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Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

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2/- JULY, 1943

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JULY, 1943

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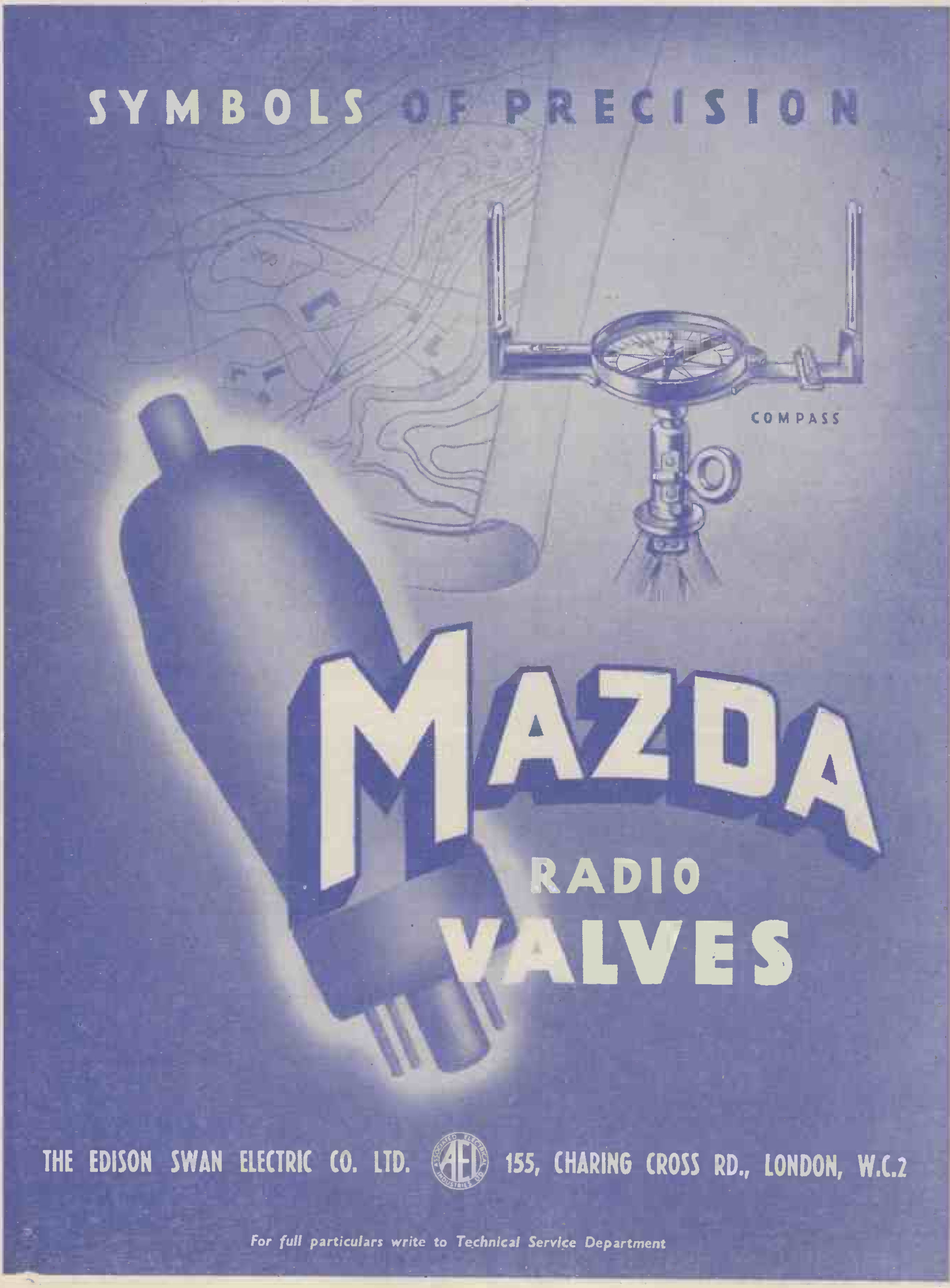
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More Training

LAST month we referred to two memoranda which have been issued on the training of students for science and allied subjects. These have now been followed by a Report on the training of Physicists, issued by the Board of the Institute of Physics.

The report, which has been prepared by a strong committee under the chairmanship of Sir Lawrence Bragg, outlines proposals which will ensure to intending physicists an education which will enable them to make the fullest contribution to the service of the community.

There are two points of particular interest, particularly in these days of universal planning, blue-printing, and general messing about with things for the sake of making a change:

The report expresses its recognition of the valuable features of the existing courses and has no desire to see changes made merely to embody them in some uniform educational system.

Secondly, the main theme of the report is the necessity for physicists to have a broad education, and it is recommended that in the post-School Certificate curriculum at least one third of the available time for study should be spent on non-scientific subjects.

The necessity for physicists to keep abreast of the rapid developments of the subject, and especially of its applications in industry, is reflected in a recommendation that arrangements should be made for post graduate courses both on the theoretical and experimental side of physics.

The committee recognise that there is a definite distinction between the technical college on one hand and the function of the University on the other. They look forward to the time when as a result of the introduction of a State Bursary Scheme and the consequent increase in the number of students educated at universities, the training of technical college students for external university degrees will be a minor function of the technical college.

These views endorse those of the late Silvanus Thompson, who held that the prime function of the Technical College was to train students to be useful and practical engineers and not to enable them to pass examinations for degrees. The value of the degree in physics or any other branch of science seems to undergo a fluctuation like any other fashion, and time was when no employer would look at a research worker without an Honours degree.

(The salary paid, however, was not always commensurate with the number of letters after the employees name). Now the pendulum seems to be swinging the other way, and prospective employees are asked what they have done, and not what they apparently know.

The mean seems to be the satisfactory solution, and the report's recommendation that students at technical colleges should be enabled to obtain some recognised qualification in physics covers the difference between the two educational courses.

Finally, the Committee considers that many students would benefit (many?—all, surely) from some direct contact with industry as part of their training and mention the various ways in which this can be done.

Copies of the Report can be obtained from the Secretary to the Board, Dr. H. Lang, The University, Reading, Berks.

TOO LATE

By the time this Journal appears the official Salvage Week will be over, but the need for salvage of all kinds is still urgent.

It is never too late to put out paper salvage—every bit is used.

Pre-war catalogues, obsolete circuit diagrams, notes, drawings—all will play a vital part in the war effort.

Don't leave your salvage till too late. The war will be over one day, and you won't have helped to win it.

Safety with X-Rays

The Detection and Measurement of Radiation

By A. G. LONG*

THE number of uses to which X-rays are put is increasing day by day: X-ray generators are finding their way into many new fields and the operators of these machines are perhaps using X-rays for the first time. It is for these new workers that this article is primarily intended, though perhaps some of the older workers will be glad to have their minds refreshed.

X-rays, in sufficient quantity, give rise to permanent changes in living tissue, and it was due to ignorance of this fact that the pioneers in X-ray work suffered. It is not, however, proposed to enter into the biological changes due to X-radiation, but it will suffice to say that the effects are detrimental from the point of view of the operator's health. A most important characteristic of X-radiation is that it is cumulative in its effect; that is to say, the effect of radiation received by an operator in the current week will, in the main, be added to any he received in the previous week.

The effects of X-rays depend both upon their quality and their quantity, and both must be known before any definite conclusions can be drawn as to the safety of personnel. By quality is meant the range of wave length of the radiation. By decreasing or increasing the kV. across the tube we can lengthen or shorten the wavelength, the long wave giving the lesser penetration and the short wave the greater penetration. Long wave radiation, or, as it is sometimes called, soft radiation, from a tube at low voltage (30-40 kV.) will not penetrate deeply into the tissues with the result that the superficial layers of tissue absorb a large percentage of the radiation to which they are exposed. Short wave, or hard, radiation penetrates more deeply into the tissues and its effect is, therefore, spread through a greater mass. Now the biological change in living tissue is in the main determined by the amount of radiation absorbed by the exposed tissue, and this is seen to be greater superficially in the case of the long wave radiation, but more far-reaching with short waves.

Tubes operating on pulsating H.T. go through two periods of long wave radiation each half cycle. (*See* Fig. 1). Provided that the work in question does not require this long wave radiation there are two ways of minimising this risk to the operator. The more common method is to fit in the window of the X-ray tube an aluminium filter which is capable of absorbing the maximum soft radiation while interfering but little with the harder radiation. The second method is to equip the tube cathode with a control grid so biased as to cut off electron emission when the anode voltage is below the value needed.†

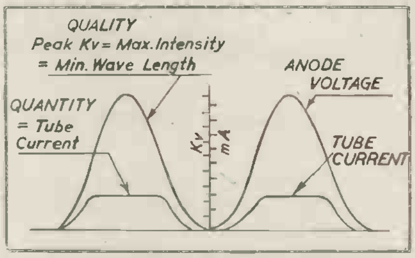


Fig. 1. Quality and quantity characteristics of a tube under full wave operation.

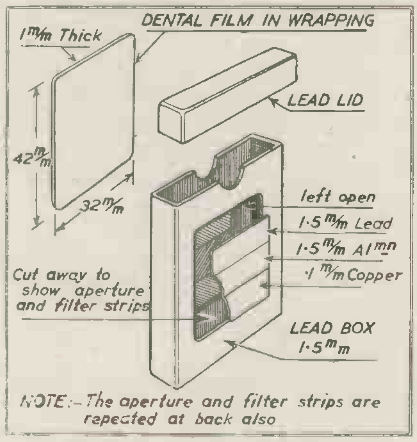


Fig. 2. Operators Test Film box.

Mention must also be made here of what is known as "characteristic radiation." This, as its name implies, depends on the character of the metal of which the tube target is made, and is additional to the general radiation. Each metal requires a definite anode voltage before its particular characteristic radiation becomes evident. For instance, for a tungsten target the necessary minimum anode voltage is 69,200 V, for copper it is 9,000 V, this voltage required to excite the characteristic radiation being proportional to the square of the atomic number of the target material. The higher the atomic number of the anode material the shorter will be the wave length of the emitted radiation, or, all other things being equal, the higher the atomic number the deeper the penetration of this particular component of the radiation.

A very simple rule governs the intensity of an X-ray beam, namely, that it is inversely proportional to the square of the distance from the source. Therefore, if an operator suspects stray radiation he should keep as far away from the source as possible.

The operator should never expose himself to the main, primary X-ray beam, but it is more than likely that he may be in the scattered beam without knowledge of its existence. When X-rays fall on any matter, including the air through which the radiation passes, part of it is scattered, and also secondary radiation is emitted from the matter. The quality of this scattered radiation is mainly the same as that of the primary radiation and is governed by the tube anode voltage at any given instant. This radiation takes place in all directions—a very important point to remember. The secondary radiation has a characteristic wave-length dependent upon the atomic number of the material from which it is emitted in the same way as the characteristic radiation of the tube target. Scatter can again be scattered, each time with a reduction in energy. Ignorance of this property of X-rays often leads to a false sense of security.

Having gained some idea of the nature of the dangers to be avoided, let us see how these conditions can be detected and measured. Perhaps the most simple test for the presence of X-radiation is that of the radiographic film. A double-coated dental film is the most useful for this purpose and is best fitted into a lead test box. (*See* Fig. 2). The box and lid are constructed of 1.5 mm. lead throughout, and the film should fit into the box firmly but not too tightly. An aperture, approximately 28 mm. × 36 mm., is cut both in the back and in the front of the box, the 36 mm. length being then divided up into four sections each of 9 mm. Three of the four sections are covered respectively by a strip of 1.5 mm. lead, 1.5 mm.

* Messrs. Newton & Wright.

† ELECTRONIC ENGINEERING, Feb. 1943, p. 366, fig. 9.

aluminium, and 0.1 mm. copper, leaving the fourth section uncovered. Most dental films are wrapped in paper, but also have a strip of lead foil on one side, which is marked. The side without the lead foil should face the direction from which the radiation is suspected. The test box containing the film can be placed in convenient positions about the apparatus or carried by the operator. The film should be developed after about 40 hours of total test period, based on 5 days of 8 hours duration. The development of the film requires care; the mixture and the temperature of the developer and the time of development must all receive close attention. The blackening of the film exposed by the uncovered portion of the aperture will be the result of radiation of all wave lengths, while the blackening of the areas covered by the various filters, whose function now becomes evident, will be a measure of the radiations of different wave lengths. By careful control quantitative measurement of the radiation can be adduced from the various degrees of blackening by photo-electric measurement of the amount of light transmitted by the developed film. The depth of blackening is brought to a standard by exposing a test film to a radiation of known intensity. For general purposes it is a sufficient gauge of safety to say that if a film under the uncovered portion of the aperture is only lightly fogged the amount of radiation is not dangerous, provided little or no radiation blackening appears in the areas covered by the filters. If the operators carry these test boxes as a routine, carelessness or mistakes come to light in time to prevent serious consequences.

To detect from which direction radiation is coming the device shown in Fig. 3 is useful. The hole which gives the sharpest image lies in the direction of the source of the X-rays.

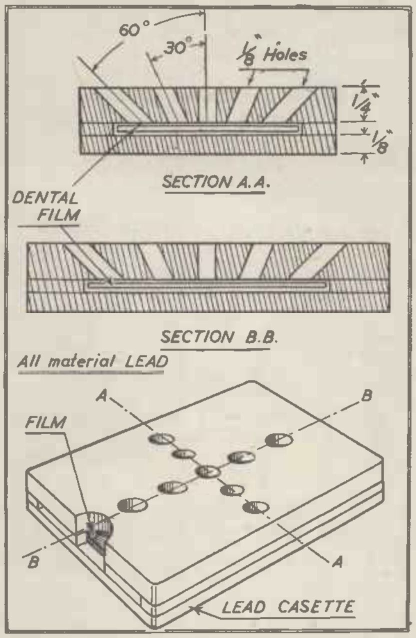


Fig. 3. Radiation direction indicator.

Strong radiation can be detected by means of a small fluorescent screen fitted to the end of a stick. When using this method to explore for radiation the operator should remain in darkness for at least five minutes to allow the eyes to accommodate themselves to the dark conditions. As a rough guide it can be said that an amount of radiation sufficient to make a modern sensitive screen just visible in the position where the operator works, is just safe.

Having discussed some rather rough and ready methods for the detection of X-radiation we shall now see what can be done with more exact apparatus. The electroscope is, of all instruments, the most useful for detecting the presence of X-radiation. The construction of a simple electroscope suitable for rough measurements is shown in Fig. 4, and needs no further explanation. Such an electroscope, when its natural leakage is known, can be converted into a true measuring instrument by the addition of a glass scale to enable one to read the rate of fall of the gold leaf. The scale is, as a rule, part of the eye piece. (*See* Fig. 5).

The electrostatic capacity of the electroscope and the volume of the ionisation chamber will obviously govern its sensitivity, therefore, for accurate measurements of quantity or dose rate the capacity must be kept to a workable minimum. The electroscope can be fitted with a removable ionisation chamber of suitable electrostatic capacity which, when *in situ*, receives the same charge as does the electroscope from the charging source. The chamber is then removed from the electroscope and placed in the position where radiation is suspected; after a time interval of perhaps one hour the chamber is returned to the electroscope and the fall of the leaf will indicate the loss of charge in the chamber due to radiation received, this loss of charge being almost all due to ionisation conduction due to radiation.

In some types of work it is desirable for the operator to carry the chamber on his person in much the same way as the test film. The advantage of the chamber over the test film lies in the fact that the chamber provides a true measurement of radiation quantity when the capacity of the chamber is known. The air volume of the chamber should not exceed 1 cc. The general construction of a chamber and suitable electroscope is shown in Fig. 6.

The capacity of the chamber is chosen to give the most accurate results for the intensity of the radiation

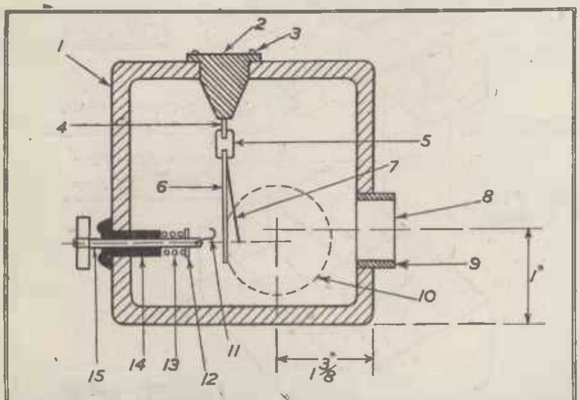
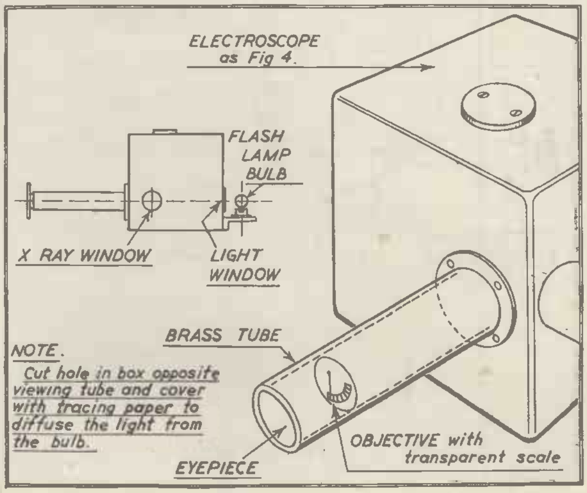


Fig. 4. 1, Box 3" x 3" and 3" from brass. 2. Support bush, brass. 3. Fixing screws. 4. Support rod, brass. 5. Main insulation, Polystryene. 6. Leaf rod Ni. 7. Leaf Al 0.001". 8. Cellophane covering. 9. Shoulder for collimator tube if required. 10. Observation window position. 11. Contact spring. 12. Spring fixing. 13. Spring. 14. Ebonite bush. 15. Charging rod, brass.

Fig. 5.



under measurement, and the volume above-mentioned will be found most suitable for measuring the stray radiation met with in usual practice. In medical treatment by X-radiation special chambers are constructed to measure the dose rate in *r* units. (Roentgen units). The *r* unit is defined as follows: 1 *r*, or 1 roentgen, is the amount of X-ray energy that will, under controlled conditions, produce in 1 cc. of air an amount of conductivity enabling an electric current of 1 electrostatic unit to be transmitted. In medical measuring equipment the radiation received ionises the air in the chamber causing a capacity to discharge to a predetermined value whereupon a counter-mechanism is tripped. The same mechanism re-charges the chamber for the next period. This equipment enables operators to gauge the amount of radiation received by the patient as the chamber receives the same radiation density. Other instruments are constructed to show the dose rate in *r* per minute direct on a scale.

A more delicate form of electroscope can be used to measure scattered radiation, a general idea of which is shown in Fig. 7. Its great value lies in the fact that, when calibrated against available standards, it gives an immediate indication as to the amount of radiation present. The writer, indeed, would go so far as to say that no-one who uses any form of X-ray apparatus should be without this form of radiation detection. The principle of this electroscope is after Lauritsen.

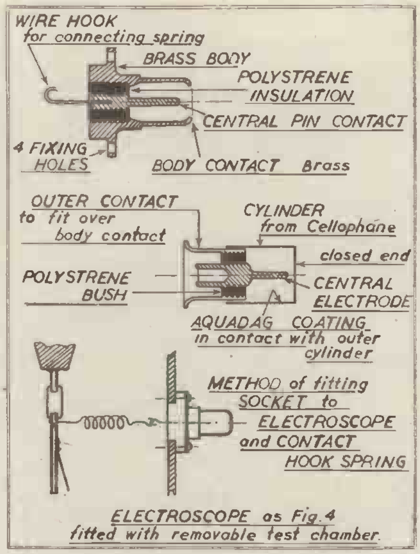


Fig. 6. This diagram is approximately half size.

This instrument can be held in the hand where fairly strong radiation is suspected or can be clamped in a retort stand and placed in various positions about the apparatus. The amount of radiation reaching the chamber enclosed by the aluminium cover box in a given time is revealed by the amount of discharge effected in that time and can be read direct by means of a scale showing the rate of discharge and calibrated in terms of *r* per minute. The time period of this test is determined by the amount of radiation in the particular position. The complete instrument is quite simple to make and the author will be pleased to advise in cases of difficulty. Reference should be made to the books listed at the end of this article which give much useful information. For practical purposes the filtration by the .01″ cover box can be neglected, and if the user has no means of calibrating the instrument in terms of *r* units this will be undertaken by the National Physical Laboratory for a small charge.

Tolerance Dose. From the study of data collected over many years it has been agreed that a dose rate of .2*r* per 8-hour day for a 5-day week is a safe one. The test apparatus used should be capable of reading this rate or some fraction of it. In the case of the test film carried by the operator during his duties, where the quality of the radiation is known within reasonable limits, a 0.5 blackening of the film over a period of 5 days of 8 hours is considered concomitant with safety. The 0.5 blackening is measured by means of a photometer and is the relation between the light transmitted through the exposed unfiltered area and that transmitted by the unexposed

(*Concluded on p.* 84)

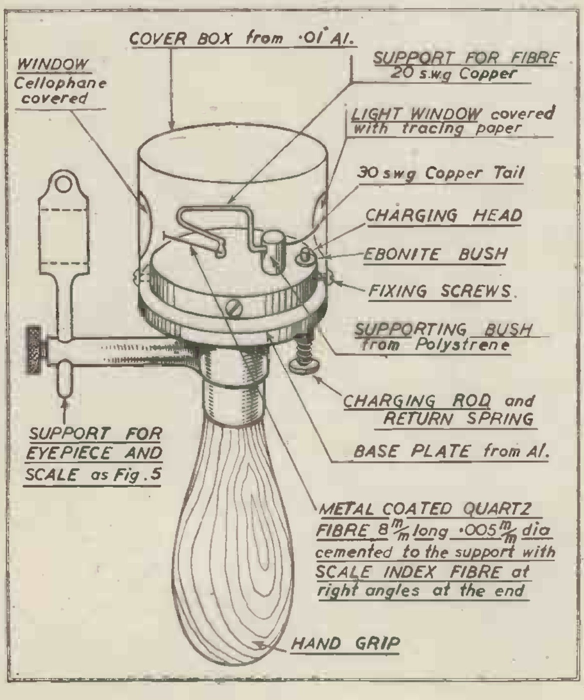


Fig. 7.

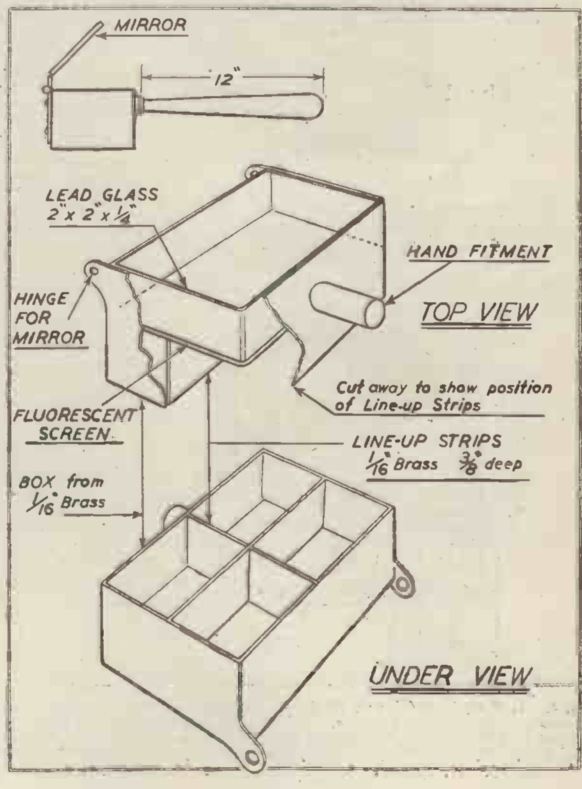


Fig. 8.

Cathode-coupled Push-Pull Amplifiers

By O. S. PUCKLE, M.I.E.E.*

This article, which deals particularly with push-pull amplifiers for time base circuits, forms part of the author's book "Time Bases," and is reproduced by permission of the publishers, Messrs. Chapman & Hall.

Introduction

THE advantages to be gained by the use of push-pull for deflection are so great that unbalanced time bases are rarely employed in cathode-ray tube circuits. If it is essential to employ unbalanced deflection, it is advisable to use an anti-trapezium-distortion cathode-ray tube. The time base in many commercial oscillographs is directly connected to one X-plate and a single-valve phase-reversing stage, *e.g.*, an amplifier having an overall unity gain with the output taken from the anode, is used to supply the other X-plate. In certain cases, where the repetition frequency is low and a rapid fly-back is not essential, it is possible to employ a push-pull transformer, but this solution of the problem is not applicable when it is desired to vary the frequency over a wide range. The insertion of a valve amplifier between the time base and the cathode-ray tube often involves some sacrifice in linearity and in fly-back velocity, although it is possible to arrange the circuit so that the distortion introduced by the valve approximately cancels out the effects of an exponential curvature in the wave-form of the time base. Unfortunately, variations in the gain of the phase-reversing stage are liable to occur and the deflector plates only receive symmetrical potentials if the circuit is kept in good adjustment. A small amount of unbalance of, say, 5 per cent. to 10 per cent. is not serious unless both the horizontal and vertical deflections are fairly large, but this error is not difficult to avoid if the amplifier is provided with negative feed-back to the extent of, say, 50 per cent. to 100 per cent. In these conditions, it is well known that although the gain is greatly reduced, it is influenced only to a small extent by wide variations in the characteristics of the valve while distortion due to curvature of the valve characteristics is likewise reduced.

The amplifier may be used, as indicated above, to reverse the phase of the time base potential applied to one X plate of the cathode-ray tube before application to the other. This method requires that the time base wave-form be generated at the potential level required for application to an X plate.

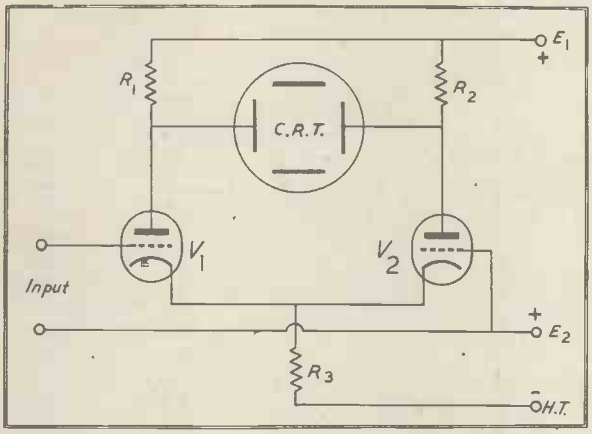


Fig. 1. A cathode-coupled push-pull amplifier.

An alternative method is to generate the time base potential at a low level and to amplify it by means of a circuit which provides a push-pull output of the required potential, the input being an unbalanced one.

Advantages

When the output potential of a time base with the addition of a phase-reversing stage is insufficient to provide the required push-pull deflection potentials, a cathode-coupled amplifier will generally provide a satisfactory solution. This device is suitable for amplifying either the horizontal or the vertical deflection potentials and its attractive features include:

(*a*) Low distortion and relatively small value of grid current when overloaded.

(*b*) Freedom from any tendency to self-oscillation.

(*c*) Absence of "jitter" or hum derived from fluctuations of the H.T. supply potential.

(*d*) Facilities for arranging D.C. connexions at the input and output.

(*e*) Facilities for providing shift, astigmatism correction and balance controls.

(*f*) Facilities for providing sweep expansion.

In the case of oscillographic investigations at very low frequencies the cathode-coupled amplifier is extremely popular and is almost invariably employed as the output stage of the signal amplifier. For time bases, particularly if the repetition frequency is high, the utility of such an amplifier is limited because it is difficult to obtain a rapid fly-back when the anode load resistances are sufficiently high to minimise the effects of curvature of the valve characteristics. However, the features noted above make it very suitable for providing an expanded sweep.

The amplifier is preferably directly coupled to the deflector plates, so that the spot lies at the centre of the screen when the two anode potentials are equal. This automatically provides a foolproof means of adjusting the relative bias on the valves, because the bias adjustment serves as the shift control, and if the valves are wrongly biased with respect to each other the image will be deflected to one side of the screen.

Cathode-coupled Amplifier Circuit

The circuit of a cathode-coupled push-pull amplifier is shown in Fig. 1. In this circuit, the potential across the time base condenser is applied between the grid of V_1 and the grid of V_2 which is held at a fixed potential E_2.

Provided that the common cathode resistance R_3 is made large, so that each valve is capable of behaving like a cathode follower when the other valve is removed or its anode current cut-off, the sum of the anode currents in the two valves will be nearly constant when both are conducting. Thus, any reduction in anode current of one valve is almost exactly balanced by an increase in that of the other. Normally, R_1 and R_2 are made equal and two similar valves are used, but it

* Messrs. A. C. Cossor.

is not usually found necessary to obtain specially matched valves. In order to secure the best results, the values of the resistances should be chosen in relation to the values of the fixed potentials, E_1 and E_2 and the valve characteristics.

When the input potential is zero, the valves are equally biased by the difference between the potential drop across R_3 and the fixed potential E_2. The latter is normally made ten or twenty times the grid base (*i.e.*, the grid volts required to cut-off anode current when the potential between the anode and the cathode is $E_1 - E_2$) so that a small percentage increase in the combined cathode currents is sufficient to change the grid-cathode bias potential from zero to the cut-off point, or vice versa. In these conditions the total cathode current is automatically regulated at a value approximately equal to E_2/R_3 and is not greatly dependent on the valve characteristics or the values of R_1 and R_2. If one valve is removed from the amplifier the potential across R_3 becomes slightly less and the grid-cathode bias on the remaining valve falls, allowing its anode current to increase so that the current through R_3 remains nearly at the original value.

When the grid potentials are unequal, as is the case when an input potential is applied to the grid of V_1, the total cathode current is roughly proportional to the average of the grid potentials, measured from the negative rail, so long as neither valve is cut off. Thus, if the grid potential of V_1 is raised, say 4 per cent., above E_2, the average grid potential rises by 2 per cent. and the total current increases by about 2 per cent., although V_1 may now take practically all the current. The increase of current in V_1 is obtained almost entirely at the expense of the current in V_2. The anode currents of the two valves are complementary and if the anode loads are balanced, almost equal push-pull potential changes are developed. Exact equality of the output potentials from the two anodes is obtainable by making

$$R_2 = R_1\left(1 + \frac{R_{a2} + R_2}{R_3(\mu_2 + 1)}\right)$$

where μ_2 and R_{a2} are the amplification factor and anode impedance respectively of V_2. If it is desired to produce an output having some ratio of potentials other than 1:1, it is only necessary to adjust the anode load resistance values to the desired ratio.

When the input potential is sufficiently negative, V_1 is cut off and V_2 takes its maximum current, although grid current does not flow. Beyond this point, the input potential may be made still more negative without producing any further change in either valve. On the other hand, if the grid of V_1 is made sufficiently positive to cut off V_2, then the cathodes begin to follow the grid of V_1 and the bias on this valve only changes slowly with further increase of grid potential. Although this change is slow by comparison with the changes which occur when both valves are conducting, a point is reached at which the grid-cathode bias is low enough for grid current to commence and further increase of grid potential will produce an increase of grid current. The value of the grid current corresponding to a given overload is small when compared with that in an ordinary amplifier without the protection provided by the high cathode load resistance.

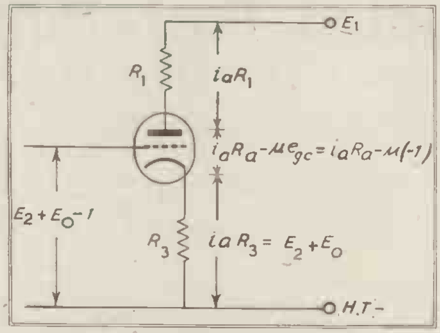


Fig. 2. The conditions existing in the cathode-coupled amplifier of Fig. 1.

Since the changes of anode current in the two valves are nearly equal and opposite, the ratio of the output potentials at the anodes is substantially the same as the ratio of R_1 to R_2, even if the anode loads are very unequal. One aspect of this condition, due to the presence of R_3, is that the output impedance at each anode is high and therefore the output potentials relative to earth are apt to be disturbed by the connexion of external circuits which may apply unequal capacitances or resistances in parallel with R_1 and R_2. When the external impedances have the same ratio as the anode load resistances or appear only between the anodes, instead of between anode and earth, the effects are no worse than would be obtained if the same valves and effective anode loads were employed in a single-valve amplifier or a push-pull amplifier which is not cathode-coupled.

In order to reduce amplitude distortion, the anode load resistances should be made large in comparison with the internal anode impedances of the valves and the two valves should be of the same type. The high impedance of pentodes makes their use unprofitable in this circuit because the anode load resistances cannot be made high enough to reduce distortion. Pentodes and tetrodes may, of course, be used if their screens are connected to the anodes so that they behave as triodes. The reason for the comparative absence of amplitude distortion may be seen from the equation given below. If the amplification factors of V_1 and V_2 are equal and the fixed potential E_2 is large compared with the grid base, the gain from the grid of V_1 to the anode of V_1 is given approximately by :

$$\frac{\mu R_1}{R_{a1} + R_{a2} + R_1 + R_2}$$

where μ is the amplification factor, and R_{a1} and R_{a2} the anode impedances of V_1 and V_2 respectively.

In a triode, μ is relatively constant while R_a varies considerably, depending on the anode current. In a cathode-coupled amplifier, with a pair of similar valves, the variations of R_a tend to cancel each other because R_{a1} increases when R_{a2} decreases and the gain depends only on their sum. The changes of $(R_{a1} + R_{a2})$ are rendered ineffective by making $(R_1 + R_2)$ relatively large. If R_2 is made equal to R_1 the gain becomes, approximately :

$$\tfrac{1}{2}\left(\frac{\mu R_1}{R_a + R_1}\right)$$

where R_a is the nominal anode impedance of one valve. This is half the gain which would be anticipated in a straight-forward single-valve amplifier.

If the resistance R_3 is split into two parallel sections, one in each cathode lead, and if a variable resistance is placed between the two cathodes which are now not directly connected together, the variable resistance will serve to control the gain of the amplifier.*

Design

In order to design a cathode-coupled amplifier, one may choose the value of the anode load resistance R_1 in the ordinary way, making it large compared with the value of R_a, while the required H.T. potential E_1 may be determined by allowing E_2 volts above the value which would normally be required. E_2 should be as high as can conveniently be obtained, at least ten times the grid base corresponding to an anode potential equal to $E_1 - E_2$. The required value of R_3 is then determined from the equation :

$$R_3 = \frac{(E_2 + E_o)(R_1 + R_a)}{E_1 - \mu - E_2 - E_o}$$

where E_o is the grid base of the valve for an anode potential of $E_1 - E_2$. The above equation states the conditions necessary to avoid grid current in V_1 before V_2 is cut off. Fig. 2 de-

* M. L. Jofeh, Brit. Pat. 529044.

picts the conditions existing when V_2 is at the cut-off point, and it will be seen that the grid-cathode potential of V_1 has been fixed at minus one volt in order to prevent the flow of grid current.

If R_3 is made variable, the minimum value should not be less than that given by the above equation. The value of R_2 may be determined from the equation:

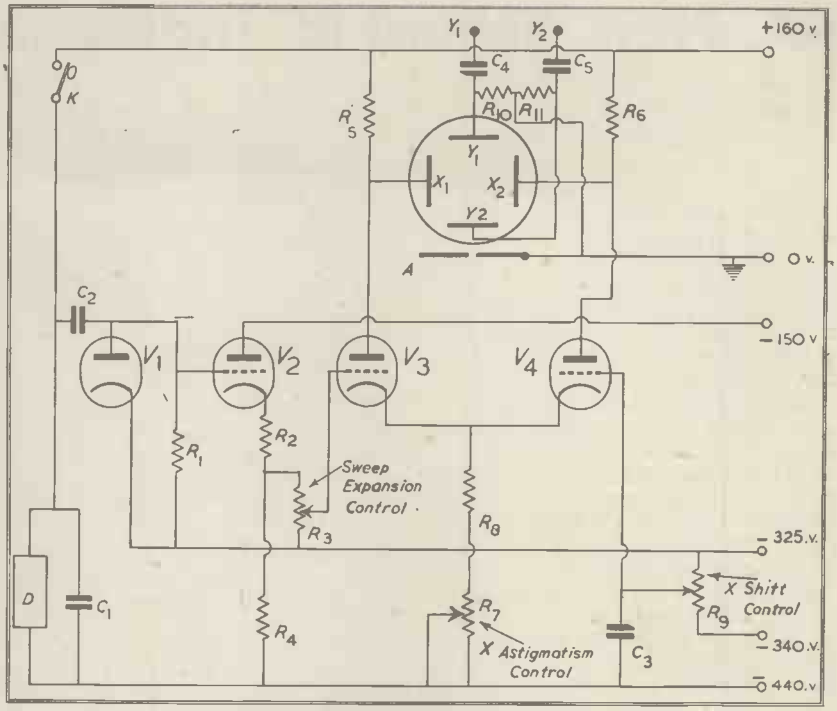
$$R_2 = R_1\left(1 + \frac{R_{a2} + R_2}{R_3(\mu_2 + 1)}\right)$$

or, if precise symmetry is not demanded, R_2 may be made equal to R_1.

It is to be noted that a cathode-coupled amplifier may be designed with comparatively small values for E_2 and R_3 and yet the output potentials may be kept balanced by making R_2 considerably larger than R_1. However, in a design of this type, the variations of anode impedance in the two valves do not compensate each other and distortion is likely to be greater than is the case when E_2 and R_3 are large.

An Amplifier providing Facilities for Sweep Expansion

Fig. 3 shows a circuit for a time base in which a cathode-coupled amplifier is arranged to provide sweep expansion. The condenser C_1 is rapidly charged from the H.T. supply rail by means of any suitable trigger device or gas-filled relay tube (indicated by the key K) and discharged slowly through the constant current device D. The potential across C_1 is applied to the anode of the diode V_1 and the grid of the triode V_2. The effect of the diode is to bring the grid potential of V_2 to a definite potential each time C_1 becomes fully charged. Any leakage of the charge on C_2 is also compensated. The diode therefore acts in the same way as a D.C. restorer and fixes the potential at the commencement of the trace without reference to the extinction potential of the switching device K. The valve V_2 is a cathode follower and the potentiometer R_3 and resistance R_4 are effectively in parallel since, from an A.C. point of view, all the supply rails are at the same potential. The change of potential applied to the grid of V_3 is thus adjusted by altering the position of the slider of R_3, but the value of the resistance R_2 is so chosen that the potential at the grid of V_3 at the commencement of the trace remains constant irrespective of the adjustment of the gain potentiometer R_3. Thus, when the key is closed, R_2 is adjusted to make the lower end of R_3 have the same potential as its upper end. The trace on the cathode-ray tube screen therefore always commences from a fixed point.



COMPONENT VALUES

R_1	2 megohms
R_2	500 ohms (variable)
R_3 and R_4	20,000 ohms each
R_5 and R_6	100,000 ohms each
R_7	10,000 ohms
R_8	30,000 ohms
R_9	50,000 ohms
R_{10} and R_{11}	2 megohms each
C_1 and C_2	dependent upon repetition frequency
C_3	not less than 1 mfd.
C_4 and C_5	dependent upon the frequency of the signal under examination
V_1	D1, EA50 or DDL4
V_2, V_3 and V_4	MH4

Fig. 3. A cathode-coupled amplifier time base providing facilities for sweep expansion.

Since the potential change across C_1 is far more than is necessary to cut off V_2 and V_3 the output potential on the X-plates may be expanded until the whole of the trace is produced by about 25 volts out of possibly several hundred available across C_1, the remainder producing no further deflection. As the potential applied to the grid of V_3 is reduced, a greater percentage of it produces the trace and, as a result, the velocity of the cathode-ray spot is reduced. Thus the sweep expansion does not increase the length of the trace, but it increases the spot velocity so as to open out the first part of the trace.

The value of the fixed bias on the grid of V_4 is controlled by adjustment of R_9. This has the effect of moving the trace bodily in the X direction. Adjustment of the resistance R_7 controls the degree of astigmatism because it changes the mean potential on the anodes of the valves with respect to the final anode of the cathode-ray tube.

The percentage of the repetition period represented by the trace is normally controlled by the expansion potentiometer R_3, but if it is desired to raise the percentage to 100 it will be necessary to adjust the trigger device K so that the maximum potential change across C_1 is only about 50-60 volts.

Since the cathode of the valves, except that represented by D, are all at approximately the same potential, their heaters may be fed from a single winding on the transformer. The heaters should be connected to the −325-volt supply rail. The constant current valve D should have its heater fed from a separate winding connected to the −440-volt rail.

The time constant C_2R_1 must be large compared with T, the repetition period of the time base, in order not to introduce curvature of the waveform. C_3 is made large to eliminate hum on the grid of V_4. The output obtainable from the time base using the components specified is of the order of 300 volts.

A New School of Industrial Radiography

The recent inauguration of the Kodak School of Industrial and Engineering Radiography is worthy of notice because it is the only centre of training in the British Isles which covers this highly specialised field. It is also a very significant index of the growing employment and the widening scope of radiographic methods in the engineering industries.

THE rapid development of industrial radiography under the stimulus of war-time effort created an urgent need for an organised course of specialised instruction in technique which was not offered by an existing technical college or training institution.

On the other hand, the Research Laboratories of Messrs. Kodak, Ltd., have had an industrial X-ray Department established for several years in order to keep abreast of all developments in this field—and the basis of dependable industrial radiography lies in the thorough study of the photographic side of the technique.

In this situation it was logical that the training centre so urgently required should be established by Messrs. Kodak, and although in the nature of a private enterprise the school has been welcomed by interested Government departments, official institutions, and manufacturers of X-ray equipment.

The school was officially opened by Prof. E. N. Andrade, accompanied by Dr. V. E. Pullin, C.B.E., Chief Radiological Inspector, A.I.D., and Group Capt. J. Sowrey, of the A.I.D.

In the period of three or four months since its opening, the school has been attended by students numerous enough and sufficiently diverse in type to provide a thorough test of its organisation and syllabus and to provide evidence of its value as a training centre.

Students who have already attended the course range from beginners to radiographers of considerable industrial experience; and they have included engineers, metallurgists and chemists, some having a specific problem demanding the employment of radiography and others desiring to explore the possibilities and scope of radiographic methods in their particular branch of industry. On account of this wide divergence in the type of students for whom the school is intended to cater, the classes are kept small enough to allow of effective grading—not more than six students take the course at one time. This is one of the main reasons for the success of the school. It allows the teaching given to each class to be adapted to the attainments, experience and interests of the particular group of students: it means that students receive almost personal tuition throughout: and it has the great advantage that students have the opportunity to associate with other workers in the same or a closely allied field.

Altogether it means that the greatest advantage in tuition and experience which can possibly be derived from a highly specialised two-weeks' course is offered. The school is, of course, equipped with this purpose in view. A 200 kV. industrial X-ray set is provided for practical work, and in addition students have the opportunity to familiarise themselves with a 140-kV. set and a 100 kV. set designed for crystal analysis. Processing and viewing rooms which are models of up-to-date practice serve to encourage the high standards of practical technique which critical radiographic inspection demands. One object which underlies the planning of the school throughout is to ensure that the best use is made of the constantly improved X-ray materials now made for industrial use, and that the best results of which these materials are capable in their special fields are realised by the students through the systematic practice of correct procedure. Industrial radiography is itself a rapidly growing technique, and the formulation of dependable standard practice gathered from the best sources and experience is one of the main objects which the organisers of the school have held in view. It is for this reason that the course has been appreciated even by those students with considerable previous of practical work in industry.

Tuition is under the direct personal supervision of L. Mullins, M.Sc., Ph.D., A.Inst.P., who is able to call upon the services of a number of technical experts from the manufacturing side of Messrs. Kodak, Ltd., especially so far as the photographic aspects of the course are concerned.

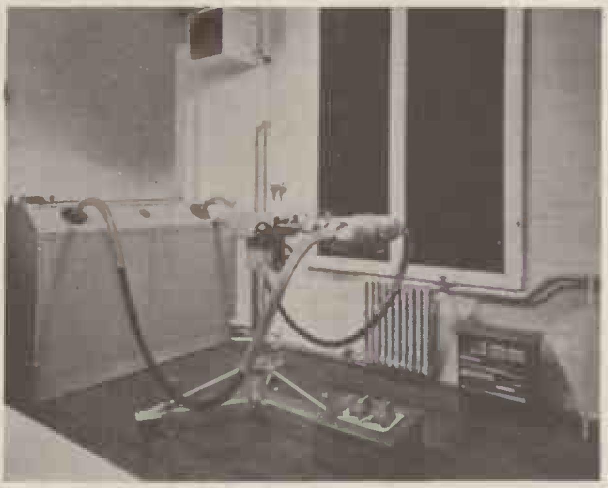
Although the course may be modified for particular groups of students, it generally begins with the fundamentals—with the basic physical principles of radiology, the design and operation of X-ray tubes and circuits, and the characteristics and the behaviour of X-rays, scattered rays and secondary radiation. The next phase of the course goes comprehensively into the photographic aspects of radiography, and leaves the student fully acquainted with the properties of sensitive materials, the fundamentals of sensitometry, the theory and practice of development and after-treatment, and the making of prints and lantern slides from radiographs. This leads to a discussion of the uses of fluorescent and lead intensifying screens, and their effects on exposure, contrast and sharpness: the choice of films for various types of X-ray work; the handling of X-ray films and the defects caused by faulty handling: the viewing of radiographs, and the designing of a darkroom for an X-ray Department. The basis is thus prepared for the main and final section, devoted to radiography proper, in all its aspects and industrial applications. This begins with the arithmetic of X-ray exposures, and the effects of changes in milli-amperage, time, focus-film distance and kilovoltage, with special reference to the necessity for different kilovoltage radiations for different purposes. The alignment and setting-up of specimens, exposures with and without intensifying screens, the use of exposure charts, fluoroscopy, the sensitivity of fault detection, the localisation of defects and the use of steroscopic methods are then dealt with. Then follows the important section covering special aspects of the radiography of light-alloy castings, of heavy-metal castings and of welds, and a number of uncommon applications of radiography. The succeeding section deals with the elimination of scattered radiation, by means of the Potter-Bucky grid and the stationary grid, and the reduction of excessive radiographic contrast and of scattered radiation by the use of filters or blacking media. The regular course concludes with an introduction to gamma-radiography and to X-ray crystallography, and with the design of X-ray departments, particularly from the point of view of the protection of personnel from X-radiation.

Apart from the regular course the School is able to offer special facilities for advanced work extending beyond the syllabus described, in cases in which evidence can be provided of the urgency of the work for which the special training is required. All such advanced courses will be matters of special arrangement and at agreed fees.

Photographs of some of the departments in the School are shown.

Views at the Kodak School

Top (right) : A view of the 200 kV. X-Ray Equipment



Below (right) : The Lecture Room

Above (left) : Film drying equipment and dry bench

Bottom : Part of the Dark room showing the film processing unit

Television After the War

The question of what form the television transmissions will take and how soon they will be resumed after the war has been debated unofficially for some months in radio circles. At the Institution of Electrical Engineers in May last an informal discussion was opened in the Wireless Section by Mr. B. J. Edwards (Pye Radio) on

"Factors determining the Choice of Carrier Frequency for an Improved Television System"

and his remarks, together with those of some of the other speakers taking part in the discussion, are given below.

Mr. B. J. Edwards:

IN opening this discussion, it is necessary first to consider what improvements should be made to the existing television picture, and then to decide how these changes will affect the video and hence the carrier frequency.

The television station at Alexandra Palace, according to published information, transmitted a 2:1 interlaced picture of 405 lines 25 times per second, at a carrier frequency of 45 Mc/s., effectively modulated over a total bandwith of 5 Mc/s. This gave a video band of 2.5 Mc/s., which enabled a horizontal definition of approximately 250 lines to be achieved. It is obvious, therefore, that even with the existing line structure the definition of the Alexandra Palace transmission could be considerably improved if the transmitted bandwidth were increased to say 10 megacycles.

It is possible that sufficient information regarding wide band modulation now exists to enable this to be achieved on the original carrier frequency, but the problem would be difficult. Even with this increased video band, however, I consider that the definition would still be inadequate for reasons that are indicated in the following experience.

Some years ago, while carrying out experiments to determine the optimum viewing distances, I noticed that if viewers were allowed to locate themselves freely before the receiver, they would nearly always show preference for a position approximately four times the picture height from the screen, and not at a distance of approximately eight times where the individual lines cease to be resolved by the normal eye. This suggested that the standard of definition was not adequate since the line structure of the television image was observed at the distance at which the viewer placed himself to avoid eye strain.

This experience has been confirmed by a number of other observers, and it is desirable, therefore, that the image should be such that at the preferred viewing distance there is no obvious lack of definition. This indicates that if the number of lines were approximately doubled, any further increase would be unnecessary, since the line structure would not be resolved by the normal eye.

Assuming for the moment that the frame frequency remains the same, then the first factor determining the choice of a carrier frequency, *e.g.*, the video frequency, can be deduced.

Using accepted formulæ and assuming a picture construction of approximately 800 lines interlaced to produce 25 complete pictures per second, the video frequency arrived at is of the order of 20 Mc/s. This, if we consider double side band transmissions, will necessitate the transmitter being effectively modulated over a bandwidth of 40 megacycles.

From considerations governing the modulation of high frequency transmitters, this means that a minimum carrier frequency of 400 Mc/s will be needed, and it is at this point that the second governing factor, that of propagation difficulties, must be considered.

Interference

One of the greatest difficulties likely to be encountered is interference with the main picture by reflexions of the signal from buildings, etc., which give rise to secondary images displaced by a small distance from the main image.

Evidence of this type of interference was noted on the old television system, and in that case the path difference necessary to give a delay of one picture element was of the order of 500 feet, whereas with the suggested video frequency of 20 Mc/s. a reflected signal arriving with a path difference of 50 feet will result in a delay of one picture element. This means that with a television system of higher resolution, we are faced with the possibilities of considerably greater trouble due to this effect, since reflexion from a greatly increased number of buildings will be resolved.

It should be noted that this interference is primarily dependent upon the video frequency and hence the resolving power of the system and not upon the carrier frequency, although it is likely that at the higher carrier frequencies the reflecting power of buildings is increased, which will result in an increase in the amplitude of the spurious signal.

One method of minimising the effect of these unwanted signals is to increase the directivity of the receiving aerial system by the addition of some form of reflector. To achieve a polar diagram in which the rear and side lobes are very small compared with the main lobe complicates the aerial design and imposes a serious practical difficulty of erection, unless the frequency is such that an extremely small aerial system with a paraboloid reflector can be used. From the point of view of wind pressure and economic factors, it would appear that in practice it would not be possible to use a paraboloid greater than 2 feet in diameter, and preferably not greater than 18 inches in diameter.

Taking the smaller size and assuming that we require a polar diagram which will show a reduction of ten times at $\pm 10^\circ$, it can be shown that a carrier frequency of the order of some thousands of megacycles is necessary.

The use of such frequencies for broadcast distribution, apart from difficulties of generation and detection which I will touch upon later, appears at first sight to be an almost impossible task, since, due to the optical nature of the propagation characteristics of such waves, it would necessitate a line of sight working between transmitter and receiver.

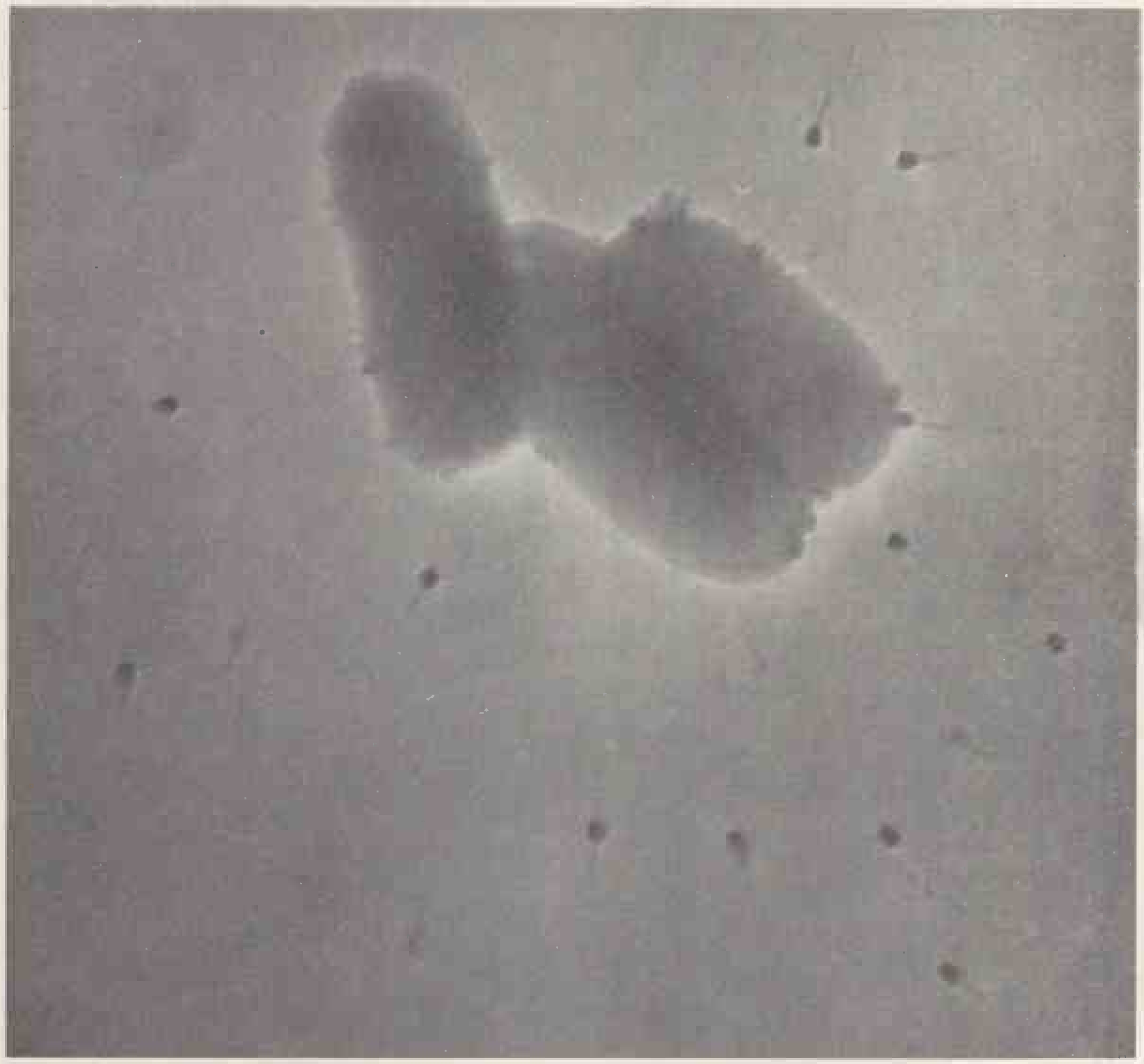
A possible method of overcoming this problem lies in the use of a communal aerial which can be elevated to the necessary height, connected to a suitable detector and amplifier which would distribute the signal at video frequency over a local coaxial cable network.

An incidental advantage of this method is that the television receiver connected to such a system would not require any signal frequency or intermediate frequency amplification or detector, with a consequent saving in cost.

This is a method I would strongly

Unique Electron Micrographs

The Electron Microscope Discovers the Bacteria of Bacteria



BACTERIOPHAGE ANTI-COLI AND ESCHERICHIA COLI × 30,000
(5 minutes in suspension)

The bacteriophages, or bacterial viruses, of which three strains have been identified under the electron microscope are the smallest known living organisms. For some time it was doubtful whether they could be classed as such. The strain here shown, Bacteriophage anti-coli PC is the largest of the three. The " head " has a diameter of about 800 Å, (0.08 microns), the " tail " has a length of about 1,300 Å. One particle of phage is sufficient to originate the lysis of a bacterial cell, and during the lysis an average of about a hundred new phage particles are " liberated." (See next page)

" Great fleas have little fleas upon their backs to bite 'em,

And little fleas have lesser fleas, and so ad infinitum ! "

Ever since Pasteur and Koch laid the foundations of the breeding of pure bacterial strains, bacteriologists were periodically driven to despair by epidemics in their cultures. But little was known of these epidemics until F. W. Twort in 1915 and F. d'Hérelle in 1918 made them the objects of serious investigation. It was d'Hérelle who coined the word " *bacteriophage* " for the cause of the epidemic, and maintained that the phage is an ultramicroscopic living organism, parasitic in bacteria and reproducing itself. Others suspected that the phage could not properly be classed as living, but belonged to the borderland of living matter, like the tobacco mosaic virus, which manifests lifelike qualities only in the presence of living matter. In the years before the war evidence was slowly accumulating to support d'Hérelle's brilliant guess, until finally, in 1940–42 the Electron Microscope decided the question and completed what must be called one of the most thrilling biological discoveries of modern times.

Pfankuch and Kausche[1] and Ruska[2] were the first to discover in electron micrograms of bacteria infected with the phage extremely small particles, remarkably like sperms, but about a hundred times smaller, or like tadpoles, but hundred thousand times smaller. Finally, Luria and Anderson[3] identified them with the R.C.A. Electron Microscope beyond any possibility of doubt.

Two of their brilliant electron micrograms are reproduced here, by courtesy of Dr. V. K. Zworykin, Associate Director of Research of the R.C.A.

(Contd. overleaf.)

Results of an Orgy

BACTERIOPHAGE ANTI-COLI AND ESCHERICHIA COLI × 47,300

The picture shows complete lysis of the bacterial cell after 30 minutes.

Cf. "The Identification and Characterization of Bacteriophages with the Electron Microscope," S. E. Luria and T. F. Anderson, *Proc. Nat. Acad. Amer.*, *28*, 127, 1942.

(By Courtesy of Dr. V. K. Zworykin, R.C.A.)

The first photograph is taken in a culture of *Escherichia coli* which was dried on to a thin membrane, five minutes after it was injected with a drop of a dilute suspension of the *Bacteriophage anti-coli PC*. The drying process has caught the phages vigorously swimming towards the bacteria. We do not know whether they are actually lashing their tails, but if they do the undulations of their tails are shorter than a wavelength of light! A few have already managed to bury their heads in the bacteria. The result of their activity is shown in the second picture, which was taken after the coli bacillus was exposed for 30 minutes to the phage. It shows destruction so complete that the phages themselves seem to be buried under the debris. But there is ample evidence that they have not committed suicide, but have rather indulged in an orgy of procreation. While feeding on bacteria they can multiply their numbers by a factor of about a hundred in half an hour, which shows that a "generation" for them means about the span of four minutes! This beats even the record of yeast which doubles in about 20–30 minutes.

It remains to be seen what benefit practical medicine will draw from these discoveries. D'Hérelle's prophecy that the bacteriophage will become the most potent remedy against infectious diseases may yet come true. But the theoretical possibilities of the discovery are scarcely less interesting The smallest bacteriophage contains only about a million atoms; some investigators consider it as a single giant protein molecule. Yet this molecule shows all the attributes of living organisms. Never before was the problem of life confined to such a small compass, and one must feel that science has made an important step towards its ultimate solution.

D.G.

[1] E. Pfankuch & G. A. Kausche, *Naturwiss.* 28, 46, 1940.
[2] E. Ruska, *Naturwiss.* 29, 367, 1941.
[3] S. E. Luria & T. F. Anderson, *Proc. Nat. Acad. Sci.* 28, 127, 1942.

advocate, since, to my mind, no matter what video and carrier frequencies are ultimately used, it will be necessary to use local line distribution in a large number of areas. Experience in New York with its high percentage of flat dwellers has definitely indicated the necessity for this.

Due to the earth's curvature, it is not possible to transmit over distances much in excess of 15 miles with receiving aerials elevated to the maximum practical limit, which in suburban areas is of the order of 30 feet. Due to this short range and the high aerial gain, it may be possible to dispense with high frequency and intermediate frequency amplification, and use a simple detector followed by a suitable video amplifier. One obvious drawback to such a system is the poorness of selectivity, but this is minimised to some extent by the high directivity of the aerial system.

Consideration of a third factor—that of valves and circuits suitable for use at very high frequencies is rendered difficult since, due to war conditions, no full discussion on this subject can take place. It is reasonable to assume, however, that ultra high frequency technique has made considerable advancement in the past three years, and it is possible, therefore, to hope that the use of very high carrier frequencies may be practicable.

It should be noted here that the power requirements of the transmitter would be modest if the line of sight working were used with a high gain receiving aerial, and, as I have previously pointed out, it may be possible under these conditions to use a simple detector followed immediately by a video amplifier. In these circumstances, a transmitter power of only a few hundred watts may suffice.

This brings me to my fourth and last factor—that of cost. This is possibly the most important of all since it is obvious that all the foregoing factors are influenced by economic considerations. If we assume for the moment that we shall be forced to use the very high carrier frequency for an improved television system, then the possibility of increased cost of transmission and reception must be considered.

Firstly, the reduced coverage of high frequency systems would necessitate the use of a large number of transmitters, but this increased cost would to some extent be balanced by the reduced cost per transmitter since the power requirements are considerably lower.

It is possible that the service area of the existing television transmitter at Alexandra Palace can be covered by, say, six low power transmitters suitably positioned to take advantage of any increase in elevation due to hills or high buildings in the area.

An additional cost of such a system of distribution would be in the provisioning of links between the main transmitter and the relay transmitters. This would probably be best accomplished by highly directive centimetre links, the cost of such links being comparatively low.

Secondly, due to the higher carrier frequency, greater video bandwidth, and possibly a different form of picture reconstituting device, it is reasonable to expect an increase in the cost of the receiver, although this may not be as high as one might at first expect, due to the continual improvements in manufacturing technique.

Mr. Lawson (Pye Radio) :

I have been interested in Mr. Edwards' reasons in favour of increasing the frequency of television transmission, particularly in the implications of this with regard to multipath interference.

If we consider the programme radiated from Alexandra Palace we find that the time between successive picture elements is 2/5 microseconds and therefore if the transmission is reflected from a building so that a path difference of 400 ft. corresponding to a time delay of 2/5 microseconds is introduced, we shall see a ghost picture displaced one picture element to the right of the main picture. Delays of less than one picture element, although effectively reducing the definition of the received picture, will not cause a ghost picture to be resolved and will therefore be less harmful.

Zones of Freedom from Interference

For any given position of the transmitter and receiver, we can construct a surface on which all reflecting bodies give a delay of one picture element. Reflexions from bodies outside this zone will be serious, while reflexions from inside will be less harmful. The surface will be an ellipsoid of revolution with the transmitter and receiver at the foci. It may be shown that the minor axis of this ellipse is inversely proportional to the number of lines used in transmission. The major axis of the ellipse will be the distance between the transmitter and receiver together with the distance a radio wave travels in one picture element. Some idea of the magnitudes involved may be obtained from the following figures :—

Distance of Transmitter 10,000 *metres.*

Definition	*Major Axis*	*Minor Axis*
405 lines	10,120 m	1,520 m
810 ,,	10,060 m	760 m

The aim, therefore, would be to confine the directivity of the receiving aerial to the region inside this ellipsoid. It should be noted that we cannot do this altogether because we have to look at the transmitter, and hence at the region beyond, but fortunately the transmitter aerial is usually placed high above any reflecting building and so we are not likely to be troubled by reflexions from the transmitter end of the ellipse.

The sceptical person may now say that this is all very well, but after all we did get a tolerably good picture at a frequency of 45 Mc/s and that the receiving aerial was not particularly directive. This is true, but it will not necessarily be true as the carrier frequency is increased. A body may either reflect or scatter the incident radiation depending on the size of the body and the transmitted wavelength. If the wavelength is long, *e.g.*, corresponding to 45 megacycles, normal sized buildings (< 40 m. square) will scatter the incident radiation, and the amplitude of the received scattered wave will, among other things, be *inversely proportional* to $R_1^2R_2^2$ where R_1 and R_2 are respectively the distances from the building to the transmitter and receiver. The product R_1R_2 varies as we move our building round, the ellipse being small when the building is behind the receiver and increasing rapidly as the building moves to the end of the minor axis. Thus we can see that on the long wavelengths the important buildings lie behind the receiving aerial, and the directive system is required only to discriminate against these reflexions. The situation is very different on centimetre wavelengths. Here the buildings are big enough to cover many Fresnel zones and behave as perfect reflectors. This means that the reflected amplitude from the buildings is inversely proportional to $(R_1 + R_2)^2$ and hence is independent of the position of the buildings on the ellipse. It is, therefore, necessary to restrict the directivity of the receiving aerial and fortunately, as has been pointed out, this becomes easier as the frequency is raised. Another favourable factor is that since reflexions on very high frequencies will be specular, the buildings would have to be correctly orientated before the reflected signal could be received.

Conclusion

I may summarise the situation in the following manner. If the wavelength is long, the bulk of the interference will come from buildings situated to the rear of the receiver. At very high frequencies interference may come from bodies situated in all directions with respect to the receiver, providing they are correctly orientated to give a reflexion. There will be an ellipsoidal surface within which reflexions from buildings give delays in the reflected signal of less than one picture element, and it would be preferable to confine the directivity of the receiving aerial to this zone.

Mr. O. S. Puckle (A. C. Cossor) :

Mr. Edwards' opening remarks, while being, in my opinion, unduly pessimistic, provide a very fine basis for discussion of the multiple problems existing in post war television.

There are two points which I would like to stress.

The first is that it is of the utmost importance that no television transmission should take place in this country after the war which employs the old transmission standards, unless it is made perfectly clear that it is only a temporary service, and unless the manufacture and sale of further television receivers employing these standards are forbidden. This is necessary in order to avoid creating a large quantity of receivers in service which would render it impossible, within a reasonable period, to bring the transmitting system up to date. Since it is more than likely that the Alexandra Palace transmitters and aerials are not now in a fit working state, and could not easily be made so, it is probable that it would be advisable to ban any such transmission even of a temporary nature. It should be pointed out that the 2 year period during which no alteration of the television standards would be made had expired at the commencement of the war. There would thus be no question of breaking faith with those who have purchased receivers.

My second point is that I would strongly disagree with Mr. Edwards' suggestions for the use of communal aerials and the distribution of the signal via video frequency local coaxial cable net-works. This scheme, while proving excellent for blocks of flats and for the special conditions which exist in densely packed areas having very high buildings, such as New York, would not prove suitable in the average London residential neighbourhood. In any case, Mr. Edwards is not, I feel, justified in requiring the use of such a short wave length and it would appear to me that a maximum frequency of 100 Mc/s is quite as far as one need go at the moment. It is possible, of course, that in 10-15 years' time, we may require to go to shorter wave lengths if, by that time satisfactory colour or steroscopic television becomes a feasible project. At the present moment, there are transmission limitations which render it uneconomical to broadcast scenes in either of these forms.

Mr. L. H. Bedford (A. C. Cossor) :

The proposal that television transmission should be carried out on centimetre wavelengths only is one of great boldness, and has many attractive features. It seems, however, that the numerics by which the method is shown to be a unique solution are not entirely satisfactory.

To review this, we must refer to the formula :—

$$f = \tfrac{1}{2}a^2Rn \quad \ldots \quad \ldots \quad (1)$$

which has been said to relate the required video band f to the number of lines a, aspect ratio R and picture repetition frequency n.

In interpreting any such formula we should first of all note an element of paradox; to express it dramatically we may say that the equality reads only one way, namely, right to left. To the question "What frequency band is required for number of lines a?" there is no answer; the definition continues to improve progressively with increase of frequency band. However, there is an answer to the question "Given a frequency band f, what is the optimum number of lines a?" Thus to make formula (1) a significant statement, we must interpret f not as the required frequency band, but as an assigned frequency band for which the number of lines, a, is optimum.

Even with this understanding, formula (1) requires amendment. First, we must read a as the actual number of picture lines as distinct from the gross number including the lines absorbed in flyback and masking. Next we must replace n by $1/T$ where T is the actual time in which the nett picture is scanned. Thirdly, we have to apply an empirical constant k to allow for the fact that the expression on the right hand side is merely the fundamental frequency corresponding to alternate black and white squares spaced at line pitch, which is clearly proportional to the desired quantity f, but not necessarily identical with it.

With these modifications, the formula becomes :—

$$f = \tfrac{1}{2}ka^2R(1/T) \quad \ldots \quad \ldots \quad (2)$$

Kell, Bedford and Trainer (*Proc. I.R.E.*, November, 1934) gave an empirical value of k for sequential scanning at 0.64. The present writer has determined an almost identical constant, 0.66, for the case of interlaced scanning. The latter constant arises from the consideration that with interlaced scanning one cannot take full advantage of the close line-pitch owing to the tendency for eye movement to result in untying of the interlacing by stroboscopy. In round terms, therefore, we may write for either interlaced or sequential scanning :—

$$f = \tfrac{1}{3}{}^{2}R(1/T) \quad \ldots \quad (3)$$

as relating an assigned frequency band f and the optimum number of scanning lines a. This formula leads to the following numerics :—

	a (gross)	*a* (nett)	*R*	*T*	*f*.
Alexandra Palace ...	405	385	1.25	.0323 sec.	1.9 Mc.
B. J. Edwards	800	770	1.25	.0323 sec.	7.6 Mc.
	525	500	1.25	.0323 sec.	3.2 Mc.

Now as regards the required number of lines, it seems that the argument which leads to the proposal for 800 lines is a little arbitrary. The present writer has made repeated tests of viewing angle in the cinema and finds that an acceptable viewing distance for a good priced cinema seat is 6 times the picture height. Surely television audiences should not expect a wider viewing angle at home than they would get in the cinema. If we accept that a 405 line interlaced picture is viewable from 8 times picture height without line resolution (including stroboscope effects), the increased number of lines required to allow the viewing distance to be reduced to 6 times picture height is $8/6 \times 405 = 540$ say, 525 lines on considerations of factorisation.

This standard is exhibited as the third line of the table above and it is seen that a 3.2 megacycle video band allows us to offer a 525 line picture. This should be transmissable on the existing order of carrier frequency and at the same time offers a picture which properly interpreted in terms of brightness, contrast, picture size and spot size, should be adequate for all normal domestic requirements.

A further selection from the contributions to the discussion will be given in the next issue.

In the meantime, readers are invited to send in their own views, which will be published in so far as space permits.

Sibilant Speech Sounds

The Elimination of Relative Spectral Energy Distortion in Electronic Compressors*

By BURTON F. MILLER

FOLLOWING the installation of electronic compressor units in all the recording and re-recording channels at Warner Bros. studios, it was consistently noted that sibilant speech sounds were reproduced with unusual prominence, occasionally being exaggerated to the point of being reproduced as harsh whistling tones when these sounds were stressed in the original speech. For a time this effect was attributed to the residual high-frequency distortion in the recording and reproducing channels, and numerous circuit developments were studied and employed to minimise such distortion. Meanwhile, the process of re-recording was hampered since it was impossible to remove the objectionable sibilance merely by introducing a suitable value of high-frequency equalisation in the re-recording channel without, at the same time, producing a finished sound-track that was definitely lacking in high-frequency signal energy content.

It was found necessary, therefore, to reduce the energy content of the numerous exaggerated sibilants in each reel of sound-track prior to re-recording by manually applying a layer of semi-opaque ink over each of the offending sections of the record. This process, needless to say, was both time-consuming and costly, since it was necessary to reproduce each reel of the master re-recording print several times to permit locating the objectionable sibilants with reference to the sound-start mark, and then to "paint-out" manually the corresponding sections of the track. On the average, from thirty to fifty such spots would appear in each reel of dialogue track, requiring approximately two hours of work for the location and "painting-out" of these sections.

It soon became evident that all attempts to reduce the excessive prominence of recorded sibilants through reduction of high-frequency channel distortion were accomplishing almost nothing, and that the cause of the difficulty being experienced was likely due to some factor that had thus far been completely ignored.

In consequence of the above conclusion, attention was directed to the results of the several statistical studies of the spectral distribution of speech energy. Notable among these is the paper by Dunn and White,[1] outlining the results of recent studies on this subject at the Bell Telephone Laboratories. The curves and data presented in the Dunn and White paper indicate that while no single curve can be taken as universally representative of the distribution of speech energy throughout the audio-frequency band, it is nevertheless possible to arrive at statistical averages of speech-energy distribution that can, in any event, be employed to determine the probable energy relationships existing between different portions of the normal band of speech frequencies.

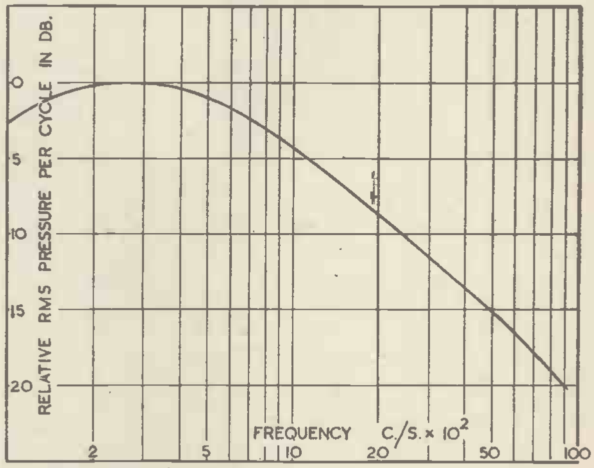


Fig. 1. Average relation between rms. speech-pressure per cycle and speech component frequency.

The curve in Fig. 1 represents a "smoothed-over" relationship between root-mean-square speech-pressure per cycle, and frequency, which has been prepared from data taken from the Dunn and White paper. The averaging process employed in obtaining this curve ignores the normal differences in energy distribution between male and female voices, as well as the departures from a smooth curve that actual measurements of speech-energy distribution indicate. In view of the use that is to be made of the above curve, however, this averaging process is believed legitimate.

Assuming this curve to be representative of the relative pressure distribution with frequency for the various frequency components of each spoken work, it may, in general, be observed that the pressures corresponding to the lower-frequency vowel sounds of speech are many times higher than those corresponding to the higher-frequency sibilant sounds. Correspondingly, the low-frequency components of speech signal voltage in the recording channel will normally be many times greater in amplitude than the high-frequency components. If the total amplification of the recording channel is made an inverse function of the instantaneous signal voltage at some point of the recording circuit, as is done when electronic compression is employed, the channel amplification may be expected to be notably higher when speech sibilants are being recorded than when vowel sounds are traversing the recording system. Such a condition gives rise to a form of amplitude-selective frequency distortion, which will be incapable of correction by any straightforward process of signal-frequency equalisation during reproduction of the sound record.

This situation may, perhaps, be clarified somewhat by a simple analytical treatment of the several factors involved. In a normal amplifier system the overall amplification may be defined as the ratio of the amplifier output voltage E_o to the amplifier input voltage E_1. This ratio may be a function of signal frequency, but throughout the working range of signal input levels, is independent of signal voltage. Presuming the amplification to be made independent of frequency as well, the ratio of ampli-

* Reproduced with slight omissions from the *Journal of the Society of Motion Picture Engineers*, (Nov. 1942).

fier output to input voltages may be expressed as

$$\frac{E_o}{E_1} = \mu_a \qquad \ldots \quad (1)$$

were μ_a is constant.

In the case of the electronic compressor, however, the amplification obtained is purposely made a function of a tube electrode control-voltage e_c. This control-voltage is normally derived by rectifying a portion of the compressor output voltage, which is then so applied to the amplifier tubes that the expression for amplification through the compressor generally takes the form

$$\frac{E_c}{E_1} = \frac{\mu_c}{(e_c)^m} = \frac{\mu_c}{(k_1 E_o)^m} \qquad \ldots \quad (2)$$

where μ_c and k_1 are constants, and where the exponent m varies from approximately zero at low values of E_o to a positive limiting value approached as E_o assumes progressively higher values.

Solving Eq. 2 for the ratio E_o/E_1 in terms of the input voltage E_1,

$$\frac{E_o}{E_1} = \mu_e(E_1)^n \qquad \ldots \quad (3)$$

where μ_e is a constant, and $n = -m/(m + 1)$. A curve showing the actual relationship between compressor amplification and input signal level at constant frequency for the compressors employed at Warner Bros. studio is shown in Fig. 2, the amplification being expressed in decibels rather than in the arithmetical ratio employed in Eq. 3. It will be noted that throughout the greater portion of the compression range of input signal levels, the exponent n employed in Eq. 3 would correspond to approximately -0.5.

Returning to consideration of the expression for compressor amplification, let it first be noted that the compressor input voltage corresponding to a speech signal may be written as

$$E_1 = A\sigma(f) \qquad \ldots \quad (4)$$

where A is a constant for any single word, and where the function $\sigma(f)$ expresses the relationship between probable speech-pressure per cycle and frequency as given by the curve of Fig. 1.

Combining Eq. 3 and Eq. 4, the compressor output voltage is given by

$$E_o = \mu_e(E_1)^{n+1} = \mu_e A^{n+1}[\sigma(f)]^{n+1} \qquad (5)$$

In this equation the factor A^{n+1} indicates that the amplitude of the compressor output signal is a non-linear function of the input signal amplitude, and is indicative of the fact that amplitude compression may be obtained. On the other hand, it is also evident that the normal spectral distribution function $\sigma(f)$ has been distorted to the new distribution function $[\sigma(f)]^{n+1}$. It is this latter distortion of the compressed signal that is, in general, responsible for the excessive prominence of speech-signal sibilants in the recorded signal. A simple example may serve to indicate the relative magnitude of this distortion.

Assume that the word *say* is to be recorded. If the predominant frequency[2] of the sibilant *s* is assumed to be approximately 6,000 c/s, while that of the vowel *a* is taken as approximately 500 c/s, reference to Fig. 1 and Eq. 4 indicates that the probable amplitude of the signal delivered to the compressor input terminals which corresponds to the *s* sound will be approximately 15.5 db lower than that corresponding to the *a* sound. Assuming a value $n = -0.5$ for the exponent in the compressor output-voltage equation (Eq. 5), the signal corresponding to the *s* sound at the compressor output terminals will be only 7.75 db lower in amplitude than that corresponding to the *a* sound. In other words, the *s* sound has been exaggerated 7.75 db relative to the *a* sound.

A clue to the method of correcting the distortion just described is offered by the form of Eq. 2. Let it be assumed that before the compressor output voltage is delivered to the compressor control rectifier, the portion of the output voltage employed for control purposes is equalised to the form

$$E_o' = \psi(f)E_o \qquad \ldots \quad (6)$$

where the form of the function $\psi(f)$ is as yet unspecified. Substituting Eq. 6 for E_o in the right-hand member of Eq. 2, and solving for the ratio E_o/E_1, one obtains

$$\frac{E_o}{E_1} = \mu_e(E_1)^n[\psi(f)]^n \qquad \ldots \quad (7)$$

Substituting Eq. 4 in Eq. 7,

$$\frac{E_o}{E_1} = \mu_e A^n[\sigma(f)]^n[\psi(f)]^n \qquad \ldots \quad (8)$$

If, then we set

$$\psi(f) = \frac{k}{\sigma(f)} \qquad \ldots \quad (9)$$

k being a constant, the right-hand member of Eq. 8 is independent of the normal frequency distribution of speech energy.

Electrically, the correction implied by Eq. 9 is obtained by inserting an equaliser between the compressor output terminals and the control-rectifier input circuit, the loss-characteristic of this equaliser being designed to vary with frequency according to the inverse of the pressure-frequency distribution curve of Fig. 1.

In conclusion, it may be stated that recordings made with the modified form of compressor are singularly free of any tendency toward exaggerated sibilance, yet exhibit a normal brilliance equivalent to that obtained during reproduction of normal uncompressed recordings.

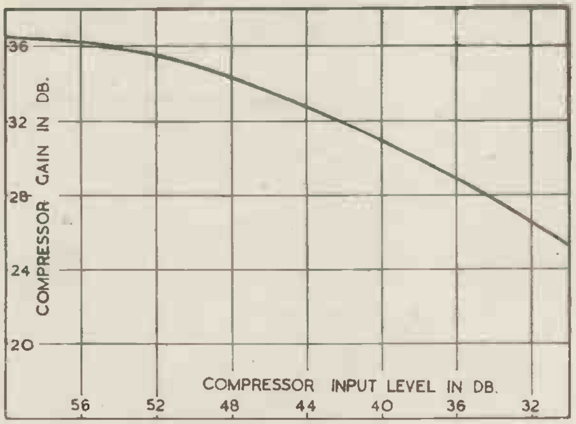


Fig. 2. Relation between compressor amplification and compressor input signal level. Reference level employed is 6 mW.

1 Dunn and White : "Statistical Measurements on Conversational Speech," *J. Acoust. Soc.Am.* 11, (Jan) 1940, p.278.

2 Fletcher, H. : "Speech and Hearing," D. Van Nostrand Co. (New York) 1929, pp. 56-62.

Cadmium Plating for Variable Condensers

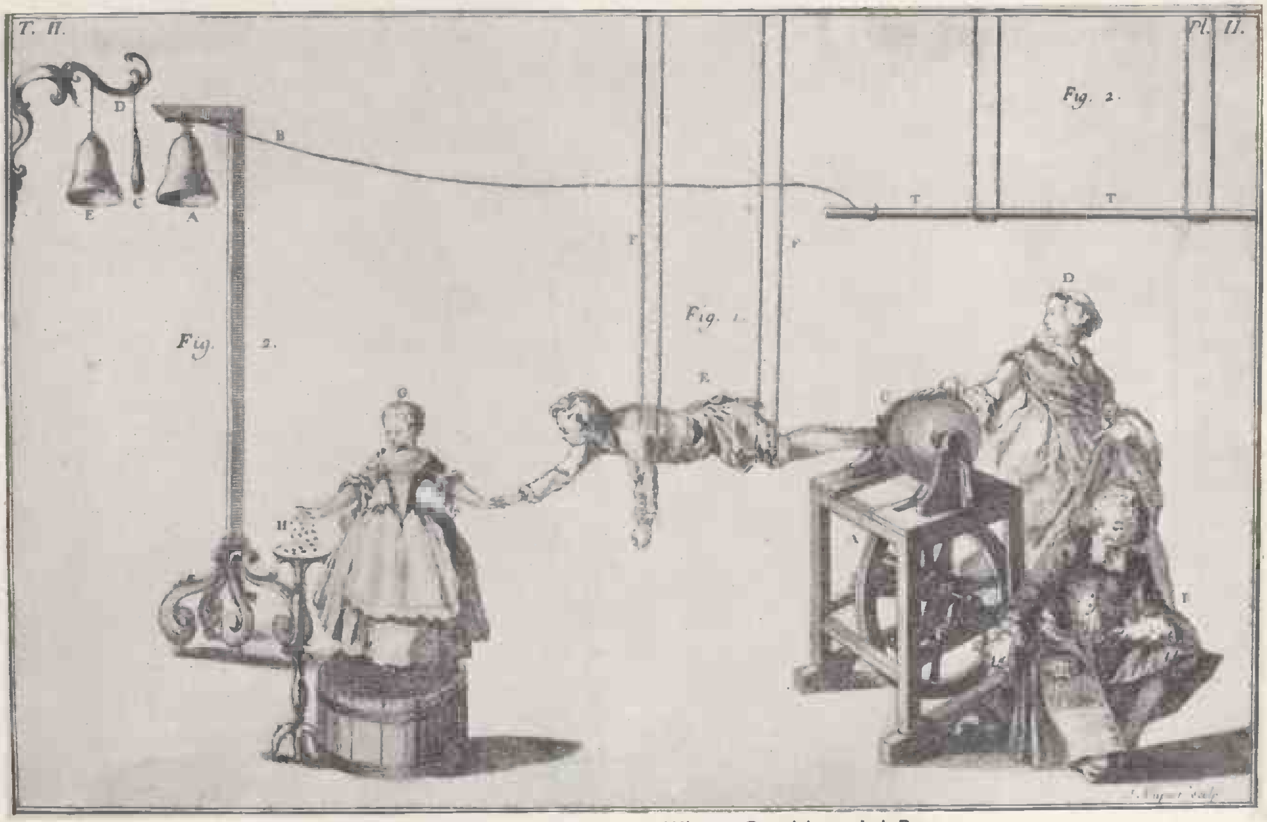
Washington.

It was brought out at a recent meeting of the industry advisory committee, conducted by Elmer Crane, chief of the Components Section of the W.P.B. Radio Division, that producers of variable condensers used in military radio will request that the specifications be changed from the present requirement for silver plating to cadmium plating.

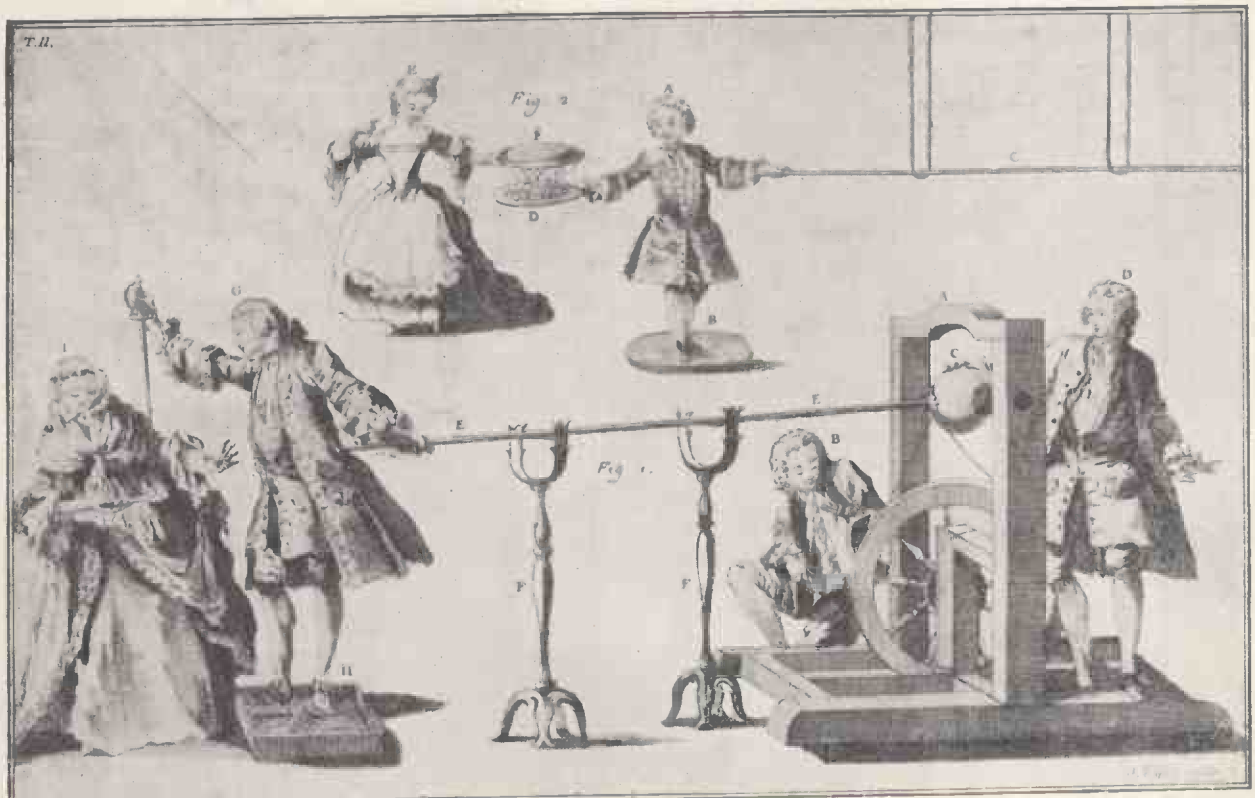
Under the salt-spray tests of the armed services, it was contended, silver turns to silver chloride, whereas cadmium plating remains intact.

F.N.

Suggestions from the Past



Overcoming the Copper Shortage, or What to Do with our Lab Boys.



Giving a Lady a Light. (Above) Electron Flakes—the Children's Cereal.

—from " *Receuil des traités sur l'Electricite*," 1748 (Winkler) by courtesy of H.M. Patent Library.

The Centenary of the Wheatstone Bridge

Graphical Methods for Solving the D.C. Bridge Network

By R. NEUMANN, Dipl. Ing.

After a brief historical survey, two different graphical methods are given for determining the current distribution and the partial voltages in a d.c. Wheatstone Bridge network. The second method is also applicable to non-linear resistors.

ON June 15, 1943, a hundred years have passed since Wheatstone presented his Bakerian lecture "An account of several new instruments and processes for determining the constants of a voltaic circuit" to the Royal Society.[1] It was in this paper that he described among other things his "Differential Resistance Measurer" or what is known to-day as the Wheatstone bridge network. Wheatstone himself remarked in a footnote to his paper:

> MR. CHRISTIE, in his "Experimental determination of the laws of magneto-electric induction" . . . has described a differential arrangement of which the principle is the same as that on which the instruments described in this section have been devised. To MR. CHRISTIE must, therefore, be attributed the first idea of this useful and accurate method of measuring resistances."[2]

A few biographical remarks on Christie and on Wheatstone may be of some interest.[3]

Samuel Hunter Christie (1785-1865) was the fourth son of James Christie the elder, the founder of the well-known firm of auctioneers still existing. As a boy he was on good terms with his father's friend, Sir Joshua Reynolds. His mathematical talents were manifest in his early school work and he was second wrangler at Trinity College, Cambridge, and inaugurated the Cambridge University Boat Club. 1806-1838 he was Assistant and 1838-1854 Professor of Mathematics at the Royal Military Academy, Woolwich, where his energy and organising ability were highly appreciated. His son, Sir William H. M. Christie, was Astronomer Royal from 1881-1910.

In his Bakerian Lecture of 1833 mentioned by Wheatstone, one of Christie's main problems was the determination of how the resistance of a wire depends on its length L and its diameter D. Some physicists of that time were of the opinion that the "conducting power" was proportional to $D/L^{\frac{1}{2}}$. While he quotes the work of Davy, Becquerel, Cumming, and Barlow, the treatise of Ohm was not known to him, and he found from his own experiments the proportionality to be D^2/L.

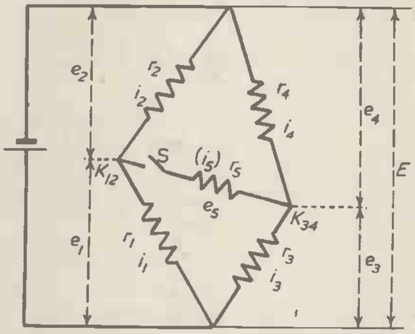


Fig. 1. The Wheatstone Bridge Network.

It was some years later that an English translation of Ohm's treatise of 1827 appeared in the 2nd volume of Richard Taylor's "Scientific Memoirs," and it was Wheatstone who had participated in the revision of W. Francis's translation and had encouraged its publication. He was among the first scientists in England to appreciate the importance of Ohm's law.

Charles Wheatstone was born 1802 in Gloucester as son of a music seller and educated in a private school there. 1823 he commenced a business in London as a musical instrument maker. He wrote several papers on his experiments on sound and developed the "Kaleidophone" for illustrating the combination of harmonic motions of different periods. His studies on Chladni's figures led him to the principle of "superposition of small motions" by which "simple geometrical relations without profound analysis allowed of predicting the curves produced by given modes of vibration."

In optical science he not only was the first to suggest the possibilities of the stereoscope, but also as early as 1835—24 years prior than Kirchhoff and Bunsen—published a paper on "Prismatic Analysis of Electric Light" in which he observed that the electric spark from different metals presents more or less numerous rays of different refrangibility 'producing lines differing in position and colour. The presence of a very minute portion of metal may thus be determined. We have here a mode of discriminating metallic bodies more readily than by chemical examination, and which may hereafter be employed for useful purposes."

In 1834 he had been appointed Professor of Experimental Physics at Kings College, London, and two years later was elected as a Fellow of the Royal Society. But due to his almost morbid timidity in the presence of an audience he seldom lectured after 1840.

Numerous improvements in the electrical telegraph are due to him, e.g., the dial telegraph showing letters, the type printing telegraph, and submarine telegraphy for which purposes he carried out experiments in Swansea Bay in 1844. For his researches on the rate of transmission of electricity along wires he made use of a rotating mirror. Independent of, and about simultaneously with, Werner Siemens he proposed the self-excitation of the dynamo. Oxford and Cambridge conferred honorary doctor's degrees upon him and he received many distinctions from British and foreign learned societies. In 1868 he was knighted. He died in February, 1875, in Paris, and was buried at Kensal Green Cemetery.

For about 45 years after the Bakerian Lecture of 1843 the use of Wheatstone's "resistance balance" was mainly confined to d.c. current systems and to the exact measurement of electric resistances, although as early as 1865 Maxwell had shown that inductances also could be determined if a ballistic galvanometer with known calibration was used. Since the early nineties the field of application of the bridge network was enormously enlarged by the introduction of what is called to-day a.c. bridge methods. B. Hague's classical treatise on this subject is evidence of the important work done in this field within the last half century.[4]

The inherently much simpler problems of d.c. bridge networks have of late not received similar attention, although there exists quite a considerable number of applications for this network too. And not only in the form of the resistance balance in which "the Wheatstone bridge is a null method for the comparison of resistances and . . . capable of considerable sensitiveness and precision," but also in the more general case where the balance is disturbed and a current is flowing in the bridge conductor, or, as we might call it, the bridge network with "loaded bridge."

As examples for applications of this type of network the following may be mentioned:

- Resistance thermometer bridges.
- Resistance stabilisers.
- Electric gas analysers, *e.g.*, for CO_2.
- Measurement of heats of reaction or mixture, *e.g.* CO + H.
- Regulation bridges for one or more variables.
- Calculating operators for addition, subtraction, multiplication and division.
- Bridge networks with electronic valves (amplifier connexions, potentiometric measurements).
- Current and voltage regulators, *e.g.*, constant current with variable voltage.
- Controlling the state of charge of a battery.
- Measuring the resistance of galvanic elements.

Details of all these applications are given by J. Krönert.[5]

As is well known, there exist quite a number of methods for solving analytically the current and voltage distribution of the bridge network. As the network consists of four points interconnected by six conductors, one of them containing the source of current and the other the measuring instrument (or generally speaking, the bridge load), the voltage and current distribution may be determined if the

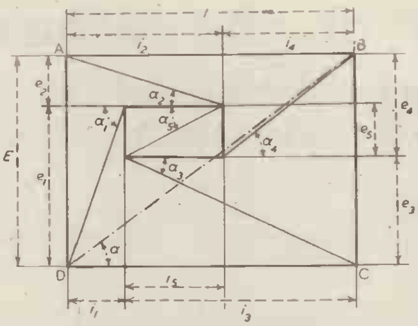


Fig. 2. Current-voltage diagram of bridge network. (Rauschburg).

e.m.f. of the source and the resistances of the six conductors are given. Applying Kirchhoff's laws six linear equations are found for the six currents and they may be solved by sixth order determinants.

The method may be considerably simplified by using Maxwell's method of cyclic currents which allows of determining the bridge current as quotient of two third-order determinants.[6 7] Also Thévenin's theorem[8] or Kennelly's star-mesh transformation[9] have repeatedly been recommended for solving the bridge network.

In the graphical solutions to be described presently the resistance of the current source and of the leads connecting it to the network proper is neglected. This is admissible in most cases as this resistance is usually small in comparison with the resistances in the branch conductors. How the graphical method may also be used if this neglect is not permissible will be dealt with later.

The advantage of graphical methods is that they furnish a lucid diagram which is also suitable for assessing the influence of changes in the system, *e.g.*, the changes caused by varying one or more of the resistances in the branches or that of the bridge itself.

Another common feature of these methods is that they use a rectangular coordinate system in which the currents are drawn parallel to the abscissa and the voltages parallel to the ordinate. Resistance values therefore appear as tangents of angles:

$$r_1 = e_1/i_1 = \tan \alpha_1$$
$$r_2 = e_2/i_2 = \tan \alpha_2$$
$$r_3 = e_3/i_3 = \tan \alpha_3$$
$$r_4 = e_4/i_4 = \tan \alpha_4$$
$$r_5 = e_5/i_5 = \tan \alpha_5$$

Applying Kirchhoff's rules, the following relations are found from the diagram of connexions given in Fig. 1 (if with switch S open the potential of point K_{12} is higher than that of point K_{34}):

$$E = e_1 + e_2 = e_3 + e_4$$
$$e_1 = e_3 + e_5$$
$$e_4 = e_2 + e_5$$
$$I = i_1 + i_3 = i_2 + i_4$$

The total resistance of the bridge network as seen from the current source is

$$E = E/I = \tan \alpha$$

The current voltage diagram as proposed by Rauschburg[10] is shown in Fig. 2. All the relations given above may be readily read from this diagram.

The question now arises how this diagram may be found if the e.m.f. E of the current source and the resistances r_1, r_2, r_3, r_4 and r_5 are given. The procedure is as follows: First r_5 is represented by a rectangle of optional size, but with a ratio of height to width equalling $r_5 = \tan \alpha_5$ (Fig. 3). Now the angles $\alpha_1 \ldots \alpha_4$ are drawn from the corners of this rectangle as shown in Fig. 3 to furnish the resistance lines $r_1 \ldots r_4$. Starting from an optional point M (Fig. 4) a rectangular spiral is drawn parallel to the sides of the rectangle. If after the first circulation the spiral gets larger and larger or meets one of the resistance lines at such a point N that the spiral could not be completed without using the negative parts of the resistance lines the spiral is drawn in the opposite sense and will then converge after a few circulations to form a closed rectangle ABCD (Fig. 5) which is the same as that shown in Fig. 2. The scale of the diagram is now found by equalling the side DA to the given value of E and all the other values required may be taken from the diagram.

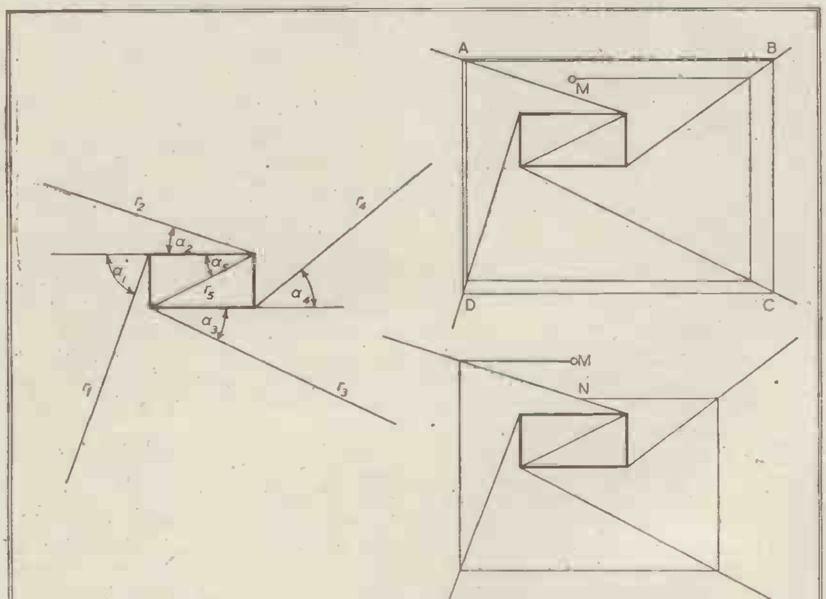


Fig. 3. Construction of the Rauschburg diagram starting from r_5.
Fig. 4. (lower right) Rectangular spiral (unsuccessful).
Fig. 5. (top right) Rectangular spiral (converging).

Ingenious as this method is it has some disadvantages. If the rectangle representing the current and voltage in the bridge wire is chosen too large the size of the sheet may be too small for obtaining the closed rectangle ABCD. The scale of the diagram is only found after the diagram has been completed and may be not very convient. Besides the method is not applicable to non-linear resistances, *e.g.*, barretters.

A method originally devised and published by the author about 30 years ago[11] avoids these drawbacks and solves the problem in a closed form without resorting to the geometrical analogy of a divergent or convergent series.* The method is the following:

The resistances are drawn with their characteristics I, II, III, and IV as shown in Fig. 6. If the bridge switch S is open the vertical distance of points P and Q gives the potential difference between the points K_{34} and K_{12} of Fig. 1 or what we may call the "no-load voltage" corresponding to $r_5 = \infty$. Projecting P and Q on the ordinate axis and connecting P_1 with P′ and Q_1 with Q′ we find the "short-circuit current" XX′ of the bridge corresponding to $r_5 = 0$. For finite values of r_5 we draw $\tan \alpha_5 = r_5$ from point P′ (characteristic V), find the intersection Y of this resistance line with the horizontal line Q′Q, connect X and Y and find the current $i_5 = VS'$. The vertical line WV gives the value of e_5 and the diagram may now be completed by finding U on characteristic I, S on II, R on III and T on IV.

All the values derived from Kirchhoff's rules as given above may be taken from the diagram. In order to convert the diagram Fig. 6 into that given in Fig. 2 it is only necessary to turn the lines ORTA around the axis ZZ_1 which is found as the vertical line bisecting TS_1, S_1 being the vertical projection of S on TR, so that the current I and the total resistance R of the network may also be found without further calculation.† The influence of changes in the resistance values is exhaustively dealt with in the original publication[11] to which interested readers are referred. Only a few words need be said in conclusion on the influence of the resistance of the current source.

The influence of changing the voltage E is easily found from the diagram as all relations are linear and for $E = O$ all currents and voltages disappear. It is therefore only necessary to draw straight lines through O to the points V, W, S, T and to draw the corresponding horizontal lines in order to find corresponding values of i_5, e_5, etc. The resistance characteristics II and IV and the auxiliary lines P_1X and Q_1X are moved parallel to themselves.

Now it is also possible to consider a voltage drop in the source of current or in the leads connecting it to the network proper. The diagram is first drawn for E = const. Then the voltage drop corresponding to the current value $I = i_1 + i_3 = i_2 + i_4$ is determined. After repeating the construction a few times the definite values are obtained as the approximation gets more accurate with each repetition. But for this case the analytic solution[12] is certainly more convenient.

Then the point of intersection is found between c and V (which latter has been drawn to the left of the ordinate axis for the sake of convenience). Projecting this point of intersection on to a and b furnishes the points V and W and, on the respective horizontals, the points S′, U, S and R′, T, R and thus all the required currents and voltages of the generalised diagram.

The latter, of course, gives the relations for the stable state only, *i.e.*, for the case that the temperatures have reached their final values.

Such a variator possessing a high inertia may be used for example for reversing the current automatically after a certain time. Selecting one of the branch resistances, *e.g.*, r_2 so

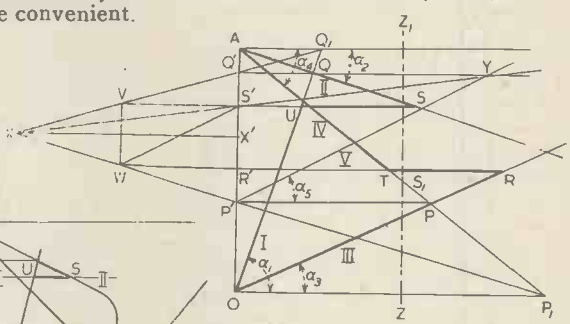


Fig. 6. (above) Diagram of bridge network with linear resistors.

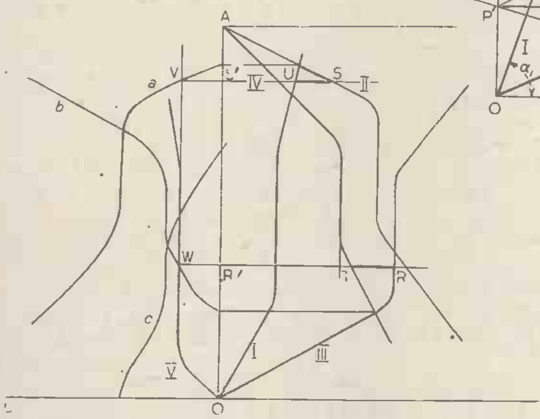


Fig. 7. (left). Diagram of bridge network with barretters.

Finally, it will be shown that the diagram is also suitable for solving a problem hardly accessible to analytical solution. As is well known resistances are frequently used in engineering the temperature coefficient of which is not negligible, *e.g.*, the so-called variators or barretters, *i.e.*, iron resistors possessing a marked positive temperature coefficient. Their resistance characteristic is a line which rises slowly at the start, then much quicker and then slower again.

In Fig. 7 such variators are chosen for all the five resistors. The characteristics are again called I, II, III, IV and V. The horizontal distances between I and II on one hand and between III and IV on the other are drawn from the ordinate axis to the left and thus the curves a and b are found. The vertical distances between a and b are drawn from the line OL upwards to the respective abscissae and this furnishes the curve c.

that it is smaller in the cold state than r_1r_4/r_3, but larger in the heated state, then the current in r_5 will be reversed during the change of temperature of r_2.

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12 Ref. 4, p. 41.

* The question of convergence of Rauschburg's construction for the general case of *n* straight lines and *n* optional directions was investigated by Mrs. Hanna Neumann in a paper read before a students' section at Oxford (not published).

† Private communication K. Roston, Johannesburg, (1931).

Measuring Instruments for Radio

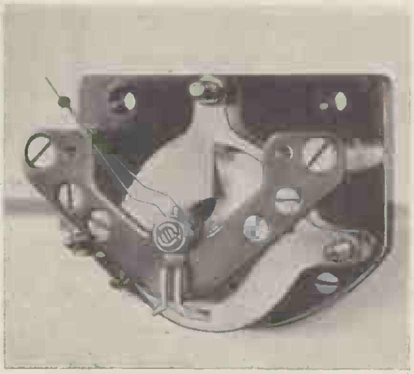
By E. H. W. BANNER, M.Sc., M.I.E.E., F.Inst.P.

Instruments for use in radio are described, the high frequency types in some detail, with constructional features. Tables classify instruments according to range of working frequencies, range of measurement, and consumption, in general terms. Sufficient information is given to determine the best type to use for a given radio measurement. Some typical scale shapes are shown to assist identification.

A BRIEF study of the characteristics of indicating electrical measuring instruments used for radio is of considerable aid in making measurements. Generally one type is better than another for any given purpose and it is the present plan to give the various characteristics for consideration. Pointer indicating instruments alone are concerned here; other measuring instruments such as oscillographs, and testing instruments such as signal generators are excluded from the scope.

For radio purposes it is convenient to group instruments first according to whether they measure d.c., a.c. of power, audio or radio frequencies, although, of course, there are no fixed dividing lines between the various frequency ranges and some types operate on all, including d.c. To measure d.c. the moving coil is the commonest type, although the polarised moving iron type would often be satisfactory where the highest accuracy and minimum consumption (load on the circuit) is unnecessary. The moving iron instrument, the commonest for power frequency work, is also serviceable on d.c. to a much greater extent than is generally realised, again where minimum consumption is not essential and excluding very low ranges. For power frequencies the moving iron instrument is generally applicable; it has been much improved in design and use of better iron in the past ten years or so and is far from being the cheap inaccurate instrument it is still often considered. Rectifier instruments are also used for power frequency work, but in general they are less to be preferred than are moving iron instruments, mainly on account of their waveform error which may be serious unless direct on mains, where the waveform is good. Their great advantage for such measurements is on account of their low consumption, making multi-range test-sets easily possible, especially combined for d.c. use by omitting the rectifier from the circuit by switching.

The rectifier instrument has especial application to audio frequency circuits; it shares this frequency range with the thermal type, but has the robustness and generally the low consumption of the moving coil, whereas thermal instruments almost always have a low overload capacity and so cannot be considered robust. In the audio frequency range may be considered valve voltmeters, although their frequency ranges are extensive and vary with the particular type of valve and form of circuit used. Generally only voltmeters are possible, but indirect current measurement by measurement of voltage drop across a known resistance—or reactance—is frequently possible. Valve voltmeters are unfortunately not the simple self-contained instruments as are all others, but one or two sources of voltage are necessary, although in some simple forms a single dry cell inside the instrument may be all that is required. Most modern valve voltmeters are a.c. mains operated, by the inclusion of a transformer, rectifier, smoothing circuit and voltage stabiliser.



Movement of single-vane high-range electrostatic voltmeter.

By courtesy of Messrs. Ferranti Ltd.

For audio frequencies thermal instruments are almost the only type applicable. They have no frequency limits, other than at ultra high frequencies where again design considerations may extend the range to frequencies as high as are required in practice. This immediately renders them of use for d.c. and l.f., also, of course, and occasionally their use is justified here. Their main application to frequencies other than high is in cases of known bad waveforms where the characteristic of reading true r.m.s. value independently of waveform error is used. The electrostatic voltmeter is also a universal instrument, within limits; it may be used on d.c., power frequencies and a.f. On h.f. it is limited mainly by the excessive current consumption, which increases directly with the frequency—but even this current is wattless as it is a drop across a condenser—a nearly pure reactance. For extremely high frequencies the valve voltmeter is often the only type that can be used.

A brief summary shows the electrical effects used and the types of instrument in each class.

Two other types are used in power work, the electrodynamic and the induction, but neither has any real radio application and they can be ignored. Possible exceptions are precision laboratory measurements of d.c. and of power frequencies for the electrodynamic, and as switchboard instruments for power frequency measurements for the induction type. Table 1 summarises the leading characteristics as to frequency ranges. Carrier frequencies are here not differentiated from a.f. and h.f.

In addition to tabulation by types it is also desirable to show the limits of range, as this is commonly one factor determining the type to be used, within the initial limits of the frequency table. Table 2 shows the range limits and Table 3 the approximate order of consumption.

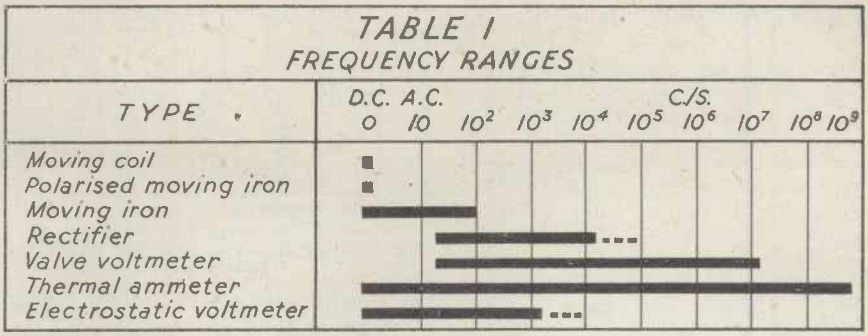
Each type will now be briefly considered. Moving coil instruments are well known and no detailed description is necessary here. Recent improvements have been almost entirely in the use of better magnet steels leading to smaller size and weight, and to lower consumption with a correspondingly high resistance, such as 20,000 ohms per volt. Ranges are wider than

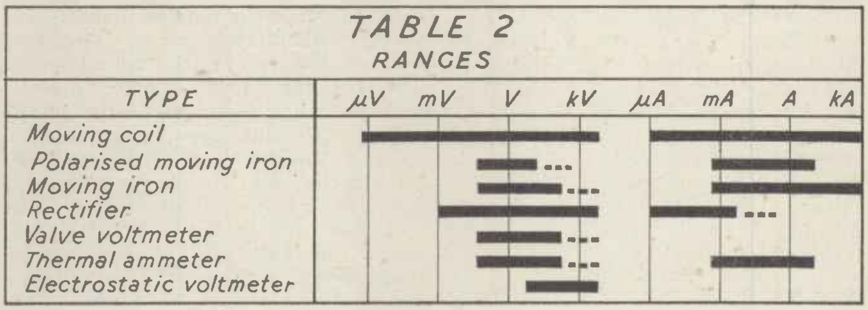
Magnetic effect:	With permanent magnet: Moving coil and polarised moving iron	DC only
	Without permanent magnet: Moving iron and electrodynamic	DC & AC (LF)
Thermal effect:	Hot-wire (or thermo-expansion) Thermo-e.m.f. (or electro-thermal)	DC & AC (& HF)
Electrostatic effect:	Electrostatic voltmeter	DC & AC

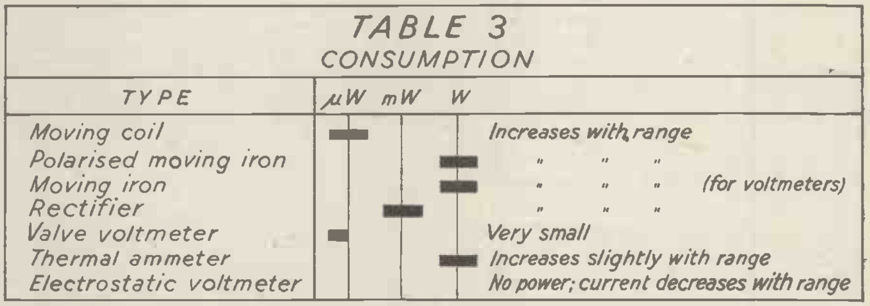
those of any other type, from millivolts (microvolts for suspended types) to any upper voltage limit and microamperes to any upper current limit.

Direct-reading resistance-testers incorporate a m.c. voltmeter and battery, and usually comprise a voltmeter in series with the test resistance. Thus a short-circuit across the terminals causes full scale deflection and is marked zero ohms. Conversely a high resistance causes a small deflection. A typical scale shape is shown in Fig. 1.

The polarised moving iron instrument is less well-known and used than it might be; it is often confused with the moving iron, but it is entirely different in principle, as it contains a magnet and so is polarised and reads on d.c. only. Its chief use at present is as a charge and discharge ammeter for vehicle dashboard use; it is also used for cheap pocket testing instruments. In principle it comprises a fixed magnet, which may be a short bar or a modified horseshoe, and a pivoted soft iron armature which is magnetically constrained to lie along the magnetic field, no spring control being used. Around or near to the magnet is a conductor; a coil for voltmeter and milliammeters and a strip for vehicle ammeters of about 20 amperes range. The conductor is placed so as to tend to deflect the armature by its field being at right angles to that of the magnet. Such an instrument is commonly centre-zero, but it need not be, and in the latter case the pointer is displaced from its control position at zero so that only movement of the armature in one direction is effective. This is a cheap instrument, having no expensive magnet, jewels and control spring, nor fine clearances. Its magnet is a very simple one and instead of jewels (synthetic sapphires or glass) indentations in a brass fixing plate are usual. A well-designed instrument of this type, having better pivoting than the above, has a good scope for limited ranges of voltage and current as a cheaper instrument than the moving coil where a somewhat lower accuracy is sufficient for the purpose—as is much preliminary and general testing work. The scale shape is nearly uniform and is generally indistinguishable from that of the moving coil instrument, but as the damping is not as good as that of the moving coil type the pointer takes longer to come to rest, or alternatively when the instrument is sharply rotated the rapid or slow settling of the pointer shows the moving coil or the polarised moving iron type, respectively. It should be noted also that the "moving magnet" type of galvanometer is also of the polarised moving iron type, although in this instrument part or all of the magnetic control is due to the earth's field.







The moving iron instrument is fairly well known; it comprises a coil to provide a magnetic field and either a moving iron which is attracted into the coil or a fixed and a moving iron, mutual repulsion between which causes movement of the pointer. Each is in use and likely to persist. Having no magnet it is not polarised and so can read d.c. or a.c. It is robust, and good examples of this type will stand an instantaneous or short-time overload of ten times full-scale current. It reads r.m.s. values nearly independent of wave form, and so has the advantage over the rectifier type where the waveform is doubtful—as it often is in radio circuits, apart from directly on the mains. Whilst this is a "square-law" type the design is always such as to minimise the contracted initial part of the scale and provide a scale nearly uniform above about the first 10 per cent. (Fig. 2).

Rectifier instruments are only about 14 years old, as a type, and comprise a metal rectifier, usually copper-oxide, with a moving coil movement. They read the mean value of the rectified current, and as the r.m.s. value is

Fig. 1. Typical scale of ohmmeter (voltmeter and battery).

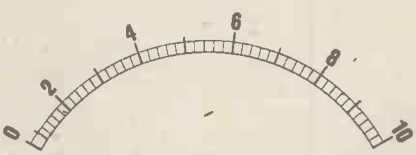


Fig. 2. Typical scale of modern moving iron instrument.

almost always required they are calibrated as for r.m.s. value, but this introduces a possible error of the order of 10 per cent. Four rectifier elements in a bridge are usual, providing full-wave rectification. The great advantage of this type is the low consumption of the moving coil, with a wide voltage range, but limited current range other than by auxiliary means. The rectifier impedance varies very considerably with the current passed, therefore a rectifier instrument may have such an effect on a low-power circuit that the current intended to be measured is altered appreciably. No common correction can be employed, as it depends on the circuit and on the current being measured. Fortunately this source of error is low in circuits other than low power and low voltage, but the possible error should be realised. Except for low voltage ranges the scale shape is as that of the moving coil—uniform. For low voltage ranges the scale shape is crowded at the beginning—somewhat as for the thermal type.

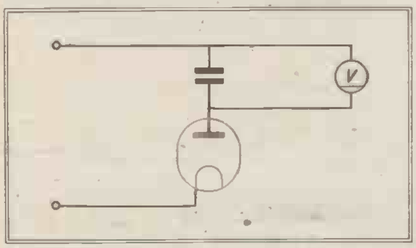


Fig. 5. Basic circuit of electrostatic peak voltmeter.

Valve voltmeters are comparatively recent, but have already reached a definite place in measuring technique for radio and allied circuits and the applications are growing. Their main characteristic is that of negligible load on the circuit. In the simplest form a diode or triode valve and a moving coil instrument are used; in others a multi-electrode valve with mains stabilisers and adjustable resistors for multi-range work are employed. There are three general types which serve most requirements, the grid leak type and the anode bend type, using triodes, and the peak voltmeter, using a diode. The first, or grid leak type, uses the grid current/grid voltage characteristic. The input is applied to a condenser in series with the grid of a triode and a grid leak connects the grid to the filament. In the anode circuit is a moving coil microammeter and a battery. Depending on the part of the valve characteristic used the resulting current may be directly proportional to input voltage or if the latter is large anode bend rectification will take place as well, with reduced sensitivity. The reading is thus not true r.m.s. for wave forms other than sinusoidal. The basic circuit is shown in Fig. 3.

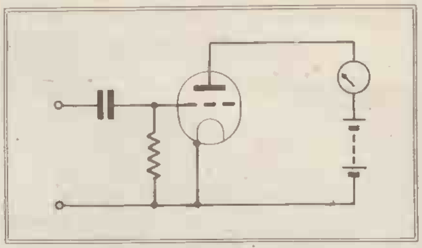


Fig. 3. Basic circuit of grid-leak type valve voltmeter.

Anode-bend voltmeters are more common, they use the anode current/grid voltage characteristic for rectification: depending on the actual characteristic the response may be proportional to the square of the input voltage. In this case the true r.m.s. value is indicated, independently of wave form. But if a high resistance is included in the anode circuit, with a higher voltage the relationship is nearly linear and the anode current is proportional to the square of the voltage for low voltages, but to the mean for higher voltages, and the mean rectified current through a condenser is proportional to peak voltage. Consequently there will again be a wave form error, as the scale is generally calibrated in r.m.s. units. Multi-range instruments are obtained by the use of various resistors in the anode circuit, with a selector switch. Fig. 4 shows the basic circuit. Diode voltmeters are based on the peak voltmeter in which a condenser is charged through a rectifier and the condenser voltage read on an electrostatic voltmeter. Sometimes a moving coil voltmeter of very high resistance is used instead, and as no anode battery is needed a simple dry cell for filament heating is often all that is needed for power input. The reading is directly proportional to peak voltage, but if r.m.s. calibration is required then a wave-form error is introduced. The basic circuit is shown in Fig. 5.

For use at very high frequencies, the chief field of valve voltmeters since no other type will serve, the input capacitance must be very small, in addition to the resistance being very high. This is attained by the use of special valves, such as electrometer triodes, and by mounting the valve in a metal-cased probe terminal applied directly to the high-frequency point. Some of these latter instruments are useful up to 50 Mc./s., with an impedance of about a quarter of a megohm and a terminal capacitance of about 5 $\mu\mu$F.

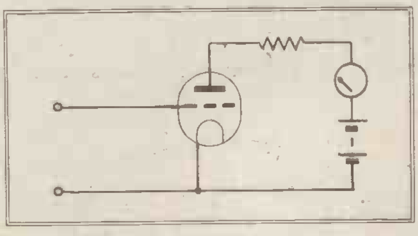


Fig. 4. Basic circuit of anode bend valve voltmeter.

Two types of thermal instrument are commonly used for radio work, the hot-wire (or thermo-expansion) and the thermo-e.m.f. type. The former is the older, but it is less satisfactory as it usually has a wandering zero and is less robust. As an aerial ammeter where a maximum reading is sought it is still of great use, and it is cheaper than the thermo-e.m.f. The thermo-e.m.f. type comprises a moving coil movement indicating the millivolts generated by one or more thermo-couples which are heated by the circuit current. For low ranges the thermo-couple is *in vacuo,* but above about 1 ampere open couples are used. There are two general types of thermo-couple, insulated and contact.

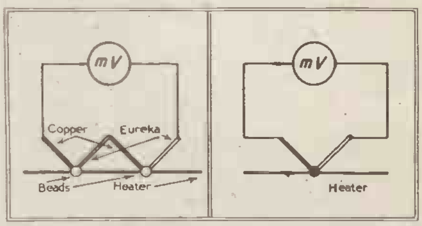
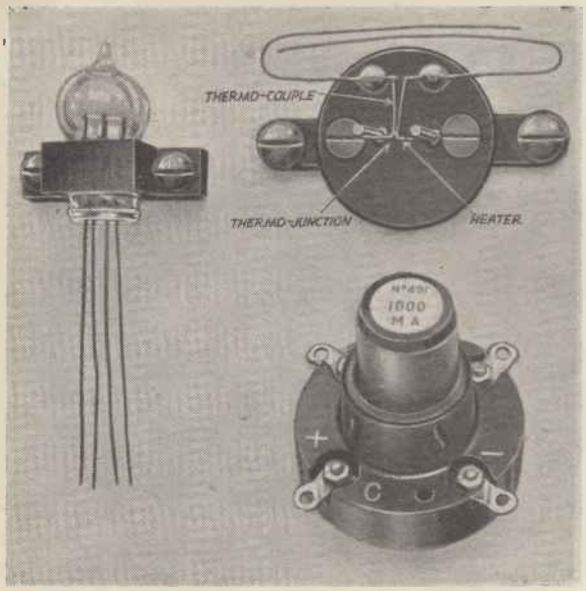


Fig. 6 (left). Thermo-couple instrument with two insulated couples. Fig. 7 (right). Thermo-couple instrument with one couple directly connected to heater.

In the former the couple is insulated from the heater carrying the line current by a bead of glass or similar material; consequently two or more couples may be used in series. The speed of response is slightly lower than in the contact type, where only one couple is possible, or all but one would be short-circuited by the heater. Figs. 6 and 7 show the insulated and the contact types, respectively.

Another advantage of the insulated type is that there is no reversal error on d.c., but with the contact type unless the heater wire is accurately welded to the centre of the couple there will be a small d.c. error shown on reversal of the line current. The heater wire is generally made of eureka or a copper nickel alloy and the couple elements are of iron and eureka. Thermal instruments are square-law types and the working force available is so low that scale improvement, which always involves increased consumption, is not resorted to: square-law scales thus result, in which half-scale deflection is about 70



Typical Thermo-couples. (left) Vacuum thermo-couple, (right) Open air thermo-couples, (lower right) Vacuum thermo-couple mounted in holder.

By courtesy of Messrs. Elliott Bros. Ltd.

per cent. of full scale value, as is seen in Fig. 8. All thermal instruments are more or less sluggish in action, with no tendency to overshoot the final indication, but the thermo-e.m.f. type is quicker in indication than is the hot-wire.

Electrostatic voltmeters are a long-established type, but now have less application than formerly due to improvements in moving iron instruments for power frequencies and valve voltmeters for radio circuits, where the condition of low load on the circuit applies. They comprise a variable condenser with one set of electrodes fixed and the other pivoted. In low ranges many vanes and small gaps are necessary, while in high ranges few vanes and long gaps are found.

In each case the low and high range limits are set by the clearances attainable—small clearances by excellence of workmanship and high clearances by case size. Present ranges are from 150 volts upwards to almost any value, and the type is suitable for both d.c. and a.c. For d.c. the main scope is to circuits where even the low current consumption of a very high resistance moving coil instrument is too high. An earlier paper on some indirect uses of the electrostatic voltmeter, as well as of some other types, in radio work may be referred to.* The instrument being a condenser it will be seen that its current consumption, at a given voltage, will be proportional to the frequency: this sets the upper frequency limits, for any given instrument. Although there is a current consumption on a.c. and a charging current on d.c., no power is absorbed from the circuit as the current is 90° leading the volts, and the resistance is that of the insulation, which should be so high as to be considered as infinity in relation to the reactance of the condenser.

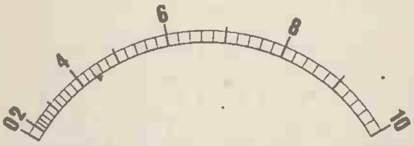


Fig. 8. Typical scale of thermal instrument.

This instrument also obeys a square law and reads true r.m.s. values and d.c. The basic scale shape is thus a square-law one, as for the thermal types, but it is almost always modified in design so as to produce a more nearly linear or uniform scale. A typical instrument has a scale gradually increasing for about one third of the distance, then nearly uniform until near the top, where it again contracts. The peak value instead of the r.m.s. may be read by incorporating a valve rectifier and series condenser, with the voltmeter in parallel with the condenser, which becomes charged to the peak value of one half of the wave; which half depending on the polarity of connexion of the rectifier. This has been referred to in connexion with the valve voltmeter, and the basic circuit is shown in Fig. 5.

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NOTES FROM THE INDUSTRY

Radio Industries Club

At the Radio Industries Club luncheon on May 25, Sir R. Watson Watt gave his personal views on the problems of post-war broadcast distribution, and referred to the possibilities of wired wireless, or, a more expressive phrase, "piped radio." He did not think that the wide use of piped radio would adversely affect the development and sale of improved radio receivers, and the receivers for wire reception would offer scope for technical developments.

Sir Louis Sterling spoke in defence of the existing system and referred to "pipe-dreamers." He did not want any restriction on the choice of programmes such as would be imposed by wired wireless, and considered that such a trend would seriously affect our export market in addition to cramping the style of home radio receiver development.

The following officers have been elected for the ensuing session: President, Sir Noel Ashbridge. Chairman, H. de A. Donisthorpe. Hon. Secretary, W. E. Miller. Hon. Treasurer, H. A. Curtis.

Aslib

ASLIB (Association of Special Libraries and Information Bureaux) will hold its eighteenth annual conference by kind permission at the rooms of the Royal Society, Burlington House, Piccadilly, W.1, on September 18 and 19, 1943. Further particulars of the programme will be available later, but those wishing to attend the conference are advised to make their arrangements for accommodation as soon as possible. The report of the last conference, held in November, 1942, is now ready at 3s. to members; 6s. to non-members. Communications should be addressed to the General Secretary, Miss E. M. R. Ditmas, ASLIB, 31 Museum Street, London, W.C.1.

Electronic O.B.E.'s

We are pleased to record the award of the O.B.E. to the following well-known personalities in the radio and electronic industry:

L. H. Bedford, Chief Research Engineer, Messrs. A. C. Cossor.
P. I. Dee, P.S.O., T.R.E.
N. F. Newsome, B.B.C. European Broadcasts.

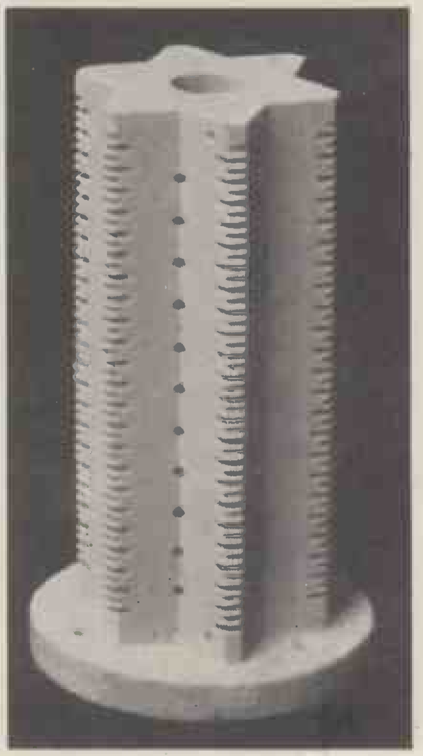
Mr. A. B. Stockwell, of Messrs. A. C. Cossor, has received the B.E.M.

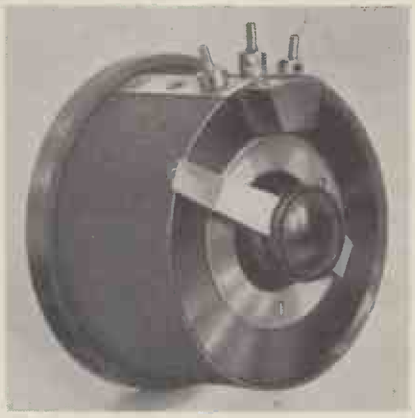
Mr. Bedford is particularly well-known for his contributions to the science of electron optics and the cathode-ray tube, and is a first-class mathematician in addition to being an original thinker and research engineer. He has contributed largely to the success of many present-day electronic developments.

H.F. Coil Former

The illustration shows a high quality ceramic coil former developed by Messrs. Raymart for aerial coupling coils or tapped tank coils. The former is double-grooved for coupling windings and has 11 holes for tappings down the centre of the core.

Dimensions: 1½ in. winding diameter, 2 in. base diameter, 3½ in. o/a height, 46 winding grooves. Price: 4s. 6d. Inquiries to Raymart, Ltd., 48 Holloway Road, Birmingham, 1.





Painton Potentiometers

The photograph shows a 25 w. potentiometer manufactured by Painton & Co., Kingsthorpe, Northampton. These are made in various sizes and ratings:—

Dissipation	Resistance Values	Diameter	Price*
2 watt	25–5,000	0.875"	3/6-3/9
5 watt	100–50,000	1⅞"	6/6-8/6
25 watt	100–100,000	3½"	15/-

*Plus 15%

In addition the type CV.25 shown can be supplied totally enclosed in a dust-proof metal shielding case.

We have had an opportunity of testing these components in laboratory work and can recommend them. Workmanship and finish are excellent.

A Practical Lathe Handbook

Messrs. Saunders Roe, Ltd., recently produced a handbook for lathe operators which was intended to help trainees to acquire a knowledge of lathes and their working.

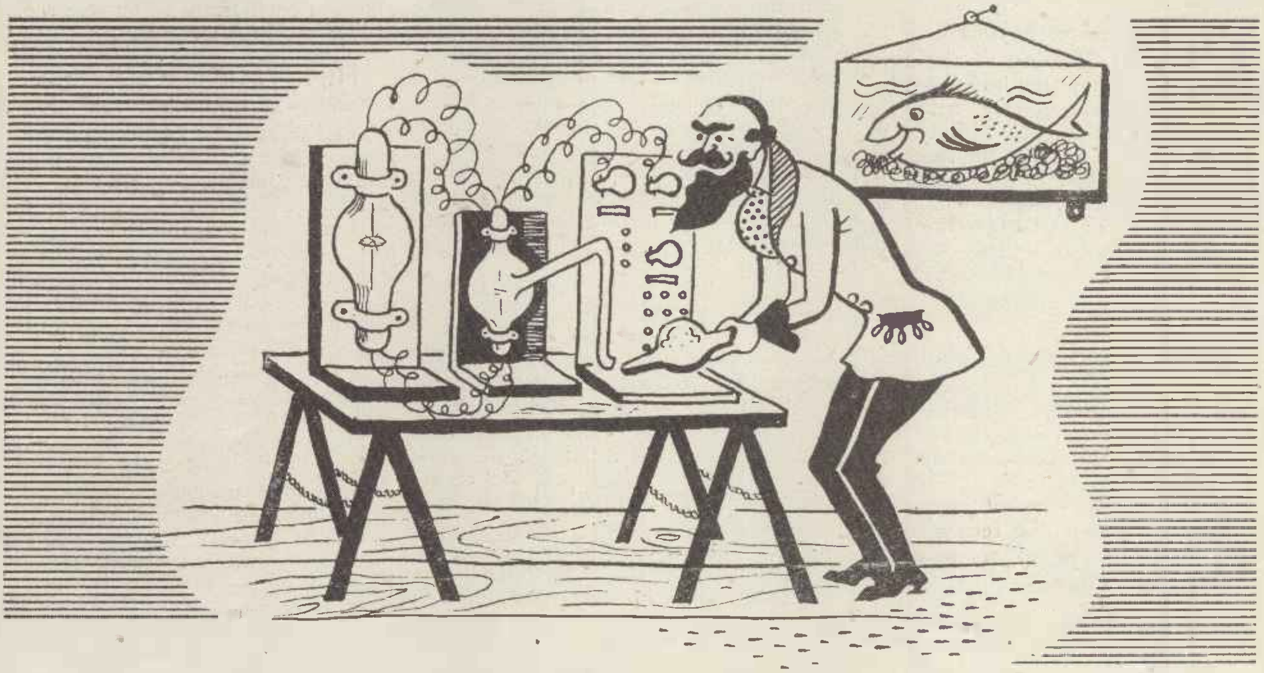
It is copiously illustrated with drawings, and the appendix includes a glossary of technical terms in use in shop work.

In view of its success, it has been decided to make it available to other engineering firms, and copies can now be obtained direct from the printers and publishers, The Press at Coombelands, Addlestone, near Weybridge, Surrey.

Messrs. Saunders Roe have agreed to give all copyright fees to the R.A.F. Benevolent Fund. The price per copy, stiff bound in quantities of 1,000 is 2s. 3d., and this includes printing the purchaser's name on the cover. Orders for less than 1,000 bear a slight extra charge for the purchaser's name. Limp bound copies are 1s. 9d. each.

The book is written in a very readable and practical style and is thoroughly recommended to works managers who want something to augment the instruction given to trainees or new labour.

WILLIAM MORGAN DISCOVERED X-RAYS IN 1785



AND NEVER KNEW IT

William Morgan was a scientist who experimented with the passage of electric currents inside a glass tube. When there was a vacuum in the tube, he found that no discharge could pass; but when a little air was admitted, the glass glowed with a green colour. Morgan little knew that he had, in fact, produced X-rays and the first X-ray tube.

Distrene (Regd.) insulating material has proved invaluable for radio and X-ray work. Its low loss factor at high frequencies is as surprising as its high dielectric strength. The brief data below can be checked with working samples we would like to send you. Distrene is made in sheets, rods and tubes, and in powder form for injection moulding.

COMPRESSION STRENGTH	7 tons per sq. in.
SPECIFIC GRAVITY	1·06
WATER ABSORPTION	Nil
COEFFICIENT OF LINEAR EXPANSION	·0001
SURFACE RESISTIVITY (24 hours in water)	3×10^6 megohms
DIELECTRIC CONSTANT 60—10^6 CYCLES	2·60—2·70
POWER FACTOR UP TO 100 MEGACYCLES	·0002—·0003

★

BX PLASTICS LTD., LONDON E.4, AND ELSEWHERE

July Meetings

Industrial Radiology Group

The next meeting of the Group will take place on July 10 at 2.30 p.m. at the Institution of Electrical Engineers and will take the form of an open discussion. Questions, previously submitted by members will be put before those present for answer. Visitors are welcomed, but must be introduced by a member.

Institute of Physics

The Summer Meeting of the London Branch of the Institute of Physics will be held jointly with the London Mathematical Society on Saturday, July 3, 1943, in the rooms of the Royal Society, Burlington House, Piccadilly, London, W.1, commencing at 2.0 p.m., and will take the form of a Conference on "The Applications of Mathematics to Physics."

Papers will be presented as follows:—

1. "Matrices in Practical Mathematics," by Dr. A. C. Aitken, F.R.S. (University of Edinburgh).
2. "Computational Methods and Mathematical Tables," by Dr. L. J. Comrie.
3. Mathematical Solutions by Models," by Mr. H. L. Blackburne (Messrs. Merz & McLellan, Consulting Engineers).
4. "Applications of Elementary Mathematical Processes — with Special Reference to Circuit Theory," by Dr. S. Whitehead (The British Electrical and Allied Industries Research Association).

Opportunity will be given for discussion on each paper. A break will be made for tea. Visitors will be welcome without formality.

ELECTRONIC MUSICAL INSTRUMENTS

It has been suggested that a Discussion Group be formed of those interested in the design and performance of electronic musical instruments, particularly electronic organs and pianos.

Will any readers who are interested in the formation of such a group please write to the Editorial Department of this journal at 43 Shoe Lane, E.C.4.

It is hoped to hold periodical meetings in London or elsewhere for the interchange of experiences and discussion of experimental work.

BOOK REVIEWS

Electrical Technology for Radio Communications

W. H. Date (Longmans, Green & Co. 5s.)

The author, who is Senior Lecturer in the Electrical Engineering Dept. at the Polytechnic, Regent Street, has been engaged for many years in training students in Telecommunications and this book is the outcome of his experience.

As pointed out in the preface, the usual approach to the subject through the well-worn path of electrical technology brings in the theory of electrical machines, armature windings, and a number of other subjects which the student of radio engineering cannot but think are irrelevant to the special branch in which he is interested.

The emphasis in the book is laid on the a.c. circuit and the associated properties of inductance, resonance, waveforms—all of which can be easily appreciated to have a direct bearing on the theory of radio. The concluding chapters cover instruments and measurements, and accumulators, and the whole book gives just the right basis for more detailed work in the third and fourth year.

Only one or two minor omissions are noted—the word "barretter," for example, might have been mentioned under temperature coefficient of resistance, and thermo-couples are not referred to in the section on instruments. But if a textbook covered everything there would be no questions asked of the lecturer!

Prism and Lens Making

F. Twyman, F.R.S. (Adam Hilger Ltd. 15s.)

When television returns there will be an increasing interest in the optical projection side of receiving and many manufacturers will be concerned with testing and checking optical apparatus, if not in its actual manufacture.

This book, by the managing director of Messrs. Adam Hilger, describes the methods in use in their workshops for making high quality prisms and lenses and is full of suggestions based on their own experience and that of other authorities.

The opening chapters deal with single lens working, tools, materials, grinding and polishing. The production of lenses and prisms in quantity is illustrated by photographs of machines in use by Hilgers. A section of particular interest to the technician is that on centring and balsaming lenses and prisms, and finally, the testing of optical work, including optical glass in the piece.

The appendix quotes Davidson's method of silvering glass (*Proc. Phys. Soc.* 1920, p. 18) as one which is extensively employed in the Hilger workshops, and gives short notes on sputtering and evaporating metal films and anti-glare films on glass.

It is confidently expected that every works laboratory dealing with optical glasswork will want to possess a copy of this book for reference.

High Vacuum Technique

J. Yarwood (Chapman & Hall, 10s 6d net).

The literature of high vacuum technique is not extensive. One usually thinks of Dushman or Dunoyer, both of whom published books about 1922-26, but since that date no other book has appeared in English on the subject, although it is not too much to say that vacuum practice has been revolutionised in the last ten years.

As an instance of this we have only to recall the advent of the oil diffusion pump, improved rotary pumps, and barium and other getters.

The author (late of E.M.I.) has covered the whole field of vacuum practice in this book, and, if not in great detail, in such a manner that it will be of use to students and technicians who are introduced to the intricacies of exhausting modern vacuum devices for the first time. The production and measurement of high vacua are described with illustrations of typical pumps, and a chapter on the measurement of pumping speed is followed by one on getters and degassing. Applications of high vacua in industry include an outline of photo-cell manufacture and the deposition of metal films.

There is also a useful chapter on properties of materials and electronic data. (It is curious to note that various manufacturers have their own slang terms for the same product—thus, "copper-clad" is referred to as "red platinum"). An interesting and useful monograph to have in the college or works library. G.P.

A Dictionary of Science

E. B. Uvarov. (Penguin Special—9d.)

This handy little dictionary contains over 190 pages of concise explanations of terms used in physics, chemistry, and mathematics. The author disarms criticism in his preface in acknowledging the difficulty of preparing a general scientific dictionary in a small compass, but has accomplished the feat remarkably well. It is particularly suitable for the layman as he suggests, and also for students and technicians.

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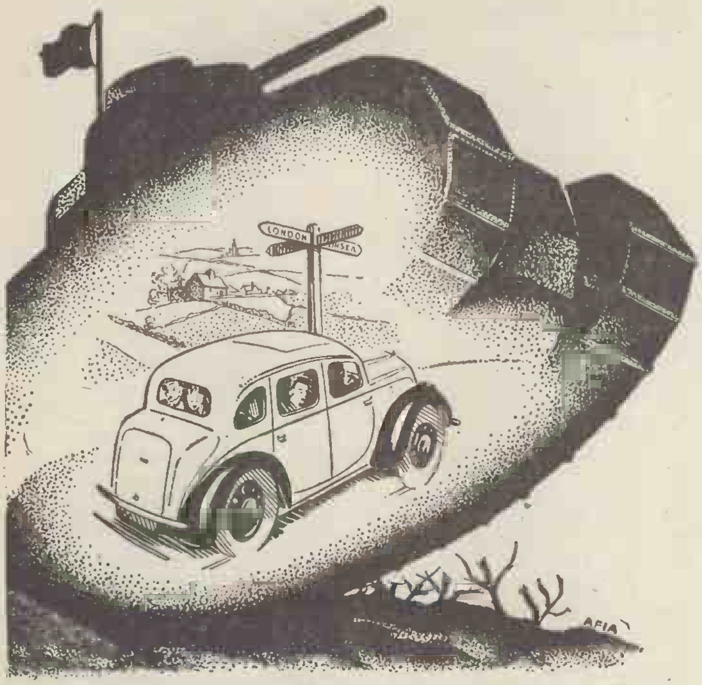

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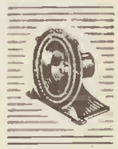

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ABSTRACTS OF ELECTRONIC LITERATURE

TELEVISION

Contemporary Problems in Television Sound

(*C. L. Townsend*)

For a better understanding of television requirements the methods normally employed in motion pictures and standard radio broadcasting are compared with those in use in the present television studio. Some indications as to what may be required in the near future are discussed and possible developments suitable for such use are described.

—*Proc. I.R.E.*, Vol. 31, No. 1, p. 3.

RADIO

Frequency Modulation Distortion in Loud Speakers

(*G. L. Beers and H. Belar*)

As the frequency-response range of a sound-reproducing system is extended the necessity for minimising all forms of distortion is correspondingly increased. The part that the loud speaker can contribute to the overall distortion of a reproducing system has been frequently considered. A type of loud speaker distortion that has not received general consideration is described. This distortion is a result of the Doppler effect and produces frequency-modulation in loud speakers reproducing complex tones. Equations for this type of distortion are given. Measurements confirming the calculated distortion in several loud speakers are shown. An appendix giving the derivation of the equations is included.

—*Jour. S.M.P.E.*, Vol. 40, p. 207.

CIRCUITS

Comparison of Voltage and Current Feedback Amplifiers

(*E. H. Schulz*)

This paper points out the differences between an amplifier with voltage feedback and one with current feedback. The effect of variations of amplifier constants on output voltage and current is decreased by either type of negative feedback. Voltage feedback decreases the effect of load impedance on output voltage and current feedback decreases the effect of load impedance on load current. Voltage feedback increases the damping of a loudspeaker and improves its response. A table also is given to assist in the choice of type and amount of feedback to be used in a given application.

—*Proc. I.R.E.*, Vol. 31, No. 1 (1943), page 25.

A Frequency Modulated R.C. Oscillator

(*C. K. Chang*)

A method of producing frequency-modulated waves is described in which a resistance element in a resistance-capacitance tuned oscillator is replaced by the output resistance of a variable mu tube. As the grid potential of the latter tube is varied, its output resistance varies and a wide band frequency modulation of the oscillator is obtained. Mathematical relations between the frequency variation and the grid-potential change are derived. Experimental results are discussed

—*Proc. I.R.E.*, Vol. 31, No. 1. (1943), page 22.

INDUSTRY

The Photography of High-Speed Transient Phenomena with Sealed-off Glass-tube Cathode Ray Oscillograph

(*W. Nethercot and H. Beattie*)

The paper describes the photographic technique which the authors have found to give optimum results in recording single high-speed transients by external photography of the luminous trace on the fluorescent screen of the high-vacuum, sealed off glass-tube oscillograph. Examples are given which show that satisfactory records can be obtained at writing speeds comparable to those usually associated only with the high voltage, continuously evacuated oscillograph and internal photography.

—*Jour. Sci. Inst.*, Vol. 20. No. 5 (1943), page 75.

Heatronic Moulding

(*V. E. Meharg*)

High frequency electrostatic fields, as now used for heating wood and resins to form bonded plywood, also find an application in moulded plastics. The range of application of this method is discussed with reference to voltage, frequency and the loss factor of the plastic. Details are given of the heating system as applied to compression and transfer moulding. The economics of the process are discussed and it is claimed that the method leads to direct saving in press costs and time. The main feature of the process, however, is the uniform heating that can be obtained over thick sections, thus overcoming one of the chief difficulties encountered to-day.

—*Modern Plastics*, March, 1943, page 87.*

Low Loss Ceramics

(*G. H. Gillam*)

A brief description of the composition of low loss ceramics is given and some of their advantages are discussed. The design of a part for manufacture is outlined with special reference to tolerances. Some points for the special attention of designers are given, viz., die construction, holes and walls, angles, draw and flatness. It is stated that metallic inserts cannot be moulded into ceramic parts; the designer is also urged not to impose close tolerances unnecessarily.

—*El. Times*, May 13, 1943, p. 544.*

* Supplied by courtesy of Metropolitan-Vickers, Electric Co., Trafford Park.

Safety with X-Rays

(*concluded from p. 54.*)

area of the film. The author strongly advises all X-ray operators, whether medical, industrial, or research to carry a test film in addition to making use of the instrument illustrated in Fig. 7, the film being the best physical method of collective measurement over long time periods. It also records any routine carelessness.

Protection. There can be few hard and fast rules governing protection as the equipment used is so varied in its construction. It is well to filter out the long wave radiation at the tube window if the work will so permit, though it must be remembered that the filter will give rise to considerable scatter. Do whatever is possible to intercept scatter at the source, particularly the scatter from any material which is in the primary beam. Never use the hand to locate the primary beam—the apparatus shown in Fig. 8 is most useful for this purpose. The adjustable mirror will be found to give a picture of all that is needed without the operator exposing himself to the beam. It will also be seen that the line-up strips help to determine the angle of the beam in relation to the work. Above all remember the safety that distance affords, and remember, too, that if there are other people in or about the department their safety is in your hands.

REFERENCES

Protection in Industrial Radiology, W. Binks, M.Sc., F.Inst.,P. *The British Journal of Radiology*, February, 1943, p. 49.

Modern Physical Laboratory Practice, J. Strong, pp. 217, 258.

Recommendation of the British X-Ray and Radium Protection Committee. Fifth Revised Report, January, 1938.

Radiology Physics, J. K. Robertson, F.R.S.C.

Applied X-Rays, G. L. Clark, Ph.D., D.Sc.

Recent R.C.A. Cathode Ray Tubes

(Tentative Data)

3BP1

A 3 in. high vacuum cathode-ray tube having electrostatic deflection and focusing, green fluorescence and medium persistence. It has a 2 in. diameter bulb neck, separate leads to all deflecting electrodes and the cathode and an overall length of approximately 10 inches. The tube is fitted with a new diheptal base which permits wide separation of the low-voltage pins from the high-voltage pins.

Rating

Heater Voltage (A.C. or D.C.)	6.3
Heater Current (Amps.)	0.6
Maximum A_2 Voltage	2,200
Maximum A_1 Voltage	1,100
Maximum Peak Voltage between A_2 and any deflecting electrode	500
Maximum Grid Circuit Resistance (megohms)	1.5

3EP1/1906. P.I.

A high vacuum cathode-ray tube similar to the 38P1. It has the same ratings but with a different bulb with $1\frac{3}{8}$ in. diameter neck and a magnal base. Separate leads to all deflecting electrodes are provided, but the cathode is connected to the heater within the tube.

7CP1/1811-P1.

A short 7 in. high vacuum cathode-ray tube having magnetic deflection, electrostatic focusing and medium persistence. It has a $1\frac{3}{8}$ in. diameter bulb neck and an overall length of approximately $13\frac{1}{2}$ in. Except for Anode No. 2 which is connected to a snap terminal on the side of the bulb, the other electrodes including the cathode, all have separate leads terminating in an octal base.

Rating

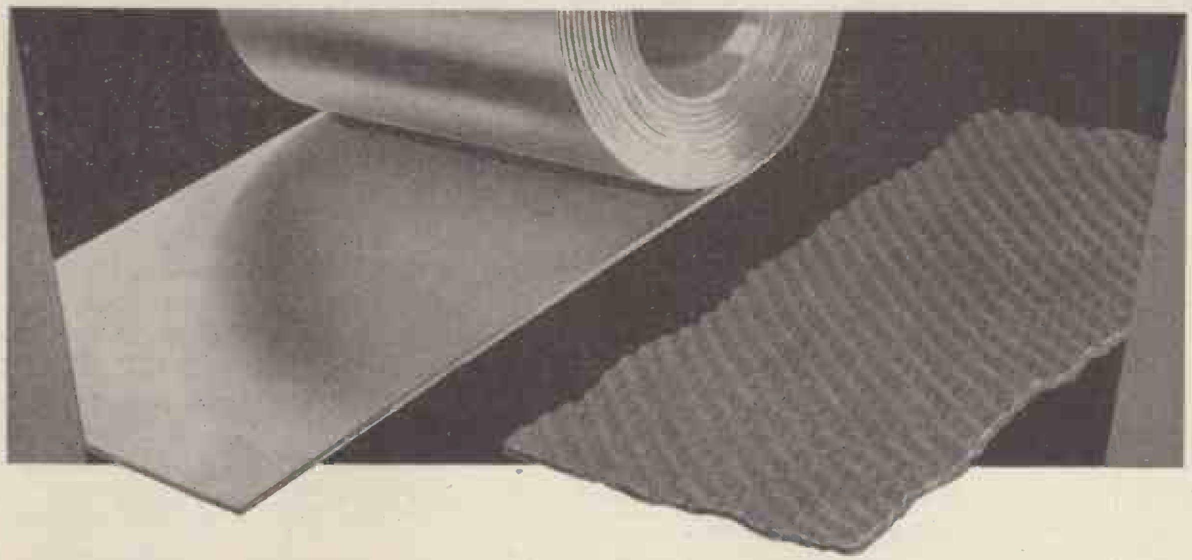
Heater Voltage (A.C. or D.C.)	6.3
Heater Current (Amps.)	0.6
Maximum A_2 voltage	7,700
Maximum A_1 Voltage	2,200
Maximum G_2 Voltage	330
Maximum G_1 Circuit Resistance (megohms)	1.5

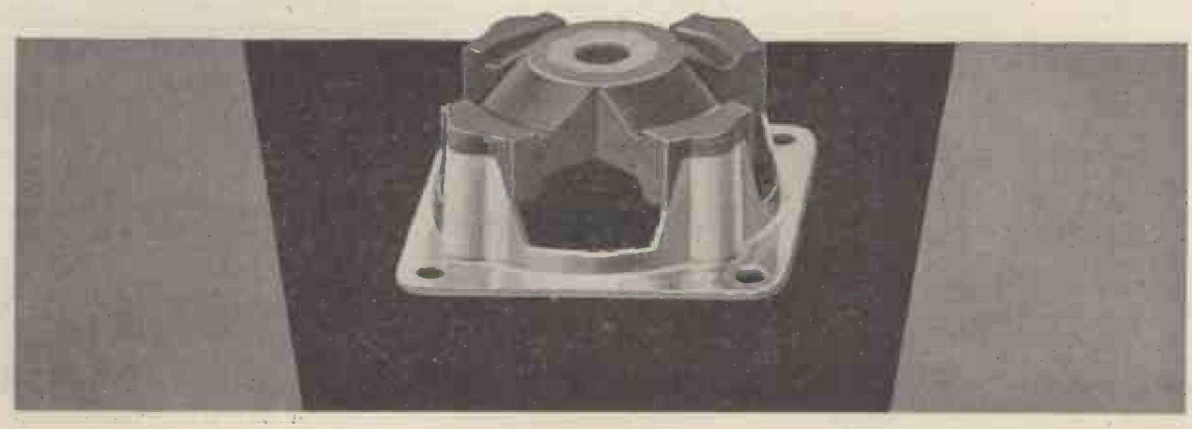
2AP1

A high vacuum cathode-ray tube similar to the 902 except that it has separate leads to all deflecting electrodes and the cathode, employs a magnal 11 pin base, and can be operated with higher anode voltages.

Rating

Heater Voltage (A.C. or D.C.)	6.3
Heater Current (Amps.)	0.6
Maximum A_2 Voltage	1,100
Maximum A_1 Voltage	500
Maximum Peak Voltage between A_2 and any deflecting electrode	660
Maximum Grid-Circuit Resistance (megohms)	1.5





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