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Electronic Engineering

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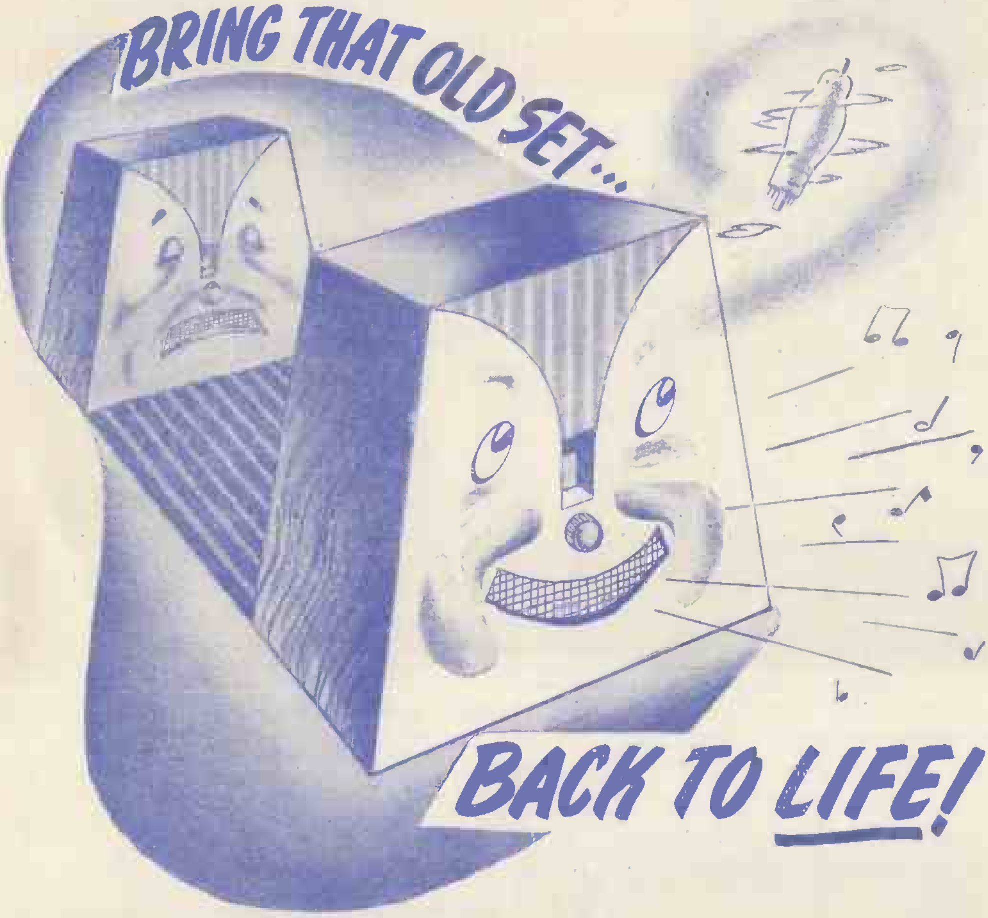
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R.I.C.

THE event of the last month in the radio industry has been the inauguration of the new Radio Industries Council, which is a federation of the four independent Associations who cover the whole field of radio and electronics in this country.

They are, as most readers know, the Radio Equipment Manufacturers' Association (formerly the R.M.A.), the British Radio Valve Manufacturers' Association, The Radio Component Manufacturers' Federation, and the lately formed Radio Communication and Electronic Engineering* Association.

These four Associations will continue to act independently in certain respects, but the Council will have the important function of co-ordinating the industry as a whole and acting for it in special technical or political matters as they arise.

Already the Council has tackled several problems in co-operation with the Government, and it is now concentrating on plans for the reconversion of the industry and the expansion of the export trade.

At the Inaugural Luncheon on January 18, Mr. F. B. Duncan, the Chairman of the Council, spoke of the work which had been done by the various Associations and stated that in 1942 the radio industry had grown to 2½ times its 1939 size.

Dealing specifically with some of the immediate post-war problems, Mr. Duncan said that the first post-war receiving sets will be similar to those of 1939, the design and quality of which had already achieved a very high standard. The developments in short wave technique during the war would lead to better transmission and reception on this band and to greater reliability.

On television : " The Radio Industry Council has made its submission to the Television Committee under Lord Hankey, and this was for an immediate restarting of the pre-war system of television as soon as the German war shall end, this restarting to be not only a station in London but an immediate commencement of work on the linking-up of the whole country by a network of radio, which had, in fact, been envisaged before the war began."

" The Industry aims to provide good television sets for the largest possible public. I am not going to suggest a price at which the first sets may be sold. The public must not expect that the price of post-war television will be any lower than 1939 in the early stages. Our object is to serve everyone, and it is elementary economics that a downward price curve follows an upward demand curve."

Apart from television, Mr. Duncan pointed out that a whole new industry was developing in the technique of radio frequency heating and other developments which will absorb the energies of a large number of scientific workers and provide steadily increasing employment for those already in the industry.

A hopeful address and an auspicious start for the post-war prospects of the radio industry as a whole.

"Can I have it repaired for you by four o'clock! Of what day and month?"

—Radio News

* Usual disclaimer !—Ed.

The "Miniscope"

A Miniature Cathode-Ray Oscilloscope

By M. MICHAELIS, B.Sc.(Eng.), A.Inst.P.*

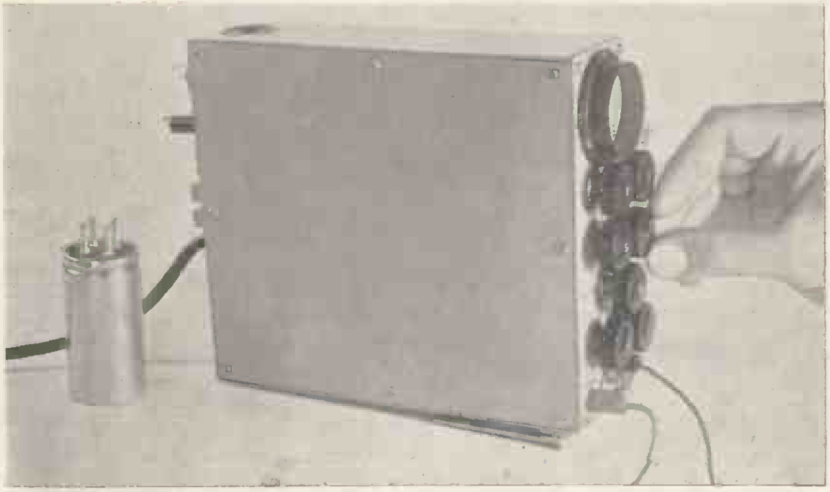

Fig. 1. External view of the "Miniscope."

DURING recent years the cathode-ray oscilloscope has shown itself to be indispensable for numerous purposes. In future it will undoubtedly achieve even more general use in such diverse activities as electronic research and development, measurement and checking of industrial processes, teaching of science and technology and servicing of electrical and electronic apparatus, to mention only a few outstanding examples.

The use of an oscilloscope is often precluded by its weight and bulk and the lack of supply mains on the spot. The Miniature Cathode-Ray Oscilloscope, called the "Miniscope"† for short, has therefore been designed to combine general usefulness with smallness and lightness. Especially under war-time conditions, when its use is often called for in most inaccessible places, this miniature instrument is repeatedly showing its worth.

An external view of the Miniscope is shown in Fig. 1. It is a self-contained unit measuring about 8 in. × 6 in. × 2 in. and weighing 6 lb. It comprises a power pack operating from either A.C. mains or an accumulator, a 1½ in. cathode-ray tube, linear time base, signal amplifier and attenuator as well as various other features.

In the following notes a more detailed account of the circuit and construction of the Miniscope is given.

Circuit

The complete circuit diagram is shown in Fig. 2, and the following description is written with reference to this diagram.

(a) Power Pack

With suitable adjustment of the supply voltage selector, the instrument may be operated from either an accumulator or the usual a.c. mains. In the former case, the vibrator embodied in the instrument is used. The total power consumption of the Miniscope is about 15 watts. Provision for operation from an accumulator greatly enlarges the sphere of application of the Miniscope. Its use in the field, in vehicles, boats and aircraft becomes an immediate possibility. Inspection, aligning, checking and servicing of installations can thus be carried out anywhere on the scene of operations and waste of time and labour in returning faulty gear to the laboratory or workshop is eliminated. In these applications in particular, the small size and light weight of the Miniscope are greatly appreciated; it is carried in a small leather case slung over the shoulder and is no bigger or heavier than an average amateur's plate camera.

Two metal rectifiers MR1 and MR2 in a voltage doubler circuit provide the H.T. supplies for the cathode-ray tube, time base and amplifier.

When the amplifier is not in use, direct access to the deflector plates is provided. Since, however, it seldom happens that the alternating component of the observed signal is of a convenient amplitude to be applied directly to the plates, an attenuator is provided to reduce large signals by the necessary amount.

The earthy side of the signal under observation has to be connected either to the negative or positive end of the H.T. supply according as the amplifier is being used or not. The toggle switch "S_w" connects the earthy input socket "E" to the appropriate point in the circuit.

The use of a single H.T. supply for cathode-ray tube and amplifier permits of a great reduction in size and weight, and the minor inconvenience of having to operate the switch "S_w" as well as changing input sockets in selecting either amplifier or attenuator does not outweigh the advantage gained.

(b) Cathode-Ray Tube

The 1½ in. cathode-ray tube is used because of its small overall size and low operating voltage. Its focal properties are excellent and the spot size in relation to screen diameter compares well with the standard set by larger tubes. The advance made in recent years in the quality of these small tubes is so considerable that anyone whose opinion was formed on those available even only two or three years ago will be surprised at the improvement. The definition of the luminous trace permits comfortable and accurate observation of the most complex wave pattern.

The usual brilliance "B" and focus "F" controls are provided. In addition external signals may be applied to the modulator of the tube through the socket marked "MOD.IN." This brilliance modulation is particularly useful in examination of short duration transients, when the normal brightness obtainable would prove to be

* Research Laboratories of The General Electric Co., Ltd., England.

† Trade Mark Registration applied for.

insufficient for the high writing speeds involved. There are many other uses of this facility, detailed description of which, however, falls outside the scope of this article.

One of each pair of deflector plates is joined to the final accelerator electrode, while direct connexion to the other plate of each pair is available through the sockets " X " and " Y " on the back panel of the instrument. The input capacities are about 20 $\mu\mu$F and the input resistances 3.3 MΩ.

(c) Time Base

A soft-valve time base with a frequency range of about 20 c/s. to 25,000 c/s. provides a linear horizontal sweep on the cathode-ray tube.

The coarse velocity control " V_c " selects one suitable condenser for the desired range of frequency, continuous adjustment throughout this range being provided by the fine control " V_f." The first position of " V_c " renders the time base inoperative and disconnects the X plate and socket from it so that an external signal may be applied to the X plate through " X " socket.

A sweep amplitude control " S " is provided and the synchronising signal for the time base should be fed into the socket " SYNC. IN." The synchronising voltage is normally derived from the signal itself by using part of the signal to the Y deflector plate appearing at the socket " SIGNAL FREQ. OUT." Alternatively, it may also be obtained from the socket " MAINS FREQ. OUT " or from an external source.

(d) Signal Amplifier and Attenuator

The single stage resistance-capacity coupled amplifier using pentode V_1 is of conventional design. The gain is continuously variable by means of the input potentiometer " G." The maximum gain is about × 400 with a sensibly flat response from 50 c/s. to 10,000 c/s. The waveforms of signals of only 0.1 volt amplitude can thus be conveniently examined. The input capacity is about 15 $\mu\mu$F with an input resistance of 1MΩ. The input capacity of the attenuator circuit is about 30 $\mu\mu$F and the input resistance 1MΩ.

The toggle switch " S_w," mentioned above as providing alternative earthing arrangements of the oscilloscope circuit, also serves to select either the output of the amplifier or attenuator and to join it to the socket " SIGNAL OUT." Access to both input and output of either the amplifier or attenuator therefore enables them to be used separate from the rest of the Miniscope proper. In order to display the output from either of them on the tube, however, it is only necessary to link the socket " SIGNAL OUT " to the " Y " or " X " sockets.

In addition to these alternative input circuits for A.C. signals, D.C. observations may be carried out by applying the signal direct to the "X" or " Y " sockets.

Construction

The internal construction of the Miniscope is shown in Figs. 3 and 4. Some of the components are shown numbered as follows:—

1. Mains transformer.
2. Metal rectifiers.
3. Voltage doubler and smoothing condensers.
4. Mumetal tube enclosing cathode-ray tube.
5. Time-base condensers.
6. Time-base gas-filled triode V_2.
7. Amplifier pentode V_1.
8. Octal base valve holder on top of case.
9. 4-pin valve holder for vibrator.

The Mumetal screen around the cathode-ray tube is provided to eliminate unwanted deflections of the

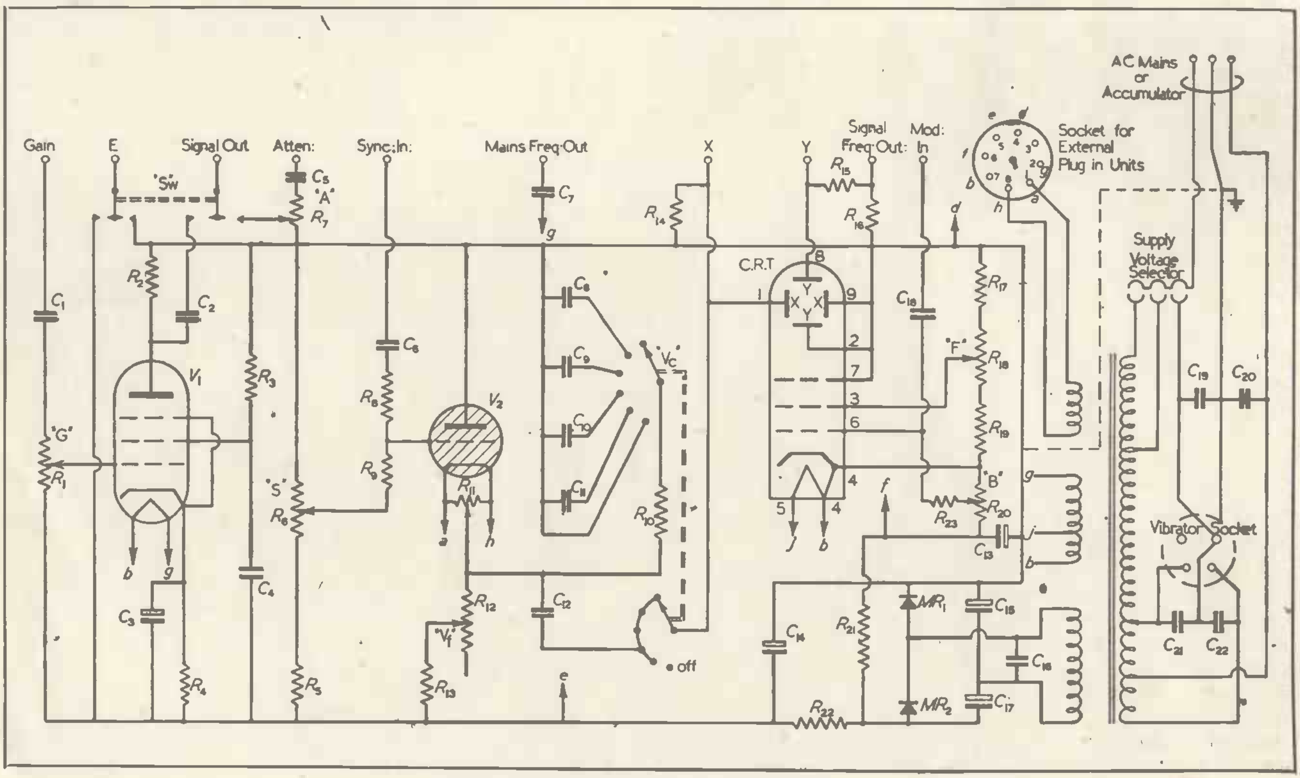

Fig. 2. Circuit diagram of the " Miniscope."

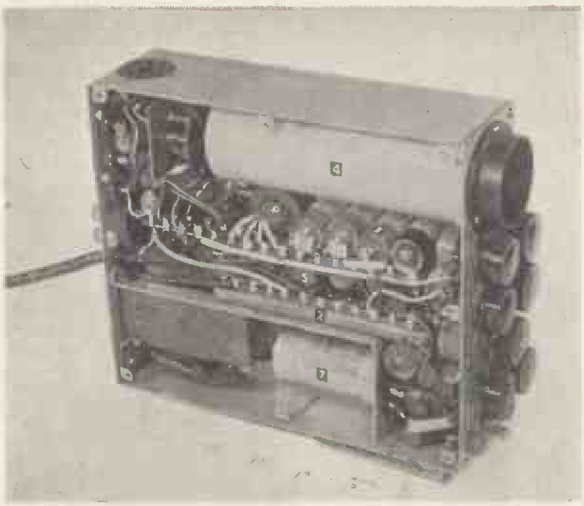

Fig. 3. Internal view of the "Miniscope" (with left side panel removed).

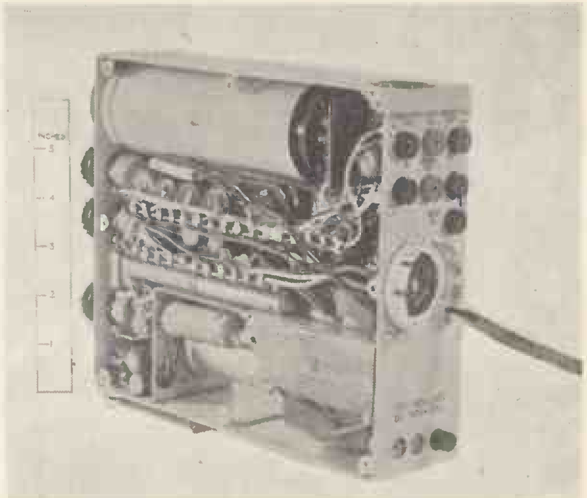

Fig. 4. Internal view of the "Miniscope" (with right side panel removed).

spot by magnetic fields such as may be caused by transformers, magnets, etc., in the vicinity.

The octal base valve holder on the top of the instrument (*see* Fig. 3) carries L.T. and H.T. supplies from the power pack. These supplies may be used to operate external plug-in units of sufficiently small dimensions to fit on to the top of the case. Among such units mention may be made of the following:—

(1) A second cathode-ray tube, time base sweep voltage for which may be obtained from "X" socket. This will give a "double-beam" facility, although, of course, the two traces can only be superimposed by some external optical method.

(2) Various types of time bases generating, for example, high-speed, single-stroke or circular sweep voltages.

(3) Various types of amplifiers, *e.g.*, those providing wide-band response or D.C. amplification.

These units can be operated singly or in combinations as required.

A short tubular hood is fixed over the screen end of the cathode-ray tube to provide means of supporting viewing lenses or camera attachments if required. It also serves to hold a green celluloid filter in front of the screen. This renders the luminous trace much more easily seen in daylight because, since the trace is green, light from it will not be appreciably attenuated in intensity on passing through the filter. Light from external illumination, however, after reaching the screen and being reflected from it, has passed twice through the filter and is therefore considerably attenuated in all but the green parts of the spectrum. The apparent brightness of the luminous trace in comparison with its background is thus enhanced.

A hinged support under the front panel of the instrument enables the Miniscope to be tilted so that the screen may be viewed at an angle of about 20° to the vertical. This position is found most useful in general bench work. It was decided to tilt the whole instrument, instead of mounting the tube at an angle in the case, in order to conserve space.

All the tube, time base, amplifier and attenuator controls are mounted on the front panel underneath the screen, as are the three input terminals and toggle selector switch (*see* Fig. 3). The potentiometer and variable resistors used are miniature components rated at 1/10 watt.

Deflector plate, signal output and synchronising input sockets are arranged on the back panel in a manner convenient for joining up the various internal circuits by short links (*see* Fig. 4).

The back panel also carries the mains input lead and supply voltage selector as well as the valve holder for the vibrator. The vibrator may be seen standing at the left of the Miniscope in Fig. 1. It need only be plugged into its holder when using the instrument on the accumulator supply but it may be left in position without being damaged when operating from A.C. mains supplies.

Most of the components are mounted on two tag boards across the width of the instrument and are thus easily accessible after removing the two side panels. In addition, the front panel can be removed separately, and the same applies to the internal sub-assembly holding the mains transformer, amplifier valve and tag boards.

Future Development

The Miniscope in its present form represents the first step towards a general purpose miniature oscilloscope. Different applications will doubtless entail special modifications of its circuit and, in fact, work is already being done in this direction.

The system of providing small external plug-in units to cater for particular requirements should, however, enable the Miniscope to be readily adapted to meet new problems as they arise.

Photographic Materials for the Electron Microscope

By L. V. CHILTON,* E. M. CROOK† and F. M. L. SHEFFIELD†

This paper, from which the following is an abbreviated extract, was delivered at a joint meeting of the Royal Photographic Society (Scientific and Technical Group) and the Association for Scientific Photography held on November 25, 1944.

THE work to be described arose from some tests carried out with the limited objects (a) of examining the performance of a wide range of Ilford plates in the R.C.A. Type B Electron Microscope; (b) of determining the best Ilford plates for recording electron images of a rather specialised class of objects, *viz.*, plant viruses, and the best conditions in which to use these plates. The majority of the plates studied were selected as being likely to give high contrast. The general scheme was that selected types of plates were exposed to electrons at Rothamsted and returned to Ilford for processing and measurement, in comparison with similar plates exposed to light.

In spite of the narrowness of the scope of the tests it became evident that some of the observations made were likely to be of general interest, whether from a practical or theoretical point of view, the more so because relatively little had hitherto been published on the subject.

Experimental Details

A. The Electron Microscope and General Exposing Procedure

The R.C.A. Electron Microscope (Type B) in which the exposures were done consists of an electron gun with controllable accelerating potential and a set of magnetic lenses comprising condenser objective and projector ("eyepiece"). When used for microscopy, the focused electron image is received on a fluorescent screen coated with willemite (Zn orthosilicate). This can be swung out of the beam to expose the photographic plate beneath, and acts as the camera shutter. The plates are 10 in. × 2 in., and a masking device makes it possible to select picture lengths from ½ in. to 3 in., but does not allow the width to be varied from 2 in. In most of the work reported here the plates were cut 10 in. × 1 in., so that two could be accommodated side by side in the cassette.

The accelerating potential can be varied from a nominal 30 kV to a nominal 60 kV in steps of 5 kV by a panel-mounted control. The control is effected by means of a reference dry battery and electronic stabiliser. It was found, by reducing the size of the battery, that the lower range could be extended to 15 kV without overloading the stabiliser. The high voltage is controlled by feeding the stabiliser through a 1,000-megohm potentiometer, one side of which is connected to the H.T. and the other grounded. There is thus a leakage current through the high resistance—approximately 1 μA per kV accelerating potential—and this is included in the current registered by the microammeter measuring the electron beam current.

In making exposures, the objective lens current was always adjusted approximately to focal value for the accelerating potential in use. The magnification produced by this lens, used at a fixed object and image distance, is inversely proportional to the focal length and is thus (i) directly proportional to the square of the current in the lens coil; (ii) inversely proportional to the accelerating potential.

As the energy density incident on the plate is inversely proportional to the square of the magnification, some means had to be found to correct for this so that incident energy density at the plate is always the same irrespective of kV. While it would have been possible to calculate approximately the necessary magnification corrections and make them by means of adjustments in the projector lens current, the following procedure,* which allows a definite relation to be established between the energy density at one kV and that at another, was adopted.

A Leitz "Monlar" lamp was fitted with two No. 78 and one No. 58 Wratten filters and a neutral grey filter so that it gave a light of approximately the same colour as the fluorescent screen, and of the correct intensity. This was used to project a bar of light onto the screen, contiguous with the fluorescent bar produced by the masked-down electron beam. With the controls set at 60 kV, focal value for condenser and objective lenses, and maximum value for projector lens, the beam current was varied until the intensity of the two fields was the same. The required gross current was 370 μA, and this was regarded as the (arbitrary) "calibration" current. Exposures were done at the 60 kV range with control settings as for calibration.

For any other kV range, the condenser and objective lenses were set at focal value (determined previously, using a specimen in the machine), the beam current adjusted to 370 μA and the projector setting (*i.e.*, final magnification) varied until the fluorescence and reference fields were the same intensity. Exposures were then made at these settings. It became necessary to modify this procedure for the low kilovolt ranges. Here, in the low projector ranges, the available steps are too large to make possible accurate matching of the fields. The projector was therefore set at the nearest step *above* matching value and the final adjustment was effected by slightly de-focusing the condenser.

The procedure used for making the exposures was as follows. The plates were loaded into the cassette in the darkroom using appropriate safelights, after appropriate numbering—two 10 in. × 1 in. plates side by side. The cassette was then inserted into the machine and pumped out (20 to 30 min.). After centring the electron beam, "calibration" was carried out as described above, the mask width set to take 1½ in. long pictures and the exposures made as rapidly as possible. Two operators worked, one recentring the beam and making the exposures, the other holding the beam current as constant as possible during each exposure. It was not always possible, owing to mains fluctuations, to maintain a constant beam current, and when this was so

* Messrs. Ilford, Ltd.
† The Rothamsted Experimental Station.

* Based on method described by Dr. Smiles (N.M.R.C., Hampstead) and due originally to the N.P.L.

an "eye estimate" was made of the average current during the exposure. Recentring was in general necessary between exposures, but experiment showed that the intensity was not detectably altered by this procedure when the reference light was used as standard. After exposure, the plates were removed and packed in the darkroom, and sent to Ilford for processing and measurement.

B. Details of Actual Tests

(i) *Plates Tested.* These were:—

S 1505* No. 1. Gaslight lantern.
S 1495 No. 2. Photomechanical.
S 1492 No. 3. Halftone (without usual sensitising dye).
6914 A No. 4. Contrasty special lantern (process).
6941 E No. 5. Special process (with panchromatic sensitising dye).
S 1494 No. 6. Rapid process panchromatic (but without sensitising dye).
S 1496 No. 7. X-ray (single-coated on glass).

* Experimental coating numbers.

As they stand, these plates form a series roughly of increasing speed and decreasing contrast to light. Of these plates Nos. 4 and 5 are substantially identical except for the presence of an optical sensitising dye in No. 5.

(ii). *Exposure and Development.* The *exposure* of these plates to electron beams has been described in general terms above. At each kilovoltage studied each plate was actually given, in the electron microscope, a logarithmic scale of exposures—generally an intensity scale. Six steps of exposure were usually given, covering the range of net beam currents from 20 μA (considered the minimum reliable value) to 440 μA (the maximum possible at 60 kV), *i.e.*, the nominal net beam currents aimed at formed the series 20, 37, 69, 128, 237 and 440 μA. Table 1 gives a typical experimental set of electron beam exposing data for a pair of plates exposed together.

Similar series were exposed, for each type of plate, at kilovoltages increasing from 15 kV by 5 kV steps to 60 kV. Additional plates were exposed to light for the same time (10 secs.) and developed alongside the electron-exposed plates. The light exposures were made behind a neutral wedge, suitable illumination levels for the very diverse types of plates examined being obtained by varying either the intensity of the light source or the exposing distance.

Development of the plates was carried out using brushing technique with groups of six plates, comprising five exposed to electrons and a control exposed to light. In every case the developer employed was of a type which might normally be used with the plates concerned; thus, in all cases but Plates Nos. 7 and 8, development was for 3 min. at 65° F. in ID-13 (caustic hydroquinone), but for No. 7 an ordinary X-ray developer was used (M.Q. carbonate, ID-19, 5 min. at 65° F.). The plates were fixed, washed and dried in the usual manner and their densities read on a B.P.R.A.-type densitometer.

(iii) *Electron-Beam Characteristic Curves.* For each type of plate a family of characteristic curves was constructed, each curve being a plot of measured density against the log of net beam current (I_n). For convenience the curves of each family were plotted with a constant small displacement of one curve from the next of 0.2 unit of log I_n, the change of accelerating voltage from one curve to the next being 5 kV. Typical curves for some of the plates studied are shown in Figs. 1 and 2. Plate No. 1 (gaslight lantern) was found to be too insensitive to give any appreciable density under the electron exposure conditions employed.

Great difficulties were experienced in exposing some of the plates with sufficient reliability. Most of these difficulties were associated with variations in the electron beam current during exposure, though in some cases (especially at low kilovoltages) the developed photographic density was not uniform and was consequently difficult to measure with confidence. The shutter-operating mechanism was also found difficult to handle with precision. It was hoped that variations due to this cause would be reduced by employing the fairly long exposing time of 10 secs., but the choice of such exposure introduced a greater difficulty in maintaining the requisite beam uniformity. In passing, it should be mentioned that exposures of 2 secs. or less on this instrument are extremely difficult to apply, and it is hoped that a radically improved form of shutter and shutter control will be introduced in electron microscopes that may come on the market in the future.

(i) *Contrast Data.* Plates Nos. 2 (Fig. 1) and 6 (Fig. 2) were the first to be examined. Their characteristic curves show a number of points of similarity, but others of significant difference. In the first place, both plates showed a progressive rise in gamma (maximum slope) with increasing kilovoltage, and a tendency for the curves obtained at lower kilovoltages to develop "shoulder" at relatively low densities, indicating that the materials would have low contrast in these regions, or even perhaps a low maximum density. Actually, Plate No. 6, exposed at 15 kV, showed a maximum density of about 1.36, whereas similar plates exposed at kilovoltages above 40 kV gave densities beyond the range of the densitometer (3.8 approx.). The somewhat restricted range of exposing conditions made it impossible to follow the complete course of the characteristic curve at many of the kilovoltages studied and values quoted for gamma are in some cases correspondingly uncertain. However, gamma has been plotted against kilovoltage for these two plates as shown in Figs. 1 and 2. The curves are substantially linear, but there is naturally some doubt as to their course at the higher kilovoltages; for example, they may turn over to a maximum value. In the case of Plate No. 2, the gamma values are considered reliable up to 45 kV, at which the curve between gamma and kV shows signs of flattening. Similar reliance can, it is thought, be placed on curves for Plate No. 6 up to 45 kV. *This variation of gamma with kilovoltage was entirely new to us at the time it was observed.* It is at variance with the observation of

TABLE I

Plate Type No. 2: Photomechanical – – – – Plate marking 2/60
,, No. 6: Undyed Process Pan – – – ,, 6/60

Plates exposed side by side at nominal 60 kV (beam current correction —59 μA at this kilovoltage)

Exposure time: 10 secs.

Beam Current:	Nominal	79	96	128	187	296	499 μA
	Est. Mean (I_e)	79	96	128	186	294	505 μA
	Net (I_n)	20	37	69	127	235	446 μA
	Log I_n	1.30	1.57	1.84	2.10	2.37	2.65

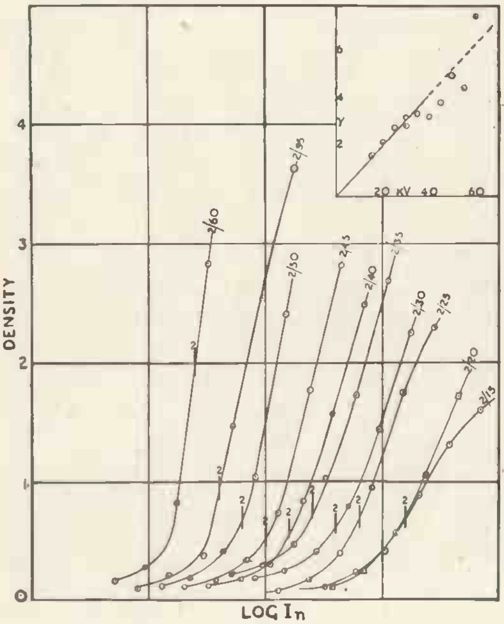

Fig. 1. Electron-beam characteristic curves of Plate No. 2—Photomechanical. (Abscissa scale unit same as that of ordinates: short vertical stroke on each curve corresponds to log I_n = 2.)

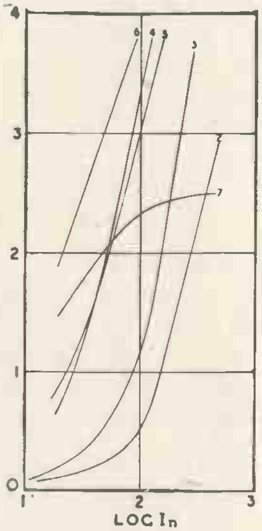

Fig. 2. Electron-beam characteristic curves of Plate No. 6—Rapid process panchromatic (without sensitising dye).

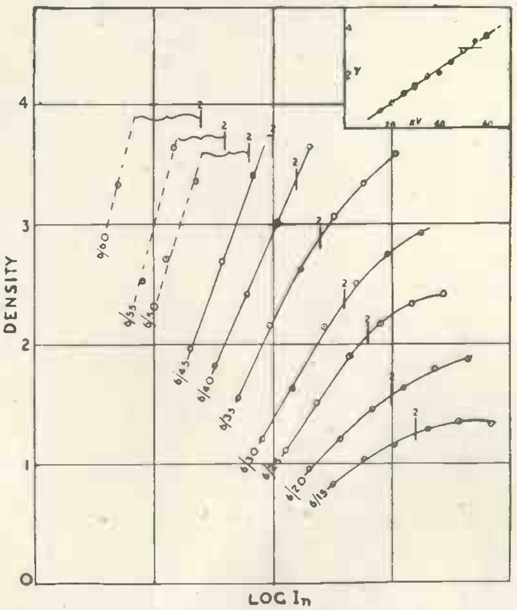

Fig. 3. Comparison of characteristic curves to 45-kV electrons (curves identified by Plate numbers).

Baker, Ramberg and Hillier[1] that with the Eastman medium lantern plates the characteristic curves obtained had the same form over the kV range from 40 to 212 kV. Reference to similar variations to that found by us has since come to light in a paper by von Borries[2] who examined a series of Agfa and Perutz plates at kilovoltages from 18 to 220 kV.

Plate No. 7 showed this variation of slope with kV to an even more marked extent. At kilovoltages in the range 45 to 60 kV the characteristic curves obtained have a maximum at a density round about 2.5.

Plates Nos. 4 and 5 were of generally similar behaviour, but great difficulty was experienced in obtaining smoothly reproducible exposures on the occasion when they were studied.

Plate No. 3 gave results qualitatively very similar to Plate No. 2.

This increase of contrast with kilovoltage, at first sight somewhat surprising, appears to be undoubtedly due to the absorption of electrons by the outermost parts of the photographic emulsion layer, an absorption which will be the more complete the lower the energy of the electrons. It does not seem to indicate any essentially different photo-chemical reaction between electrons of different energy with the emulsions studied. No doubt the suggestion might be made, though we adduce no evidence in its support, that if an emulsion could be produced having a sufficiently high content of sensitive material in a medium of sufficiently low absorption, a unique electron characteristic curve might be obtained at all kilovoltages, just as in the case of X-rays the inherent sensitivity of a photographic emulsion to X-rays is similar at all kilovoltages.

Although the characteristic curve of a photographic emulsion to X-rays is independent of kilovoltage, it is well known that the contrast of a radiograph of a given object decreases the higher the energy of the X-rays, and that this is simply due to the greater absorption of low-voltage X-rays by the object, and the correspondingly greater differentiation of different parts of the object having different absorptions, when rays of low energy are used. It may be that a similar result is to be expected with electron exposures, *i.e.*, that with higher electron kilovoltages the contrast of an electron microgram of an object would be *lower* than at low kilovoltages. Such an effect has not been observed in the study of viruses at Rothamsted. In fact, visual inspection of micrograms on photomechanical plates would suggest that higher contrast is obtained at higher kilovoltages, though the difference in contrast is small over the rather restricted range of kilovoltages normally used in the R.C.A. instrument.

(ii) Speed Data: Relative Speeds of Different Plates to Electrons and to Light

(a) *Comparison at a Given Kilovoltage.*—At any kilovoltage the relative speeds of different plates may be compared directly in terms of the values of log I_n required to produce selected densities. For example, in Fig. 3 are assembled the characteristic curves of six plates to 45-kV electrons. Table 2 summarises the interpolated values of log I_n (electron exposures) and log E (light exposures) to produce densities of 1, 2 and 3.

It will be seen from the Table that the plates studied exhibit a much smaller range of speeds to 45-kV electrons than to light; for example, at a density of 2, the range of light speeds is 100 to 1 (antilog of 2.00), while the range of electron speeds is only 12.9 to 1 (antilog of 1.11). The relation between light speed and electron speed is fairly systematic, as shown in Fig. 4. It may be noted that plates 4 and 5, whose speeds to light differ in the ratio of about 3.3 to 1 (due to the sensitising dye), have practically the same speeds to electrons, as might be expected.

(b) *Comparison of Speeds at Different Kilovoltages.*—An absolute comparison of plate speeds at different kilovoltages from our data depends on a knowledge of the fluores-

TABLE 2

Plate No.	Electron Exposures (Rel. log I_n)			Light Exposures (Rel. log E)		
	Density			Density		
	1	2	3	1	2	3
2	2.18	2.44	2.70	0.94	1 06	1.16
3	1.94	2.18	2.34	0.16	0.34	0.49
4	1.42	1.71	1.93	$\bar{1}$.52	$\bar{1}$.72	$\bar{1}$.86
5	1.36	1.73	1.99	$\bar{1}$.02	$\bar{1}$.19	$\bar{1}$.34
6	—	1.33	1.68	2.72	$\bar{1}$.06	$\bar{1}$.36
7	—	1.67	—	2.90	$\bar{1}$.46	—

cence efficiency of willemite to electron beams.

If the accelerating potential is V, the net beam current I_n, and the magnification M, then the energy E incident on unit area of the plate or the fluorescent screen is

$E = KI_nV/M^2$, where K is a constant.

Regarding the relation between E and fluorescent brightness B, Rupp[3] quotes results by Schnabel[4] showing that, for willemite in waterglass suspension bombarded by electrons of energy up to 36 kV, $B = K_1(V-10)$, V being measured in kilovolts, while for electrons of constant energy (12 kV) B is also proportional to beam current. Combining these two relations, $B = K_2I(V-10)$. Rupp supposed that the departure of the straight line from the origin was due to the water-glass medium and suggested that the inherent fluorescence of the willemite should be represented by $B = K_3IV$. Applying these last two relations to the electron microscope, with net beam current I_n when working at magnification M, we have:—

$$B = K_4I_n(V-10)/M^2,$$

or, as an alternative,

$$B = K_5I_nV/M^2.$$

Now M was so chosen that, when gross beam current was fixed at 370 μA, B was brought to a fixed value. M was measured on two occasions as a function of kV, the second giving results believed to be the more reliable. Plotting M^2/I_n against V, it was found that the data were reasonably well represented by:—

$$M^2/I_n = (1.1 \times 10^9)(V-5).$$

There was some uncertainty about the last constant, but the best line certainly did not pass through the origin.

We could thus make the desired speed comparison by replotting the curves of Figs. 1 and 2 (and similar curves for the other plates) with abscissae increased by log $(V\sqrt{V-5})$, bringing them together on a common abscissa scale.

The amount of the correction is very small at higher kilovoltages (0.04 at 60 kV) and rises to 0.18 at 15 kV. The curves so replotted are not reproduced here, but showed that the plates studied fall roughly into three groups: (1) those which, like Nos. 2 and 3, exhibit little change of sensitivity with kV over the greater part of the kV range studied, but a sharp rise in sensitivity at the highest kV's; (2) those like Nos. 4 (and its analogue 5) and 7, which show a steady rise of sensitivity with kV to a maximum near the upper end of the range, and (3) No. 6, which shows a practically linear increase of density with kV, with no sign of a maximum. It may be mentioned that Baker, Hillier and Ramberg[1] found maximum sensitivity in the Eastman medium lantern plates in the neighbourhood of 100 kV, while von Borries[2] found that the sensitivity of Agfa and Perutz plates varied with kilovoltage and passed through maxima at kilovoltages varying from 32 kV upwards.

General Notes on Choice of Plates and on Reproduction Techniques

In the case of tobacco-mosaic virus, one of the principal objects studied at Rothamsted, even a relatively slow plate such as photomechanical was amply fast enough. The main need was to obtain adequate contrast. Since the photomechanical plate exhibits some "foot" and does not attain its maximum slope below a density of approximately 0.7, there is an evident advantage in increasing the exposure (beam-current control) to give such minimum densities in the electron microgram. More opaque objects, such a bacteria, are not so readily penetrated, however, and a faster material such as No. 6 is probably required; in any case, however, an endeavour should be made to expose on the straight region of the characteristic curve.

The objection is sometimes made that such relatively dense electron micrograms become difficult to enlarge. Some rough experiments have been carried out, however, using a simple intermediate printing technique which does away with this objection and, at the same time, provides a further control of contrast. According to this technique, the electron microgram is first contact-printed onto any selected material to form an intermediate "positive" transparency having a sufficiently low minimum density and this "positive" is then projection-printed. If desired, of course, a further printing stage can be introduced to bring about a reversal of the image.

Acknowledgments

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4 Ibid., Figs. 26 and 27.

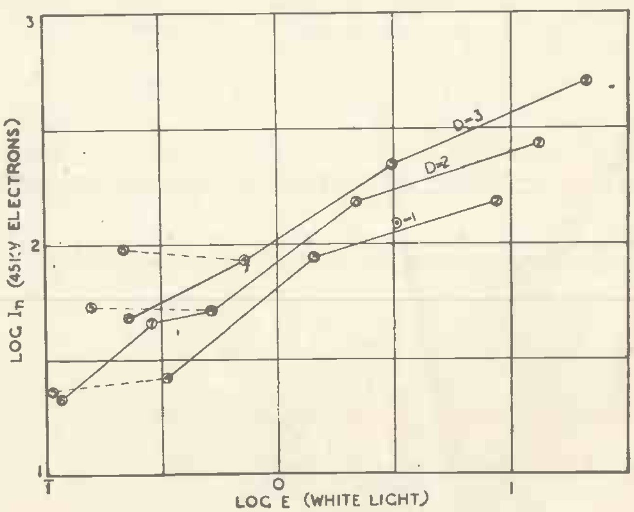


Fig. 4. Relation between light speed and (45-kV) electron speed (N.B.—Scales are of log *exposure* for the reference densities used: *i.e.* the inverse of log *speed*.)

High Vacuum Gauges

By M. PIRANI, Dr.Phil., F.Inst.P., F.S.G.T., and R. NEUMANN, Dipl.Ing.

Part III

(c) Heat Conductivity

AS was shown by the investigations of Maxwell,[51] Kundt and Warburg[52] and others there exists a close relation between heat conductivity and viscosity of a gas. Therefore, some of the statements made above refer also to conductivity gauges. This refers especially to the pressure ranges for which these gauges are applicable. Maxwell had stated that viscosity and thermal conductivity must be independent of the density of the gas, as in the expression derived for viscosity the latter is proportional to the product of mean free path and density and as the mean free path changes inversely with the density. But this result loses its validity for very dilute gases in which the mean free path is large in comparison to the dimensions of the apparatus. In this case "the conductivity for heat must rise from zero at first proportionally to the density of the gas, then more slowly when the lengths are commensurable" (Nernst).[53]

The deviation from Maxwell's prediction is seen if one plots the results of the experiments of Kundt and Warburg concerning the time of cooling of a thermometer in air as a function of pressure. While for pressures between 760 and about 10 mm. Hg the prediction holds true there is a definite rise of the cooling time to be noticed at smaller pressures.

Crookes[54] repeated Kundt and Warburg's experiments extending them down to a pressure of a few millionths of an atmosphere (about 10^{-3} mm. Hg). He gives in a very instructive graph the results of his measurements together with the curve showing the mean free path as a function of pressure.

A similar behaviour is shown by Schleiermacher's experiments.[55] He observed the temperature rise of an electrically heated platinum wire at different pressures. While for pressures between 365 and 0.3 mm. Hg the temperature rise was nearly constant (between 6.9° and 7.8° C.) it rose to 15.7° C. at 7×10^{-2} mm. Hg.

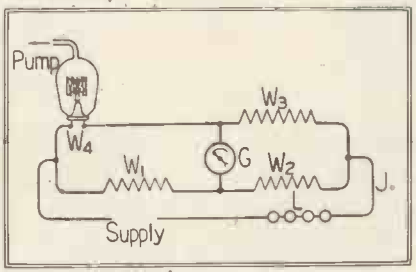


Fig. 19. Pirani's hot wire gauge.

Bottomley's experiments[56] extended to still higher vacua and he showed that in lowering the pressure from 760 to 7×10^{-5} mm. Hg the total emission drops in the ratio 21.5 : 1 and correspondingly the current in the ratio 4.6 : 1. Among the gauges based on the conductivity principle the hot wire gauge (Pirani, 1906) in its original form and in its different modification is the one most extensively used.[57]

The following quotations may not be out of place:—

Kundt and Warburg:[52] "The cooling speed of a thermometer which can be measured with great accuracy is an excellent yardstick for the quality of the vacuum."

Smoluchowski[58] (Abstract): The reduction of the heat conductivity and the viscosity in a gas at reduced pressure begins when the mean free path of the gases becomes of the same order as the dimensions of the vessel in which the measurement is made. At very high vacua when practically no collisions take place, but the molecules fly from one wall to the other without colliding, the heat transmission is exactly proportional to the number of molecules which are present, *i.e.*, the gas pressure.

Pirani's Diary of 8th June, 1906: Note.—" The present attempt to use the heat conductivity for the measurement of low pressures does not present a new concept, but seems anyway a promising practical application of the observations of Warburg and others."

Generally speaking, the interest in high vacuum measurement is the outcome of modern technical development with its need for speedy and if possible automatic operation. Evidently the start has been made by the needs of the vacuum lamp industry for which first the pumps and then the measuring methods were developed. In 1905 the manufacture of tantalum lamps was started at the works of Siemens and Halske. These lamps required a higher vacuum than the carbon filament lamp as the metal was very sensitive against gases in the presence of which it becomes very brittle. A quickly acting automatic method was needed for the measurement of the gas quantities evolved during the different stages of the exhausting operation. One of the authors was given the task of designing an appropriate instrument and solved it by developing the hot wire gauge.

As an effect of the measurements with this gauge the exhausting schedule was altered as it had been found to be much more advantageous repeatedly to "flash" the filament to very high temperatures for a short time than to heat it gradually up to the operating temperature and keep on with pumping as was done before. The gauge also gave the possibility to study the differences of different glasses used for the bulbs and stems —especially with regard to the "water skin"—as well as the behaviour of different metals used as supports.

The principle of the hot wire gauge consists in observing the changes of resistance, voltage or current of an electrically heated wire enclosed in a container communicating with the vacuum system the pressure of which is to be measured. One of the three characteristic quantities is kept constant and the changes of one or both of the other two as dependent on different pressures are observed. There is quite a variety of different connexions for carrying out the measurement. The one principally used is the Wheatstone bridge connexion shown in Fig. 19. In order to make the measurements as far as possible independent of changes of the surrounding temperature and of

Fig. 20. Pirani gauge. *(W. Edwards and Co.)*

the operating voltage it is advisable to make resistance W_3 of the same design as W_4 and to adjust it to the conditions preferably to be measured with regard to pressure, kind of gas, etc.

Fig. 20 shows the design of a hot wire gauge as manufactured by W. Edwards & Co., Ltd., Figs. 21 and 22 that of Cambridge Instrument Co., Ltd. The hot wire gauge is calibrated with a McLeod gauge. As heat conductivity depends not only on pressure but also on the specific heat, and the size of the molecules, the calibration must be carried out for every gas separately. If the pressure of corrosive gases is to be measured, the wire may be enclosed in a glass or preferably quartz sheathing. King[40] proposed to use a glass spiral filled with mercury as a resistance.

Various modifications have been proposed for the hot wire gauge, but most of them are hinted at in the first publication. Fig. 23 shows a design proposed by Brown-Boveri. Here the opposing arms a, c of the Wheatstone bridge network are arranged inside an H-shaped extension of the vacuum chamber, the other arms b, d being connected between the ends of the cross tubes. In order to make the gauge independent of the room temperature all the arms of the bridge network are made of conductors of the same temperature coefficient (German Patent 429791).

Fig. 24 shows a design in which a number of wires *c* connected in parallel and arranged so that they run parallel to the walls of the bulb serve for increasing the sensitiveness of the gauge. The heat lag is decreased and the temperature jump between wire and gas is reduced. The design is due to v. Issendorf (German Patent 541758).

Various means for increasing the sensitiveness of the gauge were investigated by Hale,[59] who recommends the use of a fine wire with a high temperature-resistance coefficient to be connected in a bridge network with three resistances of negligible temperature coefficient. A constant potential is applied to the network, and the change in resistance of the wire due to its change of temperature with varying gas pressure is measured. Hale also describes in detail the method of calibration of this gauge with a compression gauge. He found the gauge to be reliable down to pressures of 10^{-5} mm. Hg.

Contrary to Hale, but according to a method also mentioned by Pirani in the original publication, N. R. Campbell and collaborators[60] measured the potential which must be applied to the bridge network in order to keep the resistance and temperature of the wire constant. In this arrangement the gauge was used successfully for the microanalysis of gases.

A sensitive hot wire gauge applicable for pressures down to 2×10^{-6} mm. Hg was developed at the Research Laboratory of the M.O. Valve Co. by Le Rossignol and used by A. L. Reimann[61] for the investigations of the clean-up of hydrogen by a magnesium getter.

A combination of a hot wire gauge with a McLeod gauge was proposed by A. H. Pfund[62] in order to extend the range of the latter in a similar manner as was proposed a few years later in the combination of McLeod gauge and discharge tube (Stintzing, *see above*). Both proposals make use of the fact that the pressure in the closed capillary of the McLeod gauge is considerably higher than in the vacuum to be measured and, there-

Fig. 21. Cambridge micro-vacuum gauge-Indicator. *(Cambridge Instrument Co., Ltd.)*

fore, measurable by means of gauges applicable to higher pressures.

Quite recently a recording hot wire gauge has been developed by Dr. G. Keinath for Great American Industries Inc., U.S.A. (unpublished private communication). The recording instrument proper is based on the "sweep balance" principle and capable of higher speeds than older designs. A special recording paper is applied as it is used with facsimile recorders. It takes only 0.1 millisecond to make a recorded point. In place of the hot wire a platinum ribbon is used, about 0.01 mm. thick. The gauge covers the range from 10^{-1} to 10^{-6} mm. Hg in five decades with perfect logarithmic calibration. The main difficulty was that the change of resistance between 10^{-5} and 10^{-6} mm. Hg is only of the order of 0.1 ohm.

Various proposals have also been made to design hot wire gauges on the same principle as hot wire ammeters, using the change of length of a heated wire in an indicating instrument (*e.g.*, German Patents 202524, 295259), or to use a thermocross inside a vacuum bulb, one wire being fed by a constant A.C. and the e.m.f. of the soldering point being measured by galvanometer of the indicator or mirror type (Voege).[63] Another design uses thermocouples in a vacuum tube irradiated from outside by a constant source of light (Rohn, German Patent 268896). As an example Rohn gives the following results of measurements:—

760	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	mm. Hg
1.1	1.2	1.3	1.7	4	6.5	7.2	mV

Also, the deformation of a bimetallic strip enclosed in the vacuum chamber may be used for indicating the pressure. (*E.g.*, German Patent 437846 Brown-Boveri.)

Finally, the vaporisation manometer of Herzog and Scherrer[64] should be mentioned which is applicable for pressure between 10^{-2} and 10^{-5} and which measures by means of a simple U-tube the speed of vaporisation of solid carbonic acid or liquid air contained in a chamber similar to that used in a liquid air trap. The device is specially suitable for demonstrations in lectures.

(d) Ionisation

One kind of ionisation gauge has previously been dealt with. It is the discharge tube used for a qualitative determination of pressure. The ionisation gauge for quantitative measurement was developed during the last war independently by Hausser-Ganswindt and Rukop (Telefunken)[65] on the Continent and by Buckley[66] in U.S.A.

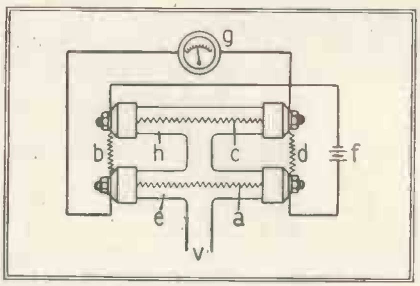
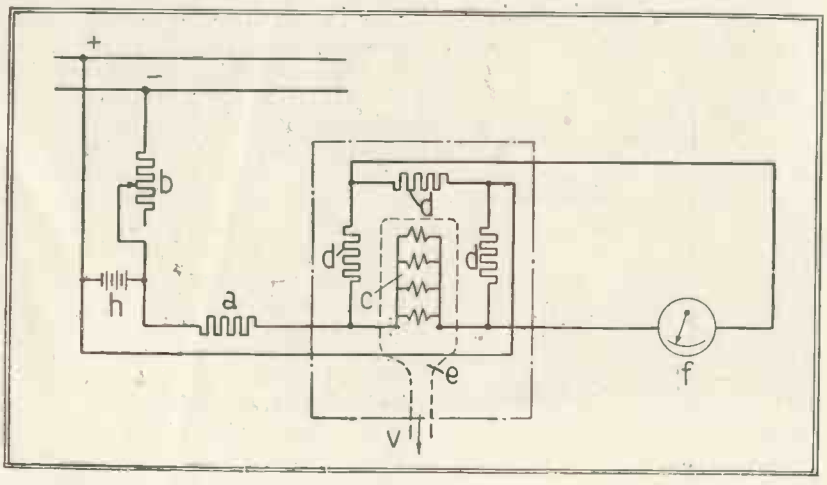


Fig. 23 (above). Pirani gauge of Brown-Boveri.

Fig. 24 (below). Pirani gauge of Siemens-Schuckert (v. Issendorf).



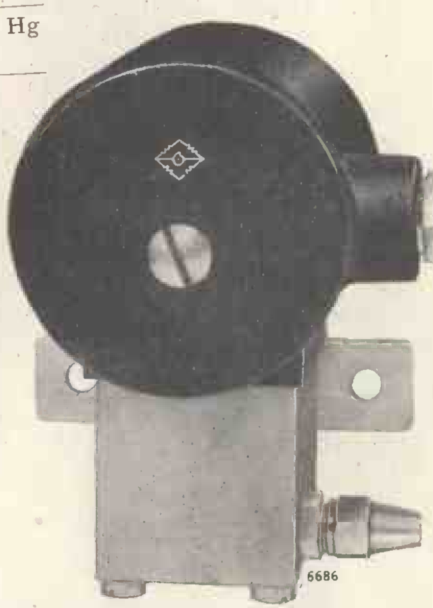


Fig. 22. Cambridge micro-vacuum gauge-Katharometer. (*Cambridge Instrument Co., Ltd.*)

In Buckley's design the manometer "consists of three electrodes—the cathode, anode and collector of positive ions. The cathode may be any source of pure electron discharge, *e.g.*, Wehnelt cathode or heated metallic filament. The collector is preferably situated between anode and cathode. A milliammeter measures the current to the anode and a sensitive galvanometer that to the collector, which is maintained negative with regard to the cathode and thus picks up only positive ions. If no gas were present in the tube a pure electron current would flow, no current would flow to the collector. When gas is present, positive ions are formed in amount proportional to the electron current and to the number of gas molecules present and a certain proportion of the positive ions will flow to the collector. Hence the ratio of the collector current to the anode current is proportional to the pressure and may be used to measure the pressure when the constant proportionality is known."

The Telefunken gauge is very similar but is used in two different connexions as shown in Figs. 25 and 26. The gauge consists of an ordinary triode with a hot tungsten cathode. Ionisation takes place by impact. In connexion A the ion current flows to the grid which has a small negative potential, the electron current is measured in the anode circuit. In connexion B the ions are collected at the negative potential anode while the electron current is measured in the grid circuit. While connexion A is easier for theoretical treatment connexion B is more sensitive as may be seen from Fig. 27, based on measurements with Telefunken valve N91a in nitrogen. This figure shows the functional relation between pressure and ratio of ionisation current and electron current. Proportionality between the positive ion current and pressure exists if the electron current is chosen so that, on the one hand, glow discharge and on the other hand—with strong currents and very low pressure—saturation of the ionisation current are prevented. The ionisation gauge must be calibrated with a McLeod gauge separately for the kind of gas for which it is to be used.

According to A. M. Skellett,[67] for an investigation on the dissociation of hydrogen the ionisation gauge had to be replaced by a hot wire gauge as the former absorbed too much of the gas.

This drawback is also mentioned by Gaede[68] who states that in an ionisation gauge in which the electron path

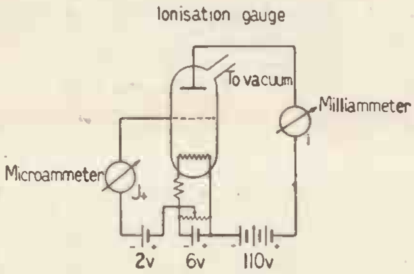


Fig. 25. Ionisation gauge, connexion A.

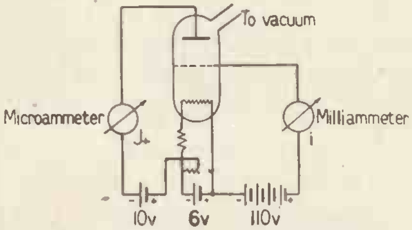


Fig. 26. Ionisation gauge, connexion B.

was lengthened by a magnetic field the gas absorption was so strong that the pressure dropped to 1/30 of its former value "with a speed as if a pump was connected." Also the chemical decomposition of the gaseous compounds may be obnoxious.

Mr. J. Blears, of the Research Department of the Metropolitan-Vickers El. Co., draws our attention to his interesting suggestion to maintain the pressure of the interelectrode space by allowing very free access for new molecules to take the place of those consumed. He investigated the relative indications of normal and high speed ionisation gauges in their application to systems evacuated by oil diffusion pumps.[69]

A great advantage of these ionisation gauges is that the valve is comparatively small and may therefore be arranged in the immediate vicinity of the place where the pressure is to be measured. In fact, the bulb in which the pressure is to be measured may be identical with the bulb of the gauge as is frequently the case in the testing of thermionic valves or vacuum incandescent lamps. This is especially important when chemical reactions are used for the removal of gases, *e.g.*, in the gettering process with Ba metal or the like. On the other hand, the manipulation of the ionisation gauge is somewhat cumbersome and takes up considerable time and the necessary electrical instruments are complicated. This refers especially to the various methods which have been described lately by different contributors to the *Review of Scientific Instruments*, methods which serve for maintaining a constant electron current from filament to grid or anode. For this purpose the following means have been proposed: a mechanical relay[70] or a saturable core transformer[71] or a thyratron,[72] a full wave rectifier consisting of two triodes, the grid voltage of which serves for controlling the power supplied to the filament,[73] or an additional grid inside the ionisation gauge serving for accelerating only those electrons which have passed the first grid.[74]

With a triode the "vacuum factor," *i.e.*, the ratio between positive ion current and electron current, may be readily determined as both currents may be exactly measured. As was observed by Selenyi[75] the vacuum factor obtaining inside an ordinary high vacuum incandescent lamp may be estimated by approaching a negatively charged body to the outside of the bulb. The vacuum is the more perfect the smaller the speed of approach at which no electrostatic attraction between the filament and the outside electrode occurs. Also quantitative measurement is possible by using the filament and the outside electrode as the two coatings of a capacitor (Fig. 28) and either measuring directly the ionisation current raised by a constant A.C. voltage or inserting the capacitor in an oscillating circuit the frequency

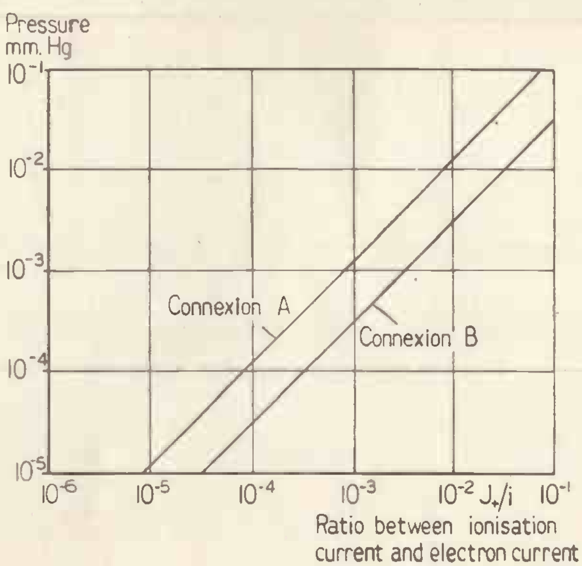


Fig. 27. Ionisation gauge, calibration.

of which may be readily determined. By the latter method the improvement of the vacuum during the "clean-up" process of the bulbs may be observed. Thus an improvement of the vacuum from 10^{-3} to 2.2×10^{-7} mm. Hg could be established during a clean-up process of 258 minutes' duration.

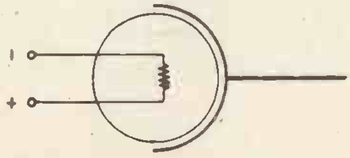


Fig. 28. Lamp capacitor (" clean-up").

In the investigations carried out by Alterthum and Ewest[76] D.C. was used for heating the filament and the bulbs consisted of a sodium glass, while in Selenyi's investigations a lead glass was used for the bulbs. A transition of electrons through the glass takes place. Apparently, an electrolysis of the glass occurs in this case with a migration of sodium, a phenomenon previously observed and made use of by Pirani and Lax[77] for incorporating at high temperature sodium into bulbs made of a lead-free glass.

Besides, it was shown that especially in the presence of phosphorus used as a getter within the bulb for removing the residual gases, the curves showing pressure and vacuum factor as functions of the voltage applied were in satisfactory agreement.

Thorough investigations made by H. D. Miller in U.S.A. showed the influence of high frequency voltages applied to the outer electrode of such a " lamp capacitor " on the clean-up process and the removal of hidden gases which cannot be found by the usual methods of vacuum testing. He also observed the transition of electrons through the glass walls and sorption of gases and vapours into the glass walls or on to their surface (private communication).

While, as was mentioned above, glow discharge is undesirable with the ordinary ionisation gauge, the manometer described by F. M. Penning,[78] the " Philips gauge," is based on glow discharge. It is an outcome of investigations made by S. S. Thomson, J. S. Townsend, R. G. Strutt, Edgar Meyer and others concerning the influence of a magnetic field on an electric discharge. As a predecessor of the Philips gauge, a gauge proposed by Brown-Boveri may be mentioned (German Patent 369326) which uses a magnetron type tube for measuring low pressure. Cathode and anode are arranged concentrically and a magnetic field is generated by a coil wound around the tube. With a certain magnetic field the current from cathode to anode may be suppressed. But the presence of gas molecules causes collisions which tend to increase the current as more electrons reach the anode.

In the Philips gauge the configuration of cathode, anode and magnetic field is somewhat different (Fig. 29). The cathode is formed by two parallel plates P within the tube M. A strong magnet H arranged outside the tube forms a " beam " of magnetic lines of force connecting the two plates, while the anode R intermediate between the two cathode plates is formed by a wire frame surrounding the beam. The electrons move in a helical path between the cathode portions until finally they are deviated towards the anode. Thus the path of the electrons is greatly lengthened and the probability of ionisation by collision is materially increased (but see Gaede's remark mentioned above). Thus an appreciable current will flow even at pressures so low that a discharge would normally be impossible and similarly the ignition voltage of the glow discharge is greatly reduced.

(To be concluded)

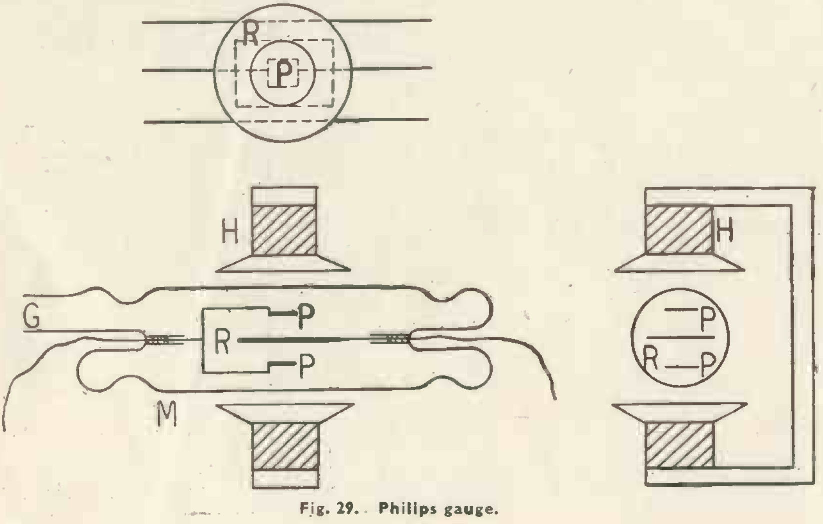


Fig. 29. Philips gauge.

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A Note on Grid Control Characteristics of Gas-Filled Relays

By D. W. Gillings, A.Inst.P.*

GAS-FILLED relay tubes have many applications in instrument design. The properties which render them useful are:—

(a) The ability of small and inexpensive tubes to pass relatively heavy currents with low voltage drop, with negligible power loss in the control circuits.

(b) The "trigger" action obtainable in the control circuits.

The first of these properties is characteristic of practically all gas-filled relays. There are, however, considerable differences in the trigger action obtainable from different types of tubes, which are not readily deduced from the usual tube characteristics control ratio and voltage drop.

In respect of their trigger action, small gas-filled relay triodes available commercially seem to be in two classes:—

(a) Those in which the gas discharge, once established, cannot be extinguished by the application to the control grid of a negative potential of the same order as the anode potential;

(b) Those in which the gas discharge can be extinguished with certainty by a negative grid potential much less than the anode potential; assuming that in each case circuit conditions allow a continuous discharge to be maintained.

Examples of the two classes of behaviour can be quoted by reference to typical measurements comparing two commercial gas-filled triodes, Osram GT1C and Mazda T31. Fig. 1 shows the measurement circuit, designed only for the purpose, and not referring to any special application of the relay, and the Table shows a sequence of grid potential changes, maintaining a constant anode supply potential and continuous anode circuit, and the corresponding anode potentials. It is clear that the GT1C represents the class where grid control is ineffective, T31 that for which grid control can be established after gas discharge commences. Three typical applications show in which instance each type is appropriate.

* Ministry of Supply.

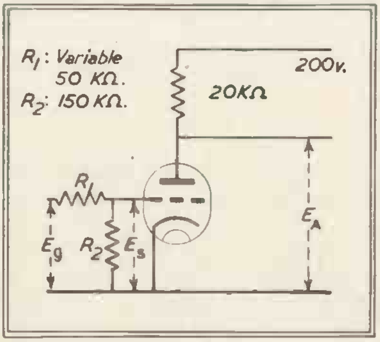


Fig. 1.

(i) The scaling circuit of Wynn Williams employing pairs of "scale of two" circuits, each a pair of gas-filled relays, requires that the maintenance of the gas discharge in one relay of every pair be independent of negative impulses arising from the anode circuits of the preceding pair. If the relays are actuated by these negative impulses, the counter set fails to scale, and the relays act only as amplifiers.

(ii) The input circuits of electronic chronographs generally employ gas-filled relays, and it is important, once the initiation or cessation impulses have been received by the relays that the succeeding circuit elements are unaffected by any further disturbance in input circuits. A relay with no grid control of the discharge once established is clearly required. If this is not the case, time intervals may be recorded between spurious events in the initiation circuit.

(iii) The output circuits of counters which drive a message register may employ a gas tube. If the grid control of the discharge is ineffective, it is necessary to employ auxiliary circuit elements to break the anode circuits. This may be avoided if a tube of the grid-controlling type is employed. Fig. 2 shows a counter-output circuit using gas-filled relays of different types in the penultimate and output stages. The T31 output relay V_3 is operated by positive pulses and is extinguished by the return of the grid to bias potential.

Notes on the stages:

(*a*) for relay T31.

Stages 1, 2, 3, 4 represent four consecutively applied grid potentials. Stage 5 differs from Stage 4 in that a change of grid volts from Stage 5 conditions to $E_g = 0$ is reversible, while Stage 4 is irreversible.

(*b*) for relay GT1C.

Stages 3-6 demonstrate that no small change of grid potential restores grid control. Stages 7 and 8 show re-establishment of grid control by extinction of arc following return of E_A to zero.

The permission of the Chief Superintendent, Chemical Defence Experimental Station, Porton, to publish this note is gratefully acknowledged.

Fig. 2.

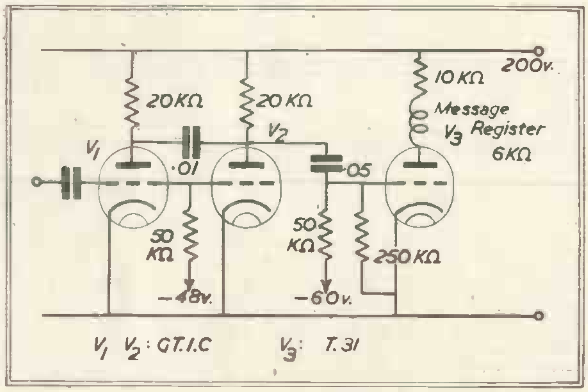


Table :

Stage	Total H.T.(E+)	E_g v. − ve	E_s v. − ve	E_A v. + ve
	(a) Mazda T31			
1	190	24	18	190
2	190	0	0	24
3	190	24	12	40
4	190	24	22	190
5	190	24	24	190
	(b) Osram GTIC			
1	190	72	54	190
2	190	54	40.5	190
3	190		12	16
4	190		0	15
5	190		54	19
6	190	120	90	19
7	0	120	90	0
8	190	120	90	190

Aerial Coupling Circuits

A Series of Data Sheets

Part I.—Introduction

By S. W. AMOS, B.Sc.(Hons.), Grad.I.E.E.

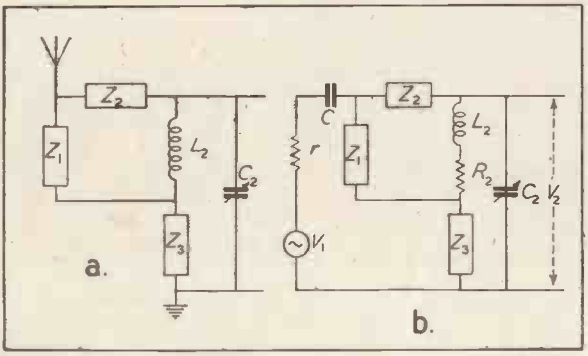


Fig. 1. (a) Generalised aerial coupling circuit, and (b) its electrical equivalent.

THE present series of data sheets has been prepared in order to present, in a convenient form, information about the performance to be expected from certain well-known methods of coupling aerials to tuned circuits. The data sheets will apply only to the type of tuned circuits and the kind of aerial like' to be used on the medium waveband, 550-1,500 kc/s. The information desired about any aerial coupling circuit in which we are interested can be conveniently divided into three main headings, namely, "voltage gain," "selectivity" and "mistuning effect." It is convenient at this point to define these three terms.

Voltage Gain

This can be defined as the ratio between the voltage developed across the tuning condenser of the resonant circuit and the voltage induced in the aerial by the passage of the electromagnetic wave across it. Fig. 1(a) represents a generalised aerial coupling circuit, Z_1, Z_2 and Z_3 being the coupling components and L_2C_2 the tuning circuit. The electrical equivalent of the circuit is given at Fig. 1(b). In a complex aerial coupling circuit it is possible that all three coupling impedances may be important and thus require taking into account in a full analysis of the performance of the circuit, but in most practical cases one particular component predominates and the effects of the others are negligible. If, for example, Z_1 is infinite, Z_3 zero and Z_2 a condenser, then the aerial coupling circuit is known as the series capacitance type—the performance of which will be the subject of Part II of this series. This and some other forms of aerial couplings are illustrated overleaf.

The type of aerial generally used for medium-wave reception has a length which is small compared with the received wavelength. In fact, its length is usually less than $\lambda/4$ so that the impedance of the aerial-earth system is predominantly capacitative. The aerial-earth system may thus be regarded as a generator of e.m.f. V_1 (V_1 equalling the product of the effective height of the aerial and the field strength of the transmitter at the aerial) with internal resistance r and internal capacitance c. R_2 is the total RF resistance of the tuning inductance L_2 (including skin and proximity effects). In Fig. 1(b) the voltage gain is given by the value of V_2/V_1. A term which will be frequently used in the subsequent text is the "voltage gain factor." This is defined as the fraction (usually expressed as a percentage) of the maximum possible gain which is realised in practice at a given frequency. It is well known that the maximum gain realisable at anv frequency from a given coil is equal to one-half the value of the Q factor of the coil ($Q = \frac{L_2\omega}{R_2}$, in this case) at that particular frequency. This maximum voltage transfer occurs at that frequency for which the aerial coupling circuit accurately matches the aerial impedance to the dynamic resistance of the tuned circuit. It follows, therefore, that the voltage gain factor is given by $\frac{2V_2}{QV_1}$.

Selectivity Factor

This is defined in a similar way to voltage gain factor as the fraction (again usually expressed as a percentage) of the maximum possible selectivity which is realised in practice. We shall evaluate it numerically in the subsequent analysis of the problem from the relationship

$$\text{selectivity factor} = \frac{\text{effective Q of } L_2 \text{ at a particular frequency}}{\text{real Q of } L_2 \text{ at the same frequency}}$$

$$= \frac{\text{Q of } L_2 \text{ with damping due to aerial}}{\text{Q of } L_2 \text{ without damping due to aerial}}$$

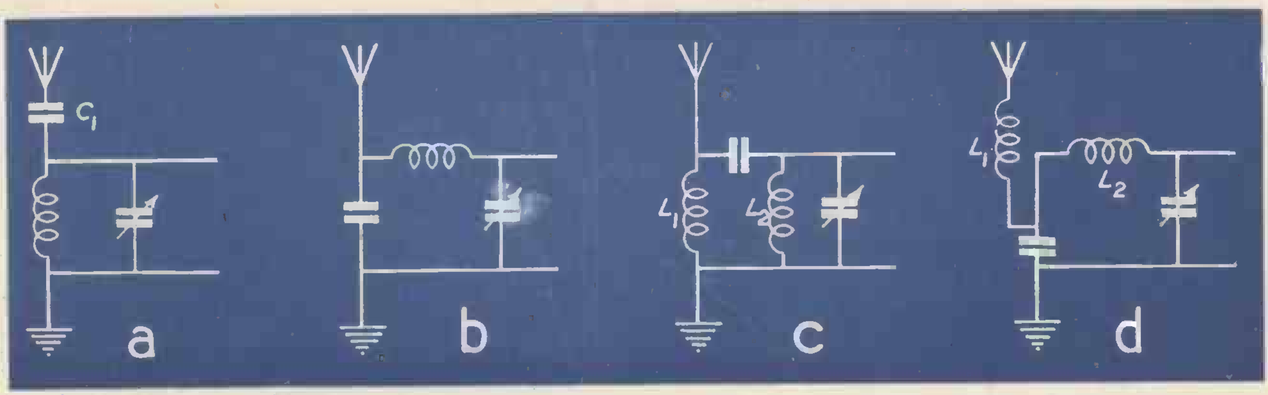
$$= \frac{L_2\omega}{R_2 + R} \cdot \frac{R_2}{L_2\omega} = \frac{R_2}{R_2 + R}$$

in which R is the value of the extra RF resistance "reflected" into the resonant circuit as a consequence of the addition of the aerial coupling circuit and the aerial.

Mistuning Effect

The actual effect of the primary of the secondary circuit is to "reflect" an impedance, *i.e.*, a complex quantity involving reactance and resistance, into the secondary circuit. The resistive part of it, as just explained, reduces the effective selectivity of the tuned circuit; the reactance upsets the tuning of the secondary circuit and reduces or increases the value of the resonant frequency for any particular setting of the tuning control. The most convenient method of assessing the magnitude of this disturbance of the secondary circuit is to calculate the magnitude of the capacitance (which may be positive or negative depending on the nature of the aerial coupling circuit) which is effectively added in parallel with the existing tuning capacitance. This is the method which will be used throughout this series. This extra capacitance will be referred to as the "reflected capacitance" or "capacitance correction" and will be designated by ΔC_2.

Usual Types of



(a) Series capacitance coupling. (b) Shunt capacitance coupling generally giving low gain but high selectivity. (c) Series capacitance coupling with aerial loading by inductance to " hold up " voltage gain at low frequency end of waveband. L_1 and L_2 are not magnetically coupled. (d) Shunt capacitance coupling with inductance loading. See article by the author in *Wireless Engineer* for December, 1942.

Assumptions made in the Analysis

Before any calculations of these three factors can be made, values must be postulated for r, c, L_2, R_2 and C_2. In preparing these data sheets, attention was paid only to the medium waveband and L_2 and C_2 were given the values of 157 μH and 500 $\mu\mu$F (maximum) respectively. The Q value for the inductance was assumed constant at 100 for all frequencies in the waveband. Since

$$Q = \frac{L_2\omega}{R_2} \text{ then } R_2 = \frac{L_2\omega}{Q}, \text{ so that}$$

the value of R_2 for every frequency is automatically fixed by this assumption. Some values are listed in Table I. For the aerial characteristics c and r were assumed equal to 200 $\mu\mu$F and 40 ohms respectively, both being of the order to be expected from an average outdoor aerial. These values for L_2, C_2, R_2, r and c will be used throughout this series of data sheets.

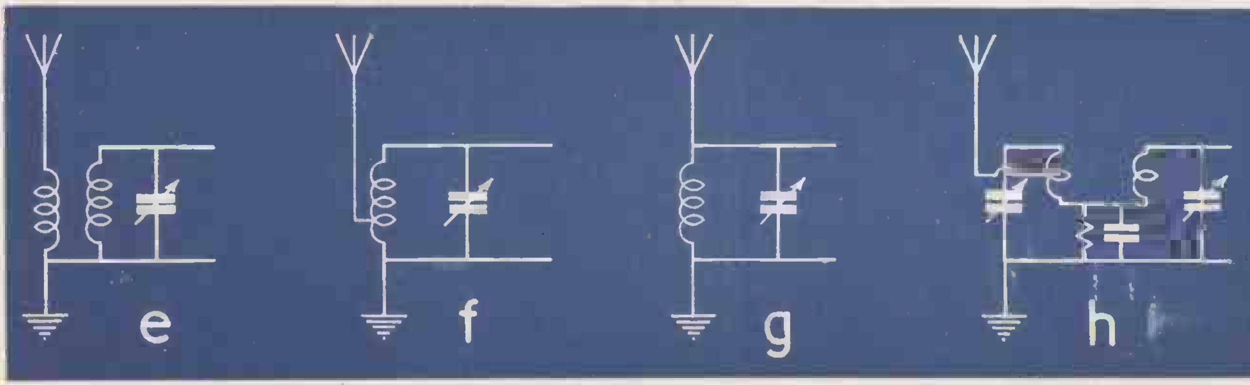
Variation of Selectivity and Voltage Gain Factors with Frequency

The assumption made above that the aerial generator impedance contains capacitance and resistance only is not quite justified in practice, though it is a useful approximation in analyses. Actually, an aerial wire possesses, in addition, a small amount of inductance, and quite frequently aerial coupling circuits involve the addition of more inductance so that the equivalent aerial generator circuit is resonant at a particular frequency. Since, for a particular aerial-earth system, the aerial capacitance is constant, we can place this resonant frequency more or less at what value we please by giving the added inductance a suitable value —and the performance of the aerial coupling circuit with respect to voltage gain, selectivity and "reflected" capacitance is very largely determined by the value of this resonant frequency.

It is not advisable, for example, to place this resonant frequency within the frequency range the tuning circuit is intended to cover, in spite of the fact that this is the condition for maximum voltage gain, for this will lead to a very poor performance with respect to selectivity as the damping imposed on the tuning circuit by the aerial-earth system is clearly a maximum in these circumstances. Moreover, as the frequency of the tuning circuit passes through the resonant value of the aerial-earth system, there will be a change in the sign of the reactive component of the impedance "reflected" into the tuning circuit, *i.e.*, the "reflected" capacitance will change from positive to negative (or from negative to positive, depending on whether frequency is increasing or decreasing), and there will therefore be a consequent anomaly in the calibration of the tuning condenser, making accurate ganging of this component with other tuning condensers in the receiver almost impossible.

Suppose, however, the aerial circuit is made resonant at a frequency in excess of the greatest in the wanted waveband. This condition is obtained by including very little or no inductance in the coupling circuit. As the tuning is adjusted so as to increase the received frequency the voltage gain will rise, since the frequency approaches the resonant value for the aerial circuit. Selectivity, however, will decrease as the resistive component of the aerial circuit impedance decreases as the resonant frequency is approached. Increase of gain is therefore obtained at the expense of selectivity, and the problem in aerial coupling circuits is to obtain a reasonable compromise between these two mutually conflicting properties. In the case where the aerial circuit is resonant at a high frequency, *i.e.*, for a capacitative aerial circuit, the variation with frequency of voltage gain and selectivity factors will be considerable. The selectivity-frequency and voltage gain-frequency curves will be far from level, since we are attempting, with our aerial coupling circuit, to match a capacitative generator (the aerial-earth system), the impedance of which naturally decreases with increase of frequency, to a load (the tuning circuit), the resistance of which rises with increase of frequency. For the aerial circuit the impedance is roughly indirectly proportional to frequency, and for the tuning circuit the dynamic resistance is given by $L_2\omega Q$, of which L_2 and Q are assumed fixed so that this resistance is directly proportional to fre-

Aerial Coupling



(e) R.F. transformer coupling : probably the commonest of all aerial coupling methods. (f) Aerial coupling by tapped coil method. May be regarded as a special case of (e) (see *Electronic Engineering* for June, 1943). g) The simplest of aerial coupling circuits. May be regarded as a limiting case of (a) in which C_1 approaches infinity, or of (f) in which the tapping point coincides with the end of the coil. (h) One of many possible varieties of band-pass circuit. These circuits give a good approach to the ideal square-topped response curve, but difficulty is usually experienced in keeping the band-width constant.

quency. With such a load and such a generator it is natural that even small changes in frequency bring about large changes in mismatching, and hence correspondingly large changes in selectivity and voltage gain factors.

A far better performance with respect to the constancy of voltage gain and selectivity factors is possible by making the generator inductive. Its impedance then increases with increase of frequency as for the tuning circuit, and hence the matching holds far better than for a capacitative aerial-earth system. To make the aerial circuit inductive over the received waveband, it is necessary to add sufficient inductance to place the resonant frequency of the aerial circuit below the lower extreme of the received waveband. Voltage gain will now increase as the received frequency decreases, since it is now necessary to decrease the frequency in order to approach the resonant value of the aerial circuit. Conversely, selectivity will decrease as frequency decreases, both results being just the opposite of those obtained above for the capacitative circuit, but the curves of selectivity-frequency and gain-frequency will, for the inductive aerial circuit, show greater constancy than those for the other case. These points are all illustrated in Fig. 2, which also indicates the broad generalisation that all selectivity-frequency and voltage-gain frequency curves for any aerial coupling circuit are portions only of the universal resonance curve. The qualitative curve of Fig. 2 will serve as a very rough guide to the variations of gain and selectivity with frequency likely to be encountered. In interpreting the curves of the various data sheets to follow, one should bear in mind that they only apply when $e=200$ $\mu\mu$F, $r=40$ ohms, $L_2=157\mu$H, and Q=100. Exact interpolation from the curves is thus inadvisable as one is unlikely in practice to have all the circuit constants with these particular values. Nevertheless, the data sheets should prove useful as a means of indicating approximately the results to be expected from various common methods of aerial coupling.

Table 1

Value of $\omega \times 10^6$ (rads per sec)	3	4	5	6	7	8	9	10	11	12
Value of f (kc/s)	471	628	785	942	1099	1256	1413	1570	1727	1884
Value of R_2 (ohms) for Q = 100.	4·71	6·28	7·85	9·42	10·99	12·56	14·13	15·7	17·27	18·84

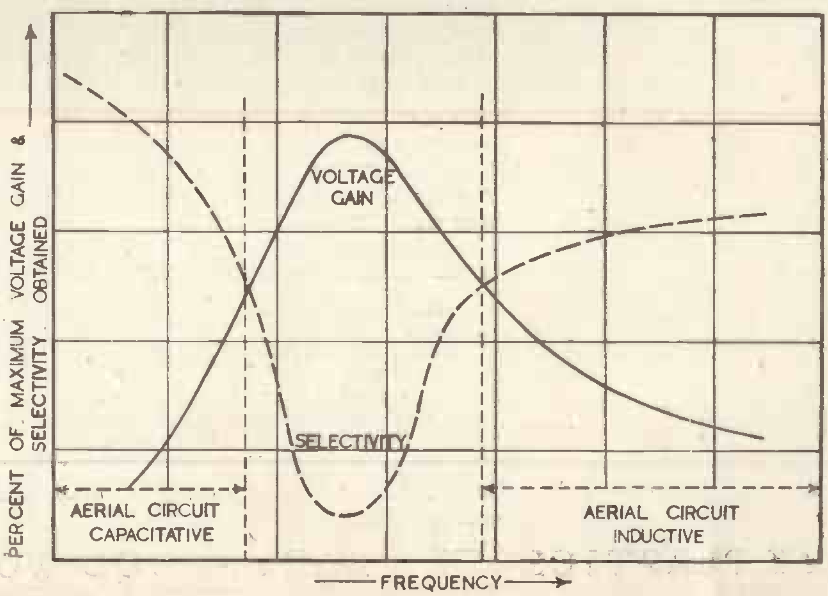


Fig. 2. Variation of voltage gain and selectivity with frequency for capacitative and inductive aerial circuits.

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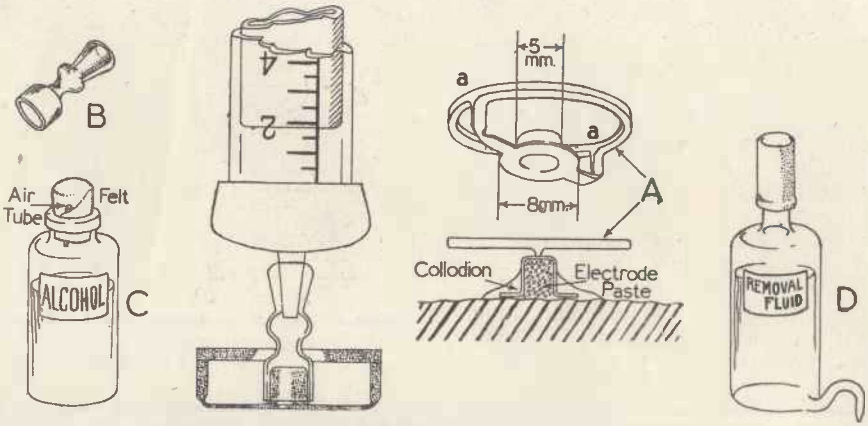
Cup-Electrode Technique in Electroencephalography

By G. D. GREVILLE, Ph.D., and P. St.JOHN-LOE*

IN electroencephalograph practice in this country it is customary to use saline pad electrodes held on the head by a system of rubber bands.[1] This has disadvantages when dealing with children, mental patients, patients with scalp wounds, and subjects who find the rubber bands irksome. Electrodes firmly attached to the scalp are then preferable. In America, solder pellets on the end of fine wires and fixed with collodion are in general use, but their application requires much practice,[2] although the use of an adhesive bentonite-$CaCl_2$ paste is said to make it easier.[3] We have developed a technique using silver cup-electrodes which has proved so satisfactory that we have adopted it for routine use.

The electrodes (A), containing electrode paste, are fixed on to cleaned areas of scalp by means of collodion delivered from a syringe. The amplifier leads are clipped on to the rings. The electrodes may be spun from tubing and soldered, or preferably spot-welded, to the ring. Soldered joins should be made at the points *a*, to avoid contact of the solder with the head or paste.

The syringe bears a nozzle attachment (B) of glass or metal, which will fit over the electrode with rather less than 1 mm. clearance. It is of advantage to give the plunger a slightly looser fit than usual by grinding with fine carborundum.



Components and accessories for the Cup-electrode technique.

Materials Required

(1) *Electrode paste.* Potassium chloride is ground in a mortar and about 3 vols. of soft soap worked in. Glycerine and a little water are added until a suitable paste is obtained.

(2) *Methylated spirit* for cleaning the scalp.

(3) *Alcohol-ether mixture* (50 per cent. v/v), used both as solvent for the collodion and for cleaning the electrodes.

(4) *Collodion.* British Drug Houses "Collodion for preparing permeable membranes" is suitable.

(5) *Removal fluid.* Acetone containing approx. 10 per cent. castor oil.

Technique: A small area of skin is cleaned with spirit, conveniently applied with the device *C*. An electrode, filled with paste from a syringe or metal tube, is held on the area, the nozzle attachment of the syringe placed over it, and a small quantity of collodion delivered. To remove the electrodes, removal fluid is squirted on to each in turn from a convenient form of teat pipette (D). The electrodes can then be lifted off, and residual collodion removed from the hair with a fine comb. The electrodes are dropped into alcohol-ether mixture, which completely cleans them.

Notes: (1) Instead of the paste described, Cambridge electrode jelly can be used, but it has not been possible to remove this and the collodion simultaneously with one solvent after use.

(2) It is extremely important to keep the collodion adjusted to a suitable viscosity to ensure wetting of the skin, and rapid adhesion. With the collodion specified above, no air blast is necessary as the electrode remains in place. Twelve electrodes may be attached to the head without difficulty in less than ten minutes, by which time the first four are ready for use.

(3) The contraction of the collodion on drying results in a firm pressure on the skin and a resistance usually considerably lower than that of saline pads. It is almost impossible for subjects to dislodge electrodes placed in the hair.

(4) New electrodes should be chlorided, but repetition of this appears to be unnecessary, as judged by the absence of polarisation. No artefacts attributable to the type of electrode have been observed.

(5) If plenty of removal fluid is used, no difficulty is found in freeing the hair from collodion. The castor oil in the fluid leaves the hair soft and glossy.

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Correction

Dr. H. Moss points out two corrections to be made in the series "Cathode-Ray Tube Traces," Part II, December issue (p. 285), col. i.

For: "(c) that the deflecting field is uniform and wholly axial"

Read: "(c) that the deflecting field is uniform and wholly normal to the axis."

January issue (p. 329), col. ii. Equation 36 should read:
Fractional displacement error

$$-\frac{E_m}{e}.ln(1-e/E_m)-1 \quad \ldots\ldots\ldots\ldots \quad 36$$

Low Frequency Amplification

Part IV. Cathode Self-Bias and Attenuation Distortion

By K. R. STURLEY, Ph.D., M.I.E.E.

A VALVE having an indirectly-heated cathode can be made to provide its own grid-bias voltage by inserting a resistance R_k between the cathode and H.T. negative lead as shown in Fig. 29a. The D.C. component of anode current flowing through R_k produces a positive voltage between the cathode and H.T. negative, and since the grid leak is returned to H.T. negative it means that the grid is biased negatively with respect to the cathode. R_k must be bypassed by a large capacitance C_k in order to prevent the A.C. components of the anode current producing voltages between cathode and grid. These A.C. voltages are in opposition to the grid voltages producing them and overall amplification may be seriously reduced. That the grid and cathode voltages are in opposition can be proved by considering an increase of the input grid voltage in a positive direction; this increases the anode current and the voltage across R_k. The net positive increase in grid-to-cathode voltage (the difference between the increase of input voltage and increase of cathode voltage) is less—it may be much less—than the input voltage change.

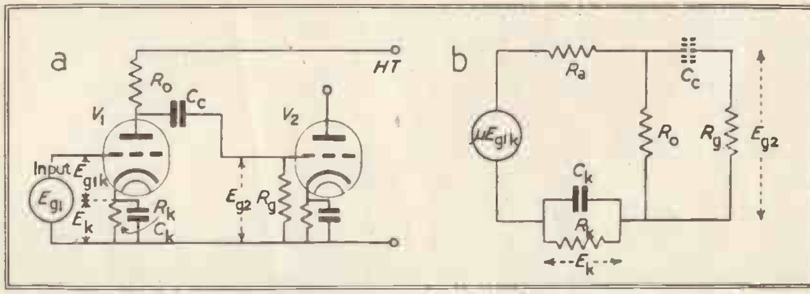

Fig. 29. (a) A low frequency amplifier with self-bias. (b) The equivalent circuit for a valve with cathode self-bias.

The capacitor C_k clearly cannot be equally effective at all frequencies, and negative feedback (reduced amplification) occurs at the lower end of the frequency range owing to the increase in the reactance of C_k. In the equivalent circuit, shown in Fig. 29b, the stray capacitance C_s is omitted because its reactance over the range of frequencies affected by C_k is very high; the coupling capacitance C_c is assumed to have negligible reactance so that R_g is effectively in parallel with R_o. This is generally justified because it is easier to make the reactance of C_c small compared with R_g than to make the reactance of C_k at the same frequency small compared with R_k.

Analysing the circuit of Fig. 29b, the output voltage is

$$E_{g2} = \frac{\mu E_{g1k} R'_o}{R_a + R'_o + Z_k} \quad \ldots\ldots\ldots\ldots \quad 14$$

where E_{g1k} = net A.C. voltage between the grid and cathode

$$R'_o = \frac{R_o R_g}{R_o + R_g}$$

Z_k = impedance of the self-bias circuit

$$= \frac{R_k}{1 + j\omega C_k R_k}$$

$$E_{g1k} = E_{g1} - E_k \quad \ldots\ldots\ldots\ldots \quad 15$$

where E_{g1} = input voltage from grid to H.T. negative

and E_k = A.C. voltage component developed across Z_k

$$E_k = \frac{\mu E_{g1k} Z_k}{R_a + R'_o + Z_k} \quad \ldots\ldots\ldots\ldots \quad 16$$

From (15) and (16)

$$E_{g1k} = \frac{E_{g1}(R_a + R'_o + Z_k)}{R_a + R'_o + Z_k(1+\mu)} \quad \ldots\ldots\ldots\ldots \quad 17$$

Replacing E_{g1k} in (14) by its value in (17)

$$E_{g2} = \frac{\mu E_{g1} R'_o}{R_a + R'_o + Z_k(1+\mu)} \quad \ldots\ldots\ldots\ldots \quad 18$$

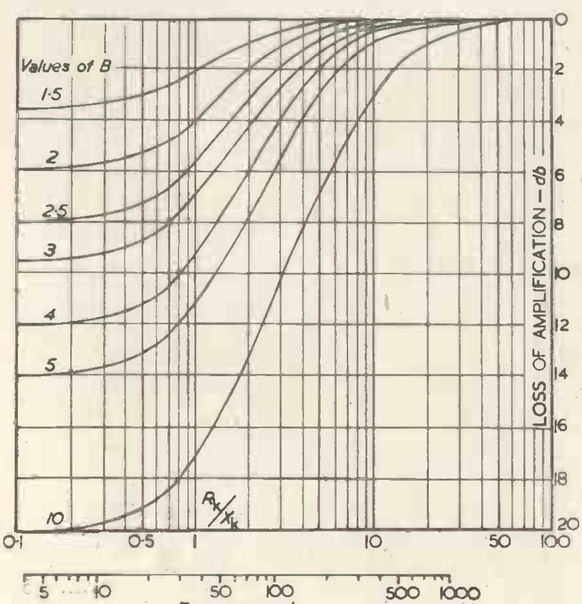

Fig. 30. Generalised curves of attenuation distortion (loss) for the cathode self-bias circuit.

Overall amplification with cathode feedback = A_f

$$=\frac{E_{g2}}{E_{g1}}=\frac{\mu R'_o}{R_a+R'_o+Z_k(1+\mu)} \quad \ldots\ldots\ldots\ldots 19$$

Overall amplification at the medium frequencies, where C_k has a very small reactance, is

$$A_m=\frac{\mu R'_o}{R_a+R'_o}$$

Therefore
$$\frac{A_f}{A_m}=\frac{1}{1+\dfrac{Z_k(1+\mu)}{R_a+R'_o}} \quad \ldots\ldots\ldots 20$$

Replacing Z_k in 20 by $\dfrac{R_k}{1+j\omega C_k R_k}$,

we have
$$\frac{A_f}{A_m}=\frac{1}{1+\dfrac{R_k(1+\mu)}{(R_a+R'_o)(1+j\omega C_k R_k)}}$$

$$=\frac{1+j\omega C_k R_k}{1+\dfrac{R_k(1+\mu)}{R_a+R'_o}+j\omega C_k R_k} \quad \ldots\ldots\ldots\ldots 21a$$

$$=\frac{1+j(R_k/X_k)}{B+j(R_k X_k)} \quad \ldots\ldots\ldots\ldots\ldots\ldots 21b$$

where $X_k=\dfrac{1}{\omega C_k}$ and $B=1+\dfrac{R_k(1+\mu)}{R_a+R'_o}$

Attenuation distortion, measured by the loss of amplification, is

$$-20\log_{10}\frac{A_m}{A_f}=-10\log_{10}\frac{B^2+\left(\dfrac{R_k}{X_k}\right)^2}{1+\left(\dfrac{R_k}{X_k}\right)^2}\text{db} \quad \ldots 22$$

Expression (22) is plotted against $\dfrac{R_k}{X_k}$ to a logarithmic scale for different values of B in Fig. 30. As $\dfrac{R_k}{X_k}$ increases, *i.e.*, C_k becomes more effective in bypassing the A.C. components, the loss of amplification decreases to zero, whilst as $\dfrac{R_k}{X_k}$ decreases (decreasing frequency), the loss tends to the value which is realised when $C_k = 0$. The maximum value of loss depends on B and is, from expression (22),

$$-20\log_{10}B=-20\log_{10}\left[1+\frac{R_k(1+\mu)}{R_a+R'_o}\right]\text{db}$$

For a particular value of R_k, maximum loss is increased when μ is increased or R_a or R'_o decreased. Hence a decrease in high frequency attenuation distortion in the anode circuit by decreasing the anode load resistance R_o leads to an increase in low frequency attenuation distortion from the cathode self-bias circuit.

With a tetrode or pentode valve for which $\mu \gg 1$ and $R_a \gg R'_o$, maximum loss

$$=-20\log_{10}\left[1+\frac{\mu R_k}{R_a}\right]$$

$$=-20\log_{10}(1+g_m R_k).$$

Phase angle displacement curves can be derived by rationalising expression (21b) and plotting its phase-angle component against $\dfrac{R_k}{X_k}$.

Thus
$$\frac{A_f}{A_m}=\frac{\left(1+j\dfrac{R_k}{X_k}\right)\left(B-j\dfrac{R_k}{X_k}\right)}{B^2+\left[\dfrac{R_k}{X_k}\right]^2}=$$

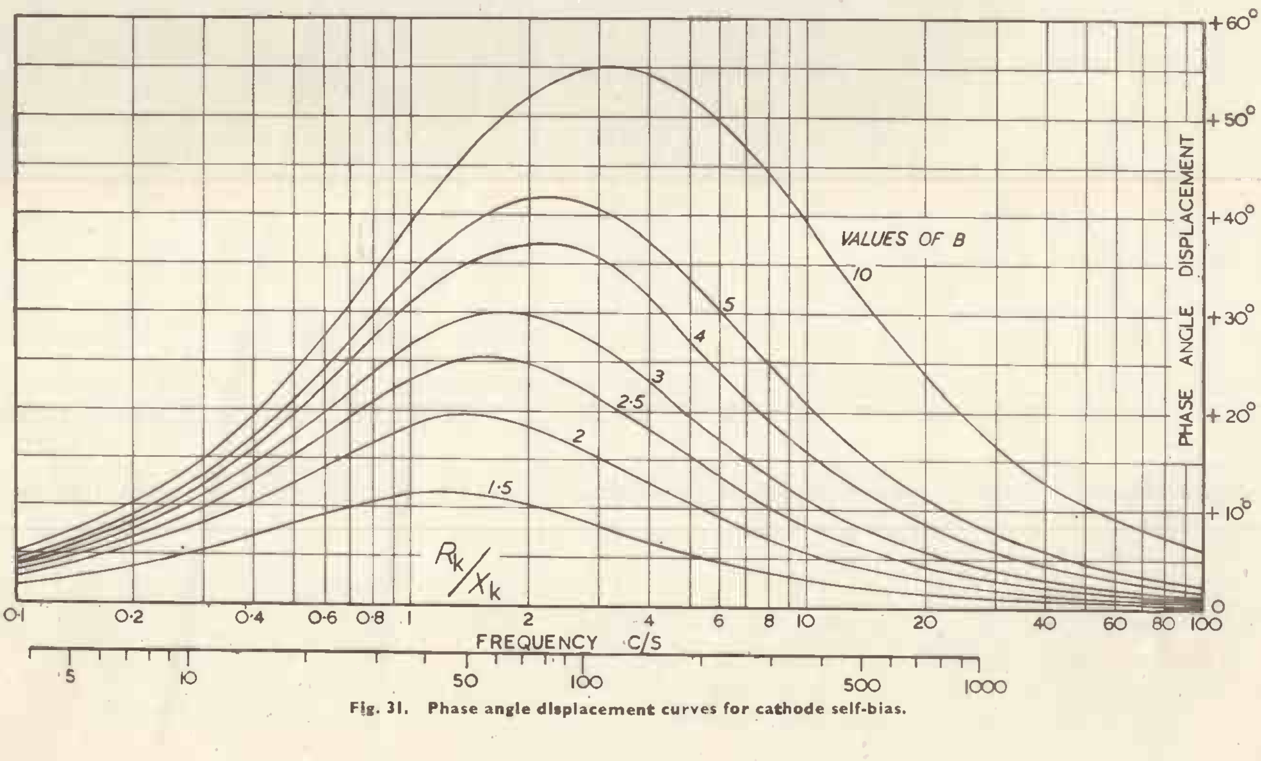

Fig. 31. Phase angle displacement curves for cathode self-bias.

$$= \frac{B + \left(\frac{R_k}{X_k}\right)^2 + j(B-1)\frac{R_k}{X_k}}{B^2 + \left[\frac{R_k}{X_k}\right]^2} \quad \ldots\ldots\ldots \text{21c}$$

from which

$$\phi_k = \tan^{-1} \frac{(B-1)\frac{R_k}{X_k}}{B + \left(\frac{R_k}{X_k}\right)^2} \quad \ldots 23$$

Fig. 31 shows the result of plotting ϕ_k against R_k/X_k for the same values of B as are used for Fig. 30. This curve may be converted to time advance curves by assuming that $f = 1$ c/s. at $R_k/X_k = 1$ and plotting $\frac{\phi_k \times 10^6}{360^\circ \times R_k/X_k}$ microsecs. against R_k/X_k as in Fig. 32. The phase displacement represents a time advance because the angle ϕ_k is positive. As R_k/X_k is decreased the phase displacement approaches $\tan^{-1} \frac{(B-1)R_k}{BX_k}$, *i.e.*, $\frac{(B-1)R_k}{BX_k}$ rads., and time advance therefore approaches a constant value of $\frac{(B-1)10^6}{2\pi B}$ microsecs. Hence it is possible to produce time error curves similar to that of Fig. 25, by plotting the difference between the constant and actual value at a given R_k/X_k. The result is indicated in Fig. 33.

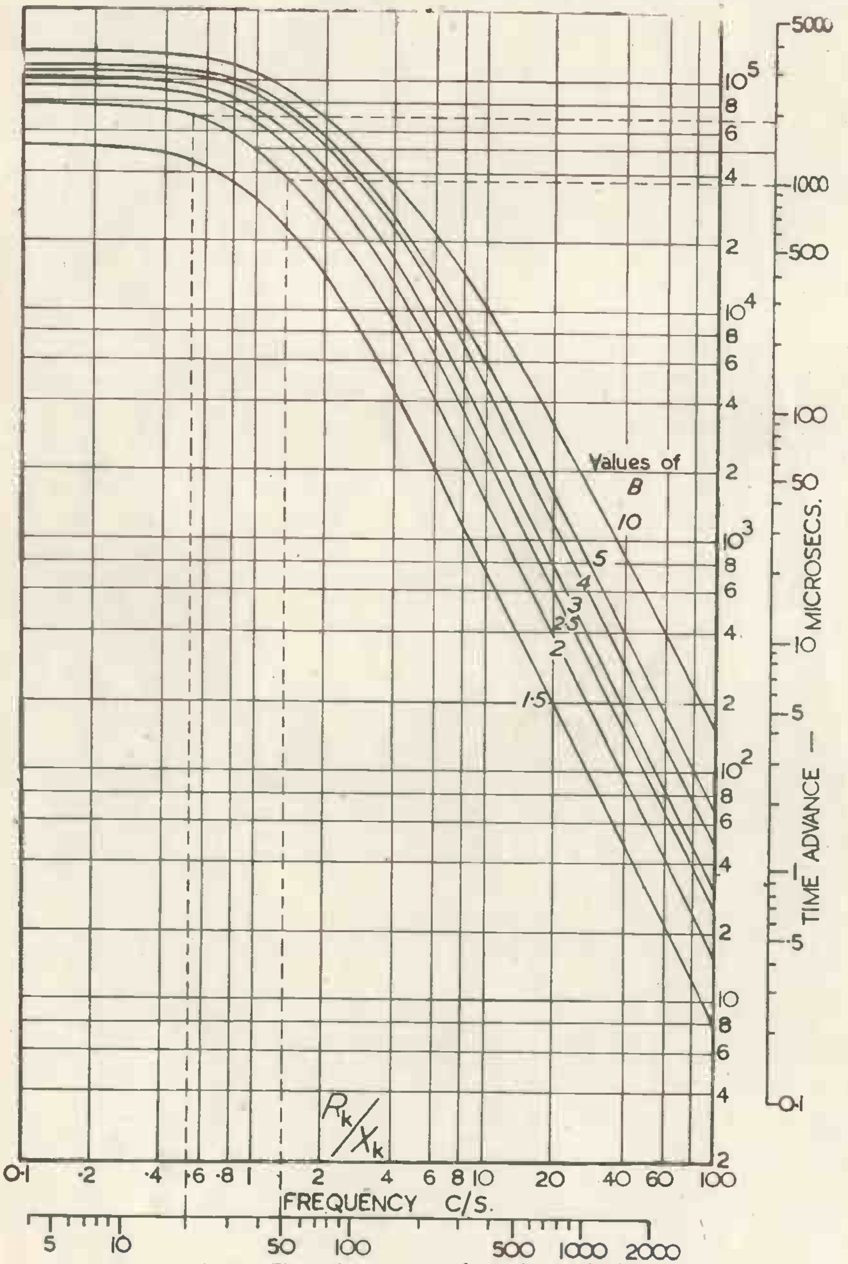

Fig. 32. Time advance curves for cathode self-bias.

Figures 30 and 31 are made applicable to a particular case by suitably locating a logarithmic frequency scale underneath the R_k/X_k scale as described previously. Thus, if $R_o = 200{,}000\Omega$, $R_a = 50{,}000\Omega$, $R_g = 1\text{M}\Omega$, $\mu = 100$, $R_k = 2{,}150\Omega$, $C_k = 2\mu$F, $R'_o = 166{,}666\Omega$

$$\frac{\mu + 1}{R_a + R'_o} = 4.65 \times 10^{-4}, \; B = 2.$$

$$\frac{R_k}{X_k} = 1 \text{ when } f = \frac{10^6}{2\pi \times 2 \times 2{,}150} = 37 \text{ c/s.}$$

The logarithmic frequency scale is adjusted beneath the R_k/X_k scale in all the figures so that $f = 37$ c/s. registers with $R_k/X_k = 1$, and frequency response (Fig. 30) and phase angle displacement (Fig. 31) are read from the $B = 2$ curve. The total overall frequency response including the effect of C_s and C_c is obtained by adding the losses due to these two capacitances as found from Figs. 19 and 20 to the loss due to C_k. Some error is introduced at low frequencies in taking the frequency response from Fig. 30 because of the assumption that the reactance of C_c is small compared with R_g, but the effect will not usually be very serious.

Time advance and time error for a particular set of component values are obtained by suitably positioning a vertical logarithmic curve. For the component values selected, the $B = 2$ curve is applicable and it will be seen that the time advance at $R_k/X_k = 1$ is 51,200 microsecs. This time is divided by 37, the frequency corresponding to $R_k/X_k = 1$, and the sliding vertical logarithmic scale is located so that $\frac{51{,}200}{37} = 1{,}385$ microsecs. on its scale registers with 51,200 microsecs. on the fixed scale. Actual time advance at any frequency is then read from the sliding scale. Thus at 20 and 50 c/s., the actual time advances are approximately 1,900 and 1,000 microsecs., respectively. Similarly, actual time error is read by locating $\frac{28{,}300}{37} = 766$ microsecs. on the sliding scale against 28,300 microsecs. on the fixed scale.

The correct value of R_k to choose for any set of operating conditions is obtained by drawing the D.C. load line on the $I_a E_a$ characteristic curves and estimating by inspection the bias voltage to give maximum output voltage with minimum distortion. The locus of operation should be over that part of the load line which makes equal intercepts with curves of constant grid voltage difference; at the same time it must not be allowed to pass beyond the start of grid current. The ratio of the bias voltage finally selected to the anode current at the intersection of the load line with this bias voltage curve gives the required value of R_k. In many cases R_k will be a non-standard value and it is usual to select the nearest standard value. The D.C. load line should be drawn for $(R_o + R_k)$, but R_k is so much less than R_o that its effect may usually be neglected.

Example in use of Response Curves

As explained in the previous article, a logarithmic frequency scale may be positioned under the (R'/X') and (R''/X'') scales of Figs. 19 and 20, so that the response at various frequencies may be read directly.

The following example shows the method of calculating the response.

A triode has a μ of 50 and a slope resistance (R_a) of 50,000Ω. The anode load resistance (R_o) is 100,000 ohms and the grid leak (R_g) of the succeeding valve is 1.0 megohm. The coupling capacitance is 0.005 μF.

First, determine the value of the slope resistance of the valve in parallel with the anode load resistance plus grid leak :—

$$R' = \frac{R_a R_o}{R_a + R_o} + R_g = 1.04 \text{ megohms.}$$

Substitute this in the formula

$$f_{lo} = \frac{1}{2\pi C_c R'}$$ where C_c is the coupling capacitance.

$$f_{lo} = \frac{1}{6.28 \times .005 \times 1.04} = 30.6 \text{ c/s.}$$

Set this value of frequency against $(R'/X') = 1$ on the horizontal scale and read off the loss at other frequencies.

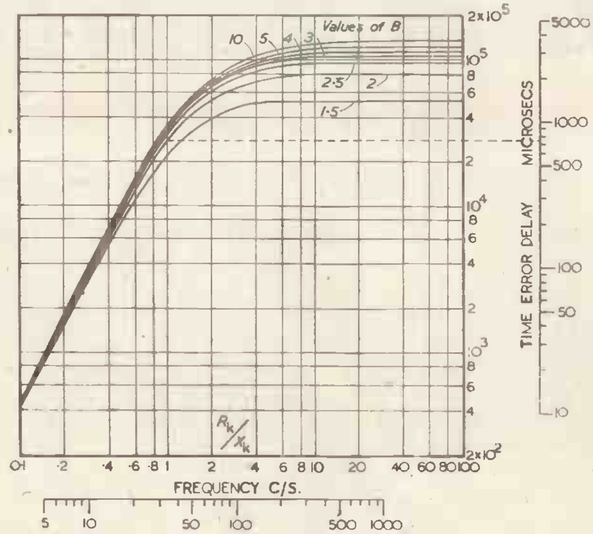

Fig. 33. Time error delay curves for cathode self-bias.

To obtain the high-frequency response, calculate the value of R''

$$= \frac{R_a R_o R_g}{R_a R_o + R_a R_g + R_o R_g}$$ where R_a, R_o and R_g have the same values as before.

Find the value of f_{ho} from the expression :—

$$f_{ho} = \frac{1}{2\pi C_s R''}$$ where C_s is the shunt capacitance (assumed to be 0.0005 μF)

$$f_{ho} = \frac{10^6}{6.28 \times .0005 \times 38{,}500} = 8{,}260 \text{ c/s.}$$

This value of frequency is set against $(R''/X'') = 1$ on the horizontal scale of Fig. 20, and the loss at other frequencies read off.

Time Advance and Delay

In the time advance and delay curves given in Figs. 23, 24, 25 and 32 an inner vertical logarithmic scale will be noticed.

This is a reference time advance or delay scale which is obtained from the phase angle displacement at the particular value of R/X considered.

$$\text{Thus :— Reference time advance} = \frac{\phi^\circ \times 10^6}{360^\circ \times (R/X)}$$

where ϕ is the phase angle displacement at the particular value of (R/X), obtained from the corresponding figures of ϕ against R/X (Fig. 21 or 22).

For the low-frequency range (Figs. 21 and 23)

$$\text{Actual time advance} = \frac{\text{Reference time advance} \times (R'/X')}{f_1 \text{ corresponding to a particular value of } (R'/X')}$$

$$\text{Actual time advance at } (R'X') = 1 = \frac{\text{Reference time advance at } (R'/X') = 1}{f_{lo} \text{ corresponding to } (R'/X') = 1}$$

$$= 125{,}000/f_{1c} \text{ microseconds.}$$

For the high-frequency range (Figs. 22 and 24)

$$\text{Actual time delay at } (R''/X'') = 1 = \frac{\text{Reference time delay at } (R''/X'') = 1}{f_{ho} \text{ corresponding to } (R''/X'') = 1}$$

$$= 125{,}000/f_{ho} \text{ microseconds.}$$

In the case of Fig. 25, which shows the time-delay error, the vertical scale is a reference time-delay error scale, and

$$\text{Actual time delay error at } (R''X'') = 1 = \frac{\text{Reference time delay error at } (R''/X'') = 1}{f_{ho} \text{ corresponding to } (R''/X'') = 1}$$

$$= 134{,}000/f_{ho} \text{ microseconds.}$$

The Principles and Design of Valve Oscillators

Part I—Separation of Functions

By A. C. LYNCH, M.A., and J. R. TILLMAN, Ph.D.*

An oscillator circuit can be separated into two parts: (1) a maintaining circuit (more conveniently referred to as a "driving circuit"); and (2) a frequency-discriminating circuit (or "tuning circuit"). In a few special oscillators there are more than one of each of these circuits. The separation of these two functions is not theoretically perfect, but is justified by its practical convenience. It is more obvious in multi-valve circuits than in some of the apparently simpler circuits previously in favour. An example of an oscillator circuit showing this clear division is given in Fig. 1; the oscillator consists of a parallel resonant circuit coupled through resistors to an amplifier of flat frequency characteristic.

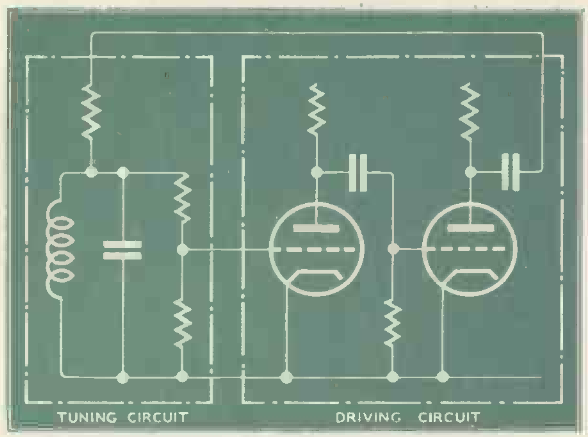

Fig. 1. Oscillator showing separation of functions.

It is convenient from a theoretical viewpoint to divide the driving circuit into a linear amplifier (*i.e.*, one whose gain is the same at all amplitudes) and a limiter. Up to the present time these two functions have not usually been physically separated, except in certain oscillators of high precision.

The tuning circuit may be an oscillatory circuit, a mechanical resonator (such as a crystal, a tuning fork, or a magnetostrictor), or a network of resistors and either capacitors or inductors. This article is concerned mainly with driving circuits, and its conclusions apply to all types of tuning circuits.

Modern oscillators, except those for very high frequencies, almost invariably use a separate amplifier to obtain the required power output. Questions of power output or efficiency of oscillator circuits, therefore, do not usually arise.

Equivalence of Positive Feedback and Negative Resistance

Driving circuits may be classified as "positive feedback" (*e.g.*, the Hartley, the Colpitts, or the Franklin circuits) and "negative resistance" (*e.g.*, the dynatron or the transitron) types. But suppose a resonant circuit to be connected to a network of unknown properties, and thereby to be maintained in oscillation; then the network may be interpreted as one of either type. The distinction is, at most, one of convenience. Both types of circuit supply power to the tuning circuit, and their instantaneous output is controlled by it.

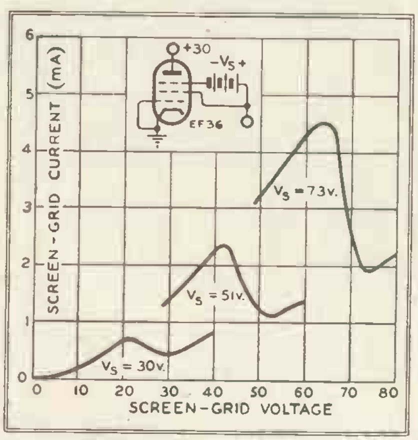

Fig. 2. Negative resistance characteristics of transitron measured statistically.

The more general type is the positive feed-back circuit, whose property is that an applied potential E at a point P results in the development at another point Q of an amplified e.m.f. μE. If P and Q are connected through an impedance Z (whose value includes the output impedance of the amplifier), a current of $\frac{(\mu-1)E}{Z}$ flows to P, and the result at P is the same as if it had been connected to a resistance of $-\frac{Z}{\mu-1}$. A "negative resistance" possesses a similar property, but P and Q are already connected internally, and the impedance Z is not, in general, available as a separate entity to be selected at will.

General results can thus be obtained by consideration of the positive feed-back circuit, which is easily pictured, and it is in theory unnecessary to consider negative resistance oscillators separately. However, there are certain circuits, such as the

* Post Office Research Station.

dynatron, which can be more easily studied by using the conception of negative resistance.

Negative Resistances

The negative resistance method of analysis is applicable to oscillators in which the tuning circuit is a two-terminal network, *i.e.*, can be resolved into a simple parallel resonant circuit. The name "negative resistance" is applied to any device whose voltage-current characteristic, in some limited range, has a negative slope. (*See*, for example, Fig. 2.) The term is not confined to those devices, such as dynatrons and transitrons, whose negative resistance characteristic can be measured by d.c. tests; it can be applied to devices in which the characteristic is revealed only by a.c. tests—an example being a two-stage amplifier with output and input terminals connected together.

There are two types of negative resistance,[1] distinguished by their behaviour outside the range of negative slope. The "voltage-controlled" type gives a unique current for any one value of applied voltage, but for certain values of current there are three possible applied voltages. (Fig. 3.) Similarly the "current-controlled" type maintains a unique potential for any one value of current. Dynatrons, transitrons, and back-coupled amplifiers are voltage-controlled, and to form oscillators they are connected in parallel with the resonant circuit.

The amplitude of oscillation becomes such that at one or both peaks of the oscillation the resistance is large (it may even pass through an infinite value and become positive), and the average value of negative resistance during each cycle is equal to the positive resistance of the tuning circuit. It is, however, difficult to calculate this "average" negative resistance. The variation in negative resistance introduces harmonics into the generated waveform. The condition that oscillation shall occur spontaneously is that the value of the negative resistance in the initial conditions is arithmetically less than the positive equivalent shunt resistance of the tuning circuit which it is to maintain. The initial conditions can, however, be such that, although there is no spontaneous oscillation, oscillations started by a sufficiently large transient will continue with stable amplitude.

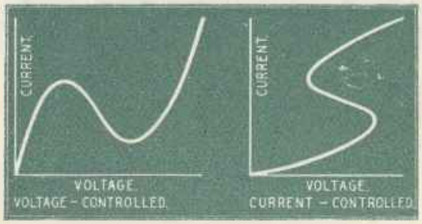

Fig. 3. Two types of negative resistance.

If the relationship between current and voltage is known and can be expressed algebraically both inside and outside the range of negative slope, a full mathematical analysis of the oscillator is possible; but it involves the solution of a differential equation with non-linear coefficients. Some interesting results have been obtained by this method;[2] the connexion found between the frequency of oscillation and the harmonic content has been shown to agree with that derived by a more direct consideration of the influence of the harmonics. The method is important historically but the mathematical difficulties involved seem to have limited its use.

The shunt capacitance of several of these devices varies with the current flowing,[3] and is therefore changing during each cycle of oscillation. This variation causes the generated wave to differ from a sine curve, and should be allowed for in a complete investigation of such oscillators. It is well known, for example, that the input capacitance of a valve increases with increase of anode current—the effect is explained as a movement of the hypothetical "virtual cathode" formed under the influence of space-change. In some circuits (*e.g.*, the dynatron) the valve capacitance is not that between grid and cathode, but is one of the other inter-electrode capacitances, which are, in general, more stable.

Positive Feedback : Conditions for Steady Oscillation

The condition for steady oscillation expressed in terms of feedback, is that if at some point the circuit is interrupted, then an oscillation originating at this point returns to it with the same amplitude and in the same phase after passing through the driving and tuning circuits.[4] For if not, the returning signal modifies the original one; a different amplitude causes the circulating signal to build up or to decay, while a phase shift tends to produce a wave of different frequency. The condition requires the gain in the driving circuit to be equal to the loss in the tuning circuit and the total of the phase shifts in the two circuits to be zero or a multiple of 2π.

The essential property of the tuning circuit is that it transmits different frequencies with different

The frequency of the oscillation, if any, may be imagined to adjust itself to satisfy the phase condition. Then, if the gain of the driving circuit at that frequency is adequate, the oscillation will persist.

Since the driving circuit usually transmits a wide range of frequencies with little difference in phase-shift, the oscillation frequency is determined mainly by the tuning circuit, and its dependence on the properties of the driving circuit is often ignored. As, however, the result is to make the oscillation frequency different from the "natural frequency" of the tuning circuit, it must be considered in a full account of the action of the oscillator.

The adjustment of driving circuit gain, as usually understood, to exact equality with the tuning circuit loss would be impossibly difficult to maintain with normal circuits; yet without it the steady state cannot be reached. The adjustment is, of course, brought about by non-linearity of the amplifier; the ratio of output to input voltage must, at some value of the output, fall. Overloading or non-linearity at some point in the circuit is therefore an essential feature of normal oscillator circuits.

(*To be continued*)

References

1 Herold, *Proc. I.R.E.* 23, p. 1201 (1935).
2 Appleton and Greaves, *Phil. Mag.* 45, p. 401 (1923); Moullin, *Jour. I.E.E.* 73, p. 186 (1933).
3 Baker, *Jour. I.E.E.* 73, p. 196 (1933).
4 Thomas, "Theory and Design of Valve Oscillators," p. 12.

The Cossor-Robertson Electrocardiograph

By K. RICHARDS*

A CONSIDERABLE amount of interest has been aroused in the above instrument due to the fact that it has recently been installed in the Stalingrad Hospital. This electrocardiograph has been considerably improved since it was originally described in 1937 by Robertson.[1] It is a portable instrument for both the visual and photographic observation of the small electrical potentials developed by the heart, by which its condition may be more accurately diagnosed. It can be operated from an A.C. mains supply, or alternatively from dry batteries. The recorder unit is common to both types of power unit and comprises a gas-focused, directly-heated cathode-ray tube with split deflector plates suitably biased for the correction of origin distortion.[2] The screen of the tube has a blue-green fluorescence with an afterglow in total darkness of approximately 10 seconds, thus rendering it suitable for continuous visual observation of the electrocardiogram.

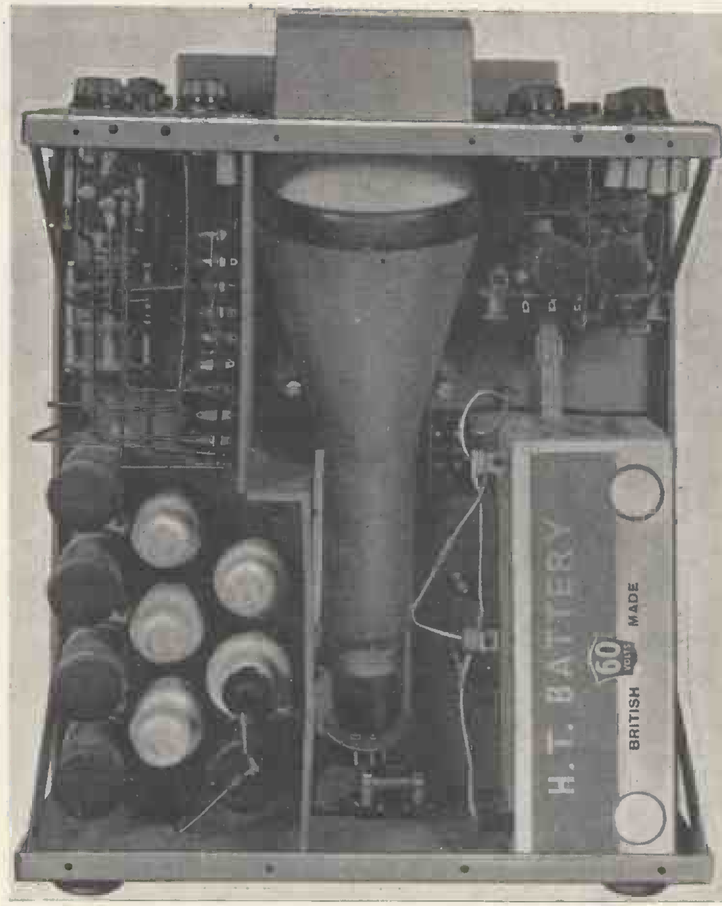

Fig. 1. Recorder unit showing tube enclosed in Mu-metal screen. Time-base circuit (top right); Amplifier and Input circuit (left).

The amplifier circuit comprises three resistance-capacity coupled stages with filter circuits having an overall time constant of 1.33 seconds to cut off the higher frequencies which are not important for electrocardiography. These filter circuits also have the advantage of reducing the amount of screening necessary in the amplifiers and screened leads from the patient to the instrument are not required. The advantage of using a resistance-capacity coupled amplifier over a D.C. coupled amplifier is that it is not necessary to compensate for skin currents and the use of non-polarisable electrodes is obviated. The patient electrodes on the instrument consist of Monel metal cores, which do not corrode in saline solution, wrapped round with cotton wool and bandage and soaked in a saturated solution of saline. These pads can be easily remade and sterilised if necessary. Use of this type of electrode avoids the necessity of using the strap type electrode and electrode jelly. The overall gain of the amplifier to provide a screen deflection of 6 cms. is 80,000 times. A balanced input circuit is also used so that interfering potentials such as pick-up by the patient from the field of electric wiring, etc., can be cancelled out and the patient's heart potentials amplified. By using this type of circuit, interference can be balanced out with the battery unit, even if it is being operated in a building with an A.C. mains supply.

The time-base circuit of the instrument is of a high voltage resistance charged condenser type and is manually operated by a press-button key on the control panel. It provides a screen traverse of 10 cms. with a linearity to within 5 per cent. The speed of the time base can be varied by the selection of one of five charging resistances, giving a speed variation of from 3.3 to 10 cms./sec.

In order to provide photographic recordings as well as a visual trace a clockwork driven film camera is employed having a speed of from zero up to 6 cms./sec., and a tuning fork time marker makes a true 0.1 sec. marking across the record. A mechanism is also provided which automatically marks on the record the respective patient lead which is being used. This is in the form of one, two or three small gaps at the top of each time mark, thus indicating the respective lead and also the top of the record. This marking is caused by small prongs which interrupt part of the light in the time marker slit, and the markings are automatically

* A. C. Cossor, Ltd.

selected by the patient lead switch. The camera drive is of the friction type, and saves the necessity of using perforated film or paper, thereby allowing the full width of the recording material to be used. The loading cassette of the camera accommodates 25 ft. of 35 mm. recording paper or film, and the receiving cassette will accept records up to 10 ft. in length. In order that the trace can be observed during the time that the photographic record is being made, the camera is designed to photograph from the back of the cathode ray tube through a mirror.

The calibration of the instrument is obtained from a resistance potentiometer circuit connected to the valve filament supply, and is controlled by a press-key switch which applies 1 mV to the input of the amplifier. The calibration is set for a spot excursion of 2 cms. for 1 mV input, and the camera lens makes an exact 2 : 1 reduction so that the resultant record is standardised at 1 mV for 1 cm. deflection.

The A.C. mains unit for the instrument is intended to be operated from a 100-250 volt supply having a periodicity of 40-60 cycles, and consists of a voltage doubler rectifier circuit which provides 600 volts for the anode of the cathode-ray tube, and a resistance network is included to give the 60 volts required for the modulator of the tube.

The mains unit is fitted with a moving coil voltmeter embodying suitable shunts to measure the amplifier low tension, amplifier high tension and cathode-ray tube high tension. A neon stabiliser is also incorporated to provide a constant focus, irrespective of slight anode voltage variations. The total power consumption of the instrument is 40 watts.

The battery unit employs two 300 volt batteries for the provision of tube high tension, and a tapping at 60 volts is used for the modulator voltage. A moving coil voltmeter is also used to enable the various supply voltages to be checked.

The advantages claimed for the instrument are : distortionless electrocardiograms due to the fact that the cathode-ray tube is free from inertia effects, and therefore there is no overdamping or overshooting as with electro-mechanical recorders; the records are free from the string shadow, which has been one of the disadvantages of the galvanometer type of instrument; long period examination of the patient can be made without the necessity of taking photographs; the instrument cannot be damaged by overload, and by employing a cathode-ray tube as a recording device there is no possibility of a broken string; the switching for the various patient leads is so designed that there is no delay between leads, as is usual with valve amplifier equipments; by using photographic paper a direct positive is obtained and it is not necessary to make prints; the instrument is very robust and can be serviced by any good-class radio engineer.

References

[1] Robertson, D., *J.I.E.E.*, Vol. 81, 1937.
[2] British Patent 442513 (A. C. Cossor).

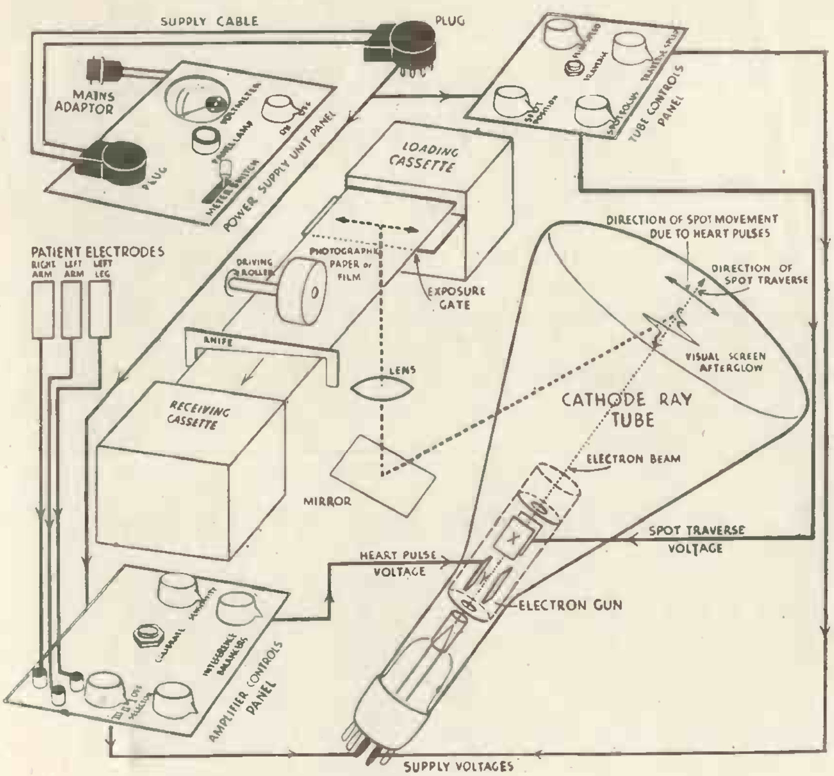

Fig. 2. Schematic diagram illustrating method of photographic recording employed and disposition of controls. *(From Cossor Electrocardiograph Instruction Booklet.)*

Parallel "R" and Series "C" on the Slide Rule

Users of the ordinary 4-scale type of slide rule (*i.e.*, without the reciprocal scale) will no doubt be interested in the following facts which are not generally known :

To find the reciprocal of any number, all that is necessary is to reverse the slider and close rule up fully. Reciprocals of numbers appearing on scale "A" may now be read directly opposite on scale "B" (now upside down). By leaving slider in this position, it is now possible to calculate any combination of resistors in parallel—or condensers in series—without further movement of slider : the cursor only is required.

For, say, 3 resistors in parallel, proceed as follows :—

Set cursor to value of R_1 on scale "A" and note corresponding number on scale "B." Repeat for R_2 and R_3 and add total of numbers on scale "B." Reset cursor to this total on scale "B" and absolute resistance value appears opposite in scale "A."

After a little practice this will be found to be a much quicker method of calculation than the old formula and reduces the operation to one of simple addition. This system may, of course, be used with equal ease for calculating total capacity of any number of condensers in series.

H. E. Smith.


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NOTES FROM THE INDUSTRY

Metro-Vick Research

In issuing a short report on the activities of the Research Department during 1944, Metropolitan-Vickers point out that circumstances do not permit a full report to be issued at the present time.

Among the materials of note that have been investigated are magnetic fluids for crack detection, the Apiezon range of low vapour pressure oils and compounds, and Metrosil, the carborundum product with non-linear resistance characteristics.

The department has also constructed special dryers for penicillin and several complete electron microscopes with a magnification of 10,000. A wattmeter has been designed and made for 500 A. 1,000 v. at 10,000 c/s with a power factor down to 0.02.

Bakelite, Ltd.

A new booklet on Bakelite resins has been issued by the Bakelite Company, covering cements, varnishes and lacquers, together with sealing solutions and filling compound. Copies can be obtained on request from the head office of the company at Brackley, Northants.

Gecalloy Radio Cores

The 1944 list of Gecalloy magnetic dust cores gives general technical data and dimensions of a number of typical cores which are usually available from stock or at short notice. Full particulars and advice can be obtained from Salford Electrical Instruments, Ltd., Peel Works, Salford 3.

British Sound Recording Association

This Association, which was formed in 1936 for the study of problems connected with sound recording on disk, film or wire, has issued a revised leaflet and membership application form. Under present conditions it is not possible to hold meetings, and the membership fee has been reduced. Interested readers are invited to write for further particulars to the Hon. Secretary, Mr. D. W. Aldous, "Strathdee," Studley Road, Torquay.

B.K.S. Scholarships

The B.K.S. have decided to award two scholarships to an annual value of between £25 and £50 tenable at the Polytechnic, Regent Street, for students of the Kinematography Course.

Applications for the awards should be made to the Headmaster, School of Photography, the Polytechnic, Regent Street, W.1. The scholarships are tenable till July, 1946.

Dr. A. P. M. Fleming

The award of a knighthood to Dr. A. P. M. Fleming, C.B.E., M.I.E.E., F.Inst.P. marks the recognition of a long untiring service in the cause of technical education and research.

Trained at Finsbury Technical College, Dr. Fleming joined the Westinghouse Electrical Co. (now Metropolitan-Vickers) and since 1916 has been Director of Research and Education in the company. He was responsible for founding the Research Laboratory which is known all over the world for its work on high voltage phenomena and the discovery of low vapour pressure oils, continuously evacuated plant, and other fundamental electronic developments.

The training scheme for apprentices, founded by Dr. Fleming has served as a model for similar organisations.

For his work in education and research the Manchester University conferred on him the degree of M.Sc. (Tech.) and the University of Liverpool that of D.Eng. He also holds the Faraday Medal of the I.E.E., of which he was president in 1938-39.

Our congratulations to Dr. Fleming on his honour will be shared by a wide circle of friends in the electrical and electronic industry.

Other New Year Honours

Mr. J. M. Lawrence, production manager of the Philips factory has been awarded the M.B.E., and Mr. G. T. Egan, tool room superintendent, the British Empire Medal.

A knighthood has also been conferred on Professor J. Chadwick, of the University of Liverpool, and Professor E. T. Whittaker, of Edinburgh University, lately president of the R.S.E.

Changes

Mr. B. St. J. Sadler has been appointed manager at Messrs. Rediffusion, Ltd. He recently retired from the post of commercial manager at Marconi's W/T Co.

Mr. H. S. Bennett, M.I.E.E., has joined the Philco Group as telecommunications manager and technical adviser to the chairman and managing director.

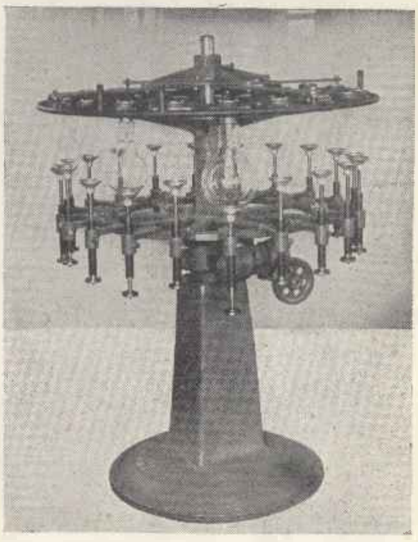
Dr. K. R. Sturley, the author of the present series of articles on Low Frequency Amplification, takes up his new appointment as Head of the Engineering Training Department of the B.B.C. on February 1.

Mr. A. W. Ladner has retired from the post of Principal at the Marconi School of Wireless Communication, Chelmsford, and his successor is Mr. N. C. Stamford.

Dr. Whitehead, the assistant director of the E.R.A. Laboratories, becomes acting director on the retirement of Mr. E. B. Wedmore, C.B.E.

Quadrant Engineering Co.

The illustration shows a new 20-head capping machine developed by the Quadrant Engineering Co. for lamps or valves up to 6 in. diameter and 12 in. long. The heads are specially insulated to minimise heat losses to the frame and the burner ring has one cooling and two heating sections, independently controlled. Full particulars can be obtained from the Quadrant Eng. Co., Imperial Works, Perrin Street, N.W.5.



Abstracts of Electronic Literature

CIRCUITS

Grounded-Grid Radio-Frequency Voltage Amplifiers

(M. C. Jones)

Triode radio-frequency amplifiers have come into extensive use for medium-high-frequency applications. The use of triodes results from the reduced noise-equivalent resistance of a triode amplifier as compared to a multi-grid type amplifier tube. It is not possible with a triode to use conventional circuits with the input into the grid circuit and the output from the plate circuit, because this connexion results in excessive output to input feedback which produces regeneration and even oscillation. The grounded-grid amplifier[1] circuit alleviates these difficulties by utilising the grid as a shield between the input or cathode circuit and the output or plate circuit. Such a circuit exhibits certain peculiarities, particularly when several such stages are operated in tandem. Following is an analysis of the performance of several types of grounded-grid radio-frequency amplifiers.

[1]*C. E. Strong, "The Inverted Amplifier," Electronics*, p. 87; July, 1940.

—*Proc. I.R.E.* Vol. 32 (1944), p. 423.

MEASUREMENT

Testing High-Frequency Cables

(F. Jones and R. Sear)

The paper describes a method for the measurement of electrical impedances, and its particular application to the routine testing of cables in the decimetre wave range. Details of the method and the working equations are given, together with a description of the necessary equipment and its operation. Particular attention is paid to difficulties encountered with the measuring line and its detector, the problem of measuring line calibration, and the effect on measurements of reactive discontinuities at the junction of the line and cable and at the centre line support. The measurement of twin cables with a velocity unbalance is discussed. Full treatment of the theory is given in an appendix.

—*Wireless Engineer.* November, 1944, p. 512.

INDUSTRY

Fluorescent Lighting

(S. E. Pugh)

This article describes some of the constructional and operating features of the fluorescent tube and its associated control gear, and gives some suggestions for the installation and maintenance of fluorescent lighting fittings.

—*P.O.E.E.J.* (Part 3). October, 1944, p. 65.

Efficiency of Induction Heating Coils

(G. H. Brown)

Examination of the action occurring in induction heating of metals, including analysis of current distribution in work coil and load, relation between frequency and coupling efficiency, impedance considerations and discussion of factors affecting choice of frequency.

—*Electronics*, August, 1944.

X-Ray Powder Diffraction Camera

(J. Shearer)

An X-ray powder camera is described which is designed for speed of working. This is achieved (at the cost of certain disadvantages) by improving factors that control exposure time and by eliminating the necessity of any adjustments and of any calibration when these have once and for all been carried out. The camera is applicable to the analysis of soil colloids.

—*Jour. Sci. Inst.* November, 1944, p. 198.

Electronically-controlled Adjustable-speed Motors

(B. T. Anderson)

The author considers electric motor drives in which power, rectified by means of thyratron tubes, is supplied to the armature and field of a D.C. shunt-wound motor and the speed may be varied by adjusting one or other of the two supplies. In addition, the electronic control automatically limits the motor current to a safe value so that during acceleration or stalling the motor will draw only a preset value of current. Three applications of this particular drive to machine tools are discussed.

—*Machinery* (Lond.), 24/8/1944, p. 197.*

* **Abstracts supplied by the courtesy of Metropolitan Vickers Electrical Co. Ltd., Trafford Park, Manchester**

CORRESPONDENCE

Frequency Modulation

SIR,—While post-war plans for television and U.H.F. sound broadcasting are under discussion, it is important that the *pros* and *cons* of F.M. should be understood. Space will not permit a full discussion here; but I wish to correct a misconception which is found even among responsible engineers, that F.M. can give no protection against ignition noise or other similar pulses which have an amplitude much greater than that of the signal carrier. The actual response of an F.M. receiver to very powerful impulsive interference can be summarised as follows:

(1) In the absence of a signal, the F.M. receiver gives no output from impulsive interference.

(2) In the presence of an unmodulated carrier to which the F.M. receiver is accurately tuned, the impulsive interference causes no audible output. If the receiver is not accurately tuned, there will be an audible output, but the amplitude of the pulses in the audio-frequency circuits of the receiver will correspond to a modulation of the carrier of less than 100 per cent., in fact, to a modulation depth equal to the ratio of the frequency error in tuning to the frequency swing corresponding to full modulation of a frequency-modulated signal.

(3) In the presence of a frequency-modulated signal to which the receiver is accurately tuned, the audio-frequency noise pulses are limited to the *instantaneous* level of signal modulation. If the receiver is not accurately tuned, the amplitude of the audio-frequency pulses will be increased by the amount defined in (2) above.

If it is true, as sometimes suggested, that ignition noise is the chief trouble in U.H.F. broadcasting, this summary provides a basis for the comparison of F.M. with other systems, such as wide-band A.M. with audio-frequency limiting.

Yours faithfully,
D. A. BELL.

Amplitude Distortion

DEAR SIR,—I have been reading in the November issue of your journal a very interesting article on L.F. amplification by Sturley and am a little pained to note his frequent use of the term "amplitude distortion" when, in fact, he is referring to "non-linear (or harmonic) distortion."

It is only too true that the use of this term for this purpose has very many precedents and probably, in the contexts in which it is used in this article, there is no serious danger of misunderstanding it. Nevertheless, if agreed standardisation is a good thing, it is undesirable to flout it, and it is a fact that the B.S.I. Glossary has laid down clear definitions of these various types of distortion.

It is, of course, true that amplitude distortion (as defined by B.S.I.) is a form of distortion which occurs hardly at all in radio, except when deliberately introduced as in contrast expanders or compressors: where it is even then achieved to the accompaniment of non-linear distortion. Amplitude distortion, in fact, is principally of interest as being endemic amongst carbon microphones, but it cannot therefore be altogether overlooked. The strongest argument against the misuse of the term "amplitude distortion," when one, in fact, means "non-linear (or harmonic) distortion," is surely that it leaves one no means of describing true amplitude distortion when one is so unfortunate as to meet it.

Yours faithfully,
J. R. HUGHES.

Photo-cell Nomenclature

DEAR SIRS,—Referring to "A Note on Photo-cell Nomenclature," by Dr. W. Sommer, in your December, 1944, issue, we would venture to support in some respects the plea for a better nomenclature and non-ambiguous symbol-shorthand, but we would also venture to disagree with some of the remarks.

We think, generally, that the dot anode in the general photo-cell symbols should disappear in favour of the appropriate bar anode (as in valves in general where it has to collect substantially all of the electronic stream from one or more cathode(s)).

As the old photo-electronic cathode consisting of a semicircle with central connexion now confuses with some magnetron or similar types of electrodes in certain symbols, our feeling is that the semicircular cathode (thus indicated as being emissive under the influence of light) should have its connexion taken from one end as other cathodes.

Under these conditions it does not appear necessary to have the adjacent arrow to indicate some energy impact.

We agree very strongly with the suggestions about light sensitive resistors and in such instances it may be desirable, together with the tidying-up of the symbol, to use some form of impact arrow. We believe it is already a useful practice in some directions, which can still more usefully be extended, to give the resistor symbol, within the circle, a curved arrow (instead of the straight arrow which indicates manual variability) to indicate some non-manual changing.

In a light sensitive resistor, the envelope being indicated by a circle or other surround, the gas dot can be added when required, or the gas symbol (*e.g.*, He=helium) if there is need to be specific.

In regard to a photo-e.m.f. cell, it might be desirable to use the standard symbol for a battery-cell, within the circle, and with the indication of self-change, with or without the arrow to indicate influence impacting.

We feel that it is very important indeed, not only to have simple non-ambiguous symbols, but to have standard units in symbols so that new symbols, as required, can be built up quickly and speedily and can be readily accepted by anyone coming across them for the first time. That is why we suggest the standard anode, and why it seems preferable to have light emissive cathodes with a side connexion; and why we support Dr. Sommer in the light sensitive resistor symbol, and why we suggest the photo-e.m.f. cell symbol.

The British Standards Institution are revising the B.S. Symbols at the present time and it is up to interested parties (through their appropriate organisations, trade or technical), to make representation if they feel strongly on the subject.

We feel sure that the B.S.I. will appreciate constructive criticisms, but if there is disagreement with existing arrangements they should be given constructive suggestions at all times for improvements.

Yours faithfully,
H. T. STOTT,
Technical Director,
A. F. Bulgin & Co., Ltd.

FEBRUARY MEETINGS

*NOTE.—In general, visitors are admitted to the meetings of scientific bodies on the invitation of a member, or on application in writing to the Organising Secretary at the address given. In certain cases (marked *) tickets may also be obtained on application to the Editorial offices of this Journal.*

Institution of Electrical Engineers

All meetings of the London Section will be held at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Radio Section

Date: February 7. Time: 5.30 p.m.
Lecture:
"Aerials for Use on Aircraft—a comparison between fixed and trailing types on the 900-metre waveband."
By:
C. B. Bovill.

Date: February 20. Time: 5.30 p.m.
Discussion on:
"Aspects of Post-war Valve Standardisation."
Opened by:
A. H. Cooper, B.Sc.

Date: February 28. Time: 5.30 p.m.
Lecture:
"Multipath Interference in Television Transmission."
By:
D. I. Lawson, M.Sc.

Measurement Section

Date: February 16. Time: 5.30 p.m.
Lecture:
"The Economic Utilisation of Modern Permanent Magnets."
By:
D. J. Desmond, M.Sc.
The Secretary:
The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Students Section

Date: February 13. Time: 7 p.m.
Lecture:
"The Cathode-Ray Tube and its Applications."
By:
Dr. W. Wilson.
Hon. Assistant Secretary:
R. V. Barton, 27 Church Rise, Forest Hill, London, S.E.23.

Cambridge Radio Group

Meetings held at the Cambridge Technical College.
Date: February 13. Time: 6 p.m.
Lecture:
"The Development of Polythene as a High Frequency Dielectric."
By:
Professor Willis Jackson, D.Sc., D.Phil., and J. S. A. Forsyth, B.Sc.

Date: February 26. Time: 6 p.m.
Lecture:
"The Acoustic Design of Broadcasting Studios."
By:
Alex. Wood, M.A., D.Sc.
Hon. Secretary:
D. I. Lawson, c/o Pye Ltd., Radio Works, Cambridge.

North-Western Centre

All meetings will be held in the Engineers' Club, Albert Square, Manchester 2.

Ordinary Meeting

Date: February 13. Time: 6 p.m.
Lecture:
"Thermoplastic Cables."
By:
T. R. Scott, D.F.C., B.Sc., H. Barron, Ph.D. and J. N. Dean, B.Sc.

Radio Group

Date: February 23. Time: 6 p.m.
Lecture:
Particulars from the Secretary.
Hon. Secretary:
T. T. Evans, 9 Kingston Drive, Sale, Cheshire.

The Television Society*

Date: February 27. Time: 6 p.m.
Held at:
The Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Lecture:
"Vertical v. Horizontal Polarisation."
By:
H. P. Williams, Ph.D.
Lecture Secretary:
G. Parr, 43 Shoe Lane, London, E.C.4.
General Secretary:
O. S. Puckle, 8 Mill Ridge, Edgware, Middlesex.

British Kinematograph Society

Date: February 21. Time: 6 p.m.
Held at:
Gaumont-British Theatre, Film House, Wardour Street, London, W.1.
Lecture:
"Film Production in 16 mm."
By:
E. C. Davey.
Organising Secretary:
R. H. Cricks, Dean House, 2 Dean Street, London, W.1.

The Association for Scientific Photography*

Date: February 24. Time: 2.30 p.m.
Held at:
The Caxton Hall, Westminster.
Lecture:
Spectrography—"Factors Influenc- the Choice of Photographic Materials for Use in Quantitative Spectrography."
By:
D. R. Barber, B.Sc., F.Inst.P., F.R.P.S., and E. H. Amstein, B.Sc., A.R.C.S.
The Secretary:
Association for Scientific Photography, 34 Twyford Avenue, Fortis Green, London, N.2.

Institution of Electronics

North-West Branch

Date: February 2. Time: 7.30 p.m.
Held at:
The Reynolds Hall, College of Technology, Manchester.
Lecture:
"Neon Stroboscopic Lamps—with special reference to lamps of the cold-cathode type."
By:
D. Besso, B.A., and H. Brown, B.Sc.
General Secretary:
L. F. Berry, 14 Heywood Avenue, Austerlands, Oldham.

Bradford Electronics Society

All meetings to be held at the Technical College, Bradford.
Date: February 15. Time: 7 p.m.
Lecture:
"A 700-kV D.C. Electrostatic Generator."
By:
J. F. Smee, A.M.I.E.E. (Metropolitan Vickers Electrical Co., Ltd.).
Hon. Secretary:
G. N. Patchett, The Technical College, Bradford.

Kingston-upon-Hull Electronic Engineering Society

Date: February 9. Time: 7.30 p.m.
Held at:
Hull Corporation Electricity Showrooms, Ferensway, Hull.
Lecture:
"Acoustics of the Electronic Organ."
By:
G. W. Robson, B.Sc.
The Secretary:
H. W. Akester, 720 Anlaby Road, Hull.

BOOK REVIEWS

Handbook of Industrial Radiology

Edited by J. A. Crowther, 193 pp. (E. Arnold & Sons, 21s. net).

This is an excellent book compiled by the members of the Industrial Radiology Group of the Institute of Physics.

Each chapter is written by an expert in the particular branch of the subject and the whole has been welded together to make more coherent reading than is usual in books of collected papers. The opening chapter describes the principles of radiology, the second, the generation and control of X-rays from the industrial viewpoint, then follow chapters on measurement, and choice of photographic materials.

The radiography of heavy and light metals is described and Dr. Mullins contributes a chapter on Uncommon Applications of Radiology with a full bibliography of the various applications.

An interesting contribution, and one which will be new to most radio engineers, is that on Gamma Radiography with examples of technique.

The book is very well produced on good quality paper and is a credit to the members of the Institute of Physics who participated in it, as well as to the publishers.

G. P.

Symposium on Radiography

Published by The American Society for Testing Materials, $4.

The first symposium on Radiography held by the American Society for Testing Materials was held at Detroit in 1935, and the papers read then have been recently published, together with others of a symposium held in 1942.

The book also includes a recommended Industrial Radiographic Terminology which will help to establish the meanings of the terms used and serve as a glossary for newcomers in the field.

One of the articles deals with the G.-E. million-volt portable X-ray unit which can be adapted for the examination of castings *in situ*.

Further articles in the symposium are :—

Miscellaneous Applications of Radiography and Fluoroscopy. By H. E. Seemann.
An Introduction to Gamma Ray Radiography. By N. L. Mochel.
The Problem of Radiographic Inspection. By H. H. Lester.
Some Application of X-Ray Inspection to Prod. Problems. By M. McCutcheon.
Radiography of Welds and Weldments. By R. E. Lorentz.
An Investigation of the Apparatus Used in Radium Radiography. By L. W. Ball and D. R. Draper.
An Exposure Meter for X-Radiography. By H. Freidmann and A. L. Christensen.
A Study of Casette Design for the Radiography of Castings. By L. W. Ball.
Equivalent Penetrameters in Radiographic Testing By R. J. Schier and G. E. Doan.
Precision Radiography. By R. J. Schier and G. E. Doan.
X-Ray Film Evaluation. By F. Danford.
Industrial X-Ray Protection. By L. J. Taylor.

Books reviewed on this page or advertised in this Journal, can be obtained from
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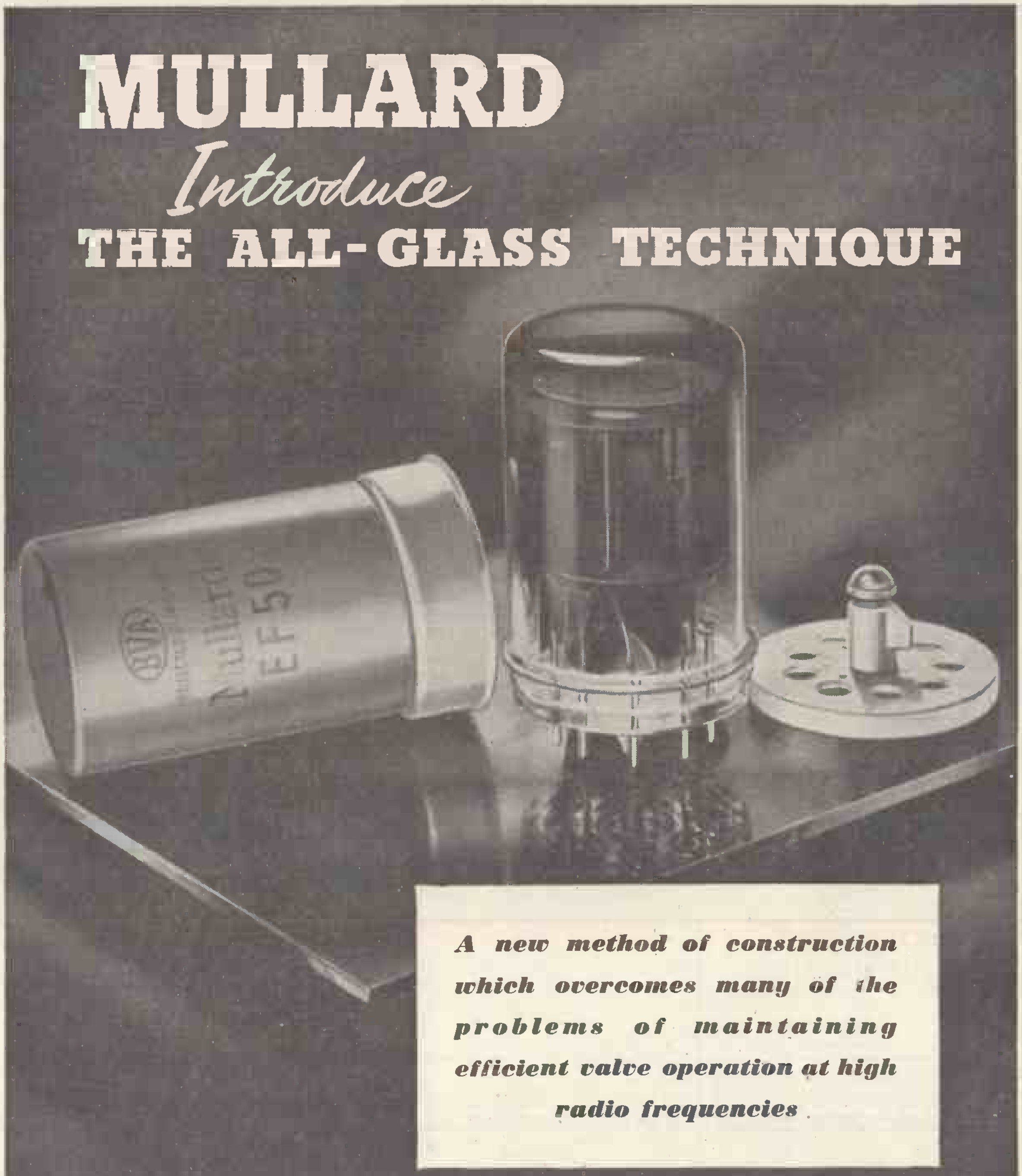
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Classified Announcements (Contd.)

SITUATIONS VACANT

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CATHODE RAY OSCILLOGRAPHS
By J. H. Reyner. Second edition, 8s. 6d. net.

WIRELESS TERMS EXPLAINED
By "Decibel." Second edition, 3s. net.

D/F HANDBOOK FOR WIRELESS OPERATORS
By W. E. Crook. Second edition, 3s. 6d. net.

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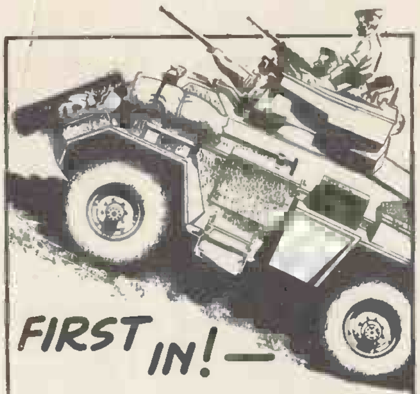

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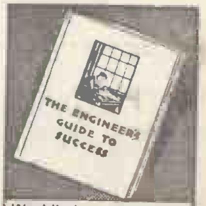

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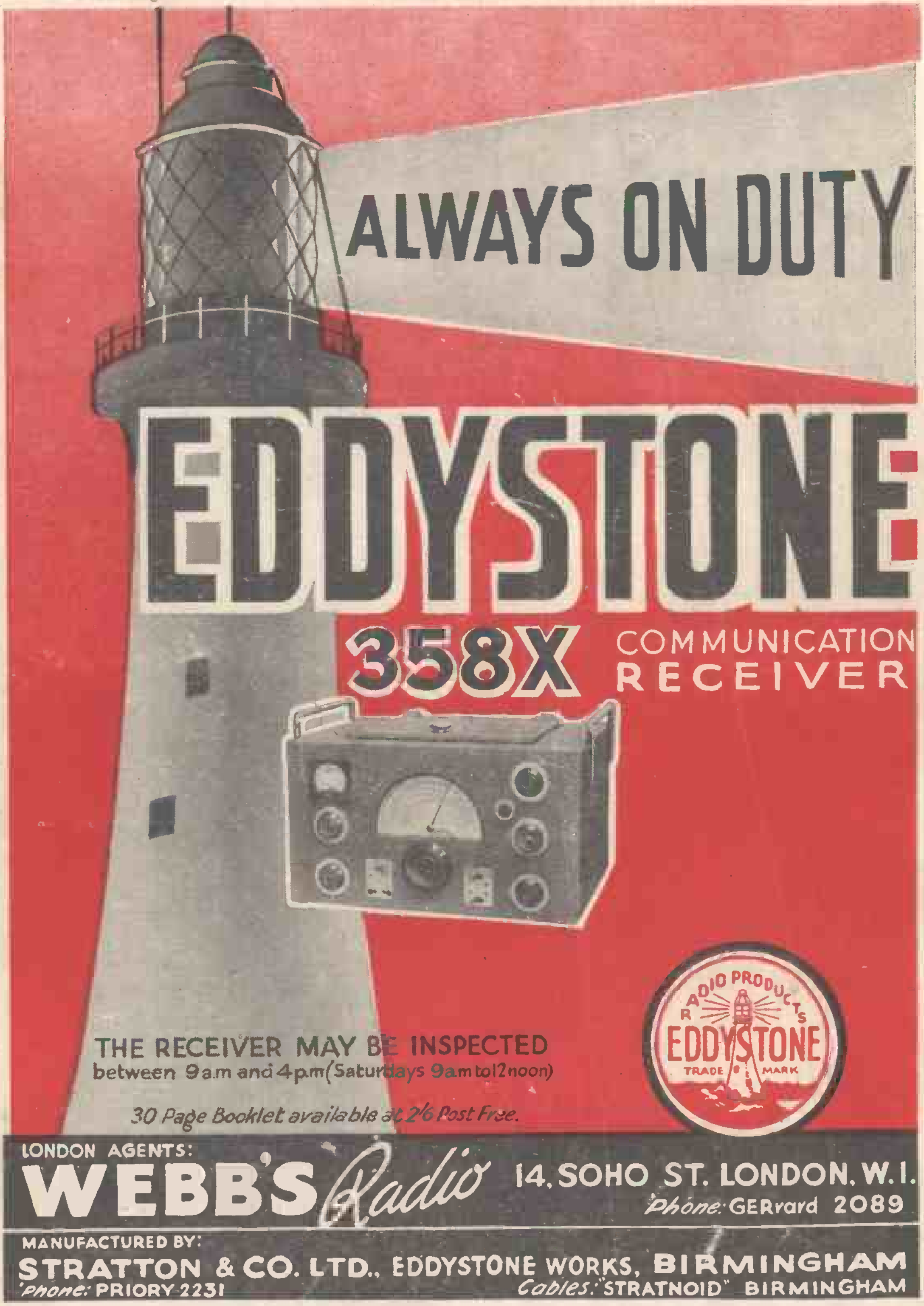

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