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G. PARR.

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Patents

AN interesting report has recently been issued by the Council of the Chartered Institute of Patent Agents which should be read by all patentees and intending patentees.

It stands up for the existing British Patent System, while at the same time admitting that one or two omissions might be rectified, and quotes as an example of its working efficiency that only thirty cases of patent abuse have been alleged since the provisions were enacted twenty-five years ago.

The patent law already provides for such cases as failure to work a patented invention, or to meet a demand for it on reasonable terms, and in fact, " the provisions are so widely drawn that it is difficult to conceive any abuse which is not caught in their net."

The view is held in some quarters that the monopoly aspect of a patented invention is out of harmony with modern social and industrial conditions, and there are some who would even see the patent system abolished rather than tolerate any form of monopoly. The more moderate view of these reformers is that a method of compulsory licensing of patents should be adopted and that a general system of issuing licences under all patents as a right, open to all interested in the manufacture, would lead to a freer exchange of ideas and a wider availability of products.

The Institute does not agree that patent monopoly rights are abused to any appreciable extent and it holds the definite opinion that the majority of patent holders exercise their rights in a manner which is quite satisfying to the community.

The sound argument is put forward that if a manufacturer patents a radical improvement necessitating new plant and a cultivation of a new demand, he will feel hardly used if, having done the spadework, others may come in and share the fruits of his enterprise under a compulsory licensing system.

It would be a direct encouragement for a small manufacturer to sit back and let someone else do the developing, and the commercial use of many inventions would be stifled by caution on the part of the originator.

Another argument against the " licences of right " is that they would be an incentive to secret development and working. It is not so many years ago since large firms carried on " secret " processes in innumerable corners of their works and the whole system of spying and counter-spying was flourishing to the detriment of industry as a whole.

Summing up, the Institute is of the opinion that a general system of compulsory licensing of patents is inadvisable. Enterprise in development would suffer, research by private firms would be restricted, and secret working of inventions would be revived, thus removing the incentive to scientific progress which has resulted from publicity and the circulation of information.

" Patent Law, in contrast with the laws for preventing malpractice and ill-doing, deals with a system for rewarding and encouraging those who are assumed to be the benefactors of the public, and the existing system of fostering invention by the granting of effective monopolies, with adequate safeguard against abuse, seems the most practicable."

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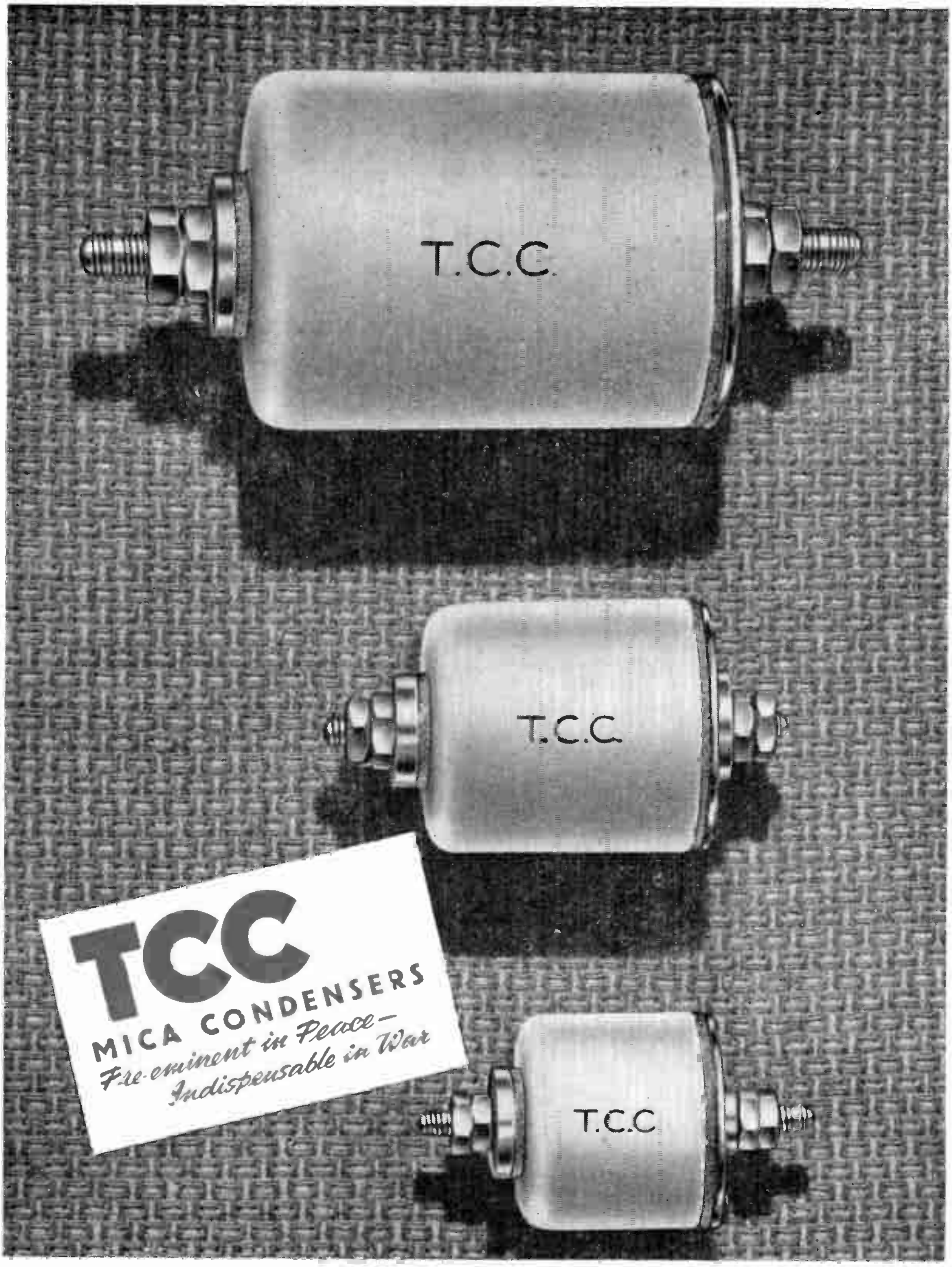
T.C.C.
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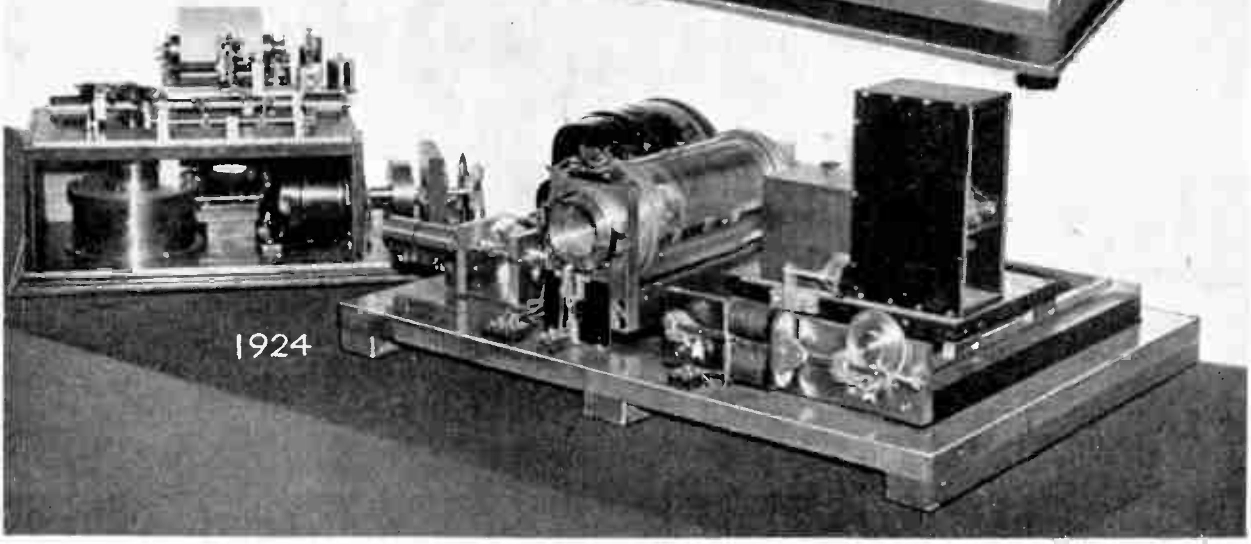
MICA CONDENSERS
Pre-eminent in Peace—
Indispensable in War

20 Years' Improvement in Radio Facsimile

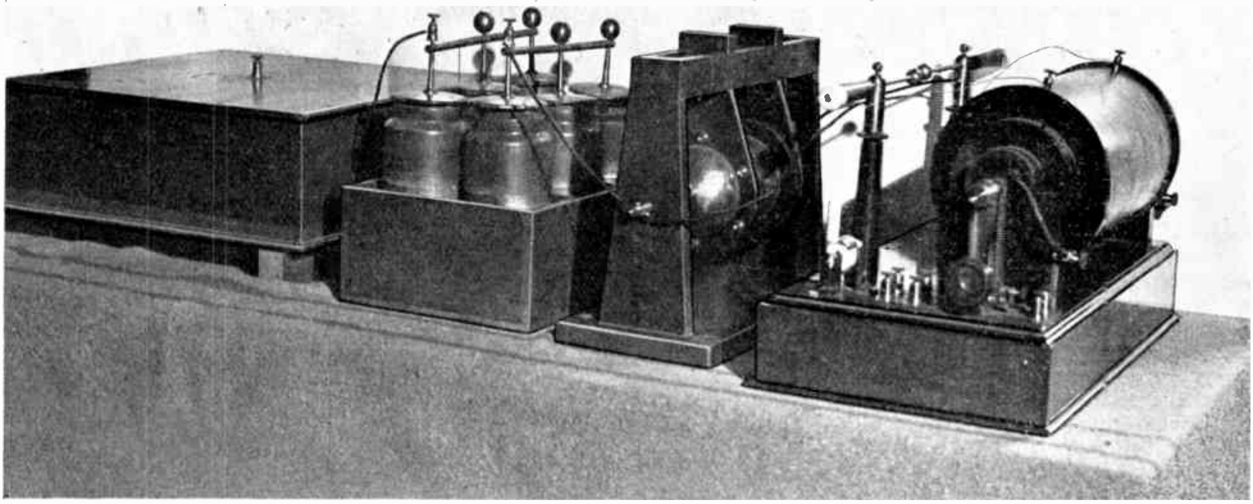
1943

1924



The photograph shows the original apparatus used in November 1924 for the transmission of photographs between England and America. The photo above it was one of the first transmitted and is of Mr. R. A. Chattock, Past President of the I.E.E.

The modern apparatus is shown at the top of the page together with a photograph received in London from Stockholm in August 1943.



Original Marconi Transmitter of 1900 used on ship service. The power was supplied from a 10 in. induction coil. Note the hemi-spherical spark gap and box of Leyden jars. Wavelength about 300 m.

25 Years of Wireless History

The Commemoration Meeting of the Wireless Section of the Institution of Electrical Engineers

ON May 24, the Wireless Section of the I.E.E. held its Commemoration Meeting to celebrate the 25th anniversary of its formation as the first specialist section of the Institution.

The proceedings opened at 5.0 with addresses from the President of the Institution, Sir Stanley Angwin, and Past Chairman of the Section, Prof. W. H. Eccles, F.R.S., Prof. G. W. O. Howe, Prof. C. L. Fortescue, and a recorded address from the immediate Past-Chairman, Dr. R. L. Smith-Rose.

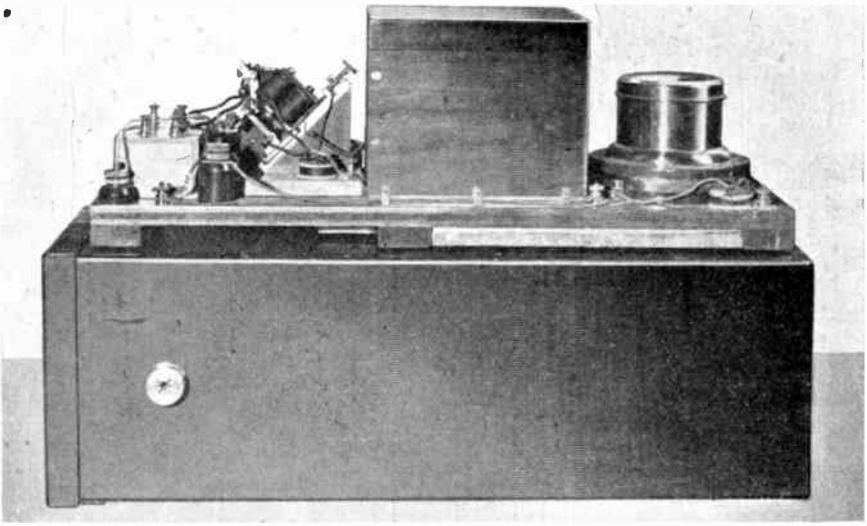
This recorded address was unique in that the speaker was in America at the time, and his speech was conveyed to England and reproduced by apparatus provided by the B.B.C. in the lecture theatre. A recorded address by Sir Ambrose Fleming, the inventor of the two-electrode valve, was also given.

At the conclusion of the meeting the members re-assembled for a Commemoration Dinner at which the principal guests were the Delegates of the Commonwealth Communications Council, Sir Ernest Fisk, Managing Director of Amalgamated Wireless of Australasia, and Sir Edward Wilshaw, Chairman of Cable and Wireless Ltd.

The chair was taken by Mr. T. E. Goldup, Chairman of the Wireless Section, and representatives of the Radio Industry and Past Chairmen of the Wireless Section were also present, together with 200 members and guests.

An exhibition of historic wireless apparatus was arranged in the entrance hall and reading room of the Institution, and some of the noteworthy exhibits are illustrated in this report.

Space permits of reproducing only one of the excellent addresses which were given at the meeting—that of Prof. G. W. O. Howe—which is printed by kind permission of the Institution.



Marconi's coherer receiver (1900 model). This is similar to that used in the original Newfoundland transmission. The box on top holds the battery and the relay is on the right hand side. *(Marconi W/T Co.)*

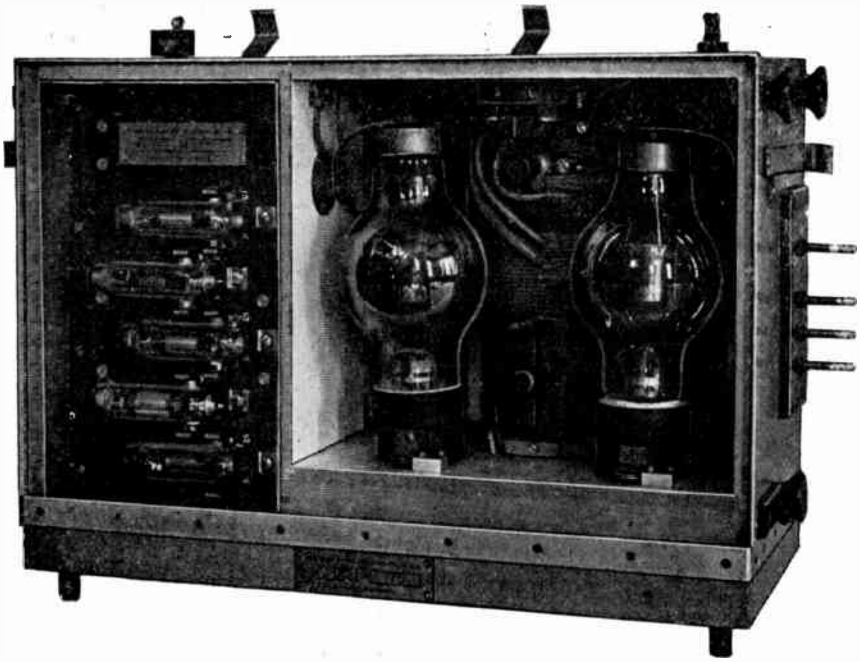
Principles and Theory

By Prof. G. W. O. HOWE, D.Sc.

An Address given at the Wireless Section Commemoration Meeting May 3rd, 1944

THE most outstanding achievements in the early days of Wireless Telegraphy were accomplished in spite of principles and theory. It is only fifty-five years since Hertz wrote on Dec. 3rd, 1889, in reply to an enquiry from Herr Huber that there was no prospect of his discovery being used for telephony as the wave-length would be about 300 kilometres; if, he said, "you could construct a mirror as large as a Continent you might succeed with such experiments."

Hertz died on Jan. 1st, 1894, that is, fifty years ago without knowing that he had laid the foundations of a new and revolutionary branch of electric communications, although Crookes had written in 1892, "Here is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present costly appliances . . . and by concerted signals, messages in the Morse Code can thus pass from one operator to another."

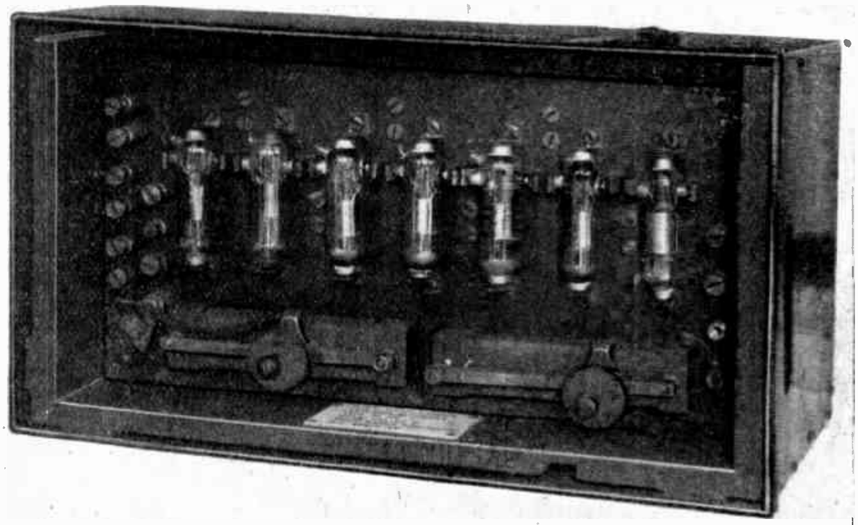


Aircraft W/T equipment of 1920. This combined transmitter and receiver was in use at the end of the last war and was designed for CW, ICW, and telephony. The 5-valve receiver had 3 h.f. stages, detector and l.f. stage. *(Marconi W/T Co.)*

Many of the most outstanding advances in Wireless Telegraphy have been made, not along lines indicated by a study of principles and theory but rather contrary to such indications, and the success achieved has then led to a revision of the principles and theory. It is nearly forty years since Professor Ayrton told me—with a slightly malicious twinkle in his eye —that the reason that Marconi and not Lodge was the first to transmit radio signals across the English Channel was that Lodge was so well versed in electromagnetic theory that he knew that it was impossible, whereas Marconi, not knowing that it was impossible, went and did it!

If in 1900 Marconi had consulted a panel of the leading scientists as to the feasibility of sending wireless signals across the Atlantic, it is doubtful whether he would have made his classic experiment. They would have pointed out to him that the electromagnetic waves employed were of the same nature as light, and that between Cornwall and Newfoundland there was a mountain of sea water over a hundred miles high. Principles and theory were all against him, but fortunately he made the experiment and gave those versed in the principles and theory the task of adjusting them to explain the facts, a task commenced by Heaviside and Kennelly in 1902 and carried on ever since by a number of scientists with wonderful results.

In explanation of the mystery of the transmission of the waves around an eighth of the earth's circumference, Fleming says,* "It has been suggested that the conductivity of the upper layers of our atmosphere is sufficiently great to confine the waves to a spheri-



7-valve Marconi Amplifier of 1919, using 6 h.f. stages (V.24 valves) and detector ('Q' valve). The most sensitive operating conditions were obtained by the adjustment of the filament rheostats at the bottom of the panel.

* "Elementary Manual of Radio Telegraphy and Telephony" (1908).

cal shell of the lower atmosphere, but no data at present available gives support to the conclusion. We have already indicated that the possible cause of this advantageous transmission round the terrestrial sphere is due to the earth connexion of the transmitting and receiving antennae, whereby both these antennae and the earth are practically converted into a single oscillator."

We see therefore that in 1908 the Heaviside layer was just mentioned as having been suggested but not taken very seriously, other quite impossible alternatives being preferred.

Ten years elapsed after Heaviside's suggestion before any appreciable progress was made in the principles and theory of the ionosphere. I think that the first clue as to the real nature of the mechanism by which the waves are refracted was provided by Dr. Eccles in 1912 and 1913. He said, "The hypothesis introduced by the author is based on the assumption that the sun's rays ionise the atmosphere in such a way that the concentration of ions increases gradually as we ascend in the atmosphere. In this event a ray started horizontally will pursue a curved path with its concavity towards the earth, and thus, if the ionisation is great enough an electric ray may follow and overtake the curvature of the earth." In his calculations Dr. Eccles assumed that the decrease of apparent permittivity was due to the movements of ions of molecular size and it was a sign of the times that the wave-length assumed in his example was 5.4 kilometres.

Although in September 1925, Smith-Rose and Barfield in connexion with their direction-finding researches were of the opinion that "adequate experimental evidence of the existence of the Heaviside Layer is still lacking," in the following month Appleton and Barnett showed from an experimental examination of the phenomenon of fading that it was due to waves deviated through large angles by the upper atmosphere, and that the waves were elliptically polarised in accordance with the magneto-ionic theory; they also concluded that there must be at least 100,000 electrons per cubic centimetre in the ionised layer.

Thus seventeen years ago, some doubted the existence of the ionosphere while others were exploring it and even determining the density of its population.

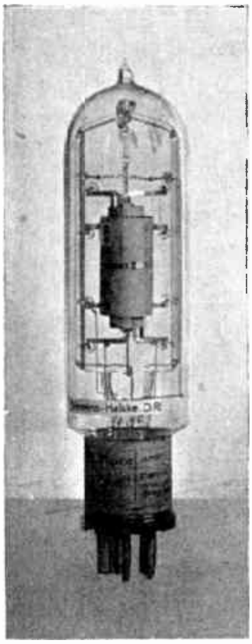
In 1927 we find Prof. Pedersen in his book *Propagation of Radio Waves* accepting the ionosphere but saying with regard to the idea that it should normally be divided into several independent layers, an opinion which, he says, seems to be very widespread, "we cannot see any reason for assuming such a separation to exist. The features in connexion with the propagation of radio waves may be explained in a fully satisfactory manner on the basis of the ionisation of one single coherent portion of the atmosphere."

It is not perhaps for me, however, to throw any stones at Pedersen or Banneitz, for in September 1931 the Editorial in the *Wireless Engineer* was entitled "How many ionised layers?" It was based on experiments made in Germany by Zenneck from which he concluded that the effects which suggested a second ionised layer were really due to waves reflected from the earth, which had done a second journey to the ionosphere and back. His experiments were all made, however, at a wave-length of 533 metres and the intervals which elapsed between successive signals always corresponded within the errors of observation to successive reflections from a single ionised layer. The Editorial pointed out, however, that great caution should be exercised in comparing the results with those obtained at other wave-lengths. This was after Sir Edward Appleton had christened the two layers E and F, but it shows that some doubt was still felt as to their existence. One had a suspicion that it was an easy way out of a difficulty in interpreting results to invent a new Heaviside layer, but the powerful experimental method first devised by Brent and Tuve, and used with such brilliant results by Sir Edward Appleton and a number of workers guided and inspired by him has put the matter beyond any doubt.

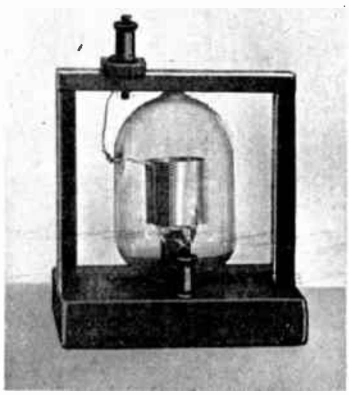
To realise the complexity of the problem, one has to remember that the echo signal may have been turned back by either the E, F_1 or F_2 layer after doing the return journey once or twice or even three times, and that owing to the earth's magnetic field each signal sent out is divided into two with different ionospheric properties but fortunately with different polarisations by which they can be identified. The conditions vary with the wave-length employed and with the time of day or night.

The knowledge that we now have of the constitution and properties of the ionosphere represents a triumph of combined operations between experimental research and principles and theory.

Early low-capacity triode—the "horned valve,"



Schottky tetrode ca. 1923, made by Siemens & Halske.



One of the original Fleming valves in its mounting stand.
(All from the collection of Mr. R. M. Weston).

Maintenance of Quality in Film-Recorded Sound

I.—Recording and Processing

By R. HOWARD CRICKS, F.R.P.S.

IN spite of its small dimensions the sound track on the edge of the film is capable of a very high standard of reproduced sound quality. Thanks to modern developments, it is safe to say that *at its best*, the sound film will produce a greater frequency range and a higher signal/noise ratio (and therefore greater volume range) than the finest commercial disc recording.

But nobody would claim that this high standard is at all commonly met with in the average kinema. Many of the deficiencies are, of course, due to a war-time lowering of standards: but the same difficulties have been always with us, and may be considered under two headings:—

I. Recording and Processing.
II. Reproduction.

It can safely be said that the average recording in the studio leaves little to be desired: this result has been achieved by the closest possible attention to all aspects of the recording process. It is a regrettable fact that a certain amount of sound quality is lost in the duplicating process, and still more in the average reproducing system.

I. Studio Acoustics

There is probably no field of sound recording or reproduction more critical in its acoustic requirements than sound-on-film. Let us start by considering the acoustics of the studio.

First, it is absolutely necessary that the acoustics of the studio set shall bear some relationship to the scene portrayed, so that, for instance, an outdoor scene taken in the studio—as the majority of such scenes are—requires the studio walls to be dead, in order to simulate the lack of reverberation of the open-air, while an indoor set must have a sound perspective corresponding to its character: a small study will naturally require totally different acoustics from a cathedral.

Yet in the studio, every type of set, whether it be exterior or a large or small interior, has to be built out of the same range of materials—plywood, hessian, plaster, and the like. The average set consists of merely three walls, with no fourth wall or ceiling.

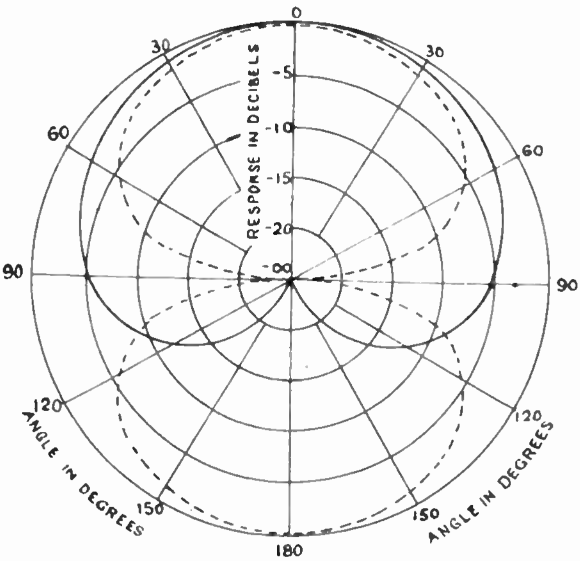
The walls of the studio are, as a matter of course, lined with rock-wool or other absorbent material, and are virtually dead: but reflexion from the set itself, and possibly even from other near-by sets, is inevitable.

Types of Microphones

This difficulty has led to the development of a special technique in the choice and placing of the microphone. A directional microphone, trained on the actor, will obviously pick up far less reverberant sound than a non-directional one. The direction in which the microphone is pointed, and its distance from the speaker, play an important part. The "boom-swinger," or manipulator of the microphone boom, has therefore a highly-skilled task.

A directional microphone has also the advantage that it will cut out incidental noises from the camera or from people off the set.

Every recordist has therefore a col-



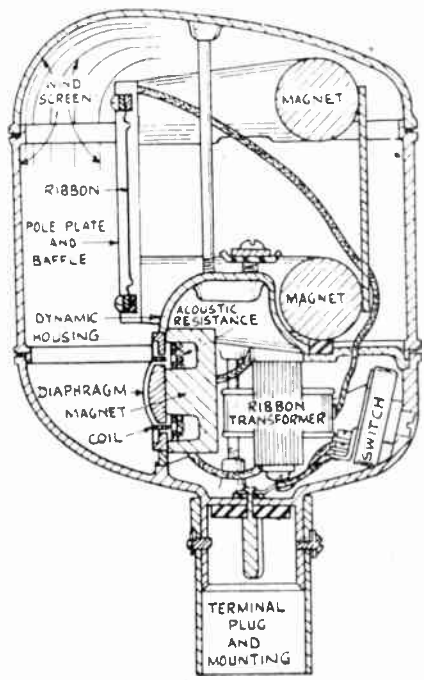


Fig. 1. Western Electric Cardioid Microphone and its Polar Curve. *(From Journal of The B.K.S.).*

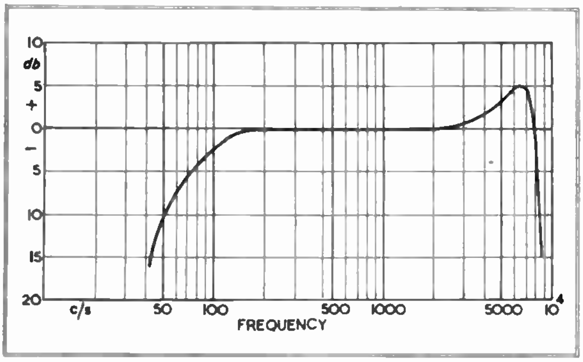


Fig. 2. Typical over-all frequency response of Recording Channel.

lection of microphones, with whose characteristics he is fully conversant, and which he uses according to the type of sound perspective he requires. He normally has the choice between carbon, condenser, moving-coil, and ribbon microphones, all with different polar characteristics. A type of microphone that is gaining popularity in American studios, but apparently requires very careful use in view of its polar curve, is the so-called cardioid microphone, which is a combination of moving-coil and ribbon, and is so called because of its heart-shaped polar curve (Fig. 1).[1]

II. Electrical Requirements

The output from the microphone is often amplified by a single-stage amplifier built into the microphone housing. The speech currents are then led through necessarily lengthy cables to the recording room. Here they pass through the main amplifier, and into the recording camera.

Amplifier Characteristics

A particularly important feature of this amplifier is the precise control of the frequency range. For reasons that will be mentioned later, it is important that the frequency characteristics of the final recording should be adjustable to very close limits. A typical recording frequency curve is shown in Fig. 2; the droop in the bass is necessary to allow for the acoustics of the average kinema, the peak in the treble compensates for losses in processing and reproduction, while the treble cut is a concession to the limitations of processing.

The amplifier characteristic must be such as will produce the chosen form of curve after making due allowance for the recorder characteristics. The latter will sometimes contain unwanted resonances whose effect must be cancelled. Thus the production of a frequency curve, on film, by means of an oscillator, is a daily precaution in the studio.

Recording Devices

In the recording of the variable density track, the device originally used was a glow-lamp whose intensity was modulated in accordance with the speech currents, so producing corresponding tones of light and shade on the film. Western Electric have always favoured the density track, but employ a device known as a light valve, in which two fine duralumin ribbons are strained in the field of a magnet, and carry the speech currents, modulations in which cause the ribbons to vibrate and so vary their separation; the exposing light passes through the slit between the ribbons, so that variations in the separation of the ribbons cause corresponding variations in the exposure of the negative.[2]

The variable area track is recorded by means of a mirror galvanometer, generally oil-damped, as in the Duddell oscilloscope. Through different types of masks, various forms of tracks are produced.

It will be evident that any recording device has a definite limitation to the degree of modulation that may be applied to it. In the case of the light valve, over-modulation will cause clashing of the ribbons and serious distortion; over-modulation of an oscillograph will cause the beam to exceed the useable width of film track, so causing peak-chopping. Hence another function of the amplifier is to limit the modulations applied to the recorder. Numerous types of visual volume controls have been devised, all necessarily of the peak-reading type.

This does not imply that over-modulation leading to peak-chopping never occurs; on the contrary, certain sounds—loud noises and shouting—are normally over-shot, and reproduced quality may even be improved by the resultant peak-chopping.

Noise Reduction

Yet a third function of the amplifier is associated with the fact that the principal source of ground-noise in reproduction is dirt and scratching on the clear portion of the positive track. All modern systems of recording reduce this clear area in the positive, either by biasing the recorder in such a way that it will give the maximum clear area in the negative, or by the use of an auxiliary shutter which reduces the light beam during silent or quiet passages.

Details of these systems are too involved for discussion here, but in the recording circuit, a special noise-reduction amplifier is fed with a portion of the speech current from the main amplifier, which is rectified and smoothed, the envelope current being applied either as a bias to the recorder, or to control a magnetically-operated shutter.

It will be evident that the use of noise reduction has the effect of increasing the effective volume

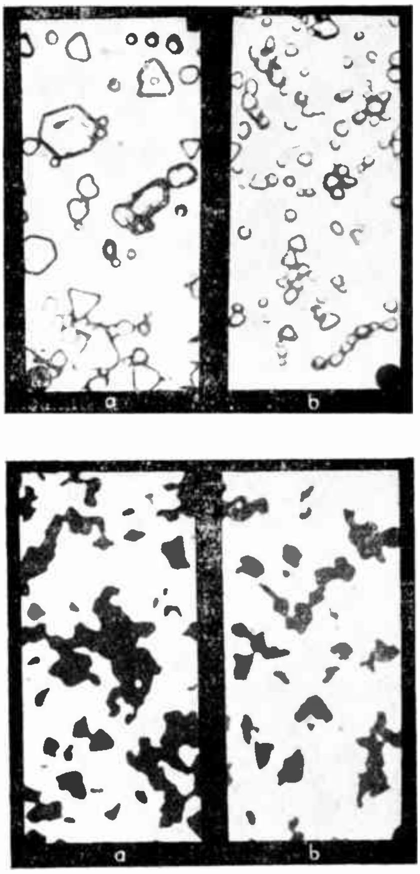


Fig. 3. Normal (*a*) and Fine-grain (*b*) Emulsions, before and after Development (x 1200).
(By courtesy of Ilford, Ltd., and the B.K.S.).

range.[3] Recent developments, in which a separate control track on the film controls the amplifier gain will still further increase this range.[4]

Published figures vary widely as to the volume range obtainable with different recording systems, but the following approximate figures indicate the progress that is being made in the increase of volume range. The stereophonic systems referred to comprise a four-track film controlling three sets of speakers and volume enhancement.[5]

Without noise reduction	**Variable Density 35 db.** **Variable Area 40 db.**
With noise reduction	**Variable Density 45 db.** **Variable Area 50 db.**
Control-track systems	**70 db.**
Stereophonic systems	**100 to 110 db.**

III. Mechanical Requirements

The mechanical and optical essentials of the recorder are substantially identical with those of the reproducer. The film must be fed at a perfectly constant speed past the recording point, and the slit of light must provide perfectly even illumination along its length.

In a previous article[6] the author discussed briefly the mechnical requirements of the reproducer head. It will be convenient to consider the influence upon sound quality of the various mechanical and optical aspects in a second article.

IV. Editing and Recording

In the studio, the sound is recorded upon a separate film from the picture. This enables the two films to be processed and edited separately, and then " married " in the printing machine.

In the case of the sound track, editing involves far more than merely cutting and re-assembling it. There are numerous sounds to be added—background music, crowd noises, special effects, etc.; incidental sounds in the original recording may have to be toned down (many natural sounds record unnaturally loudly): finally, it is essential that in the completed track, the volume level should be approximately constant (or, to be more precise, should be capable of reproduction at a fixed fader setting). Therefore, the whole track after editing is re-recorded; as many as half-a-dozen separately produced tracks may be simultaneously re-corded upon the one negative.

Duping Sound Tracks

This final negative is usually too precious to be allowed on the printing machines for the direct production of release prints (in the case of foreign-made films, there are also questions of customs duties to be considered) and therefore almost invariably, from the complete negative a master positive and then a dupe negative are made, and it is the latter that is used for producing the release copies.

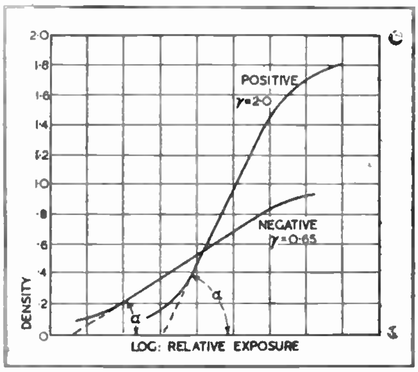


Fig. 4. Typical H. and D. Curves for Negative and Positive Films.

V. Photographic Requirements

It must not be overlooked that basically, sound-on-film recording is a photographic process, and the photographic characteristics of the film stock and of the processing play an important part in the maintenance of quality in the final reproduction.

The photographic image consists of crystals of metallic silver suspended in gelatine, themselves less than 1μ in diameter, and therefore singly insignificant.[7] But they have a tendency to clump together in development, and this clumping together of grains which may be too small to see with the naked eye can be the cause of a grainy image, and of much increased background noise. Thus the first effect of photographic faults is a reduction in the signal/noise ratio.

A post-war solution to this difficulty will undoubtedly be the use of fine-grain film stocks and special methods of processing, whose object is to reduce the clumping of grains.[8]

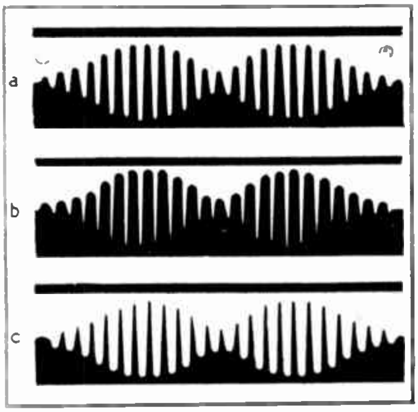


Fig. 5. Rectification of high-frequency recording modulated at a lower frequency : (a) correct, (b) over-exposed, (c) under-exposed. The variation in mean density gives rise to spurious harmonics in reproduction.

Sensitometric Control

From the point of view of the film laboratory, consistency of output of both negative and positive is a prime essential. In order to maintain a reasonable standard of quality and consistency, every film laboratory has to make copious use of the science of sensitometry—the study of the sensitivity of photographic materials.[9]

The basis of sensitometry is the Hurter and Driffield, or H. and D., curve. In this curve, density (= log. opacity) is plotted against log. exposure. Fig. 4 shows typical curves for negative and positive films.

It will be seen that for a large part of the curve, there is a linear relationship between these two quantities, and the slope of this straight-line portion of the curve is a measure of the relative contrast of the original and the copy (compare this with the slope of a valve curve). The photographic contrast is measured by the slope of the straight-line portion of the curve, and is termed *gamma*; mathematically,

$$\gamma = \tan. \alpha$$

It need hardly be mentioned that electronic devices play an important part in the practical applications of sensitometry. While the most generally used densitometer (the instrument that measures the density of a photographic image) is of the visual type, photo-electric types are being introduced as standards of accuracy improve, while, due to the selective sensitivity of the recording and positive stocks to light within the ultra-violet, violet and blue regions, a potassium or sodium photo-cell is a truer measure of the exposing light than any visual instrument.

The first application of sensitometry will be evident: that, by passing test strips which have been subjected to known exposures through the developing bath, the consistency of this bath and of the picture and sound films can be maintained. But it has more specialised applications in the realm of sound.

Contrast in Density Recording

First, let us consider the variable-density track. Obviously, volume level is dependent upon the range of tones present in the track, and there-

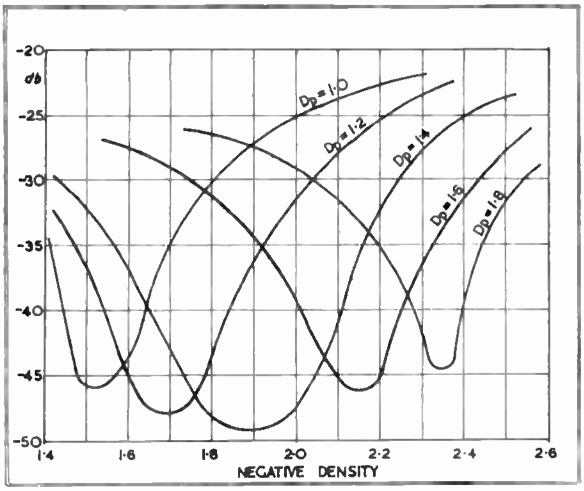


Fig. 6. Typical Cancellation Curves, showing the elimination of spurious 400 c/s modulation by correct choice of negative and positive density. By the correct choice of densities, not only can cross-modulation be much reduced, but the tolerance in processing is increased.

fore upon the contrast of the track. This range of contrasts depends first upon the amplitude of the recorder modulations; next, upon the degree of development of the original negative; and also upon the degree of development in every subsequent photographic process. In theory, the mean density should not enter into the question; but in practice, it is customary in variable-density systems to work at low negative exposures, near the toe of the curve, when, due to the curvature of the toe, the effective gamma is less than the apparent gamma.

When it is realised that upwards of 100,000 ft. of sound negative may be exposed in a major film production, that additionally there are numerous "library" shots, that the finished negative, of possibly 10,000 or 12,000 ft., has to be duped, and then a considerable number of prints produced, the importance of the application of sensitometric methods of control to large-scale production will be appreciated.

Cross-Modulation Tests

If contrast or gamma is the principal factor in the case of the variable density track, it is density that has to be chiefly considered in the variable area track.

Consider a recording of a high frequency, whose amplitude varies (Fig. 5). Due to halation and irradiation in recording or printing, and image spread in development, the edge dividing the opaque and transparent portions of the track is never perfectly sharp, and in the original negative, this may result in the filling in of the valleys of the track. This, it will be seen, is essentially a form of rectification. It is measured by recording a high frequency—say 6,000 to 9,000 c/s.—modulated with a lower frequency of, say, 400 c/s; if there were no rectification, then the 400 c/s. note would not be audible as such, but any rectification will cause it to appear as a parasitic frequency.

Fortunately, the effect will, of course, be reversed when the negative is printed. By a suitable choice of densities, it can in fact be completely cancelled out. Therefore, cross-modulation tests form a regular part of laboratory routine, and by making prints with different densities and plotting the degree of 400 c/s. in the print, so-called cancellation curves are produced, which serve to show the optimum positive density to suit a given negative density. (Fig. 6).

Monochromatic Recording and Printing

The faults of halation and irradiation which are largely the causes of the problems just discussed occur within the thickness of the emulsion. If we make use of light of a colour to which the emulsion is opaque, such faults are much reduced; the image will, of course, be confined to the surface of the emulsion.

Ultra-violet light meets this requirement, and by its use in recording and printing, cross-modulation can be much reduced, and track definition improved. A similar effect can be achieved by the use of blue light in conjunction with yellow-tinted emulsion.

The use of monochromatic light of whatever colour has, of course, the further advantage of improving the image definition of the optical components, so effecting a further improvement in quality.

Development Control

A point that will be observed from Fig. 4 is that, over the range of densities commonly employed, a change in gamma of the negative will make little difference in density, and the change in contrast will be the predominant effect. On the other hand, in the case of the positive, a small change in gamma will produce a relatively large change in density. Therefore, while in negative development it is gamma that is worked to, in the case of the positive it is customary to work to mean density.

In regard to variable area recording, it is fortunate that this is so, since, as we have seen, it is density that controls the cancellation of rectification effects. In regard to the picture, too, it is of more importance that the density should be held constant than the contrast, which is far less noticeable.

Sound-Film Printing

There are serious mechanical difficulties in the printing of sound tracks. Celluloid is a very unstable material, whose dimensions vary considerably during processing and in storage, according to humidity and age. It is improbable that the negative and the raw positive stock will be of the same pitch, and slippage or creep occurs in the printing machine. There is also some difficulty in assuring absolute contact between the two films.

The effect of printer slippage is to distort the wave form of the higher frequencies, causing distortion of consonantal sounds. Therefore, in the interests of the release print, the higher frequencies are, as already indicated, always removed in the original recording. In spite of developments in non-slip printers, there is little immediate likelihood of this limitation permitting of any important extension of the frequency range.

In this brief review, we have so far considered the factors that affect sound quality in the recording and duplicating processes. In a further article, it is proposed dealing with the corresponding factors in the reproduction process.

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(To be continued.)

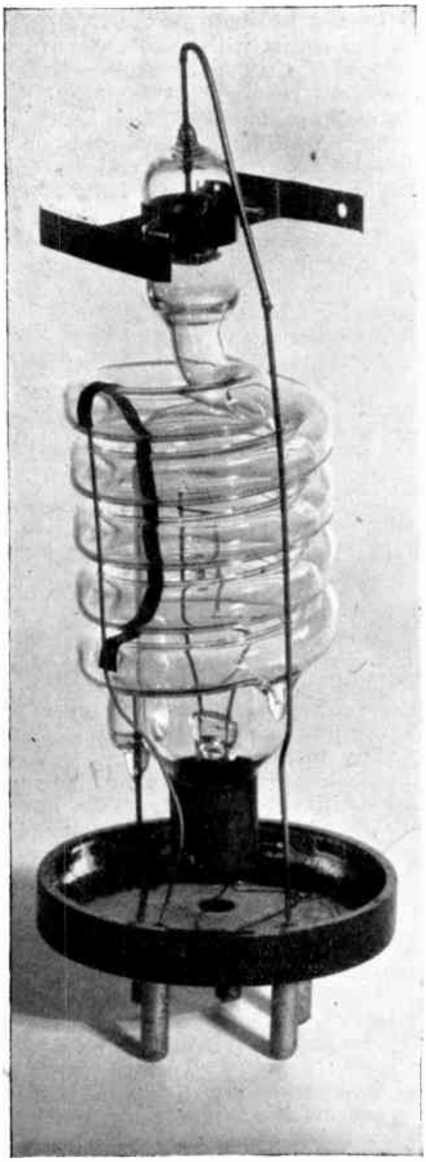


Fig. 2. Discharge tube of the Speedlamp, showing the modelling lamp inside.

The "Kodatron" Speedlamp

By G. A. JONES*

DURING the war high-speed photography has been used to an ever-increasing extent for the examination and analysis of swift movement. The working of machine tools of all types and the operation of many weapons of war have been improved by means of photographic analysis. This may be carried out by means of the ultra-high-speed cine camera, which can provide slow-motion effects down to one-two-hundredth of the speed of the original motion, or even less. But it is also often necessary to take single still photographs to show the exact situation at any given instant, and here the gaseous discharge tube has proved a valuable piece of apparatus, providing a discharge of intense brilliance which lasts for an extremely brief period of time. The mechanical shutters fitted to commercial cameras are normally made to work up to about one-thousandth of a second, but this is not nearly short enough to provide a sharp image of objects moving at high speeds. For purely mechanical reasons, however, it is not easy to design an efficient shutter capable of opening and closing in periods of this order. Rotating sector shutters have been made which are capable of giving extremely short exposures, but they are usually somewhat clumsy. Above all, when very short exposure times are employed, it is necessary to provide very intense illumination in order to obtain sufficiently well-exposed negatives. Hence the gaseous discharge tube, with its brilliant flash of light lasting only a minute fraction of a second, is a very valuable tool, for with it one can obtain the same result without the necessity for a mechanical shutter working at high speeds.

The "Kodatron" Speedlamp (Fig. 1) is a commercial form of such a discharge tube. It normally produces a flash giving sufficient light to take a fully exposed negative of an object fifty feet distant at a lens aperture of only f/11. The exposure time at this intensity is of the order of one five-thousandth of a second, though the exact value depends upon the exposure criterion adopted, as explained below. Exposures shorter than one thirty-thousandth of a second can be obtained if some reduction in intensity can be tolerated.

The "Kodatron" lamp consists essentially of a tube containing a mixture of rare gases, through which a condenser is discharged. This tube is made in the form of a coil, in order to provide a compact source, in the centre of which is a small tungsten-filament bulb used for setting up the lamp on the subject to be photographed (Fig. 2). The gas pressure in the tube is such that the potential across the two end electrodes is too low to discharge it. In order to trip the circuit, the gas is ionised by a third electrode round the outside of the tube. When a high-potential pulse is applied to this, the gas is ionised and the condenser is discharged through the tube, thus producing the flash. In order to avoid the use of mechanical contacts at this high voltage, the lamp is triggered by a Strobotron circuit. This has other advantages as it enables various forms of electrical trip to be arranged and several lamps to be discharged, in perfect synchronism, if desired Devices for discharging several lamps simultaneously and for synchronising the flash with the operation of a camara shutter are supplied as accessories to the lamp.

In the outfit as marketed, the condenser has a capacity of 112 microfarads. This is charged by high voltage (1,850 volts) D.C. provided by a rectifier tube, as shown in Fig. 3. R_1 and R_2 are biasing resistors for the inner grid of the Strobotron. When the trip switch, which is in a low-tension circuit, is closed the grid is made sufficiently positive to cause the Strobotron to pass a fairly large current. This energises the induction coil, which causes the third electrode to ionise the gas in the tube. The time lag from the time of making contact to the start of the flash is less than a millionth of a second.

The tube, which is enclosed in a frosted glass cover for safety and convenience, is used in a special reflector designed to give a beam intermediate between spot- and flood-lighting. The induction coil is held in the back of this reflector, the whole unit being mounted on a vertical extension rod so that it can be held at varying heights. This rod is mounted on a trolley on which is also held the detachable unit containing condensers, tripping gear and fuses. The controls consist only of the trip switch and two toggle switches, one to control the modelling light and one the main supply to the condensers (fitted with a red warning light). A plug contact is wired in parallel with the trip switch to enable the extension leads and electrical tripping devices to be used.

The intensity-time characteristics of the lamp (Fig. 4) are interesting. The flash builds up to its full intensity very quickly and starts to die away within 120 microseconds.

* Kodak Research Laboratories.

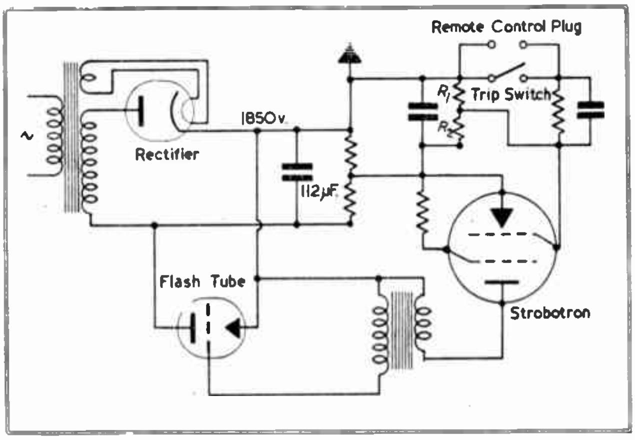


Fig. 3. Circuit diagram of the lamp and condenser.

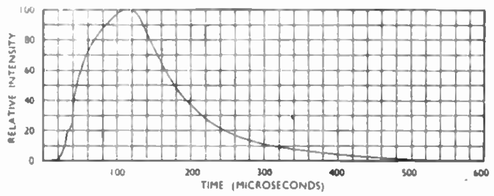


Fig. 4. Intensity-time curve for No. 1 lamp with a condenser capacity of 112 mfd.

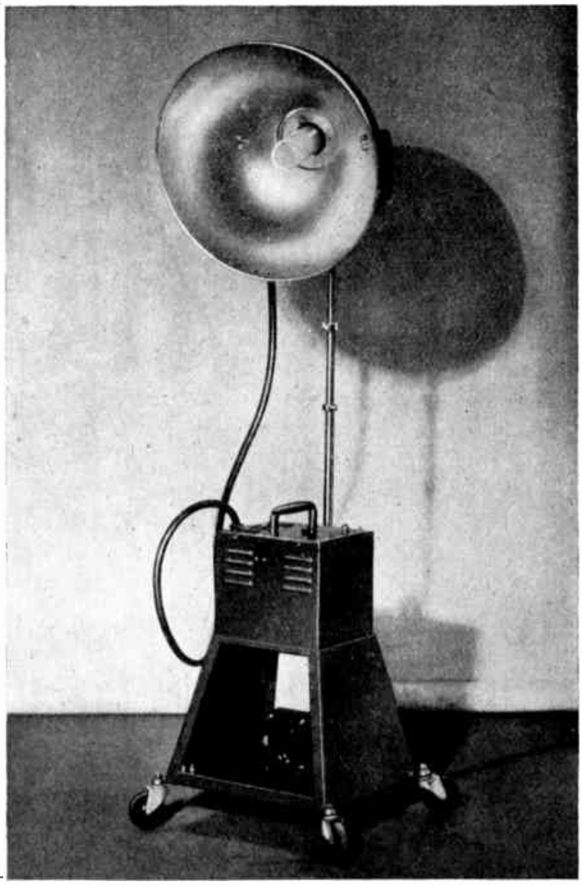


Fig. 1. General view of the " Kodatron " Speedlamp.

But the intensity then falls away progressively less rapidly, leaving a pronounced tail. It is thus clear why it is difficult to quote a specific duration-time for the flash—if the camera lens aperture is opened up to make use of the lower intensity portions of the flash, the base of the curve is used and the effective exposure will be about 450 microseconds, whereas if it closed down until only the tip is used, the effective exposure will be only 20 microseconds. These are extreme cases, which could not occur in practice, but the effect can be seen where photographs are taken of light and dark objects moving together at high velocity; the light one, reflecting more of the illumination, appears less sharp than the dark, owing to the longer time of exposure it has received.

The effect of reducing the condenser capacity is to reduce both the duration and the intensity of the flash; for instance, a 7-microfarad condenser produces an effective duration of about one thirty-thousandth of a second, together with a corresponding decrease in intensity. The effect of reducing the voltage to which the condenser is charged is to decrease the intensity only. For most industrial and scientific work it is therefore desirable to have small-capacity condensers capable of operation at very high voltages. The " Kodatron " lamp achieves this in an easily portable form by the use of specially-designed condensers.

Two discharge tubes are available, No. 1 having slightly lower photographic effectiveness than No. 2, and a rather shorter duration of flash under given conditions. The greater effect of the No. 2 tube is largely due to a higher output of light in the green and red regions of the spectrum and this also makes it very suitable for use with " Kodachrome " colour film. The spectral composition of the light is nearer to daylight than to tungsten-filament (half-watt) lighting and all that is necessary for good colour rendering on Regular (daylight) " Kodachrome " is a " Wratten " No. 1 filter to cut out ultra-violet radiation.. The spectral energy radiated by the tube is shown by the curve given in Fig. 5 (overleaf).

A portable model of the " Kodatron " lamp has been made for use with batteries in places where electric mains are not available. A 9-inch reflector houses the flash tube and is attached to the camera. A four-volt battery charges a 28-microfarad condenser to 2,000 volts through a vibrator-converter, a high-ratio transformer and a rectifier. A trickle charger is incorporated and the battery is capable of providing two hundred flashes before it requires recharging.

This form of lamp is proving of ever-increasing use in industrial research, especially when employed as a supplement, the ultra-high-speed cine camera. Synchronisation of the " Kodatron " lamp is so simple that records can easily be taken at any predetermined point, either by means of adjustable contacts on the mechanism or by means of a photo-cell, microphone or similar electrical means. Owing to wartime conditions, it is, unfortunately, impossible to show the more interesting applications, but Figs. 6, 7 and 8 overleaf will give an idea of the possibilities.

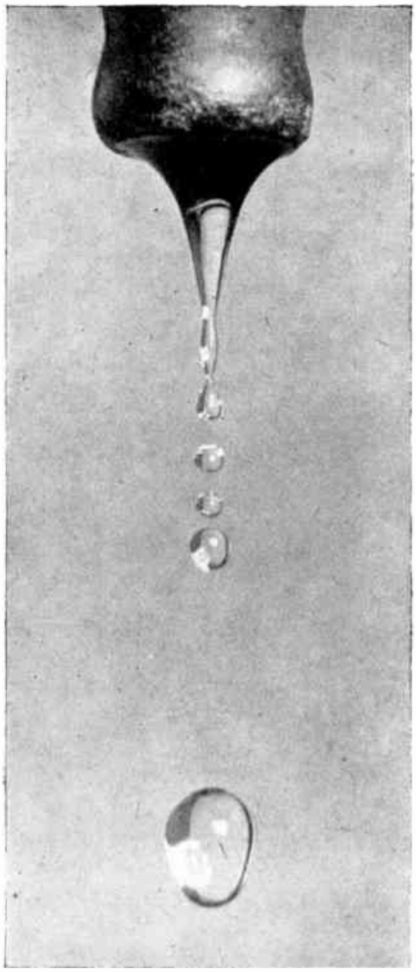
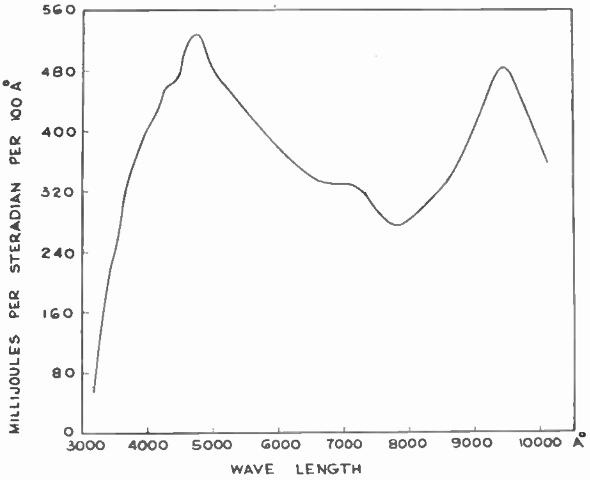


Fig. 7. Water dripping from a tap
(Photo by A. L. Shuffrey, A.R.P.S.)

Fig. 5. Curve showing the spectral energy radiated by the tube when using a 56 mfd. condenser for discharge.
(By courtesy of the G.E.Co., Cleveland)



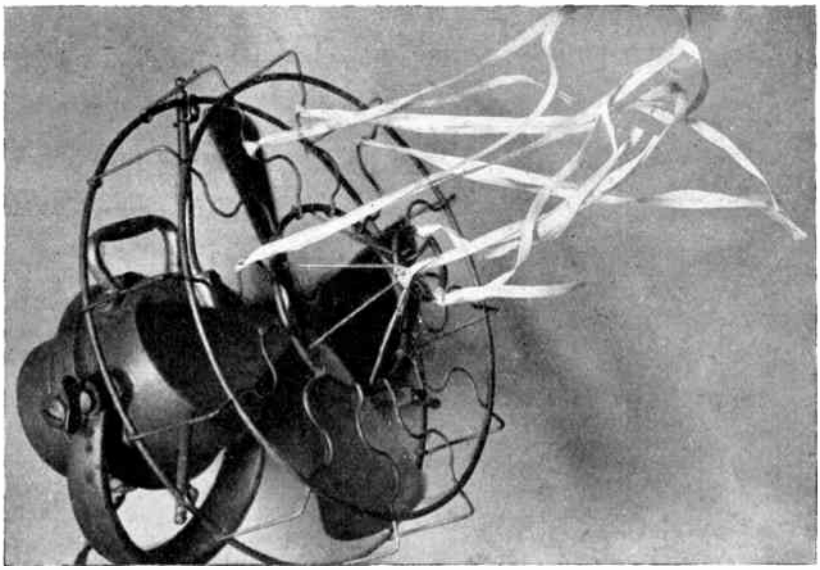


Fig. 6. Electric fan rotating at full speed (1/30,000th. sec. exposure with Leica camera).
(Photo by R. M. Weston, A.R.P.S.)

Photographs taken with the "Kodatron" Speedlamp.

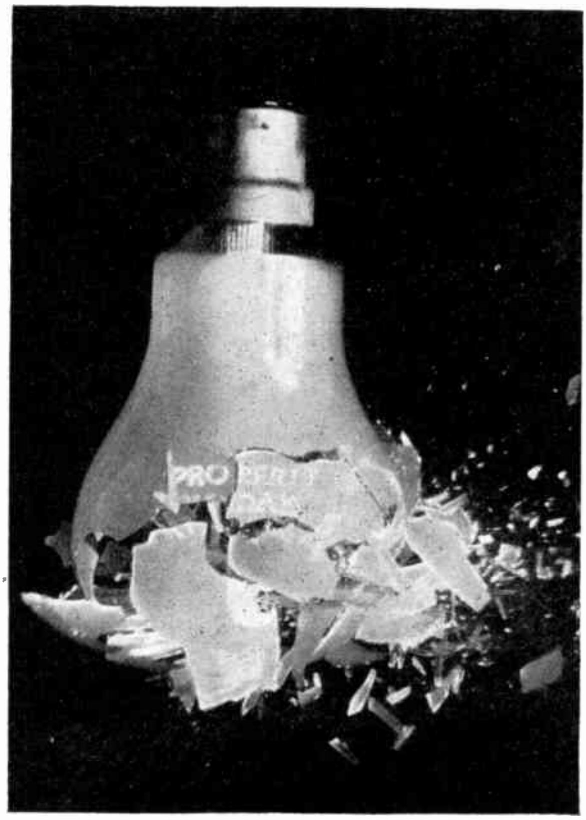


Fig. 8. Lamp bulb breaking on impact with concrete floor.
(Photo by A. L. Shuffrey, A.R.P.S.)

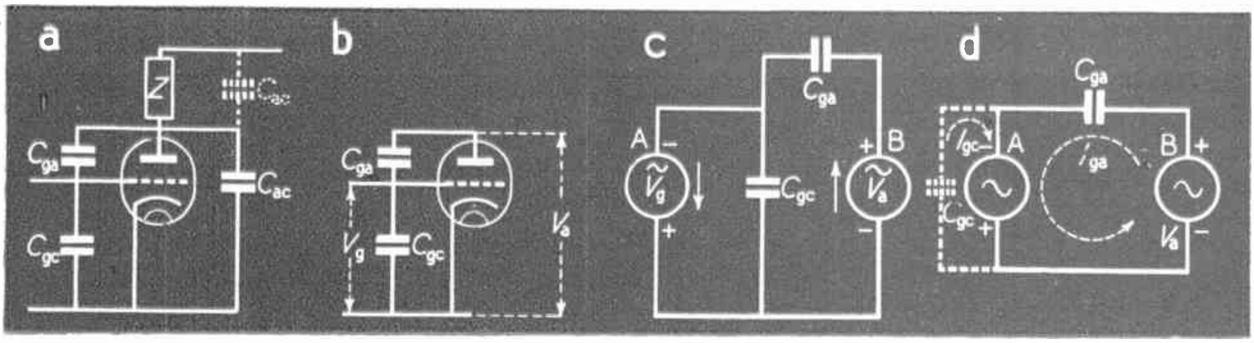


Fig. 1 (a). The interelectrode capacitances are represented as condensers connected externally to the valve. Since the HT + line is at earth potential (to alternating components) *Cac* can be transferred to the position indicated by the broken lines. (b) Since *Cac* is virtually in parallel with the anode load, the equivalent circuit can be represented as above. (c) *Vg* and *Va* can be represented as the output voltages of two alternators in antiphase. (d) *Cgc* is removed temporarily and the current through *Cga* is calculated.

Miller Effect Simplified

By C. J. MITCHELL, A.M.I.E.E.*

THE curious behaviour of reflected inter-electrode capacitances or "Miller Effect," is well known, but it is not easy to acquire a clear conception of the effect. The following treatment is an approach from a new angle which, in the author's opinion, reduces very considerably the work involved in deriving the equations for input capacitance and input resistance, and at the same time, provides a clear picture of the precise operation of a triode amplifier.

Fig 1 (a) is the equivalent circuit of a triode amplifier with the normal inter-electrode capacitances shown as condensers connected externally to the valve. The anode to cathode capacitance can be considered to be in parallel with the anode load, for the high tension positive line, although actually above earth potential, is shunted to earth through a large by-pass condenser in the power pack, so as far as radio frequencies are concerned, it can be regarded as being at earth potential; transferring the cathode end of C_{ac} from the cathode to the high tension positive will not affect the circuit constants.

The next step is to simplify the circuit by regarding C_{ac} as part of the capacitance in the anode load, which reduces the equivalent circuit to that of Fig. 1 (b).

When an alternating voltage V_g is applied between the grid and cathode of the valve, an alternating voltage V_a appears between the anode and cathode. The value of V_a is $A \times V_g$, and if the anode load is perfectly resistive, V_a will be 180° out of phase with V_g, so the circuit can be represented as two alternators A and B in antiphase, connected to the condensers C_{gc} and C_{ga} as shown in Fig. 1 (c).

It is clear from the diagram that alternator A (the signal source), is supplying a current to C_{gc}, but it is not quite clear how C_{ga} is being affected, so C_{gc} is removed temporarily from the diagram, leaving the arrangement as shown in Fig. 1 (d), where it can be seen that the two alternators are virtually in series and are connected across C_{ga}.

Now since the current through C_{ga} is passing through both alternators, alternator A is being called upon to supply this current in addition to that through C_{gc}. The effect is that of an additional capacitance across the signal source, and it is this "reflected" grid to anode capacitance which plays such an important part in the behaviour of a valve at radio frequencies, as will be seen later.

It can be seen that the potential difference between the plates of C_{ga} is equal to

$$V_g + V_a \quad \ldots\ldots (1)$$

but $V_a = A \times V_g$ where A = the gain of the valve.

$\therefore$ the p.d. across $C_{ga} = (1+A)V_g$ ... (2) (*see* Fig. 2).

The current through the signal source due to reflected capacitance can be calculated as follows:—

$$I_{ga} = \frac{jV_a}{x_{ga}} = j(1+A)V_g \times 2\pi f C_{ga} \quad \ldots (3)$$

The reactance of the capacitance reflected into the grid circuit

$$= \frac{V_g}{I_{ga}} = \frac{1}{j2\pi f C_{ref}}$$

$$\therefore \text{Reflected capacitance} = \frac{I_{ga}}{j2\pi f V_g} \quad (4)$$

substituting in equation (3),

$$C_{ref} = \frac{j(1+A)V_g \times 2\pi f C_{ga}}{j2\pi f V_g}$$

$$= C_{ga}(1+A) \quad \ldots\ldots (5)$$

The last result shows that the reflected capacitance is $(1+A)$ times the actual grid to anode capacitance: this must be added to the normal grid to cathode capacitance, thus,

$$\text{Input capacitance} = C_{gc} + C_{ga}(1+A) \quad (6)$$

The last derived equation is only true when there is no phase shift in the amplifier apart from the normal 180°. This is seldom attained in practice, and there is usually some departure from this condition, so the effect will be reviewed from a new angle.

If the anode load is not purely resistive, there will be some phase shift. As before, the anode to cathode capacitance can be conveniently "lost" in the anode load, and the investigation can be carried out as before, with the exception that the two alternators in the diagrams are no longer in strict antiphase.

Fig. 3 is similar to Fig. 1 (d) except that the voltage across alternator B has been advanced by ϕ degrees. This condition corresponds to an inductive anode load, the voltage across the load leading the current, and the

* Northampton Polytechnic Institute.

current through the two alternators can be calculated by expressing the resultant voltage as a complex quantity.

From the vector diagram in Fig. 4 (a), it can be seen that the voltage of alternator B is equal to:

$$A.V_g\cos.\phi + jA.V_g\sin.\phi \quad \text{........... (7)}$$

The resultant voltage across C_{ga}

$$= V_g + A.V_g\cos.\phi + jA.V_g\sin.\phi \quad \text{... (8)}$$

which contains both real (power) and reactive components.

The current through the virtual condenser C_{ga} can be calculated as follows:—

$$I_{ga} = jV_g(1 + A.\cos.\phi)\times 2\pi fC_{ga} + j^2A.V_g.\sin.\phi \times 2\pi fC_{ga}$$

$$= jV_g(1 + A.\cos.\phi)\times 2\pi fC_{ga} - A.V_g.\sin.\phi \times 2\pi fC_{ga} \quad \text{... (9)}$$

(since $j^2 = -1$)

Taking the first term in equation (9), the effective input capacitance can be calculated.

$$C_{ref} = \frac{I_{ga}}{j2\pi fV_g} \quad \text{......... (from eq. 4)}$$

$$= \frac{jV_g(1 + A.\cos.\phi)\times 2\pi fC_{ga}}{j2\pi fV_g}$$

$$= C_{ga}(1 + A.\cos.\phi)$$

Adding the grid to cathode capacitance as before:

Effective input capacitance

$$= C_{gc} + C_{ga}(1 + A.\cos.\phi) \quad \text{.............. (10)}$$

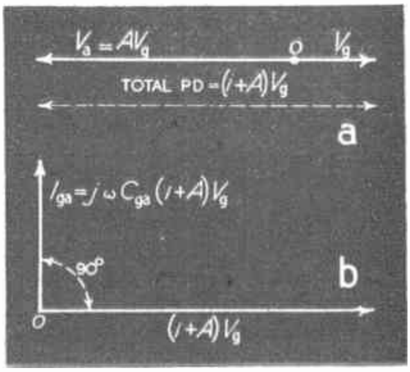
The second term in equation 9 represents a *power* component and causes a *resistance* to be reflected into the grid circuit. The value of the input resistance is equal to:—

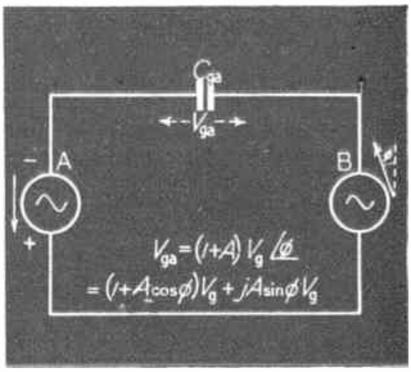
$$\frac{V_g}{\text{Power component of current}}$$

$$= \frac{V_g}{-A.V_g\sin.\phi \times 2\pi fC_{ga}}$$

$$R_{input} = \frac{-1}{2\pi fC_{ga} \times A.\sin.\phi} \quad \text{.......... (11)}$$

On examining the equations derived, it is seen that phase shift in an amplifier results in a reduction in the value of the effective input capacitance, but an effective resistance appears across the tuned grid circuit. If ϕ is positive (*i.e.*, the anode voltage





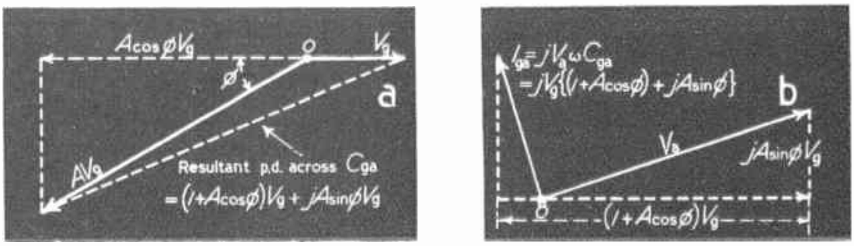


Fig. 2. Vector relationship between the grid/anode voltage and current.

Fig. 3. In this case the phase of alternator B has been advanced by ϕ degrees.

Fig. 4. The Vector diagrams show that the reflected current contains a resistive component. When ϕ is positive, the reflected resistance is negative.

leads the signal voltage), this resistance is *negative*, and if ϕ is negative, the reflected resistance is positive.

The reflected capacitance does not necessarily involve a loss of power, for it merely becomes an additional capacitance in parallel with the tuning condenser in the grid circuit, but the resistance causes power to be drawn from the signal source, thus damping the tuned circuit in the grid, and reducing its selectivity. If the anode load is inductive, however, the reflected resistance is actually *negative* and power is supplied to the grid circuit thus increasing its selectivity by offsetting the normal losses in this circuit. Frequently the power supplied by the reflected negative resistance is greater than the losses, with the result that self-oscillation occurs.

Miller Effect plays an important part in all radio-frequency valve circuits, and accounts for the rather curious behaviour of a tuned anode/tuned grid amplifier, for if the anode load is tuned to the correct frequency it will behave like a pure resistance and cause only capacitance to be reflected into the grid circuit, but if the two circuits are not exactly in tune—say the grid circuit is tuned slightly above the correct frequency and the anode circuit slightly below, the grid circuit will be damped by the reflected positive resistance; if the tuning of the anode circuit is adjusted to bring it into resonance, the reflected resistance will be removed and thus the grid circuit will become more selective, and at the same time, the reflected capacitance across the grid circuit will increase, thereby tending to correct the tuning. In short, there will be an apparent "pulling" between the anode and grid circuits.

Since the input capacitance of a valve is made up chiefly of the reflected grid to anode capacitance, the effects are reduced considerably by the use of pentodes or tetrodes, for the screening of the grid from the anode results in an extremely low value of C_{ga}. It should be borne in mind, however, that the reflected capacitance is nearly proportional to the gain of the valve, and since the screened valves have a much greater amplification than triodes, their actual input capacitances are not quite so low as might at first be expected.

Cathode-Ray Tube Traces

A Series to Illustrate Cathode-Ray Tube Technique

Part I.—Lissajous Figures

By HILARY MOSS, Ph.D., A.M.I.E.E.

General

THE Lissajous figure is important in cathode-ray tube work, because it provides an elegant and precise method of comparing frequencies and phases in oscillatory circuits. These figures are named after Prof. Lissajous, who first produced them by combining at right angles the component oscillations of two tuning forks. The combination was effected by optical means. Since the displacement of the prong of an oscillating tuning fork is very closely of simple harmonic form, the term "Lissajous figure" has become generally applied to the loci of any point moving under the simultaneous influence of two mutually perpendicular simple harmonic displacements.

There appears to be some doubt as to how far the term is applicable to curves in which either or both the displacements are composed of more than one harmonic term. Some writers use the term "complex Lissajous figure" for such cases, but it is very doubtful whether this is justifiable. The fundamental equation of such a system is

$$x = \Sigma A_k.\sin(m_k.\theta+\beta_k)$$
$$y = \Sigma B_k.\sin(n_k.\theta+\alpha_k) \quad \text{............ (1)}$$

and is therefore of most extreme generality. A saw-tooth, or square wave, for instance, conforms with (1), when an infinite number of terms are taken, and one might well be forgiven for failing to recognise these as Lissajous figures. Admittedly, when only a small number of terms are used in (1), the resulting figure does bear some connexion with the simple case defined by

$$x = A.\sin m.\theta$$
$$y = B.\sin(n.\theta+c) \quad \text{............... (2)}$$

to which the term Lissajous figure can be properly applied. We shall therefore treat the system (2) only, in detail, but for the sake of completeness a few simple cases of the much more general system (1) are included by way of illustration.

There are two distinct cases of (2)—firstly, that in which $n/m = p$, where

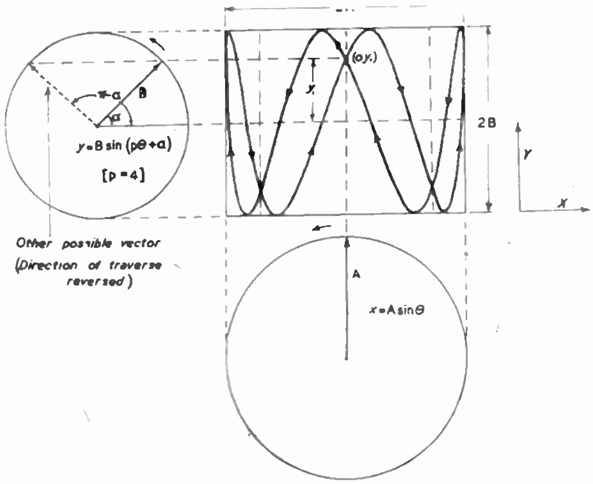


Fig. 1. The formation of the Lissajous figure.

p is integral, and secondly that in which n/m is non-integral.

Case I. Simple Lissajous figures with Integral Frequency Ratio

Let $n/m = p$, where p is integral so that eqt. (2) may be written

$$x = A.\sin\theta$$
$$y = B.\sin(p.\theta+\alpha) \quad \text{.............. (3)}$$

p is defined as the frequency ratio, and α as the phase angle. Fig. 1 shows a special case of (3) in which $p = 4$. The construction is almost self-evident. The projection of the rotating vector B on the vertical axis represents the "y" term in (3). Note that initially the vector is inclined at angle α to the horizontal to provide the correct phase. The rotating vector A is initially vertical, since the phase of the "x" term in (3) is zero. Vector B rotates at four times the speed of A, thus defining $p = 4$.

We shall now deal briefly with the more important properties of the system (3).

Periodicity

The sine function has a period of $2.\pi$. Hence the curve is traced once while θ goes through $2.\pi$ radians.

Envelope of the System

Clearly for all values of p and α, this is the rectangle defined by $x = \pm A$, $y = \pm B$.

Determination of the Phase Angle

Setting $\theta = 0$ in (3) immediately defines the point having coordinates $(0, y_1)$, where $y_1 = B.\sin\alpha$. Hence the phase angle is defined by

$$\alpha = \arcsin y_1/B \quad \text{................ (4)}$$

This is shown in Fig. 1. B is the length of the $p.\theta$ vector and is thus inherently positive. If we define the positive direction of the coordinates in the manner indicated, then y_1 is also positive, so that the general solution of (4) is

$$\alpha = K.\pi + (-1)^K.\alpha \text{ where } K \text{ is any integer.}$$

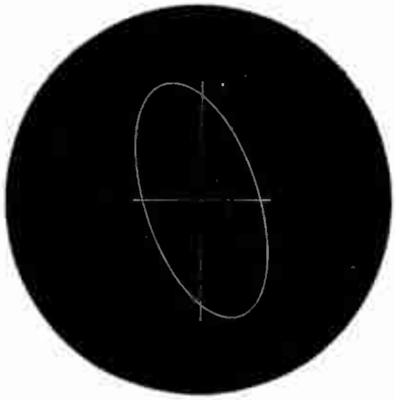
Since the periodicity of the curve is $2.\pi$ it therefore follows that there are two numerically distinct solutions for the phase angle, these being α, and $\pi - \alpha$. These are shown on Fig. 1. Consideration of the figure will show that the ambiguity in phase angle is resolved if the direction of traverse of the spot round the figure is known.

It is necessary to be perfectly clear as to the question of the sign of the phase angle. The sign of y_1 in Fig. 1 is purely arbitrary, being dependent on the coordinate convention, which is not heaven sent. A little consideration of Fig. 1 will show that both in shape and direction of traverse round the figure, the curves traced by phase angle of α (leading), *i.e.*, positive, and a phase angle of $\pi - \alpha$ (lagging),

Lissajous Figures with Integral Frequency Ratios

$x = A \sin \theta$ $y = B \sin (\theta + \alpha)$

1



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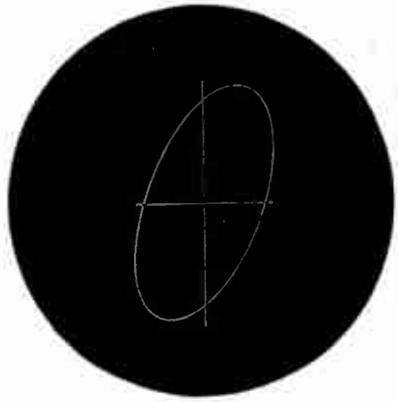
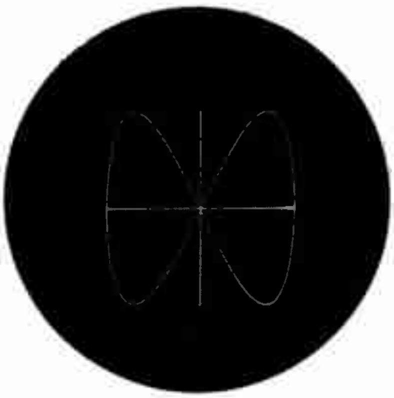


3

$x = A \sin \theta$ $y = B \sin (2\theta + \alpha)$



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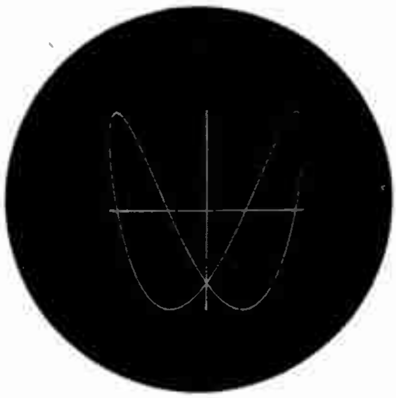

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6

$x = A \sin \theta$ $y = B \sin (3\theta + \alpha)$

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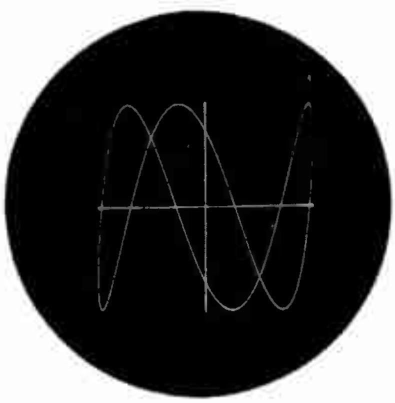

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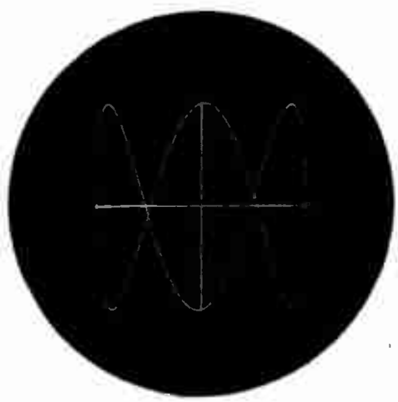


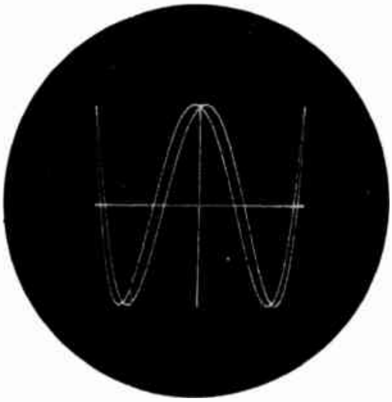
9

For discussion on absolute values of phase angle refer to text.

Lissajous Figures with Integral Frequency Ratios

$x = A \sin \theta$ $y = B \sin (4\theta + a)$

10



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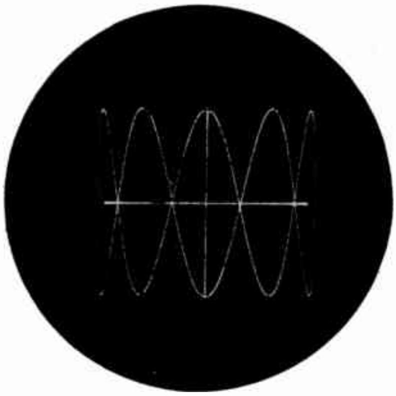
$x = A \sin \theta$ $y = B \sin (5\theta + a)$

13

14



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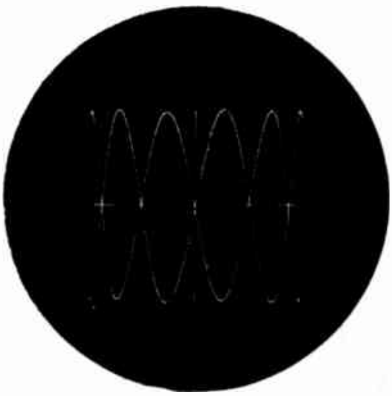
$x = A \sin \theta$ $y = B \sin (6\theta + a)$



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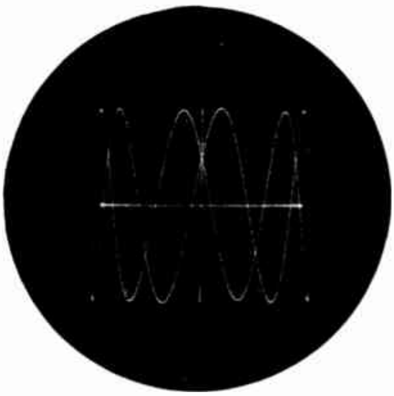

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18

For discussion on absolute values of phase angle refer to text.

i.e., negative, are identical. Similarly the curves traced with a phase angle of α (lagging) and $\pi - \alpha$ (leading) are identical.

This, however, need not worry us unduly, because there is here no physical difference between a phase angle of $+\alpha$ (*i.e.*, leading) and a phase angle of $\pi - \alpha$ (lagging), or *vice versa*. This difference becomes apparent and is resolved only when the sense in which the voltages are applied to the plates is known.

Determination of Frequency Ratio

Consider the intersections of the line $y = +B$ with the curve. These intersections can occur only when $y = +B$, *i.e.*, from (3) when

$$\sin(p.\theta + \alpha) = 1$$

i.e., when

$$p.\theta + \alpha = (4.K + 1).\pi/2$$ where K is any integer.

i.e., when

$$\theta = 2.\pi.K/p + \pi/2.p - \alpha/p \quad \ldots\ldots (5)$$

From (5) it is apparent that there are p distinct values of θ between 0 and $2.\pi$ which satisfy the condition. Hence there will be in general p intersections between the curve and the line $y = +B$ (or $y = -B$). This gives us an easy rule for determining the frequency ratio.

It is necessary to add that in certain cases, where $\alpha = \pm k.\pi/2$ and k is integral, some of these intersections coincide and the rule breaks down. (*See* traces 7 and 12 overleaf.) This is treated in the next section. In practice it is sufficient when making a count to see that the figure forms at least one closed loop.

Miscellaneous Properties

Consider two values of θ defined by

$$\theta = (2.K + 1).\pi/2 + \lambda$$
$$\ldots\ldots\ldots\ldots (6)$$
$$\theta = (2.K + 1).\pi/2 - \lambda$$

Since the sine function is symmetrical about any odd multiple of $\pi/2$, these must correspond to equal values of x. The corresponding values of y are given by

$$y = B.\sin\left[p\left\{(2K+1)\pi/2 + \lambda\right\} + \alpha\right]$$
$$\ldots\ldots\ldots\ldots (7)$$
$$y = B.\sin\left[p\left\{(2K+1)\pi/2 - \lambda\right\} + \alpha\right]$$

and these two values are therefore equal if

$$p\left\{(2K+1)\pi/2 + \lambda\right\} + \alpha = p\left\{(2K+1)\pi/2 - \lambda\right\} + \alpha + 2\pi k$$

i.e., if

$$\lambda = k.\pi/p$$

Substituting back in (6) gives for θ the values

$$\theta = (2.K+1).\pi/2 \pm k.\pi/p \quad \ldots\ldots\ldots (8)$$

Ignoring the solutions $k=0$, $k=p$, $k=2p$ (which merely represent the ends of the "x" trace) we see from (8) that there are $2(p-1)$ values of θ inside the range 0 to $2.\pi$ which make the two values of y in (7) equal. Hence the important result—*if the frequency ratio is p, the figure has $p - 1$ intersections with itself, i.e., encloses p loops.* This is an alternative rule for determining the frequency ratio.

Special Case

An important special case arises when the phase angle α is either zero or a multiple of $\pi/2$, as mentioned in the last section. Setting $\alpha = k\pi/2$ in (7) gives

$$y = B.\sin\left[p(2K + 1 + k/p)\pi/2 + p\lambda\right]$$
$$\ldots\ldots\ldots\ldots (9)$$
$$y = B.\sin\left[p(2K + 1 + k/p)\pi/2 - p\lambda\right]$$

whence the two values of y in (9) are equal for *all* values of λ provided that

$$p(2.K + 1 + k/p) \text{ is } odd$$

i.e., provided that $p + k$ is *odd* since $2.K.p.$ is always even. In this event then, the values of y for all values of x on the "forward" and "return" sweeps are equal, and hence the figure degenerates into a curved line which encloses no area. This is shown in traces 7 and 12.

Hence the simple rule: for frequency ratios which are *even* the figure encloses no area if the phase angle is $\pi/2$ or an *odd* multiple thereof, while for frequency ratios which are *odd* the figure encloses no area if the phase angle is zero or an *even* multiple thereof.

Finally, we see that (8) is independent of the phase angle so that the loci of the intersections are parallel to the "Y" axis, with varying phase. This is an aid when sketching the figures. Another point to remember is that the curve always goes through origin when the phase angle is zero or a multiple of π.

Notes on the Experimental Technique

Figs. 1-18 are various special cases of the system (3). The general form of the equations is indicated on the curves. Those on the same horizontal row are for the same frequency ratio, with varying phase, and sometimes with varying amplitude.

Nos. 7 and 12 are especially interesting because they display the effect shown in equation (9) in which the curve encloses no area. In 7 the frequency ratio is odd (3 to 1) so the phase angle is zero. In 12 the frequency ratio is even (4 to 1) so the phase angle is $\pi/2$.

Fig. 2 shows a block diagram of the circuit technique used. The important point is that the component oscillations are derived from a common source, so that the synchronisation is perfect. Again, the frequencies have been so chosen that the resonant circuits of high "Q" can be easily constructed. It is well known that any such low decrement circuits tend to give sinusoidal outputs even when the exciting current wave forms are far from pure. Hence there is no difficulty in obtaining almost pure sine waves. This is well shown by Figs. 7 and 12, in which the forward and return x sweeps would not coincide so perfectly if there were any appreciable harmonic content in either wave component.

All the photographs are untouched reproductions of the originals. The tube used was the new Cossor type 26 J with blue photographic screen, run at 2 kV. A Cossor type 427 camera with Ilford oscillograph film type "F" was employed. The developer was metol-hydroquinone similar to Ilford ID-2.

As a guide to the analysis of the figures, the coordinate axes have been included. These were obtained by switching off each component oscillation in turn, every complete photograph consisting, therefore, of three distinct exposures.

For details of the specific application of these figures to circuit investigations, the reader is referred to the standard texts on the cathode-ray tube. These notes are merely intended as guides to the type of pattern produced, and to their analysis.

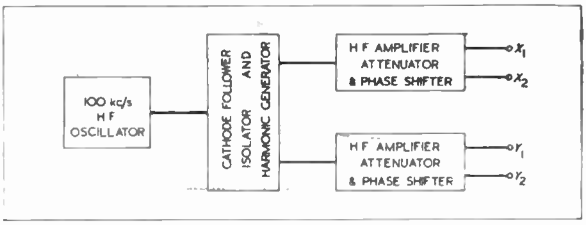


Fig. 2. Diagram of apparatus for obtaining Lissajous figures shown in the text.

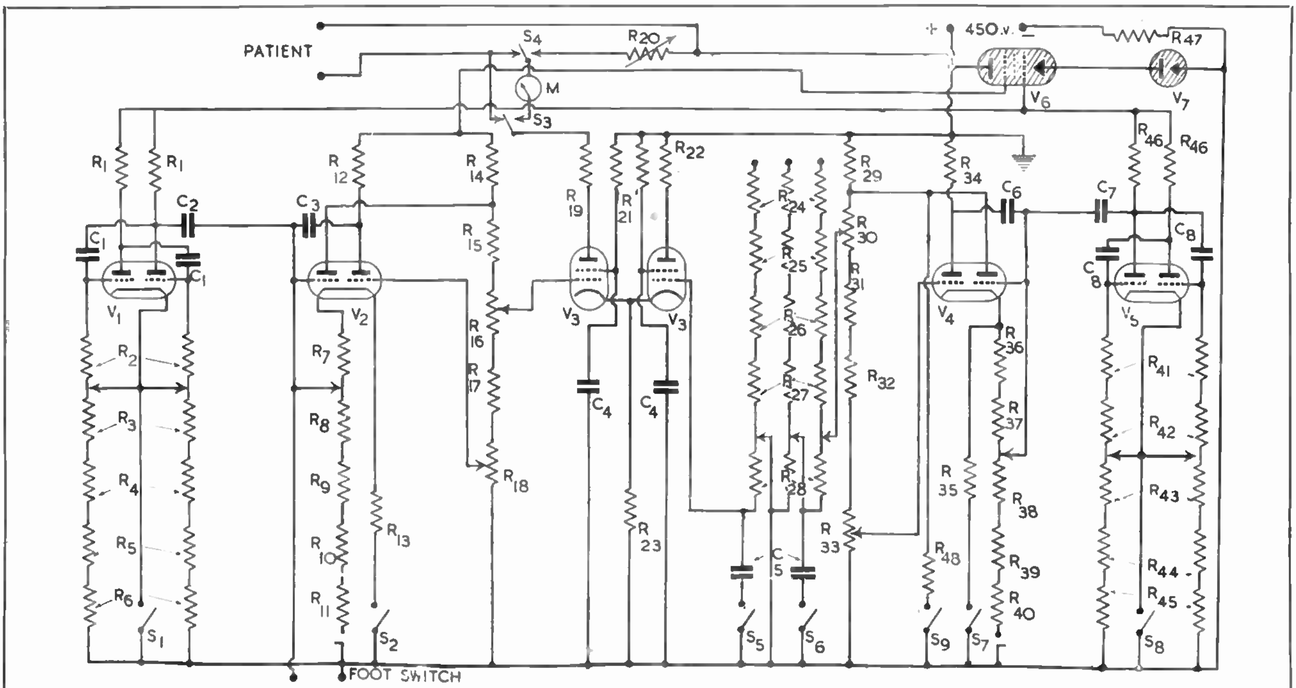


Fig. 8. The complete circuit of the stimulator.

Typical Component Values

R_1 = 50 K Ω.
R_2 to R_6 inclusive total R = 5M Ω.
R_7 to R_{11} „ „ R = 2.5.M Ω.
R_{12} = 10 K Ω.
R_{13} = 4 K Ω.
R_{14} = 10 K Ω.
R_{15} = 80 K Ω.
R_{16} = ¼ M potentiometer shunted by 20 K Ω
R_{17} = 5 K Ω.
R_{18} = 15 K Ω.
R_{19} = 1 K Ω. 20 watts.
R_{20} = 10 K Ω. 20 watts.

R_{21} = 7 K Ω. 2 watts.
R_{22} = 2.5 K Ω. 20 watts.
R_{23} = 1.0 K Ω. 20 watts.
R_{24} to R_{28} inclusive, total R = 5 M Ω.
R_{29} = 50 K Ω.
R_{30} = ¼ M potentiometer shunted by 50 K Ω.
R_{31} = 80 K Ω.
R_{32} = 7 K Ω.
R_{33} = 25 K Ω.
R_{34} = 50 K Ω.
R_{35} = 10 K Ω.
R_{36} to R_{40} inclusive, total R = 5 M Ω.

R_{41} to R_{45} inclusive, total R = 5 M Ω.
R_{46} = 50 K Ω.
R_{47} = 2 K Ω.
C_1, C_3, C_4 = 1 μF.
C_2 = .0005 μF.
C_5, C_6 = 2 μF.
C_7 = .001 μF.
C_8 = 4 μF.
V_1, V_2, V_4, V_5 = 6N7.
V_3 = KT66.
V_6 = Stabilovolt.
V_7 5.130.

A Chronaxie Meter and Electronic Stimulator

By BRIAN DENNY*

THIS apparatus has been developed from the original circuits of Dr. Philippe Bauwens, Medical Officer in Charge of the Electro-therapeutic Department, St. Thomas's Hospital, and aims at providing the means of determining accurately the response to electrical stimulation of muscle and nerve and of applying electrical treatment of known character and dosage. For such purposes it is essential that the amplitude, duration of impulse and impulse frequency be known accurately and that the range of control of each of these dimensions be sufficiently wide to cover all practical contingencies.

Amplitude is considered in terms of current with a range of 0 to 60 milliamperes; provision for very fine adjustment at the lower end permits the control of values from 0 to 250 microamperes for use on exposed tissues in the operating theatre.

Specification

As the apparatus is used for the measurement of chronaxie the duration of the applied impulses has been made variable from 1 milli-second to 1.5 seconds in suitable steps. Duration control is illustrated in Fig. 1, which shows varying duration times d_1, d_2, d_3 and d_4.

For treatment purposes a range of frequencies between 50 and 500 cycles per second may be used and the duration of the component impulses controlled. It will be obvious, however, that the duration range must be limited by pulse frequency. In using such a current for treatment it is desirable to apply it in "surges" of more or less sinusoidal form, *i.e.*, the current impulses are modulated between zero and a predetermined maximum in rhythmic periods. Such modulation is provided for and can be varied between 6 and 30 cycles per minute; the modulation envelope can also be adjusted from the approximately sinusoidal to the direct interruption of a square-topped wave, Fig. 2.

Direct current is also available for iontophoresis† and electro-chemical

* Late Electro Medical Equipment Laboratory.

† The introduction of pharmaceutical ions into the tissues by means of an electric current.

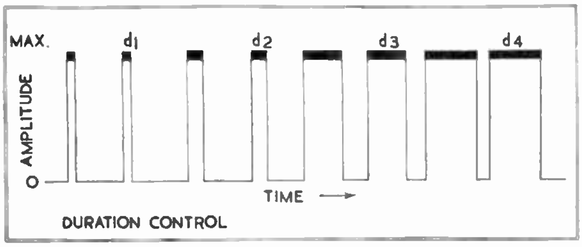


Fig. 1 (left). Illustrating varying duration of pulses

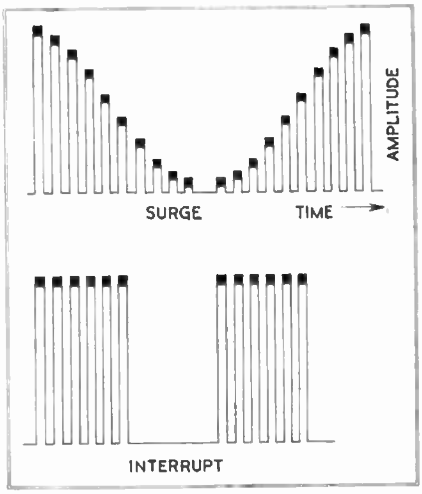


Fig. 2 (right). Illustrating varying types of modulation.

cauterisation or can be applied in surges or interruptions if required.

Chronaxie

Before proceeding with the technical description of the apparatus, the following brief description of "chronaxie" will be of use.

Muscular tissue will contract in response to electrical stimulation applied either directly to the muscle or indirectly through the motor nerves associated with it. In any neuro-muscular system to which electrical stimulation is applied, limiting values of current and time become apparent in the production of a contraction. There is a critical minimum value of current required to produce a contraction and no current below that value will be effective no matter for how long it is applied. Similarly, there is a critical minimum time period for which a current must flow and no current is effective in a shorter period no matter how much its value is increased. It should be borne in mind, too, that the strength of a contraction in any muscle depends upon the number of muscle-fibres taking part and not upon the extent of the contraction of individual fibres. A muscle fibre contracts when stimulated or it does not, there are no degrees of contraction. These facts give us a scientific basis upon which to work when measuring response to electrical stimulation, and such measurements, when accurately made, provide valuable data for the physician in making a diagnosis and from which favourable or unfavourable prognosis may be derived.

In measuring chronaxie a current value is found which, when caused to flow for infinite time, will produce a minimal contraction in the muscle under observation. (For this purpose any period in excess of one second can be referred to as infinity.) This current value is called the Rheobase and from it the true chronaxie may be obtained. Chronaxie is defined as that period of time for which a current, having twice the rheobasic value, must flow in order to produce the same minimal contraction.

It becomes obvious from all the above remarks that in an apparatus to be used for such purposes *currents of known value must flow for known periods of time* and it is also apparent that the time taken in attaining maximum value from zero and in returning to zero from maximum must be negligible in comparison with the shortest duration of current flow to be used.

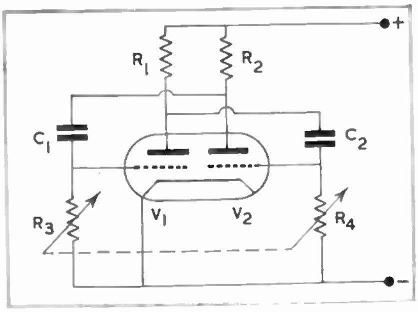


Fig. 3. Conventional multivibrator circuit.

Taking all the above requirements into consideration it was decided to design the apparatus to give a rectangular wave form to the impulses delivered to the output circuit.

Basic Circuit

Fig. 3 shows the conventional balanced multi-vibrator circuit used for impulse generation, frequency control being obtained by the dual adjustment of R_3 and R_4. Fig. 4 gives the circuit of the following stage in which the negative impulses from the generator are converted to positive impulses of rectangular wave form for application to the grid of the output valve. The impulse convertor circuit of V_3 and V_4 is best considered first in a static condition, *i.e.*, with the grid of V_3 switched to negative from R_{10}. It will be noticed that the anode resistor R_6 of V_3 forms part of the potentiometer across the H.T. supply with R_7 and R_8 and that V_3 — V_4 have a common cathode resistor R_9. By the adjustment of R_8 it becomes possible

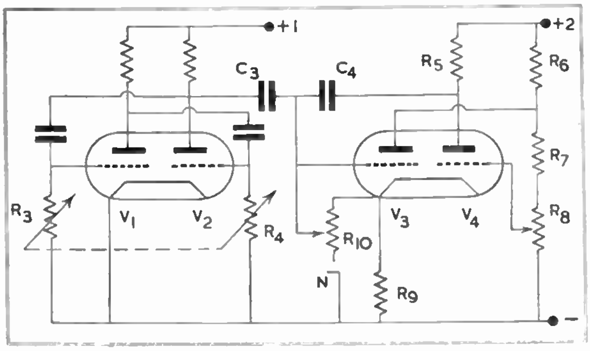


Fig. 4 (left) Impulse converter circuit.

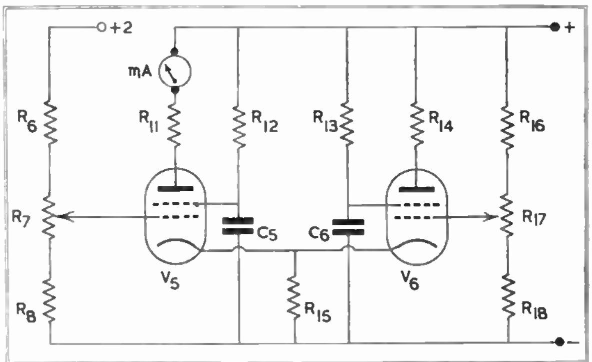


Fig. 5 (right) Output circuit. for Fig. 4.

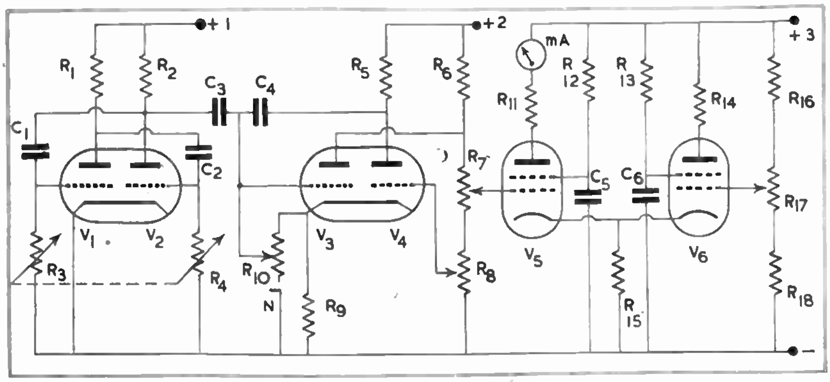


Fig. 6. Circuit embodying the three stages of Figs. 3, 4 and 5.

to cut off anode current in V_3 completely by reason of the p.d. developed across R_9 due to anode current in V_4. Now if the grid of V_3 is returned to cathode potential at R_{10} anode current will flow with a resultant IR drop in R_6 and a fall in potential across R_7 and R_8. This is sufficient to cause the anode current in V_4 to become cut off as the grid volts, taken from R_8, become more negative. The coupling condenser C_3 permits negative impulses to reach the grid of V_3 from V_2 and the grid is held negative by the charge on C_4 for a period of time depending on the relative values of C_4 and R_{10}. As the charge on C_4 leaks away through R_{10} a point will be reached at which V_3 will again draw anode current due to the simultaneous changes of grid potential on V_4 through R_8 and V_3 through C_4 and the original condition will be restored.

It will be seen that the potential occurring in R_7 and R_8 will have a rectangular wave form of a duration which depends upon the value of R_{10} and a frequency determined by the setting of the values of R_3 and R_4 and can now be fed to an output circuit such as that shown in Fig. 5.

This stage consists of two tetrodes having a common cathode resistor R_{15}. The anode resistances $R_{11} - R_{14}$ have similar values and screen potentials are fed through $R_{12} - R_{13}$ in the usual way. V_6 is, in this case, a ballast valve which assists in maintaining a constant load on the supply source. The circuit is adjusted in the first place with the $V_3 - V_4$ stage switched out and $R_6 - R_7 - R_8$ functioning purely as potentiometer across the supply to these valves; R_7 is set at the negative end and R_{17} adjusted until the anode current in V_5 is completely cut off while that in V_6 is at maximum. Adjustment of R_7 to the positive end will reverse this condition, the anode current in V_5 becoming maximum and that in V_6 a certain minimum value depending upon circuit constants. In this stage, then is provided the full amplitude control.

Fig. 6 is a circuit diagram incorporating the three essential stages and the method of operation is easy to follow. The grid of V_3 is made negative by being switched from R_{10} to N and R_7 is adjusted to give the required value of anode current in V_5. The grid of V_3 is now returned to R_{10} at the appropriate setting for the impulse duration required. $R_3 - R_4$ are set to the correct value for the impulse frequency and the $V_1 - V_2$ circuit switched on. As each negative impulse is delivered to the grid of V_3 from V_2 the V_3 anode current is cut off and held off by the action of C_4, a positive impulse of the same duration is applied to the grid of V_6 and a current impulse of the required value flows through V_5 in the output circuit.

So much for fundamental circuit operation. It will have been realised by now that a great deal depends upon the correct calculation of resistance values for success and not a little upon reasonable stability of H.T. supply, which latter can be attained by the use of a Stabilovolt tube. The positive side of the supply is earthed in order to protect the patient.

Certain modifications to the output stage are required before the circuit can be put to practical use, these are shown, together with the modulating

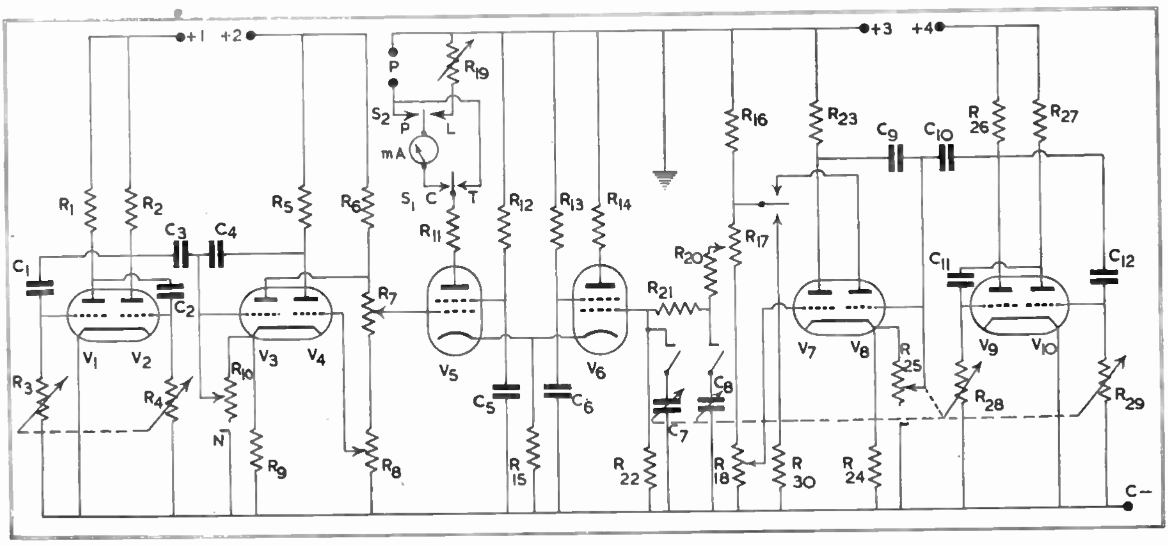


Fig. 7. Complete circuit with modifications and "dummy patient."

circuit in Fig. 7. It is desirable, though not essential, that the patient load be known, and for this purpose a dummy load comprising the variable resistance R_{19} may be substituted for the patient by means of the switch S_2 in conjunction with the switch S_1 which functions as a "Treatment-Calibrate" change over. With the patient connected at terminals P, S_1 is put to the calibrate position C and S_2 to the patient position. R_7 is now adjusted carefully until the smallest readable current is indicated on the meter (this will depend, of course, upon the full-scale reading of the instrument which should not be greater than 1 mA., without shunt resistances).

R_7 is left set and S_2 changed over to include R_{19} in circuit and this is adjusted until the meter reads the same current value as that taken by the patient. Conditions in the dummy circuit will now be the same as those in the patient circuit whch may be considered as a purely resistive load.

With regard to the modulating circuit, it will be seen that this is similar in most respects to the impulse generator and convertor circuits of $V_1 - V_2$ and $V_3 - V_4$. In this case the valves $V_9 - V_{10}$ function as an impulse generator in exactly the same way, the only difference is in the time constants of $C_{11} - C_{12}$ and $R_{24} - R_{29}$, which give the range 0.05 to 0.5 impulses per second, controllable through $R_{24} - R_{29}$. The impulse convertor circuit $V_7 - V_8$ differs from that of $V_3 - V_4$ in that the time constant of $C_9 - R_{25}$ is longer than that of $C_4 - R_{10}$ and is controlled through R_{25} in tandem with $R_{28} - R_{29}$. The reason for this is to maintain a constant relationship between the periodicity and the duration time of the surges. The network formed by $R_{20} - R_{21} - R_{22}$ with $C_7 - C_8$ in circuit distorts the rectangular wave of potential normally developed across $R_{17} - R_{18}$ into a wave form closely approximating the sinusoidal for the purpose of "surging" the output from V_5. When sudden interruptions are required in place of the gradual surge the condensers $C_7 - C_8$ are switched out of circuit. $C_7 - C_8$ are simultaneously adjusted in steps of suitable value to conform with the periodicity of the surges and are ganged together with $R_{25} - R_{28} - R_{29}$. The resistances $R_{20} - R_{21} - R_{22}$ are all of the same value so that in order to provide the necessary grid-swing to V_6 across R_{22} the potential change in $R_{17} - R_{18}$ must be three times that required.

It is important to remember that V_3 operates in opposition to V_5 (it is 180 degrees out of phase in other words) and that in order to reduce the output from V_5 to zero from its present maximum it is necessary to swing the grid of V_6 in a positive direction. The adjustment of R_{17} must therefore be carried out when V_8 is drawing anode current through R_{16}, and when the surger or interrupter circuit is not required a suitable shunt resistance R_{30} is substituted.

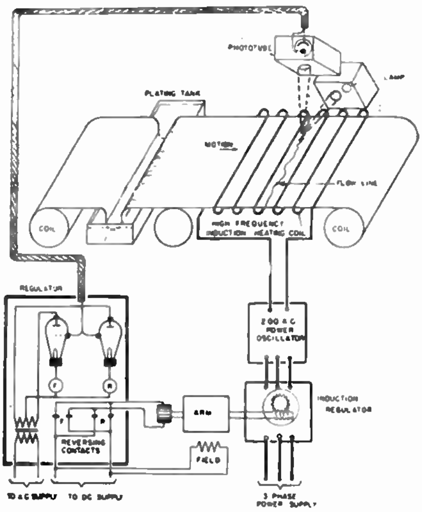
An apparatus with a circuit similar to that of Fig. 6 is in constant use by Dr. Bauwens at St. Thomas's Hospital and has proved to be extremely satisfactory: an experimental unit incorporating the surger and interrupter circuit has been built and, though not at present used for physiological or electro-therapeutic purposes, is a useful and interesting piece of equipment. Fig. 8 shows the complete circuit with the output modification mentioned above and indicates the method of stabilisation used. The values of the components are only approximate, as so much depends upon individual requirements.

The circuit forms the subject matter of Provisional Patent Specification No. 6199 dated April 17, 1943, and Patent No. 506544.

Electronic Control of Tinning

—From a paper read before the American Institute of Mechanical Engineers by E. H. Vedder, Westinghouse Elec. and Mfg. Co., Pittsburgh.

THE wartime shortage of tin has brought about the necessity for thinner coating of tin on strip steel for cans. This has been accomplished by the electrolytic tinning process, which leaves the tin surface with a silvery appearance and somewhat porous structure. It is necessary to heat the strip enough to melt and flow the tin, and thus obtain a more perfect coating. Not only does an electronic high frequency oscillator supply power for flowing the tin after electroplating, but it is also necessary to regulate the flowing of the tin so that exactly the right amount of high frequency power is furnished and thus avoid spoilage. If too much power is furnished to the high frequency induction heating coil, the flow line will occur much earlier in passing through the heating coil than it would at lower power levels. It is therefore desirable to maintain



TIN FLOW REGULATOR

Diagrammatic arrangement of control unit.

the power input to the heating coil at a level which will cause the tin to flow at a certain predetermined position in the coil. The flow line is readily distinguished because the tin coming directly from the plating tank has a very diffusing surface whereas that tin which has been flowed has a mirror surface. The regulating system is shown in the diagram in which a light source and photo-tube scans the plated strip and detects the exact line at which this change of condition occurs. If the position of the tinning line changes it is necessary to accordnglyi modify the power input. This is accomplished through the scanner which observes that the position of flow line has changed and through the regulator energizes the induction regulator motor so as to increase or decrease the amount of power and bring the flow line back to the proper position.

The Future of Electronic Music

By S. K. LEWER, B.Sc.

A RAPID broadening of the interest in electronic music may be expected in the post-war years both in technical circles and in the sphere of public entertainment. In order to prepare the way for future developments, it is important to take stock of past history in the art of electronic music and to look fairly and squarely into the possibilities and the dangers which lie ahead.

There is no doubt that a great deal of harm can be done by permitting premature public demonstrations of insipid novelties. Public opinion can easily be prejudiced by the exhibition of immature technical developments to such an extent as to cause it to reject out of hand a subsequent invitation to hear the perfected instrument—a case of " once bitten, twice shy."

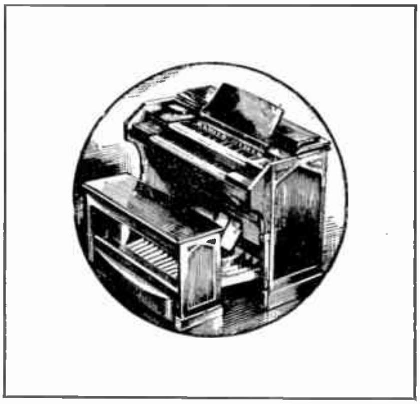
The Musical Profession

While the electronic profession may look upon these new musical instruments with enthusiasm, the public cannot be expected automatically to respond favourably to any and every technical development, however ingenious it may be. Moreover, the professional musician is strongly conservative and abhorrent of change. This is quite natural, of course, for his livelihood depends upon his skill in exposition with established instruments, and he may be in danger of losing his status if he experiments with novel techniques and new-fangled devices. There may even be a feeling of resentment if there is a risk of being out-moded.

It should be remembered, however, that the present-day professional musicians are in fact enjoying the fruits of their forefathers' labours in the establishment of new instruments and the acquiring of new skill. Like their ancestors, modern musicians will have to be prepared to march with the technical progress of the age.

Electronic v. Acoustic Instruments

The degree of tolerance which has been, and still is, shown towards the conventional musical instruments is truly amazing. The pipe organ contains some hundreds or thousands of pipes which occupy large volumes of valuable space and have to be tuned every few months. An ordinary grand piano is inconveniently large for the average small house (positively too large for some) and all pianos are far too heavy to be lifted by one man.



The Hammond Organ: a well-known electronic musical instrument.
(Messrs. Boosey & Hawkes)

Amongst the orchestral instruments, the brass and woodwind have to be drained out on to the carpet during the performance.

It is, of course, largely sentiment as well as true musical appreciation that accounts for the ready tolerance of these defects, and the new electronic instruments will have to be able to offer more important and more striking advantages than the mere removal of such drawbacks as these to which the public habitually turns a blind eye. The arguments in favour of the new instruments must be overwhelming: hence the vital necessity of demonstrating nothing but the best that can be devised.

No harm is caused when new and perhaps only half-developed electronic methods of producing music are discussed in technical circles, for it is then possible that constructive criticism may lead to more rapid progress. But the public is satisfied only with the finished article and will not generally give its support to new devices which are still in their teething stages.

Perhaps it would be presumptious to look for the complete substitution of all existing acoustic instruments by their electronic counterparts. It is reasonable to retain those which can continue to give satisfactory performance, especially in circumstances where the lack of a supply of electrical energy precludes the use of electronic instruments. Further, the combination, as in a *concerto*, of acoustic and electronic instruments may shortly become one of the most popular forms of musical exposition.

Acoustic Instruments at their Zenith

A state of finality appears to have been reached in the progress of acoustic musical instruments. It is a fact that there has been remarkably little change in the design and construction of practically all orchestral instruments for many generations, and probably no important improvements can be expected. The piano. which is the outcome of a long line of developments starting with the clavichord in the 16th century and following on through the spinet and the harpsichord, was introduced in the early 18th century, but has undergone little alteration in the last hundred years.

The organ has taken over 1,000 years to reach its present stage. In the latter part of its career, after its capabilities were more fully appreciated, it was called upon to imitate various instruments of the orchestra as a major function. The quality of the imitations is undeniably poor, although the musical effect is generally acceptable. The stops are still given such fanciful names as *viola da gamba*, *trumpet*, and *trombone*, but nobody with an ear for musical tone could fail to distinguish between the organ and the instrument itself. To explain the enormous popularity of the pipe-organ we must recognise its appeal as a " one-man band " and its suggestion of power arising simply from the relatively large sound-wave amplitudes which motor-blowers can produce. Its vast complexity of tones and the effects of " build-up " are more subtle but also important.

The Electronic Organ

Serious work extending over the last 10 to 20 years has been carried out on the design of electronic organs of various types, and there is no doubt that this is the kind of development which is most strongly attracting the attention of electronic engineers at the present time. It is pertinent to ask, therefore, whether an attempt should be made to imitate the tones of the pipe-organ (which are themselves imitations) or whether, if it be a technical possibility, the new electronic organs should be designed to imitate the tones of the orchestral instruments directly. The characteristic pipe organ stops, such as the *diapason*, do not enter into this question, of course, and naturally call for separate consideration. It is the author's opinion that any measures which can be taken to make the introduction of electronic-musical instruments more gradual, will surely make their acceptance more certain. Therefore, it is suggested that in designing an electronic organ, every effort should be made to simulate accurately the conventional pipe-organ tones, and as far as possible to provide *in addition*, tones which can be accepted as an improvement upon the orthodox organ tones.

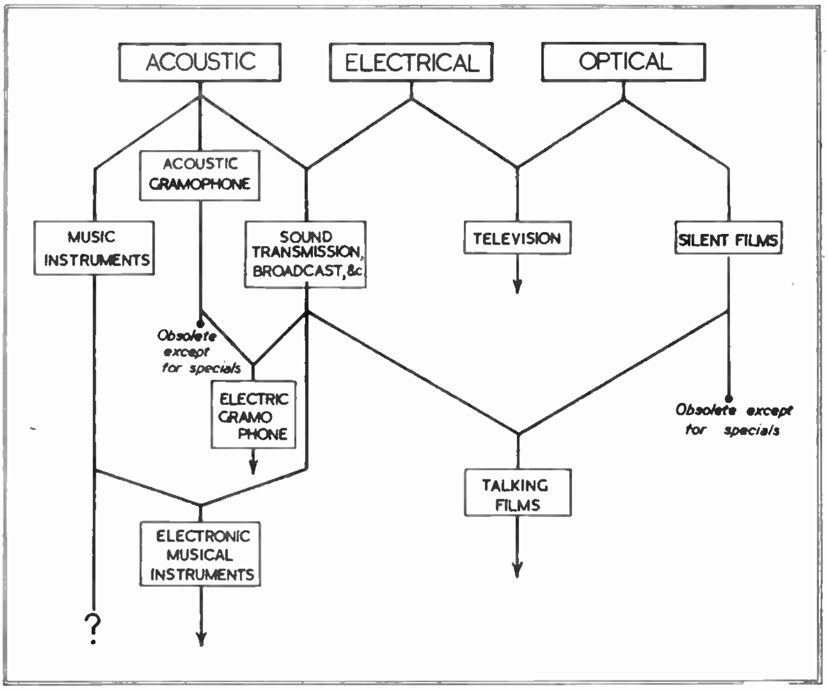
The Electronic Piano

There is unquestionably ample scope in the realm of the electronic piano. It is no longer necessary to resort to the use of heavy steel wires stretched under colossal tension, huge cast-iron frames and expansive sounding-boards. These can be replaced by lighter and more compact systems using electronic generation with the added advantage of vastly improved control over the sound intensity and quality. Not the least of the advantages of dispensing with the sound-board is the unhampered freedom which can be accorded to the learner, for headphones or a loudspeaker operating at a reduced amplitude will provide the necessary sound for practice purposes.

The acoustic gramophone has given way to the electric pick-up and nobody disputes the superiority of the modern method over the old. Similarly, there seems to be no reason why the electronic piano should not eventually displace the present-day acoustic type of instrument. Technically, the electronic piano is ready for the market, but before it can be established it will be necessary to overcome the sheer sentiment which is inevitable with an instrument having such a fine tradition. In many cases, also, there is a certain amount of snobbery associated with the possession of a good-looking piano, particularly if it is a " grand."

The Union of two Techniques

With the advent of the talking picture, the existing art of the silent film underwent a metamorphosis. The cinema, with its wordy captions and its versatile pianist, was a well-founded institution before the recording and reproduction of sound had reached a sufficiently advanced stage for its application to film technique, but in spite of the financial and artistic stability of the silent-film business the adventurous transition to the sound film had to be faced. The union of the two arts—the photographic and the electro-acoustic—had at last become a technical possibility and nothing could prevent its ultimate acceptance.



The physical basis of music and entertainment, showing the influence of electricity.

Such a union of different techniques may be hampered by pitfalls and misguided enthusiasm. The process is not an easy one. It requires tact and tolerance and a sincere appreciation of existing traditions and prejudices. There must be give and take between art and science. In the case of electronic music, it is evident that the motive originates in the electrical profession rather than in the musical profession. The theoretical study and the practical experience of the electrical man are constantly suggesting to him interesting methods of generating and controlling sound by electronic systems. If he has some appreciation of musical requirements, sooner or later he will devise an instrument for producing music electronically. It is highly improbable, on the other hand, that the professional musician will encounter anything in the course of his work to suggest new methods of producing music—electronically or otherwise.

The advances must therefore be expected to come from the electronic engineer, but it should be remembered that he is in no position to dictate to the musical world. He can offer new instruments, produce new tones, and devise new systems of control, but it is musical opinion which will eventually decide whether they are acceptable.

The Technical Possibilities of Electronic Music

A closer examination of the possibilities of electronic music can best be made under the following headings: (1) tone, (2) envelope, (3) playing technique, (4) exposition, performance, combination.

(1) With regard to tone, it is suggested that this is primarily a matter of education. The human perception of sound has not been saturated with all the possible pleasurable varieties of tone. The soft sound of a felt hammer on a steel string in a pianoforte was once a novelty, and not immediately welcomed, but the greater range of expression of the piano over the previously popular instruments held the attention of the public long enough for the new tones to be generally appreciated and accepted.

(2) Similarly in respect of envelope, there remains a large unexplored field. In the past, envelope and tone have been almost inseparably linked together owing to the unavoidable restriction of the control over the mechanism of sound generation. With electronic methods, the complete separation is readily achieved. It has been said that if the main constituents of the tone of a piano could be sustained, the effect would resemble that of a saxophone. The importance of the shape of the envelope can be demonstrated most convincingly by playing a gramophone record backwards: the pitch and harmonic content of every tone remain unchanged, but the shape of the envelope is reversed on a time scale—with such effect as to make the

recognition of the instrumental tone character very difficult, if not impossible.

(3) The question of playing technique has been entirely dependent on the practicalities of the instrument in the past. The posture of the player has been dictated by the mechanical fundamentals of the instrument, as for instance, in the case of the violin, 'cello, French horn and bassoon, and not always has it been a comfortable pose conducive to easy performance. In electronic instruments, complete freedom can be assumed in the design, so as to place the smallest demand on the physical dexterity and endurance of the player.

(4) It is not proposed to discuss exposition, performance and combination at length, for this is a question of musical art. It may be remarked, however, that the tonal beauty of an instrument is evident only when it is played—and that the same instrument can, unfortunately, be made to produce hideous noises if the necessary skill is lacking. Mention need only be made of a scraping violin, a jangling piano, or even a gramophone with varying speed. The real charm of a new instrument may not become apparent until it is played with true, sympathetic understanding of its character. And in close connexion with this is the question of the musical score. Many instruments demand special scoring if their intrinsic beauty is to be revealed—for instance, the harp and the flute—and this may be true also in respect of new electronic instruments, although it would appear more rational to design the new instrument to be suitable for rendering existing scores and to await the advancement in the technique of specialised composition.

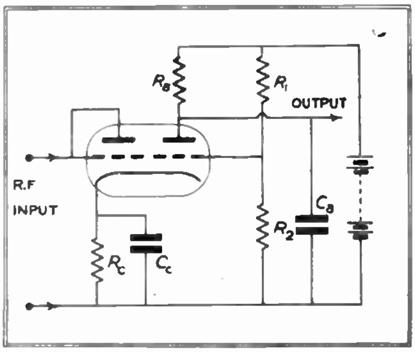
The Importance of Electronics to Musical Art

An analysis of the technical developments in public entertainment which have taken place in the acoustic, electrical and optical branches of applied science is set out in the chart. This suggests that where electrical methods have been applied to the previously established practices, the results are progressive, but where electrical methods have been excluded, the tendency is for the art to become stagnant or obsolescent, or at least restricted to special requirements. The implication is that by the adoption of electronic processes, musical instruments will enter a new sphere of popularity. The unchanging acoustic instruments may continue to fill a minority need, like the acoustic gramophone and the silent film.

CORRESPONDENCE

The Cathode-Coupled Double-Triode Stage

SIR,—In your issue for May, Dr. Williams considers the circuit where two halves of a double triode are coupled by a common cathode resistance. We have for some time made use of a connexion rather similar to his Fig. 6(a), for the measurement of small changes in R.F. amplitude, at frequencies from zero upwards.



As can be seen from the diagram, the R.F. input is rectified by one-half of the double triode, driving the cathode positive. If the second grid is biased to a suitable fixed potential by means of R_1 and R_2, voltage changes on the cathode are reproduced in amplified form at the second anode. The cathode condenser C_c must be made small enough for the cathode to follow the highest modulation frequency encountered; R_c is not therefore effectively by-passed for audio-frequencies, and introduces negative feed-back, but by keeping $R_a \geqslant R_c$, this can be prevented from reducing the gain too much. C_a is introduced to cut out any residual R.F. from the output.

With an H.T. supply of 350 volts, a peak R.F. input of 100 volts can be handled, when an output of perhaps 100 volts is provided from a 10 per cent. change in input.

Yours faithfully, B. E. NOLTINGK.

(Research Dept., The Institution of Automobile Engineers.)

Extension of Patents

From the Chartered Institute of Patent Agents.

SIR,—The war has prevented or hindered the working of many patented inventions which are commercially useful in ordinary times but which must be more or less put aside in wartime. By way of compensation (and provided that the patentee keeps the patent in force by payment of renewal fees to the end of the full normal period) the law provides that the term may be extended in cases in which such war loss can be proved.

In no sense is this extension of patent term automatic. Application must be made to the High Court supported by affidavits which have to contain complete evidence as to the nature and extent of the effective loss of term due to the war. The Court will consider the case in the light of the arguments of the patentee's Counsel and "opposing" Counsel briefed by the Board of Trade, and, if satisfied, will grant a period of extension equivalent to the period deemed to have been lost on account of the war up to the normal date of expiry. Application for extension must be made when this date is approaching, so that in the case of patents which expire during the war any extension granted is inadequate and in due time the patentee must come to the Court for a further extension to render the previous extension an effective compensation.

This procedure involves the patentee in no small expense to recover part of the life of his patent, lost through circumstances beyond his control. Experience has shown that the cost of an application in Court is generally of the order of £200 and may be considerably more. When he applies again to the Court towards the end of the extended term of the patent to ask for a further extension to render the original extension effective, the patentee will have further costs to pay.

My Institute considers that this trouble and expense, inherent in High Court proceedings, impose an unfair hardship on patentees and undoubtedly deter many from putting forward a justifiable application for extension. In its opinion, the procedure should be greatly simplified and cheapened, and it urges again the recommendation it made with this object two years ago that these applications for extension of the term of patents should be dealt with by the Comptroller-General of Patents (who is well accustomed to adjudicating on matters supported by evidence in the form of Statutory Declarations). The matter is urgent, for delay in dealing with it will deprive many a patentee of the opportunity of recovering his lost rights on fair and reasonable terms.

Yours faithfully, E. J. BLOOMFIELD,
Acting Secretary and Registrar.

Plastic Enamelled Wire

"THERMEX" enamel, produced by The British Thomson-Houston Company, is probably the most outstanding development in wire insulation of recent years. As will be seen from the data given later, the characteristics are far superior to those of conventional enamel and other wire coverings.

It may be added that this same type of wire under the name of 'Formex" has been extensively used in America.

There have been considerable difficulties in improving on conventional enamelled wire, but a skilful combination of a polyvinyl acetal resin, which possesses exceptional toughness and resistance to abrasion, with a thermo-setting phenolic resin has enabled "Thermex" enamel to be produced from wholly synthetic sources.

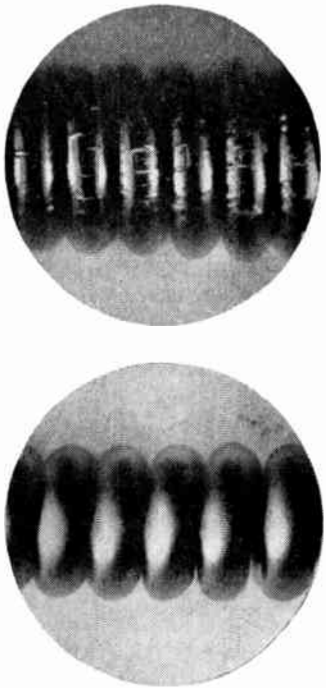
"Thermex" enamelled wire complies with the requirements of B.S.S.156 for enamelled high conductivity annealed copper wire in every respect. It has, however, certain definite advantages which are summarised in the following paragraphs.

Flexibility and Abrasion Resistance

Plastic enamelled wire is decidedly more flexible and much more resistant to abrasion than conventional enamelled wire. In the absence of any accepted abrasion test, it is difficult to draw any quantitative comparisons; but tests show that "Thermex" enamelled wire is at least three times as good as conventional wire in this respect, and extended production experience has amply confirmed that this theoretical superiority is more than borne out by shop experience. It has in fact been established that the plastic enamel film, due to its toughness and tenacity of adhesion to the copper, is so resistant to accidental damage during winding operations that it has been possible to dispense with the cotton covering or other means commonly used to protect enamelled wire from damage.

Thermo-Plastic Flow

Most protective films on copper wire have a tendency to soften at high temperatures and some of the newer synthetic insulations have a distinct tendency to soften to a decided extent at comparatively low temperatures, *i.e.*, 70° C. Under similar conditions "Thermex" enamelled wire will withstand temperatures of the order of 170-185° C. for many hours without any serious tendency to deformation.



Comparison of Thermex and ordinary enamelled wire (at top) after stretching and winding on mandrels.

Thermex wire (right) and enamelled wire after 150° C. heat shock.

This description of Thermex wire with the accompanying photographs is abstracted from "B.T.-H. Activities," (Vol. 18, No. 2), by permission of the B.T.-H. Company.

Conventional enamel has some tendency to thermo-plastic flow at temperatures close to the maximum operating limit, but "Thermex" enamel has no softening tendency whatever within the temperature range met with in actual service.

Resistance to Solvents, Acids, etc.

The wire will successfully withstand immersion for prolonged periods in dilute acids, such as sulphuric, nitric, hydrochloric, and acetic, and in this respect is superior to other types of conventional and synthetic enamelled wire.

It is also more resistant to dilute caustic solutions than conventional enamel. "Thermex" enamel is not affected by prolonged immersion in most of the common solvents, such as acetone, white spirit, petrol, toluol, xylol, and methylated spirits. It is thus now possible to use certain types of thermosetting varnishes which could not previously be used except with extreme caution on account of their destructive effect on the enamelled wire film.

Temperature Rating

Although "Thermex" enamelled wire has very good heat ageing and heat shock resisting properties, it is essentially organic in nature and is therefore classified as a Class A insulating material according to B.S.S. standards.

Electrical Characteristics

A really well insulated wire should retain adequate dielectric strength at any temperature which the apparatus is likely to meet under service conditions. "Thermex" enamelled wire at 180° C. has an even slightly better breakdown strength than at 20° C. and is undoubtedly unique in this respect. The electrical characteristics of the plastic film are also substantially unaffected by exposure to humid conditions. Typical electrical characteristics of the wire are given in the tabulated summary below.

Diameter of bare wire (inch)	0.036
Thickness of covering (mils.)	1.25
Overall diameter (inches) ...	0.0385
Electric Strength (Volts):	
In air at 60° C. with rapidly applied voltage ...	4500
In air at 180° C. with rapidly applied voltage ...	4700
In air at 20° C. after 7 days in tropical atmosphere ...	4100
Insulation Resistance (megohms) at 150° C. ...	Above 500

Self - Testing Relays

By W. BACON, B.Sc. (Eng.) Hons.

NOT long ago the telephone engineer was thought to have almost a monopoly in the use of the relay. Developments such as automatic tuning have changed this. The number of relays used on radio communications apparatus is now considerable and is growing rapidly. Any means for reducing the time taken in testing relays are therefore of some importance.

Below is described a scheme by means of which several of the normal operations of relay testing may be performed automatically. Practical details are given of a piece of apparatus incorporating this principle, by means of which the majority of relays may be tested, and some suggestions are made for the extension of the method.

Normal Testing

The two properties of a relay normally required are the current at which it operates, and the current at which it releases.

Fig. 1 shows the method normally adopted. P is a D.C. power supply, the output of which may be varied continuously from zero upwards. The power supply is connected through a current-measuring meter to the relay on test. Output is increased till the relay operates, when the meter is read, and the "operate" current is obtained. A sufficient current is then passed to saturate the relay, after which the current is decreased till the relay releases and the release current read.

The disadvantages of this method are twofold.

(1) The operator has to turn output up slowly, in order to avoid overshooting the operating point of the relay. This therefore cuts down

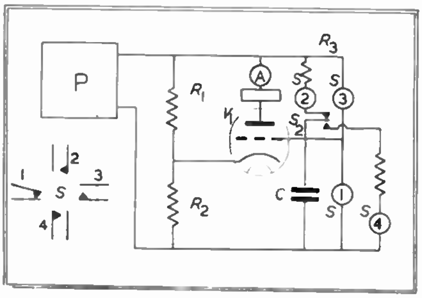


Fig. 3. Circuit for change-over contacts

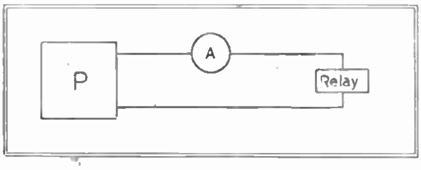


Fig. 1. Normal method of testing relay from D.C. supply

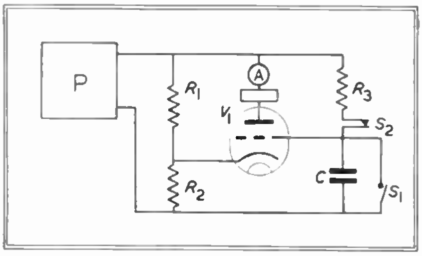


Fig. 2. Self-testing principle

the speed at which the measurement can be taken.

(2) There is no guarantee that the operating point has not been passed, and some difference might be expected in the results obtained by different operators.

The Self-Testing Principle

Fig. 2 shows the principle by means of which such a test may be made automatic.

The power supply is turned fully up and connected to the relay and current meter in series with the valve V_1. R_1 and R_2 are two resistances of values such that with the switch S_1 closed, the valve V_1 has a large negative bias. It hence takes only a small current, much less than that required to operate the relay. S_2 are any contacts which open when the relay is operated.

The action is as follows. On opening the switch S_1 condenser C charges through the resistance R_3. The voltage on the grid of V_1 hence goes less and less negative. The current through V_1 and the relay therefore increases until the operating point of the relay is reached. Contacts S_2 then open. C is now no longer being charged, but if of large capacity and good quality, will retain the charge it has for some considerable time. The anode current of the valve read on the meter, thus stays constant at the "operate" current of the relay.

A similar circuit may be used to determine the release current of the relay. In this case, however, the condenser is initially charged; it discharges through a resistance which is cut off by means of a pair of contacts which break when the relay is not operated.

Circuit for Change-over Contacts

The circuit of a complete tester suitable for any relay having change-over contacts is shown in Fig. 3. A development of this circuit is considered later which enables any relay possessing break contacts to be tested in addition.

S_2 are the relay change-over contacts. (1), (2), (3), and (4) are the sets of contacts of a four-position switch, shown in Fig. 3a. One set of contacts is closed in each position, *e.g.*, set (1) in position one.

With the switch in position (1), the condenser C is shorted and the current through the relay is very low. On turning to position (2), C charges through the resistance R_3 and the relay contacts. This continues until S_2 changes over, the meter then reading the operate current steadily.

Switching to position (3), makes grid voltage considerably more positive, thereby giving the saturate position. In position (4), C discharges through R_1 until the release current of the relay is reached. S_2 changes over, stopping the discharge, but there is now no charge path through

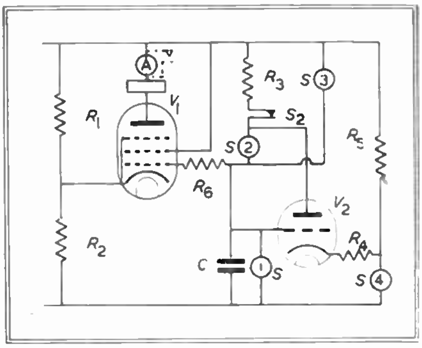


Fig. 4. Circuit for break contacts

R_1 = 5,000 Ω	R_6 = 220,000 Ω
R_2 = 750 Ω	C = 8 μf
R_3 = 220,000 Ω	V_1 = Mullard EL2
R_4 = 50,000 Ω	V_2 = Osram L63
R_5 = 20,000 Ω	

R_3. The meter thus reads steadily the release current of the relay. Turning to position (1) again restores the initial conditions.

It will be observed that the entire operational test of the relay has been performed by rotating the switch S_1. If a jig is provided for making contact with the relay tags, the test can thus be carried out very quickly and easily.

Circuit for Break Contacts

Fig. (4) shows a development of the circuit of Fig. 3 which may be used to test any relay having contacts which open when the relay is operated. This, of course, includes all relays having change-over contacts.

An additional valve, V_2, is used, connected as shown. In positions (1), (2) and (3), the cathode of this valve is at the same potential as its anode. No current is therefore taken by V_2, and the operation in the first three positions of the switch is as has been described previously. In position (4), V_2 cathode is earthed through R_1. V_2 hence draws grid current and C discharges until the release current of the relay is reached. Contacts S_2 then close, thereby completing the anode circuit of V_2. V_2 now draws anode current. The voltage drop produced by this in the resistance R_4 raises the cathode potential of V_2 above the grid potential, and V_2 hence no longer takes grid current. C, therefore, no longer discharges and hence the meter reads steadily the release current of the relay.

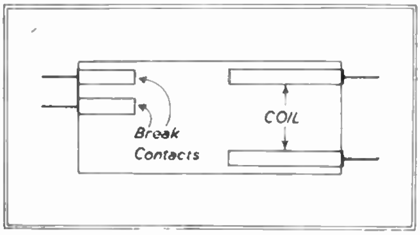


Fig. 5. Test jig.

Practical Details

Values used by the writer in a tester suitable for relays taking a few milliamps are indicated in Fig. 4. The time constants of the resistor-condenser combinations were adjusted with some care to give reasonably rapid operation without overshooting the operating or release currents of the relay. In addition to the contacts shown, it is convenient to add an extra pair in position (3) (shown dotted) for shorting out the meter when saturate current is being passed. The grid resistance R_6 is necessary in order to avoid excessive V_1 grid current in the saturate position.

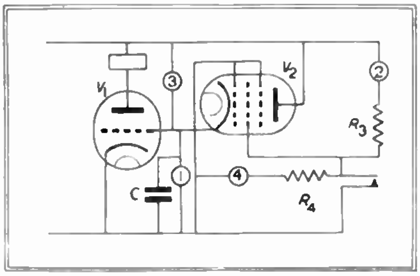


Fig. 6. Circuit for make contacts.

A simple jig used is shown in Fig. 5. It consists of four tinned copper strips, slightly sprung, and spaced to suit the relay tags. The relay is held on to this during test with one hand, whilst the switch is rotated with the other.

Suggestion for Make Contacts

The circuit described above will test the majority of relays but not those possessing only contacts which close when the relay is operated. The writer has not as yet constructed a tester for doing this, but in case others may wish to undertake work along these lines, a suggestion is appended for doing so. It should be emphasised that this circuit has not been tried out, and might therefore involve practical difficulties. (*See* Fig. 6.)

A charging valve V_2 is used. On position (1) C is shorted and V_1 current is low. On position (2), C charges through V_2 until the operating point of the relay is reached. Contacts S_2 then close, earthing the screen of V_2 and stopping the charging current of C. Operate current is then read. Saturation is carried out as before in position (3). In position (4) C discharges through R_4 until the contacts S_2 open. There is now no charge path through R_3, the charge on C hence remains steady and release current is read. Position (1) restores the initial conditions.

Application

The method is obviously of most use where it is necessary to test a large number of relays of the same, or a similar, type. At the expense of greater complications the test could be made even more automatic; for example, a small motor might be used to rotate the switch at a predetermined rate.

NOTES FROM THE INDUSTRY

(*Photo—Odhams Press*)

Radio Industries Club

At the Annual General Meeting of the Club, held at the Connaught Rooms in April, Sir Noel Ashbridge was again invited to act as President for the ensuing year.

Mr. H. de A. Donisthorpe, the Chairman, was presented with a cheque and testimonial as a token of appreciation of the work which he has done in organising the Club so successfully.

Before the formal business, the meeting was addressed by Col. David Sarnoff, the President of the R.C.A., who was the guest of honour. The photograph shows Col. Sarnoff with Sir Noel and Mr. Donisthorpe, with Major Peter in the background.

Taylor, Tunnicliff & Co.
Change of Address

Messrs. Taylor, Tunnicliff, including Taylor Tunnicliff Refractories, Ltd., and Electric & Ordnance Accessories, Ltd., have removed to 125, High Holborn, W.C.1. Phone: HOLborn 1951/2.

Mr. W. F. Newell to AVO

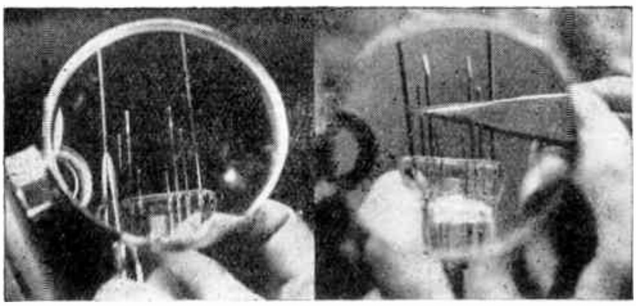
Mr. W. F. Newell, who is well known to many in the radio industry from his long association with Sangamo-Weston, Ltd., has resigned his position to take up that of Technical Contracts Manager with The Automatic Coil Winder & Electrical Equipment Co.

Discharge Tubes in Industry

A recently issued leaflet by the G.E.C. shows the remarkable improvement in lighting of small part assembly benches by the use of Osram fluorescent lamps of the discharge tube type.

The photograph shows a magnified view of a valve stem as seen by light from a localised tungsten lamp and by light from a fluorescent tube. In the second case there is almost complete absence of shadow and hard reflexions, the illumination being even and soft over the whole area.

Copies of the leaflet are of particular interest to the lamp and valve making industry. Ref. GW/8950/4/44.



Valve pinch viewed by ordinary lighting and by fluorescent lighting.

(By courtesy of the G.E.C.)

"Elastomeric Engineering"

This is the title of a well-produced data booklet by the Andre Rubber Co., of Kingston By-pass, Surbiton.

It describes the application of elastic materials to engineering structures, principally in combination with metal to produce shock-absorbing mountings and couplings. Full dimensions of typical components are given and there is a useful glossary of terms. Copies of the booklet are available to *bona fide* engineers on application to the Company.

JUNE MEETINGS

Institution of Electrical Engineers
Students Section

A visit has been arranged for Saturday, June 3, at 9.30 a.m., to the works of Messrs. Everett, Edgcumbe and Co., Ltd. (precision instrument makers), Hendon.

Institute of Physics
Electronics Group

The next meeting of the above will be held on June 10, at 2.30 p.m., in the rooms of the Royal Society, Burlington House, London, W.1. The meeting will take the form of a discussion on "Some Aspects of High Vacuum Technique—High Vacuum Gauges and Glass Manipulation" and will be opened by Dr. M. Pirani and Dr. B. P. Dudding.

Association for Scientific Photography

The Annual General Meeting of the Association will be held on Saturday, June 24, at 2.0 p.m., at the Group Room, Y.W.C.A., Central Club, Great Russell Street, London, W.C.1.

This will be followed by a meeting at 3.0 p.m. (held jointly with the Scientific Films Association), at the Large Theatre, Ministry of Information, Malet Street, London, W.C.1. The subject will be: "The Construction and Presentation of Scientific Films."

Television Society

A meeting of the Society will be held at the Institution of Electrical Engineers, on Saturday, June 3, 3.0 p.m., when a paper will be read on: "The Colour Characteristics of Photo-cells" by Dr. A. Sommer (Messrs. Cinema Television, Ltd.). Tickets of admission for visitors can be obtained from the Editorial offices of this Journal.