Electronic Engineering

Published Monthly on the last Friday of the preceding month at 28 Essex Street, Strand, London, W.C.2.

Telephone CENTRAL 6565 Telegrams 'LECTRONING, ESTRAND, LONDON'

Managing Editor H. G. Foster, M.Sc., M.I.E.E.

Subscription Rate: (Home or Abroad) Post Paid 12 months 26/- or $3·75 (U.S.).

Vol. 22. No. 271. September, 1950

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B. A. A. S.

In the excitement attending the opening of the Radio Exhibition in Birmingham the radio and electronic profession is apt to overlook an even more important scientific event which will conclude on the opening day of the Exhibition. The British Association for the Advancement of Science is holding its 112th Annual Meeting at Birmingham University from August 31 to September 6.

The B.A.A.S., or, as it has been irreverently called, the British Ass, is not by any means the somewhat dry scientific gathering that popular and even technical minds are led to believe. It has had for its presidents most of the eminent names in the scientific world and many notable discoveries have been announced for the first time at its meetings. Faraday demonstrated the heating effect of induced currents at the second meeting after its foundation in 1831 and was vice-president on several occasions afterwards. Joule read his original paper on The Mechanical Equivalent of Heat before the 1845 meeting; Crookes delivered a paper on "Radiant Matter," which foreshadowed the cathode-ray tube.

The British Association had its origin in the attempt to collate various pieces of scientific research which were being performed in scattered laboratories and, in the words of its founder "to direct general attention to scientific matters." Its scope has widened with the expansion of science until there are now no less than thirteen specialist sections, of which Mathematics and Physics, Engineering, and Education form an important trio. This year atomic energy is prominent on the programme of papers, and Prof. Peierls and Sir John Cockcroft are both speaking on problems of high-energy particles. The engineers will hear papers on automatic control systems and the new science of radio-astronomy. There is a choice of visits to Accles and Pollock, Chance Bros., or Bass's Brewery, among many others.

Apart from its annual meetings, the British Association is noted for its contributions to standardization. It was a committee of the Association called by Lord Kelvin in 1861 which determined our present system of electrical units, and this committee continues to exist for the purpose of revising electrical standards when necessary. When the need for a fine screwthread to take the place of the Whitworth thread became evident, the British Association Committee laid down the dimensions of the B.A. fine pitch threads which are used so extensively by electronic engineers.

An engineer who feels that he ought to "do something" during part of his vacation might, in future, time it to coincide with a meetng of the B.A. He will find entertaining company, food for thought, and see works and places of interest that he would not normally visit. And on his return from the meeting he will probably handle a 6 B.A. tap with a little more interest.

G.P.

Microwave Lenses

By J. BROWN, M.A., and S. S. D. JONES, M.A.*

Part V

Recent Developments

IN addition to the types of lens dealt with in preceding articles of this series, all of which have been the subject of a considerable amount of theoretical and experimental research, the last few months have produced a number of new developments which are still awaiting practical application. These new developments make use of principles which are not a practical possibility in optical lens design.

Path Length Lenses

The first of these new developments is the path length lens, recently introduced by Kock.[6] It is well known that a stack of plane parallel conducting sheets, spaced in the direction of the electric vector, will allow the propagation of a plane wave to continue as if the plates were absent (cf. Part III). If such a stack is distorted or tilted so as to cause the incident radiation to deviate from its original path, it forms the basis of a path length lens, in which focusing is achieved by controlling the geometrical path length of the energy being radiated from the focus. In all the other types of lens so far discussed, focusing has been achieved by alterations in the electrical path length, obtained by means of changes in refractive index. The lens medium in the path length lens is always of refractive index unity; focusing depends on phase correction by varying the ray path length rather than by varying the velocity of propagation.

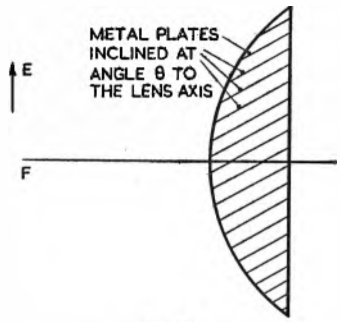


Fig. 36.
Inclined plate lens

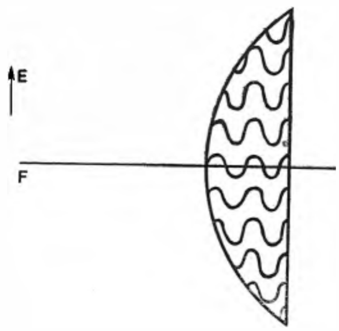


Fig. 37.
Serpentine lens

The simplest of these systems is shown in Fig. 36. The lens "medium" is the region constrained between the tilted parallel plates, which are spaced in the direction of the electric vector and separated by less than one-half wavelength apart, so that only the principal mode can be supported. It is apparent that, on account of the path deviation introduced by the tilting of the plates, the "medium" can be regarded as a refractive material of refractive index equal to sec θ, θ being the angle between the plates and the direction of the axis. Provided that the spacing between plates is less than $\lambda/2$, this type of lens has optical properties independent of wavelength, and, therefore, has even better broad band characteristics than the delay lens.

Another form of path length lens, also proposed by Kock,[6] is called the "Serpentine Lens" (Fig. 37). In this, the path length is increased by corrugating the conducting sheets into a series of sinusoids, rather than tilting them. This method overcomes the inherent disadvantage of the inclined plate lens, which, inevitably, distorts the amplitude distribution across the aperture with consequent increase in side-lobe level in the electric plane.

No detailed theoretical analysis of these path length lenses has yet been published; but it appears that Kock's treatment of the serpentine lens is somewhat over-simplified. The mode of propagation between the plates of a lens of this type must be essentially the same as that which occurs in the corrugated strip transmission lines used in the construction of travelling wave tubes. The assumption made by Kock that the medium has a refractive index given by the ratio of the length of the sinusoidal curve to the length of its axis of symmetry is therefore probably not entirely justified. Further theoretical work on this point remains to be done, together with an investigation of the reflexion losses of such lenses. It is worth noting that a path length lens may be regarded as a limiting case of a delay lens, in the same way as a metal plate lens is a limiting case of a rodded lens.

There is a further type of path length lens, which, although of rather limited practical application, is of interest as a realization of an optical device suggested by Wood.[24] A non-homogeneous transparent disk, whose refractive index is a suitably chosen function of the radial distance from the axis, will collimate the radiation from a point source. The required variation of refractive index is given by the

* Radar Research and Development Establishment, Ministry of Supply

equation $n = \dfrac{n_0 t + f - \sqrt{f^2 r^2}}{t}$ .... (56)

where n is the refractive index at the point distance r from the axis,

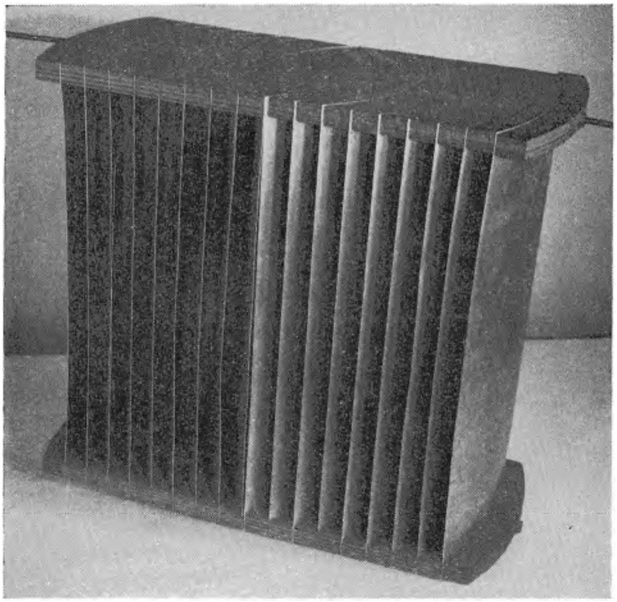
n_0 is the refractive index at the centre,

f is the focal length of the lens,

and t is the thickness of the lens.

A cylindrical analogue of this system is shown in Fig. 38, and consists of curved metal plates. The ratio of the length of the curved sheet at distance r from the axis to the thickness of the lens is chosen to be equal to the refractive index n as given by Equation (56). The lens shown in Fig. 38 is designed to collimate the radiation from a line source, and the shape of the plates is such that the geometrical path length from the line source to the outer face of the lens is the same for all possible paths through the lens. As in all configuration focusing devices, the electric vector must be normal to the direction of the conducting plates, and the spacing between the plates must be less than half the free-space wavelength. The method of lens construction which has just been described is limited to the production of cylindrical lenses, as the plates must always be perpendicular to the electric vector. The advantages of this method are the ease of construction and the inherent mechanical rigidity. A lens of this type will still operate satisfactorily after considerable accidental damage. It has the broad-band characteristics of all configuration focusing devices.

Fig. 38.
Cylindrical path-length lens



The subject of configuration focusing, i.e., focusing by means of variations in the geometrical path-length of the rays, is dealt with in general terms by S. B. Myers,[21] who considers the propagation between two parallel plates spaced apart by less than half a wavelength. It may be shown that in such systems the waves travel along the geodesics of the mean surface between the plates. Myers studies possible scanning systems making use of this principle: a surface has to be found such that all the geodesics from each of the possible feed positions to the aperture from which the radiated beam emerges, are of the same length. For practical reasons the aperture should usually be a straight line, and the curve along which the feed moves should be circular. Systems of this type form a possible basis of high speed scanners, and will be considered further at the end of the next section.

Non-Homogeneous Lenses

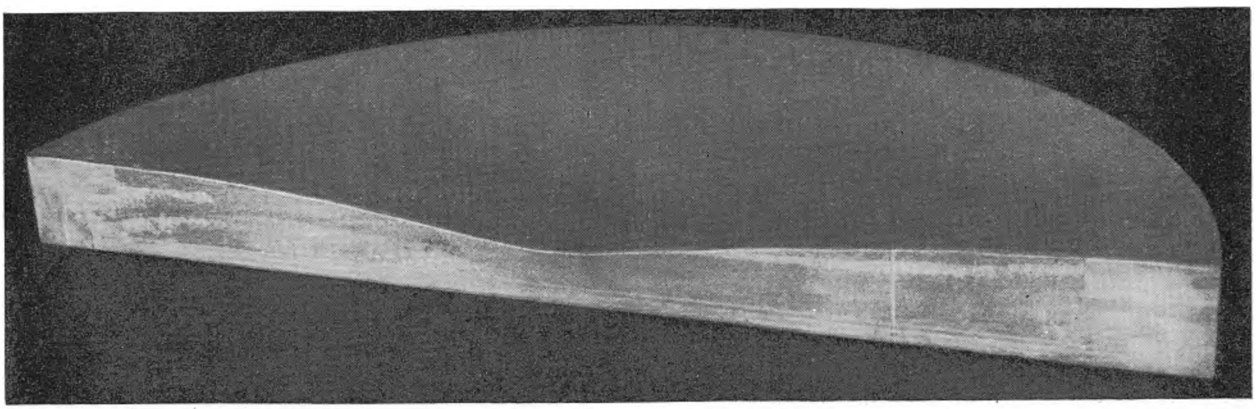
In optical lenses, the refractive medium must of necessity be isotropic. In microwave lenses, however, it is possible to make use of media in which the refractive index varies from point to point. The lens designer may make use of this variation in order to achieve many useful properties.

It has already been shown that the refractive index between a pair of parallel conducting sheets is given by Equation (31), which is repeated here for convenience.

$$n = \sqrt{(1 - \lambda^2/4a^2)} \quad \text{.................} \quad (31)$$

Since the refractive index is a function of the spacing a, between the plates, it is obviously possible to achieve any desired variation of refractive index by suitably altering the plate spacing. A region of non-homogeneous refractive index, produced in this way, will therefore consist of a pair of metal plates suit-

Fig. 39.
Half Fish-eye



ably bulged. One application of this principle is shown in Fig. 39, and is the practical realization of a suggestion of Clerk Maxwell. Maxwell showed in 1865 that a sphere, in which the refractive index varies according to the relation

$$n = n_0 / 1 + (r/R)^2 \quad \ldots\ldots\ldots\ldots (57)$$

where r is the radial distance and R is the radius of the sphere forms an image of a point on its surface at the diametrically opposite point. It is clear from symmetry that a hemisphere cut from such a sphere will produce a parallel beam from a point source, as shown in Fig. 40.

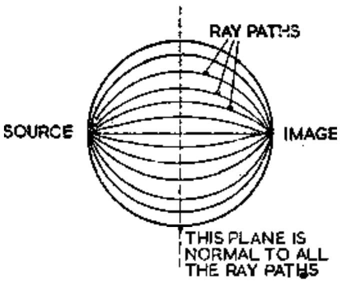


Fig. 40.
Maxwell's Fish-eye

The spherical system is known as "Maxwell's Fish-eye," and so the microwave analogue shown in Fig. 39 has been called the "Half Fish-Eye." One of the conducting sheets forming the systems is plane and the other curved: only the curved sheet is shown in Fig. 39. The equation for the profile of the curved sheet is obtained by combining the two Equations (31) and (57), and is

$$a = \frac{\lambda}{2[1 - n_0/(1 + r^2/R^2)^2]^{\frac{1}{2}}} \quad \ldots\ldots\ldots (58)$$

where λ is the free-space wavelength,

n_0 is the refractive index at the centre of the aperture,

r is the radial distance from the centre of the aperture,

and a is the spacing between the sheets.

It is desirable that the maximum value of a should not exceed the free-space wavelength, in order that there should be no possibility of ambiguity in the value of the refractive index. If the spacing exceeds the free-space wavelength, the H_{02} mode may be supported.[19] This restriction on the spacing limits the value of n to 0.866.

Because of the symmetrical nature of the "Half Fish-Eye," a theoretical analysis is comparatively simple. Equation (57) may be derived by considering the ray paths on the surface of a sphere, travelling from a point to the image at the diametrically opposite point. These paths will be great circles. If these paths are projected on to the diametrical plane as shown in Fig. 41, circular ray paths are again obtained. It may also be shown that in order that the rays may travel along these circular paths, then the refractive index must vary as in Equation (57).

It is also possible to calculate the amplitude distribution of the wave emerging from the Half Fish-Eye, and then by using the fact that the phase of this

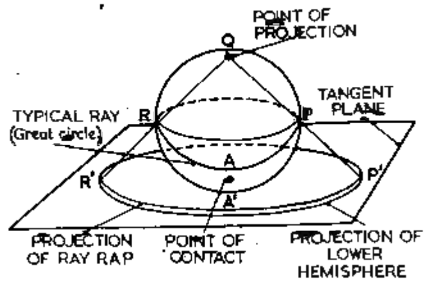


Fig. 41.
Derivation of equation (57)

wave is constant, as of course it is designed to be, the radiation pattern may be calculated. It may be shown that the equations of the circular ray paths through the lens are given by

$$r = \frac{R\sin\theta}{1 + \cos\theta} \quad \ldots\ldots\ldots\ldots (59)$$

where θ is the angle the ray paths make with the z-axis, as they leave the feed.

The primary feed will have its own radiation pattern, which may be specified by the function $P(\theta)$, which represents the power leaving the feed between the angles θ and $\theta + d\theta$. This power will leave the aperture between r and $r + dr$, where r and θ are related by Equation (59). If $A(r)$ represents the power leaving the aperture between r and $r + dr$, then

$$A(r) = P(\theta) \; d\theta/dr \quad \ldots\ldots\ldots\ldots (60)$$

where $d\theta/dr$ is obtained by differentiating Equation (59) and has the value

$$d\theta/dr = \frac{2R}{r^2 + R^2} \quad \ldots\ldots\ldots\ldots (61)$$

So far no allowance has been made for the reflexion which will occur at the aperture. The power reflexion coefficient will have the value $\frac{(1-n)^2}{(1+n)^2}$ obtained from Equation (52), where n varies with r according to Equation (57). To obtain the correct power distribution across the aperture, $A(r)$ must be multiplied by the transmission coefficient corresponding to the above value of the reflexion coefficient. metrical amplitude distribution is given by[27]

$$A'(r) = P(\theta) \; . \; d\theta/dr \; . \; \frac{4n}{(1+n)^2} \quad \ldots\ldots (62)$$

Since the phase distribution across the aperture is constant, the amplitude distribution will be proportional to the square root of the value of $A'(r)$ given by Equation (62). The radiation pattern to a symmetrical amplitude distribution is given by[27]

$$G(u) = 2K \int_0^R \sqrt{A'(r)} \cos 2\pi ur \; . \; dr \quad \ldots\ldots (63)$$

where $u = 1/\lambda \sin\phi$, ϕ being the angle with the normal to the aperture, and K is a numerical constant which will not affect the shape of the radiation pattern.

When the appropriate form of the amplitude distribution is substituted in Equation (63), a rather complicated integration is obtained. This integration may, however, be carried out numerically, and it is found that for a uniformly radiating primary feed, i.e., one for which $P(\theta)$ is a constant, the amplitude of the first and largest side-lobe is about 17 db. below that of the main beam. This represents an improvement of about 4 db. upon the level for a uniformly illuminated aperture. A further reduction of the side-lobe may be obtained by a suitable choice of the function $P(\theta)$.

At the time of writing, the theoretical performance of the Half Fish-Eye has not been experimentally verified. However, another cylindrical system using the same method of obtaining a medium of non-homogeneous refractive index has been the subject of experimental work. This system is the microwave analogue of a theorem, proved by R. K. Luneberg,[28] which states that a cylinder of unit radius, in which the refractive index is related to the radial distance r by the equation

$$n = \sqrt{(2 - r^2)} \quad \ldots\ldots\ldots\ldots \quad (64)$$

will cause a parallel beam, which is incident on the cylinder normally to the axis, to come to a line focus at the surface of the cylinder, as shown in Fig. 42.

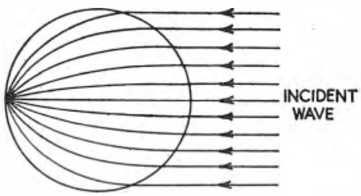


Fig. 42.
Luneberg's lens

An application of this theorem,[29,30] which may be used to provide a line source of microwave energy has been shown in Fig. 2 of Part I. The lens consists of a circular portion, bounded by conducting sheets, one of which is plane and the other curved. Only the curved sheet is shown in Fig. 2. The curvature of the sheet is so chosen that the refractive index within this portion is determined by a relation similar to that of Equation (64). Outside the circular portion there is a further region in which the plates are plane and parallel. This added region is called the " normalizing region " and is required for two reasons. Firstly, a lens of this type only provides a line source which is, in general, insufficient in itself to act as a practical beam aerial system and must be used in conjunction with a cylindrical focusing element, such as a further lens or a mirror. Clearly, this latter element must be fed from a straight line parallel to its axis, as its focusing action would be impaired if it were fed from the arc of a circle rather than a straight line. A second and more fundamental reason for the normalizing region follows from Equation (64) above. Luneburg's equation demands that the refractive index shall vary between $\sqrt{2}$ at the centre of the cylinder and unity at the surface. The waveguide action of the conducting sheets, however, can only provide refractive indices lying between zero and unity. It is possible to replace Equation (64) by the more general relation

$$n = n_0\sqrt{(2 - r^2/R^2)} \quad \ldots\ldots\ldots\ldots \quad (65)$$

where n is the refractive index of the normalizing region, and R is the radius of the cylinder.

If n_0 is chosen to be less than $1/\sqrt{2}$, the possibility of satisfying Equation (65) by using spaced conducting sheets is apparent. The sheets must be surrounded by an infinite pair of plane parallel sheets so spaced that they produce a refractive index $n_0 = n_c/\sqrt{2}$, where n_c is the refractive index at the centre of the circular portion. In the experimental model the value of n_c was fixed at 0.866, which corresponds to a spacing at the centre equal to λ: this value, as in the case of the Half Fish-Eye, was chosen as being the largest spacing which would not support the H_{02} mode.

When Equations (31) and (35) are combined, the following equation for the spacing between the sheets is obtained:

$$a = \frac{\lambda}{2[1 - n_0^2(2 - r^2/R^2)]^{\frac{1}{2}}} \quad \ldots\ldots\ldots\ldots \quad (66)$$

λ is the free-space wavelength,

r is the radial distance from the centre

and R is the radius of the lens.

The spacing between the plane normalizing sheets is therefore given by

$$a = \frac{\lambda}{2\sqrt{(1 - n_0^2)}} \quad \ldots\ldots\ldots\ldots \quad (67)$$

The measured performance of this system shows satisfactory scanning properties over an angle of 20° together with reasonable side-lobe suppression over a range of wavelengths of about 5 per cent. At the design wavelength, the side-lobe level is better than 23 db. below the level of the main beam, when the feed is an open-ended waveguide. The side-lobe level rises to about 17 db. when the wavelength of operation is changed by 5 per cent in either direction.

Both the above non-homogeneous lens systems require the electric vector to be parallel to the plates. A technique for producing similar systems when the electric vector is normal to the plate has been developed by the Radio Corporation of America, and has been described by DeVore and Iams.[31] The particular system described employs the principle of Luneberg, the non-homogeneous refractive index being produced by inserting a varying thickness of dielectric between the plates as shown in Fig. 43.

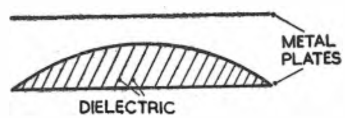


Fig. 43.
Alternative form of Luneberg's lens (cross section)

Details of the performance of this system have not yet, to the author's knowledge, been published, but difficulties in obtaining large disks of dielectric, of which the diameter may be several feet, of the necessary homogeneity, are to be expected.

A wide-angle scanning system is also described in the same paper, and will be discussed here as it is an interesting application of configuration focusing, which has been described in the section on path length lenses. The system is known as the R-2R lens. As in all the configuration focusing systems, the electro-magnetic energy is constructed to flow between spaced conducing sheets, the electric vector being normal to the sheets. As in the case of the path lenses already described the spacing between the sheets must be less than one-half the free space wavelength.

The R-2R lens is developed from the geometrical configuration shown in Fig. 46, *A* and *B* being the shapes of pairs of parallel sheets viewed from the direction in which they are spaced. This diagram will be used in the following description, but in the practical system the plates are bent in such a way that PQ may be welded to the circumference of the circle *B* and so that *ST* remains a straight line. It is possible to bend the sheets in this way if they are large compared with their spacing. When this is done the points *V* and *V′* will coincide, as the distances s, s', are both equal to $2R\theta$, where θ is the angle shown in Fig. 44. Also, since the path length

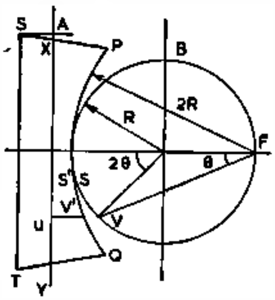


Fig. 44.
Basis of the R-2R lens

$FV + VU$ has the constant value $2R$, the path length of any ray from the feed position F to the straight line XY is independent of the value of θ. Radiation from a point source at F will therefore produce an equiphase surface at ST. The geometry of Fig. 46 may be extended to show that a point source at any other point F' on the circumference of B will produce a line source at ST, radiating a beam inclined to the normal to the aperture.

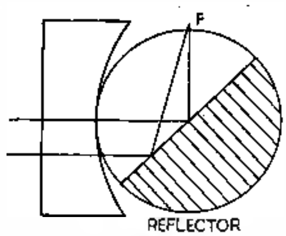


Fig. 45.
Practical form of the R-2R lens

The practical R-2R scanner is developed from Fig. 45, in which the sheets B are semi-circles with a diagonal reflector through the centre. The primary feed does not move precisely along the circumference of B, as a slight deviation is stated to improve the scanning properties at the expense of perfection of focusing. It is claimed that an R-2R scanner has been constructed to sweep a 1° beam through 40° at a maximum rate of 60 sweeps per second.

As in the case of all the path length lenses, there is no fundamental reason why the electric vector should not be parallel to the plates, provided that the plate spacing lies between $\lambda/2$ and λ. However, since the refractive index is in this case a function of the plate spacing, this spacing becomes impracticably critical, and so a system like this is not likely to be used. Moreover, such a system would only operate satisfactorily over a very narrow band of wavelengths.

(*To be concluded*)

References

[24] Wood: "Physical Optics," 3rd Edn. Macmillan, 1934, p. 88.
[25] S. B. Myers: "Parallel Plate Optics for Rapid Scanning," *J. App. Phys.*, Vo. 18, p. 221, Feb., 1947.
[26] Clerk Maxwell: "Collected Papers."
[27] S. Silver: "Microwave Antenna Theory and Design," McGraw-Hill Book Company, 1949, Chap. 6.
[28] Luneberg. "Mathematical Theory of Optics." Brown University Press, 1944, p.213.
[29] British Patent Specifications, Provisional Applications, Nos. 19409/49 and 27009/49.
[30] S. S. D. Jones: "A Wide-Angle Microwave Radiator." (*Proc. I.E.E.*, Vo. 97, p. 255, 1950.)
[31] Devore and Iams: "Microwave Optics between Parallel Conducting Sheets," *R.C.A. Review*, p. 721.

The Suppression of Radiation Interference

With the extension of television transmission to the Midland area last December, the problem of interference to normal radio reception by television receivers reached major proportions. A number of leading manufacturers began extensive research into methods of overcoming the difficulty.

Although the trouble originates in the line time base circuit, the associated circuits also radiate, including in a number of cases the wall coating of the C.R.T. itself. It soon became apparent that screens around individual components were not effective, and the only satisfactory method found was a screen around the whole receiver.

In the course of the investigation into this problem Messrs. Acheson Colloids, Limited, were approached concerning a suitable conducting paint for applying to the cabinet, with a view to eliminating the trouble. A special product was developed for the purpose which proved to be satisfactory in eliminating the radiation.

The product in question, "dag" Dispersion 479, is a quick-drying water-based paint designed to be brushed on the inside of the cabinet. According to a report from the makers:

"Tests show that a radio receiver will operate satisfactorily, even on the long wave band, only a few feet away from a tested television set. Screening is so simple and economical to carry out that it can be applied by any capable television dealer for a moderate charge and, if necessary, on the owner's premises.

Thus dealers now have an effective weapon to abate the nuisance to the listening public. Manufacturers, by treating future models, can ensure that in time the problem will be reduced to negligible proportions."

Those interested are asked to write for further technical information regarded the use of Dispersion 479 to Messrs. Acheson Colloids, Limited, 18 Pall Mall, London, S.W.1.

Electronically-Controlled Ciné-radiographic Apparatus

By V. QUITTNER, Dr. Phil., A.M.I.E.E.

(*General Radiological Ltd.*)

EVER since the discovery of X-rays and the invention of the cinematograph—which happened to occur at approximately the same time—it has been recognized that it would be a great advantage to medical diagnosis and, even more perhaps, to scientific research in medicine, anatomy and physiology if it were possible to produce X-ray ciné-films which would allow observation at any time of the movements occurring inside the bodies of men or animals on a screen.

Such hopes could not be realized at a time when an X-ray exposure required a time of at least a few seconds, if not minutes. With powerful X-ray tubes, however, and equally efficient high-tension generators, exposure times down to a few hundredths of second are possible, so that a number of exposures more than sufficient for projection can be made easily every second.

There are two possible methods of X-ray cinematography. The direct method allows the X-rays, after passage through the object to be radiographed, to impinge directly on the photographic film. It is obvious that, in this case, the frame on the film must be of the same size as the object itself, therefore this method is, at least with the normal 35 mm. film, only applicable to very small objects.

This restriction does not apply to the indirect method which is, therefore, the one in general use. It is based on the same principle as the well-known "mass miniature radiography," so widely used during and after the last war for the early diagnosis of tuberculosis. The X-rays, after passage through the object, fall on a fluorescent screen, where they produce a full-size radiographic image in green or blue colour. This image is reproduced at a greatly reduced scale by the optical system of a conventional film camera on 35 mm. (or sometimes 16 mm.) ordinary ciné-film.

When this indirect or fluorographic method is used with a normal four valve H.T. generator (A.C. rectified by four valves in bridge connexion), which is the most usual type of X-ray apparatus, the fluorescent image is not continuous but appears and disappears (with 50 cycles frequency) a hundred times per second. It follows that the individual frames on the ciné-film can only be of equal intensity if the time interval between successive frames is an integral multiple of 0.01 sec. In many cases, however, it is desirable to have no restriction of this kind and in this case constant or nearly constant high voltage is required. The source of H.T., in this case, can be a large H.T. capacitor, capable of storing the total energy required for the full film-length, or a normal four valve generator with adequate smoothing capacitors.

With a generator supplying constant high voltage the fluorescent image remains continuously on the screen and it is therefore quite possible to use a normal ciné-camera without any special equipment for the recording of this moving image on ciné-film. This simple method is, indeed, sometimes used. Its main disadvantage is that the X-ray tube is loaded and X-rays are going through the object not only when it is needed, but also during the transport time of the film when the camera shutter is closed. If the object is a human patient the quantity of X-rays passing through his body must be kept below the limit which could do him harm, and this limits the permissible total exposure time.

If, during the time of film transport the patient can be protected against the X-rays the total time or number of frames can be considerably increased. This is sometimes done by a lead shutter between the X-ray tube and the object, which rotates in synchronism with the transport mechanism of the camera and cuts off the X-ray beam during the periods of film transport. In this way the dangerous over-exposure of the patient can be avoided.

But there still remains the disadvantage that the X-ray tube is loaded not only when its X-ray output is required, but also, uselessly, during the intervals between the individual frames. As each exposure is necessarily very short the tube current and voltage must be high to produce sufficient effect on the film, and the tube is mostly working at or near its maximum load. If the load could be removed from the tube during the intervals between exposure (i.e., while the film is being transported) the total permissible exposure time or number of individual exposures could be increased by between 40 and 100 per cent.

It is obvious that the intervals between exposures are far too short for switching on and off the H.T. transformer at the low tension side, as the primary current may be as high as 50 A or more and a heavy contactor is necessary for the switching. So the only possible method of switching off the tube between exposures is the use of a valve capable of closing and interrupting instantaneously a current of 200 mA or more at a voltage of 100 or even 150 kilovolts, corresponding to a load of 20 to 30 kilowatts.

When a switch valve is used to close and interrupt the H.T. supply of the tube it is necessary for it to work in exact synchronism with the film transport mechanism of the ciné-camera. Now the switch valve is inserted in the H.T. circuit, and its cathode and grid may therefore be at a potential of 50 kV below earth potential, while the camera with its transport mechanism is naturally at earth potential. So the problem arises how to transmit without delay signals from a point at earth potential to another at a very high potential to earth.

Various methods have been tried to solve this problem. Mechanical transmitters, such as long insulating rods, can be used for single signals, but they must fail if the signals follow each other in quick succession. One German firm used a high frequency generator (300 kc/s.) switched on and off by the signals from the ciné-camera. The H.F. energy was transmitted through a pair of coils to the H.T. circuit, where it was rectified and then used to change the grid potential of the switch-valve. This method works quite satisfactorily, but is very complicated.

The method to be described now is very much simpler and has proved to be equally satisfactory and reliable for X-ray cinematography. It makes use of the fact that ciné-radiographic exposures are certainly not longer than, say, a quarter of a second. If, therefore, an impulse transmitted from earth potential to high potential by a suitable transformer can be made to last long enough, it could directly be used not only to initiate but also to maintain the exposure for the required time up to the moment when it will be brought to a close by another impulse of opposite sign. It is then not necessary to use repeated impulses (the use of H.F. can, indeed, be considered as a great number of repeated impulses following each other in quick succession) or any kind of triggering mechanism, and the controlling system becomes extremely simple.

Fig. 1 shows the basic diagram of the control system using the "long-impulse" transformer. The X-ray tube and the main switch valve 1 are inserted in series in the H.T. circuit, so that to pass current through the tube the switch-valve must be conducting. But it is not sufficient for the switch-valve to be just "conducting", it must allow a considerable current to go through it without a drop of voltage exceeding a few kilovolts, so that nearly the full voltage of the H.T. generator goes to the tube. This is not possible without applying a positive grid voltage of a few hundred volts to it, and, under these circumstances, the grid will take a grid-current of something between 50 and 100 mA. This grid-current is supplied by the voltage source D and controlled by the auxiliary switch-valve 2, as will be described later on. On the other hand, in order to render the switch-valve completely non-conducting with an anode voltage of 100 kV or more, a negative voltage of 1,000 to 2,000 V must be applied to its grid. This voltage is derived from the voltage source C (of high voltage, but only capable of supplying a low current) and reaches the grid of 1 through the high resistance ρ (200,000 ohms).

The design of the auxiliary switch-valve is such that, with its grid biased to −200 V, it does not allow any current to pass, when exposed to the sum of the voltages of both C and D (2,000-2,500 V). With its grid at zero voltage, it allows a current of 100 mA to pass with a drop not exceeding 300 volts, so that with a voltage source D of 600 V it is easy to supply the required grid current to the main switch-valve. When 2 is conducting, a small part of its anode current takes the way via ρ and C, and its voltage drop when passing across ρ keeps the negative voltage from C away from the grid of 1, so that it can assume a positive voltage, rendering the main switch-valve fully conducting.

It will now be easy to understand how the system works. Apart from those components which have already been mentioned there is a third valve 3, a normal small receiving amplifier, whose anode is coupled by the coupling resistance r_c to the grid of valve 2; its anode voltage is supplied by a third, rather small, voltage source B. 4 is the long-impulse transformer, whose secondary coil acts directly on the grid of valve 3, while its primary coil receives voltage and current from source A (24 V accumulator or well-smoothed rectifier), when the exposure switch is closed and the rotating interrupter 5, directly coupled to the film-transport mechanism of the camera, is in the position where it makes contact.

As long as no voltage is induced in the secondary coil of the long-impulse transformer valve 3 has no grid bias and is therefore fully conducting. Its anode current flowing through the coupling resistance r_c makes the grid of the auxiliary switch-valve 2 sufficiently negative to cut off this valve. Consequently the grid of main switch-valve 1 is kept at the high negative voltage of C, and the main switch-valve is cut off, too, and does not allow any current to pass through itself and through the X-ray tube.

When, however, a voltage of sufficient magnitude in the direction as indicated by the arrow is induced in the secondary coil of the transformer, the grid of valve 3 becomes negative and the current through this valve and through the coupling resistance ceases to flow. The auxiliary switch-valve 2 loses its

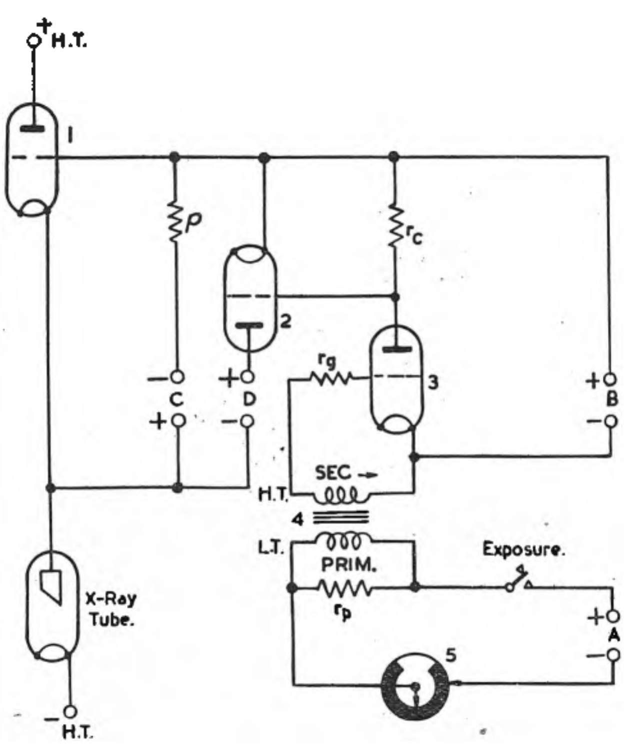


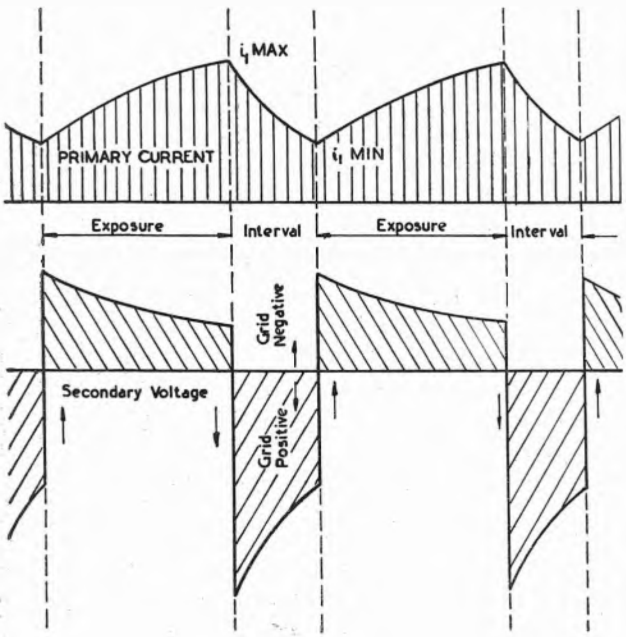
Fig. 1.
Diagram of control system

negative grid bias and becomes conducting and—in the way described earlier—the grid of the main switch-valve 1 goes from negative to positive, this valve also becomes conducting, and current from the H.T. generator can pass through the tube.

Such voltage in the transformer's secondary coil will be produced when the rotating interrupter 5 (supposed to have been in the "open" position before) closes and allows current from A to flow through the primary coil of the transformer. The induced voltage will start instantaneously at its top value and remain as long as the current in the primary coil is still rising. As the primary current approaches its final value (voltage of source divided by total resistance) the induced secondary voltage will decay gradually. When it has fallen below a certain value the valve 1 will gradually lose conductivity, the current through the X-ray tube will be more and more choked and finally interrupted, so bringing the exposure to an end.

An exposure should, however, never be allowed to die out in this way (though it constitutes quite a good safety device against gross overload), because the duration of the exposure would not be exactly determined and its end would be sluggish and irregular. The exposure is, indeed, cut off before its natural close when the brush of the rotating interrupter leaves the conducting segment and cuts off further current supply from the voltage source A. To avoid damagingly high voltages in the secondary coil the primary coil is bridged by a suitable by-pass resistor r_p. This has the effect that the primary current is not suddenly interrupted, but its increase is instantaneously reversed into a decrease, generally of considerably higher gradient than the previous increase. Consequently the induced secondary voltage will instantaneously change its sign and the grid

Fig. 2.
Primary current and secondary voltage curves of long-impulse transformer



voltage of valve 3 jumps from a negative to a positive value (the high grid resistance r_g—3 megohm—protects the grid and reduces the grid current to a small fraction of 1 mA). So anode current through valve 3 flows again, valves 2 and 1 are cut off instantaneously, and the exposure comes to an instantaneous and exactly fixed close.

When—as is the case with ciné-radiography the exposures follow each other at short intervals, a fresh supply of current from source A will start before the primary current has had time to fall to a value not far from zero. There will, consequently, always be current in the same direction in the primary coil, but its magnitude will go up and down between two limiting values. This current can be regarded as a D.C. current with superimposed A.C. of frame frequency and of very distorted wave shape. The D.C. component is obviously not transmitted to the secondary circuit, but the A.C. component is transmitted and produces a still more distorted-looking curve of secondary voltage of frames frequency.

The general shape of the curves of primary current and of secondary voltage according to these theoretical considerations are represented in the diagram Fig. 2. As the induced secondary voltage is obviously a pure A.C. voltage the positive and negative parts of it must define surfaces of equal size between themselves and the zero line. In the case represented in Fig. 2, where the exposures were three times longer than the intervals, the positive (useless) grid voltage during the intervals is roughly three times as high as, and decays much faster than, the negative voltage which makes the exposures.

The most important part of the switching mechanism, on which its correct functioning depends, is the long-impulse transformer. The first condition which such transformer must fulfil is an exceptionally high time constant (L/R) of the primary coil, so that the rise of current extends over a sufficiently long time. High self-inductance and relatively low primary resistance are therefore necessary. On the other hand, however, a very high time constant will reduce the difference between highest and lowest primary current ($i_{1\,max}$ and $i_{1\,min}$ in Fig. 2); consequently the induced secondary voltages will be reduced as well. Calculation and practical experience show that there is an optimum value for the time constant, when it is approximately equal to the longest exposure required.

As the long-impulse transformer has to stand full H.T. voltage between its primary and secondary coils, there must be a considerable distance between the two coils, and the transformer is therefore bound to have some magnetic leakage, which produces oscillations of audio frequency superimposed on the impulses. Such oscillations, which may easily cause serious trouble, can be suppressed, or at least reduced to such a value as to cause no disturbance, by connecting a load resistance of a few hundred kilohms across the transformer's secondary coil. A small capacitor, in parallel with the resistance, in some cases gives a further improvement.

The transformer actually used in the ciné-radiographic unit has a ratio of 1:4 with 10,000 primary and 40,000 secondary turns on a core of 2.1 sq. in. The resistance of the primary coil is 640 ohms, the bridging resistance r_p is 2,000 ohms. Its primary self-inductance and time constant are

At prim. current mA	Self-inductance Henry	Time constant Milliseconds
0	193	302
30	100	156

The highest possible current through the primary coil is 24 volts/640 ohms = 37.5 mA.

The maximum length of exposure which can safely be made with this transformer is 250 milliseconds; if the camera is so designed that the ratio of exposure time to transport time is equal to 3:1, the number of frames per second can be as low as three.

The working of the long-impulse transformer is illustrated by the oscillogram Fig. 3. This shows the secondary voltage of the transformer with the interrupter at the camera running at approximately twenty frames per second. It can be seen that the negative voltage during the exposure drops very slowly (the drop is naturally larger at the lowest speed of four frames per second), while the positive voltage during the intervals drops fairly quickly. There are practically no superimposed oscillations left.

The most important part of the electronic switching system and certainly the most difficult one to design and manufacture is the main switch-valve (Fig. 4).* With its grid at a sufficiently high negative

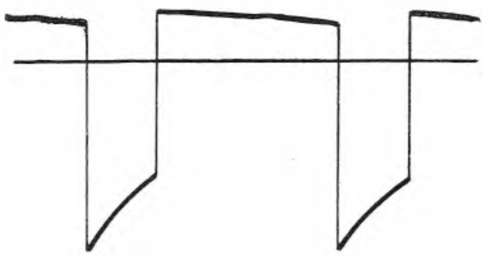


Fig. 3.
Oscillogram of secondary voltage produced by impulse transformer

potential it must withstand an anode voltage of 100 kV or more, without allowing any measurable current to pass. This requires the highest possible vacuum to be maintained indefinitely, a vacuum very much better than in commercial valves. It cannot be obtained without very thorough degassing of each component and again of the complete valve, each process at the highest temperature that the respective material can stand. On the other hand, it must at a moderate positive grid voltage (100-200 volts) allow a current of 500-1,000 mA to pass with no higher voltage drop than a few kilovolts.

As can be seen from the photograph, the valve is similar to large transmitter valves, with a cylindrical electrode system and a copper anode forming part of the envelope. Its filament, when fully heated, requires 8 volts and 40 amps. The filament is pure tungsten wire, as neither thoriated tungsten nor oxide cathodes have given satisfaction at such high voltages. The grid, which has to carry a considerable grid-current and should not have high secondary emission, is also wound from tungsten wire.

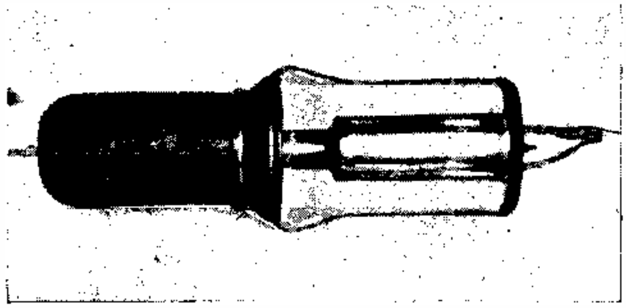


Fig. 4.
Main Switch Valve

The choice of the amplification factor for the valve is of great importance. A low value facilitates the passage of high currents with relatively low positive grid voltage and grid current, but it requires a very high negative grid-voltage for the complete cut-off. The valve was ultimately made with an amplification factor of about 180, and complete cut-off at 100 kV was reached with −630 V on the grid, while, at a positive grid voltage of 130 V (and 80 mA grid current) 500 mA could pass through the valve at a drop of approximately 3 kV. In fact, both the negative and positive voltage sources were chosen considerably higher than these values. The main dimensions of the valve are: overall length 300 mm., maximum diameter 110 mm., outside diameter of copper anode 75 mm.

The auxiliary switch-valve, too, had to be designed specially, as no suitable valve was to be found on the market. As its anode voltage does not exceed 2,000 V, a thoriated cathode could be used, requiring 14 V and 4 A. The amplification factor had to be chosen at the relatively low value of 14 in order to allow an anode current of 120 mA to go through it at a voltage drop of approximately 350 V at zero grid voltage. It will be remembered that the valve is always working at negative or zero grid voltage.

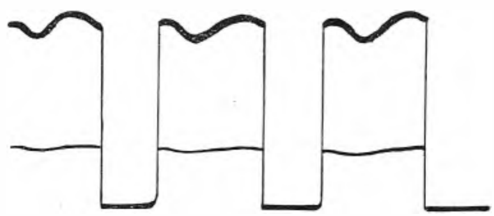


Fig. 5.
Oscillogram of voltage and current of X-ray tube (40 frames per second)

The oscillogram of Fig. 5 shows the working of the electronic switching system. It was made on a Cossor double beam cathode-ray oscilloscope, which for this purpose had to be used directly in the H.T. circuit, its current supply being taken from a highly insulated 1:1 transformer and all its controls adjusted by means of long insulating rods. Single stroke technique was thereby used. The number of frames/sec. was in this case as high as 40. The short straight lines represent the intervals during which tube voltage and current were zero, the two other broken lines are tube voltage and current during the exposures. The voltage line is perfectly straight, while the

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* I should like to express my appreciation for the help given by Mr. Cane of the Edison Swan Electrical Co. Ltd., in manufacturing the special switch valves to the design requirements of the General Radiological Co. Ltd.

current line shows waves with a frequency of 100 c/s.; this is a consequence of the tube being heated by A.C., so that the filament temperature undergoes corresponding slight changes during each half-cycle of mains voltage.

Ciné-radiographic Equipment at Manchester University, Department of Anatomy (Prof. Mitchell)

A ciné-radiographic equipment, designed and constructed on the principles that have been described above, was installed in the Department of Anatomy of Manchester University in 1949.

The ciné-radiographic equipment had to be used in connexion with a previously installed conventional four-valve X-ray apparatus for voltages up to 100 kV and tube currents up to 400 mA. The ciné-radiographic unit had to be so designed and connected to the existing apparatus, that the change-over from normal radiographic work to ciné-radiography should be possible without any alterations on the generator or control-table.

The number of frames was to be between 4 and 32/sec., and the makers of the camera, Messrs. W. Vinten, Ltd., succeeded in making a film-transport mechanism which requires only 25 per cent of the total time for the transport, so that 75 per cent was available for the exposure itself.

The maximum voltage should be 100 kV, both for ordinary radiography and ciné-radiography, but, while ordinary exposures could be made with tube currents up to 400 mA, cinéradiography should be made with currents up to 200 mA only. Higher currents are indeed undesirable for ciné-radiography, because the load which can be supported by the tube would only allow a very limited number of frames.

Besides conventional radiography, observation on the fluorescent screen and ciné-radiography, special provision was made for what is called "serial exposures", that is, exposures following each other automatically at intervals which can be adjusted between two and fifty seconds.

The principal parts of the equipment are:

1. The four-valve H.T. generator of normal design for a maximum of 100 kV peak and a maximum current of 400 mA;
2. The switch-table, containing the necessary control equipment and measuring instruments. It is the normal control-table as used for ordinary radiography, apart from a few slight modifications. A three-position switch does the change-over from normal radiography to ciné-radiography and serial exposures;
3. The additional ciné-radiographic unit, comprising the whole electronic switching equipment and the H.T. smoothing capacitors;
4. The ciné-camera unit, including the camera, the fluorescent screen and the tunnels connecting them;
5. Accessories, such as the special timer unit for serial exposures, a 24 V Nife battery with tappings supplying current for the two camera-motors, etc.

The Additional Ciné-radiographic Unit

This unit is contained in an oil-filled tank, 40 in. long, 20 in. wide and 24 in. high. On one of the long sides of the tank is fixed a panel with those parts of the equipment which are not at high potential, such as a number of relays, a rectifier (24 V) supplying the primary current for the impulse transformer, the filament resistance for the main switch-valve (which has a separate filament transformer) and a number of other parts. It is connected by a flexible "snake" to the H.T. generator and by a cable to the camera unit, while another cable of 13 leads connects it to the interior of the oil tank.

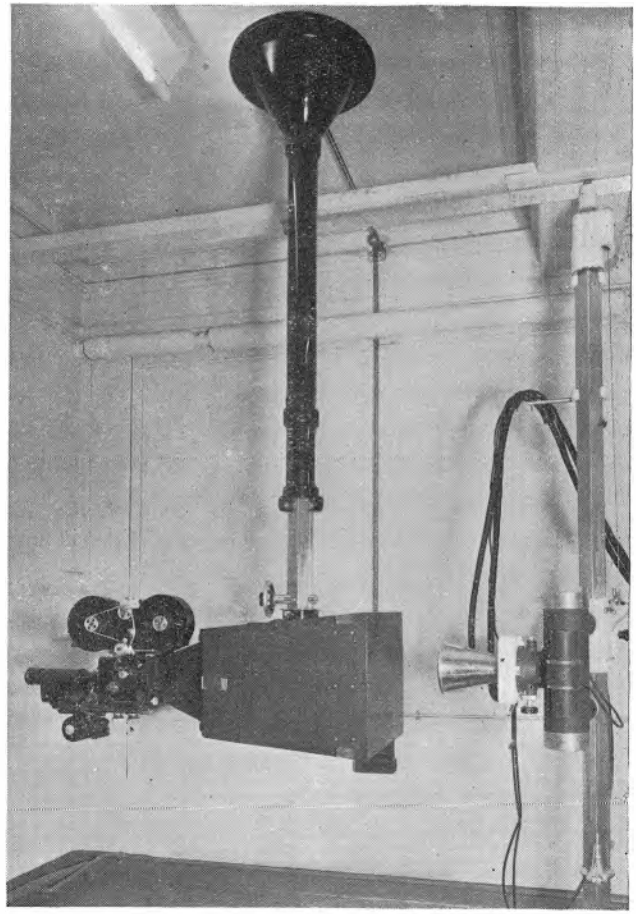


Fig. 6.
Ciné-radiographic unit in horizontal position

The oil tank contains the two H.T. smoothing capacitors, the main switch-valve in a special cylindrical casing, seven transformers, insulated to stand 60 kV between primary and secondary coils (among them the long-impulse transformer) and a removable frame supported from the top and containing the auxiliary switch-valve, the amplifier valve and the rectifier units for the three voltages (compare Fig. 1). After loosening a few screws this frame can be lifted out of the oil for inspection; a flexible cable connects it to the rest of the equipment inside the tank. In a similar way the main switch-valve can also be taken out easily for inspection or replacement. Two shockproof H.T. cables connect the tank to the generator and another two to the X-ray tube.

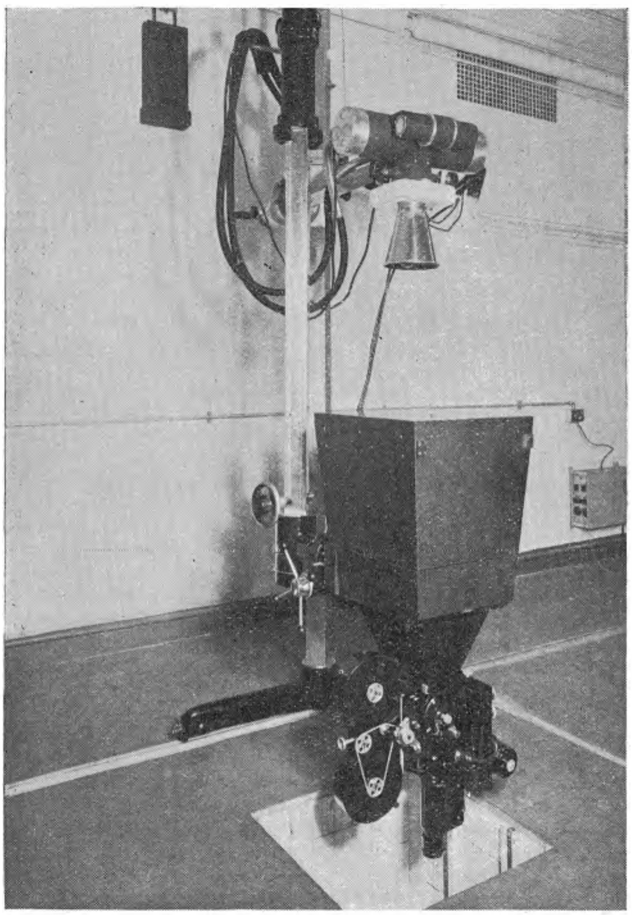
The capacitors have a capacitance of 0.2 microfarads each or 0.1 microfarad in series connexion and can stand 60 kV each or 120 kV in series. Each has a safety resistance of 1,000 ohms and a discharge resistance of 150 megohms, which discharges them below the danger point within four minutes. They provide practically perfect smoothing for currents up to 200 mA (the maximum used for ciné-radiography).

The Ciné camera Unit

The purpose of the apparatus is to record on standard 35-mm. film ciné-radiographic exposures at the rate of four to thirty-two frames per second and serial exposures, i.e., exposures following each other automatically at intervals adjustable between two and fifty seconds.

Figs. 6 and 7 show the unit ready for use together with the X-ray tube in horizontal and vertical position. The X-ray tube is quite independent from the camera, as it is also used for ordinary radiographic work. It is fixed in the usual way on a vertical column running between a pair of rails in the floor and on the ceiling. The camera unit hangs, quite independently of the tube, from the ceiling and can be adjusted to different heights as well as to inclinations varying from horizontal to vertical. It consists of a large tunnel of square cross-section and slightly conical shape, directly connected to the ceiling support, the camera itself and a set of three smaller tunnels of different lengths, one of which is always inserted between the large tunnel and the camera. The fluorescent screen is fixed to the other end of the large tunnel. The choice of three different distances between screen and camera makes it possible to have a full-size image on the 35-mm. film for various sizes of screen images.

Fig. 7.
Ciné-radiographic unit adjusted for vertical operation



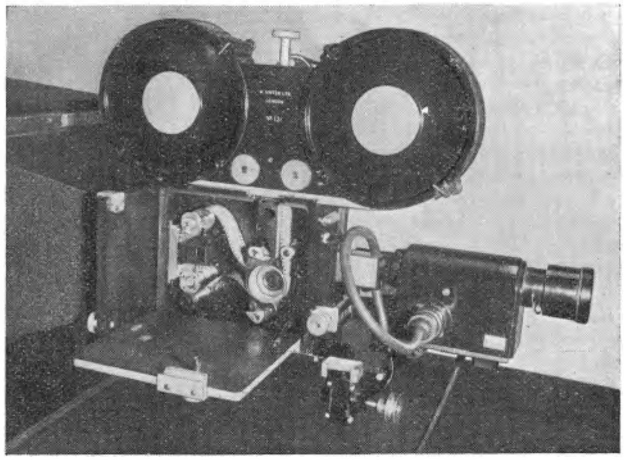


Fig. 8.
Ciné camera opened to show transport mechanism

The ciné-camera itself is of special design and was made by W. Vinten, Ltd., of London. It is fitted with a Cooke coated radiographic lens of 1 aperture and 2.25 in. focal length. The lens is fitted in a focusing mount, the flange of which is engraved to give preset focusing for each tunnel.

The camera itself (Fig. 8) is designed as usual with the exception that a special film transport mechanism is used in order to speed up the motion of the film. The ratio of stationary time to moving time is as high as three to one, and the shutter has consequently 270° light sector and 90° dark sector. The camera is driven by a 24 V D.C. motor fed from an accumulator battery, the adjustment of speed being made through tappings on the battery and for fine adjustment by a rheostat.

Fitted to the side of the camera is the interrupter in the shape of a face-type commutator, which rotates in synchronism with the film transport mechanism and the shutter and provides, as described earlier, the impulses for the electronic control of the individual exposures. It works on 24 V D.C., supplied by a rectifier unit.

When the camera is to be used for serial exposures, the motor has to be replaced by another motor fitted with a magnetic clutch, which, when energized, allows the shutter and rotating interrupter to make one complete turn, during which the film is transported by one frame. The exposure is initiated by the rotating interrupter and the long-impulse transformer immediately the film has come to rest after the transport.

The impulses which energize the clutch are derived from a serial timer of the kind used for the automatic production of successive aerial photographs. A special contact on this timer is used to switch on the motor for the tube's rotating anode a few seconds before each exposure; immediately following the close of the exposure the anode is again brought to standstill until the next exposure. The length of each individual exposure can be adjusted in quite the same way as for normal radiographic work.

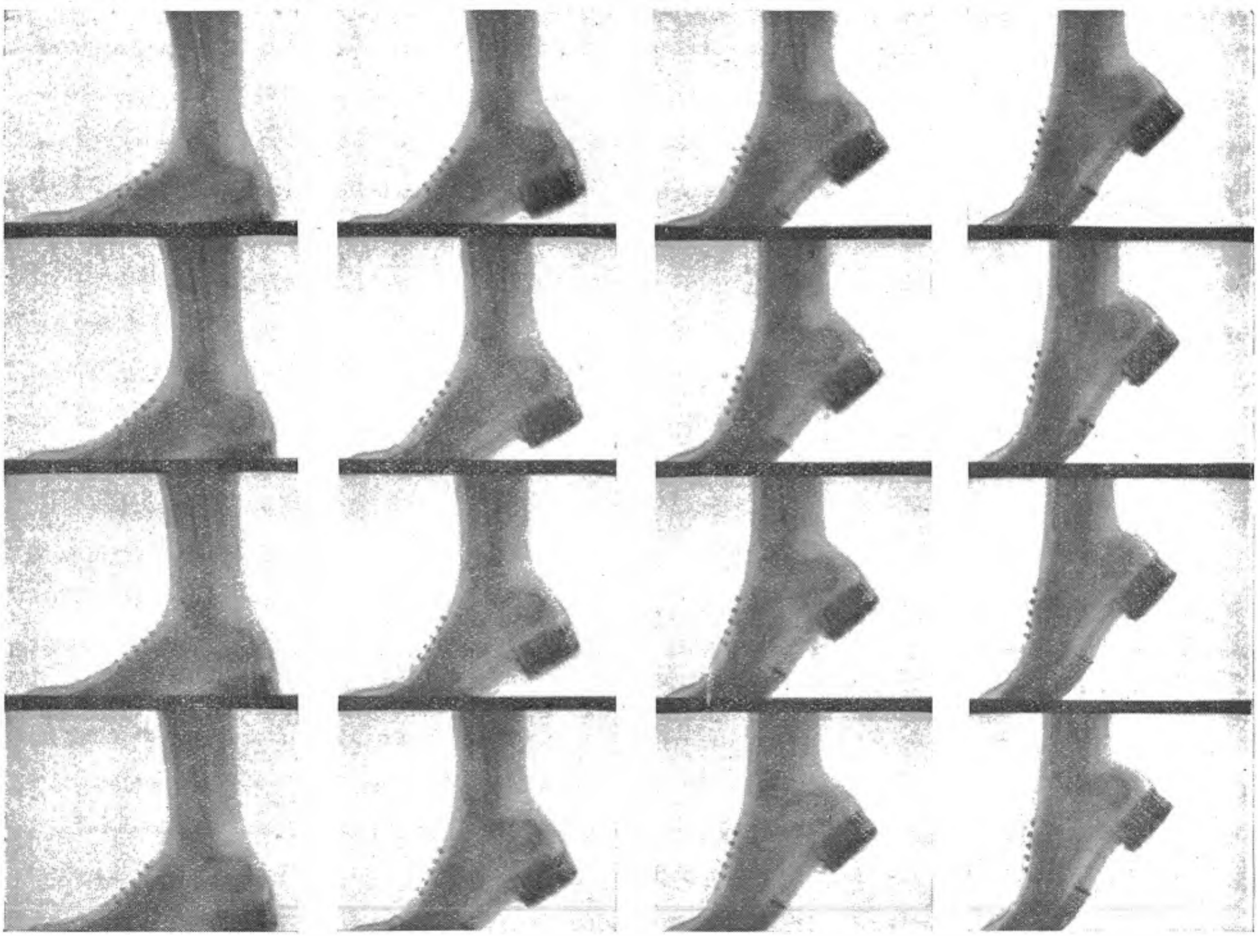


Fig. 9.
Ciné radiograph of human foot in movement (16 frames per second, 100kV, 100 mA tube conditions)

Coincident with the preparation of Dr. Quittner's article the following description of a new production ciné-radiography equipment was received

New British Ciné-radiography Equipment

(Communicated by the General Electric Co., Ltd.)

THE introduction by Watson & Sons (Electro-Medical) Ltd., (an associated company of the G.E.C.) of a new high voltage equipment for the making of cinematographic X-ray films has placed Britain in the fore-front of X-ray technology.

The history of the new achievement started in the years 1935-37, when Watson & Sons, in conjunction with Dr. Russell J. Reynolds, produced the first ciné-radiography equipment. This equipment was arranged to take cineradiographs by the indirect method (photography of a fluorescent screen) using 16 mm. film and a 10 kilowatt stationary-anode X-ray tube. In order to minimize the exposure of the patient to X-rays, the apparatus was fitted with a synchronous mechanical switching device which reduced the voltage applied to the tube during the periods when the camera shutter was closed.

Although this apparatus has been used for much useful work, its design had some serious limitations. The patient could only be radiographed in an upright position; the equipment was cumbersome and had to be operated in complete darkness. This was due to the long focal length of the lens used, a Zeiss Biotar, specially developed for the work and with an aperture of $f0.85$.

With the X-ray tubes then available this aperture was the minimum which could be practicably used, and because of its small acceptance angle, a long focal

New British Ciné-radiography Equipment—Continued

length (58 mm. to cover 16 mm. film) was unavoidable. This necessitated the camera and fluorescent screen being mounted on separate stands to secure the correct reduction ratio, and so led to operating in darkness. Other disadvantages were poor definition and " grainy " films arising from the need to use a highly sensitive emulsion.

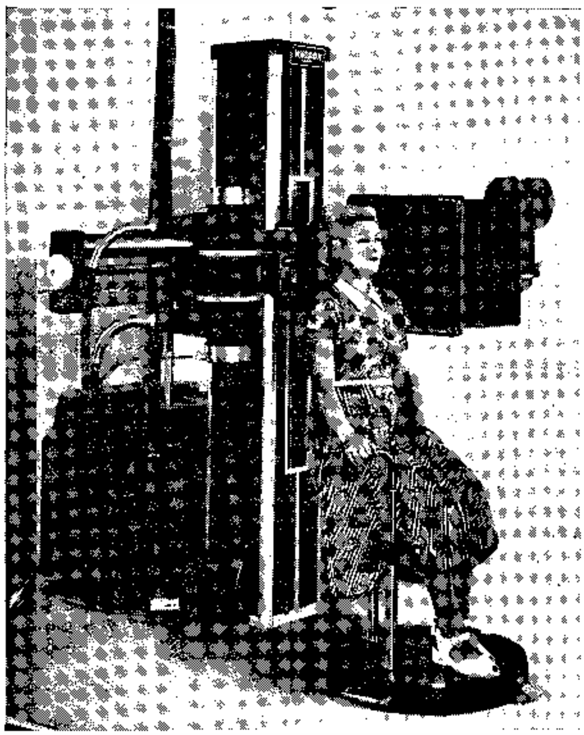
The new Watson equipment, however, is a great improvement on the early instrument and uses a rotating anode X-ray tube energized at 120 kV, 400 mA, in conjunction with a specially designed 35 mm. ciné camera fitted with an f1.5 Taylor-Hobson lens of 4 cm. focal length. The high voltage generator has an electronic switching device, by means of which the X-ray tube is only energized during the time that the camera shutter is open.

The speed of the ciné camera can be adjusted from $3\frac{1}{8}$ to 50 frames a second in submultiples of the A.C. mains frequency, the driving motor being of the synchronous type.

Film loading and unloading is in daylight. The unexposed film magazine holds 400 ft. of film, and the exposed cassette up to 20 ft. The latter length is ample for making endless loops, in which form cineradiographs are usually examined.

The X-ray tube, together with the fluorescent screen and ciné camera, are arranged on a balanced arm mounted on a floor pedestal, and the tube, screen and camera assembly are mounted so that they can be rotated, and radiography carried out in any position from the vertical to the horizontal. The equipment is designed for use at focus-to-screen distances of 24, 36, 42 and 48 inches and the camera is arranged so that various sizes of fluorescent image can be photographed, which is analogous to using different sizes of cassettes in normal radiography. The camera, screen and tube assembly is adjustable to various heights from the floor by a simple hand-wheel adjustment and can be rotated about its axis by means of motor drive controlled by a press button.

A simple couch is provided by which radiography with the patient prone can be carried out. Also a rotating platform is fitted by means of which the patient can be rotated during radiography.



The X-Ray Tube is mounted in the housing on the patient's right and the fluorescent screen is housed on her left. Beyond the fluorescent screen, at the far end of the bellows is the precision 35mm. cinema camera

To enable the radiologist to position the patient correctly, means are provided for visual inspection of the fluorescent screen through an aperture which is self-closing, so that no light can enter during the time when the image is being photographed.

Control of the equipment, once the patient has been placed in position, is from a separate control unit. The initial operation is to close a hand switch which brings in a preparatory circuit, energizes the rotating anode of the X-ray tube and the camera motor. Then after a three second delay period during which time the camera is synchronized the X-ray tube anode runs up to speed and the tube and rectifier valve filaments are fully heated, an exposure button will control the exposure in conjunction with the synchronous timer, which is set for the total duration of the exposure required. The automatic contacts built into the camera will then take charge during the exposure period and arrange for the X-ray tube to be energized only during those periods when the camera shutter is open. Besides reducing the X-ray dose to the patient this also reduces the power dissipated in the tube and enables higher loadings to be utilized without fear of tube failure.

For use at extremely slow film speeds, e.g., those used for viewing slow movements of the body, the X-ray exposure can be arranged to occupy any proportion of the shutter-open period. This is done by means of a subsidiary timing control in the electronic contactor circuit.

If desired, the camera and timing and synchronizing equipment can be switched out of use and radiographs made on large size films by the usual still-radiography technique. In this case the synchronous timer of the equipment will determine the length of exposure.

The entire apparatus is designed for use on 200/260 volt 50 c/s. single-phase mains or may be operated in conjunction with an additional step-down transformer or static balancer from three-phase mains or high voltage single-phase supplies up to 500 volts. Power consumption is about 1 kW when idling and 20 kW (average) when exposures are being made.

Precision A.C. Voltage Stabilizers

By G. N. PATCHETT, Ph.D., B.Sc.(London), A.M.I.E.E., M.I.R.E.

(Bradford Technical College)

Part I

THERE are many instances where a source of constant voltage is required. With direct current this can be obtained from storage batteries, but these are costly and require continual maintenance. These difficulties can largely be overcome by the use of stabilizers and many articles and circuits have appeared,[1-8] varying from simple circuits of limited accuracy, to circuits capable of giving extremely constant output voltages. A number of stabilizers based on these circuits are available commercially.

With alternating current there is no equivalent to the storage battery and some type of stabilizer has to be used, either correcting the normal A.C. supply or controlling a motor alternator. Good results may be obtained from the latter,[9,10] but the equipment is costly and bulky. On turning to the former type, one finds many published circuits and commercial instruments of stabilities of the order of one-half to 1 per cent,[4,11-14] but very little information is available on instruments having output voltages constant to within 0.1 to 0.01 per cent.

As far as is known, no such instruments, of large power output, giving these high stabilities have been available commercially in this country. The subject of D.C. stabilizers and of the lower accuracy type of A.C. stabilizer has recently been considered in detail[4] and, therefore, the author will concentrate on precision A.C. stabilizers having output voltages constant to the order of 0.01 per cent.

Types of Stabilizer

Stabilizers may be divided into three main classes as follows:—

Type A—corrects for changes of input voltage, but not for changes of load.

Type B—corrects for changes of load, but not for changes of input voltage.

Type C—corrects for changes of load and for changes of input voltage.

A type C stabilizer can be formed by a combination of types A and B, but may also be constructed independently. A type C is by far the most useful and the type generally required.

Requirements of a precision A.C. Stabilizer

Accuracy of maintenance of output voltage

This can be divided into two classes:—

(a) Short period stability, i.e., over a period of minutes due to changes in input voltage and/or load. This may be divided into

(1) Changes due to changes in input voltage. This is usually expressed as dv_o/dv_i where v_o is the output voltage and v_i is the input voltage. This has been called the regulation factor "S" by Hill.[15] The inverse is usually termed the "stabilization ratio".

(2) Changes due to changes of load. This is expressed as dv_o/di_o where i_o is the output current. This corresponds to the internal slope impedance Z_i.

(b) Long period accuracy, i.e., over a period of hours due to changes in ambient temperature, vibration, ageing of components, etc. It is important to note that a badly designed stabilizer may actually produce larger changes in output voltage than those of the supply.

Time of Response

In a D.C. stabilizer it is not difficult to make the response time practically zero. In A.C. stabilizers it is possible to maintain either the R.M.S., mean or peak voltage constant, but since these are not instantaneous quantities, but ones that can only be measured once per half cycle, it follows that it is impossible to make the response time of an A.C. stabilizer zero. It is usually desirable to make the response time as small as possible, say one or two cycles.

Distortion

For many applications it is desirable that the stabilizer output be as near sinusoidal as possible and, in general, the harmonic distortion should be kept below, say 1 per cent.

Input Frequency

It is important that the stabilizer should operate correctly over the normal range of frequency (say 48 to 52 c/s) and that the output voltage should not change with change of frequency. This is a common defect of the simpler type of stabilizer depending on saturated transformers.

Output Power

The cost and complexity of a stabilizer generally increases with increase in the power output, but there are a number of cases where considerable power (½ to 1 kVA) is required.

Range of Input Voltage

In most cases the cost of a stabilizer increases as the range of input voltage over which it must operate is increased, the " size " of the stabilizer being determined by the product of the output current and the range of input voltage over which the stabilizer will operate. The range of input voltage over which the stabilizer must operate will depend on the nature of the supply and on the use to which the stabilizer is to be put.

Operation

The stabilizer should be completely automatic and should not require to be operated by skilled personnel. It should not be damaged by reasonable changes in the input voltage and failure to stabilize should be clearly indicated.

Principle of a Voltage Stabilizer

A voltage stabilizer consists essentially of two parts, the " indicator " whose function is that of detecting a change in voltage and the " controller " whose function is that of correcting the input voltage. These may each be placed in one of two positions which will now be considered. In order to explain the importance of the position of the indicator a term called the " stabilizer amplification " " M " is introduced, which is dv_{co}/dv where v_{co} is the voltage across the controller (or the change of output voltage produced by the controller) and v is the voltage input to the indicator.

Position of the Indicator

(a) Across the input to the stabilizer. This is shown in Fig. 1(a) from which it is seen that:

$$dv_i = dv_{co} + dv_o$$

but, from the definition of the stabilizer amplification:

$$dv_{co} = M.dv_i$$

therefore $dv_i = M.dv_i + dv_o$

from which the regulation factor S is:

$$\frac{dv_o}{dv_i} = 1 - M$$

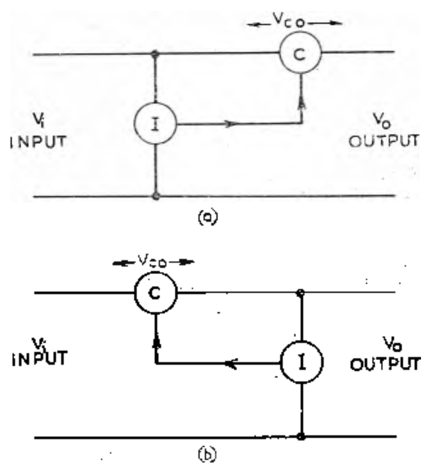


Fig. 1.

Position of indicator in a stabilizer. I—indicator, C—controller

The advantages and disadvantages of this position are:

Advantages :—

(1) The stabilizer amplification required is small, being unity.

(2) The regulation factor S can be made exactly zero by making M exactly unity.

(3) Since changes produced by the controller are not fed back to the indicator " hunting " cannot occur.

Disadvantages :—

(1) The regulation factor depends directly on the stabilizer amplification M. If M changes 10 per cent from unity to 1.1, then S becomes 0.1 instead of zero. Not only must M be unity at one particular voltage, but it must remain constant over the whole working range and must not change with changes in ambient temperature or age. It is also desirable that it should remain the same with various loads, as otherwise some adjustment must be made every time the load is changed. These requirements are difficult, if not impossible, to realize in practice.

(2) No correction is made for load changes and the arrangement therefore produces a type A stabilizer. The " regulation " will be worse than that of the supply due to the impedance of the controller.

(3) The response time is that of the indicator.

This position of the indicator has been used by Glynne[16] in an A.C. stabilizer.

(b) Across the output of the stabilizer as shown in Fig. 1(b) where as before

$$dv_i = dv_{co} + dv_o$$

but now

$$dv_{co} = M.dv_o$$

therefore

$$dv_i = M.dv_o + dv_o$$

and the regulation factor S is

$$\frac{dv_o}{dv_i} = \frac{1}{1 + M}$$

It is obvious that S is decreased by increasing M. The advantages and disadvantages of this position are:

Advantages :—

(1) The regulation factor is not affected by normal changes in the stabilizer amplification M, so long as this is large, a condition which is normally satisfied in order to get a sufficiently low value of S. If M is normally 99 then $S = 0.01$, but if M changes 10 per cent to 89.1 then S is still only 0.01109. This should be compared with the case of the indicator across the input.

(2) The arrangement corrects for changes of output voltage due to changes of load as well as for changes due to variations of input voltage, i.e., it forms a type C stabilizer.

(3) Owing to feedback action the response time of the stabilizer may be much less than that of the indicator alone.

Disadvantages :—

(1) For a low regulation factor a high value of M is required. It is often stated that with this arrangement it is impossible for the output voltage to remain constant as some change must take place in order to operate the controller. This is not really true when the special indicator to be described later is used.

(2) Since variations produced by the controller are fed back to the indicator there is a possibility of hunting, but this can be taken care of in the design.

A compromise between the two positions has been made in D.C. stabilizers by using two indicators,[1,2,17] one in each position when it can be shown that:

$$S = \frac{1 - M_1}{1 + M_2}$$

where M_1 is the stabilizer amplification of the indicator connected across the input and M_2 is the stabilizer amplification of the indicator connected across the output. This does not appear to have been attempted in A.C. stabilizers.

In view of the difficulties of maintaining a constant value of M as required if the indicator is placed across the input, and due to the fact that a type C stabilizer is much more useful, the best position for the indicator appears to be across the output of the stabilizer.

Position of the Controller

The controller can be placed in one of two positions as shown in Fig. 2, either in series with output or across the supply, together with a series impedance Z. If the change of input voltage over which the stabilizer must operate is dv_i and the output current is i_o then the power or volt-ampere output of the controller in position (a) is $dv_i.i_o$ or, if the controller bucks and boosts by the same amount, $\frac{1}{2}\ dv_i.i_o$. The volt-ampere output of the controller in position (b) is, in general, greater and it has the following disadvantages:

(a) The output voltage must usually be less than the input voltage.

(b) The sum of the currents taken by the load and the controller must be approximately constant so that full load current is continually consumed from the supply.

The indicator and controller will now be considered in detail.

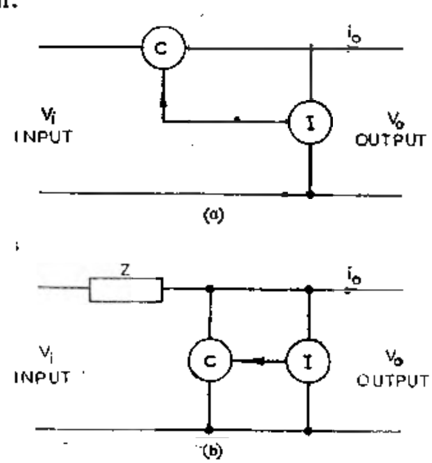


Fig. 2.
Position of the controller
I—Indicator, C—controller

The Indicator

The indicator is the most important part of a precision stabilizer since the accuracy is directly dependent on it. If it is placed across the output of the stabilizer it is also the only part of the stabilizer which controls the accuracy to any great extent. The requirements may be summarized as follows:

(a) The ratio of the change of output voltage to change of input voltage should be as large as possible. This will be termed the " figure of merit " of the indicator.

(b) The balance voltage of the indicator should remain constant independent of reasonable changes in ambient temperatures, normal vibration and time.

(c) The response time should be small, particularly if placed across the input to the stabilizer.

(d) The harmonic voltages produced by the bridge at the balance voltage should be small.

In D.C. stabilizers it is common practice to compare the unknown voltage with a battery (or other reference voltage) and use the difference to operate the controller. This idea cannot be used on A.C. as there is no A.C. equivalent of the battery. It is possible to rectify and smooth the A.C. which may then be compared with a battery,[18,19] but this has the following disadvantages:—

(a) The rectified alternating voltage must be well smoothed as otherwise, when it is compared with the battery, a large ripple voltage is produced.

(b) Owing to the requirements of good smoothing the response time tends to be large.

(c) The rectified A.C. voltage will be proportional to the mean or peak value and not the R.M.S. value. For many purposes it is desirable to maintain constant the value of the fundamental component of the output voltage. The value of the R.M.S. voltage will be practically identical for small distortions (1 per cent harmonic only altering the R.M.S. value by 0.005 per cent).This is not the same in the case of the mean or peak values where 1 per cent harmonic may change the peak value by 1 per cent and the mean value by one-third per cent. It is therefore very desirable to maintain either the fundamental component or the R.M.S. value constant in high precision stabilizers.

It is therefore more usual and better to use some form of voltage sensitive bridge, as shown in Fig. 3, consisting of four resistors, r_1, r_2, r_3 and r_4. To make the bridge voltage sensitive, at least one of these resistors must be made non-linear, i.e., composed of a material of which the resistance changes with the applied voltage. The theory and design of such non-linear bridges has been dealt with in detail by the author.[20]

A number of non-linear devices are available, but those which are instantaneous in action (e.g., Metrosil, copper oxide and selenium rectifiers) cannot be used as the indicator would then "follow" the variations during the cycle, and produce a large unwanted voltage which would completely obscure the balance point. The following devices may be used:—

1. Lamps (tungsten and carbon filament).
2. Barretters.
3. Saturated diodes.
4. Thermistors.

In all the above devices the non-linear action is brought about by temperature and there is, therefore, a lag in the change of resistance (or emission) following a change of voltage. When used on A.C. a small cyclical variation in temperature occurs which results in cyclical changes in resistance and an unwanted voltage output from the bridge which is not removed by the normal balancing of the bridge. This unwanted voltage is extremely important and it will be shown later that this consists essentially of two equal components:—

(a) A voltage of three times the supply frequency.

(b) A voltage of supply frequency, but 90° out of phase with it. These various non-linear devices will now be considered in more detail.

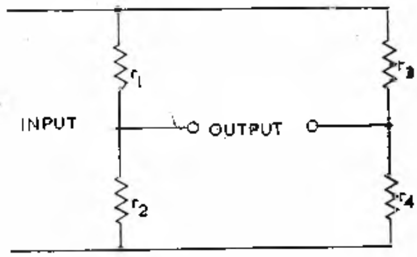


Fig. 3.
Non-linear bridge circuit

Lamps

Figure of merit

The characteristics of lamps as applied to the non-linear bridge operating on D.C. have already been considered in detail by the author,[21] where it is shown that, over a limited range of voltage, lamps obey the law $V = k.I^n$ where k and n are constants depending on the type and size of lamp. It has been shown that the best practical arrangement is two tungsten filament lamps and two linear resistors (a slightly better result is obtained by replacing the linear resistors by carbon filament lamps, but these are now difficult to obtain). For this arrangement the figure of merit[22] is:—

$$\frac{n-1}{n+1}$$

Since the maximum value[21] of n is about 2, obtained by using tungsten filament gasfilled lamps, this results in a maximum figure of merit of 0.33. This is small, but what is even more important is the ratio of the wanted to the unwanted voltages.

Unwanted Voltages at Balance

The next item to be considered is the magnitude and nature of this unwanted voltage. This will be considered in some detail as the theory applies in a general way to all of the non-linear devices which depend on temperatures for their non-linear property. The methods of eliminating these voltages is also similar in all cases. The problem of the fluctuations in the temperature of the filament of a lamp appears to have been attempted in the first place by Ebeling[2] in 1908. Modified calculations and results have been given by Corbino,[23] Langmuir,[24] Smith and Bigler,[25] Kurth[26] and others. All these authors refer to lamps operated directly off A.C. and not in series with a resistor as in a lamp bridge circuit and therefore cannot be used directly. In order to simplify the analysis, the author has restricted the work to a bridge composed of two similar lamps and two linear resistors having the same resistance as the lamps. In the appendix is given the derivation of the expression for the unwanted voltage. For the case of normal lamps this is shown to be:—

$$e_0 = E_u[\sin(\omega t - \pi/2) - \sin(3\omega t - \pi/2)]$$

$$\text{where } E_u = \frac{K_3 \,.\, \alpha \,.\, E^{(2 + 1/n_1 - n_3)}}{64(2\sqrt{2})^{(1/n_1 - n_3 - 1)} \,.\, K_4 \,.\, c \,.\, m \,.\, \omega}$$

and E is the bridge voltage, $\omega = 2\pi f$ and n_1, n_2, K_3, K_4, c and m are constants.

The expression shows that two equal voltages are produced, one of supply frequency but 90° out of phase with the supply, and the other of three times the supply frequency.

TABLE 1
VALUE OF THE CONSTANTS FOR 230 VOLT LAMPS

Lamp	α	β	n_1	n_3	K_3	K_4	m gms.	c.m. joules °C.
Tungsten								
15W Vac.	1.06	4.7	1.63	0.34	0.0023	290	0.0025	0.0004
25W Vac.	1.06	4.3	1.63	0.36	0.0037	260	0.0056	0.0009
Gasfilled Single Coil								
40W	1.06	2.5	2.00	0.29	0.012	400	0.0047	0.00075
60W	1.06	3.0	2.00	0.29	0.017	370	0.0100	0.0016
100 W	1.06	3.1	2.00	0.29	0.027	420	0.0203	0.0033
Coiled Coil								
40W	1.06	3.6	1.82	0.25	0.0085	450	0.0072	0.0012
60W	1.06	3.4	1.82	0.23	0.0131	490	0.0131	0.0021
Carbon Filament								
16 c.p.	−0.46	3.5	0.785	0.66	0.00024	45.7	0.0022	0.0032
32 c.p.	−0.40	3.4	0.785	0.68	0.00052	42.7	0.0085	0.013

The value of the constants[21] which were obtained experimentally are given in Table 1. These are for a lamp voltage of 100, but they do not vary rapidly with voltage. By examination of the above the following conclusions may be obtained:—

(1) The amplitude of the voltages increases with the voltage E since $2 + 1/n_1 - n_3$ is positive, being approximately 2.

(2) Increasing the lamp wattage increases c and m more than K_3 and therefore E_u is decreased.

(3) Gasfilled lamps of the same wattage give a value of E_u that is larger than for vacuum lamps, single coil being larger than coiled coil.

(4) Carbon filament lamps give a small value of E_u since α and K_3 are reduced and c and m are increased. The unwanted voltage is also of opposite phase since α is negative.

(5) Increasing the frequency decreases the value of E_u.

A typical experimental waveform of this unwanted voltage is shown in Fig. 4 which can easily be shown to consist of a fundamental and third harmonic of equal magnitude as given by the above expression.

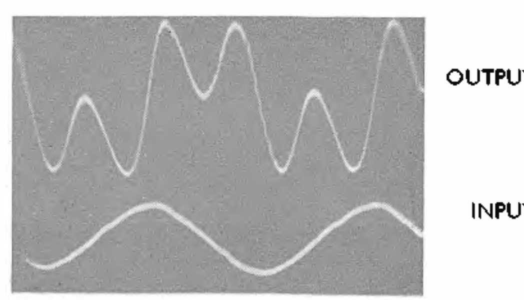


Fig. 4.
Unwanted voltage output of a lamp bridge

A number of experimental results of the magnitudes of the unwanted components are compared with the calculated values (using the constants given in

Table 1) in Table 2. Considering the complexity of the problem and the possible experimental errors, the results are in good agreement and the general results stated earlier are confirmed.

It is seen that the unwanted voltage is by no means negligible, the effect being to obscure the balance point of the bridge, since a small in-phase component will have little effect on the mean or R.M.S. value of the bridge output voltage. Considering a typical example of a bridge using 40 watt, single coil, gas-filled tungsten filament lamps at a bridge voltage of 200 volts, the value of E_u is 1.2 volts. The figure of merit will be 0.33 and therefore a 1 per cent change in the input voltage will cause an in-phase component of 0.6 volt R.M.S. or 0.85 volt peak. This is less than the unwanted voltage and a comparatively large change in bridge voltage has been assumed. If the indicator is placed across the output of the stabilizer the likely change is more of the order of 0.01 per cent or less, giving a wanted voltage output from the bridge of 0.0085 volt peak or 1/140th of the unwanted voltage. It is obvious that it is extremely difficult to detect this small wanted voltage in the presence of the unwanted voltage.

It is surprising how many authors have used this lamp bridge on A.C., but make no mention of this unwanted voltage. Graff[27] gives a graph showing the output voltage dropping to zero at balance and Weinland,[28] Benson,[29] Campbell,[30] Hull[31] and Austin and Cooper[32] have used the circuit without mention of this difficulty. Gulliksen[33,34] describes a "monitor" which is claimed to have an accuracy of 0.1 per cent, but he does not mention the unwanted voltages which must be about ten times his wanted voltage. In the discussion to reference 33, La Pierre refers to the second harmonic output, but it is shown that this is not present. Turner[35] refers to these unwanted output voltages, but gives wrong reasons for the cause of the output, both the fundamental and third harmonic. Glynne[10] is the only author to deal in any detail with this unwanted voltage. He obtains an expression similar to that of the author's, but a number of approximations are made in his proof which he does not justify:—

(a) It is assumed that the bridge current is sinusoidal, whereas it may contain up to 3 per cent harmonic.

(b) The instantaneous rate of heat production is taken as equal to $i^2.r$ and r is assumed constant. This cannot be true, or there would be no unwanted output.

(c) It is further assumed that the rate of heat loss is constant. In typical cases this varies by as much as 15 per cent.

Although, in the case of normal lamps, these approximations appear to make little difference, they should be justified. It should also be noted that in the result given by Glynne, (α), the temperature coefficient, is not a constant but varies with the operating temperature, being the temperature coefficient referred to 1 ohm at the mean temperature and not to 1 ohm at 0° C.

As would be expected, and as mentioned by Glynne, there is a connexion between the incremental response time[21] and the magnitude of the unwanted voltage.

$$E_u \times \text{Incremental Response Time} = \frac{E\alpha}{\omega\beta}$$

For a given type of lamp and operating frequency the product is proportional to E. This means that for a given incremental response time E_u is the same percentage of E so that the ratio of wanted to unwanted voltages remains constant.

It now remains to investigate methods of eliminating these unwanted voltages.

TABLE 2

MAGNITUDE OF UNWANTED OUTPUT VOLTAGE

(a) Variation of Wattage and Type of Lamp

Bridge Voltage, 200 r.m.s., 50c/s., 230 volt lamps

Lamp	K	1/K	ϕ degrees	E_u (volts) Calculated	E_u (volts) Expt.
Tungsten fil., 15 watt vacuum	0.05	19.8	87	0.79	0.75
Tungsten fil., 25 watt vacuum	0.034	29.4	88	0.60	0.57
Tungsten fil., 40 watt gasfilled single coil	0.042	23.7	87½	1.27	1.20
Tungsten fil., 60 watt gasfilled single coil	0.036	27.5	88	0.92	0.79
Tungsten fil., 100 watt gasfilled single coil	0.029	34.9	88½	0.69	0.63
Tungsten fil., 40 watt gasfilled coiled coil	0.030	33.8	88½	0.76	0.69
Tungsten fil., 60 watt gasfilled coiled coil	0.024	41.4	88½	0.65	0.57
Carbon fil., 16 c.p. ...	−0.002	−500	90	0.18	0.19

(b) Variation of Voltage 230 volt, 25 watt Vacuum Tungsten Filament Lamp

Bridge Voltage (r.m.s. volts)	E_u (volts) Calculated	E_u (volts) Experimental
100	0.12	0.16
150	0.31	0.31
200	0.60	0.56
250	0.97	0.97
300	1.47	1.30
350	2.06	1.90
400	2.72	2.54

230 volt, 40 watt, Single Coil, Gasfilled Tungsten Filament Lamp

Bridge Voltage (r.m.s. volts)	E_u (volts) Calculated	E_u (volts) Experimental
100	0.27	0.38
150	0.66	0.85
200	1.25	1.20
250	2.1	1.9
300	3.2	2.7
350	4.4	3.6
400	5.9	4.5

230 volt, 16 c.p. Carbon Filament Lamp

Bridge Voltage (r.m.s. volts)	E_u (volts) Calculated	E_u (volts) Experimental
200	0.18	0.19
300	0.55	0.51
400	1.1	1.07

Appendix

Magnitude of the unwanted voltage of a bridge composed of two equal resistors and two similar lamps having the same resistance.

Let the bridge be supplied with a sine wave voltage $E.\sin.\omega t$. It has been shown[21] that over a limited range of temperature:—

$$r_1 = r_0\,(T/T_0)^{\alpha} \text{ and } p_1 = p_0\,(T/T_0)^{\beta}$$

where r_0 and r_1 = the resistance of the lamp filament at temperatures T_0° C. and T° C. respectively,

p_o and p_1 = power loss from the lamp filament at temperatures $T_o°$ C. and $T°$ C. respectively,

and α and β are constants.

Let θ be the variation of the filament temperature about the mean value $T_o°$ C. then $T = T_o + \theta$ and $r_1 = r_o\,(1 + \theta/T_o)^\alpha$ and $p_1 = p_o\,(1 + \theta/T_o)^\beta$

If θ is small compared with T_o (an approximation justified in practice) the above can be expanded by the Binomial theorem and accurate results obtained by taking only the first two terms, thus:—

$$r_1 = r_o\,(1 + \alpha\theta/T_o) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$p_1 = p_o\,(1 + \beta\theta/T_o) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Suppose the bridge is initially balanced on D.C. so that the filament temperature is T_o and $r_o = r_2$ = the resistance of the other arm, r_2. If the mean temperature is the same on A.C., then:—

$$\text{Instantaneous lamp current } i_1 = \frac{E\,.\,\sin\omega t}{r_1 + r_2} \quad \ldots\ldots \quad (3)$$

$$= \frac{E\,.\,\sin\omega t}{r_2 + r_o\,(1 + \alpha\theta/T_o)} = \frac{E\,.\,\sin\omega t}{r_o\,(2 + \alpha\theta/T_o)} \quad \ldots\ldots \quad (4)$$

Instantaneous power to lamp $w_1 = i^2\,.\,r_1$

$$= \frac{(1 + \alpha\theta/T_o)\,E^2\,.\,\sin^2\omega t}{r_o\,(4 + 4\alpha\theta/T_o + \alpha^2\theta^2/T_o^2)}$$

Since θ/T_o is small, $\alpha^2\theta^2/T_o^2$ may be neglected,

$$\text{hence } w_1 = \frac{E^2\sin^2\omega t}{4\,r_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

The general heat equation for the filament is

$$c\,.\,m\,.\,d\theta/dt + p_1 = w_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

where c = specific heat of the filament,
m = mass of the filament,
w_1 = power input to the filament,
p_1 = power dissipated by the filament.

Substituting from (2) and (5)

$$d\theta/dt + \left(\frac{p_o\,.\,\beta}{T_o\,.\,c\,.\,m}\right)\theta = \frac{E^2\sin^2\omega t}{4\,r_o\,.\,c.m} - p_o/c.m \quad \ldots \quad (7)$$

$$\text{or } d\theta/dt + Q\theta = D\sin^2\omega t - S \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

$$\text{where } Q = \frac{p_o\,.\,\beta}{T_o\,.\,c\,.\,m}$$

$$D = \frac{E^2}{4\,r_o\,.\,c\,.\,m}$$

$$S = \frac{p_o}{c\,.\,m}$$

The solution is:—

$$\theta_e{}^{Qt} = (D/2 - S)\,e^{Qt}/Q - \frac{D\,e^{Qt}}{4\,\omega\,(1 + K^2)}$$

$$(\sin 2\,\omega t + K\cos 2\,\omega t) + Z \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

$$\text{where } K = Q/2\omega = \frac{p_o\,\beta}{2\,\omega\,T_o\,c\,.\,m}$$

Suppose the bridge balanced on D.C. and changed to A.C. of the same R.M.S. value (i.e., $E = \sqrt{2}$ D.C. voltage) at instant when A.C. voltage is zero, then, when $t = 0$, $\theta = 0$.

Substituting this condition in (9) we obtain Z, and the final equation is:—

$$\theta = \frac{1}{Q}\,(D/2 - S)(1 - e^{-Qt}) - \frac{D}{4\,\omega\,(1 + K^2)}$$

$$(\sin 2\,\omega t + K\cos 2\,\omega t) + \frac{K\,D\,e^{-Qt}}{4\,\omega\,(1 + K^2)} \quad \ldots\ldots \quad (10)$$

By substituting for D, S and Q the first term can be shown to be zero and the final term is a transient term having zero final value.

The second term gives the fluctuations in filament temperature having a frequency of twice the supply frequency. Letting $1/K = \tan\phi$ and neglecting the transient terms:—

$$\theta = \frac{D}{4\,\omega\,\sqrt{(1 + K^2)}}\cos(\pi + \phi - 2\,\omega t) \quad \ldots\ldots \quad (11)$$

The voltage across the lamp is $v_1 = i_1\,.\,r_1$.

Substituting for i_1 and r_1 from (1) and (4) and neglecting $\frac{\alpha^2\theta^2}{T_o^2}$

$$v_1 = (E/2)\sin\omega t + \frac{E\,.\,\alpha\,.\,\theta}{4\,T_o}\sin\omega t \quad \ldots\ldots\ldots \quad (12)$$

Substituting for θ from (11)

$$v_1 = (E/2)\sin\omega t + \frac{E\,\alpha\,D}{32\,T_o\omega\,\sqrt{(1 + K^2)}}$$

$$[\sin(\omega t - \phi) - \sin(3\,\omega t - \phi)] \quad \ldots\ldots\ldots\ldots\ldots \quad (13)$$

The voltage across the resistor r_2 is:—

Supply voltage $E\sin\omega t$ − lamp voltage v_1

and the unwanted voltage e_o is the difference between the voltage across the lamp and that across r_2, hence:

$$e_o = \frac{E\,\alpha\,D}{16\,T_o\omega\,\sqrt{(1 + K^2)}}[\sin(\omega t - \phi) - \sin(3\,\omega t - \phi)] \quad (14)$$

Substituting for D

$$e_o = \frac{E^3\,\alpha}{64\,r_o\,T_o\,c.m\,\omega\,\sqrt{(1 + K^2)}}$$

$$[\sin(\omega t - \phi) - \sin(3\,\omega t - \phi)] \quad \ldots\ldots\ldots\ldots\ldots \quad (15)$$

It has been shown that[n]

$$r_o = 1/K_2\,V_1{}^{1 - 1/n_1}$$

$$p_o = K_3\,V_1{}^{1 + 1/n_1}$$

$$T_o = K_4\,V_1{}^{n_3}$$

where V_1 is the lamp voltage on D.C. $= \dfrac{E}{2\,.\,\sqrt{2}}$

K_3, K_4, n_1 and n_3 are constants.

Substituting these values

$$e_o = \frac{K_3\,.\,\alpha\,.\,E^{\,(2 + 1/n_1 - n_3)}}{64\,(2\sqrt{2})^{\,(1/n_1 - n_3 - 1)}\,K_4\,.\,c.m\,\omega\,\sqrt{(1 + K^2)}}$$

$$[\sin(\omega t - \phi) - \sin(3\,\omega t - \phi)] \quad \ldots\ldots\ldots\ldots \quad (16)$$

$$\text{where } K = \frac{K_3\,\beta}{2\,\omega\,K_4\,c.m}\left(\frac{E}{2\sqrt{2}}\right)^{1 + 1/n_1 - n_3}$$

$$\tan\phi = \frac{2\,\omega\,K_4\,c.m}{K_3\,\beta}\left(\frac{E}{2\sqrt{2}}\right)^{n_3 - 1 - 1/n_1}$$

For ordinary lamps it is shown (Table II) that

Accurate Triggering of Multivibrators

AN interesting aspect of the problem of synchronizing multivibrators has arisen in the process of recording television programmes on film. The problem occurs specifically in the generation of a test pattern suitable for determining the right contrast in the photographic development of the film.

One method of finding the correct development that has the advantage of being simple in principle is to present to the recording camera, either before or after the strip is taken, a standard picture or some standard pattern. In practice this procedure unnecessarily encumbers the work of the camera operator, and the more desirable course is to inject into the channel, prior or subsequent to recording, a standard waveform of stepped character corresponding to a gradation of vertical stripes.

It is not difficult to devise in outline a circuit for setting up such a waveform. A multivibrator may be arranged to provide 10 pulses, for instance, in the duration of every picture line, and a counter circuit fed with these pulses can be made conveniently to generate the stepped waveform from them. The multivibrator will be synchronized by the line pulses and will be triggered by them every 10th cycle. A circuit of this kind has been tried, but it has been found to give trouble on account of the large ratio between multivibrator frequency and synchronizing impulse frequency. For short periods the circuit may be set up to function satisfactorily. Longer tests, however, show that it is possible on occasions for the multivibrator to drift so that synchronizing impulses arrive too late to exert their proper control. The start of the stepped waveform is then not coincident with the arrival of a line pulse, but occurs at some uncertain time ahead of the line pulse, and the gradation pattern accordingly loses its definite shape.

One obvious cure is to stabilize better the supplies to the multivibrator. A more feasible way that has met with success is to permit the multivibrator to drift, so that on occasion it may, in fact, run fast of the synchronized impulses. At the same time, as a counter measure, the synchronizing impulses are modified in a special way so that, if the multivibrator has triggered before the arrival of a synchronizing impulse, it is first re-set and can in consequence then be triggered properly by the synchronizing impulse at the correct instant.

This scheme may be carried out by inverting the synchonizing impulses and differentiating them so that every pulse becomes a pair of pulses of opposite polarity. By virtue of this device, should the multivibrator have triggered ahead of the correct instant it is kicked back automatically by the leading pulse polarity. By virtue of this device, should the multivibrator in the correct manner at the right moment. If the multivibrator has not triggered prematurely it remains unaffected by the leading pulse and waits for the arrival of the second pulse to trip it. The scheme can be employed in any instance where it is required to preset a multivibrator which otherwise could not be correctly controlled by a timing pulse.

—Communication from E.M.I., Ltd.

$\sqrt{(1 + K^2)}$ may be taken as unity and $\tan \phi$ as infinity or $\phi = \pi/2$ with little error, hence (16) becomes:—

$$e_0 = E_0[\sin(\omega t - \pi/2) - \sin(3\omega t - \pi/2)] \quad \ldots\ldots (17)$$

$$\text{where } E_0 = \frac{K_3 \,.\, \alpha \,.\, E^{(2+1/n_1 - n_3)}}{64\,(2\sqrt{2}^{(1/n_1 - n_3 - 1)} K_4 \,.\, c.m \,.\, \omega}$$

(To be continued)

References

1. F. V. Hunt and R. W. Hickman: "On Electronic Voltage Stabilizers," *Rev. Sci. Inst.*, *10*, p. 6, 1939.
2. A. Glynne: "A New Electronic Stabilizer and Regulator for D.C. Voltages and the Use of a Simple A.C. Potentiometer for the Precision Testing of Instrument Transformers, *J.I.E.E.*, *91*, Pt. II, p. 174, 1944.
3. A. Abate: "Basic Theory and Design of Electronically Regulated Power Supplies," *Proc. I.R.E.*, *32*, p. 478, 1945.
4. F. A. Benson: "Voltage Stabilizers," *Electronic Engineering*, *21*, p. 155, 1949.
5. F. L. Hogg: "Electronic Voltage Regulators," *Wireless World*, *49*, pp. 327 and 371, 1943.
6. M. G. Scroggie: "Stabilized Power Supplies," *Wireless World*, *54*, p. 373, 1948.
7. P. Koontz and E. Dilatush: "Voltage Regulated Power Supplies," *Electronics*, *20*, p. 119, July, 1947.
8. J. McG. Sowerby: "Shunt Voltage Stabilizers," *Wireless World*, *54*, p. 200, 1948.
9. L. C. Verman and L. A. Richards: "A Vacuum Tube Voltage Regulator," *Journal of the American I.E.E.*, *50*, p. 436, 1931; and "Vacuum Tube Voltage Regulator for A.C.," *Rev. Sci. Inst.*, *1*, p. 581, 1930.
10. A. L. Whiteley: "Applications of the Hot Cathode Grid-controlled Rectifier or Thyratron," *J.I.E.E.*, *78*, p. 576, 1936.
11. A. H. B. Walker: "The Stabilistor," *Wireless World*, *50*, p. 339, 1944.
12. H. A. R. Samson: "A Photocell Voltage Control Gear," *Electronic Engineering*, *15*, p. 516, 1943.
13. P. H. Craig: "An Automatic Voltage Regulator Without Moving Parts Employing Ferroresonance," *Trans. American I.E.E.*, *58*, p. 830, 1939.
14. A. E. Maine: "An Electro-mechanically Stabilized Mains Supply Unit," *Electronic Engineering*, *21*, p. 319, 1949.
15. W. R. Hill: "Analysis of Voltage Regulator Operation," *Proc. I.R.E.*, *32*, p. 38, 1945.
16. A. Glynne: "A Differential Electronic Stabilizer for Alternating Voltages and Some Applications," *J.I.E.E.*, *90*, Pt. II, p. 101, 1943.
17. S. E. Miller: "Sensitive D.C. Amplifier for A.C. Operation," *Electronics*, *14*, p. 27, Nov., 1941.
18. A. Rosenstein and H. A. Barnett: "Electronically Controlled Dry Disk Rectifier," *Trans. American I.E.E.*, *63*, p. 21, 1944.
19. D. L. Harris: "Electronic A.C. Voltage Regulator," *Electronics*, *19*, p. 150, Jan., 1946.
20. G. N. Patchett: "The Theory of the Non-linear Bridge Circuit Applied to Voltage Stabilizers," *J.I.E.E.*, *93*, Pt. III, p. 16, 1946.
21. G. N. Patchett: "The Characteristics of Lamps as Applied to the Non-linear Bridge, Used as the Indicator in Voltage Stabilizers," *J.I.E.E.*, *93*, Pt. III, p. 305, 1946.
22. H. Ebeling: "On Temperature Variations of a Filament Carrying an Alternating Current," *Annelen der Physik*, *27*, p. 391, 1908.
23. O. M. Corbino: "Variations in Temperature of Lamps Carrying Alternating Current," *Physik Zeitschrift*, *11*, p. 443, 1910.
24. I. Langmuir: "The Flicker of Incandescent Lamps on Alternating Current and the Stroposcopic Effect," *General Electric Review*, p. 294, 1914.
25. K. K. Smith and P. W. Bigler: "Oscillations of the Temperature of a Filament and the Specific Heat of Tungsten," *Physical Review*, *19*, p. 288, 1922.
26. K. Kurth: "On the Light and Temperature Variation of a Lamp Carrying Alternating Current," *Archiv. fur Elektrotechnik*, 23, p. 124, 1930.
27. J. W. Graff, "An Electronic Voltage Relay," *Electronics*, *7*, p. 80, Mar., 1934.
28. C. E. Weinland: "A Thyratron Voltage Regulator for an Alternator," *Rev. Sci. Inst.*, *3*, p. 9, 1932.
29. A. Benson: "Electronic Regulators for A.C. Generators," *Electronics*, *16*, p. 104, Apr., 1943; and *16*, p. 112, Aug., 1943.
30. A. Campbell: "On Test Room Methods of Alternating Current Measurement," *J.I.E.E.*, *30*, p. 889, 1901.
31. A. W. Hull: "Hot Cathode Thyratrons," *General Electric Review*, *32*, pp. 213 and 390, 1929.
32. T. M. Austin and F. W. Cooper: "Two Applications of Non-linear Circuits," *Journal Amer. I.E.E.*, *53*, p. 293, 1934.
33. F. H. Gulliksen: "Electronic Regulators for A.C. Generators," *Trans. Amer. I.E.E.*, *53*, p. 877, 1934.
34. F. H. Gulliksen and E. H. Vedder: "Industrial Electronics," John Wiley and Sons, New York, 1935.
35. L. B. Turner: "Voltmeter for A.C. Mains Fluctuations," *Jour. Sci. Inst.* *14*, p. 379, 1937.

The 17th National Radio Exhibition

Castle Bromwich, September 6 to 16, 1950

A selection of radio and television equipment and accessories to be exhibited, compiled from information supplied by the manufacturers

THE RADIO SHOW
CASTLE BROMWICH
Birmingham Sept. 6-16

THE RADIO SHOW
CASTLE BROMWICH
Birmingham Sept. 6-16

Electronic Engineering will be pleased to welcome visitors at Stand No. 15.

Figures in parentheses refer to Stand Numbers

Antiference Ltd. (18)

A range of television aerials will be shown, including the "Antex" Series 2, which has a new mechanical design.

It embodies a new junction unit of bakelite, reinforced by aluminium die-castings which is a great improvement mechanically over the original "Antex" insulator. All electrical connexions are fully enclosed and weatherproof. A feature is the provision of rod sealing glands which ensure both a watertight seal and complete freedom from movement due to vibration once the rod element is screwed into the junction unit. The "Antex" Mk. 2 is fitted with ½ in. diameter anodized aluminium alloy rods which provide better performance than the original model. Four models will be available: two with 5 ft. cranked masts for chimney or wall mounting; one for mounting to a wooden mast of any height, and the other complete with a 10 ft. aluminium alloy mast and chimney lashing equipment.

Another feature will be the "2-way" Dipole Aerial which is a new light-weight and low-priced single dipole for wall mounting. It incorporates the Antiference patent method of aerial rod connexion which simplifies assembly and erection. Terminal connexions are protected by means of a P.V.C. cover and the design of the insulator enables the aerial to be used in a choice of two positions. The mounting bracket is reversible and provides for a stand-off clearance where required.

A simple flexible aerial for internal mounting in strong signal areas will also be exhibited. It comprises a neat junction box and two flexible conductors, and can be mounted inconspicuously in any part of the room. It is suitable for use with all types of television receivers and cables. A junction box for fitting flexible conductor is available separately.

Antiference Ltd.,
67, Bryanston Street,
London, W.1.

Automatic Coil Winder & Electrical Equipment Co., Ltd. (26)

VARIOUS examples of "Avo" radio television servicing equipment will be on view, and the new "Avo" Valve Testing Manual which has just been produced will be of interest to users of the Valve Tester and Valve Characteristic Meter.

A new Universal Bridge, illustrated above, will be shown, whilst it is hoped to give practical demonstrations of the use of various instruments. Also exhibited will be the high sensitivity AvoMeter, and the Electronic Testmeter, Signal Generator and the Electronic Test unit working in combination, covering a wide range.

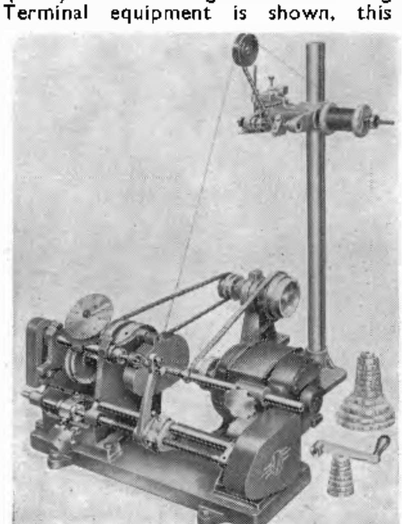
Several different types of coil winding machines have been selected for exhibition, including a working model of the Douglas fully automatic multi-winder, which is capable of producing 12 coils simultaneously at high speed, and the Douglas Progressive Wave Winder, illustrated right.

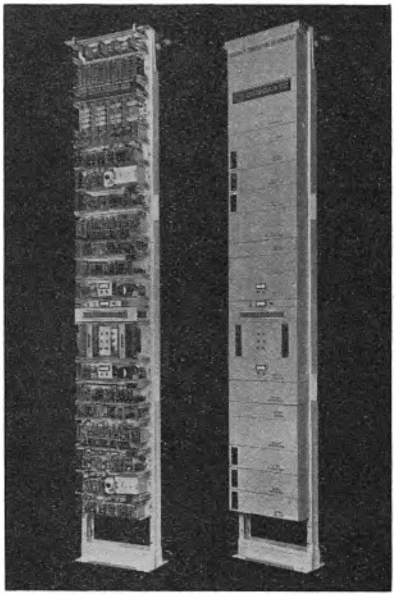
Automatic Coil Winder and Electrical Equipment Co. Ltd.,
Winder House,
Douglas Street,
London, S.W.1.

Automatic Telephone & Electric Co., Ltd. (41)

SEVERAL examples of the latest types of long distance telephone carrier circuit equipment may be seen at this firm's stand, ranging from a four-channel portable carrier equipment to a twelve-channel terminal similar to that used by the British Post Office. (Illustrated opposite).

A great deal of the world's communications traffic is transmitted by telegraphic code and whether the medium of transmission is line or radio, distortions of the original signals can easily occur en route, resulting in incorrect versions being received and time being wasted on corrections. An Electronic Regenerative Repeater is shown, designed to reform distorted teleprinter code signals, which can be interposed at any point in a link in order to retransmit correctly formed characters. This equipment is shown in operation receiving heavily distorted signals and retransmitting perfectly formed characters. In addition, frequency shift receiving and Transmitting Terminal equipment is shown, this





equipment being designed to take advantage of the great improvement in performance which the system of Frequency Shift is capable of providing over the more conventional on/off system.

*Automatic Telephone and Electric Co., Ltd
Strowger Works,
Liverpool 7.*

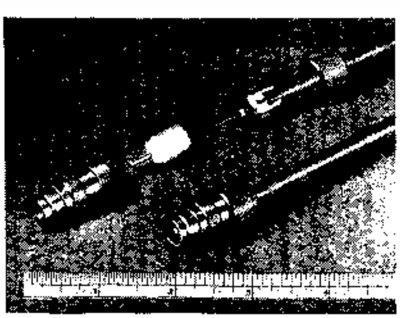
Belling & Lee Ltd. (71)

THE new "Belling-Lee" universal co-axial plug **L.734/P** fits all the firm's co-axial sockets and termination boxes, and accepts co-axial cables from 5/32 to 5/16, which covers television feeders for domestic purposes with impedances from 50 ohms, and including 72 ohm semi-air spaced.

This plug complies with the new R.E.C.M.F. draft specification, and the component parts interlock in such a way as to simplify the fitting of the plug to the cable. It is easy to load, as the soldering is done before assembly.

Other exhibits include television aerial conversion kits, television demonstration aerials and production samples of the B7G valveholder.

*Belling and Lee Ltd.,
Cambridge Arterial Road,
Enfield, Middx.*

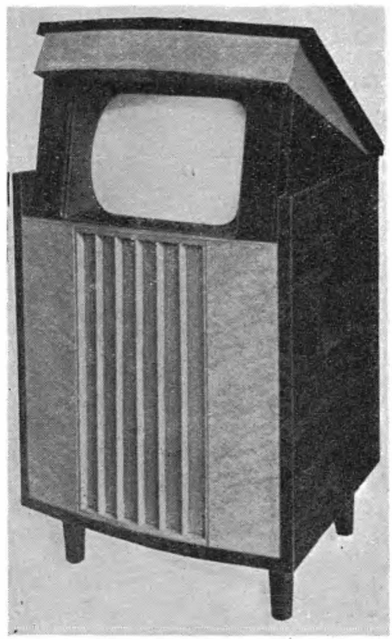


E. K. Cole Ltd. (11, 53 and 92)

AN interesting item on this firm's stand will be the Ekcovision Model TSC 113, a combined radio and television set, shown below.

The radio unit of this model is a three-plus-one superhet with four pre-set stations covering three medium and one long wavebands.

The television unit has 18 valves, including the cathode ray tube. A 15-inch tube is used, giving a 137 square inch viewing area. The model has a consumption of 150 watts.



Another new item will be a 12-inch Console model in an attractive cabinet fitted with doors and an aluminized tube giving increased brilliance and contrast.

Extension speakers, television pre-amplifiers (illustrated right), attenuators, indoor aerials and other accessories, will also be on view.

*E. K. Cole Ltd.,
Ekco Works,
Southend-on-Sea,
Essex.*

A. C. Cossor Ltd. (7 and 52)

THE Cossor "Telecheck" Television Alignment Oscillator and Pattern Generator, to be exhibited for the first time, is a lightweight instrument designed to enable service engineers to align R.F. and I.F. circuits and to check the timebases of commercial television receivers. Illustrated at the top of column one overleaf.

Alignment is carried out by using the instrument in conjunction with a cathode ray oscilloscope. A feature of the instrument is that the frequency modulation of the carrier injected into the television receiver is carried out electronically, the X-sweep voltage of the oscilloscope being used to control the modulation. This arrangement results in the instrument being substantially lighter than similar instruments using mechanical frequency modulation methods.

The response curves of R.F. and I.F. tuned circuits are displayed on the oscillograph producing the sweep voltage, the 7 Mc/s. bandwidth of the F.M. sweep filling the entire length of the trace.

The carrier can be set at any frequency between 7 and 70 Mc/s., and can be fed into any suitable point between the aerial input of the receiver and the detector. The output from the television receiver, when fed to the oscilloscope X amplifiers, will provide a picture of the response curve of the tuned circuits under examination over a range of frequencies up to 3.5 Mc/s. either side of the selected carrier frequency.

If a Cossor Double Beam Oscillograph is used it is possible to feed the vision output to one amplifier and the sound to the other, thus showing the response curve of both sections of the receiver and also any interaction effects which may be present.

A wide range of output voltage is available, from 25 micro-volts to 50 millivolts, adjustment being made by coarse and fine variable attenuator networks. Provision has been made for a carrier frequency calibration check to be made using a signal generator. Any signal generator covering the band 7-70 Mc/s. and with an output up to 50 mV may be used to provide this calibration, which appears as a marker pip on the trace. The frequency range of the Alignment Oscillator is such that it will cover all the carrier frequencies on which the vision and associated sound programme of the British Broadcasting Corporation are or will be transmitted, as well as any intermediate frequency

that might be selected for a superheterodyne receiver, thus making allowance for future requirements.

The pattern generator consists of a square wave generator working at frequencies of 400 c/s. and 80 kc/s. This generator amplitude-modulates the output of the alignment oscillator and provides a picture of alternate, evenly-spaced black and white bars, horizontal or vertical, on the television receiver screen. The purpose of this modulation is to provide an accurate test of time base linearity. No ancillary equipment is required for the linearity test.

The Cossor exhibit also displays a range of radio and television receivers, combined tele-radio consoles, radiograms, valves, cathode ray tubes and electronic instruments.

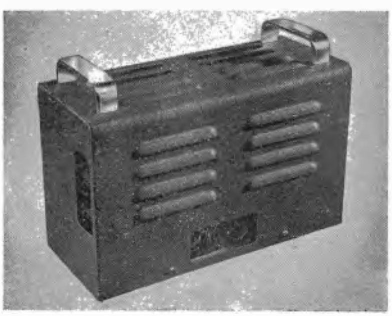
Cossor valves, including the latest lock-in types, will be shown, together with a range of Cathode ray tubes for television and industrial uses. These latter include the unique double-beam tubes as used in the Cossor Oscillographs, Models 1035 and 1049, examples of which will be shown. The Cossor Direct-Writing Electro-Cardiograph, Model 1314, is also to be displayed.

A. C. Cossor Ltd.,
Cossor House,
Highbury Grove,
London, N.5.

The Decca Record Co., Ltd. (22, 37 and 40)

THIS firm will exhibit a range of television receivers, radiograms, record players, and their associated equipment.

A high fidelity corner speaker is to be exhibited, which is a high-flux (14,000 lines) unit for handling up to ten watts, loaded by a folded near-resonant tapered air column. The walls of the room provide the final termination and high frequency diffusion. Efficient electro-acoustic conversion damping is employed. It has three impedances: type CS/3, three ohms; type CS/6, six ohms; and type CS/15, 15 ohms.



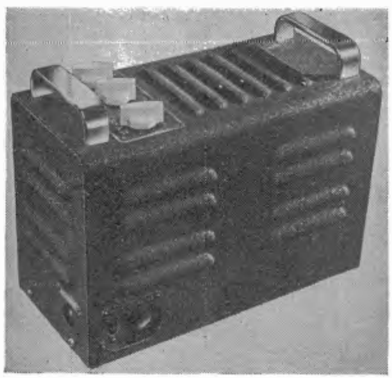
Of particular interest will be two new types of amplifiers, the PA/VI (illustrated below) and PA/IX.

The PA/VI type has an output of 4.5 watts, and a frequency response of 30-16,000 c/s. It is designed for high fidelity magnetic pick-ups and microphones. The valves employed are two EF37's, an L63, two PX 4's and a 5U4G.

The PA/IX has three push-pull stages of matched L63's, push-pull matched PX 25's and a 5U4G. The output is 6.5 watts, with a frequency response of 20-20,000 c/s. Stepped brilliance and bass controls give correct compensations for ffrr, E.M.I. and N.A.B. recording characteristics. It has bass-compensated volume control and is suitable for 20-30 ohm pick-ups and microphones. It has an A.C. power unit, illustrated bottom left).

Both the amplifiers and mains units are housed in ventilated pressed steel cases, finished grey with chromium-plated handles. The power supply is 200-250 V. A.C. mains.

The Decca Record Co. Ltd.,
1-3, Brixton Road,
London, S.W.9



Dynatron Radio Ltd. (69)

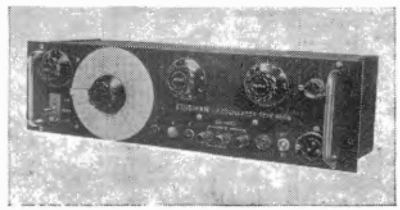
A NEW radiogramophone will be exhibited, called the Ether Princess, illustrated right, which has been designed for giving quality reproduction. Other recent additions to be shown include the Ether Consort combined Television Radiogramophone, which uses the Princess chassis, and the Falcon television chassis, and the Ether Sovereign combined Television Radiogramophone television model, in a Queen Anne cabinet. This uses the same television chassis as before, together with the Ether Conqueror radio chassis, which are housed together in a period cabinet.

Dynatron Radio Ltd.,
Perfecta Works,
Ray Lea Road,
Maidenhead, Kent

Edison Swan Electric Co., Ltd. (33)

AMONG the features of this stand will be an animated display unit designed to give the general public an idea of the method by which a picture is built up on the screen of a television receiver. A working demonstration of the Ediswan Mark II Loudspeakerphone equipment, illustrated above, will be shown.

The Low Frequency Oscillator, illustrated below, is a development designed specifically for testing, calibration and set-up of biological amplifiers and recorders, strain and vibration amplifiers and recorders, and low frequency wave analysers.



The resistance/capacitance circuit is of a special design with automatic amplitude control to ensure constant output and good waveform at all frequencies. The inclusion of an incremental frequency switch is for the measurement of Q in frequency selective circuits of filters or wave analysers.

There are seven ranges covering 1.4 c/s to 5,500 c/s., with an increment increase and decrease of not more than 1.0 c/s. The waveform has less than 2 per cent distortion at all frequencies except the extreme limit where a slight increase occurs.

On an open circuit the output is 50 volts peak to peak push-pull, and 25 volts peak to peak unbalanced. It is

constant within ±55 per cent on all frequency ranges, with an absolute value of ±10 per cent of rated voltage.

Output control is either by step attenuator for feeding into high impedance amplifier input or by a continuously variable control. Output impedance drops with decreasing output, in the first case falling 10,000 ohms maximum to a constant value of 40 ohms on last three steps (push-pull values); inthe latter case the control is calibrated 0.1 -1.0 with an accuracy of ±5 per cent of the full scale. This provides surgeless control of the output, essential when testing amplifiers with long time constants.

For distortion testing a feature is the provision for the introduction of 15 per cent 50 cycle wave super-imposed upon a selected low frequency. An external signal can be rejected if a frequency other than mains frequency is required (about 25 volts r.m.s. is required).

The Edison Swan Electric Co., Ltd.,
155, Charing Cross Road,
London, W.C.2.

Electro Dynamic Construction Co., Ltd. (9)

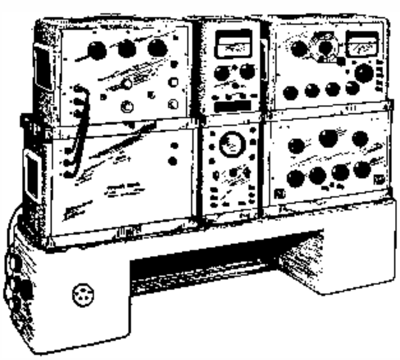
A NEW range of high frequency motor alternators will be a feature of this firm's exhibit, which are primarily for use with radar and allied navigational gear, and electronic apparatus. A new type of small rotary transformer and their usual range of rotary convertors will also be shown, including a convertor and filter complete unit in a soundproof cabinet for television, in a range of six types from 180 to 600 watts.

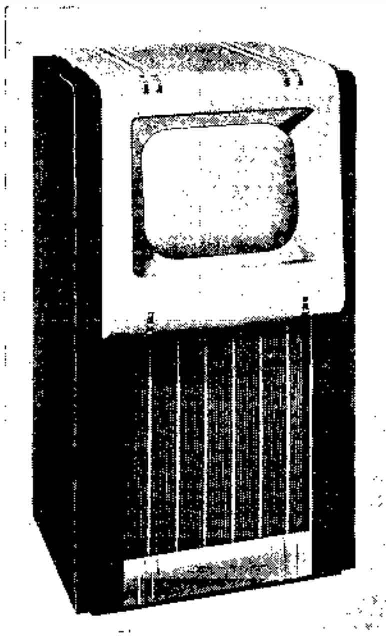
Electro Dynamic Construction Co., Ltd.,
St. Mary Cray,
Kent.

The English Electric Co., Ltd. (35)

AMONG the Company's exhibits will be the Model 1550 Television Receiver, which was introduced at the end of 1949. It has a 120 square inch screen, and is equipped with a syn-

The television test rig exhibited on the English Electric Company's Stand by Marconi Instruments Limited consists of—Top right: Receiver Tester TF888; Bottom right: Sweep Generator TF923; Top centre: Valve Voltohmmeter TF887A; Bottom centre: Oscilloscope TF966; Top left: Pattern Modulator TF954; Bottom left: Timing Unit TF965.





chrophase device which enables it to be used in those parts of the fringe areas where reception would otherwise be impossible. (Illustrated above.)

On the stand there will also be demonstrated television test instruments made by Marconi Instruments Limited, and so arranged that they can be grouped as a complete assembly for overall testing. The grouping system does not immobilze otherwise portable instruments, nor need all the individual types be acquired at the same time. Starting with only two or three, further units can be added as required.

Marconi Instruments Limited will demonstrate this equipment in use on an "English Electric" television receiver dismantled to show the chassis and components.

The English Electric Co., Ltd.
Queens House, Kingsway
London, W.C.2

Ferranti Ltd. (55)

THIS firm will show a range of radio, television and combined radio/television models.

A radiogram, Model 405, consisting of a 5-valve superhet receiver with a 10 inch p.m. speaker and built-in aerials, will also be shown. Ten 10-inch or ten 12-inch records can be automatically played, and low note uplift circuits are included to improve record response.

The television range gives a choice of table and console receivers for the Midlands and London areas, and includes models incorporating a radio receiver with built-in aerials. A projection television receiver, Model T.1605, will be also on view which gives a large flat brilliant picture 14 in. by 10½ in. in size.

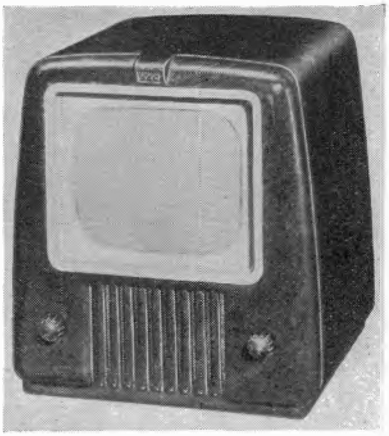
With the exception of the projection television receiver, all models have the 12 inch Ferranti cathode ray tube which is free from ion spot burn and because of its moulded construction gives a substantially flat brilliant picture approximately 10½ in. by 8 in. (Illustrated below.) All controls are conveniently pladed at the cabinet front, considerably simplifying operation. In the table Model T.1405 the controls are concealed by a hinged flap when not in sue, and in the console model T.1205 the picture screen and controls can also be concealed by a flap which retracts into the top of the cabinet and can be used, if necessary, to shield the picture from unwanted direct lighting. The combined television and radio console model T.1505 has doors to conceal screen and controls when not in use, and its radio receiver has built-in aerials. Illustrated below.

Ferranti Ltd.,
Hollinwood,
Lancs,

The General Electric Co., Ltd. (58, 77 and 85)

IN the field of television the Company will show the newly introduced model BT.2147 which is an example of a low-priced receiver embodying all important technical features, illustrated overleaf.

The circuit uses three stages of signal frequency amplification common to the



sound and vision channels, followed by a separate stage for each channel. To achieve the maximum efficiency and high sensitivity for weak-signal areas, all-glass miniature valves are used. A single stage of video amplification is employed and the overall video response is level from zero to 3 Mc/s. Interference in the sound and vision circuits is virtually eliminated by efficient spot-limiting and noise suppressing circuits. Permanent-magnet focusing together with stable time base and synchronising circuits give a completely stable picture under all conditions and ensure that the pre-set controls hardly ever need adjusting after the set has been installed by the dealer. The flat-ended cathode ray tube is aluminized and the brilliant picture can be comfortably shared by a family, without any need to darken the room. Conversion from London to Birmingham frequencies can be done in a matter of minutes, simply by changing the plug-in R.F. chassis.

The receiver can be used on any A.C. or D.C. mains between 200 and 250 volts.

The Electronics Section stand will be devoted to token displays of the Company's many other activities in the communications field, including industrial V.H.F. radio equipment, sound equipment, tape recorder, recording tape and other specialized products.

Other exhibits on this stand will be a representative selection of Osram products, including cathode ray and geiger-muller tubes, photocells and valves.

Two new types of miniature valves will be shown, the Osram X79, which is a triode-hexode frequency changer on the B9A Noval base, principally for short wave reception.

The Osram N37 is an output pentode on the B7G base, designed for frame time-base amplifier, or sound output in television receivers in which the heaters are wired in series at a current of 0.3 amp.

The Osram U37 is a sub-miniature, half-wave rectifier, designed for soldering direct into a circuit and for supplying E.H.T. from R.F. or flyback voltage sources. It has a very low heater wattage, 0.14 amps at 1.4 volt.

Other interesting valves are the types used in the London-Birmingham Television Link, having been designed for this purpose. A1714 is a high slope planar triode used in the receiver I.F. amplifier. The KT67 is a high slope R.F. tetrode used in the second amplifying and cathode follower stages in the transmitter I.F. amplifier. The DET24 is a disk seal triode used in the master oscillator and first R.F. amplifier stages in the transmitter.

The ACT25 is a forced air-cooled disk seal triode used as a transmitter frequency changer.

The General Electric Co. Ltd.,
Magnet House,
Kingsway,
London, W.C.2.

General Post Office (21 and 34)

CENTIMETRIC wave radio links may be used extensively in the future for relaying television signals and for multi-channel telephony. The demonstration on the stand will show the principles of operation of typical equipment. The transmitter consists of a 10,000 Mc/s. (3 centimetre) low power reflex klystron oscillator which is frequency modulated by the television signal. The output of the transmitter is fed through a wave guide to a lens-horn aerial which produces a narrow beam of radio waves thereby concentrating most of the radiated power towards the distant receiver. The electro-magnetic wave lenses used in these aerials operate on similar principles to the lenses used in optical equipment but are made from an artificial dielectric consisting of metallic spots sprayed on thin sheets of insulating material. Similar aerials are used on the receiver, the narrow beam width in this case serving to exclude unwanted signals and noise. The receiver is of the super-heterodyne type with a reflex klystron local oscillator and a crystal mixer. The mixer is followed by a 60 Mc/s. L.F. Amplifier, a Limiter and a Discriminator, the output from which is a replica of the television signal applied to the transmitter.

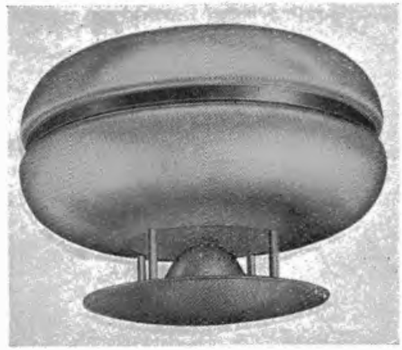
The exhibit also includes working examples of the equipment used for amplification and for modulation and demodulation at the terminal stations.

A repeatered circuit for television transmission will be shown, and television pictures are demonstrated after transmission over one mile of telephone cable, before and after equalization.

General Post Office,
Alder House,
London, E.C.1.

Goodmans Industries Ltd. (85)

THE Goodmans Concentric Diffuser has been introduced to meet the demand for an omni-directional Public Address Reproducer. This 10 Watt diffuser type loudspeaker uses a high flux 10 in. P.M. Loudspeaker mounted in a Helmholtz resonator of optimum



volumetric capacity, the diaphragm being fully loaded down to 50 c/s. The "CD/77" has a frequency range from 50 c/s. to 10,000 c/s. free of sub-harmonics and bass modulation effects. Its outstanding design guarantees sound waves evenly spread over a radius of 360 degrees. It is shown above.

Connexion to the unit is effected by means of a flush fitting plug and socket close to the eye attachment for the suspension of the diffuser.

Overall diameter: $20\frac{1}{2}$ in.

Overall height (including eye suspension attachment): $17\frac{1}{2}$ in.

Speaker unit: 10 in. P.M. High Flux.

Voice Coil Impedance: 15 Ohms.

Maximum Power Input: 10 Watts Peak A.C.

Nett weight: 21 lbs.

Also exhibited will be the "Axiom 150" High Fidelity P.M. Loudspeaker and the "Audiom 60" 12 in. P.M. Loudspeaker.

Goodmans Industries Ltd.,
Lancelot Road,
Wembley, Middx.

Hale Electric Co. Ltd. (Etronic Radio) (60)

THE latest development to be shown by Etronic consists of a Projection Televisor employing a superheterodyne circuit with a total of 23 Mullard valves. It is available for both London and Midland reception areas, and is housed in a handsome console cabinet, fitted with doors which, when opened, disclose a screen giving a picture measuring 18 in. by $13\frac{7}{16}$ in.

A full range of television receivers, radiograms and radio receivers will also be exhibited, including a midget receiver, and a de-luxe console Television Receiver.

Hale Electric Co. Ltd.,
Radio Works,
Talbot Road, West Ealing,
London, W.13.

Metro Pex Ltd. (78)

EXHIBITS will include specially designed lenses and accessories for radar development, lenses for incorporation into television receivers (export), industrial lenses and full ranges of standard and filter type lenses for current receivers. Separate filters for use on 9 in., 10 in., 12 in., and 15 in. receivers are available.

Recent additions to the range are the Console and Table Stand models, type Nos. C1X, C2, A3, incorporating new developments in stand design. They are hand forged in wrought iron, finished in polychromatic bronze; they are available for 9 in., 10 in. and 12 in. receivers.

Also on show will be the new trolley table models, introduced to solve the problem of where to put the television set. They are simply designed tubular steel tables with telescopic and swivel lens adjustment, fitted with large wheels for easy movement; available for 9 in., 10 in. and 12 in. table receivers.

Metro Pex Ltd.,
38, Great Portland Street,
London W.1.

Mullard Electronic Products Ltd. (64 and 74)

MULLARD'S will have two stands at this exhibition, and Stand No. 74 will be devoted to a display and demonstration of valves, tubes and components of interest to equipment manufacturers. The range of products will include valves for domestic receiver, car radio and audio-amplifiers; valves and C.R. tubes for television receivers; subminiature valves for hearing aids, and the very latest photocells for sound-on-film equipment. Of interest among these exhibits is a new range of noval base receiving valves specially designed for television.

A wide variety of Mullard radio and television components will also be exhibited, including a range of "Ticonal" permanent magnets, Ferroxcube—a high-permeability, low-loss ferrite, and Varite negative temperature coefficient resistors.

Mullard projection television components will also be demonstrated on Stand No. 74. These components comprise an optical system, deflexion and focusing coils, and compact E.H.T. unit and the Mullard MW6-2 projection tube.

On Stand No. 64, Mullard will present their range of radio and television receivers, whilst a section of this stand will be devoted to a comprehensive display of radio valves and television tubes suitable for all types of receivers.

Important among the range of Mullard radio and television exhibits will be five new radio receivers, Models MAS274 and MAS277, and a new television receiver Model MTS 501.

The MAS274 is a 5-valve, all-wave superhetrodyne for A.C. mains. The MAS277 is a de-luxe, 5-valve A.C. superhet giving good performance on three wavelengths, with a "magic eye" tuning indicator. The Model MTS501 is a television console with a 12-inch cathode ray tube. The picture produced on the screen is bright, sharply defined and steady so that it can be viewed comfortably in normal room lighting.

An interesting feature on stand No. 64 will be a giant model of a modern valve cut away to show the complex multi-electrode system inside. Another interesting exhibit will be a new High-Speed Valve Tester for use in dealers' shops and service departments. By means of this instrument any normal receiving valve can be completely and accurately tested in a few moments. It is compact, automatic in operation and has the advantage that it can be used by non-technical personnel.

Mullard Electronic Products Ltd.,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Multicore Solders Ltd. (86)

AT this stand practical soldering demonstrations will be given, the chief feature being a typical television assembly line worked by the G.E.C.'s staff from Coventry. They will assemble R.F. units for the G.E.C. Television Model No. BT.2147, the complete operation taking more than an hour.

Multicore Solders Ltd.,
Mellier House,
Albemarle Street,
London W.1.

Murphy Radio Ltd. (44)

THIS firm will show a new radiogram, the A172R. It has eight valves, and will play 78 r.p.m. and long-playing records. It uses the Murphy light-weight pick-up, with a moving coil for 78 r.p.m. and moving iron for long-playing records. The radio unit has long, medium and short wavebands, with flywheel tuning. Delayed A.G.C. negative feedback is used, with high-power push-pull output. It has two loudspeakers, and A.C. operation in the 50-60 cycles.

Another new item to be shown will be the Murphy V178C television receiver which employs a 12 inch aluminized tube. Unusual features of this model are: the use of oil-filled line-scan transformers producing 9 kV; the low voltage rectifier is of the selenium type instead of the usual valve type; it has two R.F. stages. Models are available for both London and Birmingham, and the cabinet is in two tones of French walnut and bird's eye maple, with fitted castors.

Other recent models to be exhibited include the V180C television console receiver for use on the combined vision-sound channels; the A170 table radio receiver, and the "168" Murphy baffle table receiver.

Murphy Radio Ltd.,
Welwyn Garden City,
Herts.

Philips Electrical Ltd. (42 and 45)

THE full range of Philips television receivers will be exhibited, comprising direct viewing and projection models. The direct viewing receivers will include two table models, the 385U with the 9 in. tube, the 492U with the 12 in. tube, and a 12 in. console model 485U. Two

of these receivers will be demonstrated in the Television Avenue.

Of particular interest at this exhibition will be the demonstration on stand No. 42 of Philips projection television. Two models will be exhibited, the table receiver 600A—which is supplied with or without stand—and the new console model, 704A.

The advantage of these new receivers is that they allow the picture to be viewed comfortably by a large group.

The screens have been developed to give the maximum horizontal angle of view from the front. This has been achieved by lenticular rulings on the back face of the screen. The flat screen also obviates high speed reflexions of sources of light, so that the picture may be viewed in normal room lighting, with no glare or any appreciable loss of contrast.

The introduction of the 600A table model brings Philips projection television within the reach of the home. It combines the important features of compactness, bigger screen and wide-angle viewing, and is most suitable for family viewing. It gives clear, soft-toned pictures on a flat screen measuring 13¾ in. by 10¼ in.

The range of radio receivers exhibited will comprise the inexpensive 5-valve, all-mains superhet 290U; the "all-in-one portable" 401UB, and the two new de-luxe models 400A and 500A. The popular battery set with mains performance—model 474B—will also be displayed.

Of special interest will be the Radiogram 603A, which is provided with a three-speed turntable, thus enabling it to accommodate long-playing records.

The new Philips motoradio model 574V will also be shown. This receiver comprises a 5-valve superhet with both manual and mechanical push-button tuning, and a separate high-fidelity loudspeaker contained in an 8-in diameter metal case. The radio unit is designed to fit on the underlip of the motorcar instrument panel; it can alternatively be inserted in the special compartment provided in many cars.

Philips Electrical Ltd.,
Century House,
Shaftesbury Avenue,
London, W.C.2

Pye Ltd. (8 and 49)

ON this stand will be shown a black screen television receiver only released this month. It is a 12 inch table model operating from either A.C. or D.C. mains.

Another new television receiver is the LV30, with a table model built to the same specification, LV30C, using black screens. The receiver has a standard 9 inch tube, and 14 valves. The loudspeaker is a 6½ inch permanent magnet moving coil type. The sound volume controls, including on/off switch and picture contrast controls are built on the front of the cabinet, with the others pre-set at the back of the receiver. Noise limiting circuits have been incorporated. The R.F. unit is separate, so the sets are easily convertible to new television stations.

The vision receiver has single sideband tuned radio frequency stages using Pye tuned coils, and incorporates automatic interference suppression with video frequency amplifier. The time base has a positive interlace filter, a "Grid blocking" type scan oscillator, Pye "positive Grid" type line scan oscillator and magnetic deflexion output stages.

Similar models are available for Sutton Coldfield.

Pye Ltd.,
Radio Works,
Cambridge.

Romac Radio Corporation Ltd. (88)

SIX types of television receivers will be shown, all using the 12 inch aluminized tube. They are convertible for reception of any B.B.C. station by exchanging three plug-in types of R.F. coils on some sets, and four on the others.

A selection of portable receivers having sling type aerials are exhibited, together with car receivers having two-unit construction enabling easy fitment in any type of car.

Another feature of this stand is the Model 160 aircraft transmitter-receiver, which incorporates a 12-channel crystal controlled transmitter-receiver, covering frequencies from 118-132 Mc/s.

Romac Radio Corporation Ltd.,
The Hyde,
London, N.W.9.

Standard Telephones and Cables Ltd. (43)

THE "Standard" Type D.S.15 radio transmitter is a 20 kW short wave equipment, which may be employed in conjunction with the appropriate external Drive Unit for a number of services such as :—

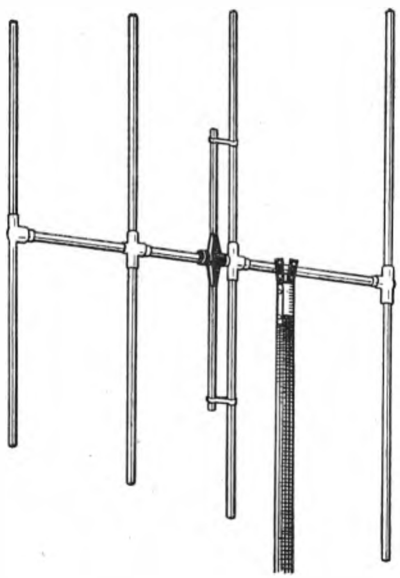
(1) Broadcasting and Telephone transmissions ;

(2) High-speed telegraph transmissions with either frequency-shift or "ON/OFF" Keying. In the latter case facilities exist for the carrier signal to be either steady for straight C.W. telegraphy, or "wobbled" about the mean value to correspond to M.C.W. telegraphy ; and

(3) Reduced carrier single or independent sideband transmission.

The transmitter may also be used for frequency modulated "facsimile" transmissions. Operating frequencies are controlled by accurately ground quartz crystals mounted in a thermostatically controlled oven. The R.F. exciter mounts up to six crystals. Alternatively, the oscillator may be self excited.

The final R.F. stage employs an inverted or grounded grid amplifier. Among the many features are simple tuning, rapid wavechange and a new type of modulation limiter. The power supply required is 380-415 volts 50 cycles three phase.



On display will be the "Brimar" Projection Tube and recommended optical unit, showing the layout employed in Domestic Television Receivers, together with "Brimar" Aluminized Teletubes for direct viewing.

Two recent additions to the range of "SenTerCel" rectifiers, developed specifically for use in A.C.-D.C. television and radio receivers are shown : type RM4, which is a compact and inexpensive rectifier extends the range of miniature H.T. rectifiers by providing the output of 290 volts 250 milliamps required by most television receivers ; types "K" and "N" which are E.H.T. low current tubular rectifiers with very high voltage plates. They are smaller, more efficient and cheaper than previous types.

Standard Telephones and Cables Ltd.,
Connaught House,
63, Aldwych,
London, W.C.2.

The Telegraph Construction and Maintenance Company Limited (79)

IN addition to the present day range of television down-lead cables, Telcon will be exhibiting both solid and air spaced low loss cables and accessories suitable for operation at frequencies as high as 10,000 Mc/s. per second.

A new type of air spaced coaxial cable having as a spacer a helical membrane of Telcothene applied edge-on around the inner conductor will also be displayed. The outer conductor is a seamless aluminium tube cold drawn on to the helix, and provides very adequate screening and water-proof protection. An effective dielectric constant of 1.08 is thus obtained in a robust and special construction with a very high degree of uniformity.

Special Alloys for the Radio and Electronic Industries will be shown, including high permeability alloys, alloys for glass-to-metal seals, electrical resistance alloys, Telcon bronze (beryllium copper), and thermostatic bimetals.

Telegraph Construction and Maintenance Co., Ltd.,
22, Old Broad Street,
London, E.C.2.

Telerection Ltd. (100)

AN interesting development, the "Maximus" 4-element television aerial, a new design embodying an adjustable matching device, enabling the impedance of the aerial to be adjusted to any receiver input, will be shown on this stand.

The sketch illustrates how, by a simple mechanical adjustment, it can be matched to 50 ohm co-axial input, 80 ohm balanced feeder, to Philips, G.E.C., Vidor or any other television receiver, irrespective of feeder and input impedance

Other types of aerials exhibited are: the "8 DB," 3-element type, designed in the same manner as the Maximus 4, with adjustable T match ; the "Extremus" 4-element type, incorporating a co-axial line transformer for matching purposes, matching this aerial into an 80 ohms input ; the "8 DB" 3 element type, as above, with a co-axial line transformer, again matching into 80 ohms ; "H" types, and single dipoles with various mountings.

Telerection Ltd.,
12, Suffolk Parade,
Cheltenham, Glos.

Vidor Ltd.

A new development in the Vidor large screen projection television is the Model CN.4205. This model shows a picture of 16 in. by 12 in. clearly. It is a two door Console type, finished in two shades of walnut. The design of the cabinet facilitates servicing the set from the front without complicated dismantling operations. Also, all controls are on the front, all secondary preset controls being covered by a hinged panel.

Vidor Ltd.,
Erith, Kent.

An Electron Diffraction Demonstration Tube

By JAMES A. DARBYSHIRE, M.Sc., Ph.D., F.Inst.P.

(*Messrs. Ferranti Ltd.*)

A SEALED-OFF tube has been designed to give a brilliant visible display of electron diffraction rings from a microcrystalline specimen of zinc oxide. The tube resembles a normal cathode ray tube with a neck diameter of 35 mm. and a screen diameter of 150 mm. (6 inches). A very good demonstration of the diffraction pattern can be obtained merely by substituting this tube for a normal cathode ray tube in a television receiver chassis. The line and frame scan valves would have to be removed and a series resistance should be inserted in the heater leads so that the voltage across the heater terminals is reduced to approximately 2.5 volts.

The position of the tube would have to be adjusted by trial until the normal focusing solenoid is in a suitable position to obtain optimum focus for the diffraction tube. The wire from the specimen should be connected to the anode terminal on the tube and the high voltage lead wire from the chassis should be connected to the anode terminal as for a normal cathode ray tube for television. The pattern is quite visible even at 5 kV, and is quite brilliant at 7 kV. The majority of present day twelve inch television receivers operate at anode voltages between 7 and 9 kV on the cathode ray tube. The best results are obtained if the anode voltage is 15 kV. The tube has been designed to operate at a maximum anode voltage of 18 kV and the focus coil should have approximately 600 ampere turns. The heater rating is 2.5 volts (0.7 – 0.9 amperes) and the bias control should be adjusted so that the beam current can be varied from 0-30 microamperes.

The tube is based with the standard international octal base and the basing is as follows:—

Pin 1. ... Blank	Pin 5. ... Modulator
Pin 2. ... Heater	Pin 6. ... Missing
Pin 3. ... Missing	Pin 7. ... Heater
Pin 4. ... Missing	Pin 8. ... Cathode

A photograph of the tube is shown above and a very good record of the ring pattern on the screen can be obtained by external photography using a lens of aperture $f\,2.5$ and exposure of 7 seconds at 15 kV on the anode. As the anode voltage is increased the beam current required to give a clearly visible diffraction pattern decreases. The value of beam current required in microamperes for various values of the anode voltage are given in Table 1.

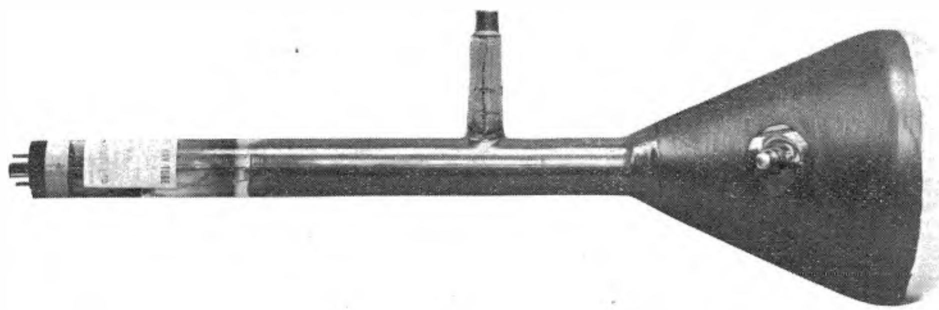


Table I

Beam current microamperes	Anode voltage
20	5
10	10
5	15

After a number of sealed-off tubes had been made up in this manner it was realised that it would be quite feasible to operate a continuously pumped modification of the same tube. In this way was designed a very simple apparatus for electron diffraction investigations in which a variety of specimens can be examined.

The continuously pumped tubes resemble, very closely, that shown here. The specimen is now mounted by means of a ground joint instead of being permanently sealed in position on the side arm. The tube has the same kind of electron gun system, consisting of an oxide-coated cathode, modulator and internal anode. The gun assembly is sealed into the neck and ample emission can always be obtained from the oxide-coated cathode even after repeated exposures to air, provided that the cathode is allowed to cool down before air is admitted to the tube.

Thus, the specimen holder itself is the only demountable part of the tube and a specimen can be changed and the tube repumped and in full operation again within approximately five minutes.

The oxide-coated cathode does not deliver anything like its normal emission current because it must obviously become poisoned owing to repeated exposure to the atmosphere. However, it will continue, almost indefinitely, to provide quite sufficient emission to give very clear diffraction patterns on the fluorescent screen.

The sealed-off tubes can be supplied with specimens of zinc oxide mounted in position in the electron beam. Also, small numbers of the demountable type of the tube are available.

The greater part of the development work on these tubes has been carried out by Mr. L. Atkinson and Mr. J. Buckley, both of the Ferranti Cathode Ray Tube Research Laboratory.

The Determination of Quiescent Voltages and Currents in Pentode Amplifiers

By A. J. SHIMMINS, B.E.E., B.Com.
(E.M.I. Engineering Development Ltd.)

VERY often designers of electronic equipment are confronted with the problem of determining the quiescent electrode voltages and currents for a given amplifier circuit, particularly when an existing design is being checked.

If a triode is used, the solution presents little difficulty, but for pentode amplifiers greater difficulty is experienced mainly because the screen grid voltage is unknown. Although values of anode and control grid voltages can be found for a known screen voltage, this voltage in a particular circuit depends on the parameters of the circuit so that the bias on the tube, and the anode and screen voltages are interdependent. The following is an approximate method of obtaining the quiescent values of anode, screen grid and control grid voltages and currents when the circuit parameters and supply voltage to the amplifier are known.

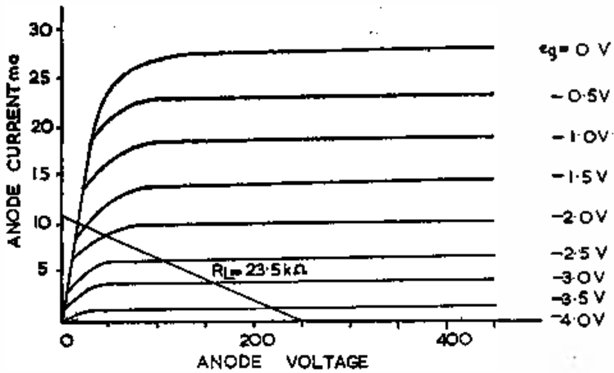


Fig. 1.
Anode characteristic of EF91 pentode
eg=250 volts

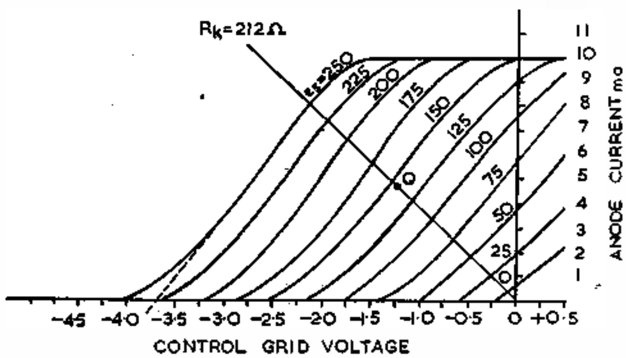


Fig. 2.
Family of dynamic characteristics, EF91
RL=23.5 kΩ, EB=250 volts

Dynamic Characteristics of Pentodes

Manufacturers of valves usually give anode characteristics for one particular screen voltage (usually 250 or 100 volts). Typical anode characteristics are shown in Fig. 1. On these characteristics a loadline can be drawn and a dynamic characteristic relating anode current and grid voltage added. It should be noted that this is drawn for the particular screen voltage at which the anode characteristics are given. If the screen voltage is changed to another value, another set of anode characteristics is obtained.

An examination of experimentally obtained dynamic characteristics* for pentodes at various fixed screen voltages shows that they are a family of curves approximately parallel to each other (particularly the lower portions), i.e., are practically the same shape, and equally spaced for equal increments or decrements in screen voltage, except when the screen voltage is very low, say below 10 volts. One interesting point is that as the screen voltage decreases the dynamic characteristics have slightly longer linear portions and slightly higher slopes for reasons discussed in section 3 below.

The spacing between the various dynamic characteristics can be determined (for any given control grid voltage) by making use of the fact that when the valve is connected as a triode we have:

$$\mu_T = \left.\frac{\Delta e_a}{\Delta e_g}\right|_{i_a \text{ constant}} = \left.\frac{\Delta e_s}{\Delta e_g}\right|_{i_a \text{ constant}}$$

or for any fixed anode current a change in screen voltage Δe_s is equivalent to a change in control grid

$$\text{voltage of } \Delta e_g = \frac{\Delta e_s}{\mu_T} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Thus if μ_T is known, the spacing between the dynamic characteristics can be calculated and a family of dynamic characteristics can be drawn, without recourse to the anode characteristics at various screen voltages.

A typical family is shown in Fig. 2; the curve for zero screen voltage is similar in shape to the others but is further spaced and of lower slope.

Relationships between Anode Current and Screen Voltage

For any given amplifier, if the screen voltage is known, the quiescent conditions are readily determined.

For an amplifier with cathode resistor R_k, there is a relationship between quiescent anode current and screen voltage which can be determined as follows.

The grid voltage and anode current are related by:

$$e_g = -(i_a + i_s)R_k$$

where i_s is the screen current. In the absence of more accurate information this screen current can be taken as a constant proportion of the anode current; $i_s = ki_a$, where k is a constant between 0.33 and 0.25 provided the anode voltage does not fall below about 15 to 20 per cent of the screen voltage, below which the screen takes a rapidly increasing proportion of the cathode current. The constant k can be determined from figures published by the valve manufacturer. The value of k begins to increase rapidly as the anode current approaches the limiting value just below E_B/R_L, where E_B is the D.C. supply voltage

* See "Radiotron Designers Handbook" 3rd Edition, p.273.
Also "Dynamic Characteristics of Pentodes" *Communications,* July 1946, p.14.

and R_L the load resistor. At any one particular screen voltage e_s, the dynamic characteristics will be straight until the anode current is about 20 e_s/E_B per cent from the limiting value, because for higher anode currents the anode voltage is below 20 per cent of the screen voltage and therefore the screen current is rising rapidly and the anode current is becoming asymptotic to its limiting value. Thus we have

$$= -(k+1)i_a R_K \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

This can be represented by a straight line on the same graph as the family of dynamic characteristics, the intersection of the cathode line and the particular dynamic characteristics giving the anode current for the particular screen voltage. From a graph such as is shown in Fig. 2 anode current versus screen voltage can be plotted, the shape of the curve being as shown in Fig. 3.

This curve is practically a straight line which bends rapidly and is asymptotic to a current slightly below E_B/R_L, the limiting value of anode current.

A second relationship between anode current and screen voltage is furnished from the conditions existing in the screen circuit. With a screen resistor R_s and screen supply voltage E_s we have

$$e_s = E_s - i_s R_s$$
$$i_s = k i_a$$
$$e_s = E_s - k i_a R_s \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

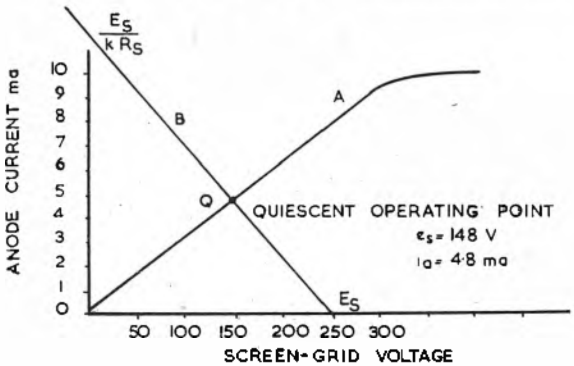


Fig. 3.
Anode current versus screen voltage

which is the second relationship needed to determine e_s and i_a for the particular amplifier. This relationship is a straight line. It should be noted that E_s and R_s are the effective values of screen supply voltage and screen resistor respectively. If a simple series dropping resistor is used, E_s is equal to E_B, the supply voltage, and R_s is the value of the series resistor, but if a voltage dividing network is used, Thèvenin's Theorem must be applied to find E_s and R_s.

The intersection of the two lines gives the quiescent screen voltage and anode current.

A Typical Example

To illustrate this graphical approach, consider an amplifier using an EF91 valve, connected as shown in Fig. 4.

The anode characteristics and dynamic characteristics for e_s = 250 volts are shown in Figs. 1 and 2 respectively. The value of μ_T for this valve is about 68 and k is 0.255. The calculated family of dynamic characteristics is shown in Fig. 2, together with the cathode loadline for R_K = 212 ohm (from Equation 2) and the anode current screen voltage relationships are shown in Fig. 3, curve A being that determined from Fig. 2 and line B being that of the screen load-line (Equation 3). The equilibrium screen voltage is given by the intersection of lines A and B.

The quiescent conditions thus determined are given in Table 1, together with the measured values for the particular circuit. It can be seen that there is fairly close agreement between the results.

TABLE I.

EF91 Pentode : R_L = 23.5 k ohm. R_S = 82 k ohm. R_K = 212 ohm. E_B = 250 volt.

Quiescent Value	Graphical Results	Measured Values
Screen Voltage	148 V	152 V
Anode Voltage	137 V	143 V
Anode Current	4.8 mA.	4.65 mA.
Screen Current	1.22 mA.	1.20 mA.
Grid Bias	1.27 V	1.31 V

6J7G Pentode : R_L = 250 k ohm. R_S = 1.2 Megohm. R_K = 1200 ohm. E_B = 300 V.

	Graphical Result	Measured Value
Screen Voltage	47 V	43 V
Anode Voltage	88 V	85 V
Anode Current	0.85 mA.	0.86 mA.
Screen Current	0.21 mA.	0.21 mA.
Grid Bias	1.28 V	1.30 V

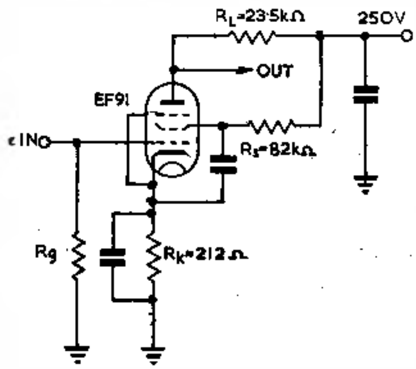


Fig. 4.
Typical pentode amplifier

In Table 1 results are also given for a pentode amplifier using a type 6J7G valve. It is thought that in the majority of cases the calculated results will be within 10 per cent of their actual values, but it must be remembered that individual valve characteristics can vary greatly from the published values, particularly if the anode current is well below the normal operating value. Also, consideration must be given to variation of resistors from their nominal values. The changes in operating conditions due to variations in resistor value can be easily determined by making the calculations outlined above for the upper and lower limits of the resistor concerned.

Analytical Treatment

The equation to a family of dynamic characteristics as shown in Fig. 2 is given by

$$i_a = a + b(e_g + \overline{e_s - A}/\mu_T) \quad \ldots\ldots\ldots \quad (4)$$

where i_a = anode current,

a = a constant equal to the projected value of i_a for $e_g = O$ at screen voltage $e_s = A$,

b = a constant equal to the slope of the dynamic characteristics at $e_s = A$,

e_g = control grid voltage, polarity being considered with respect to cathode,
e_s = screen voltage,
A = screen voltage for which constants a and b are determined, and for which the original anode characteristics are given,
$\mu_T = \partial e_s / \partial e_g$ = amplification factor of valve connected as a triode,

with the limitation that i_a does not exceed E_B / R_L.

This gives only the straight portion of the curves and does not consider curvatures near cutoff and near the limiting value of anode current.

The equation to the cathode loadline is

$$e_g = -(1 + k) i_a R_K$$

The intersection of this line and the dynamic characteristic gives

$$i_a = a + b\left\{ -(1 + k) i_a R_K + e_s - A/\mu_T \right\}$$

$$\text{or } i_a = \frac{a/b + e_s - A/\mu_T}{1/b + (1 + k)R_K}$$

$$= \frac{(E_g - A/\mu\ ) + e_s/\mu_T}{1/b + (1 + k)R_K} \quad \ldots\ldots\ldots\ldots\ (5)$$

where $E_g = a/b$ is the projected grid base at $e_s = A$. This is the equation to line A in Fig. 3.

The equation to the screen line is

$$i_s = \frac{E_s - e_s}{kR_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (6)$$

where E_s = effective screen supply voltage,
$k = i_s / i_a$,
R_s = effective screen resistor.

Combining Equations (5) and (6) we have that the quiescent screen voltage is given by

$$e_s = \frac{E_s(1/b + \overline{1 + k}\, R_K) - kR_s(E_g - A/\mu_T)}{1/b + (1 + k)R_K + kR_s/\mu_T} \quad \ldots\ (7)$$

and therefore

$$i_a = \frac{E_g - A/\mu_T + b\, E_s/\mu_T}{1/b + (1 + k)R_K + kR_s/\mu_T} \quad \ldots\ldots\ldots\ (8)$$

Since E_g is approximately equal to A/μ_T, we have

$$e_s \approx \frac{E_s}{1 + \dfrac{k\, R_s}{\mu_T\left\{ 1/b + (1 + k)R_K \right\}}} \quad \ldots\ldots\ldots\ (9)$$

This gives the quiescent screen voltage, from which all other quiescent conditions are readily determined.

For the circuit shown in Fig. 4, the value of E_g is -3.65 V and $1/b = 185$ (from Fig. 2). Substituting in the Equation (7) we have

$$e_s = \frac{250}{1 + \dfrac{.255\ .\ 82}{68\left\{ .185 + .266 \right\}}} = \frac{250}{1 + .681} = 149 \text{ V.}$$

This is close to the measured value.

Conclusion

A method has been presented which enables approximate values of the quiescent electrode values of voltages and currents in a pentode amplifier to be determined, either graphically or by calculation from a dynamic characteristic for a particular screen voltage. The graphical method is more accurate and should be used in preference to calculation since a much clearer picture of operating conditions can be obtained. The method gives an approximate solution only, but in practice it has been found to be close enough for design purposes. It must be remembered that individual valves vary from the average characteristics as given by the manufacturer, so more accurate calculations are seldom warranted. The approach is particularly useful in determining the effect of changes in circuit parameters, such as cathode resistor or screen resistor, on the operation of the amplifier.

Technical Aspects of the National Radio Exhibition

Castle Bromwich, September 6-16, 1950

By P. D. CANNING

(Vice-chairman R.I.C. Exhibition Technical Committee)

THIS year for the first time the National Radio Exhibition is not taking place in London, but is being held in part of the B.I.F. building at Castle Bromwich. Every effort has been made to cover most of the uses of radio, but in view of the great interest in the Midlands and the North in television, due to the opening of Sutton Coldfield and the projected station at Holme Moss, emphasis is laid on this section of the industry.

The Exhibition Technical Committee of the Radio Industry Council, who are responsible for all the technical services within the exhibition, were required to provide the following services:—

1. Television Distribution System relaying suitable programmes from 10 a.m. to 10 p.m. daily to Television Hall and the various exhibitors' stands.
2. Sound Distribution System relaying suitable musical programmes to the loudspeakers distributed throughout the hall.
3. Sound Reinforcement System relaying the activities within the B.B.C. Studio to the immediate surrounding area.
4. Control Studio for the origination or selection of the programmes for 2. above.

The centre of these services is the R.I.C. control room, and all the apparatus for the above services together with the announcer's studio is housed in it.

The control room itself is of simple shell type construction, sub-divided to provide rooms for the television and sound distribution systems, the technical officers' room, etc., but the studio, which abuts, is of double-skin construction throughout, with sound-proofing material between the two skins to give an almost soundproof room. On the inside wall acoustic tiles are used to ensure good audio characteristics. Plate glass, 3 ft. high, is mounted 3 ft. 6 in. above floor level, on all sides, to enable visitors to obtain a clear view of the apparatus in use, and the necessary activities connected with the distribution services.

The television distribution system, supplied by

E.M.I. Sales & Service, enables any one of three originating programme sources to be distributed in such a manner that all working television receivers will be provided with a good signal.

The programme sources are the normal B.B.C. programmes, usually from the London studios, cameras in the B.B.C. exhibition studio and a film scanner. The first two are distributed whenever available and suitable, and at other times the film scanner is used. Radiated signals from Sutton Coldfield are received and de-modulated on special receivers, and used to modulate two small transmitters working on the Alexandra Palace frequencies; alternatively, the output from the B.B.C. exhibition studio or film scanner may be used. Master faders are used to permit artistic change-over between programmes.

This changing of frequency is essential because of the very high field strength of Sutton Coldfield in the vicinity of the exhibition. It was found at Radiolympia in 1949 that if a programme, originating within the exhibition, was in use when Alexandra Palace commenced radiating, quite serious interference was experienced. This would be much worse this year owing to the higher power of Sutton Coldfield and the shorter distance between the transmitter and the exhibition. Tests on site using a small distribution network showed that this scheme would give excellent results and that undesirable effects, due to cross-modulation, etc., were absent.

The complete apparatus for the television distributor system includes a single-channel film scanner, also supplied by E.M.I., the necessary Sutton Coldfield receivers and de-modulators, transmitters adjusted to the Alexandra Palace frequencies, and the distribution amplifiers together with various monitors, etc. The signal from the distribution amplifiers at 41.5 and 45.0 Mc/s. is taken by 70Ω concentric cables to the various stands and to Television Avenue where it is correctly terminated for connexion to the receivers. A total of approximately 180 outlets each giving a signal of 1 mV is provided.

Some of the characteristics of the equipment are as follows:—

Pass band: not worse than − 2 db. at 2.5 Mc./s and − 6 db. at 3.0 Mc/s.
Linearity: within 5 % up to peak white output.
Sound: within 3 db. 50-7,500 c/s.

The sound distribution system supplied by G.E.C. commences at the announcer's console where incoming lines carry the B.B.C. Light and Midland Home Services continuously, and together with two gramophone turntables, built into the console, provide the whole of the programme material. The equipment is designed to allow continuity working similar to the normal B.B.C. practice. The duty announcer has full control of the programme sources available, each of which is correctly terminated and provided with level adjusters in addition to a master fader. Programmes are carefully worked out using the most suitable items from the B.B.C. transmissions and filling in the remainder of the time with gramophone records. Two microphones are provided with independent controls, one for use by the duty announcer and the other by guest announcers.

The output from the announcer's console is taken, via the necessary pre-amplifiers, to the final amplifier consisting of three 100-watt units in parallel. A total of 92 loudspeakers is arranged in five groups, each of which is working at different levels. These groups are separately connected to the level adjusters on the main racks and thence back to the output amplifiers.

The sound reinforcement system, also supplied by G.E.C., consists of a small amplifier; for convenience this is mounted on the same racks as the other sound apparatus, and half-a-dozen loudspeakers installed immediately outside the B.B.C. studio. The input for this amplifier is supplied directly from the B.B.C. control room, and is a complete relay of everything happening in the studio. Consequently, in addition to the artists taking part, visitors will also hear the producer's instructions, etc., during rehearsals. The sound level from the loudspeakers is under the direct control of the duty engineer at the main sound racks.

Interference is, of course, one of the bugbears of such an exhibition, and as in previous years the responsibility for determining whether apparatus is of an interfering type or not has been delegated to Belling & Lee. This company, together with the technical officers, is completely responsible for investigating complaints from exhibitors and seeing that the necessary measures for suppressing any interfering devices are taken. In order to reduce this work as much as possible certain types of articles, such as commutator motors and high voltage discharge lighting, are barred.

It is not generally realised how much work is involved, firstly in clearing such an exhibition, and then keeping it free from interference, but the importance of such work is obvious, as one source can completely blot out the whole television programme.

Not only is it necessary to investigate the apparatus used on exhibitors' stands, but the whole of the services throughout the building must be adequately cared for. Perhaps the worst offender, and certainly the most difficult to locate, is the medical apparatus which may be in use in the district, frequently a considerable distance from the exhibition itself. The effective clearance of all interference needs the active co-operation of all concerned.

Television Avenue is another of the features for which the technical committee is largely responsible. Here some 35 booths, each with a 9 ft. frontage, are arranged in the form of a "U." Each booth will contain between 1 and 4 television receivers. Lighting in the gangway will be provided by reflected light from illuminated signs, outside each booth, which permit a certain amount of upward light. Inside the booth a maximum of 50 watts is permitted and this will consist of a lamp on each side wall, placed above eye level and 2 ft. from the back wall; these lamps are screened from front radiation. This arrangement will provide sufficient light to simulate normal home viewing conditions, and will prevent glare to visitors and reflexions to other receivers across the gangway. There will be about 80 different television receivers working in Television Avenue—therefore care has to be taken to ensure that the volume of sound is kept to quite a low level in order to prevent it becoming unbearable in such a relatively small space.

Anodizing Aluminium Sheet

Condensed from an article in the May, 1950 issue of " Q.S.T."

IT is perfectly possible for any amateur to produce aluminium panels with a jewel-hard surface, in any colour he may desire. The method is not in the least critical. Some of the materials used should be treated with a degree of respect, but they are by no means really dangerous. Let us examine the procedure step by step.

Preparing the Metal

The first step is that of cleaning the metal. A thumb print or smear of grease or oil will persist and ruin the finished product. When the work is ready, give it a good scrubbing with soap and hot water and let it dry thoroughly. Holding it by the edges, wash it down with a cloth dipped in thinners, lacquer remover or almost any good solvent except carbon tetrachloride. Set it on a paper towel or clean newspaper to dry. From here it is better not to touch the surface of the metal with the bare hands. Pick it up with a piece of rag or a paper towel.

The second step is the old faithful so commonly used to such good effect. Get a pound tin of household caustic potash from the grocery. Dissolve it in warm water. An ordinary tin bucket is a satisfactory container. A better one is a large enamel dishpan which can be used in later steps of the process. Submerge the work, tied on the end of a piece of string, in the potash solution. It will immediately begin to bubble and, as time goes on, the shiny surface will change to a velvety matt. Remove the work from the solution from time to time and choose the degree of matt most pleasing to yourself. The work should then be taken out and thoroughly washed in hot water and put to dry over a hot stove or in a low oven. There are two important precautions to observe. Do not put the potash solution in an aluminium pan. A potash solution should be handled with respect. If you get splashed, rinse it off at once. It will not do much damage if a little gets on your hands, but it should be kept away from the face and, above all, the eyes.

Anodizing

During the war aluminium was almost invariably specified as "anodized". This sounds very impressive, but, like so many things, a little analysis shows that there is nothing very tough about it. The term simply means that the outer surface of the aluminium panel is changed to aluminium oxide. The oxide is the identical stuff of which many precious stones are made. It is literally "hard as rubies" and, incidentally, is an excellent insulator.

First we want some D.C. The totally unfiltered output from a half-wave rectifier is perfectly satisfactory. In amateur practice 12 volts is plenty and quite a good job can be done with 6 volts from a storage battery. If the current is low, it simply means that the work must remain in the solution longer for a given amount of anodizing.

Acid Solution

The battery department of the local garage should be able to supply the acid. If you want to make an exact mix, find out the specific gravity of the acid. The standard commercial figure is 1.84. Weigh the acid, and work out what an equivalent amount of water will weigh. Thus, 10 oz. of acid will represent 18.4 oz. of water. Now, let us take a 20 per cent solution. We will need 10 oz. of 1.84 s.g. acid and 73.6 oz. of water. In practice any commercial sulphuric acid plus about eight times as much water by volume will be satisfactory.

Put the water in the enamel dishpan or some other non-metallic container. Alternatively, use a large aluminium dishpan and let the container itself serve as the negative electrode. Pour the acid slowly into the water. Do not on any account pour the water into the acid. Suspend the work in the solution, but do not connect it with a copper wire. The wire (or strip) supporting the work and carrying current to it must be of aluminium wherever it is submerged in the solution. Connect the work to the positive terminal of the D.C. supply. The negative electrode may be any old piece of scrap aluminium suspended in the solution at any convenient spacing from the work and connected with an aluminium wire or strip. As mentioned above, the solution can be put in an aluminium container and the negative lead connected to the container itself.

After half an hour's electrolysis, give the work a good rinse in hot water and then dry it over a hot stove or in a slow oven. When it is dry it will not look much different except for a slight varnishy sheen. Put the ohmmeter on "megohms" and touch the two prods lightly to the panel. If it reads open circuit as you move the prods gently about, then you have done your job. If it reads some resistance here and there, put the work back in the bath again. As a matter of procedure it is a good idea to start off with the work and another control piece of aluminium connected together as the positive anode. You can take out the control piece for tests. It will be smaller and easier to handle, and if you smear it it does not matter.

When you have a good anodize film on the work, dry it off as earlier and set it on a clean towel or newspaper ready for the next and last step.

You can take your anodized panel and dye it any colour you want. Using an ordinary household dye, make a dye bath of twice the strength called for on the package. Some improvement comes from dissolving the dye in methyl alcohol. Add a dash of acetic acid (ordinary white vinegar will do)—about a tablespoonful. Sink the freshly-anodized panel in the bath. Take it out half an hour later. All that remains to be done is to give it a steam treatment. An inch of water in the bottom of a bucket placed on the stove will generate all the steam you need. Put the work in the bucket and suspend just clear of the water. Throw a towel over the top and let it steam for 15 minutes.

To set the dye, dissolve nickel acetate in boiling water at a concentration of 5 grammes per litre. Submerge the dyed work for 15 minutes. Remove the work, wash and dry.

Rome Ultrasonics Convention

By G. BRADFIELD

IT is somewhat of a puzzle that ultrasonics, which can provide most spectacular laboratory experiments in emulsification, disintegration, smoke precipitation and the destruction of bacteria, has not found more widespread application in industry. The International Convention on Ultrasonics at Rome, which took place from June 14 to June 17 illustrates, however, the increasing attention being paid to this subject, for it attracted about 120 delegates from over a dozen different countries, including Great Britain, U.S.A., France, Italy, Germany, Belgium, Holland, and Switzerland. The Convention was organized by the Italian National Council for Research (C.N.R.),

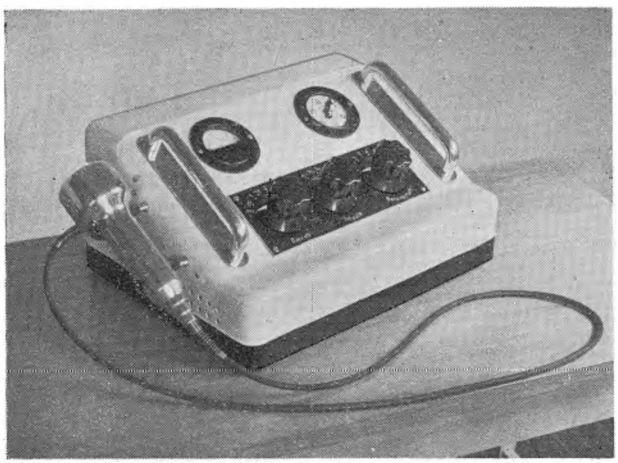


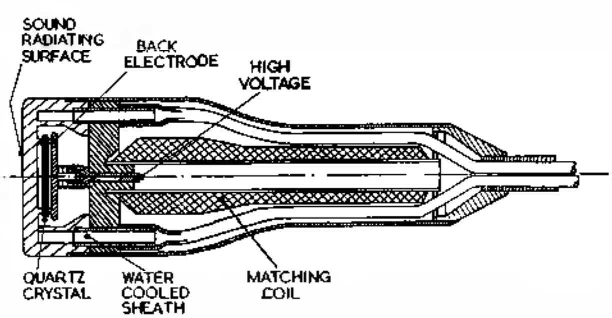
Fig. 1.
"Impulsaphon" ultrasonic therapy equipment made by Ultra-Schall-Gerätebau Dr. Born G.M.B.H.

and the Physical Society supported by the International Union of Pure and Applied Physics (U.I.P.P.A.) and by U.N.E.S.C.O. Professor Giacomini, the director of the O.M. Corbino, the Research Institute of C.N.R., was responsible for much of the organization and planning of this Convention, which proved to be highly successful and full of interest.

One part of the Convention was devoted to an exhibition of commercial ultrasonic equipment, and a considerable number of firms, French, German and Italian, took advantage of this opportunity to display and to demonstrate their apparatus. There was a great variety of ultrasonic equipment for medical purposes, all in a high state of technical development. One such equipment, made by Ultra-Schall-Gerätebau Dr. Born, G.M.B.H., of the smaller type, but still adequate for many applications, is illustrated in Fig. 1, the sound head on its connecting cable being shown on the left-hand side. The instrument operates from A.C. mains of from 110 to 220 volts, some control being provided to avoid serious change of output with mains fluctuations. The consumption is less than 100 watts. The frequency of operation is one megacycle, and a maximum of 15 watts is delivered to the radiating head, which has an area of about 5 sq. cm. The intensity is adjustable from 0.5 to 5.0 watts per sq. cm. Provision is made so that the output can be delivered in bursts at 100 p.p.s., alternative activity ratios of 1/15, 1/10 and 1/20 being available. The dimensions are approximately 16 in. by 12 in. by 8 in. and the weight about 26 lb., the head itself being only about ½ lb. (Type "J"). A clock is built into the equipment to indicate dosage time accurately. In this particular device no water cooling is provided, but more complex equipments were available with automatically controlled water cooling, a sectional view of the sound head of such a device made by Ultrakust-Vertrieb G.M.B.H. being illustrated in Fig. 2. This is fed from a low-voltage cable via a built-in matching transformer. In certain equipments the radio frequency oscillator was crystal controlled with several amplifier stages delivering power to the output quartz transducer.

A Belgian Ultrasonic Flaw Detector by Ateliers de Constructions Electrique de Charleroi (A.C.E.C.) was on show and was also demonstrated by M. Home in the course of one of the lectures. The demonstration showed the detection of an air film by a straight-through transmission test on a laminated material. The equipment in question is illustrated in Fig. 3, and consists of three electrical units, together with quartz crystals for receiving and transmitting, each mounted in a test head or probe on the end of a long cable. The frequency of operation was one megacycle and either C.W., frequency modulated (with a sweep of 75 kc/s. repeated 300 p.p.s.) or amplitude modulated at 100 c/s. In testing for flaws in laminated materials the probes are placed opposite each other with the sheet under test between them and, as is

Fig. 2.
Water-cooled radiating head with cable matching. Made by Ultrakust-Vertrieb G.M.B.H.



well-known, an air film of the order of .0001 in. will cut down the strength of the mechanical wave being transmitted very markedly, provided that the lateral dimensions of the flaw are sufficient to give a "shadow" effect. In general an area of flaw of a few per cent of the beam area is sufficient for detection, when using a sensitive indicator. For this purpose the alternative means provided were a meter, a loud speaker (giving a 300 c/s. signal) and three lamps (good transmission, feeble and bad). Segregations can be revealed in certain circumstances and, by searching, holes of a fair size can be detected and their approximate position indicated. It appears that the equipment can be used for iron and steel castings as well as for forged and rolled metals and for certain laminated insulating materials. Among other probes, one of novel construction termed "palpeur turgescent" is of interest. It has a dome shaped sheath over the quartz crystal (see Fig. 4) enclosing a special liquid. These probes, generally used moistened with oil or water, can, it is stated, be applied to quite rough surfaces, although care appears to be necessary that the inclinations of the axes of the probes be correctly adjusted.

In comparison with the above the British system of

Fig. 3.
The ultrasonic testing equipment "Ultraroue!" being used to detect laminations in sheet steel. (Ateliers de Constructions Electrique de Charleroi)

flaw detection as used in the Kelvin-Hughes equipment was discussed by various delegates in the course of the lectures. This operates on the "radar" principle, thus giving both range of flaw and, by searching or scanning, its plan position. It is naturally a much more complex equipment but, on on account of its indication of range, it is necessarily very versatile and has already given valuable service for many years in industry.

One other equipment may be mentioned. This is a commercial German equipment for high intensity irradiation by ultrasonics in which up to 300 watts of power are fed to six quartz crystals housed on the faces of a short hexagonal prism at the end of a rotating arm. This arm is inclined at about 30° to the vertical and rotates about a vertical axis with the head immersed in a bath of the liquid to be irradiated. It is claimed that this special method

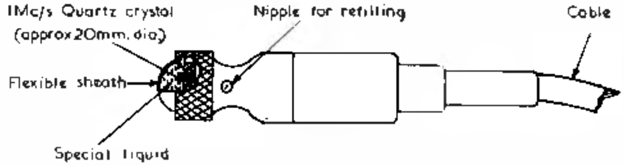


Fig. 4.
Cut-away view of special A.C.E.C. flaw detection probe "Palpeur Turgescent"

reduces the effect of standing waves. The main application appeared to be to age spirits (such as whisky) and it was stated that this ageing was accomplished in half to three-quarters of an hour.

Proceedings of the Convention

During the opening session, Professor Giacomini described the work of the Institute O.M. Corbino and the trend of researches for the future. Later, during a tour by the delegates of his organization, many demonstrations were witnessed which aptly illustrated the work. One group of researches at the Institute centred around the ultrasonic light valve, a device familiar in Great Britain because of its

Fig. 5.
Mullard ultrasonic soldering iron with 50 watt 20 kc/s. drive unit. Heating (extra) 100 watts, 50 c/s.

employment in television by Messrs. Scophony, Ltd. One application was for the communication of speech and music by the modulation of a light beam projected over a considerable distance. Other applications included the accurate measurement of the velocity of sound in liquids, the measurement of Poisson's ratio in solids and the demonstration of the performance of ultrasonic lenses for focusing beams in liquids, a matter of importance in certain flaw detector systems. Other activities included the measurement of pulsed ultrasonic radiation in terms of the audio-frequency voltage generated through radiation pressure on the diaphragm of a simple microphone, and the measurement of elastic constants of metals from liquid hydrogen temperatures up nearly to the melting point.

Dr. L. Bergmann, who has been for many years actively engaged on ultrasonic research, for instance,

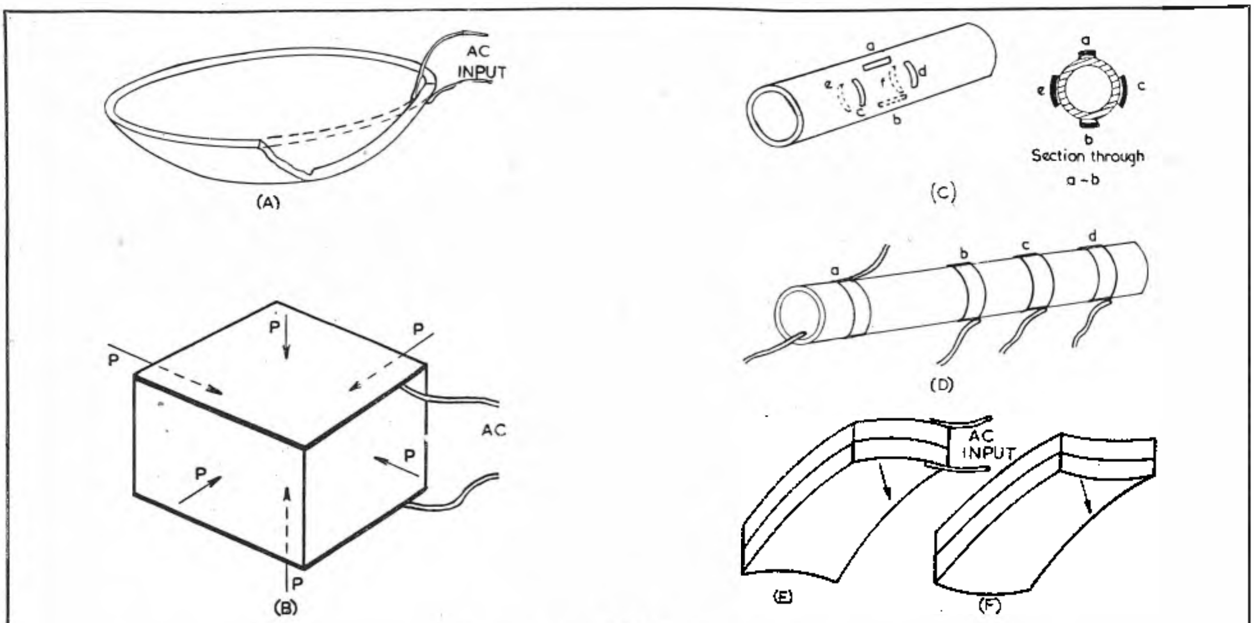


Fig. 6.
Forms of barium titanate transducers

(A) Grützmacher transducer
(B) Hydrostatic transducer
(C) Torsional transducer
(D) Delay line
(E) and (F) Bimorph transducers

in the Bergmann-Schäfer photo-elastic technique, and who is also well known to all workers in this field through his up-to-date and authoritative book, "Der Ultraschalls," gave a brilliant review of the outstanding developments of recent years, ending with an exceptionally good film showing typical ultrasonic experiments of a fundamental nature. He illustrated applications of ultrasonics to industry by the Kelvin-Hughes and the Sperry Ultrasonic Flaw Detectors, the high power sirens used in U.S.A. for smoke precipitation, and the Mullard soldering iron for aluminium and similar oxidizable metals which employs ultrasonic vibrations to remove surface films (see illustration in Fig. 5). Ultrasonic work in Great Britain was covered in seven lectures by Messrs. Bell, Bradfield (of N.P.L.), Hillier (of I.C.I., Ltd.), King (Metropolitan-Vickers, Ltd.) and Stanford (Aluminium Laboratories, Ltd.). The first named dealt with the fundamental work proceeding at Newcastle under Dr. E. G. Richardson, on propagation in fluids. The work at the National Physical Laboratory included the development of methods of measuring with precision the velocity of sound in metals, including single crystals, an accuracy of 0.5 per cent being attained in fair sized specimens and 1 per cent on specimens only a few millimetres in length. The properties of barium titanate were discussed for piezoelectric applications and it was pointed out that it had certain advantages over materials such as quartz and rochelle salt. Its polycrystalline nature facilitated its fabrication into unusual shapes, some of these being illustrated in Fig. 6. At Fig. 6(A) is a transmitter capable of focusing sound onto a small area, while a tubular form can readily be made to yield a high density along its axis when vibrating in the thickness mode. In Fig. 6(B) is shown a form suitable for measuring pressure changes, while Fig. 6(C) shows an oscillator operating torsionally when polarized between c and d oppositely to e to f, an A.C. voltage being applied to electrodes ab. Fig. 6(D) shows a delay line which gives time lags of a few microseconds at b, c and d on injection of a pulse at a. Fig. 6(E) shows a bimorph of barium titanate deformed under electrical stress, the shape being preferable for many purposes to Fig. 6(F), which is that which tends to be assumed by certain less symmetrical piezoelectric materials in bimorph form, for instance, rochelle salt. There seems little doubt that this new material will have widespread application.

Mr. Hillier described the measurement of elasticity of high polymers, a 5 to 30 kc/s. magnetostrictive transmitter launching waves into filaments .020 in. thick, using a quartz crystal detector. The difficulties arising in the use of high intensity ultrasonics at a frequency of 200 kc/s. and at 45 watts per sq. cm. were discussed by Mr. King, successful results being reported with a 0.002 in. duraluminium foil (perforated with a small central hole) over the radiating surface of the quartz crystal.

Mr. Stanford described the investigation of the elasticity and damping of aluminium up to temperatures approaching its melting point using ultrasonic frequencies to resonate the specimen. He also gave a detailed account of many years successful experience with the Kelvin-Hughes flaw detector in the aluminium industry. Testing of long bars can be carried out rapidly and thoroughly while in motion slowly past the test position.

It has been proposed to investigate the performance of a model of an auditorium at ultrasonic frequencies in an attempt to forecast full-scale behaviour at audible frequencies. There are difficulties in the general application of such methods due to the complicated frequency-absorption characteristics of many materials, but a simple case in the form of an open-air theatre was chosen by Dr. Canac for such an investigation and detailed measurements were reported on the performance of the model, showing the value of the method.

One often wonders how much activity exists at ultrasonic frequencies in the various sources of vibration encountered in every-day life. Messieurs Chavasse, Lehmann and Grognot reported on an investigation of this type using such sources as electric drills, pneumatic drills on concrete, centrifugal compressors, turbo-reactors, jet engines and insects such as bees. In the case of jet engines there was considerable intensity over the range 16 to 50 kc/s. Detailed spectrograms were given which had been taken on an automatic recorder-analyser.

The great activity in the fields of biology and of therapy has already been emphasized. The action of ultrasonic radiation in these applications is by no means fully understood, and this is perhaps to be expected, since the effect depends very much on intensity, as well as on other factors. For instance, it has been found that the development of an embryo was accelerated by irradiation at lower intensities, but higher intensities were definitely harmful. In general there appear to be two effects, one thermal and the other mechanical. The thermal effect is more marked at higher frequencies, but it must be remembered that these are more readily absorbed by animal tissue and so do not penetrate as far as the lower frequencies, while the latter seem to be more potent mechanically. Some equipments available commercially provide alternative frequencies of 1 and 3 Mc/s. for this reason. While higher intensities, for instance over about 4 watts/cm^2, produce irreversible changes, breaking up animal tissue itself, lower intensities, apart from thermal action, appear to accelerate certain chemical reactions, cause liquefaction of certain gels and increase the circulation of natural fluids through cell walls and membranes. The action on nerve cells does not happen instantaneously and it seems to continue even after the irradiation has ceased. An attempt has been made to use this time-lag in an effort to reduce the thermal effect of irradiation, which is often unwanted; with this object equipments have been developed which act intermittently, so that power is only radiated for 5 per cent, 10 per cent or 20 per cent of the time when necessary. It is thought that this provides times (about 0.01 second) of zero heating, during which the excitation of the nerves still persists. Apart from this effect there may be after-effects which become apparent after periods of an hour or more, although these are the results of too intense an irradiation. The dosage to be administered has to be accurately determined therefore, and while some equipments take care of this by incorporating calibrated controls, others contain a built-in system for monitoring the radiation obtainable from the radiating head itself.

A great deal of study has been devoted to the curative action of ultrasonics, especially by French, German and Italian workers. At the Convention in Rome some 30 papers were delivered on this subject, and a book on the subject, edited by Dr. R. Pohlmann, entitled "Die Ultraschalltherapie" has just been made available. Although no hard and fast rules of treatment can be adopted at this early stage, an approximate guide has been evolved listing about 40 ailments and giving rough estimates of appropriate values for intensity, which vary from 1 to 5 watts/cm^2, treatment time, which varies from 2 to 12 minutes and number of treatments, which must necessarily be very dependent on results and may be up to about 14. Affectations of the rheumatic type, including arthritis, form an important class which has been widely treated, while cases of neuralgia and bronchial asthma seem to have reacted favourably. Abscesses, carbuncles and certain similar troubles have also been treated. While it is clearly impossible to predict that benefit would result in any particular case, systematic analyses of results has been carried out and it seems to have been established that marked improvement has occurred in a great number of instances, even when alternative treatments had met with no success. Needless to say, expert medical supervision is essential in any application of ultrasonic radiation, since harm can occur with incorrect use, and gross misuse might even be lethal. In skilled hands, however, there seems little doubt that we have here a new means of healing which is likely to find valuable application in the future.

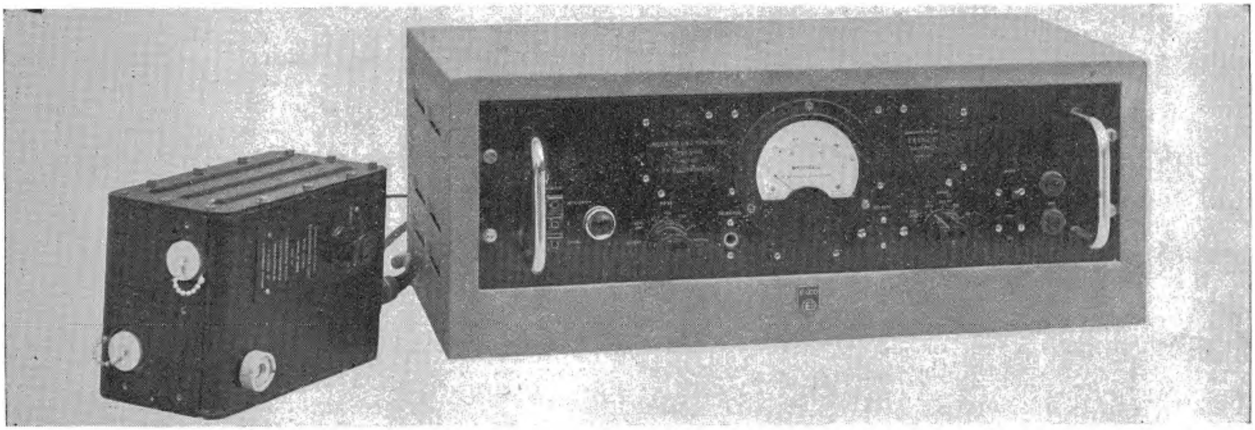
Acknowledgment is made to the Director, National Physical Laboratory and to the Comptroller, H.M. Stationery Office, for permission to publish this account. Acknowledgment is also made for permission to publish certain figures: Ultra-Schall-Gerätebau Dr. Born. G.M.B.H. (Fig. 1). Ultrakust-Vertrieb G.M.B.H. (Fig. 2), Messrs. Ateliers de Constructions Electriques de Charleroi (Fig. 3), and to the Mullard Radio Valve Co., Ltd. (Fig. 5).

B.B.C. Engineering Research

A NEW building erected alongside the B.B.C. Engineering Research Department's headquarters at Kingswood Warren, Banstead, Surrey, will this month become the home of the Television section. Studio space of similar size to that at Alexandra Palace will be available, together with an open-air roof studio and a large viewing room.

In the main this Section is concentrating on a precise evaluation of the possibilities of higher-definition systems and colour. For this purpose a vision channel has been developed and built which can produce at will 405, 525, 625, or 819 line pictures having balanced horizontal and vertical resolution, and which can also be used for determining the effects of restricted bandwidth and other forms of distortion on pictures having these standards of definition. In addition, an experimental colour channel has been constructed in order that the engineers may gain first-hand experience of the potentialities and problems of colour television.

Of more immediate application are the experiments on co-channel interference between television transmitters. A thorough study of the interference resulting from transmitters on the same or neighbouring carrier frequencies has been made, and the criteria for successful channel sharing have been determined. These results are of immediate importance since the B.B.C. has at its disposal only five channels, which will eventually be shared between ten transmitting stations.



A Simple Vibrating Condenser Electrometer

By D. G. A. THOMAS and H. W. FINCH
(A.E.R.E. Harwell) (E. K. Cole, Ltd., Electronics Division)

A simple vibrating condenser electrometer is described for measurement of small D.C. currents and voltages at high impedance. The full-scale sensitivity may be 3×10^{-14} amps. or 30 mV, and fluctuations of zero correspond to about 10^{-15} amps. or 1 mV, day to day under normal laboratory conditions. An application to ionization current measurement is discussed.

There are many applications for directly-connected amplifiers in the measurement of small currents and voltages, and it is well known that in a conventional direct-coupled thermionic amplifier the overall sensitivity is limited primarily by the drift in characteristics of the input valve. Although figures for day-to-day stability better than 1 mV are reported for certain direct-coupled amplifiers, these generally depend on careful balancing of circuits or highly stable power supplies, and it the author's experience that a day-to-day stability better than 15 mV is not readily achieved in equipment subjected to normal use, including perhaps frequent switching on and off or transportation between different laboratories.

The design and performance of a vibrating condenser electrometer for such measurements has been described by Palevsky,[1] and as a result of careful preparation of the surfaces of the plates of the vibrating condenser, zero fluctuations of a few tens of microvolts have been quoted. One of the most important applications is to ionization current measurement, where the electrometer is used to measure the voltage generated across a high resistance or capacitor, and in many instances a simpler instrument of reduced sensitivity is useful. The present electrometer has been designed for quantity production with this in mind, and the zero fluctuations amount to about 1 mV over 24 hours. For the majority of purposes this limited stability, corresponding to 10^{-15} amps. in a 10^{12} ohm resistor, has not been a serious disadvantage, partly because at lower currents other sources of error (noise in the input resistor, statistical fluctuation of the input current) become significant. For currents less than 10^{-15} amps., it is normally more satisfactory to replace the input resistance by a capacitor and make a measurement by the rate-of-drift method. Initial work on the design of the instrument was carried out at the Atomic Energy Research Establishment, Harwell, and later development and production at Messrs. E. K. Cole, Ltd., Malmesbury.

Design

The design of the vibrating condenser electrometer is based on the fact that amplification is more easily carried out with A.C. than with D.C. The input D.C. potential is therefore converted to A.C. by applying it through a series resistance to the plates of a capacitor, the capacitance of which is oscillating at some convenient frequency (here 550 c/s.). The mean voltage is that applied, but the instantaneous voltage is proportional to the reciprocal of the instantaneous capacitance. An A.C. voltage is thus developed of amplitude proportional to the input D.C. This is passed through a special high-insulation capacitor to a conventional A.C. amplifier, and subsequently rectified. The oscillating capacitor may take one of several forms; for example a rotating vane in proximity to fixed vanes, a diaphragm vibrating near a fixed plate, or a reed vibrating near a fixed plate. In the present design an earthed, polished, stainless steel reed is maintained in resonant oscillation close to a polished steel disk or " anvil ", to which the input is applied. This choice was made because the power required to drive a reed at resonance is small, and no wiping contacts are required (in the case of a rotating vane capacitor, the shaft would be earthed through some form of sliding contact which could prove troublesome, although it may be noted that the rotating shaft could very conveniently be made to work a rectifier using synchronous contacts). Owing to the fact that the variable capacitance is shunted by unavoidable stray capacitance (e.g., the input of the A.C. amplifier) the change is not a large fraction of the total, and the conversion efficiency may be between 10 per cent and 25 per cent.

The output of the A.C. amplifier is rectified, using a phase-sensitive rectifier, and applied to the input as negative feedback, as indicated in Fig. 1. In this way the electrometer acts as a null detector in feeding back a voltage equal and opposite to the input voltage, and variations in the gain of the amplifier are of secondary importance. When current is measured, a voltage is developed across a high resistance and is detected by the electrometer. The earthy end of this resistance is very convenient point for the application of the feedback.

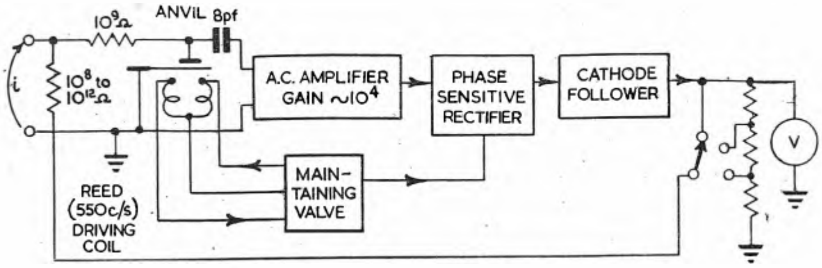
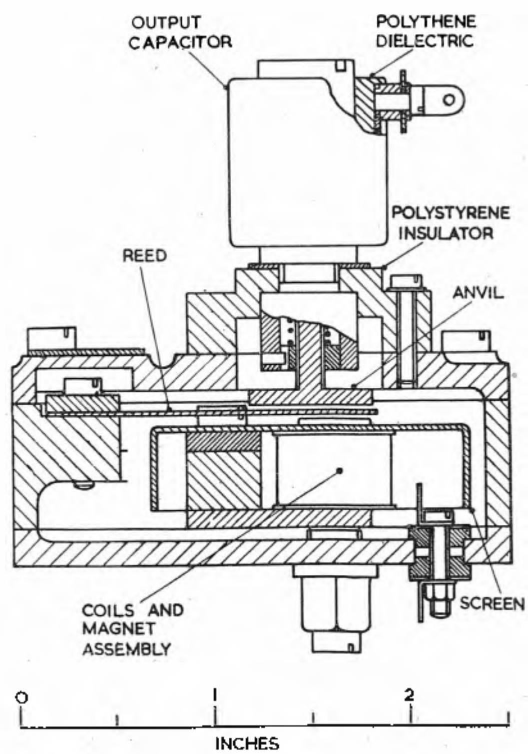


Fig. 1.
Block schematic of the Electrometer

Fig. 2 is a section of the vibrating reed unit. The reed is valve-maintained in resonant oscillation, using a magnet coil assembly taken from a pair of high resistance earphones. This arrangement using an aperiodic maintaining circuit was considered preferable to driving the reed from an independent oscillator, since it eliminates the need for a frequency adjustment. Further, if the reed is driven by a separate oscillator at or near resonance, as it must be to obtain adequate amplitude with small input power, a small drift in oscillator frequency produces relatively large changes of phasing which adversely affect the operation of the phase-sensitive rectifier circuit. The anvil is mounted on a block of polystyrene and is fitted with a screwed shank to permit adjustment of the gap. The amplitude of oscillation is about .02 in. and the minimum gap is about .005 in. These figures are not critical but are chosen as a compromise since, although the fractional change in capacitance should be as large as possible, the amplitude of oscillation should not be such as to produce excessive vibration of the associated valves and insulators, and the gap should not be much less than .005 in., owing to the risk of dust particles producing intermittent short circuits. A cylindrical capacitor of moulded construction (polythene dielectric, 10 pF capacitance and insulation resistance approaching 10^{15} ohms) is used to feed the A.C. to the amplifier input, and this is made integral with the anvil assembly. The reed and anvil surfaces are polished and carefully cleaned with methyl alcohol before assembly. A test of satisfactory cleaning is to breathe on the surface, when condensation should be in an even film, free from all traces of spotting.

Figs. 3(a) and (b) show the circuit arrangement. The vibrating reed unit, together with the first amplifying valve $V1$ and the cathode follower $V2$ is mounted in a head amplifier directly on the ionization chamber, in order to avoid the use of cables in the input circuit, with associated microphonic effects. The head amplifier takes the form of a sealed box, measuring $6\frac{1}{2}$ in. by $5\frac{1}{2}$ in. by 4 in., dried with a silica gel desiccator, to maintain a high insulation and keep the reed and anvil surfaces free from moisture. The remainder of the circuit, including power supplies and a $3\frac{1}{2}$ in. indicating meter, is mounted on a $5\frac{1}{4}$ in. by 19 in. rack panel, measuring 10 in. from front to back. $V1$, $V3$ and $V4$ form an A.C. amplifier, the frequency pass band of which is determined by the components in the anode circuit of $V3$. $V2$, the output cathode follower of the head amplifier, is provided to permit long interconnecting cables (up to 200 ft.) to be used between the head amplifier and the main unit without the performance being impaired. $V1$ is operated at lowered potentials to raise the input impedance, since, although, owing to the D.C. blocking capacitor, this need not be comparable with the D.C. input impedance before the convertor, the time constant of the vibrating capacitor capacitance (including strays) and valve input resistance (including leaks) must be long compared with the periodic time of the reed oscillation (550 c/s.). The cathode of $V4$ is taken to a negative potential for convenience in connecting the phase sensitive rectifier $V5$. $V8$ is the reed maintaining valve, consisting of two triodes in parallel. The grid is driven by one of the coils on the reed-driving magnet, and the anode feeds the

Fig. 2.
Cross-section of the vibrating reed unit



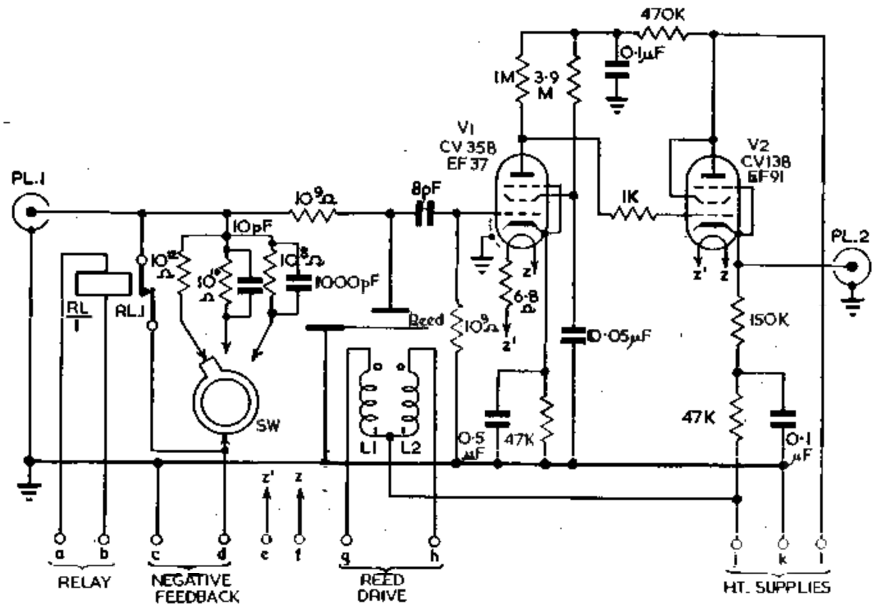


Fig. 3.(a)
Circuit of the vibrating reed unit and reed amplifier

Fig. 3 (b)—the remainder of the circuit—is shown on page 398

other coil. Oscillation at the natural frequency of the reed takes place, and spurious high frequency oscillations arising from the direct coupling between the coils is prevented by the capacitors across the anode coils.

The phase-sensitive rectifier $V5$ is a cathode-coupled double triode, the current of which is switched from one anode to the other as a result of the waveform from the oscillator applied to the right-hand grid. In the absence of signals at the grid of $V4$, the standing anode current of $V4$ is shared between the two anodes of $V5$, and the grid of the cathode follower $V7$ (connected to the right-hand anode of $V5$) rests at about earth potential. If a signal arrives at $V4$ grid in phase with the reference signal at $V5$ grid, the potential of the right-hand anode of $V5$ falls proportionately to the signal amplitude; if the signal is in anti-phase with the reference, this anode potential rises. Thus a D.C. voltage appears at $V7$ grid of amplitude proportional to the A.C. signal, and of polarity dependent on the phase of the A.C. The circuit has the advantage that no transformers are used, and no load is imposed on the source of reference waveform. Satisfactory operation of the rectifier depends on correct phasing of the signal and reference voltage, and to prevent phase shifts being introduced when the amplifier is overloaded, 1 MΩ grid stoppers are used with $V3$ and $V4$. Inspection points are provided for checking the phasing with a double beam oscilloscope.

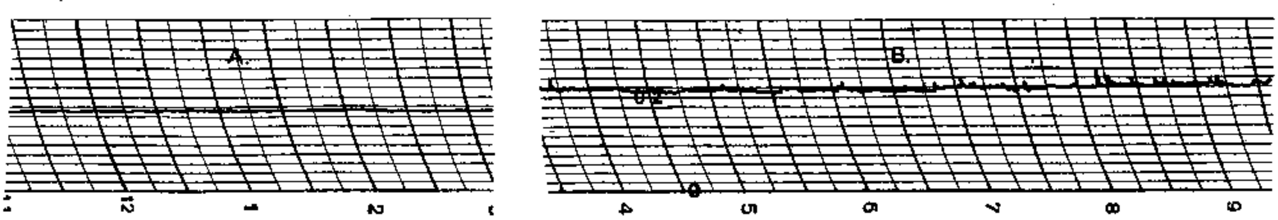
The output from $V7$ cathode is taken to a 0-1 mA meter, and negative feedback to the input taken from a tapped potentiometer in parallel with the meter. The diode V6 prevents damage to the meter as would occur if the grid of V7 were driven positive under overload conditions. Four ranges are provided giving 30 mV, 100 mV, 300 mV and 1 mV, full scale. Without feedback, full scale on the meter corresponds to 2 mV D.C. at the input. Means are provided for operating a 0-1 mA pen recorder or a 0.100 mV recorder if required, and the circuit is compensated for the resistance of the instrument so introduced. Zero adjustment is carried out by injecting a voltage in the feedback line; the voltage is taken from the slider of the set zero potentiometer via the resistances $R39$ and $R40$. A relay in the head amplifier is provided to short-circuit the input resistance when it is required to set zero without breaking the input circuit.

The power supply is conventional and provides +200 and −100 volts stabilized. Owing to the low H.T. consumption (18 mA) a voltage doubling circuit is used, and this helps to keep down the dimensions of the mains transformer. The operation of the electrometer is unaffected by variations of ±15 per cent in mains voltage. The power consumption of the equipment is 40 watts.

Performance

Fig. 4 is a record of the zero drift measured with the input short-circuited and with a 10^{12} ohm input resistance. An effect which seems to be common to all vibrating condenser electrometers is that after installing a new or freshly cleaned reed or anvil, the contact potential starts at some value, and after a few

Fig. 4.
Zero drift record
Taken with a 0-1 mA pen recorder; 1 mA corresponds to 50 mV at the electrometer input chart, speed 3 in. per hour
A. With input resistance short circuited. B. With 10^{12} ohms input resistance



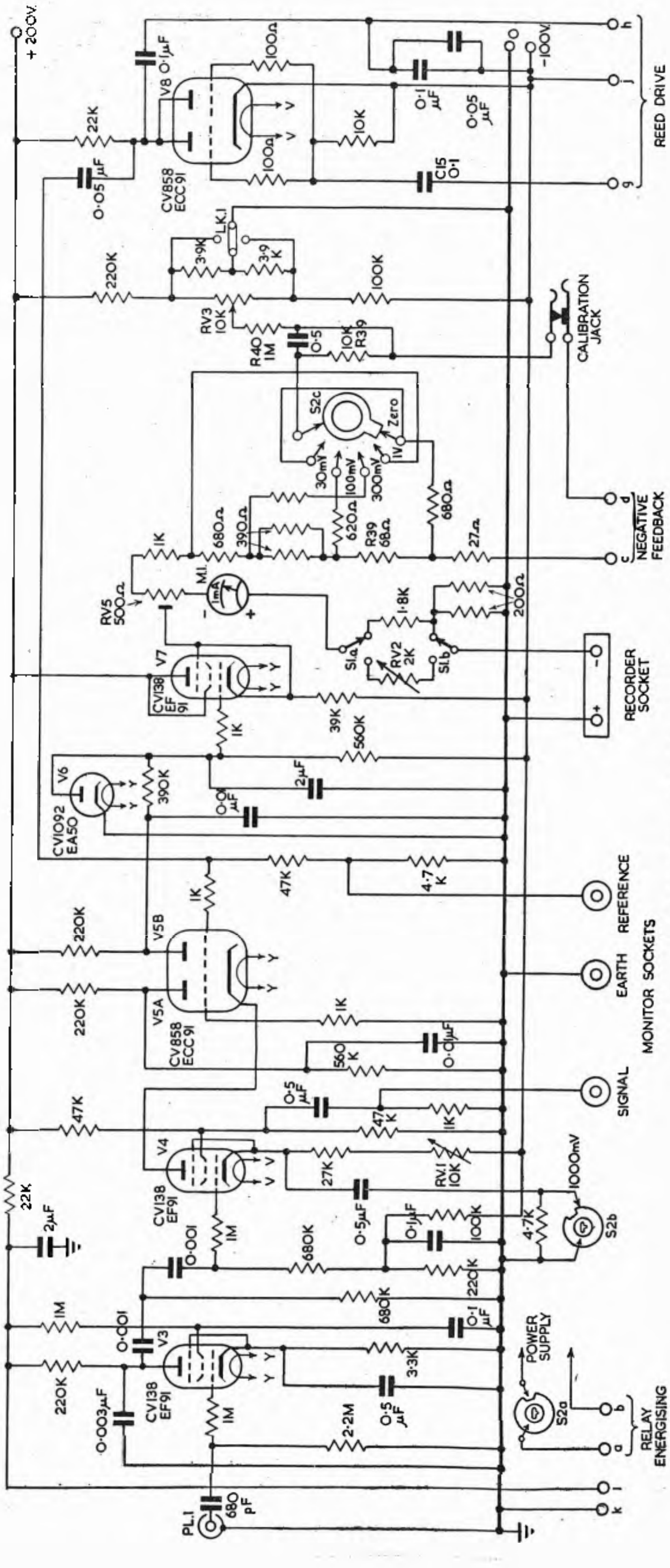


Fig. 3 (b). Circuit of the main unit

days relatively rapid drift settles down to a new value. Generally the contact potential diminishes during this initial ageing period. When the reed and anvil have been aged, the electrometer can be switched off for several days without needed re-ageing, although a slightly increased drift is then to be expected when the instrument warms up. Before adopting stainless steel for the reed and anvil, electrodeposited gold was tried, but was found to give inferior results. Although considerably greater stability could be expected from evaporated gold surfaces as described by Palevsky, this was not considered to be warranted for the present instrument. An indication of the quality of the reed and anvil surfaces is given by the minimum A.C. signal generated at balance. Theoretically this should be zero when the electric field is zero, but with the reeds and anvils used it has a value of up to 2 mV, presumably due to impurities (scratches and pitting) causing irregularities in the surfaces. The magnitude of this effect is useful for assessing the quality of the reed or anvil without awaiting completion of the ageing period. Trouble was at first experienced with direct pick-up between the reed driving circuits and the input valve $V1$. This took two forms: direct electrostatic pick-up from the driving circuit and microphonic pick-up from the vibration of the reed, and it was eliminated by shielding, and anti-microphonic mounting for $V1$.

With a 10^{12} ohm resistance in circuit, zero fluctuations are greater, largely because the action of the negative feedback is no longer instantaneous. If a capacitor of capacitance 5-10 pF is connected in parallel with the high resistance, the fluctuations do not greatly exceed those with the input resistance short circuited, although the response time of the instrument is then lengthened. Alternatively, the input resistor may be replaced by a capacitor for measurement of charge, and a simple modification to the input circuit of $V1$ enables the existing highly insulated capacitor to be used for this purpose at the same time as serving as the A.C. coupling capacitor.

A number of electrometers have been used in conjunction with pressure ionization chambers for gamma-ray measurements at low intensity. The ionization chamber gave a current of about 10^{-13} amps. of the natural gamma- and cosmic-ray background and 5×10^{11} ohm input resistances were used in the electrometer. Under laboratory conditions, changes in background of 20 per cent or more were immediately detectable. Smaller changes could be detected using a capacitor in parallel with the input resistor, as described above, to lengthen the response

The Cathode Follower as a Voltage Regulator

By A. P. WILLMORE

THE cathode follower can be used as a simple and fairly efficient voltage stabiliser. A brief analysis of the circuit of Fig. 1 will be presented.

If linear characteristics are assumed, then when

$$i_a = e_o = 0,$$

$$e_g = -e_1/\mu \qquad (1)$$

Thus, with an applied voltage e_g, using (1),

$$i_a = g_m(e_g + e_1/\mu - e_o) - e_o/r_a$$

since $(e_g + e_1/\mu + e_o)$ is the change in grid-cathode voltage, and e_o is the change in anode-cathode voltage.

$$e_o = g_m r_1(e_g + e_1/\mu) - e_o(g_m r_1 + r_1/r_a)$$

$$= \frac{e_g + e_1/\mu}{1 + 1/\mu + 1/g_m r_1} \qquad (2)$$

Since $g_m r_1 >> 1$, r_1 has only a minor effect on e_o. Fluctuations of e_1 are reduced μ times. By a well-known result,[1] the internal resistance of the supply is approximately $1/g_m$.

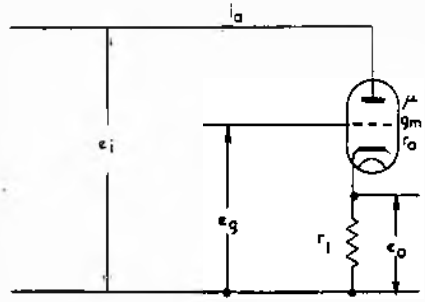


Fig. 1.
Basic cathode follower circuit

Two stabilizers of this sort are shown in Figs. 2 and 3. The first, Fig. 2, employs a triode-connected SP61, which is very well suited, having a μ of about 75. The performance is summarized in Figs. 4 and 5. The internal resistance for an output between 1 and 10 mA is about 150 Ω; the minimum value of $1/g_m$ over the working range is 110 Ω which represents a fair agreement. The minimum output obtainable was 5.5 V; the maximum, 250 V.

The cathode follower in Fig. 3 is an 807 triode-connected. While this mode of operation is not recommended by the manufacturers, the screen dissipation was not found excessive. When e_g = 250 V the output varies by 10 V, or 4 per cent, for an increase in load from 0 to 10 mA and decreases by 5 V, or 2 per cent, more, for a further increase in load of 50 mA. A change in supply voltage from 300 to 400 V caused an output change of 8 V or 3 per cent.

A disadvantage of the stabilizer is the need for an auxiliary supply of the same order as the required output voltage. This supply can usually be obtained quite simply, as the current demands are small and constant. For the stabilizers described above a J50 rectifier was used, its A.C. supply being obtained from one "leg" of the secondary winding of the mains transformer. This arrangement is adequate where, as is frequently the case with variable-voltage supplies, stability against mains voltage variations is not of great importance. Alternatively, this auxiliary supply may be obtained from small neons across the H.T.

Two uses of the stabilizer will be considered in detail. The first is to increase the load that may be

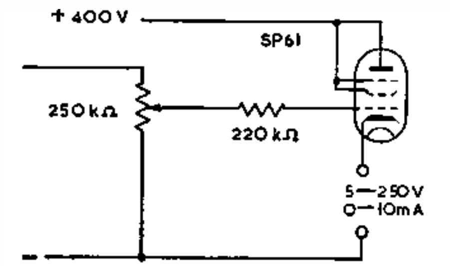


Fig. 2.
Mazda SP61 used as the cathode follower stabilizer

stabilized by a neon tube. In particular, voltage reference tubes such as the Mullard 85A1 have a preferred tube current range which is very limited. A stabilizer like that in Fig. 2 will enable the neon to be run under the best conditions. The output will remain constant to within less than 2 per cent for load changes from 1 to 10mA which is rather better than the performance of the neon alone, where the change would be more than 3 per cent. Further, the

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time and thus reduce the effects of statistical fluctuations of the gamma-rays. It was eventually found possible to carry out such measurements in a moving vehicle, (power supplies being obtained from a battery with a rotary convertor), but trouble was experienced due to collection of piezo-electric charges from the insulator supporting the ionization chamber collecting electrode; this was of quartz and had to be specially selected before satisfactory results were obtained. The zero stability of the electrometer was found to be virtually unaffected by the movement of the vehicle.

The instrument could readily be adapted as a millivoltmeter for pH measurements or general laboratory use. For the latter it would be preferable to insulate the reed from chassis and apply the feedback to it. The connexions to the driving coils would be reversed to give the correct polarity of feedback.

Acknowledgment

Our thanks are due to Mr. E. W. Pulsford and Mr. E. M. Cooke-Yarborough, for valuable advice in the initial stages of the work. The paper is published by permission of the Director of the Atomic Energy Research Establishment, Sir J. D. Cockcroft, and the Directors of Messrs. E. K. Cole, Ltd.

Reference

[1] Palevsky, Swank and Grenchik, *Rev. Sci. Inst.*, 18, 298, 1947.

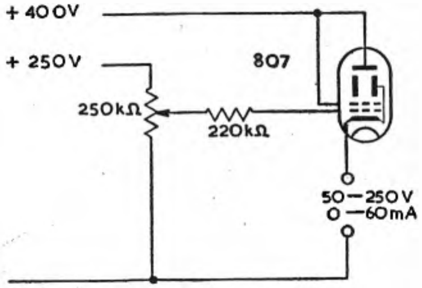


Fig. 3.
Cossor 807 used in the circuit shown in Fig. 2

load may have any value inside this range without causing a loss of stability. The noise output can be much reduced by connecting a bypass capacitor from the grid of the triode to earth.

"Amplification" of a reference potential is also possible. (Fig. 6). Since the voltage across R_1 is stabilized, that across R_2 is also. A change in the H.T. will increase materially the current through the neon tube, and this will increase the drop across R_2. Hence, i_2 should be small compared with i_1. The

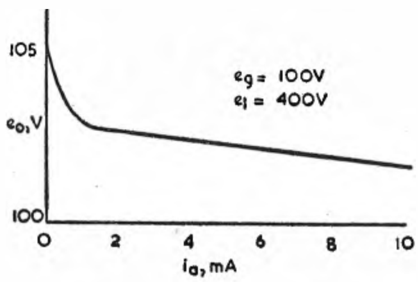
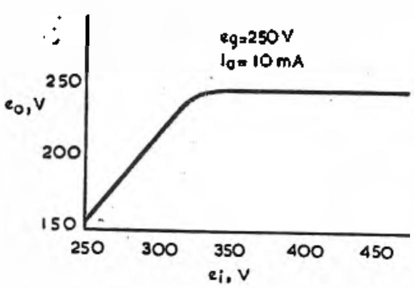


Fig. 4.
Performance curve for SP61

circuit may be used to provide a high reference potential for a series-parallel type of voltage regulator. Since the stability against H.T. changes is not particularly good, it should be fed from the stabilized side of the series valve. The internal resistance will be that of the cathode follower, multiplied by the "amplification" of the reference voltage, for any voltage changes across R_1 are amplified across R_2.

For such a reference source, Fig. 7, the internal resistance was 600Ω. About 20 per cent of any H.T.

Fig. 5.
Performance curve for SP61



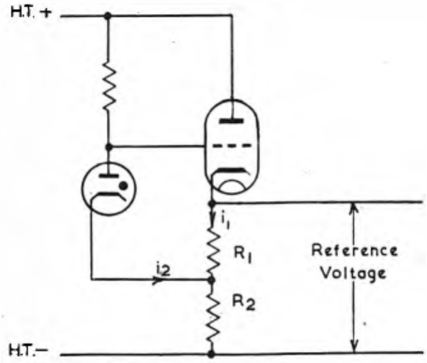


Fig. 6.
Amplification of reference potential

changes appeared across the output. Five neon tubes 85A1 in series give nearly the same voltage, but their performance would be inferior to that of the stabilizer, which is also more economical in valves. The A.C. resistance would be at least 1500Ω, and this resistance causes negative feedback in the parallel valve of a series-parallel regulator, thus reducing its gain. The lower A.C. resistance of the cathode follower usually more than offsets its dependence on the H.T. voltage when used in such a circuit. The advantages of a high reference voltage are twofold: the reduction of input voltage changes in the series-parallel combination is practically proportional to it[2], and the voltage across the amplifying valve is reduced, which may be useful at high output voltages.

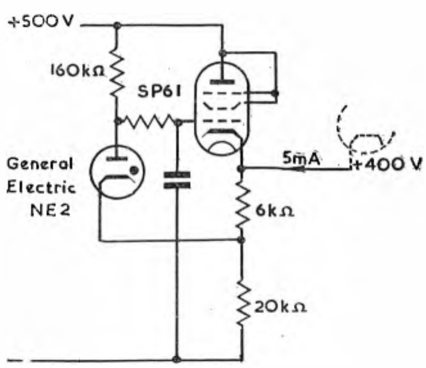
When the simplicity of the stabilizer is considered, its performance compares quite well with that of more complicated circuits. It is most useful at low currents, where triodes of high μ and high g_m can be used. The internal resistance cannot be reduced much below 100Ω, unless paralleled valves are employed.

The author wishes to thank Mr. A. M. Willmore, who set up and tested most of the stabilizers.

[1] Almost any discussion of the cathode follower; Branierd and others. *V.H.F. Techniques* (P.221) is usually accessible.

[2] F. A. Benson, "Voltage Stabilisers," *Electronic Engineering*, 21, 258, August, 1949. (Appendix).

Fig. 7.
Application of the circuit shown in Fig. 6.



LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

Magnet Lenses

DEAR SIR,—Mr. D. Hadfields article on "Permanent Magnet Lenses for Television Tubes" in your April issue contains some misleading statements.

It is stated that "Apart from the influence of this force" (due to the magnetic field) "... there is also the accelerating force due to the high anode potential above the cathode ... thus causing the particle to travel in a helical path ...". The helical path of the electron depends solely on the relative directions of the magnetic field and the electron path. It is not necessary for the magnetic field to be accompanied by any electric field, only that the electron has a component of velocity along the axis of the lens. In many television tubes there is no electric field in the space occupied by the magnetic lens.

In the following paragraph this helical motion is described in greater detail but it is not clear that it is assumed that the magnetic field is completely uniform. This means that the source of the electrons which is to be focused and the focused image are in the uniform field.

Unfortunately these descriptions of electron motion in magnetic and electric fields tell us little or nothing about the focusing action of a practical magnetic lens, the statement concerning motion in non-uniform fields is so general as to be meaningless, and the electron path of Fig. 1 is grossly incorrect. In this diagramatic representation of the focusing of cathode-ray tubes the electron enters the magnetic field of the lens without any deviation and then suddenly commences innumerable convolutions which continue right to the luminescent screen, traversing, in the main, space free from all fields magnetic and electric. This is contrary to Newton's First Law of Motion.

I would suggest that the following direct approach gives a useful picture of what is actually happening to the electron. The electron leaving the cathode or passing through the crossover in the gun (the image of the crossover is focused to form the spot) has axial and radial components of motion relative to the cathode-ray tube neck. The axial component is far the greater and the first part of the magnetic field which is encountered has a radial component. The initial movement of the electron is substantially at right angles to the radii and the axis of the tube. This movement is at right angles to the axial component of the magnetic field and produces a secondary movement towards the axis, i.e., the tendency to focus. On the way out of the lens the radial field is in the opposite sense and this slows up the movement of the electron about the axis so that it leaves the lens without the component velocity at right angles to both the radii and the axis of the tube but with components towards and along the axis only. It should be noted that the axial velocity of the electron is the important one and that the angle through which an individual electron is twisted about the axis is quite small. It may be only 90 degrees.

I should be interested to know on what evidence Mr. Hadfield bases the statement that for optimum focusing the axial field distribution is given by $H_z = H_0/(1+(z/a)^2)$.

I have always understood that the significance of this expression was that it approached the distribution obtained with shielded coils and that it was convenient for a mathematical analysis of the short magnetic lens. Other workers do not give the parameter a as the distance to the half-field-strength points but refer to that as d and define the symbol a in the expression above as $a = d/\mu\sqrt{(\sqrt{2}-1)}$ where μ approaches unity for a fully shielded coil. (See V. E. Coslett, Introduction to Electron Optics, O.U.P., p. 90.)

In the last sentence on p. 134 it is stated that "Astigmatism can be detected by rotating the magnet coaxially with the tube, when its presence will be indicated by the spot becoming oval in shape instead of circular." If the axis of the lens coincides with the axis of the electron beam and the electron beam is balanced uniformly about its axis the spot shape can not change as the magnet is rotated. The spot may not be circular but only when there is some form of aberration in the electric lens as well as the magnetic lens will you get the phenomenon described in this sentence.

Yours faithfully,

BRYAN R. OVERTON.

Redhill, Surrey.

Mr. Hadfield replies:

"Firstly, may I take this opportunity of thanking both Mr. Wayman[1] and Mr. Overton, for their very interesting and constructive letters dealing with the physical behaviour of travelling electrons under the influence of magnetic fields.

Having now gone into the matter exhaustively, it would appear that the diagrammatic representation of focusing of an electron by passing through a magnetic field as shown in Fig. 1 was not the most usual case, and probably only occurs remotely under extreme conditions. The simplest case, i.e., where the field is parallel and uniform over the whole of the electron path and the electron velocity constant, has been adequately described by Mr. Wayman, and diagrammatically may be as shown below:—

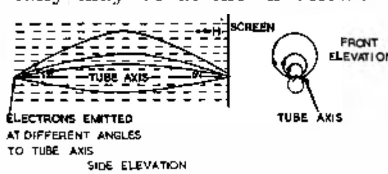


Fig. 1

The more complicated case, existing in practice, whence the magnetic field is non-homogeneous, except over a very short distance, due to the "thin" magnetic lens is argued convincingly by Mr. Overton. Diagrammatically this may be represented as shown overleaf.

The electron is emitted at a

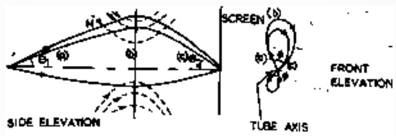


Fig. 2

certain angle in a region of little or no field, and so travels in an almost straight path away from the axis (a). However, it is entering a magnetic field of ever increasing strength as it travels towards the magnet, and due to this experiences an increasing force which acts in a direction mutually perpendicular to the directions of the electron path and the radial component of the magnetic field, and is thus deflected gradually in a path of a somewhat circular character (when viewed from the tube end) the radii of which reach a minimum value when the electron passes through the point of maximum field strength during its journey to the screen (b). After passing through the region of maximum field strength, i.e., where the axis of the tube is tangential to the lines of force, the radial force on the electron is diminished, and thus the radii of curvature of the radial path increase, until it reaches a region of little or no field (c) whence the path becomes almost tangential and straight again, when the electron regains the tube axis at the screen. The angles, in the side elevation, at which the electron leaves and returns to the axis will differ depending on the position of the lens. Focusing is produced by all electrons leaving the tube axis at different angles, returning to the axis at the same point, due to the fact that the transit time is the same in each case, in other words they all have the same horizontal component of velocity.

In the literature there appear to be some different interpretations of the specific behaviour of an electron under these conditions, although the general conceptions agree. My own visualization is an extension of those described, and is shown below:—

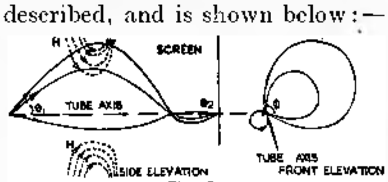


Fig. 3

The angles between the tangents to the electron paths at the points where they leave and return to the axis, as viewed from the front of the screen, may be greater than 90°, depending largely on the strength and distribution of the magnetic field.

Regarding Mr. Overton's criticism of the validity of the formula for the optimum axial field strength distribution, a permanent magnet lens can be looked upon as an approximation to an unshielded coil, there being usually no screening around the outside of the magnet. Coslett quotes a value for μ of $3/2$ for an unshielded coil and thus, if substituted in the expression given above

$a = \dfrac{d}{\mu\sqrt{(\sqrt{2}-1)}}$ will give, $a = 1.003d$.

Therefore, to a first approximation, a is equal to d, the distance along the axis from zero to the half-field strength points, in practice, the formula is sufficiently close to enable a satisfactory design to be evolved.

Astigmatism of the magnetic lens does result in a distortion of the spot shape, but this is not always easy to detect unless the magnet is rotated. I quite agree that this may not always be entirely due to the magnet.

[1] Electronic Engineering, 22, 255, (1950).

Brightness Control

Dear Sir,—May I recommend to television manufacturers the discontinuance of the term "brightness control". "Brightness" on a knob tempts viewers to advance this control when contrast adjustment is actually needed.

The chief results are pictures which do a disservice to the television industry's future, and reduction of the life of the tube.

A change of name, plus improved instructions from some manufacturers on the use of their receivers' controls would go a long way to overcoming these troubles.

—Yours faithfully,
W. P. Rowley.
East Molesey, Surrey.

Radio Interference from Incandescent Lamps

Dear Sir,—Readers of the note on this subject in your February issue may like to know that this kind of interference was reported by G. Lehmann in 1937,[1] and that an explanation was given by the present writer[2] in the course of a paper dealing with a little-known form of valve distortion.

Interference is observed only from lamps of the high-vacuum type using A.C. What happens is this: electrons emitted by the negative end of the filament are accelerated past the positive end, striking the inside of the bulb. There is usually a thin layer of evaporated metal or other slightly conducting material on the inside of the bulb which emits secondary electrons. Generally such an isolated conductor can take up one or other of two stable potentials a hundred or more volts apart, the lower involving repulsion of the incident electrons and no secondary emission, while the upper involves acceptance of the primary electrons together with the emission of an equal number of secondaries.

At the peak of the A.C. voltage cycle the energy of the incident beam is almost certain to carry the bulb to the upper stable potential, and the potential drops discontinuously to the lower value. These violent changes are periodic with twice the supply frequency, causing a low-pitched modulation to be picked up over a broad band of wavelengths in a nearby receiver. The cure for the trouble is to use gas-filled lamps, in which electron beams cannot reach the bulb.

The phenomenon also occurs in audio-frequency amplifying valves. Here the capacitive coupling between the bulb and the grid causes a sharp discontinuity to appear in the waveform of the signal. The resulting distortion (a pronounced buzzing) may easily be mistaken for something loose in the loudspeaker. The writer found the effect in a power triode purchased recently. It also occurs in pentodes, especially those of high mutual conductance. As a rule the effect disappears if one's hand is placed over the bulb, the added capacitance preventing the discontinuous jumps in potential.—

Yours truly,
Kenneth A. Macfadyen.
The University, Birmingham.

[1] Lehmann, G. L'Onde Electrique, 16, 223 (1937).
[2] Macfadyen, K. A., Wireless Engineer, 15, 310, (1938).

NOTES FROM THE INDUSTRY

Conference on Production

On November 15 and 16, the Utilization Section of the Institution of Electrical Engineers are holding a Conference on "Electricity as an Aid to Productivity" in order to make available to industry the most up-to-date information concerning the contribution that factory electrification can make to the country's efforts towards increased production.

The Conference is mainly intended for those executives in both large and small factories who are responsible for production, and will consist of a series of lectures each of which will be followed by a general discussion. It has been planned, as far as possible, from the point of view of the user, and the lectures will therefore cover, in general terms, what electricity can do to increase production rather than give full technical details of the apparatus with which these improvements can be achieved. It is thus hoped to stimulate thought on the part of the audience, so that, after the Conference is over, they may act on what they have heard, obtaining the further information they will require from established sources. The subject matter of the lectures will come under the following broad headings: (a) Motive power in the factory, (b) Industrial heating processes, (c) Welding applications, (d) The handling and inspection of materials, and (e) Lighting, heating, ventilation, etc.

The proceedings of the Conference will be published and issued to all interested parties so as to reach as wide an audience as possible.

The aim will be to focus attention on the effect that electricity can have on the economics of production, embracing both quantity and quality, and to show how electricity can help to produce an ever increasing output.

Plessey Transmitter-Receiver on Police Duty

The Plessey Company, Ltd., Ilford, Essex, announce that they have received a contract to supply to the London Metropolitan Police a quantity of Plessey Transmitter-Receivers, Type P.TR.7, for use on motor cycles, and the associated control station installation. This equipment will play a useful part in helping Scotland Yard to combat crime, and in aiding the police in their task of controlling traffic.

Full technical details of this equipment were given on page 345 of the August, 1950, issue of ELECTRONIC ENGINEERING.

Radio Show Opening

The Lord Mayor of Birmingham is to open the 17th National Radio Exhibition at Castle Bromwich, Birmingham, at 12.30 p.m. on September 6. There will be no pre-view of the Exhibition this year, but there will be a Press view throughout the morning of the opening day.

The Institute of Physics

The Board of the Institute of Physics announces that the Institute's Certificate in Laboratory Arts will not be awarded after 1951, in view of the establishment of the Intermediate Certificate for Laboratory Technicians by the City and Guilds of London Institute, which it welcomes.

The Television Society Constructors' Group

The Constructors' Group of the Television Society will in future be known as the Engineering Group, a title which more accurately expresses its scope. The policy of the Group Committee and the standard of the papers read before the Group are not affected by the change of name.

Particulars of the Society's activities can be obtained from the Hon. Secretary, Mr. G. Parr, 68 Compton Road, N.21.

The South Coast Televiewers Association

The S.C.T.A. has a membership of over one thousand viewers formed in branches at Worthing, Lancing, Brighton and Hove, Eastbourne and outlying villages.

It has affiliated viewers clubs, and the movement is expanding so rapidly since its formation in 1949 that organisation on a national scale is now contemplated.

The Association's main aim is to raise the standard of television reception in areas where such reception is unreasonably and unnecessarily poor, and to press for a television station which will adequately serve London and the South Coast of England.

Other functions include the tracing and suppression of local interference to T/V reception and a certain amount of social activity.

Membership is open to any person who owns a television set. The subscription is 5s. annually. The Honorary Secretary is R. Sawyer, of 74 Berriedale Drive, Sompting, Worthing.

Industrial Finishes Exhibition

The first national exhibition of industrial finishes is to be held at Earls Court, London, S.W.5, from August 30 to September 7. The Council of Industrial Design will have a stand to demonstrate a wide variety of finishes, including one of vitreous enamel which is high temperature resistant, and another vitreous enamel, free from lead, which can be applied to aluminium.

More BTH Radar Equipment for 28,000-ton Tankers

In addition to the BTH Marine Radar Equipment installed on the new Anglo-Saxon 28,000-ton tanker *Velutina*, the British Thomson-Houston Company has received orders for similar equipment for her three sister ships.

The company is also supplying radar equipments for five new 28,000-ton "CAP" class tankers.

Another order, received recently from the British Tanker Co., Ltd., is for supplying marine radar equipment with an extended mast for six new 28,000-ton tankers at present under construction in British yards.

B.B.C. Engineering Division Appointments

The following new appointments have been made in the Engineering Division of the B.B.C.

Mr. R. T. B. Wynn, C.B.E., M.A., M.I.E.E., becomes Deputy Chief Engineer, with responsibility under the Chief Engineer (Mr H. Bishop, C.B.E., B.Sc.(Eng.), M.I.E.E., M.I.Mech.E.) for the general control and direction of all Engineering Departments. Mr. H. L. Kirke, C.B.E., M.I.E.E., becomes Assistant Chief Engineer, with responsibility for the co-ordination and direction of the technical work of the Research, Planning and Installation, Designs, and Equipment Departments.

Mr. W. Proctor Wilson, C.B.E., B.S., M.I.E.E., succeeds Mr. Kirke as Head of the Research Department, and Mr. E. C. Drewe, M.I.E.E., becomes Assistant Head of the Department.

New Decca Company Formed

A new company with the title of Decca Radar Ltd., has been formed as a wholly-owned subsidiary of the Decca Record Company, Ltd., to handle all activities concerned with Decca radar equipment previously dealt with by the Decca Navigator Company, Ltd. The new company's registered offices are at 1/3 Brixton Road, London, S.W.9, and its interests will be concentrated entirely on the design, manufacture and sales of Decca Marine Radar, and the development of further interests in the radar field.

The Decca Navigator Company, Ltd., will continue to deal with all matters concerned with the further expansion of the Decca Navigator System.

BOOK

Radio Servicing Equipment

By E. J. G. Lewis. 1st edition, 370 pages, 193 illustrations. Chapman and Hall, 1950. Price 25s.

THE purpose of this book, as the author states in his preface, is "to assist all users of radio servicing equipment to obtain a sound working knowledge of their test gear and so to get the utmost service out of it," and it appears to be well prepared for its purpose.

Commencing with simple current and voltage measuring instruments, the principles of which the author explains by means of simple experiments at negligible cost, he proceeds to show how multi-range instruments and ohmmeters are constructed. Further chapters follow on analysers, valve testers, service oscillators, output indicators, audio frequency test gear, valve voltmeters, resistance and capacitance bridges, the cathode ray oscillograph and frequency modulators.

The book contains an extremely comprehensive range of practical information concerning the various tests that can be performed with each item of equipment, and whether the reader desires to make some of his own test gear, or prefers to buy all of it ready made, the book will prove invaluable.

It is often noted that books using a "simple" approach or explanation, in the effort to achieve directness, make statements or analogies that are highly questionable from an academic viewpoint, and hence can be misleading unless adequately qualified. This book is noteworthy for its clarity of presentation in this regard, and should readily be understood by both the "young and not so young" — to use the author's own expression. The few slight mis-statements that were noted are not sufficiently important to merit comment, as it is extremely unlikely that they would mislead. There are very few typographical errors in the book, a fact that further bespeaks great care in its preparation.

N. H. Crowhurst.

Aerials for Centimetre Wavelengths

By D. W. Fry and F. K. Goward, Modern Radio Technique Series, 172 pp. Cambridge University Press, 1950. Price 18s. net.

THIS book deals with the theoretical methods used in the design of radar aerials for such purposes as air-borne navigation and bombing, detection of surface vessels from the air, air-borne interception and gun-laying. Thus the theory presented is mainly concerned with scanning techniques and the design of aerials having polar (radiation) diagrams specially adapted to the functional requirements of the radar equipments with which they are employed. The authors have had considerable war-time experience, gained chiefly at the Telecommunications Research Establishment, on these specialized aspects of aerial design. Their treatment of the subject within this field is detailed, clear, concise and likely to be of considerable value to the radar engineer. The more practical aspects of aerial design are dealt with only briefly, however, and little information is given on constructional techniques.

The communication engineer concerned with the design of fixed directive aerials for radio relay systems will probably find that this subject is dealt with inadequately, the viewpoint of the authors being best summarized by a quotation (p. 155): "Directive non-scanning aerials are very similar to scanning aerials and it is not necessary therefore to discuss them." In point of fact, such aerials may have to satisfy much more critical requirements than radar aerials in respect of impedance matching, suppression of minor lobes and operation over a wide bandwidth.

Another important omission concerns the measurement of polar diagram, gain and area efficiency; these are by no means easy to carry out accurately, and reliable measurements are essential before it can be said that an aerial design is complete.

Although this book is welcomed for the considerable amount of information it gives on the theoretical side of scanning aerial design, much of it hitherto only available in Services reports, it is considered that a more balanced approach to the subject would have considerably enhanced the value of the book.

W. J. Bray.

Symposium on Electronics

By A. G. Peacock. 197 pp. 17 figs. Chapman & Hall in collaboration with the Scientific Instrument Manufacturers' Association. 1949. 16s. net.

THIS is a collection of the papers read at the first electronics symposium of the S.I.M.A. in 1948. The discussion which followed each paper is also included. A wealth of general information on a variety of electronic topics is thus provided.

REVIEWS

The book is divided into two parts. Part I deals with electronics in research. The papers are "Electronics in Computing," "A Review of Frequency Measurements," "The Measurement of Small Displacements by Electrical and Electronic Methods," "Measurement of Ionizing Radiations," "High Vacuum Gauges," and "The Radiosonde and its Manufacture." Part II discusses electronics in industry. It comprises papers on "Some Industrial Applications of Electronics," "Metal Detection in Industry," "Sound and Vibration Measurement," Electronics in Spectroscopy," and "Some Developments in Picture Telegraphy."

Nearly every paper concludes with a useful bibliography of articles for further reading. The book abounds with useful and necessary diagrams and illustrations. It is rather doubtful as to whether the figures 10 and 11 on pages 130 and 131 serve any useful purpose, however. These are photographs of a metal detector in use in a saw mill, and of a perhaps unwilling cow being "swept" for metal.

Only two errors were noticed by the reviewer. The sub-headings (c) and (d) are omitted in figure 2, page 45, for the resistance wire strain gauge, and the condenser type gas indicator respectively. The title heading on page 47 should read "The Measurement of Small Displacements," and not "The Radiosonde and its Manufacture."

The criticisms in this review are of but minor blemishes on an otherwise excellent survey, which can be highly recommended to those who like to know a little of the other engineer's work and problems.

H. STIBBE.

Permanent Magnets

By F. G. Spreadbury, A.M.Inst.B.E. 280 pages. 157 figures. 1st edition. Isaac Pitman & Son, Ltd., 1949. Price 35s.

THIS is probably the first book published in this country which is entirely devoted to the very wide and interesting study of permanent magnetism. Mr. Spreadbury touches upon almost every aspect of the subject, commencing with the materials available, the design, through the various production stages including testing, magnetization and demagnetization, and the applications, with a condensed chapter on the fundamentals of magnetic theory to round it off.

One or two minor criticisms may be made in respect of the earlier chapters. The (BH) max. for British Alnico is 1.6×10^6 and not 1.4×10^6 as shown in Figs. 1-17 to 1-22. There are several metallurgical inaccuracies and anomalies in the chapter on permanent magnet materials; such as the solubility of carbon in iron (less than 0.01 per cent at room temperature); the composition of FePt alloy should be 22.2 per cent iron and 77.8 per cent platinum; the Curie points quoted for the permanent magnet materials err on the low side, more accurate values being: 6 per cent Tungsten Steel 760° C., 35 per cent Cobalt Steel 890° C., Alnico 800° C. (the Curie range for the Cobalt steels is given as 850/900° C. elsewhere in the chapter).

Unfortunately for Mr. Spreadbury, advances in permanent magnet materials are taking place so rapidly that no book can remain up-to-date for long, and now the coercive force of commercially produced alloys well exceeds the 700 oersted quoted, and has reached 1,000.

The method given for calculating magnetic leakage to assist design is extremely good, and useful practically.

The applications of magnets dealt with are limited in scope, but this is compensated by the detailed analysis of those described.

Mr. Spreadbury is to be complimented on his mathematical treatment throughout, particularly in his chapter on design; also those on measurements and testing, and magnetization and demagnetization, which are original in conception. A second edition could probably be enhanced by additional references of a more specific nature.

D. HADFIELD.

Facsimile

By Charles R. Jones. Pp. xiii+422 with 223 plates and diagrams. Murray Hill Books, Inc., 232 Madison Avenue, New York 16, N.Y, 1949. Price $6.00.

SO few books have been written which give any attention to facsimile or picture telegraphy that the appearance of a new book entirely devoted to the subject is very welcome.

If the reader expects to find in this volume a treatise on the technical aspects of design of facsimile equipment he will be disappointed. This book caters for the user rather than the student or designer, and also it is essentially confined to consideration of American techniques and practices. While there is a considerable amount of technical information, this is almost entirely of a descriptive nature.

BOOK REVIEWS (Continued)

Theoretical treatment of the subject is avoided, and so is the use of mathematics.

The book is divided into four parts: part one (after a short historical section) introduces the reader to the uses of facsimile equipment; part two describes the technical features of the equipment; part three gives detailed information concerning a number of equipments manufactured by various American companies, and part four gives a few general notes on servicing followed by very detailed information on the servicing of two particular makes of American equipment. Parts three and four occupy over half of the book, and contain for the most part information such as would be included in makers' handbooks and service manuals (which is chiefly of interest to users of the particular equipments described).

When dealing with the uses of facsimile the author follows his cause with great enthusiasm, and suggests many possible commercial applications. He is, however, only able to give examples of regular use for one or two types of service.

When discussing broadcast facsimile (for home newspapers) the author compares F.M. transmission with "conventional A.M." transmission. He attributes to F.M. transmission characteristics which are as much peculiar to the high frequencies commonly used in America for F.M. transmission as to F.M. itself, and one wonders whether the author is perhaps not a little out of his depth in this particular matter.

A very useful section of the book deals with facsimile transmission facilities, and points out the limitations of both radio and line transmission channels when used for conveying facsimile signals.

J. J. E. Aspin.

Television Explained

By W. E. Miller. 112 pages. Third edition. Iliffe and Sons, Ltd., 1949. Price 5s.

THIS book is addressed to knowledgeable members of the public who, having some acquaintance with radio circuits, are equally interested in their television counterparts; and to those who have some elementary radio training.

This new edition appears in improved form, and contains much additional information on aerial systems, together with notes on frequency allocations and suppressed sideband working. Other sections of the book have been brought up to date, while actual photographs of picture faults, taken specially by the author for this edition, are included.

The Wireless and Electrical Trader Year Book, 1950.

Compiled by the Staff of the Trader Publishing Co., Ltd. 278 pages. 21st edition. The Trader Publishing Co., Ltd., 1950. Price 10s. 6d.

THE contents of this edition of The Wireless and Electrical Trader Year Book form a helpful day to day reference for traders and all engaged in radio, television and domestic electrical manufacture and marketing.

A new editorial feature is the section of useful television data, including cathode-ray tube base connexions, with diagrams, and condensed specifications of over 200 current television receivers which are now listed by British manufacturers. The section devoted to valve base connexions, which was included for the first time in the 1949 edition, has been revised as necessary, while the directory section includes up-to-date information on addresses, products, etc., for the various divisions of the industry.

Changes in the names, addresses, telephone numbers and products of the firms engaged in the radio and electrical industries have been incorporated in the directory sections.

Television in Your Home

By W. E. Miller, M.A. 64 pages. 30 diagrams. Iliffe & Sons, Ltd. 1950. Price 2s., postage 2d.

"TELEVISION in Your Home" provides the information the viewer needs before and after he purchases a receiver; it will also, it is hoped, be of interest to the confirmed viewer in answering some of the queries which may have cropped up during his viewing experience. There have been many books on various aspects of television, some of the simple explanatory type, some dealing with programmes and their production, many semi-technical in nature, and a few deeply technical. The book is entirely non-technical, and assumes no previous knowledge whatever of television. In many ways it can be regarded as supplementing the instruction card or manual which is provided by the television receiver manufacturer.