimum heat). This phase shift is accomplished in two heat ranges, the changeover point between the two ranges being the 90 degrees power factor point. Provision is made for limiting the amount of phase advance beyond the 90 degrees power factor point, so that in the maximum heat (full advance) position, the firing point is not in advance of the steady power factor point of the particular welding machine with which the control is operating. Should an attempt be made to operate the control with a phase shift setting in advance of the steady state power factor point of the welder, then obviously one tube would fail to fire.

When the firing tubes become conducting, the current through the igniters causes the ignitrons to fire, and these immediately short-circuit the firing tubes which are therefore extinguished. The ignitrons then pass current to the welder transformer primary. The number of cycles of current is thus set by the control tubes, and the mean value of the current passed in each half-cycle is set by the heat control phase shifter, which decides the firing point of the firing tubes, and thus of the ignitrons.

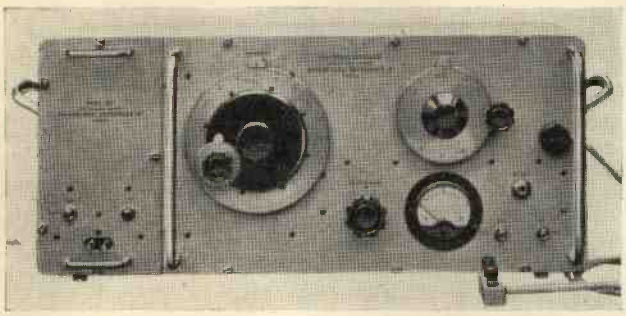
Two New Instruments

in the Marconi-Ekco Range

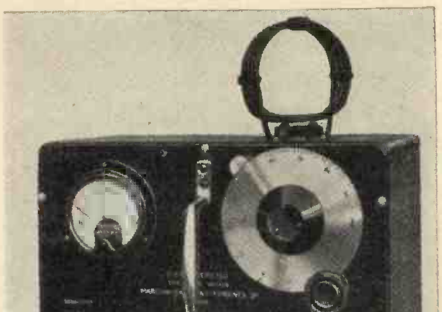
MARCONI-EKCO announce the issue of two new instruments for research in the ultra-high frequency range: a signal generator and wavemeter.

The signal generator, type TF.517A has a range from 150 to 300 Mc. and is intended for operation with a transmission line output. It employs a somewhat unorthodox arrangement for the oscillator and the attenuator.

The radio frequency oscillator uses an "acorn" triode in a form of Hartley circuit, the oscillatory circuit com-



These photographs show two new Marconi-Ekco precision instruments. On the left is the type TF517A U.H.F. Signal generator with a range of 150 to 300 Mc. (2 to 1 metres). Below is the type TF643 U.H.F. wavemeter with a frequency range of 20 to 300 Mc.



prising a short-circuited transmission line loaded with capacity to provide the variation in frequency.

The condenser, which is of special design, has each set of plates milled from solid metal and arranged for minimum series inductance. The stator is insulated with quartz and the rotor with polystyrene. The tuning condenser has an accurately cut gear reduction drive and carries a large diameter scale.

The output is obtained from a mutual inductance coupling forming a piston attenuator. This provides a linear scale of decibels and a range of 100 db can be covered.

A valve voltmeter monitors the carrier level and includes a special compensating circuit which renders the scale independent of mains voltage fluctuations.

Multiple filters are included to localise the R.F. earth return currents correctly and the complete R.F. section is constructed of brass heavily silver plated and is subsectionalised to provide excellent screening.

The attenuator which can be supplied in balanced or unbalanced forms is followed by a loaded transmission line. The terminating resistor can be omitted when the generator is required to be loaded with the apparatus under test.

A Hartley oscillator provides modulation which is injected into the H.T. supply of the R.F. oscillator in such a way that the modulation depth does not vary with carrier level.

A full wave valve rectifier and a two section resonant filter are employed in the power supply equipment. The mains transformer rectifier and fuses are mounted in a separate screened compartment, which, in conjunction with filtering at the mains inlet, effectively suppresses radiation *via* the power supply line.

The full specification is as follows:

Frequency range: 150-300 Mc./sec.

Calibration accuracy: plus or minus 1 per cent.

Output: 0.1 volt max.

Modulation: 30 per cent. peak depth, 400 cycles. 1,000 cycles can be provided on request.

Power supply: 30 watts at 200-250 volts, 40-100 cycles.

The transmission line output of the standard model has an impedance of 80 ohms and is provided with a tapped detachable terminating resistance giving output resistances of 80 ohms terminated, 40 ohms terminated and 8 ohms at the tapping.

The particular features claimed for the instrument are:

1. Stray radiation is well under 1 microvolt.
2. The inductive piston type attenuator gives great accuracy with the wide range 0.1 to 1 microvolt (100 db).
3. The instrument dial is directly calibrated in frequency.
4. For convenience in testing U.H.F. receivers balanced output provision is made.
5. Calibration characteristics will remain stable during the whole life of the instrument.

Wavemeter Type TF.643

The Marconi-Ekco wavemeter covers a range of 20 Mc. to 300 Mc. and employs a calibrated tuned circuit using plug-in coils tuned by a low-loss condenser provided with ceramic insulation.

An indication of resonance is obtained by means of a diode voltmeter; headphones may also be used to identify or tune a modulated carrier. Tuning by beat methods using an auxiliary oscillator may, of course, also be adopted. A control is provided which enables the sensitivity to be adjusted to suit the signal strength available.

It is claimed that the calibration accuracy is not only better than can normally be obtained by the Lecher wire system but there is an additional advantage of greater speed in taking these measurements.

Production of Heavy-Duty Secondary-Electron Emissive Surfaces

IT has in the past been proposed to employ, e.g., in electron multiplier tubes, secondary emissive electrodes whose surface comprises an alloy of beryllium with one or more of the metals nickel, cobalt, iron, chromium, manganese, molybdenum or tungsten, the proportion of beryllium being preferably in the neighbourhood of 1 per cent. to 2 per cent., and in no case greater than 10 per cent.

Work done on these alloys led to the conclusion that their secondary emissivity varies with their hardness. The alloys were therefore treated by cold rolling, and the results confirmed the expectation that the additional hardness thus induced would be accompanied by a corresponding increase in secondary emissivity.

Surfaces thus prepared may be used where the so-called "built-up" layers usually comprising caesium are unsuitable owing to liability of attack by harmful gases or on account of heating in operation, i.e., in the later stages of electron multipliers.

Testing Amplifier Output Valves by Means of the Cathode-ray Tube

By A. J. Heins van der Ven

In testing amplifier output valves, the most important data are contained in the I_a-V_a diagram if it is known over which part of the diagram the values of voltage and current prevailing during operation range, i.e., if the position of the load line is known. The I_a-V_a diagram as well as the load lines can very easily be obtained with the help of a cathode-ray tube. The necessary apparatus is described in this article. A number of auxiliary arrangements are also studied, by which the axes and the necessary calibration lines in the diagram can be traced on the fluorescent screen, and which make it possible to show the diagrams of two output valves, which are to be compared, to appear simultaneously on the screen. In order to obtain the load line in the correct place in the diagram, use must be made of direct current push-pull amplifiers for the deflection voltages of the cathode-ray tube. The position of the load line upon inductive loading is discussed and explained by a number of examples. In conclusion one application of the installation in the development of output pentodes is dealt with. *We wish to acknowledge our indebtedness to "Philips Technical Review," March, 1940, for the information contained in this article.*

If one wishes to characterise briefly the performance of an output valve of an amplifier or radio set, it is enough to give the sensitivity, the distortion as a function of the power output, and in some cases the maximum power which can be delivered without grid current flowing. For a more careful examination, however, particularly for the discovery of causes of deviations or errors, such for example as differences in distortion in different valves, one must in general have reference to the I_a-V_a diagram, which forms the actual basis for the judgment of the properties of an output valve.

This diagram (Fig. 1) gives the variations of the anode current I_a as a function of the anode voltage V_a with the negative control grid voltage V_g as parameter.* From the series of curves the primary quantities of the valve: slope, internal resistance and amplification factor, may be read off immediately for every operating point, as is explained in the text under the figure. A connection may, however, also be found between the shape of the curve and the above-mentioned quantities such as distortion and power output. Since these quantities are to some degree dependent on the loading impedance which is included in the anode circuit, it is first necessary to find out how the loading of the valve is expressed in the I_a-V_a curve.

If the valve is loaded with a resistance R which is connected to the anode circuit through a transformer in order to have no D.C. voltage drop in R (Fig. 2) an alternating current I_R will begin to flow in R when an A.C. voltage is applied to the grid of the valve. The A.C. voltage on the loading resistance is then $V_R = R : I_R$. The total anode voltage V_a and anode current I_a of the valve are given by the sum of V_R or I_R and the values of the anode D.C. voltage or current indicated by the operating point. The relation between I_a- and V_a of the loaded valve, the so-called load line, is therefore in this case represented by a straight line through the operating point (AB in Fig. 1) with the slope tan a = R with respect to the I_a axis.

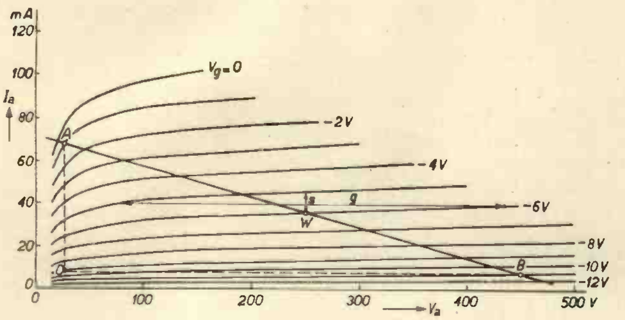


Fig. 1. The I_a-V_a diagram the output valve EL_3. W is the operating point; in this valve it ordinarily lies at V_a = 250 volts, I_a = 36 m/A., V_g = —6 volts. The screen grid voltage is permanently fixed at 250 volts. The slope S is given by the vertical distance between two successive curves, the amplification factor g by the corresponding horizontal distance, the internal resistance by the slope of the I_a-V_a curve at the operating point. AB is the load line for a pure resistance of 7,000 ohms.

If one considers the grid voltage to be varying, the value of I_a and V_a at any moment are always determined by the point of intersection of the load line with the I_a-V_a curve corresponding to the value of the grid voltage at that moment.

If, for instance, the operating point lies on the curve for $V_g = -6$ volts and the grid excitation voltage is sinusoidal with a peak value of 5 volts, then the points of intersection of the line AB with the curves $V_g = -1$ volt and $V_g = -11$ volts, give the extreme values of I_a and V_a. The distance AC is, therefore, twice the amplitude of the alternating current occurring, the distance BC twice the amplitude of the A.C. voltage. The power output to the loading resistance at the grid excitation voltage in question is thus given by $\frac{1}{4}$ of the area of the triangle ABC.

In so far as the successive I_a-V_a curves cut off equal segments of the line AB, a proportional change in anode voltage and current corresponds to any change in the grid voltage. There is, therefore, no distortion. With large amplitudes along the load line, however, the segments cut off on AB become gradually smaller (Fig. 1).

The variation of anode voltage and current with sinusoidal grid excitation voltage is then no longer sinusoidal, but exhibits a flattening. The distortion occurring could be calculated by careful measurement of the segments cut off on the load line.

If the loading impedance is not a pure resistance, the load line is not straight in the I_a-V_a diagram. Depending on the grid excitation voltage a larger or smaller portion of the whole diagram is then covered by the load lines. A knowledge of this region makes it possible to estimate the importance for the reproduction of any irregularities occurring in the I_a V_a diagram.

In the following a method will be described by which not only the I_a-V_a diagram, but also the load line can easily be obtained.

* The screen grid voltage, which forms a second parameter in the case of pentodes, is kept constant for the whole diagram.

Installation for the Recording of I_a-A_a Diagrams

An I_a-V_a characteristic can be registered on the screen of a cathode-ray tube in the following way. A given D.C. voltage is applied to the control grid of the output valve to be investigated, while the anode voltage is made to vary periodically from zero to a maximum value. This anode voltage is applied, via a potentiometer and an amplifier to the plates for horizontal deflection of the fluorescent spot. The voltage on a small measuring resistance, through which the anode current flows, causes the vertical deflection, which is therefore proportional to the anode current at every moment.

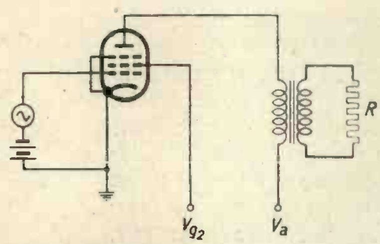


Fig. 2. A loading resistance R is included in the anode circuit of the output valve via a transformer 1 : 1.

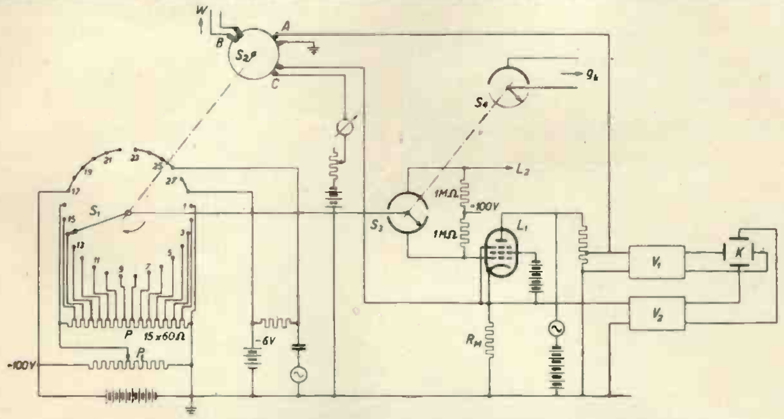


Fig. 3. The anode voltage of the output valve L_1 to be investigated is applied to the plates for horizontal deflection of the cathode-ray tube K via the amplifier V_1; the voltage over the measuring resistance R_M, through which the anode current flows, is applied via the amplifier V_2 to the plates for vertical deflection. By means of the rotating switch S_1 the grid bias of the output valve is varied in steps. The auxiliary switch S_2 which is fastened to the axis of S_1 short circuits the pairs of brushes A, B, C at certain moments, and thus causes the various auxiliary lines of the diagram to be traced on the fluorescent screen. The switches S_3 and S_4 which rotate with half the velocity of S_1 serve to record the diagrams of two output valves L_1 and L_2 at the same time, while the voltage on the grid g_k of the cathode-ray tube is lowered for the diagram of one of the valves. With the help of the potentiometer P_1 the current through the potentiometer P can be regulated and the grid bias stepwise variation can be made more or less steep.

In order to trace different I_a-V_a curves on the screen successively, the grid bias must be given different values successively for short times. A voltage which varies in steps must therefore be applied to the grid, and in order to obtain a lasting image on the screen of the cathode-ray tube, this voltage varying in steps must be run through completely several times per second.

The stepwise varying voltage is obtained by means of a rotating switch S1 which passes over 28 contacts (Fig. 3). Sixteen of these are connected to the taps of a potentiometer which correspond to the 15 steps of the desired voltage series (see Fig. 4). On the following six contacts (17 to 22) there is a high negative voltage, so that the valve to be examined passes no anode current at all during this time.

By this means, and by the great rapidity at which the switch rotates (1,000 to 1,500 r.p.m.) it is possible to record the whole I_a-V_a diagram without the valve becoming overloaded.

For the sake of orientation in the diagram, the two axes and the corresponding scale are necessary in addition to the I_a-V_a curves. The remaining contacts and the auxiliary switch S_2 which is fastened to the axis of the rotating switch and passes over the pairs of brushes ABC (Fig. 3) serve these purposes.

The horizontal axis is produced automatically due to the fact that during the currentless periods (contacts 17-22) the fluorescent spot moving back and forth is not deflected in a vertical direction.

The vertical axis is traced in the diagram when the switch passes over contacts 23 and 24. At this moment the input of the amplifier for the voltage for horizontal deflection is short circuited via the brushes, A. On the contacts 23 and 24, which now feed the grid, an A.C. voltage now acts so that the anode current may vary sufficiently to describe the whole I_a axis.

The same is true for the following two contacts, 25 and 26. At the moment at which these contacts are connected to the grid, the second pair of brushes B brings about a substitution of the anode A.C. voltage, by the normal anode D.C. voltage of 250 volts, for instance. The vertical line $V_a = 250$ volts is therefore drawn in the diagram, which facilitates finding the operating point, and at the same time provides the scale for the horizontal axis.

The scale for the vertical axis is obtained by passing a direct current of known magnitude through the measuring resistance R_m during the resting period of the valve (contacts 17 and 18). This is done by means of the two brushes C and gives in the diagram a horizontal line at a definite height above the V_a axis.

The remaining two contacts 27 and 28 are at a negative voltage of a given magnitude, -6 volts, for instance. The I_a-V_a curve with the parameter $V_g = -6$ volts is traced via these contacts. By regulating the potentiometer current and thus the voltage on the contacts 1 to 16, one of the 15 I_a-V_g curves can be made to coincide with the established curve for $V_g = -6$ volts and the parameter value for all the other curves is thus also known.

It is, however, seldom necessary, and with regard to clarity, it is sometimes even undesirable to record 15 I_a-V_a curves of the diagram. In that case the stepped voltage in Fig. 4 is made so steep by increasing the potentiometer current, that on part of the contacts 1 to 16 the voltage is high enough to completely suppress the anode current of the output valve. The valve then has a longer resting period.

The Comparison of Two Output Valves

In addition to the rotating switch S1 and the auxiliary switch S2, there is a rotating contact S3 which rotates at one-half the speed of the first switch (Figs. 3 and 5). By means of this contact the grid bias according to Fig. 4 may be applied alternately to two output valves. On the screen of the cathode-ray tube the I_a-V_a diagrams of first one and then the other valve are drawn alternately, and since this takes place for each valve, about 8 to 12 times per

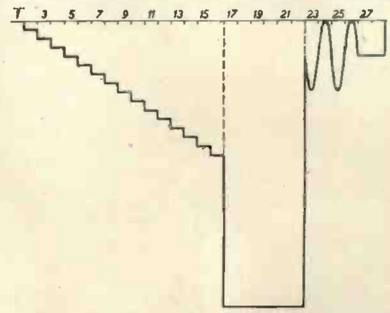


Fig. 4. The variation of the grid bias of the output valve under examination during one revolution of the rotating switch (S_1 in Fig. 3).

Tracing the Load Line

second, the two diagrams appear simultaneously on the screen.

This makes it easy to detect quickly small differences between two valves of the same type. In order to be able to distinguish the two sets of curves from each other, the current of the cathode-ray is diminished slightly with the help of the contact S4 during the time when one of the valves is in circuit, so that the set of curves for this valve appears

Fig. 5. The combination of rotating switches (S_1 to S_4 in Fig. 3.) For structural reasons, the switch arm of S_1 (a brush) is stationary while the 28 contacts (lamellae of a collector, middle axis on the right) rotate beneath it. The 15 resistances of the potentiometer P turn with the collector, the necessary voltages are applied via five slip rings. The auxiliary switch S_2, also for practical reasons, is divided into three contact makers (middle axis, left). The front axis turns at half speed and moves to two switches S_3 and S_4.

on the screen with a lower light intensity.

Fig. 6 gives an example of such an application of the apparatus. One line may also be recorded on the same negative. For this purpose the output valve is first brought into the correct operating conditions (i.e., by means of suitable D.C. voltages on grid and anode) the operating point is arrived at, and the loading impedance is put into the anode circuit via a transformer. If the anode current is now projected on the screen as a function of the anode voltage, once more, the load line is obtained.

There is, however, still a complication: without special precautions the load line is not in the correct position in the diagram. Ordinary amplifiers, such for example as those built into cathode-ray oscillographs, do not pass D.C. voltages. When a voltage, whose mean value is not equal to zero, and which, therefore, has a certain D.C. component, is applied to the cathode-ray tube, the image on the screen always adjusts itself so that this average value of the voltage lies at the centre of the screen. When such amplifiers are used, therefore, the I_a-V_a diagram is projected on the screen in such a way that the centre of the screen is the point of greatest density of all the values of voltage and current occurring.

The same is true in the case of the load line. Actually, however, the centre of the load line must coincide with the operating point of the diagram, which means that amplifiers used for R_1, $R_4 = 2\ R_1$, $R_2 = R_3 + R_4 = 20\ R_1$. If an A.C. voltage is applied to the input side AB, an A.C. voltage occurs over $R_3 + R_4$ which is ten times as great as than on R_1. The A.C. voltage over R_4 is thus equal to that over R_1, but in opposite phase. Since the potential of *a* at every moment rises as much as that of *b* falls, the tension between *a* and *b* is the desired push-pull volt-

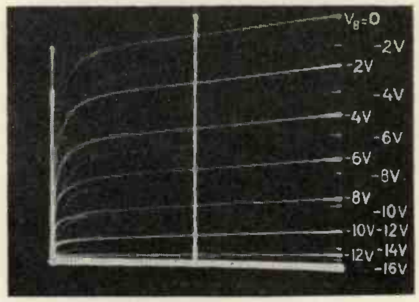


Fig. 6. Photograph of the I_a-V_a diagrams of two valves taken at the same time. One diagram is traced with lower intensity for the sake of distinction.

age, provided *a* and *b* have the same D.C. voltage potential. This may be realised by regulation of the anode direct current, for instance by means of an adjustable resistance in series with the cathode, or by a suitable adjustment of the screen-grid voltage. The further amplification of the symmetrical halves of the push-pull voltage is carried out in the manner usual for D.C. amplifiers.

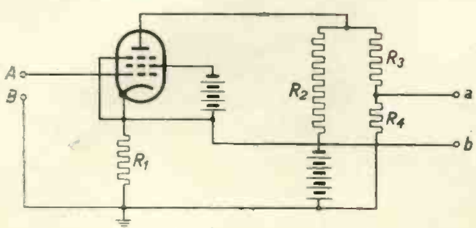


Fig. 7. First stage of the D.C. push-pull amplifiers for the deflection voltages. By giving the resistances R_1-R_4 suitable dimensions, upon application of an A.C. voltage to AB, the potential at *a* is made to increase by the same amount as that at *b* falls. The D.C. voltage potential at both points is adjusted to the same value by regulation of the anode direct current.

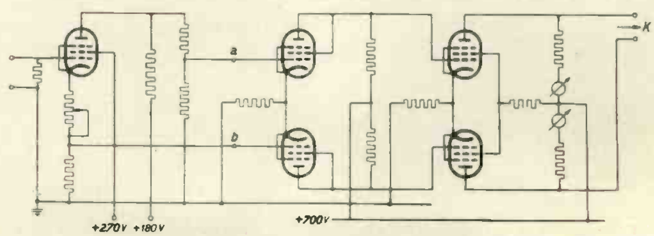


Fig. 8. Diagram of the complete circuit of the D.C. push-pull amplifiers ; a and b correspond to the points *a* and *b* in Fig. 4.

valve (curves with lower intensity) has a smaller slope and a higher maximum anode current at V_g=O (highest curve). Furthermore, the I_a-V_a curves of this valve do not run as close to the I_a axis as those of the other curve, a fact which has an unfavourable effect on the distortion at high values of the grid excitation current. Without going more deeply into this matter it may be noted that these deviations are caused by the fact that the cathode of this valve was not accurately centred with respect to the control grid.

When the I_a-V_a diagram has been photographed with a camera set up in front of the fluorescent screen, the load this purpose must not suppress the D.C. voltage component.

In order to obtain an accurately focused image on the screen of the cathode-ray tube, the potential in the middle of each set of deflection plates must remain constant (the focusing of the electron beam depends upon this). This means that the voltages must be applied to the deflection plates in a push-pull connection. One thus arrives at the somewhat unusual requirements of D.C. push-pull amplifiers.

Fig. 7 shows diagrammatically how the first stage of these amplifiers is arranged. The value of the resistance is, for example, the following : $R_3 = 18$

A diagram of the complete circuit is given in Fig. 8. The points *a* and *b* correspond to the points *a* and *b* in Fig. 7. It may be seen that in the practical application no special battery has been used for the screen grid. In addition to the anode current the screen grid current now also flows through the cathode resistance. Therefore the ratios between the resistances R_1 to R_4 (Fig. 7) are slightly altered.

In the simplest case in which the loading of the output valve consists of a pure resistance, the load line is a straight line through the operating point, as was indicated in Fig. 1. Fig. 9 is a photograph of such a case. The loading resistance in this case was equal to the so-called optimum resist-

Load Line for Different Cases

ance with which the output valve delivers the maximum power at a definite distortion (10 per cent. in this case).

For the output pentodes the optimum value is usually equal to the quotient of anode D.C. voltage and current. In that case the amplitudes of the anode A.C. voltage and current can simultaneously reach their maximum values,

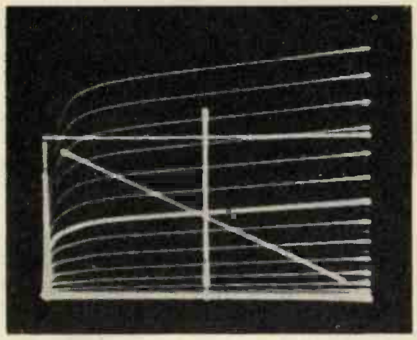


Fig. 9. Load line for the case in which the output valve is loaded with a pure resistance. The resistance here has the optimum value: the operating point lies in the middle of the section which is cut off on the straight load lines by the axes.

which are approximately equal to the anode D.C. voltage and current, respectively.

In practical cases the load on an output valve usually consists of one or

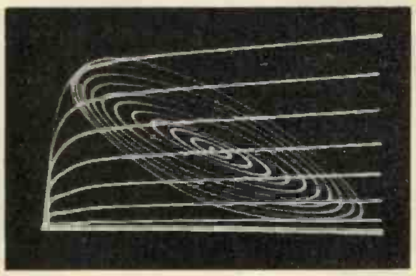


Fig. 11. With inductive loading of the output valve (connection to loud speakers) the load line becomes a more or less distorted ellipse around the operating point when the grid excitation voltage is sinusoidal. In this recording the amplitude of the grid excitation voltage was varied in steps with the frequency constant.

more loudspeakers. The impedance of these is not a pure resistance but is inductive for a large part of the frequency range, due to the self-induction of the loudspeaker coil. The variation of the absolute value and the phase angle of the impedance of an ordinary loudspeaker of good quality with appropriate transformer is represented in Fig. 10. As a measure of the magnitude of the impedance the value at 1,000 c/sec. is generally taken. In our case this amounts to about 7,000 ohms, which corresponds to the optimum resistance for the 9-watt pentode EL_3. The phase angle at the frequency mentioned is about 45 degrees.

As a result of the phase shift between anode A.C. voltage and current, a straight line is in general not obtained in the I_a-V_a diagram of the output valve. With a grid A.C. voltage of given frequency and amplitude, a more or less elliptical load line is obtained around the operating point. In Fig. 11 a number of such ellipses are shown which are obtained at different amplitudes of the grid A.C. voltage.

If the grid A.C. voltage contains different frequencies more complicated figures occur. Examples are shown in Figs. 12 and 13 in which two frequencies, having the ratios 1 : 4 and 1 : 15, respectively, were applied to the grid, and in Fig. 14 in which three frequencies were combined. Finally, in Fig.

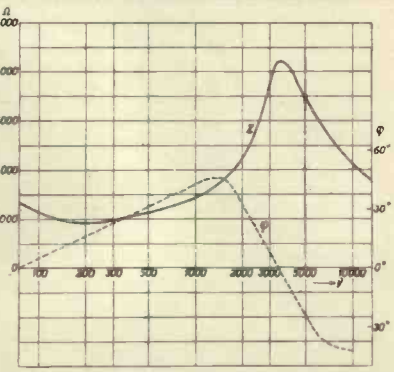


Fig. 10. Variation of the absolute value Z and the phase angle φ of the impedance of a normal loudspeaker of good quality as a function of the frequency v in c/sec. In this measurement a condenser of 2,000 μF was connected in parallel with the primary winding of the loud-speaker transformer, as is the case in many radio receivers. At 1,000 c/sec., Z = 7,000 ohms. At lower frequencies Z changes only slightly: the minimum lies at 200 c/sec. and amounts to about 5,000 ohms. At higher frequencies Z first increases sharply to about 21,000 ohms at 3,000 c/sec., it then decreases again due to the influence of the condenser. Cheaper types of loud speaker show in general a greater variation of Z and φ with the frequency.

15 the image is given which is obtained when the output valve, loaded with a loudspeaker, is allowed to amplify music for some time. One can no longer speak of a load line, but of a load field which occupies a more or less extensive portion of the I_a-V_a diagram.

The Form of the I_a-V_a Diagrams

After an idea has been obtained in this way of the size of the region used in the I_a-V_a diagram, the requirements can be more precisely defined which the I_a-V_a diagram must satisfy in order to obtain as little distortion as possible in the reproduction and as large an output as possible.

Since the anode A.C. voltage, and with it the output, is limited by the crowding of the I_a-V_a curves near the vertical axis, it is desirable that the curves should run as closely as possible along the vertical axis at low anode voltages, or in other words that in this region the anode current should increase very rapidly with the anode voltage. By the introduction of the screen grid it was possible to satisfy this requirement, without being compelled to use positive grid voltages, involving a consumption of energy by the grid as in triodes. At the same time, however, in the tetrode thus formed the phenomenon occurs that secondary electrons, formed at the anode, may pass to the screen grid,

Mention of "Electronics and Television & Short-wave World" when corresponding with advertisers will ensure prompt attention.

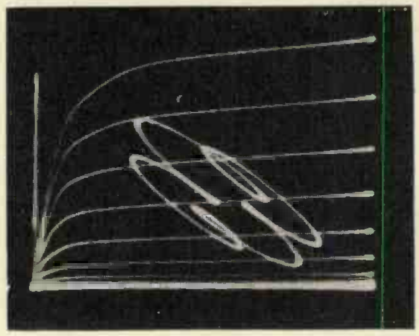


Fig. 12. Two A.C. voltages with a frequency ratio of 1 : 4 are applied to the grid of the inductively loaded output valve.

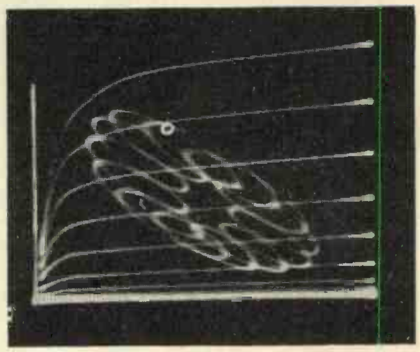


Fig. 13. As Fig. 12, but with a frequency ratio of 1 : 15.

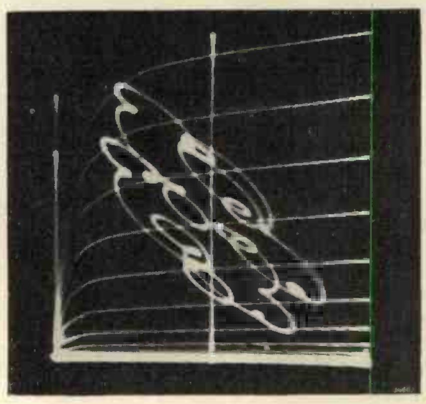


Fig. 14. Three frequencies are supplied to the grid.

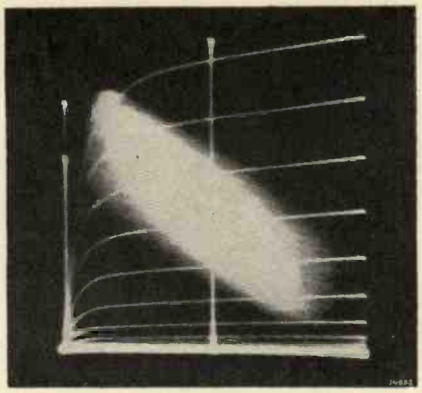


Fig. 15. The A.C. voltage of music is applied for some time to the grid of the output valve. A certain "load field" is now covered in the I_a-V_a diagram.

which causes a kink in the I_a-V_a curve (Fig. 16a).

In order to avoid these kinks which are accompanied by great distortion, a third grid (suppressor grid) is introduced, which is at cathode potential, and which suppresses the secondary emission from the anode to the screen grid. In the older types of pentodes, however, this suppression was often so thorough that at low anode voltage part of the primary electrons emitted by the cathode were also forced to reverse their direction in front of the third grid. These electrons were then lost for the anode current, and the result was that the anode current increased rapidly with the anode voltage.

By a correct choice of position and dimensions of the suppressor grid, the decrease in power output which hereby occurs can be kept very small. In the work involved in this development the method described in this article for the recording of I_a-V_a diagrams has proved very useful. A change in position and dimensions of the suppressor grid is to a certain extent equivalent to a definite change in its potential. By applying different negative or positive voltages to the suppressor grid—which in contrast to the ordinary construction must have leads to the outside—and by inspecting the I_a-V_a diagram in each case, it is possible to discover the voltage at which the most favourable form of the diagram is obtained.

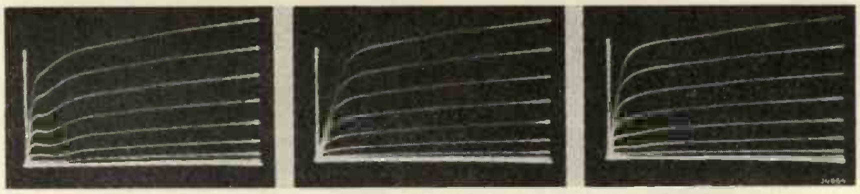


Fig. 16. The I_a-V_a diagram of a pentode at different potentials of the suppressor grid.
(a) The suppressor grid is too strongly positive, the kinks in the characteristics due to secondary emission from the anode are not sufficiently suppressed. (b) The suppressor grid is too strongly negative. The kinks in the characteristic have disappeared, but at low anode voltages the curves rise less steeply. (c) The suppressor grid has the optimum potential. This value of the potential gives an indication of the sense in which position and dimensions of the grid must be changed in order to obtain the same result with this grid at cathode potential.

Fig. 16 shows three records from such an investigation. In *a* the kinks are very pronounced, in *b* they have entirely disappeared, but at the same time the anode current increases much more slowly with the anode voltage, in *c* the correct compromise has been found in which the curves mount as steeply as possible, while the kinks are only present in the region of the diagram which, according to the investigation of the load field (see above), is not used in practical cases.

Electrical Measurements

THE average radio service engineer quickly becomes adept at making routine checks with service instruments but occasionally meets a problem where a knowledge of electrical measurement as a whole would be of great advantage. For example, how many radio engineers know how to measure the power lost in a choke without a wattmeter? In large power rectifier systems the use of three-phase supply is common and the measurement of the efficiency of such a system involves a knowledge of three-phase voltage and current measurements.

Two books are recommended for use by radio engineers who wish to enlarge their knowledge of electrical measurements. The first, "Electrical Measurements," by Turner and Banner, covers the whole field of electrical measuring instruments including some with which the reader is already familiar. The opening chapters deal with units and standards and stress the importance of accuracy in the instrument and the observer. The principles of the various types of indicating instruments are then discussed including thermal and electrostatic meters. The most useful section of the book commences with a detailed account of the measurement of current and voltage, power and energy. Further chapters are devoted to resistance and impedance measurement, inductance and capacity bridges and magnetic measurements.

In the chapter on inductance measurement all the different types of bridges are described—Anderson's, Hay's, and others. A separate chapter outlines the methods of measuring resistance at radio frequencies. The last section of the book covers 'out of the ordinary' measurements—light and illumination, speed, temperature and cable tests. A glossary of instrument terms is also given. For the radio worker who is looking for concise information on the various instruments and methods available, this book covers the whole field in a most satisfactory way.

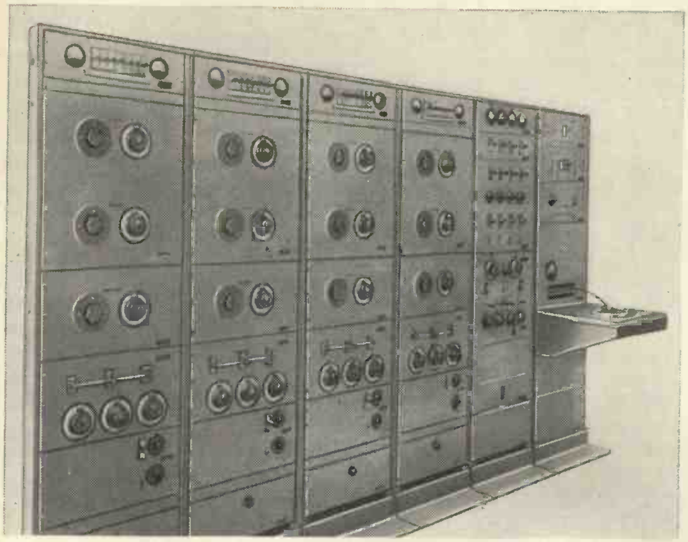
"Commercial A.C. Measurements" by G. W. Stubbings, is now in its second edition and is shortly being issued again at a moderate price.

As the title implies, it deals thoroughly with the A.C. circuit and the theory underlying the various methods of measuring power, voltage and current. The first chapters cover the theory of three-phase measurement and describe the special instruments for use in three-phase circuits. An interesting description of the N.P.L. electrostatic wattmeter is given, together with "summation" wattmeters.

The chapter on test-room equipment is intended for those who have to check commercial instruments and undertake A.C. measurement on a larger scale than that demanded by radio apparatus. An appendix gives the various trigonometrical functions used in instrument and power theory, and the principal references to the subject matter are given at the end of each chapter.

This book forms an excellent companion to the one first described, and with both at hand the radio engineer could undertake any measurement work with confidence. Both are published by Chapman & Hall at 17s. 6d.

Television and frequency-modulation radio programmes are transmitted from the same aerial structure at General Electric's new transmitter in the Helderberg Mountains in New York State, U.S.A. Two aerials located at right angles to each other at the top of the pole transmit frequency-modulated programmes, while two square structures below, made up of seven-foot copper tubes, radiate the sound signals for television programmes.



The control panels of the G.E.C. radio receivers and other equipment used for diversity reception.

A Diversity Reception Station

for Re-broadcasting European Programmes in South Africa

IN South Africa programmes of every kind are now re-broadcast from the pick of Europe's stations and re-diffused throughout the whole of South Africa from the broadcasting station Panorama, a few miles west of Johannesburg.

The aerial system on which the signals are picked up is a rhomboid arrangement of three aerials so placed that *a* is separated from *b* by 1,250 feet, *b* from *c* by 1,240 feet and *a* from *c* by 2,250 feet. At present the aerials are directional on Central and Western Europe, but it is intended that additional aerials shall later be set up to allow reception effectively to be obtained from all parts of the world. Although the present scheme is mainly intended for picking up signals on wavebands between 13 and 30 metres, it also functions effectively on the 49 metre 'band. Beyond this point reception cannot be maintained at peak efficiency.

The receivers and associated gear are mounted in eight racks each 5 ft. 6 in. by 1 ft. 7 in. wide. Rack 1 houses the aerial coupling board. Racks 2 to 5 carry the four receivers, and rack 6 holds the diversity locking equipment. The line and monitor amplifier equipment is housed in rack 7, while rack 8 is used for mounting the telephone apparatus.

The aerial coupling board is provided with flexible connectors allowing any aerial to be linked with any of the receivers. The aerial connectors and receiver interconnectors are of the concentric co-axial cable type.

Each of the receivers is an eight valve superhet, built by the General Electric Co., Ltd., for diversity reception. Several special features had to be considered in the design. For instance, the supply of both high tension and low tension current is from accumulators, to avoid risk of noise from background. To maintain full efficiency each circuit in each receiver is individually tuned. There are six circuits to be tuned before reception from any station can be obtained, as opposed to the single tuning circuit of the ordinary home receiver, three being used for I.F. and three for R.F. tuning, the former, of course, being the first station and subsequently left at the right setting then obtained.

Automatic volume control voltage is obtained from a valve which operates with its anode at earth potential and its cathode at minus 100 volts. The voltage developed across the anode load resistor of this valve is used to control the variable amplification valves. The stronger the signal therefore, the greater the negative value of the voltage developed. As an indication of the performance of the automatic volume control circuits, there is a 9db. change in output for 60db. change in input above zero level, zero level being 10 microvolts.

When receivers are coupled in diversity through the diversity locking equipment, i.e., when the outputs are coupled through a mixer unit and their automatic volume control lines bonded—the receiver which has injected into it the greatest signal will take charge of the total output. This is due to the fact that the receiver obtaining the greatest signal will bias the other receivers back so as to make them almost—or possibly entirely—inoperative. As soon as the strongest signal on aerial 1, for example, fades, aerials 2 or 3 may be in the strongest signal field, and the receiver coupled to whichever is the stronger of these will then take control. Thus the total output is being supplied by all receivers in their turn as they receive the strongest incoming signal.

Locking Equipment

It is possible, of course, to couple the output of two, three or four receivers as desired, or to extract the outputs from each receiver separately. Precautions are taken to ensure that the outputs are coupled in phase, so that cancellation, noticeable in the bass frequencies, will not take place. The line

(*Continued on page* 263)

A plan of the control panel illustrated above indicating the functions of the various sections.

ELECTRONIC COUNTING CIRCUITS

A review of various circuits for application to light operated and other counting devices

MODERN mass production methods and high speed processes usually employ a counting mechanism at some stage in the chain of manufacture in order to give information on the rate of production. In some cases the weight of the objects to be counted may be too small to actuate any mechanical counting device and in these special conditions a relay operated by a light beam is ideal as it requires no mechanical power to drive it and is practically instantaneous in action. The conventional type of relay circuit is shown in Fig. 1. A beam of light passes across the path taken by the moving object and is focused on to a photo-cell mounted at the opposite side of the path. The current from

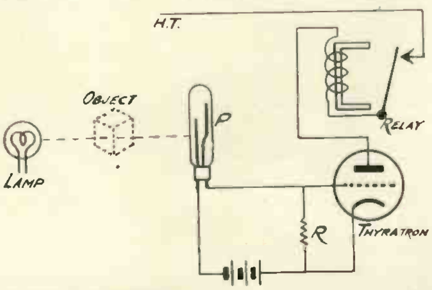


Fig. 1. Simple counting circuit operated by interrupting a beam of light on a photo-cell.

the cell is then caused to operate a mechanical counter. The cell may be connected in the circuit so that it is normally illuminated and the change in current is caused by the shadow of the moving object, or it may be normally dark and receive a light impulse by reflection from the moving object.

A typical case of a normally illuminated cell can be seen at many tube stations, where the passage of a train is caused to cut off the current and make a mark on a chart. The cell usually used is of the photo-electric type, either gas-filled or vacuum and owing to the low value of emission current a form of amplifying device must be used in conjunction with it.

The most satisfactory amplifier is the thyratron valve, since it possesses the property of releasing a comparatively heavy flow of current for a small change in grid potential. The theory of the thyratron has been explained in many previous articles, and for the present purpose it is only necessary to note that the current flow with a fixed value of anode voltage starts when the grid bias falls by a small amount below the critical value, and that the current, once started, can only be cut off by reducing the anode voltage to zero.

The critical value of grid voltage bears a definite relation to the anode voltage which is termed the "control ratio," and an average figure for this is 20 : 1. Thus for an anode voltage of 150 the critical value of grid bias is $7\frac{1}{2}$ and if a potential applied to the grid causes it to fall below this value the current will flow.

In the circuit of Fig. 1 the grid is biased to $7\frac{1}{2}$ volts through the resistance of the photo-cell P, which is illuminated. When the light is cut off, the emission in the cell ceases and the grid is virtually connected to the cathode of the thyratron through the leak R. The current starts and the relay in the anode circuit moves the counter. The movement of the relay also interrupts the anode circuit of the thyratron so that the circuit is self-resetting and is ready for the next light interruption.

One disadvantage of this circuit is that if two objects pass the cell at a very short interval, the relay may not have time to switch off the thyratron and they may be recorded as a single interruption. Similarly, if the object takes a long time in passing the light beam the relay may switch off and reset a number of times for the same interruption and record the passage of several objects. This may be overcome by the use of alternating current for feeding the thyratron, but there are several simpler alternatives such as accurate timing of the relay for the particular work to be dealt with.

The other connection of the cell to

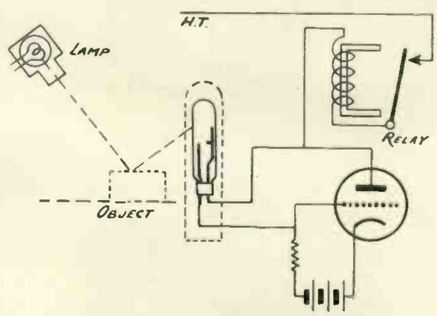


Fig. 2. Circuit for counting light flashes.

receive reflected light or a direct ray from the lamp is shown in Fig. 2. In this circuit the cell is normally dark, and care has to be taken to exclude stray light which might operate the cell at a wrong moment. Apart from the photo-electric cell shown it is possible in this circuit to use the selenium cell without amplification if the relay is sensitive enough, or the newer "barrier-layer" cell recently described in this Journal.* In the circuit shown, the grid is biased by the battery B until the cell is illuminated, when the resistance is lowered and the grid becomes positive with respect to the anode thus causing the current to flow.

Speed of Counting

The rapidity with which these counting circuits will work with fast moving objects is limited by the mechanical

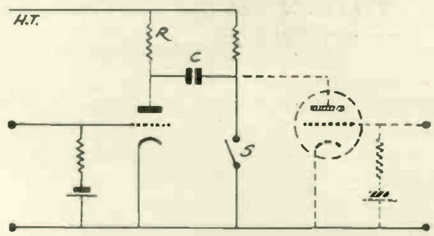


Fig. 3. Use of a condenser for breaking the circuit of a thyratron. A second thyratron acts as an automatic switch.

inertia of the relay or counting mechanism. When objects are passing the counter at the rate of one or two per second there is no difficulty, but some special applications of counting require speeds of several hundred or even thousands per second.

A clever circuit devised by Wynn-Williams† makes it possible to multiply the speed of counting without special design of the counter itself. The principle of this method is simple—if the mechanical counter is only called on to record, say, every tenth impulse, it is obviously possible to count ten times the number of objects in a given time. By extending the principle it becomes possible to count hundreds or thousands of objects in a very short time, the multiplication taking place in the circuit instead of in the counter train.

The fundamental circuit employed is shown in Fig. 3. If a thyratron has a condenser and switch connected across it as shown, the condenser will charge when the thyratron passes current, provided that the switch is open. The potential to which the condenser is charged is practically that across the thyratron load, neglecting the small voltage drop in the valve itself. If the switch is now closed, the condenser will discharge through the thyratron and will oppose the potential across it from the H.T. supply. The discharge current will then cease to flow, and if

* See January, 1940, issue p. 14.

† Proc. Royal Soc., July, 1931, p. 295, and May, 1932, p. 312.

the grid is maintained at a negative potential the thyratron will not pass current again when the condenser has discharged. The condenser thus acts as an extinguisher of the thyratron discharge, operated by the switch.

leaving V_3 still discharging. The fourth impulse re-fires V_2, switching off V_3 and switching on V_4. The counter therefore receives one impulse in four and the circuit is then re-set for another train of four impulses.

the last cathode is coupled back to the first through the condenser C_3 acting as the "extinguisher."

In operating, an impulse is applied to the first grid as before. The current passing through the cathode resistance when the first thyratron has fired reduces the bias on the grid of the second and charges the "extinguishing" condenser C_1. The second impulse will, therefore, fire V_2 in preference to any other, owing to the lower bias voltage on its grid, and at the same time the first thyratron will be extinguished by the discharge of the condenser. The action then proceeds, V_2 acting as a priming for V_3 and being extinguished in turn when the next impulse arrives. Finally, V_3 primes V_1 and is extinguished in turn, operating the relay in its anode circuit.

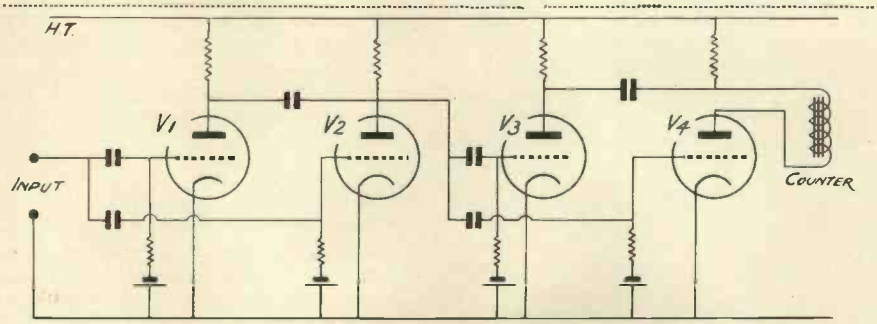


Fig. 4. The application of the circuit of Fig. 3 to counting rapid impulses.

Instead of a switch it is possible to use another thyratron, as shown by the dotted connections in the figure. In this case the condenser discharge is controlled by the striking of the second thyratron, with the added advantage that the circuit is now reversible. When V_1 is passing current V_2 is switched off and when V_2 discharges, V_1 is switched off. The alternate switching on and off of either valve is controlled by the impulses applied to the grids.

This fundamental circuit has a variety of applications apart from the one with which this article is concerned. It is possible to convert D.C. to A.C. by using a transformer in place of the load resistance and applying a D.C. potential to the anode and A.C. to the grids. Such a circuit is known as an "inverter" and is an efficient method of obtaining a low-power A.C. supply without the use of rotating machinery. Another application is the so-called "electronic switch," used for showing two wave-forms on the screen of a cathode-ray tube. The deflector plates are rapidly switched from one test circuit to the other by means of the thyratron switch and the voltage waves appear to be recorded simultaneously owing to persistence of vision.

Returning to the counting circuit, Fig. 4 shows the application of the principle to multiplication of counting. Two pairs of thyratrons are used to form a stage, the output from the second being applied to the grid of the next stage. The counter is connected in the anode circuit of the last thyratron. The action is as follows: On receiving an impulse, the first thyratron "fires" and passes current until a second impulse is applied to the stage. This "fires" the second thyratron and switches off the first in the way that has been described. At the same time the firing of the second thyratron starts the discharge in V_3 through the impulse applied to the grid. The next impulse re-fires V_1 and causes V_2 to switch off,

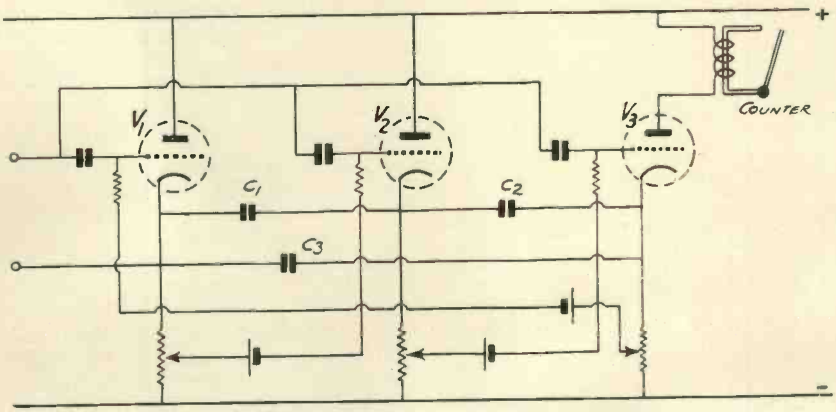


Fig. 5. The "ring" circuit for multiple counting.

The passage of the impulse can be traced through the stages by the table below which shows the position of the thyratrons at each impulse:

Impulse.	V_1	V_2	V_3	V_4
1	On	Off	Off	Off
2	Off	On	On	Off
3	On	Off	On	Off
4	Off	On	Off	On

It should be noted that the arrival of the first impulse may switch on either V_1 or V_2, but the exact order is immaterial, as the reversal takes place automatically.

By the addition of further pairs of thyratrons the multiplication can be increased to record every eighth impulse, and in general "n" stages will cause the relay to operate every "2n"th impulse.

Ring Counting Circuit

An alternative circuit to the above is the so-called "ring" circuit in which each thyratron is connected in parallel. This is shown in Fig. 5, the impulses being applied simultaneously to all the grids. It will be seen that each grid derives its impulse from the cathode circuit of the preceding valve and that

For the sake of simplicity it is assumed that the firing of the thyratrons takes place in sequence from number one, but the chain of operation may start at any point on the circle, since the impulse is applied simultaneously to all the grids. The "scale-of-two" counter circuit is, however, usually preferred for rapid working and high multiplication.

Hard-Valve Counter Circuit

Although the thyratron counter is generally satisfactory for high speed operation, it is recognised that there are inherent faults in thyratrons which make the vacuum valve preferable for work requiring extreme accuracy and reliability. Accordingly a counting circuit has been developed by Dr. W. B. Lewis * on similar lines to those described, but using battery valves of the L2 type connected as a multivibrator. The essential connections are shown in Fig. 6. The impulse is applied to the grids through the Westectors shown, the grid bias being applied through the choke L.

* Proc. Camb. Phil. Soc., Vol. 33 October, 1937, p. 549.

As in the multivibrator circuit, there are two stable conditions of operation—either V_1 is passing current and V_2 is cut off, or V_2 is passing current and V_1 is cut off. The changeover is actuated by the impulse in the following way: Assume that when switched on V_1 is passing current and V_2 is quiescent. The potential of G_2 is then positive with respect to the centre point of the rectifiers and there is negligible potential difference between G_1 and the centre point.

When the impulse arrives, rectifier 1 will conduct and rectifier 2 will be non-conducting owing to the potential across it. The anode current in V_1 will then fall owing to the increase in grid bias, and the potential of G_2 will then alter until it is nearly that of G_1. The circuit is now unstable and will "tip over" until V_2 is conducting and V_1 is switched off. The tipping over is aided by the choke inductance in the grid circuits. The next impulse tips the circuit back again, and so on, the whole arrangement acting as an unstable balance in which the impulses tip first one pan down and then the other.

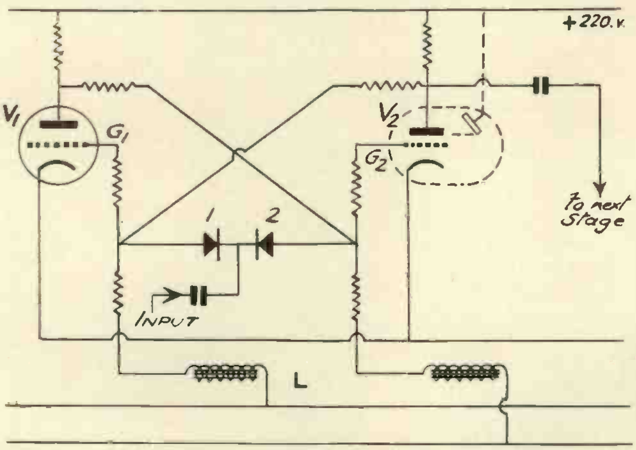


Fig. 6. A counting circuit by W. B. Lewis, using hard valves.

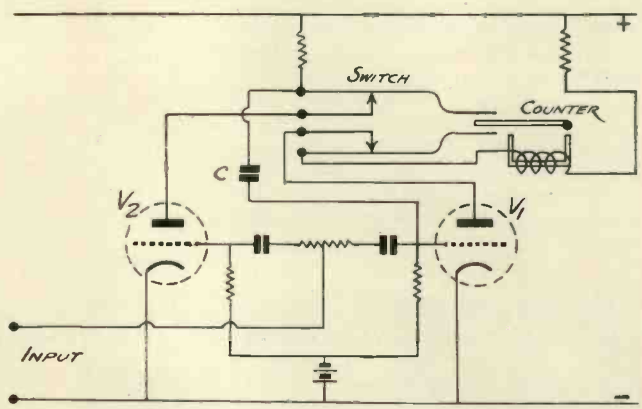


Fig. 7. "Watch-dog" circuit for storing impulses or for simple multiplication.

The next stage is coupled to the anode of the first in a similar manner to that given in the preceding diagrams. An ingenious addition to the circuit is a "magic eye" indicator to show when the valve is operating—shown by the dotted lines in the diagram. The author points out that the values of choke and coupling condenser are important and depend on the duration of the impulse it is required to measure. A time constant of .0002 sec. in the coupling circuit and a choke of 60 henries enables the circuit to count 50 cycles per second and also impulses lasting 1/40,000 sec.

"Watch-dog" Circuit

Another ingenious device which is of use in high-speed counting is a circuit which stores up an impulse if the counting circuit is not in a condition to deal with it. This circuit, which has been named a "watch-dog," is shown in Fig. 7. The lever actuating the counting mechanism is also arranged to operate a pair of switches, one in each of the anode circuits.

When the ratchet arm of the counter is actuated by the current in the coil of V_1, the anode circuit of V_1 is automatically opened, as in the diagram given in Fig. 1. If another impulse is received during this time, V_2 is ready to receive it as its anode circuit is closed, and it will "fire." The potential of the point "A" will then rise to that of the H.T. supply and will be transmitted to the grid of V_1 through the condenser C. On the return stroke of the ratchet, V_2 is open-circuited and V_1 is put in a condition to fire from the impulse applied to its grid in the interval.

This circuit has the useful application of extending the limit of counting speed of the "scale-of-two" counter previously described, and if every eighth impulse is normally recorded it can deal with impulses at the rate of 10,000 per minute. Without the additional multiplying circuit it can be used to ensure that an ordinary counting mechanism does not miss any impulses. It has been calculated that a single thyratron counter working a telephone call counting mechanism which requires 1/25th sec. for its operation will miss 2 per cent. of the arriving impulses at the rate of 30 per minute and 20 per cent. at the rate of 300 per minute. A watch-dog counter having a resolving time of 1/150th sec. will only have a total "miss" of 2 per cent. at 150 per minute and 10 per cent. at 500 per minute.

"A Diversity Reception Station"

(Continued from page 260)

and monitor amplifier and equaliser is of value should it be desired to cut off the extreme high frequencies of the audio output. The telephone line equipment transmits the modulated signal to the distributing studio.

Standby Provision

It has been proved in practice that if aerials are separated by 1,000 feet or more, the signal they receive from a distant short-wave transmitter will fade only very seldom at all three such aerials simultaneously. It is not, therefore, economically worth while to use four or more receivers in diversity, as the reduction in fading per receiver added in excess of a total of three becomes very small. A fourth receiver is used, in order that a spare may be available for substitution in case of failure, or for use as a standby.

Selective fading, that is to say, the type of fading which is accompanied by severe distortion, is not diminished by diversity working. In other words, diversity only aids in the elimination of straightforward fading.

Power Equipment

The generator equipment is electrostatically shielded in order to prevent any radiation of interfering signals. The generator set is a petrol-electric type capable of delivering 3½ kW. at 220 volts, 50 cycles. It employs automatic starting so arranged that as soon as a load in excess of 60 watts is thrown upon it, it starts from a storage battery and will continue to run until the load is removed.

The charging equipment consists of a large rectifier unit for the low-tension, employing two mercury vapour rectifiers capable of delivering a full-wave rectifier current of 50 amperes. The charger for the high-tension supply employs a mercury-vapour full-wave rectifier and is capable of charging the complete high-tension battery at 5 amperes.

A FLEXIBLE SYNC.-PULSE GENERATOR

THE Du Mont type 203 Synchronising Signal Generator has been designed for television transmitting stations to operate as a master generator for the synchronising, scanning and blanking pulses which are a necessary part of the composite video signal which is fed to the radio-frequency transmitter.

The generator incorporates the most advanced circuit designs for this type of equipment. It is claimed that it is foolproof in operation and may be satisfactorily installed and operated by untrained personnel.

The assembly provides all output signals necessary for control of a television signal, and in addition provision has been made to incorporate many future developments. The polarity of waveform of all output signals is reversible at will. The 'waveshaping' circuits have been designed to operate independently of frequency so that if the line frequency be changed at any time a complete redesign of the equipment is not essential. An operating life of 10,000 hours, may be expected.

The phase of all vertical sixty-cycle timing pulses generated may be shifted through 360 degrees with respect to the mains supply frequency. The various output signals available consist of the following :—

1. Composite blanking signal, consisting of horizontal and vertical blanking pulses available from two output circuits :

(a) 200 ohms, 10 volts peak-to-peak ;

(b) 80 ohms, coaxial, 4 volts peak-to-peak.

2. Composite synchronising signal, consisting of horizontal and vertical synchronising and equalising pulses. 80-ohm coaxial output of 4 volts peak-to-peak.

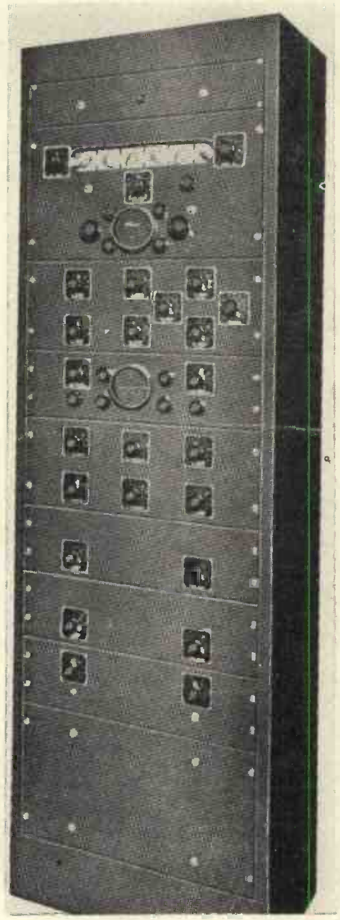
3. Linear horizontal sweep wave, 80-ohm coaxial output, 4 volts peak-to-peak.

4. Linear vertical sweep wave, 200-ohm coaxial output. 10 volts peak-to-peak.

5. Special sharp vertical synchronising pulses. 200-ohm coaxial output, 10 volts peak-to-peak.

6. Special horizontal synchronising pulses, 200 ohm coaxial output, 10 volts peak-to-peak. Input : 115 volts, 60 cycles, single phase.

The generator is composed of the following standard units :



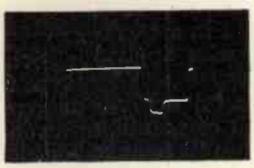
The Du Mont synchronising-signal generator.

Two-to-one frequency division shown on monitor oscillograph of frequency divider.

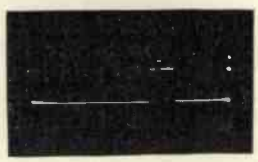
Three-to-one frequency division as shown on monitor oscillograph.

Seven-to-one frequency division showing ease with which oscillator circuits may be adjusted by use of monitor oscillograph.

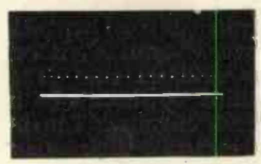
Waveform indicating phase of lock-in of frequency divider with sixty-cycle power supply.



Horizontal synchronising pulse superimposed on the horizontal blanking pulse for observation of relative phase of the two signals in the output of the equipment.



Vertical synchronising pulse superimposed on vertical blanking wave showing relative phase of the two signals.



Horizontal synchronising pulse waveform output.

Frequency Meter

This unit is the source of all vertical and horizontal timing pulses placed in correct relation for interlacing television scanning waves. There are essentially four major types of circuits incorporated in this instrument as follows :—

(a) Frequency divider.
(b) Pulse amplifiers.
(c) Frequency standardising control.
(d) Monitor oscillograph.

Frequency Divider

The frequency divider is comprised of six interlocked relaxation-type oscillators which are used as frequency dividers to obtain the horizontal and vertical timing pulse waves.

Interlocking of the oscillators is accomplished by coupling through buffer tubes. Decoupling networks are employed in all D.C. supply circuits. The oscillator anode supply is maintained at a constant voltage by means of a duplex circuit, incorporating both electronic and gaseous types of regulators. The h.t. supply for the buffer is derived from a similar source so that stable operation of the divider is insured.

The interlocking action of the oscillators has been designed so that fre-

(*Continued on page 283*)

News Brevities—

Commercial and Technical

BY the application of amplifier theory and the use of the cathode-ray tube the minute electrical potentials of the nervous system have been recorded and analysed. Modern loudspeakers reproduce the sounds of the human heart with a fidelity that cannot be attained with the conventional stethoscope. Photo - cells measure the condition of the body fluids. In every branch of surgery and physiology electricity is a valued assistant.

Towards the end of last year an article was published in this journal describing the measurement of the electrical potential of the brain by means of the electro-encephalograph. In 1938 Cerletti and Bini, of Rome, announced that the brain could be stimulated by the application of an electrical potential from the outside of the scalp and that beneficial results were obtained by the induction of convulsions in certain cases of brain abnormality.

Since their discovery several workers in England have tried out the new technique with satisfactory results, and electro - convulsion therapy, as it is called, is now playing an important part in the treatment of mental disorders.

The growing use of electrical appliances in the medical profession would seem to require further study on the part of the already busy practitioner. The best of apparatus is liable to sudden breakdowns, and the doctor who is confronted with an obscure fault may have to call in a specialist of another type as well as his professional colleague.

This will provide a useful opportunity for the skilled radio engineer. If he lets it be known that he has specialised in the construction of electro-medical apparatus he will find that his services will be in demand among the hospitals and clinics in his locality. But in turn he must take care to acquire the rudiments of the science in which he is co-operating and a vocabulary of technical terms. We have already measured the impedance angle of the human body—no doubt the radio service engineer will soon refer to a lesion in the circuit!

* * *

It is interesting to note that a different type of film recording has been developed in the Philips Laboratories, possessing several advantages over the conventional method. A special film 7 mm. wide has a coating of clear material on the base over which is deposited a microscopic film of opaque material.

A sapphire stylus is used to cut the surface of the film into a "hill and dale" record with sharp distinction between the clear and opaque parts of the track. The film is fed through an optical system and high-fidelity amplifier at a speed of 60 inches per second, and is wound for storage on a metal drum. It is claimed that the characteristics of this system of recording are such that 10,000 cycles can be reproduced easily and it is practically impossible to distinguish recorded voices from the original. It is suggested as a basis for a public service of weather announcing in America.

* * *

It is well known that multi-electrode valves of the triode-pentode and diode-triode class were in use in this country before the American receiver manufacturers took them up, but having been adopted on the other side of the Atlantic, their variety and uses have been growing. For those who have not followed the introduction of new American valve types with attention, it may be surprising to note that there is a triode-pentode-rectifier available in one bulb. The 1D8GT has power output characteristics in the pentode section and with its triode and rectifier anode provides a complete detector-output valve for transportable receivers. With a slightly higher emission from the cathode, each value could be made to provide its own H.T. supply!

* * *

There is now no doubt that the Philips factories and laboratories at Eindhoven (Holland) have fallen into the hands of the enemy, although it had been understood that a scheme was in existence for the destruction of the plant and buildings in the event of invasion. For some reason, however, it is believed that this plan has not been carried out and that the entire Philips factory (which is equipped with large quantities of plant and experimental apparatus) is undamaged.

If, however, as current reports indicate, much of the most valuable material has been removed to this country, it would appear that the occupation of Eindhoven by the Germans is of slightly less consequence than was at first imagined.

A construction permit for a television broadcastng station in New York City has just been granted by the Federal Communications Commission to the Allen B. Du Mont Labs., Inc., of Passaic, N.J. Work has already begun on the transmitter and studios which will be located on the top floor of the 42-story office building at 515 Madison Avenue.

The new Du Mont transmitter will operate on Television Channel 4, or the 78-84 mc. band, as a Class 2 television broadcaster for programme research. It is planned to utilise the Du Mont flexible system of television, whereby changes in number of lines, number of frames and interlacing schemes can be confined to the transmitter with the receivers automatically following any transmitted signal.

The Du Mont New York City transmitter is in addition to the experimental transmitter W2XVT at Passaic, which has been in operation for over a year, for engineering studies and demonstrations. Du Mont also has a mobile transmitter licence with call letters.

* * *

To meet urgent needs for more accommodation, Marconi-Ekco Instruments, Limited, have transferred the sales and administration offices to Ridgmont Road, St. Albans, Herts.

* * *

A new permanent magnet assembly, roughly three times as strong as any previously known, was disclosed recently by the General Electric Research Laboratory. It permits a tiny piece of sintered alnico to lift and hold 4,450 times its own weight.

The previous record mounting, developed in the laboratory last year, allowed a piece of the same material to lift 1,500 times its own weight. Sintered alnico is an alloy of aluminum, nickel, iron and cobalt made by pressing together the powdered metals and heating almost to the melting point. By itself, without the special assembly, an alnico magnet has a normal lifting power of 500 times its own weight.

A new mounting of brass and iron in which the magnetic flux passes through many air gaps, instead of the usual two, in bridging from pole to pole, is responsible for the greatly increased power. The new assembly is not a commercial development and the largest turned out in the laboratory to date contains but three cubic centimetres of alnico.

Though smaller than a thimble and weighing three-fourths of an ounce, this magnet in its mounting has supported as much as 200 pounds in tests. One a cubic centimetre in size, supported 67 pounds of small weights added one at a time.

* * *

The problem of defining the exposure to be given to a negative was dealt with by G. B. Harrison in a recent issue of the *Photographic Journal*. Mr. Harrison stated that it is possible to base the exposure either on the shadows, on the highlights or on the overall brightness of the subject, and he discussed the advantages of these several methods. Photo-electric meters can similarly be of three types: those with small angles of view suitable for readings of the brightness of highlight or shadow areas; those which measure the incident light on the subject; and lastly those with a large angle of view measuring overall brightness. The influence of varying tonal characteristics of the subject on the reading obtained on each basis of measurement is analysed. It is concluded that for reasons of sensitivity meters of the first type are at present impracticable; meters of the second (highlight) type are excellent for reversal processes; and those of the integrating type, which are commonest, are capable of giving tolerably good results in negative and reversal work, but require additional judgment for the best results.

* * *

An analysis has just been published of approximately three-quarters of a million tests made by the Bell Telephone System at the New York and San Francisco World's Fairs of 1939. The tests covered the frequency range from 440 to 7,040 cycles per second at intervals of one octave, and the tests were recorded together with information regarding sex of person tested, colour of skin and the particular one of five age groups to which the person belonged. It was found that at the low frequencies the falling off in hearing with age was less for men than for women, whereas at the higher frequencies the reverse was correct.

Osram Variable-Mu Screened Tetrode KTW73M

The Osram KTW73M is a valve of economical consumption suitable for use in D.C./A.C. receivers and is designed essentially for operation as the final I.F. amplifier in superhet sets in which the screen voltage is applied through a series resistance.

The small physical dimensions, resultant from a short seal construction, are of value where saving of space is important, and effect also a considerable improvement in input impedance at short wavelengths.

The characteristics are as follows:
- Heater current, 0.16 amp.
- Heater voltage, 5.8 volts.
- Operating current range, 0.154 to 0.187 amp.
- Anode voltage, 250 max.
- Screen voltage, 100 max.

- Control grid voltage, −3.
- Anode current, 6.5 mA.
- Screen current, 1.3 mA.
- Anode impedance, 0.75 megohm.
- Mutual conductance, 1.7 mA./volt.
- Input impedance at 40 mcs./sec, 20,000 ohms.

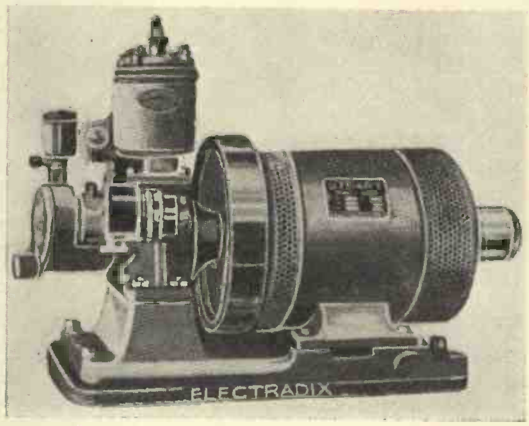
"Manganamron" Wires

The Scott Insulated Wire Co., Ltd., of Westmoreland Road, London, N.W.9, are producing a British-drawn insulated copper-nickel-manganese wire having a low temperature coefficient and low thermal E.M.F. compared with copper, suitable for the manufacture of precision instruments, shunts, etc.

"Manganamron" is an alternative to the former almost exclusively used German copper-manganese wire which has been imported and sold under the registered name "Manganin," and is now being supplied to the leading scientific instrument makers. It has been approved in instruments designed for the use of the Admiralty and Air Force. A folder giving much useful data on this and other wires can be obtained on request from the above address.

Petrol Generating Sets

For those who require low-power electric supply in areas where no power mains are available, or for emergency purposes, the combined petrol-electric generating set is the most practicable means of supply. These self-contained semi-automatic units are now available at remarkably low figures. For example, there are two Electradix (Leslie Dixon & Co., Ltd., 218 Upper Thames Street, London, E.C.)



models of 150 watts and 500 watts available which retail at £12 and £17 10s. respectively.

These sets comprise a two-stroke water-cooled engine directly coupled to the dynamo and mounted on a heavy base plate as shown in the photograph. Ignition is by magneto, and petroil lubrication is provided. Both types are provided with a governor which in the case of the 150-watt unit cuts out the ignition, and in the larger model controls the throttle. The units will run, therefore, for long periods without attention. Ball bearings are fitted to the engine big ends and the armature shaft. Output of the small generator is 6 amps. at 25 volts and the large model 10 amps. at 50 volts.

With a slight modification it is possible to run either unit on gas. We understand that a number of these sets are in use by the G.P.O. and War Office.

PROBLEMS OF H.F. DESIGN

Wide Wave Range :: Electron Transit Time :: Effect of Valve Design :: Reducing Losses :: Q Values :: Skin Effect

By O. J. Russell

THE higher frequencies are becoming of increasing importance and the design of equipment presents a problem very different to that of normal short-wave design. While it has become more usual to extend the range of receivers down to 10 metres, it is sometimes apparent that compromises have been effected, and the extreme high frequency performance is inferior to the rest of the short-wave performance. The designer must nowadays be prepared to consider the prospect of operation down to 5 metres and lower.

Wave Range

The problem of the wide range receiver operating over a wide wave range extending down to the lowest wavelengths, is extremely difficult, as it is almost impossible to avoid having to make compromises of some kind or the other, with consequent lowering of performance on some wavebands. In general it is the highest frequency band which suffers, and because of the inherent difficulty of providing high-frequency gain at these frequencies, the specialised high-frequency receiver has been evolved.

In addition, to avoid the complications of multiband operation, there are also designs for some specific single waveband. In the case of single-waveband receivers for ultra-high frequencies, the designer can adopt measures impracticable for multi-waveband receivers, and ensure maximum efficiency for the selected wave range.

A discussion of the extent to which a designer may compromise between an ideal design, and a practical design is bound up with so many factors that the question can only be decided by those concerned. The problem is naturally complicated by economic factors, and other questions outside the scope of strict radio theory and practice. However, it is of interest to examine the more strictly technical aspects of the problem of efficient operation upon the higher frequencies.

We may set the limit of normal short-wave operation as being in the neighbourhood of 20 metres (14 megacycles). At higher frequencies, the specific factors operating to limit efficient working are already becoming serious. The most serious factor is the effect of finite transit time of electrons in the valve. The lag, due to the time taken for the electrons emitted by the cathode to reach the anode, represents a loss, which may be expressed as a resistance shunted across the grid cathode input circuit; it makes itself felt as a damping of the grid tuned circuit in a high-frequency amplifier.

This input resistance decreases as the square of the wavelength, and in most high-frequency amplifying valves is of the order of only 5,000 ohms at 5 metres, or less. The valve becomes, in effect, a low resistance shunted across the input circuit, with loss of selectivity and gain. It is possible to build conventional tuned circuits having resonance resistances of much greater value than this, a value of 15,000 ohms or so being easily attainable.

A partial solution of the problem is to tap the grid of the high-frequency amplifier down on the tuned circuit. By so doing the loss in gain, due to tapping down the coil, is more than compensated, by the increased voltage developed across the tuned circuit, as the damping is removed. Selectivity is correspondingly increased. In practice, no advantage will be derived by tapping more than about half-way down the coil, as the voltage applied to the grid of the valve will fall off rapidly below this, especially as the tuned circuit has a fairly low value of dynamic resistance with normal construction.

Television Receivers

In television receivers, where even the moderate selectivity of normal tuned circuits would unduly attenuate the enormous sideband width of the vision signal, the damping, due to low input resistance, is no disadvantage. Special valves of very high mutual conductance have accordingly been evolved, in order to obtain appreciable gain with low input resistance values. It is of interest to note that with the normal type of valve construction, increase of mutual conductance is accompanied by decrease of input resistance, so that there is little advantage for normal purposes to be obtained by the use of these very high mutual conductance valves.

Finite Transit Time

The problem of finite transit time effects may be overcome in two ways. The transit time may be reduced by using higher anode voltages, or by reducing the spacing of the electrodes in the valve. Unfortunately the benefit obtained is proportional to the square root of the appropriate change, so far as the frequency of operation is concerned. Thus to obtain equivalent performance upon twice the normal frequency of operation, we should either have to decrease the electrode spacing to a quarter, or increase the anode voltage four times. In general the solution adopted is to decrease the electrode spacings. The acorn valve represents the practical limit, from present-day production viewpoint, of the reduction of electrode spacing. It must be remembered that for any specific frequency, the benefit obtained by either reducing the electrode spacing, or increasing the anode potential is directly proportional to these factors. In some cases it may be an advantage to operate a valve with increased anode potentials, and increased bias in order to improve performance at the limit of operation of some particular receiver.

It is unfortunately still true that most of the difficulties of high-frequency operation are caused by the imperfection of the valve. Losses due to other components are not nearly so serious, or can at any rate be obviated by special measures. The loss in dielectrics for example is not necessarily increased with frequency, and an excellent range of low loss insulating materials of ceramic and synthetic plastic types, is now available. Indeed the use of very low loss materials has reached at times to ludicrous lengths, as when the thin strip of paxolin type of valve holder is replaced by a holder many times thicker of low loss material, the losses of which, due to the added thickness of material, are probably not much less than the older type of holder. In any case the losses in the holder are much less than those in the base of the valve itself. It is only comparatively recently that the valve base has been modernised, and the footless types of valve have resulted in decreased losses in the valve base, and also shortened the length of the internal leads to the electrodes with reduction of the harmful back coupling effects due to the inductance of these leads.

The question of tuned circuits for high-frequency operation is at present in a state of compromise. For normal work, the conventional coil and condenser provides for reasonable values of Q down to 5 metres or so, while extremely high values of Q may be obtained by the use of resonant systems of the concentric line type. Such systems may be tuned over a waveband by the use of a variable condenser, and may be operated up to 10 metres. The values of Q obtained are so great, however, that the use of Acorn valves is virtually essential, and it is desirable to tap the Acorn valve grid well down to the concentric line system, if full advantage is to be taken of the high Q values obtained. The chief advantage of such systems is that for a given diameter of the concentric line system, the Q actually increases with frequency, unlike more conventional tuned circuits. Such concentric line systems are, however, too bulky for other than fairly specialised use.

In regard to conventional tuned circuits, it is of interest to note that at high frequencies the skin effect is accentuated by the phenomenon of the oscillatory current tending to flow only along the portion of the wire that would touch a cylinder enclosing the coil. The consequence of this effect is that the effective loss resistance of the coil is not greatly reduced by using very thick wire. However, if the coil is wound from flat strip rather than wire, the current has a larger effective surface to traverse, and the loss resistance is proportionately reduced.

While the factors militating against efficiency may most fairly be ascribed to the shortcomings of valves, rather than to serious deficiencies in other components, it is possible by circuital arrangements to obviate many of these losses. In particular, the attention given to by-passing, and to the cathode circuit are of paramount importance.

Use of Beryllium Fluoride Glasses as Binders for Fluorescent Screens

IN the use of fluorescent screens in electric discharge tubes such as mercury-vapour lamps or cathode-ray tubes, the fluorescent material is stuck to the wall of the tube by the use of a binder. Such binders have included sodium or potassium silicate and boric oxide. The fluorescent material has been applied before, after, or with the binder.

The binders used hitherto have been unsatisfactory for a number of reasons. Some, such as the silicates, depend for their adhesive properties on the presence of water and during the baking process, which is an essential part of the evacuation, they tend to flake off the walls of the tube. Others such as boric oxide have an undesirably high melting point—577° C.—which makes their use difficult.

It has been discovered that the beryllium fluoride glasses prepared by fusing together beryllium fluoride with alkali fluorides and other fluorides, are particularly suitable for use as binders owing to the low melting points available, the wide temperature range over which the glasses are soft, and also to the high transparency of these glasses to light in the ultra-violet region down to a wavelength of 2,200 A.

An example of a glass suitable is that made by fusing together equal parts by weight of sodium fluoride and beryllium fluoride. This glass has a melting point about 160-170° C. If a glass with a high melting point is required it can be obtained by using in the mixture other fluorides, such as potassium, calcium, magnesium and aluminium fluorides. It is desirable to keep the percentage of beryllium fluoride about 50 per cent. of the mixture and also to have about 20 per cent. of an alkali fluoride present.

The binder may be applied to the wall of the discharge tube in a number of known ways such as smearing the melted glass over the hot surface, spraying it in as a dry powder or as a suspension, spraying it on a solution of the constituent fluorides. The fluorescent material can be applied in similar ways either to the hot binder in soft or melted condition, or to the cold surface to be followed subsequently by a heat treatment to cause firm adhesion between the fluorescent material and the wall of the tube.

An alternative method, that may be used for example in the manufacture of mercury or neon discharge lamps where the exciting agent for the fluorescence is ultra-violet light, is to mix the fluorescent material with the binder and melt the mixture within the tube, causing it by suitable treatment to be coated evenly on the inside of the tube. Little diminution in the efficiency of excitation results from this coating process owing to the high transparency of the glass to ultra violet light, and, in fact, the layer of binder may act as a protective coating. A further layer of binder may, if desired, be applied subsequently to the fluorescent material.

The exact degree to which the fluorescent material is embedded in the binder is sometimes of importance, particularly in avoiding halation effects. For the control of this, these glasses with their range of temperature within which they are soft, and also their low melting points, are particularly suitable.

If desired, a neutral light-absorbing material such as graphite may be incorporated in the layer of binder between the fluorescent material and the glass in order to reduce halation effects.

This development is reported from the Laboratories of Electric and Musical Industries Limited.

A RECORD OF PATENTS AND PROGRESS

RECENT DEVELOPMENTS

PATENTEES

Farnsworth Television Incorporated :: Baird Television Ltd., and D.V. Ridgeway :: Fernseh Akt. :: Photo Switch Inc. :: E. L. C. White and A. D. Blumlein : W. A. Beatty :: Soc. Anon. Fimi.

Electron Multipliers

(Patent No. 512,040.)

THE secondary-emission electrodes of an electron-multiplier are made in the form of two or more conical rings, the walls of each converging towards the cathode and grid, and diverging in the direction of the anode or collecting electrode. Arranged close to the emitting electrodes is a conical-shaped accelerating grid which is made of open meshwork and biased to a high potential.

In operation, primary electrons leaving the cathode are drawn radially outwards to strike against the inner wall of the first conical-ring electrode. Here they produce secondary electrons, which are attracted by the high positive voltage on the nearby accelerating grid so that they pass through it and strike against the opposite inner wall of the second ring-electrode.

The second impact liberates still more secondary electrons, and the resulting stream is then drawn through an aperture at the top of the conical assembly where it is collected by the anode, which carries the highest positive potential. The tube can be used as an amplifier, detector or generator of oscillations.—*Farnsworth Television Inc.*

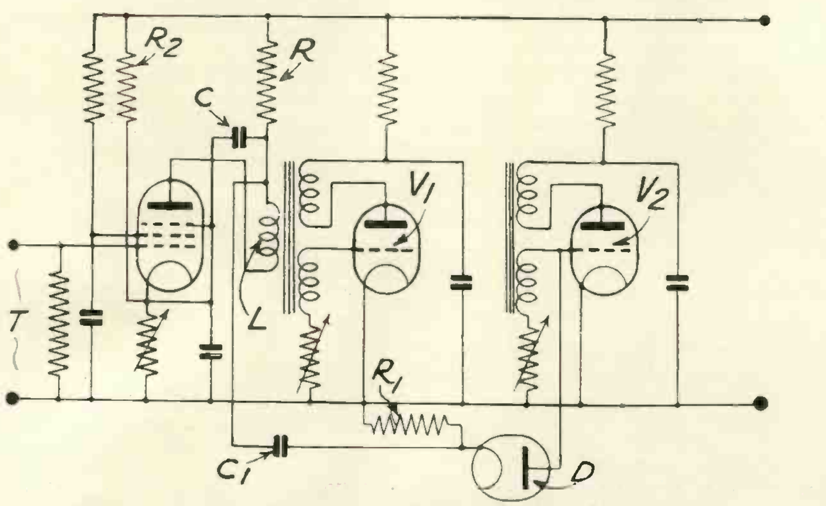
Scanning Systems

(Patent No. 512,795.)

In interlaced scanning systems, there is a tendency for those line impulses that occur immediately before the framing impulse to "trigger" the framing oscillator prematurely, thus upsetting the correct timing. As a result consecutive frames are not accurately interlaced, and the chief advantage of the method—as compared with "straight" scanning—is thereby lost. The circuit shown is intended to avoid this defect.

Mixed picture and synchronising impulses are applied to the terminals T, the picture signals being in the positive and the synchronising impulses in the negative sense. The valve V separates the two, the line impulses being fed to the oscillator V1 through a condenser C, and the frame impulses to the oscillator V2 through a resistance R, condenser C1, and diode D.

The anode of the diode is connected to the grid of the framing oscillator, and its cathode to earth through a resistance R1. Any line-frequency impulses across the resistance R that might tend to trigger the frame oscillator V2 are effectively cancelled out by impulses of opposite phase applied to the coil L by the "line" oscillator V1. The picture signals are separated out by a bleeder resistance R2. The diode D serves to re-introduce the D.C. component representing background illumination.—*Baird Television, Ltd., and D. V. Ridgeway.*



Method of improving interlace timing. Patent No. 512,795.

Projection Receivers

(Patent No. 513,740.)

In order to project a bigger picture than can be accommodated inside the cathode-ray tube, various schemes have been devised for replacing the ordinary fluorescent screen by a surface which changes its transparency from point to point, as it is scanned by the electron stream. The light from an external lamp is then projected through this sensitive surface on to a large-sized viewing-screen placed outside the C.R. tube. Owing to the changing transparency of the sensitive surface, a large image of the received picture will be shown on the viewing screen.

According to the present invention, the surface of variable transparency is made by depositing a large number of small, light particles over a "rippled" sheet of glass, the latter being arranged close to the electrode which is scanned by the electron stream of the cathode-ray tube. Under the electrostatic influence of the scanning stream, the small particles are rotated so that they lie edgewise, instead of broadside-on, to the outside lamp. In this way the light from the lamp is varied or "modulated" so as to project an image of the incoming picture on to the external viewing-screen.—*Fernseh Akt.*

Photo-electric Relays

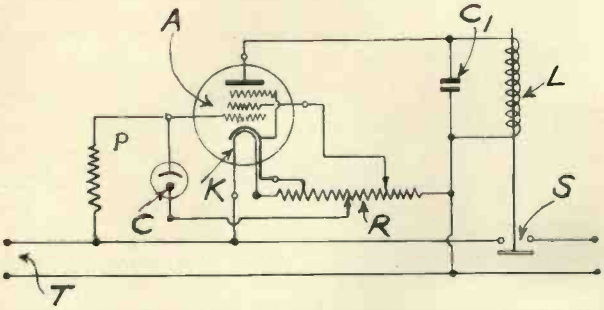
(Patent No. 514,600.)

The figure shows a valve relay A which actuates a switch S when any change of light occurs on the photo-electric cell C. The heater for the valve cathode K is supplied from A.C. or D.C. mains T through a potentiometer R, from which a tap-

The information and illustrations on this page are given with permission of the controller of H.M. Stationery Office.

ping is taken to the screen-grid of the valve. The potential on this grid is kept below 20 volts, so as to reduce the production of positive ions which tend to collect around the control grid.

When light falls upon the photo-cell C, its resistance is lowered and current will pass. If the upper terminal of the A.C. mains is then negative, the control grid of the valve becomes positive, and the relay is operated to close the switch S. When the same mains terminal goes negative, the valve relay is cut out, but sufficient charge is by then stored in the condenser C_1 to keep the coil L alive, and hold the switch closed until the phase of the supply again changes. The arrangement can be used, for instance, to ring a warning-bell for the attendant of a garage when the headlamps of a motor-car light up the cell C.—*Photo-switch Inc.*



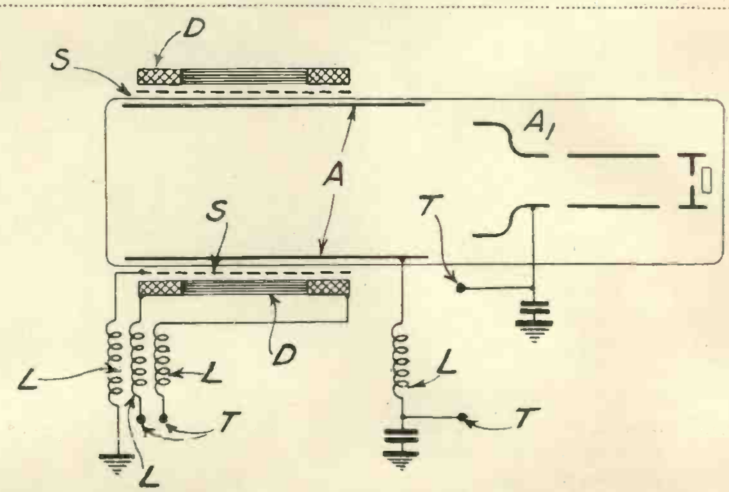
Circuit diagram of photo-electric relay. Patent No. 514,600.

Protection Against High Voltages

(Patent No. 514,825.)

The voltage applied to the final anode coating A of a cathode-ray tube may be of the order 50,000, whilst that on the first anode A_1 may be about 2,000 volts. If a flash-over occurs between these two electrodes, or if the H.T. supply is accidentally shorted, the deflecting-coils D (of which only one pair is shown on the drawing) may momentarily carry 50,000 volts negative to earth, owing to the inherent capacity between the parts, which is of the order 0.001 microfarad. Such a voltage is liable, of course, to damage the component parts of any connected circuit, besides being definitely dangerous to anyone handling the apparatus.

In order to minimise the risk, inductances L, preferably in the form of long solenoid windings, are inserted, as shown between the supply terminals T, and the anode A, electrostatic screen S, and deflecting-coils D. Then if a flash-over occurs, a large potential-drop will be set up across the protecting coils, so that the momentary voltage thrown on the various component parts of the C.R. tube is correspondingly reduced. —*E. L. C. White and A. D. Blumlein.*



Protection against high voltages in C.R. tube deflecting coils. Patent No. 514,825.

Television System

(Patent No. 515,474.)

The line and frame impulses are radiated on a carrier-wave which differs by some five megacycles from the carrier-wave used for the picture signals. The carrier-wave frequency is automatically shifted, when required, by causing the voltage-swing corresponding to the synchronising impulses to alter the effective impedance of a normally-saturated pentode valve, which is shunted across the oscillatory circuit. The picture signals are radiated on a single side-band, the frequency-shift being in the direction of that side-band.

One advantage of the system is that less power is needed to ensure a clear-cut discrimination between the picture signals and synchronising impulses.—*W. A. Beatty.*

Photo-electric Remote-control

(Patent No. 518,071.)

The indicator pointer of a wireless set is arranged to move in a straight line across the station dial. At its lower end the pointer carries a transparent strip, which is marked at equally-spaced intervals by opaque lines. As the tuning indicator is moved, these lines pass between a glow-lamp and a photo-electric cell, so that the latter is impulsed by each opaque line, and sends a momentary current to the distant control point.

The number of current impulses so produced obviously depends upon the distance through which the tuning-indicator is moved in the first instance. By applying each impulse to operate an electromagnetic relay at the distant point, the initial movement can be accurately reproduced.—*Soc. Anon. Fimi.*

Summary of other Electronic Patents

(Patent No. 510,881.)

Frequency-dividing circuit suitable for handling the scanning frequencies used in television.—*Baird Television, Ltd., and T. C. Nuttall.*

(Patent No. 511,363.)

Controlling the brightness of the spot formed on a fluorescent screen in interlaced scanning systems.—*Fernseh Akt.*

(Patent No. 511,519.)

Circuit arrangement to protect a television receiver from the effect of local interference.—*Kolster-Brandes, Ltd., C. N. Smyth and R. J. Berry.*

(Patent No. 511,600.)

Production of sharply-peaked scanning voltages of true linear shape.—*Murphy Radio, Ltd., and G. F. Hawkins.*

(Patent No. 515,426.)

Television receiver in which changes in overall gain do not alter the correct representation of the black values.—*Ferranti, Ltd., and M. K. Taylor.*

THE SHORT-WAVE RADIO WORLD

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

Variable Frequency Crystal Control

In the May issue of QST, Keith Hayes suggests that a wide range variation in quartz crystal oscillators can be obtained with variable air gap crystals.

Two methods are in common use for changing the operating frequency of a transmitter to any desired spot in the band—the electron-coupled oscillator and the " conversion exciter," which uses a low-frequency self-excited oscillator to beat with a crystal controlled oscillator. The electron coupled oscillator is to be preferred, but its adjustment for optimum results is not always easy and in any case it cannot match the performance of a good crystal. The logical development of this is the use of a variable-gap crystal holder by which the frequency of a crystal can be changed by as much as 6 kc. If the range of the crystal could be increased by as much as 100 kc., it would be possible to cover the entire 14 mc. band with one crystal, and it is this that Mr. Hayes proposes to do.

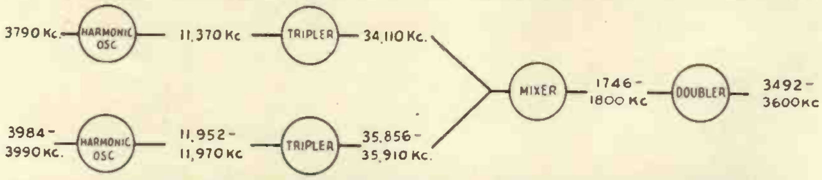


Fig. 1. A block diagram illustrating the principle of extended frequency variation. The crystal frequencies shown are not the only ones that can be used—they were selected only as examples.

The principle is simple and was suggested by work on frequency modulation. Referring to the figure, two crystal oscillators, one with a fixed crystal on 3,790 kc. and one with a variable-gap crystal on 3,984 kc., work with their outputs on the third-harmonic frequencies. The third-harmonic outputs from these two oscillators are fed independently to two frequency-tripler stages, giving the 9th harmonics of the two crystals, or 34,110 and 35,856 kc. respectively. If this energy is mixed in a converter stage, the beat or difference frequency of 1,746 kc. is obtained. The sum frequency of 69,996 kc. could also exist, but by tuning the anode circuit of the converter to 1,746 kc., the " image " is completely eliminated. The 1,746 kc. output can now be introduced to a doubler stage to obtain 3,482 kc. output. When the variable-gap crystal is set to 3,990 kc., the 9th harmonic from this oscillator becomes 35,910 kc., and the difference between this and the fixed-frequency oscillator's 9th harmonic is 1,800 kc. Doubled, the 1,800 kc. becomes 3,600 kc., and we have a variation in output on 80 metres from 3,500 to 3,600 kc. with one variable crystal.

In general, it is necessary to have two crystals, one (or both) of which is a variable-frequency unit, that have a frequency difference which when multiplied by the harmonic used will give the fundamental difference frequency required. For example, any two crystals that have a difference of 200 kc. will, when worked on their 9th harmonics, give a fundamental frequency of 9 × 200 or 1,800 kc. It is advisable to select crystals that have no harmonics within the operating range. The crystals shown in Fig. 1 will have harmonics falling outside the operating range, as would many other combinations.

If both crystals have the same temperature coefficient, the resultant drift will be exactly the same as if one crystal were used. However, by properly selecting the temperature coefficients of the two crystals used, it should be possible to obtain practically a zero coefficient as a resultant.

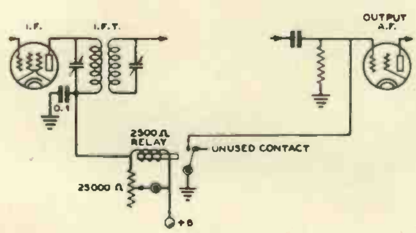


Fig. 2. Q.A.V.C. circuit using a relay.

Q.A.V.C. Using a Relay

In many applications where a Q.A.V.C. action or " squelch " circuit is desirable in a communications type receiver, the incorporation is not especially easy, because oftentimes the circuit does not lend itself to the necessary circuit changes without making drastic revisions in the existing circuit or valve line-up.

A simple and inexpensive method of squelch that can be applied to most any communications type superheterodyne is that shown in Fig. 2. The 2,500-ohm relay is of the inexpensive type which normally closes at about 7 mA. and opens at about 5 mA. The points are adjusted to reduce the allowable movement of the armature, so that the armature makes just a perceptible movement. This spacing is sufficient, because the amount of voltage handled by the contacts is very small. When the contacts are so adjusted they close and let go at more nearly the same value of anode current.

The " fixed " cathode bias or the screen voltage on the I.F. valve is then varied until the valve draws 10 mA. anode current when no signal is being received. In many receivers employing remote cutoff valves such as the 78, 6D6, 6K7, 6SK7, etc., the valve will draw just about 10 mA. without signal, and no alteration in the screen voltage or cathode bias will be required.

The 25,000-ohm variable resistor across the relay is adjusted until with no signal the relay contacts won't quite open. Then, when a signal is tuned in and the increased A.V.C. bias voltage causes the valve to draw less anode current, the contacts will open and the A.F. stage will be operative. Except on very weak signals the action of the relay will be positive and no chattering or erratic operation will be experienced, even when the relay is being jarred moderately, as would be the case in mobile service.

Observe that the operation of the relay is " backward "; the reception of a signal causes the armature to *let go*, and thus open the short across the A.F. system.

In some of the less expensive communications type receivers having no R.F. stage and but one I.F. stage, the A.V.C. action will not be sufficient to cause a satisfactory anode current change in the I.F. stage on weak signals. This condition can be helped by using a divider instead of a simple dropping resistor for screen voltage.

If the screen voltage is already "tied down" fairly well, but the anode current change is not great enough for satisfactory operation of the relay, a greater change in anode current can be obtained by substituting a sharp cutoff valve for the remote cutoff valve generally used in the I.F. stage.

It might appear that the substitution of a sharp cutoff valve (57, 6C6, 77, 6J7, 6SJ7, etc.) would result in crosstalk or distortion when receiving on or near the frequency of a nearby powerful station. In actual practice this does not happen, at least in the case of receivers having but one I.F. stage and no R.F. stage, and the A.V.C. action is improved. In other words, not only do we get a better anode current swing for operation of the relay, but for a given setting of the A.F. gain control all signals are more nearly the same A.F. volume than when a remote cutoff valve is used. Also, a fading phone signal is held at more nearly the same volume.

A sharp cutoff valve draws somewhat less anode current than its remote cutoff equivalent at the *same bias voltage*. This means that the cathode bias resistor will probably have to be lowered to a value as low as 150 ohms (and possibly the screen voltage raised slightly) in order to get the valve to draw 10 mA. with no signal. Under these conditions, however, the gain is greater than for a remote cutoff valve, and therefore the I.F. stage will provide more amplification on weak signals. This is due to the fact that a sharp cutoff valve has somewhat greater transconductance than a remote cutoff valve at the same plate current.—*Radio*, May, 1940.

A Cathode-ray Tube as Frequency Meter

It has long been known that if an A.C. voltage of frequency F is applied to one set of plates of an oscillograph and another frequency any multiple of F is applied to the other set of plates a clear stationary waveform will result. If both frequencies are F the figure will vary from a straight line to a circle, depending upon the phase. The second harmonic forms a figure 8, the third a figure with three loops, and so on. Each harmonic will give a clear pattern, and in between there will be a green "field" such as that observed with an unmodulated carrier. The fiftieth harmonic will, however, be just as clear cut as the second or any other.

The frequency meter described employs the above-mentioned principle (see Fig. 3). A small electron-coupled oscillator covering the broadcast band furnishes the signal to one set of plates. The other set of plates is coupled to the final amplifier of the transmitter which uses a V.F. oscillator for frequency control. The oscillator in the broadcast station is heterodyned against a broadcast station tuned in on the station's broadcast receiver. This can be done down to about 20 cycles of the broadcast signal by ear. The transmitter may then be tuned to any harmonic of the broadcast signal by observing the tube. It is necessary to know the approximate frequency of the transmitter in order to know on which harmonic it is operating. This can be done with almost any type of communication receiver.

For example, assume that a spot frequency in the ten-metre phone band is required. The 40th harmonic of a broadcast station on 720 kc. is 28,800 kc. and the 41st harmonic is 29,520 kc. This will give two spot frequencies in the ten-metre phone band.—R. E. Baird, *Radio*, May, 1940.

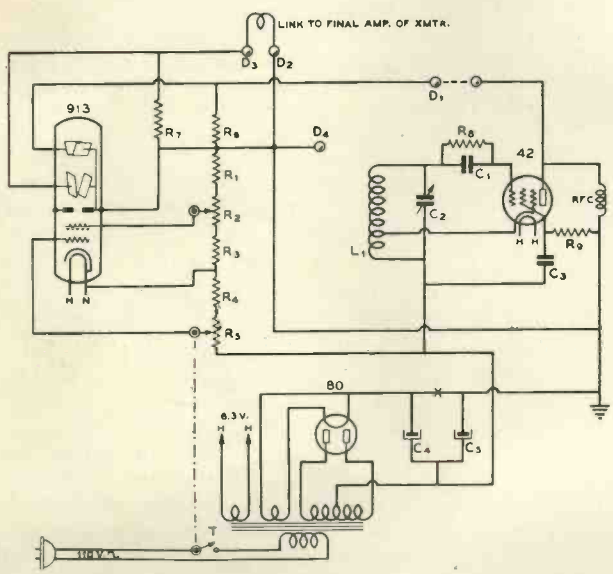


Fig. 3. Circuit diagram of the frequency monitor.

C_1—.0001-μfd. mica.
C_2—Original tuning condenser.
C_3—0.1-μfd. 400-volt tubular.
C_4, C_5—Original 8-8-μfd. elect.
R_1—100,000 ohms, 1 watt.
R_2—50,000-ohm potentiometer.
R_3—1,500 ohms, 1 watt.
R_4—500 ohms, 1 watt.
R_5—12,500-ohm potentiometer.
R_6, R_7—50,000 ohms, 1 watt.
R_8—200,000 ohms, 1 watt.
R_9—50,000 ohms, 1 watt.
L_1—Original detector coil, tapped—see text.
X—No choke because speaker field removed.
RFC—3.5-mh.

Life of Acorn Valves

Acorn valves should have long life if properly used. Care should be taken in putting them in sockets, the screen voltage should not be run above 100, and the control grid bias should be at least three volts. One of the most common troubles with the acorn valve is shorting between grids—which can be checked with an ohmmeter, and often repaired by tapping the tube. Obtaining screen voltage through a series resistor may give a degree of protection in case a short between control grid and screen results in too heavy an anode current.

The new miniature battery valves have closely spaced elements and short leads, but have such a low mutual conductance that their higher input resistance, and consequent lower loading of the tuned circuit, may not result in particularly good gain. In respect to input resistance and mutual conductance, they are the opposite of the 1852. The input resistance of the latter loads the circuit so that a high impedance cannot be developed (as well as having about 13.5 μμfd. input capacity), but can still turn out some gain at five meters.

New Beam-power Amplifier

A new push-pull beam-power amplifier has been announced by R.C.A. for use primarily on the ultra-high frequencies. It has the unusually high mutual conductance of 8,500 and a combined anode dissipation for the two units of 40 watts. The maximum anode voltage rating is 500 volts and the maximum anode current is 240 milliamperes.

A single 829 valve operated in push-pull class C telegraph service is capable of handling a power input of 120 watts with less than a watt of driving power—and at frequencies as high as 200 megacycles. The valve may be operated practically at full ratings as high in frequency as the amateur 224 mc. band. The exceptional efficiency of the 829 at the ultra-high frequencies is made possible by the balanced and compact structure of the two units, excellent internal shielding, and close electrode spacing. The internal leads are short and heavy in order to minimise internal lead inductance. The valve has no base, the terminal wires being large and heavy and brought out through heavy individual glass seals. The two anode leads are brought out through the top of the envelope. This terminal arrangement provides excellent electrical insulation and is designed to facilitate symmetry of circuit layout.

Sylvania recently announced several additions to their Loktal range. The 1232, a high mutual conductance valve designed primarily for television, is now identified as the 7G7/1232.

The additions include the 7B4, a single-ended high-mu triode similar to the type 6F5G; the 7J7, a triode-hexode converter somewhat similar to the 6J8G; and the 7L7, a single-ended triple-grid amplifier resembling the 7G7/1232 except for lower heater current and mutual conductance.

As with all Loktal valves, the nominal heater-voltage rating of 7.0 volts corresponds to a 130-volt line condition—the normal 6.3-volt rating of the heater corresponds to a line voltage of 117.

7B4 High-Mu Triode.

Heater voltage—6.3, 6.3 volts.
Heater current—0.30, 0.3 ampere.
Anode voltage—100, 250 volts.
Grid voltage— −1, −2 volts.
Anode current—0.5, 0.9 mA.
Anode resistance—85,000, 66,000 ohms.
Mutual conductance—1,175, 1,500 μmhos.

(*Continued in 3rd col., page 274*)

Progress in the Design of Augetrons for Use at High Frequencies

By the Technical Staff of Vacuum Science Products, Ltd.

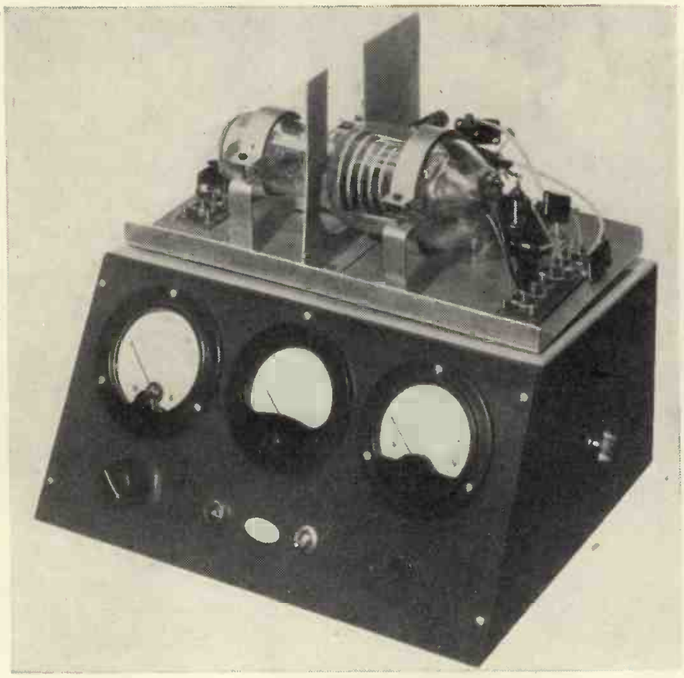


Fig. 2. Photograph of equipment used for high-frequency tests.

AN account has already been given of the performance of the six-stage Augetron at frequencies up to 50 mc/s.* It was shown that the input impedance is greatly superior to a tube which does not employ secondary emission. Although the static slope is very high there is, however, some reduction in this at U.H.F., due to the effects of transit time and lead inductance. The result has been that although very high stage gains may be obtained up to 50 mc/s., these have deteriorated greatly at higher frequencies.

The first step in overcoming these shortcomings was to set up a suitable test circuit. It was decided to concentrate on the measurement of the effective mutual conductance of the Augetron, since the input side of the tube did not appear to be at fault.

The circuit of the apparatus is given in Fig. 1. The Augetron, a six-stage model in this case, is fed from a conventional potential divider network. The final anode voltage is fixed by a neon stabiliser at 130 volts. This enables the tube to be operated over a wide range of anode currents and also accurate measurements of the static slope may be made. The grid is fed through a suitably terminated low impedance line from an oscillator covering a wide range of frequencies. The voltage applied to the grid is measured with a probe voltmeter.

The anode circuit is tuned by the capacity of the tube and its wiring, a different coil being plugged in for each test frequency. The output voltage is read by a simple diode voltmeter.

The H.F. input is normally set to 100 mV peak and the amplification determined immediately from the output voltmeter.

The dynamic mutual conductance is not so readily obtained. Bridge measurements are, of course, quite out of the question at such frequencies. If the high-frequency current was to be passed through an untuned load this would have to be very low and the voltage across it would be too low to read. The only practical course seems to be to tune the output circuit.

Unfortunately, the constants of the tuned circuit cannot be lumped at these frequencies so that the dynamic impedance of the tuned circuit cannot be determined very accurately. Reasonable results up to 100 mc/s have been obtained, however. The anode circuit is broken by removing the tuning coil and the total capacity of the anode circuit measured. A suitable addition for the self-capacity of the coil may then be made.

The Q of the tuned circuit may be measured during the amplification test by detuning the oscillator on either side of the resonance curve

* Electronics, Television & Short-wave World—March, 1940.

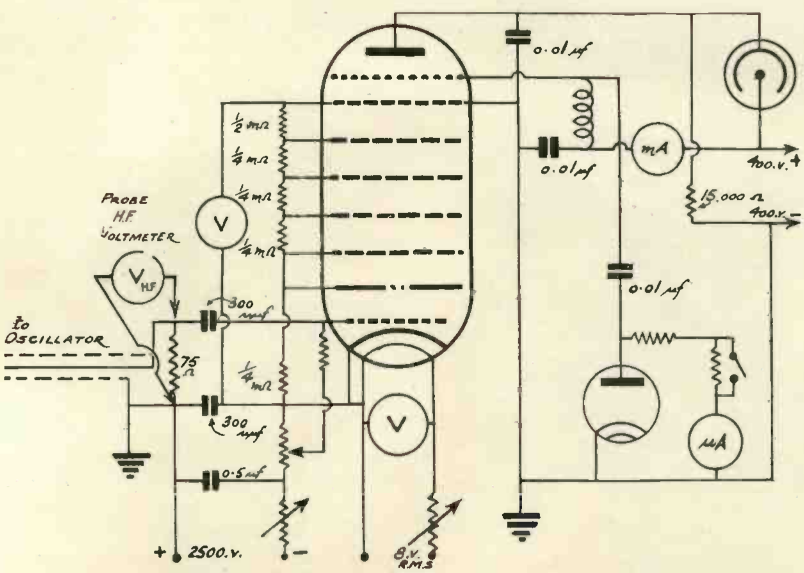


Fig. 1. Circuit diagram of the high-frequency test equipment illustrated in Fig. 2.

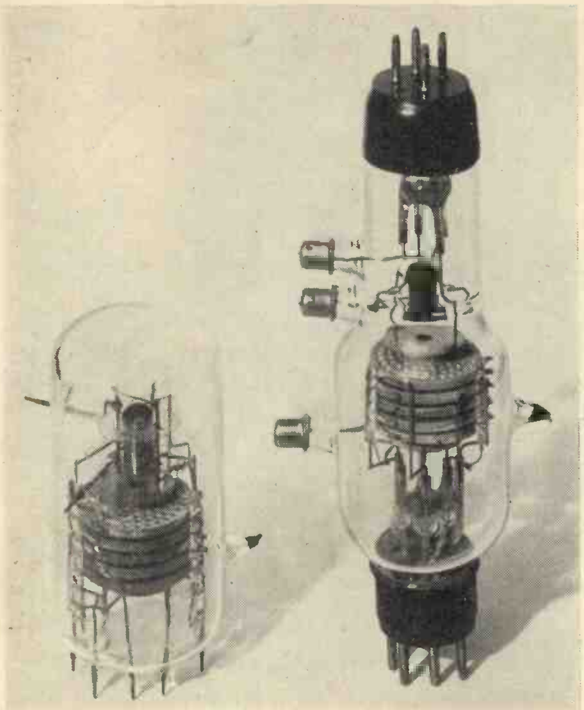


Fig. 3. Two examples of six-stage Augetrons: on the left is the footless type.

TABLE I

Frequency mcs.	Stage Gain. Voltage Ratio.	df mc/s.	$\frac{I}{wc}$ Ohms	R. Ohms	g dynamic mA/V.	$g\frac{\text{dynamic}}{\text{static}}$ %
30	180	1.2	408	10,000	18	55
36	130	1.0	339	12,000	11	32
43	100	0.8	285	15,000	6.6	20
52	88	0.8	237	15,000	5.9	17
60	48	1.2	200	10,000	4.8	14
70	58	1.0	174	12,000	4.8	14

TABLE II

Frequency mcs.	Stage Gain Voltage Ratio.	df. mc s.	$\frac{I}{wc}$ Ohms.	R. Ohms.	g dynamic mA V.	$g\frac{\text{dynamic}}{\text{static}}$ %
30	360	1.3	400	9,200	39	73
37	328	0.8	310	14,500	23	43
43	310	0.6	260	18,500	17	32
52	190	0.8	220	14,500	13	24
63	87	0.9	180	12,500	7.0	13
71	38	1.7	160	6,700	5.6	10
81	20	1.8	140	6,300	3.2	6

until the output falls to $\frac{1}{\sqrt{2}}$ of the maximum value. Then $Q \simeq \frac{f}{df}$.

When f = frequency in mc/s at resonance.
df = the total change in frequency in mc/s.

If the value of Q be multiplied by the impedance of the tuning capacity at the test frequency the dynamic impedance will be obtained.

A typical set of figures on a six-stage Augetron are given in Table 1. This Augetron was constructed in such a way as to have a particularly short transit time. No effort was made to reduce the lead inductances on this model.

It will be noticed that although there is considerable loss of effective dynamic slope, there is still sufficient left to provide an excellent stage gain with tuned circuits of only moderate Q values. This Augetron is illustrated in Fig. 3 by the side of a recent footless type.

The corresponding test results on this type of Augetron are given in Table II. There is some improvement due to the reduction in lead inductances but the main limitation would still appear to be due to transit time.

We have had many requests that the characteristics of an Augetron equivalent to those of a valve should be published. Although much comparative information has been published *we feel that it would be unwise to assume that Augetron technique is exactly parallel to that of conventional valves.* We are including in this article (Fig. 4) a series of curves of output current against grid voltage.

Each curve is taken with 150 volts between final anode and final secondary cathode, but with a different voltage between each secondary cathode. This is equivalent to a series of curves on a pentode valve with different screen voltages, but constant anode voltage.

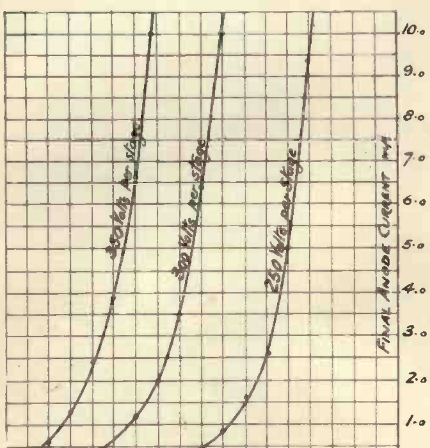


Fig. 4. The above curves of control grid voltage against output current are equivalent to the Ia-E.g_1 curves of a standard valve.

" Short-wave Radio World "

(*Continued from page* 272)

Amplification factor—100, 100.

7J7 Triode-Hexode Converter.

Heater voltage—6.3, 6.3 volts.

Heater current—0.30, 0.30 ampere.

Anode voltage ((hexode)—100, 250 volts.

Osc. anode voltage (triode)—100, *250 volts.

Screen voltage (hexode)—100, 100 volts.

Control grid voltage (hexode)— −3, −3 volts.

Osc. grid resistor (triode)—50,000 50,000 ohms.

Anode current (hexode)—1.1, 1.3 mA.

Screen current (hexode)—3.1, 2.9 mA.

Osc. anode current (triode)—3.7, 5.4 mA.

Osc. grid current (triode)—0.3, 0.4 mA.

Anode resistance (hexode)—0.3, 1.5 megohm.

Conversion conductance—260, 300 μmhos.

Conversion conductance (E_1 = −20) —2, 2 μmhos.

Total cathode current—8.2, 10 mA.

Triode Characteristics.

Anode voltage— 150 volts.

Grid voltage— −3 volts.

Anode current—7.5 mA.

Anode resistance—10,400 ohms.

Mutual conductance (approx.)—1,350 μmhos.

Amplification—14.

* Applied through 20,000 ohms series resistance properly by-passed.

Definitions and Formulae for Students. A. T. Starr, M.A., Ph.D., A.M.I.E.E., Sir Isaac Pitman and Sons Limited, 6d. net. Intended primarily for the student of radio and television engineer, this little book gives concise information on definitions, valve circuits, coupled circuits, resonance, inductance, capacitance, etc. In addition to formulae for capacities of wires to earth and between wires, it contains copper wire tables, skin effect formulae and other useful data. It should prove invaluable to engineers and service men who have to memorise a large number of definitions, processes, formulae and circuits.

Recent Progress in TELEVISION STUDIO TECHNIQUE

THE special requirements of the production of studio television have been studied for some time in this country and abroad, and visits have been paid by American engineers to the B.B.C. studios for the exchange of ideas. A great deal of the technique has been adapted from experience gained in motion picture studios, but it has been recognised that there are several major differences which render television production more difficult. The instantaneous reproduction of the scene rules out all "re-takes," and the presentation must be as near perfection as possible at the time of taking. The differences in lighting intensity required by the Iconoscope and the standard panchromatic film are such that special arrangements have had to be designed.

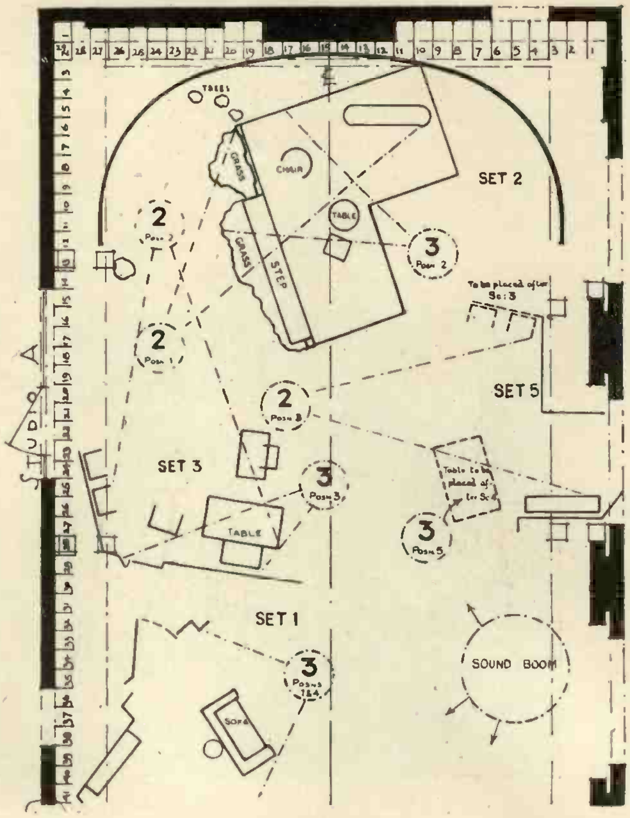


Fig. 1. Producer's plan of studio floor showing positions of cameras and props for a typical three-act play. The cameras are indicated by numbered circles, which also indicate the movement after each "take." The angle of take of the camera is shown by the dashed lines. The sound boom is so placed that it can cover the settings without movement.

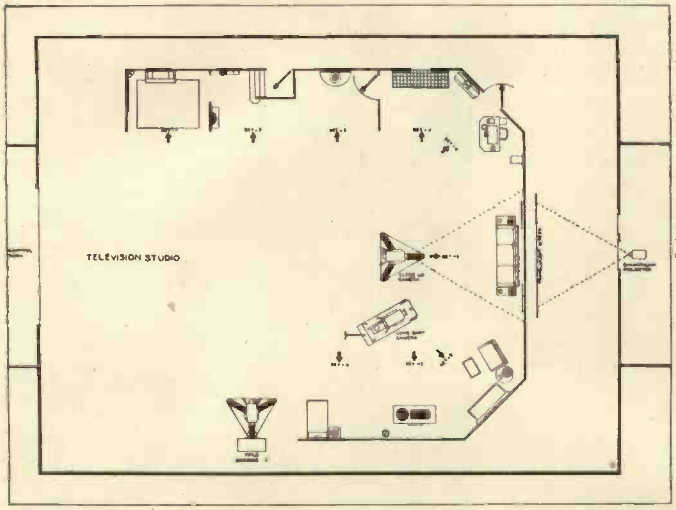


Fig. 2. Plan showing layout of television studio floor.

Studio Layout

In a paper before the Television Society,* Mr. Woolfe Murray described the layout of a typical television "set," which is reproduced in Fig. 1. The positions of the cameras for successive scenes in a three-act play are shown by the numbered circles, the whole layout being designed so that the cameras may be easily swung into their new positions without disturbing the scene or actors. The sets, numbered 1 to 5, are seen disposed round the walls of the studio, and the microphone boom is placed so that the whole area can be covered without transporting the main stand from its marked position.

Fig. 2 shows a typical American television studio layout, as described by A. W. Protzman, of the N.B.C., America.† Apart from the increased area available it will be seen that it is arranged on similar lines to the first diagram, with the notable addition of a screen for "back projection." This is an important improvement borrowed from the cine studio, and gives increased realism to the background view seen through windows, etc.

Background Projection

The problems of background projection in television differ, however, from those encountered in motion pictures. More light is necessary because of the proportionately greater incident light used on the set proper.

Considering the centre of a rear-screen projection as zero angle, it must be possible to make television shots within angles of at least 20 degrees on either side of zero without appreciable loss of picture brightness. This requirement calls for the use of a special screen having a broader viewing angle than those used in making motion picture shots. Also, in motion pictures, the size of the picture on the screen can be varied in the proper relation to the foreground for long shots or close-ups, but for television, the background picture size cannot be changed once the programme starts. The background subject matter must

* Jour. Tel. Soc. Vol. 3 No. 1, p. 1,

† R.C.A. Review, Vol. 4, No. 4, p. 399.

Restrictions Of Focal Depth

also be sharp in detail and high in contrast for good results.

At present, only glass slides are used and a self-circulating water-cell is used to absorb some of the radiant heat from the high-intensity arc. Both sides of the slide are air-cooled, and these precautions permit the use of slides for approximately 30-minute periods without damage.

The N.B.C. studio is 30 ft. wide, 50 ft. long, and 18 ft. high. Such a size should not be considered a recommendation as to the desired size and proportions of a television studio, as it was not specially designed for television. To those familiar with the large sound stages on the motion picture lots, this size may seem small, but in spite of the limited space, some involved multi-set pick-ups have been achieved by careful planning. Sets, or scenes, are usually placed at one end of the studio and control facilities are located at the opposite end in an elevated booth, affording full view of the studio for the control room staff. Any small sets supplementing the main set are placed along the side walls as near the main set as possible, and in such position as to minimise camera movement. At all times as much of the floor space as possible is kept clear for camera operations and such floor lights that are absolutely essential. At the base of the walls and also on the ceiling are numerous power points to minimise the length of lighting cables. At the rear of the studio is a permanent projection room for background projection.

In respect of available space the N.B.C. is considerably better off than the B.B.C. were, as frequent references were made last year to the difficulty of working in cramped surroundings at Alexandra Palace.

Fig. 3. Arrangement of "set" in N.B.C. studio.

Cameras

Both the British and American studios use similar types of camera mounting—the so-called "dolly-truck" on which the camera can be run to and fro, and the fixed stand for close-ups and caption photography. Each of the N.B.C. cameras is fitted with an assembly of two identical lenses displaced 6 in. vertically. The upper lens focuses the image of the scene on a ground-glass which is viewed by the camera operator. The lower lens focuses the image on the mosaic. The lens housings are demountable and interchangeable. Lenses with focal lengths from 6½ to 18 in. are used at present. Lenses of shorter focal length or wider angle of pick-up cannot be used since the distance between the mosaic and the glass envelope of the Iconoscope is approximately 6 in. Lens changes cannot be effected as fast as on a motion picture camera, since a turret arrangement for the lenses is mechanically impracticable at present.

Ordinarily, one camera utilises a 6½ in. focal length lens with a 36-degree angle, for long shots, while the others use lenses of longer focal lengths for close-up shots. Due to its large aperture, the optical system used at present has considerably less depth of focus than those used in motion pictures, making it essential for camera operators to follow focus continuously and with great care.

This restriction on the camera focus gives rise to difficulty in the arrangement of the actors in a scene when it is desired to take a group, all of whom should be in focus. Their movements must appear natural and at the same time they are restricted in order to keep in focus. An example of the difficulties due to this was experienced in a scene from "Royal Family of Broadway" produced by the B.B.C. early in 1939. Six actors were of necessity in front of the camera at the same time and they had to take position in a line to avoid moving out of range of the camera.

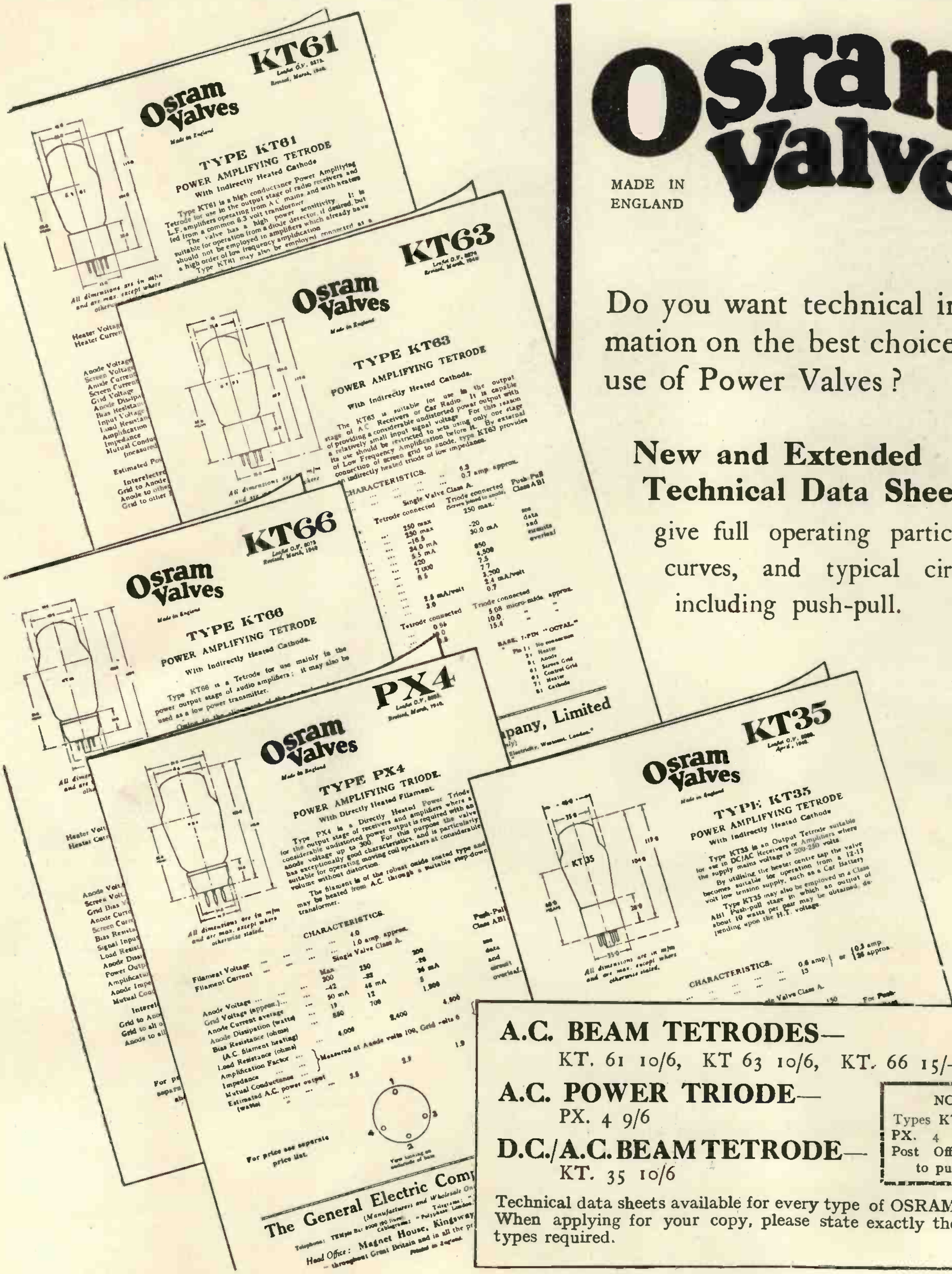
It is expected that this limitation will disappear as more sensitive types of Iconoscope will permit the use of optical systems of greater focal depths.

Vertical parallax between the view finder lens and the Iconoscope lens is compensated for by a specially designed framing device at the ground-glass that works automatically in conjunction with the lens-focusing control. It may be of interest to note here that early television cameras had no framing device, which meant that images, in addition to being inverted as they are in an ordinary view-finder, were also out of frame. The camera operator had to use his judgment in correcting the parallax. With the new framing device, the operator now knows exactly the composition of the picture being focused on the mosaic in his camera, and it can be

Fig. 4. "Single-six" portable lighting unit.

(*Continued on page* 288.)

Valves for Power Amplification



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X-RAYS IN INDUSTRY

By John H. Jupe

ALTHOUGH the form of radiation that we now call X-rays was discovered in 1895 by Conrad Roentgen, twenty years passed before it was realised that these rays might have industrial uses. This was partly due to the fact that they had always been looked upon as the tool of the pure scientist and medical man and partly because the efficiency of the early tubes was low.

Then in 1916 Coolidge, in America, invented his high-vacuum, hot-cathode tube and the door to an immense new field of development was opened.

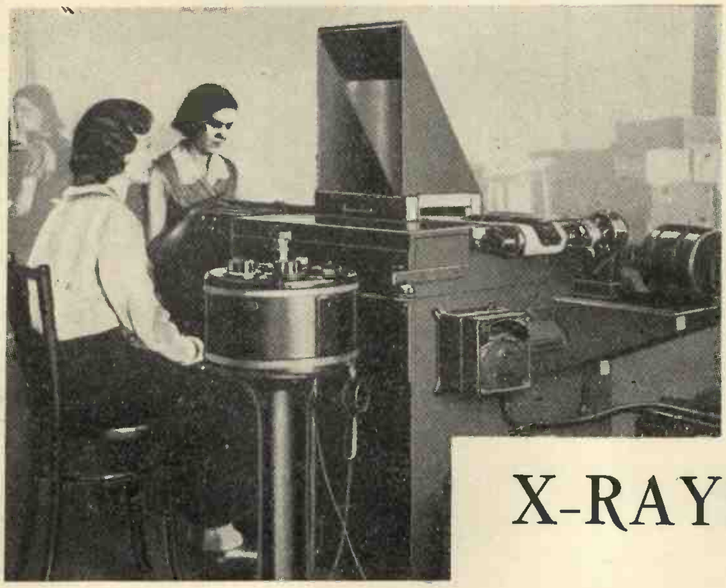
Spheres of Use

The uses of X-rays to mankind may be put under four headings.

1. The examination of manufactured and natural articles for defects.
2. Physical analysis of crystals.
3. Biological uses. Animal and vegetable worlds.
4. The action of the rays on non-living substances.

All these affect industry in some way or other, and it will become increasingly important for the electrical engineer to have some acquaintance with them, as it is he who is ultimately responsible for the installation and operation of the necessary plant. The use of X-rays in manufacturing is not rare, but on the other hand, it is not the type of test one expects to find in every works. Possible uses are only just becoming apparent and as time goes on the list must inevitably expand, as there is a growing tendency for purchasers to demand radiological examination and perhaps permanent records, of many things. For instance, certain insurance companies allow a higher factor of safety to be granted to such things as boilers and gas cylinders, providing that they have passed an X-ray examination.

The extent to which this method of approval is carried out depends on the nature of the article in question. In some cases, like radio valves, a percentage of the total may be sufficient, whilst in the case of heavy metal parts or vital aircraft components, every one may have to be tested.



The Philips X-ray apparatus arranged for the routine examination of objects on a conveyor belt. The operator sees a reflected image in a mirror, which permits a more comfortable position for viewing.

Uses in the Foundry

For the inspection of forgings, castings and weldings, the X-ray method is the only reliable one. Cracks, gas pockets, sand inclusions and porosity are some of the commoner faults which can be easily discovered, whilst an examination of the internal structure of the metal itself will determine with great accuracy whether working or chilling was carried out at the best temperature. And all this is possible without any destruction being necessary.

An excellent example of this procedure being applied to welding is in the great Boulder Dam, in the United States. This structure contains 400,000 feet of welded metal work and every inch was subjected to X-ray examination on the site.

Manufacturing Uses

There is hardly a single trade that cannot make use of X-rays to prove or improve its products. In all fields, a most important feature of the tests is that they are non-destructive and in some cases do not even require photographic equipment, a fluorescent screen being all that is necessary.

A particular use that is of interest to the radio man is the radiographing of thermionic valves, especially the expensive ones, before and after exhaustion, in order to verify that nothing has moved or has been damaged by the electronic bombardment necessary during this process. Other random industrial uses include finding pearls in living oysters, determining age rings in trees, viewing the rubber and fabric boundaries in motor-car tyres, detecting artificial gems, examining parcels and tinned goods for foreign objects.

Chemical Uses

Very little has been published on the chemical branch of X-ray applications and the few examples that have been made known point out that there is much to come in the future. For instance, starch can be converted into dextrine, iodine can be obtained from potassium iodide and glass can be

(Continued on page 282)

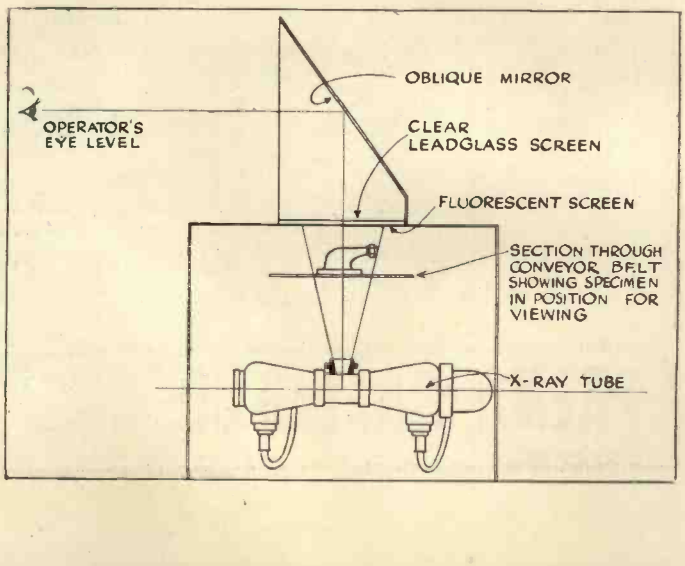


Diagram showing internal arrangement of Philips' X-ray apparatus for visual examination of objects on a conveyor belt.

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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 footnotes 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.

EQUATIONS

IN the previous article discussing the use of symbols and formulæ the reader will probably have noticed that the words "equation" and "formula" were used almost indiscriminately. The difference is slight, since a formula is used to express one quantity in terms of others, like $X = 2\pi L$, and this statement is at the same time an equation, that is, it states the equality between two quantities.

In some cases, however, a formula can be derived from an equation by simplifying or re-arranging some of the terms with a view to expressing the formula in a simple and convenient form.

For example, the equation $C = \frac{.0885A.n.K}{t}$ is used in calculating the capacity of condensers, but by re-arranging the terms we could write down a formula for the area of the plates A in this way: $A = \frac{C.t}{.0885.n.K}$ which is handier for calculation of A than the equation originally given.

The re-arranging of the terms in an equation to give the required unit in a convenient form is governed by the usual rules of multiplication, division, addition and subtraction and the only art in re-arranging is in knowing which to apply and the simplest way of applying it.

An equation is primarily a statement of truth about two or more quantities set down in a concise form. For example, the equation $I = 0.707\ I_{max.}$ means that the effective current in an A.C. circuit is always .707 of its maximum value, whatever the maximum value is.*

* See the issue for October, 1939, for the relevance of this equation, p. 616.

Provided that the fundamental truth of the statement is not altered, it is possible to write the equation in a variety of ways:

$2I = 1.414.I_{max.}$ is equally true, and on inspection will be seen to have been obtained from the first equation by doubling the values given. Similarly, it is possible to write $\frac{1}{2}I = .3535\ I_{max.}$ by dividing the values by 2.

The first rules for re-arranging the equation can therefore be given as follows:

The terms in the equation can be multiplied or divided by any quantity, provided that the truth of the statement is not affected.

This implies that whatever is done to one side of the equation must be done to the other. Taking another case, suppose we have the equation $E = V + IR$. Obviously, we cannot multiply E by 2 and say $2E = V + IR$, since this alters the original statement. But it is permissible to re-write it as $2E = 2(V + IR)$, where each side has been doubled. Note the use of the brackets to show that both the quantities on the right have been doubled. An alternative way of writing this would be $2E = 2V + 2IR$, which amounts to the same.

The use of the brackets, besides being neater, avoids the risk of incompletely multiplying. In writing down the equation and multiplying by 2 it is sometimes possible to omit one of the terms, making it $2E = 2V + IR$ which is again a wrong statement compared with the original.

The second re-arrangement which can be made to an equation is in adding or subtracting a quantity from both sides, provided that the truth is not altered. A good analogy of this is to consider a balanced scale containing two 4 lb. weights on one side and a 7 lb. and 1 lb. weight on the other. The scale is balanced and the balance is not affected if a 2 lb. weight is added to both pans.

Writing it out: $4+4+2=7+1+2$. Now if a one pound weight is taken off one side, the weights must be re-arranged to balance again, thus: $4+4+2-1=7+2$ and a 1 lb. weight must be taken from the other side.

The application of the four rules can be summed up by stating that to re-arrange or simplify an equation it is permissible to perform any mathematical process on one side, provided that a similar process is done on the other side and the truth of the equation is not affected.

Transporting Terms

It might be asked what is the object of "shuffling" an equation about by altering the terms. The answer is that by re-arranging it is often possible to write it in a simpler form or to select a term which can be used in calculations more easily. When calculating from a formula it is usual to write the original equation from which the formula is derived in such a way that the quantity which is used is on the left-hand side of the equation. Referring back to the equation for capacity which is at the head of this article, A can certainly be found from the equation in its original form, but it is simpler to work out when it is written with A on the left and the other terms on the right: $A = \frac{C.t}{.0885.n.K}$

If C, t, n, and K are known, they can be substituted in the formula and the fraction cancelled out in the usual way.

The process of simplifying the equation is sometimes known as "transposing," since the term required is transposed to the left and the others to the right.

As an example in transposing, we can take the well-known Ohm's Law formula $I=E/R$. This can be transposed into $R=E/I$ or $E=IR$ giving all the three quantities on the left-hand side in turn. The best arrangement which suits the calculation can then be used. For finding the voltage drop in a resistance we use $E = IR$, while for the resistance value we use $R=E/I$.

This formula can be used as an example of the re-arranging rules which have been given above. Suppose we wish to re-write $I = E/R$ so that E appears on the left of the equation. Multiply both sides by R, which, as we know, will not alter the truth of the statement.

Then $IR=ER/R$. The R's cancel on the right-hand side, giving $IR = E$, which, when turned round the other way, is $E = IR$, the equation form required.

The clue to which term is multiplied or divided is given by the form in which the equation is written. In the one just quoted, the E was divided by the R, and so to obtain E by itself the R had to be "got rid of" by cancellation or by transferring to the other side.

Taking another more complicated case, suppose it is required to transpose for E in the equation $V = \frac{E - V}{R}$.

To re-write this with E by itself on one side, we have to re-shuffle the R and the V.

As the R is dividing the expression on the left, we commence by multiplying both sides by R. Then $VR = \frac{(E - V).R}{R}$ and the R's cancel on the right, giving $VR = E - V$. Turn the equation round at this stage for convenience, writing it as $E - V = VR$. Now to get rid of the V from the left-hand side, we can add a V to both sides, making $E - V + V = VR + V$, and this then becomes $E = VR + V$.

This formula could be re-written as $E = V(1 + R)$ by taking out the common factor V on the right, but this is in the nature of a "frill" and does not affect the working.

Although the re-writing of the equation has taken several lines to explain in full, it becomes possible by practice to perform the several operations mentally, and the re-writing is then done in one step, thus:

$$V = \frac{E - V}{R} \text{ whence } E = V(1 + R)$$

which is similar to the somewhat bewildering statements which are found in technical articles when the writer assumes that all the intermediate re-arrangements have been made mentally by the reader.

"Changing the Sign"

In some transpositions, the terms appear on the other side of the equation with their signs mysteriously changed and, in fact, the omission to take care of the sign is one of the commonest errors in simplifying equations. The reason for the change of sign can be understood by considering the subtraction rule given above. Suppose we are simplifying the equation $v=u+at$ and finding "a." The "t" has to be removed from the "a" and put on the other side, and so has the "u." Commencing with the "u," we can subtract u from both sides making $v - u = u + at - u = at$. Notice that the "u" has actually been transferred to the other side, but with a change of sign.

The final step in the simplification is the dividing by "t" giving $a = \frac{v - u}{t}$.

In the various steps in simplifying the equation always perform the subtractions and additions first, leaving the multiplications, etc., till the end. If in the above, we had divided by "t" first, we should have had: $v/t = u/t + a$ which is not so simple to deal with. It would, however, have worked out to the same since u/t would have been taken over to the other side with the sign changed, giving $v/t - u/t = a$, and re-writing the fractions to give a common denominator, we would have $\frac{v - u}{t} = a$, as before.

As a final example, a complicated equation will be simplified in steps:

The formula for the inductance of a coil in terms of the turns of wire N is $L = \frac{1.25.u.A.N^2}{10^8.l}$ where u is the permeability of the iron path, A the area of the path, and l its length. It is required to re-write this formula for N.

Commence by removing the terms below the line of the fraction, 10^8 and l. We can do this by multiplying simultaneously by these two quantities,

$$10^8.l.L = 1.25.u.A.N^2$$

and to clear away all the terms from N^2, the one required, we can divide simultaneously by 1.25, u and A. This gives:

$$\frac{10^8 l.L}{1.25.u.A} = \frac{1.25.u.A.N^2}{1.25.u.A}$$

and cancelling out, we get

$$N^2 = \frac{10^8.l.L.}{1.25.u.A.}$$

transposing at the same time to put N^2 on the left. This is not the final answer, as we require to use N and not N^2, but the last step is made by taking the square root of both sides (again note that it will not affect the truth of the statement). Then

$$N = \sqrt{\frac{10^8.l.L.}{25.u.A.}}$$

which is in the form required.

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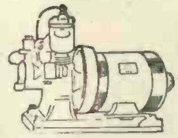

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(SEE EDITORIAL REPORT ON PAGE 266).

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The Taylor Universal Test Meter—Model 90

TAYLOR Electrical Instruments have produced a compact 32-range universal test meter to cover all the usual measurements required in radio circuits.

The Taylor Model 90 Universal test meter.

It is neat in appearance, measuring approximately 5 in. by 8 in. by 3 in. deep, and weighs only 4 lb. The meter is an open-fronted square moulded type, as will be seen from the illustration.

The meter reads direct in volts A.C. or D.C. in the following ranges:—

0— 2.5 v.
0— 10 v.
0—100 v.
0—250 v.
0—500 v.

and a separate terminal connection gives a maximum range of 1,000 v. The resistance of all ranges is 1,000 ohms per volt. The low range (2.5 v.) also indicates A.C. milliamperes with a full-scale reading of 1.0 mA.

Current is read on one of two scales, depending on whether A.C. or D.C. is used. The ranges in this case are 2.5, 25 and 250 D.C. and 15, 250 and 2,500 A.C. The A.C. ranges are thus useful for checking heater currents and the input to transformers.

The instrument measures resistance values from 1 ohm to 10 megohms. The scale is calibrated from 10 to 100,000 ohms, and by a selector switch the reading can be divided or multiplied by 10. The highest range of resistance requires the use of an auxiliary battery of the standard 60 v. type and a resistance of 54,000 ohms in series with the instrument and the resistance to be measured. The scale reading is then multiplied by 100.

On the front panel are mounted three control knobs and a row of contact sockets. Special wander leads are provided, coloured red and black, and fitted with test prods. The sockets are labelled "Common —," "Test +," "1,000 v." and "Output." The first two are used for the ordinary tests, the special 1,000 v. socket only when the high voltage is measured.

The socket marked "Output" is connected to the measuring system through a small condenser, and is therefore used when A.C. is to be applied with a D.C. component. In using this socket it is recommended that the selector switch be turned to the highest range of D.C. voltage likely to be present. The knob can then be turned to give greater sensitivity when the reading is seen on the scale.

The switch knob on the left of the panel is used for selecting D.C. and resistance measurements from A.C. and is marked to suit.

On the right of the main selector switch is the zero setting control for resistance measurements. It is advisable to set this for each scale used when measuring resistances. The instrument zero setting screw is in the usual position over the movement.

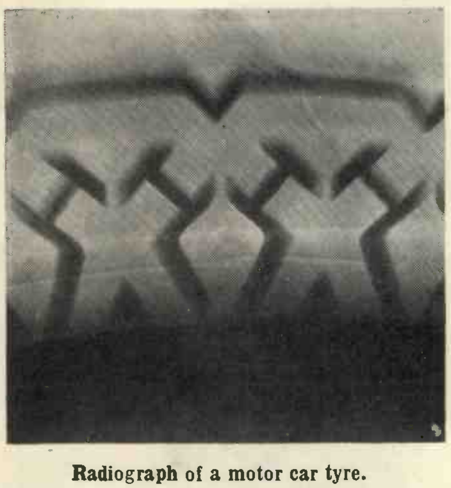
The movement is exceedingly robust and the internal workmanship is such that it can be relied on for several years' good service if treated with reasonable care. The price of the complete instrument is £8 15s., and it can be obtained from Messrs. Taylor Electrical Instruments, Limited, 419/422 Montrose Avenue, Slough, Bucks.

"X-Rays in Industry"

(*Continued from page 278*)

stained purple, merely by exposure to X-rays under suitable conditions.

The uses of X-rays in medicine is well known, but some of the more recent developments are not so widely publicised as were the earlier ones.



Radiograph of a motor car tyre.

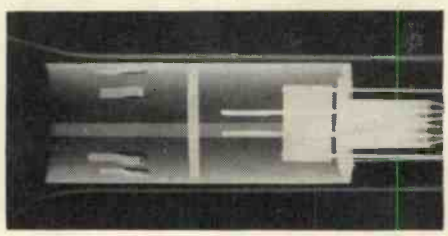
It is now possible to make short cinema films by X-rays, which last about 16 seconds and are ample for many purposes, as in the case of, say, heart radiography, only about a yard of film need be exposed as each beat is a repetition of the previous one and the results can be projected in the form of an endless band.

Other valuable films have been made of swallowing movements, which take place so quickly that the eye cannot follow them on a fluorescent screen.

Another aspect of the biological use of the rays is the effect of them on eggs and seeds, both of which have a tendency to develop along abnormal lines as a result of exposure.

The atomic arrangement of crystals acts to X-rays in a similar manner to which a thin film of oil on water acts to ordinary light. It breaks up or diffracts the rays and by allowing them to pass through crystalline bodies on to photographic plates the resulting shadows will give data as to the actual atomic pattern within the crystals. This is the key to many metallurgical uses and foremost amongst these in the minds of electrical engineers is, perhaps, magnet research. Cobalt steels and "Alnico" type alloys are vital in many branches of light engineering because of their powerful magnetic properties and as these depend entirely on molecular structure, X-ray crystal analysis is the most important tool in magnet research.

A rather wider subject is electroplating, which again depends much on molecular structure for such characteristics as hardness, brittleness, grain, etc. The conditions of deposition can readily be determined by the use of the rays and the wearing properties estimated at once, whereas tests by age, use or exposure take a long time.



Radiograph showing positions of deflecting plates in cathode-ray tube.

"Flexible Sync. Pulse Generator"

(*Continued from page 264*)

quency variations up to 15 per cent. of the master control oscillator can be tolerated before succeeding interlocked stages become unlocked and fall out of synchronism. In many of the divider stages, which have been designed with a low division-factor, variations in frequency much greater than 15 per cent. may be tolerated.

Pulse Amplifiers

The pulse amplifier circuits have been provided to transfer the pulse outputs of the frequency divider to other units in the synchronising-signal generator.

To insure flexibility, both positive and negative output phases of horizontal and vertical pulse waves have been provided. To preserve the steep wave fronts so essential for proper synchronising control, compensating networks have been employed wherever necessary in the pulse amplifier circuits.

Frequency-Standardising Circuit

A frequency-standardising circuit has been provided to compare the frequency of the final divider output with that of a standard source, such as a 60-cycle power line, and operates upon the master-frequency sinusoidal oscillator circuit to standardise the divider output frequency. Frequency control of the master-frequency relaxation oscillator is accomplished through use of a master sine wave oscillator controlled by automatic frequency control and to which the master relaxation oscillator is synchronised.

The source of quasi-d.c. control voltage for the master-frequency sinusoidal oscillator is a detector which compares the divider output frequency with that of the standard. The output of this detector is connected, through a filter, to the frequency control unit of the master sine wave oscillator circuit. The overall sensitivity of this frequency control is of the order of 400 : 1 frequency correction which is more than ample to accommodate any possible variations in either the divider output frequency or the standard frequency.

Monitor Oscillograph

A monitor oscillograph has been incorporated in the frequency divider to provide for immediate investigation of the frequency relationships of all frequency dividing circuits. An eleven-point rotary switch selects any one of eleven circuits, some of which have critical adjustments to be monitored at will. Ten separate linear sweep-frequencies, automatically synchronised, are selected by this switch; and one sixty-cycle sinusoidal sweep signal is provided.

The sixty-cycle sinusoidal sweep operates as a frequency monitor for the entire equipment, and it plots its output as a sinusoidal function of the power frequency providing continuous frequency monitoring.

Blanking-Pulse Shaping Unit

The blanking pulse shaping unit has been designed to shape the horizontal and vertical pulse outputs from the frequency divider unit to square waves corresponding to the desired percentages of blanking intervals, to mix them in the proper manner, and to transform the amplifier output to the proper coaxial output impedance.

The waveshaping circuits in this unit operate independently of the pulse frequencies. It is also possible to adjust both the percentage of blanking and timing of both horizontal and vertical blanking waves. The amplitudes of the mixed waves are then equalised in the output so that both signals remain at the same relative amplitude regardless of the level of the composite signal. The polarity of this output signal may be reversed at will.

(*Continued on next page*)

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Synchronising-pulse Shaping Unit

The synchronising pulse shaping unit has been designed to operate upon the three necessary types of synchronising waves so that they are properly shaped, mixed, and transformed to a coaxial output. Front panel controls have been provided for independently adjusting the shape, the timing, and the amplitude of each wave.

The vertical synchronising pulse is serrated in this unit by means of a simple chopping circuit producing a waveshape which is adjusted to conform to the present U.S. television standards.

The equalising pulses are obtained by a means similar to that employed for the vertical synchronising pulse, and adjustment of the number of equalising pulses may be made.

The horizontal synchronising pulse wave train is corrected, in this unit, to allow for insertion of the serrated vertical synchronising pulses and equalising pulses in the mixed composite synchronising signal.

Master Horizontal-sweep Generator

The master horizontal sweep generator generates a linear sawtooth wave for horizontal deflection at the desired scanning frequency. An 80-ohm coaxial output circuit is provided. Amplitude of the horizontal deflection may be controlled from the front panel. The phase of the output signal is reversible at will by means of a rear panel selector switch.

The sweep voltage output may be used also as a master source for driving iconoscope scanning systems, television monitors, etc. The initial flyback time of the generated wave is less than 8 per cent. of its total period.

Master Vertical-sweep Generator

The vertical sweep generator unit has been designed to generate a linear sawtooth wave which is accurately timed with the output of the frequency divider so that positive interlace action is maintained at all times. The linearity of this sawtooth wave is within at least 2 per cent., and the flyback time has been limited to less than 4 per cent. of its period.

A low-impedance output circuit has been provided. Front panel controls include a means for adjusting the output amplitude, and frequency adjustment which is not critical.

Monitor Oscillograph

The monitor oscillograph has been provided in the synchronising signal generator for the purpose of monitoring the waveshape, amplitude, and timing of all output signals and critical circuits associated with the waveform shaping units. A selector switch in this oscillograph enables the operator to quickly check any one of ten wave shapes. Another selector switch is incorporated in this unit which allows for manual operation of sweep-frequency controls for any position of the first selector switch.

The power unit operates as the main power supply for the synchronising-signal generator. A regulated d.c. output at 250 volts is maintained regardless of load variations up to 450 milliamperes, by means of an electronic regulator circuit. In addition, two separate regulators are supplied from the main regulated source for the purpose of maintaining constant voltage to the oscillator and buffer of the frequency divider.

Filament supplies for each unit are incorporated in this power supply.

Pulse Amplifier and Auxiliary Power Supply

For the purpose of flexibility, an auxiliary synchronising pulse amplifier has been provided. Separate amplified horizontal and vertical synchronising pulses may be employed for synchronisation of camera equipment at a distance.

The Limits of Inherent Frequency Stability

By Walter Van B. Roberts, Patent Department, Radio Corporation of America (*R.C.A. Review*)

GREAT improvements in oscillator stability have been made in recent years by careful attention to the mechanical design and layout of component parts and also by the development of a number of compensation arrangements. An example of the latter is the compensation for a change in anode voltage by a suitable change in screen voltage. By the proper use of such refinements and by other precautions, frequency variations due to variations of input and output impedances of the valve may be much reduced. However, it seems obvious that if the circuit could be made more stable in the first place, the addition of these schemes would bring about still better final results.

The many causes of frequency variations may be divided into three groups: First, changes in the constants of the frequency determining circuit itself; second, changes introduced by the loading on the circuit; and third, changes in the effective input and output impedances of the oscillator valve which are reflected into the circuit by the necessary coupling of the valve to the circuit. Only the third group will be considered here, and the term "inherent stability" is used to refer to the extent to which the frequency is independent of small changes in the effective valve impedances. The object of this investigation is therefore to determine just how far one can go in reducing the effect of given capacitance changes in a valve on the frequency of any ordinary oscillator circuit.

Fig. 1 shows a representative simple feed-back oscillator in which the small capacities C_g and C_p represent the maximum *variations* that may be expected in the input and output circuits of the valve. It is, of course, possible that these variations may sometimes take place in opposite senses so as to tend to compensate for each other. However, in order to deal with the worst case possible they will be assumed to take place in the same sense and at the same time. In this case the resulting frequency shift, measured in cycles per second, may readily be shown to be given approximately by the expression

$$\frac{f(\omega M_g)^2 C_p}{2L} + \frac{f(\omega M_p)^2 C_p}{2L} \qquad (1)$$

in which f is the oscillator frequency in cycles per second, ω is $2\pi f$, the inductance L and the mutual inductances M_g and M_p are measured in henrys and the capacities are in farads.

If now the mutuals are reduced to the point where the system just barely oscillates and if, furthermore, their ratio is adjusted to give the least possible frequency shift when C_g and C_p disappear or reappear, then the expression

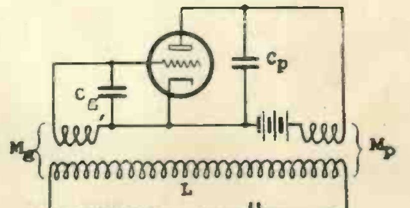

Fig. 1. Circuit of simple feed-back oscillator.

$$f\left(\frac{r}{L}\right)\left(\frac{\sqrt{C_g C_p}}{g}\right) \qquad (2)$$

gives the smallest frequency shift that can be obtained in the presence of the capacity variations C_g and C_p. In this expression r is in ohms and g is the transconductance of the valve in mhos. The derivation of the expression is given in the appendix.

From expression 2 it can be seen that the stability is limited by three independent factors. First of all, the mini-

(*Continued on next page, middle column*)

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Osram Valve Price Revisions

In view of the increased cost of materials and manufacturing charges, The General Electric Co., Ltd., announces a revision in the prices of a number of Osram valves. These valves figure among those types which are now only produced in small quantities from time to time for replacement purposes.

The list of these, and the new prices, are as follows: HL210, 7s. 6d.; L21, 6s.; P215, 7s. 6d.; QP21, 14s.; S24, 12s. 6d.; VS24K, 14s.; X21, 12s. 6d.; X23, 12s. 6d.; MSP4, 12s. These price revisions came into force on May 1.

(Continued from previous page)

mum possible frequency shift in cycles is seen to be proportional to the frequency of operation, which is natural enough and is merely a way of saying that the percentage frequency shift is independent of frequency. Secondly, this shift is proportional to the ratio r/L which means that a good coil is desirable, a conclusion that again is less startling. Finally, the shift is proportional to the ratio of the geometric mean of the valve capacity variations to the transconductance.

This result is little less obvious and might lead to the choice of a valve not ordinarily considered particularly well suited to oscillator use. For example, a certain valve may have a rather large variation of input capacity, say, 1.0 $\mu\mu$f. Nevertheless, if its output capacity is constant to within 0.01 $\mu\mu$f. the geometric mean variation is only 0.1 $\mu\mu$f. and the valve is preferable, other things being equal, to one which has only, say, 0.2 $\mu\mu$f. variation at most, but has this much variation of both its input and output capacities.

In the foregoing it was assumed that the circuit was just barely oscillating, and the looser the couplings can be made the greater the stability up to the limit given by expression 2. In practice, of course, the couplings would be made somewhat closer to allow a factor of safety in starting the oscillation, and also, to obtain a sufficiently strong oscillation to be of some use. However, for any given factor of safety, expression 2 will be proportional to the actual frequency variation, so that conclusions drawn from it will still be valid.

Harmonic Operation

When an oscillator is used to obtain excitation in several frequency bands, it is common practice to run it at the frequency of the lowest band, or even a submultiple thereof, and to obtain excitation for the other bands by frequency multiplication. Let us see what conclusions can be drawn from expression 2 regarding this mode of operation.

To be specific, suppose the fundamental frequency is in the range from about 830 to 1,020 kilocycles, say, 900 Kc. (This range is very easily calibrated by beating with broadcasting stations. The number of cycles shift is given by expression 2, and the number of cycle shift of 28.8 megacycle harmonic is thirty-two times as great, since the latter frequency is the thirty-second harmonic of the oscillator. Thus the formula for the shift in the 10-metre band would be 28,800,000.

$$\left(\frac{r}{L}\right)\left(\frac{\sqrt{C_gC_p}}{g}\right)$$

But this the same formula that would be used if the oscillator were running

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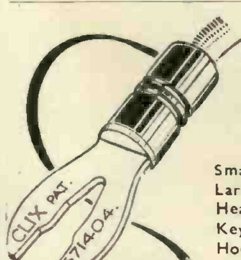

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at 28.8 megacycles as its fundamental except that the ratio r/L and the ratio $\frac{\sqrt{C_g C_p}}{g}$ were evaluated at 900 kilocycles in the one case and at 28.8 megacycles in the other. Hence, it is that expression 2 may be generalised to take care of harmonic operation as follows: f radiated

$$\left(\frac{r}{L}\;\frac{\sqrt{C_g C_p}}{g}\right) \text{fundamental} \quad (3)$$

where the subscripts indicate that the frequency is taken as the radiated frequency while the rest of the expression is evaluated at the fundamental oscillation frequency.

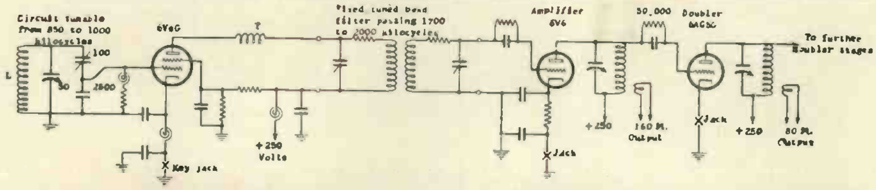

Fig. 2.—*L* **is a coil of ♯24 wire wound 32 turns per inch on a bakelite tube two and a quarter inches in diameter, the length of winding being two and three-quarter inches.** ***T*** **is the feed-back or tickler coil and consists of about six turns wound over the grounded end of** ***L*****. An aluminium box contains the entire tuned circuit, grid choke and leak, coil** ***T*****, and the band-pass filter.**

The interesting thing about expression 3 is that it indicates that for any given radiated frequency the actual number of cycles shift caused by valve variations can be reduced in theory by using a low enough fundamental oscillation frequency. This is partly because the ratio of valve capacity changes to transconductance is somewhat lower at the lower frequencies, but mostly because a low-frequency coil can be made to have a very much lower r/L ratio than a high-frequency coil of the same physical size, as is evident from the fact that the selectivity in cycles of a tuned circuit is proportional to r/L, and the fact that low-frequency circuits are much more selective than high-frequency circuits in terms of actual cycles. In practice, of course, it would be too complicated to multiply all the way up from audio frequency, for example, but a great improvement may be obtained by multiplying from reasonably low frequencies such as the range from 850 to 1,000 kilocycles.

To illustrate, let us substitute some reasonable values in expression 3. If the fundamental frequency is between 850 and 1,000 Kc., and a "Q" or 200 is assumed, the ratio r/L is about 30,000. Taking g as $3{,}000 \times 10^{-6}$ and the mean capacity variation as 1/10 micromicrofarad, the number of cycles shift given by expression 3 is, approximately, numerically equal to the output frequency measured in megacycles. Thus, at 14 Mc. the frequency variation would be 14 cycles. This is 14 times better than if the oscillator had been run at a 14 Mc. fundamental, using a coil of the same "Q," and assuming the same capacity variation and transconductance.

Since the amount of tuning capacity has not appeared in the expressions for minimum shift, it may be concluded that the stiffness of the circuit is of no importance unless it affects the ratio r/L. Data already published indicate that this ratio will be very little different in coils of the same size and shape, but wound for different inductances, using the optimum wire size in each case. Thus, there would seem to be a good deal of latitude in the amount of capacity that may be used.

If the variable condenser is very large, however, it is likely to have large and relatively flexible plates and small clearances, all of which may introduce vibration troubles and changes of the calibration curve with ageing. Hence, it does not appear desirable to approach maximum stability by using a "high C" circuit with the valve electrodes connected across the whole circuit, as the amount of capacity required for maximum stability in this type of circuit may be many thousands of micromicrofarads.

Practical Circuits

The circuit of Fig. 1 was chosen for simplicity of analysis. In practice it is likely to give parasitic oscillations. The same is true of many circuits where grid, cathode, and anode are tapped to the coil at points close together in order to loosen the couplings, as was assumed at the start of the derivation of expression 2 from expression 1. Parasitics may, of course, be suppressed by inserting resistances at suitable points, but this is likely to increase the effective resistance at the desired frequency and hence increase the r/L ratio.

It is preferable to use a circuit which does not develop parasitics. Such a circuit is included in Fig. 2 which shows the essentials of an exciter that has been in use for some time. The 100 $\mu\mu$f. condenser is adjusted until the desired frequency band, 850 to 1,000 Kc., is just a little more than covered by variation of the 50 $\mu\mu$f. condenser after which the former is left severely alone so as to keep the calibration of the oscillator unchanged. These two condensers are physically a single unit made for band-spread use, and only the 50-$\mu\mu$f. section has a shaft on it.

The other data shown in connection with Fig. 2 are what are actually in use, but have not been worked out by cut and try to their best values. The whole arrangement is merely illustrative and doubtless could be considerably polished up. In particular the band-pass filter designed to pass with fair uniformity all frequencies between 1,700 and 2,000 Kc. could be much improved by experimenting with different damping resistors and varying the coupling between coils. This filter is fixed-tuned so as to avoid any tuning reaction on the oscillator.

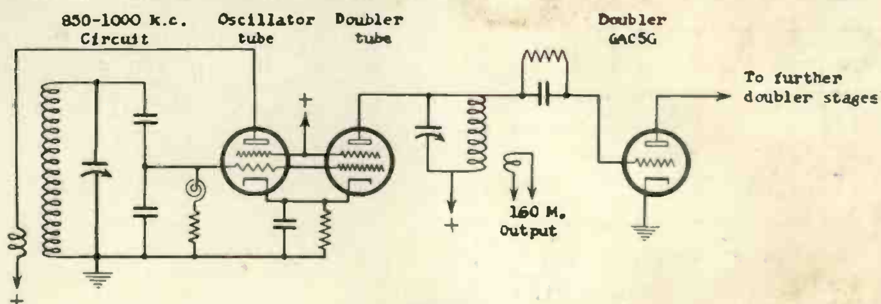

Fig. 3.

Incidentally the grid leaks on the doublers really are connected as shown since the amplification constant of these valves is so high that with the leaks connected from grid to ground the anode currents fall to nothing when the oscillator key is up. By connecting as shown, the anode currents stay up and keep the load on the power supply nearly constant during keying, and also, no R.F. chokes are needed in series with the leaks. As is evident from the diagram excitation for any band can be obtained by connecting a transmission line to any of the tank links, the only other change when changing bands

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being that it is well to pull out the valve following the link selected so as to get all the power available from the tank.

While Fig. 2 represents the arrangement in use at present, a slightly different scheme for getting the power out of the oscillator, as shown in Fig. 3, is believed to be better and avoids the band filter. In Fig. 3 the oscillator valve has enough cathode bias to bring the operating point on the steepest part of the grid voltage-anode current characteristic curve in the absence of oscillations.

The oscillator valve should be one requiring a large bias for cut-off while the following valve should be one requiring less bias for cut-off so that with no oscillations the anode current of the second valve would be just cut off by the normal bias of the oscillator. Then with even very feeble oscillations the following valve would act as an efficient doubler while with stronger oscillations, that would develop more bias on both valves by way of the grid leak, the harmonic output of the following valve would be still further increased. The following valve should, of course, be well screened to prevent reaction of its anode circuit upon the oscillator.

Conclusions

To recapitulate, in order to obtain the greatest inherent stability:

1. Make the fundamental frequency as low as possible.

2. Make the "Q" of the coil as large as possible at the fundamental frequency. This means that the coil should be as large physically as there is room for within the shield can, subject to clearance of at least half a diameter, as well as that the coil design should be good in other respects.

3. Use the loosest couplings between the tuned circuit and the valve that will give the required output, and use a low enough bias resistance so that the effective transconductance in the oscillating condition is not seriously reduced.

4. Choose for the oscillator valve one which has a high ratio of transconductance to capacity fluctuations when operating at the required level.

5. Keeping the oscillation strength constant, vary the ratio between the grid and anode couplings. The best ratio depends on the ratio between the capacity variation of the grid and anode.

After having obtained a good inherent stability, any or all the tricks known to the trade may be added. Some of these are: Temperature compensation in the tuned circuit, or at least arranging this circuit where it will not be heated by the valve or other parts of the transmitter, supporting the tuned circuit on a single rigid member to avoid bending and vibration of its parts, reducing the power taken from the oscillator as much as possible and preferably taking output at a harmonic frequency, supplying screen voltage from a voltage divider whose two portions have resistances chosen to form the combination that best compensates for variations in supply voltage, and stabilising the supply voltage.

By starting with an oscillator of high inherent stability and then adding the refinements to it, sufficient stability may be obtained for many purposes, even including oscillator keying for output at the highest frequencies used for long-distance communication.

Let $x = \frac{C_p}{C_g}$ and $y = \frac{M_p}{M}$. Then expression 1 may be written in the form

$$\frac{f}{2} \frac{\omega^2 M_g M_p}{L} \sqrt{C_g C_p} \, (1xy + xy).$$

For any given value of x the minimum value of $(1/xy + xy)$ that may be obtained by varying y is 2, and this minimum occurs when $y = 1x$, that is $\frac{M_p}{M_g} = \frac{C_g}{C_p}$.

Furthermore, in order for oscillations to occur, a given grid voltage must cause at least an equal voltage to be fed back, whence the condition for oscillation is approximately $\omega^2 M_g M_p \geq r/g$. Substituting this value of $\omega^2 M_g M_p$ and the minimum value of $(1/x + xy)$ already obtained into the expression above, expression 2 results.

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"Recent Progress in Television Studio Technique"
(*Continued from page 276*)

quickly adjusted to accommodate any lens between 6½ and 18 in. focal length.

Because of the fact that several cameras are often trained on the same scene from various angles, and because all cameras are silent in operation, performers must be informed sometimes—such as when they are speaking directly to the television audience—which camera is active at the moment. Two green signal-lamps mounted below the lens indicate which camera is "on the air."

Make-up

Mr. Woolfe Murray points out that the British cameras used by the B.B.C. appeared to vary occasionally in sensitivity to different colours and this used to necessitate "re-touching" of the artists' make-up during a long scene. It has long been known that yellow reproduces better than flat white and the ground work of most white tints is pale yellow. One of the advantages of the modern television camera is that exaggerated make-up is no longer necessary, and in fact the N.B.C. use a type similar to that for ordinary panchromatic ciné films.

Television sets are usually painted in shades of grey. As television reproduction is in black and white, colour in sets is relatively unimportant. Chalky whites are generally avoided because it is not always possible to keep high lights from these highly reflective surfaces which cause a "bloom" in the picture, and, in turn, limits the contrast range of the system.

Due to the fact that the resolution of the all-electronic system is quite high, television sets must be rendered in considerable detail, much more, in fact, than for a corresponding stage production. As in motion picture production, general construction must be as real and genuine as possible; a marked difference, for instance, can be detected between a painted door and a real door. On the legitimate stage, a canvas door may be painted with fixed highlights; that is, a fixed perspective, because the lighting remains practically constant, and the viewing angle is approximately the same from any point in the audience. But, in television the perspective changes from one camera shot to another, and painted perspectives would therefore be out of harmony with a realistic appearance.

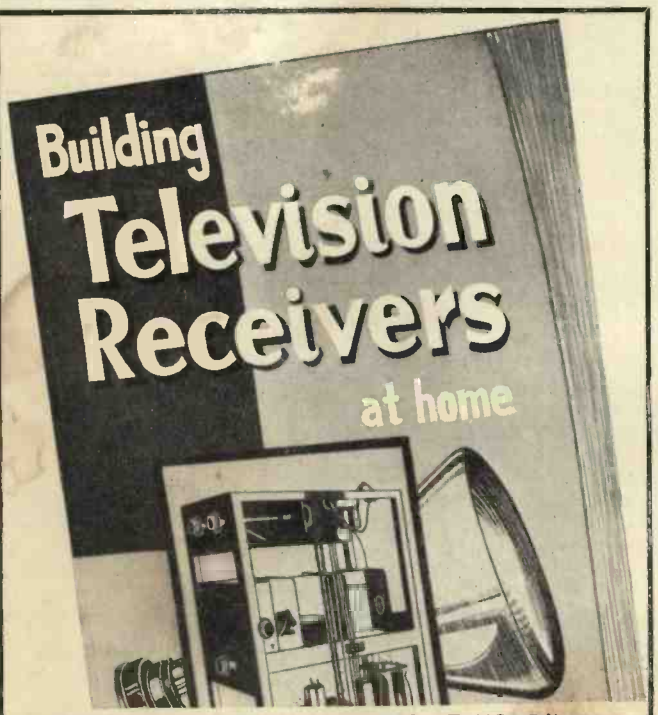
Lighting

The Americans* classify the lighting of the scene into "foundation" light and "modelling" light, the former being the flat illumination of the set necessary to give a picture on the mosaic. Modelling light is the illumination which adds to the contrast of the picture, and may be from overhead, floor or background. It adds a characteristic highlight or shadow to the uniformly illuminated scene.

An analysis of the requirements for a satisfactory system seems to indicate that flexibility and efficiency are the paramount factors to be considered, although glare and radiant heat from the units have to be taken into account. Of necessity, the light produced has to be a high-level diffused illumination in quantities encountered only in the colour-film studios. In addition, television requires that the operation, upkeep and manœuvring of this light be of

* W. C. Eddy, Jour. Soc. Motion Picture Engineers, July 1939.

(*Continued opposite*)



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such simplicity that one or two men could satisfactorily handle routine productions.

A recent step taken in the N.B.C. studio was the conversion from the concentrated unit to more diffused light from reflectors and "footlights," but the glare produced and the inefficiency led to their abandonment in favour of a battery of 500-watt units, each equipped with a reflector and lens system. These also suffered from lack of flexibility and excessive heat radiation, besides being bulky.

Photometric tests, conducted in the studio, indicated that the inside silvered spotlight would deliver into an area more light per watt than a lens, lamp, and reflector assembly or the standard incandescent bulb and exterior scoop. This new bulb was light in weight and of relatively small envelope size in the wattage required. It remained to design a fixture that would permit simple adjustment in elevation and direction to satisfy the requirements of the multi-set productions proposed by the programme staff. Such a mounting, known as the "single six," incorporates six 500-watt spotlights on a framework of thin-walled steel tubing, so arranged that the centre-to-centre distance between lights is ten inches. This ensures that the light-beams interlock at a distance of eight feet from the fixture and that the light arriving on the set is relatively free from spots and secondary shadows. The total weight of the fixture, equipped with spots, is slightly less than 19 pounds and with three kilowatts produces an index of 18,000 units, compared with an index of 7,650 units registered by an equivalent grouping of lens, lamp, and reflector units. This amounts to an increase in usable light per watt consumed of approximately 240 per cent.

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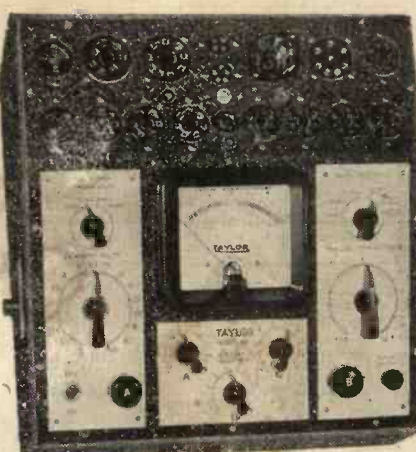

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