Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

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2/- OCT., 1943

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Controversy

An argument of interest to all electronic engineers has been taking place in the correspondence columns of *Engineering*, which published in April last a summary of a paper by Mr. T. Robson* (L.N.E.R.) on "Counter pressure brake testing of Locomotives."

In this paper a description was given of an electronic engine indicator which is claimed by Mr. Cattanes (A.C. Cossor)† to be identical with that developed by his Company in 1936, but now obsolete, although no acknowledgement is made of their patent No. 462,725.

A paragraph in Mr. Cattanes' letter runs:

"It is therefore flattering to the electronic engineer to see that after many years of development work and experience the mechanical engineer can only produce a more elaborate but intrinsically unchanged equipment which is little short of a straight copy of that which he investigated nearly ten years previously, now technically out-of-date."

This letter brought two replies,‡ one from Mr. D. R. Carling, who had worked with the indicator in question, and the other from the author of the paper.

Mr. Carling's letter appears self-contradictory in parts. After saying that there are fundamental differences in the circuit of the 'Robson' indicator, he states that the only similarity between the two lies in the amplifier circuit and in the use of the same type of c.r. tube. Further: "the indicator described was made into a useful instrument, utilising the basic principles of the original Cossor indicator, adapted only where necessary."

He concludes with the dig:

"When designers of electronic equipment can produce a really serviceable article for the mechanical engineer to use with only minor adaptations for the particular work to be done, then will they be worthy of the title of Electronic Engineers."

Mr. Robson in his reply agrees that the amplifier circuit is the same as that of A.C. Cossor, and says that he acknowledged this in the original paper. The stroke base and pressure recorders, are, however, of a completely different type, and Mr. Robson and Mr. Carling both claim that the apparatus had to be redesigned to fit it for the particular job for which they required it.

Mr. Cattanes at present has the final word. In his last letter he reiterates that the L.N.E.R. apparatus may differ in mechanical details but the principles of the original commercial equipment were retained without improvement and that the original basic defects of the circuit had not been overcome.

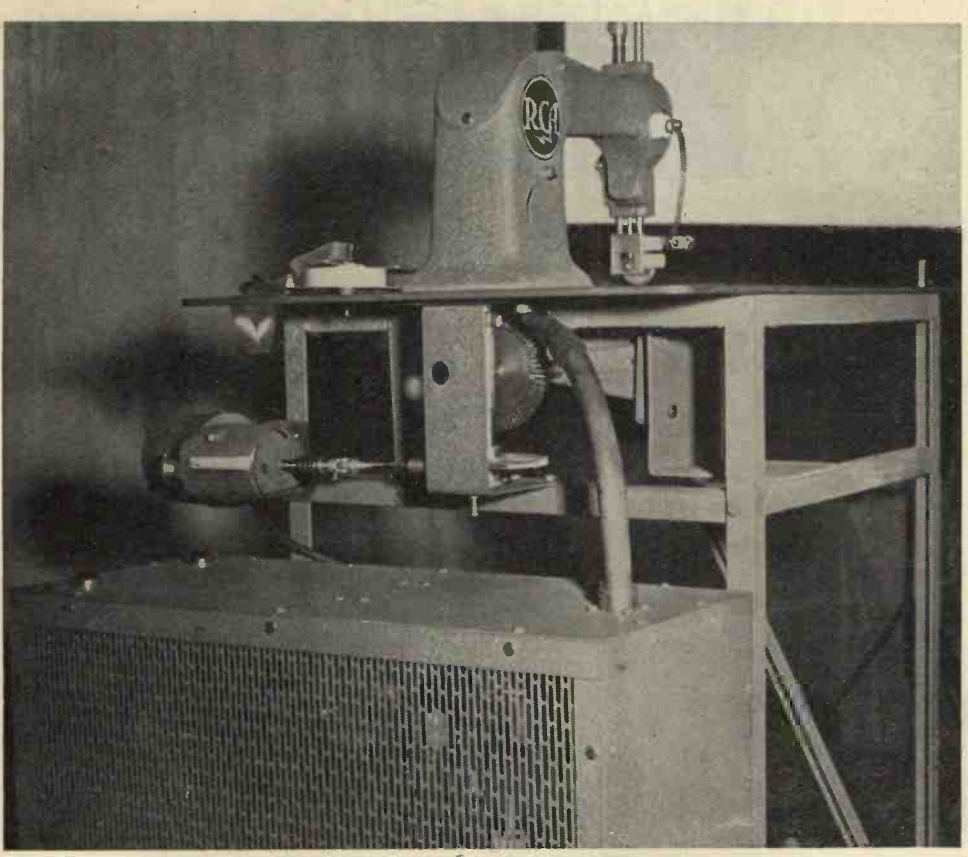
Whatever the rights and wrongs of the argument are, the concluding paragraphs of his letter are well-phrased:

"Electronics is now a highly complicated and specialized field of Engineering. As an Electronic Engineer would no longer dream of designing a locomotive, much less should a Locomotive Engineer expect to develop a piece of electronic apparatus with the presumption expressed by Mr. Robson that it would be better than that producible by an Electronic Engineer. The justification given that he was "forced to do so because Electronic Engineers do not appear to be able to make anything sufficiently robust and reliable to be of use outside a Laboratory" is too grotesque to be taken seriously to-day. It is nevertheless symptomatic of the attitude which is still obstructing the development and introduction of modern test equipment in Industry. The amount of electronic equipment which is used under the most strenuous conditions of war and the general recognition that it is one of the many factors which will be responsible for ultimate victory, should be sufficient to have dispelled this attitude long ago.

The plea I made was the natural one that each man should keep to his own job. My letter was a reminder that although it was possible for an 'outsider' to 'do' things passably well in the early stages of a new art, in the case of Electronics the art has evolved so rapidly that to meet the exigencies produced by increased knowledge and more difficult requirements its standards are now at least as high as those of the older engineering professions, and as a result it is now right out of the ambit of other than the Electronic Engineer.

To be more specific, I can restate that if a Pressure Recorder is required in Industry, as it is now agreed by everybody that the solution must be electronic, the job should be assigned to the Electronic Engineer. The time, money and labour wasted by others in trying to solve the problem should be employed for a more useful purpose in their own professions."

* *Engineering*, April 16 & 23, 1943.
† *ibid.* June 25, 1943.
‡ *ibid.* July 16 & 23, 1943.



An Electronic 'Sewing Machine'

The illustration shows a machine developed by the R.C.A. Laboratories for the 'welding' of seams in thermoplastic materials. Hitherto, moisture-proof seams have only been made possible by the use of a thermo-setting or cold-setting cement, or by treating ordinary sewing with a form of moisture-proof cement.

One of the difficulties in the use of heat for fusing seams is the uneven temperature distribution, resulting in excessive heating and flowing of the outer layers of the plastic when pressure is applied.

The electronic method overcomes this by generating the heat by dielectric loss in the material itself. This has the reverse effect of generating the maximum heat in the interior of the material while the outer layer in contact with the electrodes remains comparatively cool. Under pressure, therefore, the bonding takes place between the inner surfaces, with negligible distortion of the outer layers.

For continuous welding of seams, the material is passed between rollers mounted on a body similar in appearance to a sewing machine, the rollers being geared to rotate at the same speed to avoid slip.

The output from a small oscillator at a frequency of 60–70 Mc/s. is applied to the rollers, and the work is fed through at the rate of approximately 5 ft. per minute. In one test, a seam $\frac{1}{8}$ in. wide was made in Vinylite at this rate, the power required for a sheet .004 ins. thick being approximately 5 watts.

By fitting a binding attachment similar to that on an ordinary sewing machine, it is possible to bind the raw edge of the plastic, or to reinforce the seam with a strip of tape.

Successful results have been obtained with Vinylite and Pliofilm, but Koroseal (polyvinyl chloride) and Saran (vinylidene chloride) require an interleaving of Vinylite tape for best results. Materials having a very low power factor require higher voltages across the material to generate sufficient heating and this tends to produce electrical breakdown unless a higher frequency is used (above 60 Mc/s. is suggested).

The side view of the machine above shows the oscillator cabinet and leads to the rollers, which are driven by gearing from the small motor on the left.

The photograph on the left is that of an early experimental model with the operator guiding the work and controlling the welding by a foot pedal switch.

The German Army "Speech-on-Light" Signalling Apparatus

By D. GIFFORD HULL, Capt.

The German Army has for some years had a practicable, fool-proof Speech-on-Light apparatus, which, in certain circumstances, replaces field telephone systems and U.H.F. field radio sets

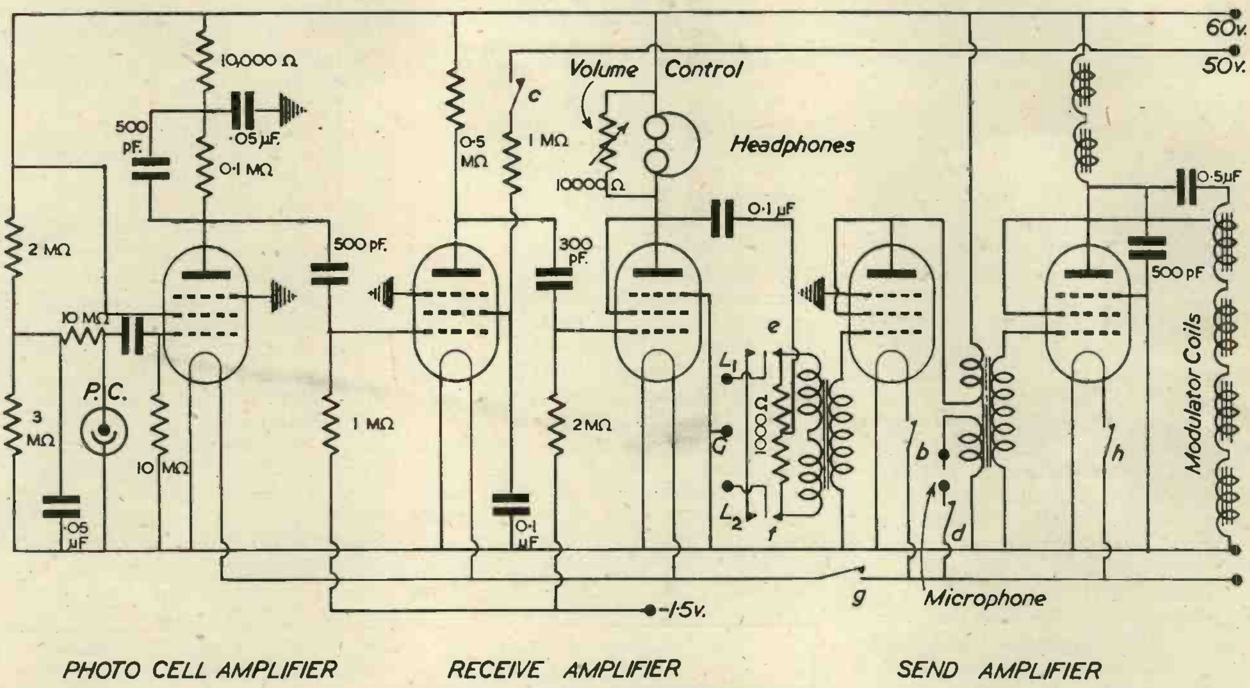


Fig. 1. Circuit diagram of amplifiers.

Introduction

THE following article describes the Speech-on-Light signalling apparatus which has been in use in the German Army since about 1935. The technique of using a light beam for voice communication over visual distances is by no means new; but it was not evident that any fool-proof systems had been developed at the outbreak of war.

For a number of years, experiments have been carried out on modulated light. There are two methods of applying the voice modulation, firstly, by directly modulating the light source by the L.F. Signals, and secondly, by using a constant intensity source and modulating the outgoing beam. No great successes have been achieved by modulating the source. With filament-type lamps, the thermal inertia of the filament presents some difficulty, especially at high voice frequencies, and gaseous discharge lamps do not seem to be the answer.

Certainly, the best method is to modulate the beam after the source, and for this, several methods, allied to talking picture technique, have been tried. But before the war speech-on-light signalling was still in the experimental stages, except for this German set.

In all such systems, the modulated beam must be sharply focused on to the distant station, at which a photo cell is used to detect the changes in light intensity and to convert them into voice currents.

The German speech-on-light apparatus was kept a closely guarded secret, but relating documents were found during the first German Libyan Campaign. It was not until the Battle of Alamein in October, 1942, that the complete apparatus was found. (It is not known whether this applies to the Russian front.) The apparatus was investigated and tested in the laboratories of the Royal Corps of Signals in the Middle East, in November.

Features of the German Set

Briefly, the German apparatus consists of a sender-receiver head, which resembles an oversize pair of binoculars. The head contains the lamp, the modulating device, the colour filters, the transmitting lens, the receiving lens, the photo cell, and its amplifier. A built-in telescope is included, and the head stands on a tripod. The L.F. amplifiers, one for sending and one for receiving, are contained in a box, together with the necessary batteries, which stands on the ground alongside the tripod. The entire apparatus may conveniently be carried by one man.

An important feature of the instrument is that it may be operated on white, red, or infra red light, merely by selecting the required filter with a knob. The use of infra red light eliminates possibility of interception, and ensures secret communication in the dark, whilst the range is not appreciably reduced.

Of course, for night operation, the instruments must either be lined up the previous day—or else at night, by showing a red light.

The outgoing light is sharply focused to a parallel beam by means of the 80 mm. lens. The beam is six yards wide at a mile, and thirty yards wide at five miles.

The amplifier has a send-receive switch, hence duplex communication is not possible. However, provision is made for operation over a telephone line, and for this, the line works into a bridge input circuit, which permits both send and receive amplifiers to operate simultaneously without instability.

It is appreciated that the instruments must be set up in view of each other, and that there must be no intervening objects. For this reason, it is desirable that the stations are sited on elevated positions, thus ensuring that passing vehicles, etc., do not interrupt the light beam.

It is observed that shimmering heat currents rising from the ground (so common in hot deserts) give rise to interference, but the circuits are so designed to minimise this effect, as will be shown later.

The effective range of the apparatus depends largely on atmospheric conditions, but five miles is about the average. Of course, this range is considerably decreased in rain, and increased when the atmosphere is very clear. The apparatus was not tested in fog, but it is assumed that although the infra-red ray will to a large extent penetrate fog, the range is considerably reduced.

Provision is made for keying the the lamp filament by means of a push button. This provides facility for morse transmission, but reception must be visual. Under these conditions, greater distances are possible.

Principles of Transmitting System

Considering the transmission system first, we start with the lamp. This has a coiled filament, is supplied with 4.8 volts, and consumes 4 watts. The lamp is held in an accurately made, detachable holder, the filament is pre-focused and the lamp base has a guide pin which engages with a groove in the holder. The lamp holder fixes into the lamp house, containing a mirror which focuses the light on to the modulator unit.

After the modulator, the light beam passes through a filter, which may be white, red, infra-red, or diffused, depending on the setting of the filter selector knob. The light beam, being now modulated and filtered, passes through the 80 mm. lens, which focuses it to a virtually parallel beam.

Principles of Receiving System

The modulated, filtered light (be it white, red or infra-red), is picked up on the 80 mm. lens of the distant receiver, and focused on to the photo cell, located at the back of the head. The characteristics of this photo cell will be described later. The photo cell changes the variations in light intensity into changes of electric potential, which are amplified by the one stage photo-cell amplifier, located within the head. The L.F. output is fed by a cable to the main receiving amplifier, located in a box on the ground beside the tripod.

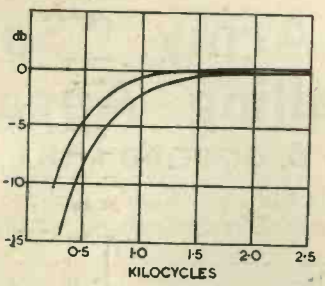


Fig. 2. Response curves of amplifiers: Upper—sending; Lower—receiving.

The Amplifier

Separate amplifiers are used for send and receive, but both are mounted as one unit in a box containing the associated batteries, cables, spare valves, lamps and photo cells. Valves are of the standard type of German Army, high gain, directly heated pentodes, R.V.2P.800. These valves resemble the British catkin type, but they are mounted upside down in a tubular holder, being supported at both ends. The photo-cell amplifier is conventional; the cell receives a positive voltage by means of a high resistance potentiometer from H.T. line. The anode circuit has a resistance capacity network that attenuates at about 4,000 c/s., the purpose being presumably to minimise photo-cell hiss.

This amplifier uses two valves in cascade, resistance-capacity coupled—and the last valve is triode connected to secure a low impedance for the phones. The output is also taken to the telephone bridge input circuit; the operation of this will be discussed later.

The sending amplifier normally uses but one valve, triode connected. This is fed by the microphone, and the anode is parallel fed by an L.F. choke, the anode load being the armature coils of the modulator.

The send-receive switch normally switches on the appropriate amplifier, thus duplex operating is not possible. But for the purpose of working into a telephone line, the switch is turned to "Telephone," and this places the bridge circuit in the sender amplifier input—and in the receiver amplifier output. The bridge is balanced, to prevent acoustic feedback over the entire system. Naturally, the bridge input circuit offers an attenuation to the microphone current—so in this condition the switch puts another

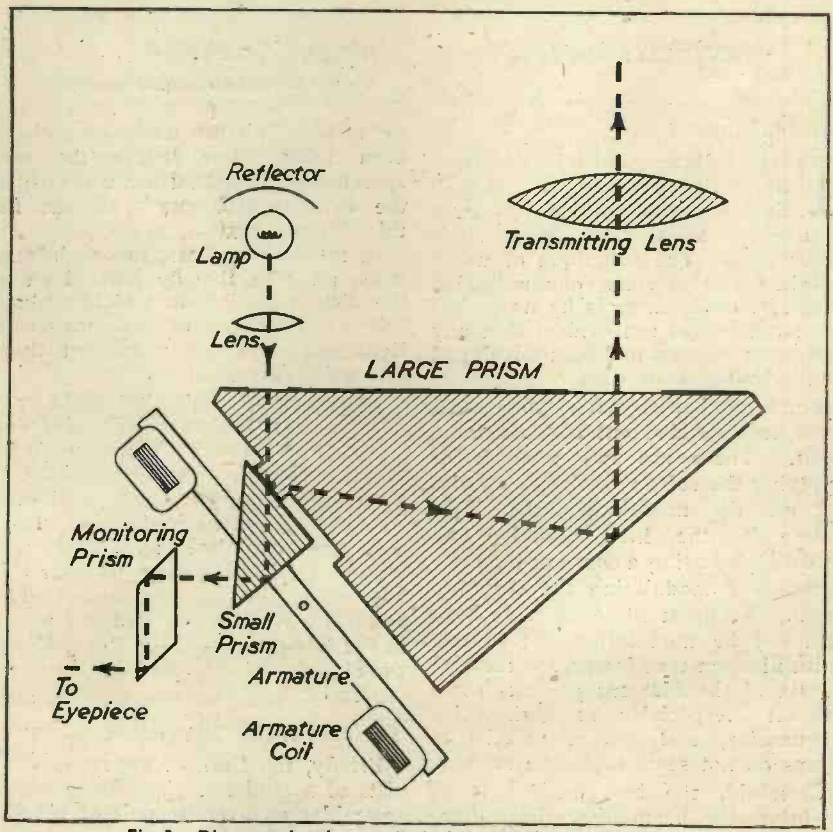


Fig. 3. Diagram showing method of modulating the light beam.

valve in the sender amplifier circuit to compensate for the attenuation of the bridge.

The audio frequency response of the amplifiers is shown in Fig. 2, and it will be noticed that both amplifiers have a falling response commencing just below mean voice frequency. The attenuation at 300 c/s. and below is very high—and this feature is very useful in that it minimises low frequency flutter due to hot air currents rising from the ground in the optical path.

The Photo Cell

The cell is small in size, resembling a button about one inch diameter. It is of the "Thalofide" type, and changes its resistance in accordance to variations of light intensity. The cell is very sensitive to red and infra-red light, and a built-in red filter is incorporated. The output of the cell is in the order of one mA. per lumen. It will be observed that the polarising voltage is taken from the H.T. line via a high resistance potentiometer and about 30 volts is applied to the cell. This relatively low voltage is desirable in order to keep the noise down, since such cells tend to be very noisy. The output of the cell is applied to the amplifier through a 100 p.f. condenser, which, together with the 10 megohm grid resistor, affords considerable attenuation at low frequencies.

The Modulator

The action of the modulator is best understood by reference to Fig. 3. The light from the lamp-house strikes the hypotenuse side of a right-angle prism. The light beam is reversed in direction by two internal reflections of the prism. The other angles of the prism are not quite 45 degrees, so that at the point of first reflection the mean angle of incidence is approximately the critical angle for glass and air media. Under these conditions, partial reflection and partial refraction takes place. The area at which this first reflection takes place is a small rectangle measuring 3 by 1½ mm., the surrounding glass being blackened. The armature consists of a flat metal strip, pivoted at its centre. Its ends are located closely between the pole pieces of the armature coils, which are so phased that one pushes and the other pulls. A small right angle prism is carried on the armature, near its centre, and it is so positioned that one of its sides rests in contact with the small rectangle of the main prism. As the armature moves in accordance with the voice currents, so the pressure of the small, moving prism against the large prism, changes in accordance with the voice currents.

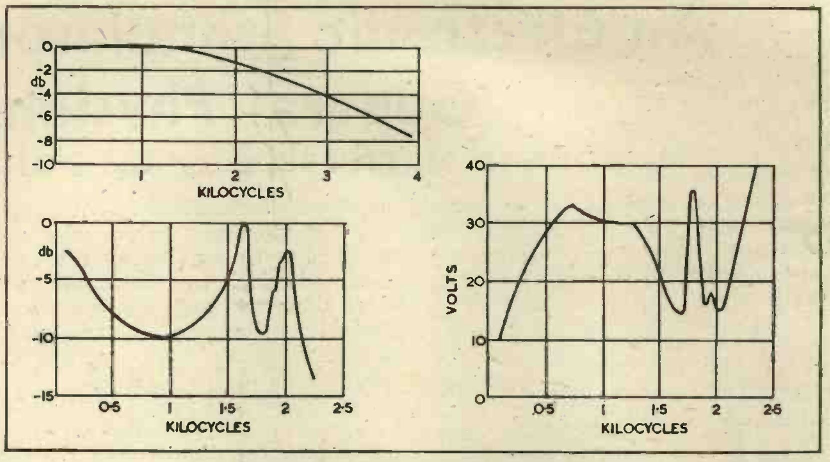


Fig. 4. (top left) Response curve of Photo cell
Fig. 5. (lower left) Response curve of modulator
Fig. 6. (right) Modulator overload characteristic

It will be appreciated that since the small prism is mounted close to the axis of rotation of the armature, its travel is small, but its pressure is great. It is necessary, then, when considering the analysis of the action of the device, to bear in mind that it is the pressure of the small prism on the large one that alters—not so much the air gap between the two. Let us consider the state of affairs that would exist if these two glass surfaces were truly optically flat and in perfect contact. Obviously there would be no change of medium at this point and no internal reflection would take place. Hence, no light would pass through the main prism. But as soon as the contact between the prisms becomes imperfect, a change of light media will occur—and internal reflection will result. In practice, the contact is never perfect, in fact, for all pressures of the prism, most of the light is reflected. But the varying pressure brings about a varying degree of contact, which, in its turn, varies the amount of light reflected through the main prism. This, coupled with the fact that the angle of incidence is nearly the critical angle, makes the modulator a relatively efficient device.

A device is incorporated to control the quiescent, no-signal, pressure of contact. The operator is supposed to adjust this to give maximum sensitivity and minimum distortion. The action of this device is interesting, in that it controls, to some extent, the direction of modulation. It is paradoxical to say that overall upward modulation takes place, if one is considering the amount of light that enters the prism; but with respect to the quiescent light level leaving the prism (*i.e.,* taking into account the amount lost at the first reflection for zero signal) it appears that upward and downward modulation does occur.

No attempt has been made to measure the depth of modulation, but if the instrument is operated on white light, and an observer stands in the beam, a very marked flicker is noted when the operator speaks.

The Monitoring System

It has already been mentioned that a telescope is provided for aligning the station to the distant terminal. The telescope has a secondary function, in that it acts as a monitoring device to check the action of the modulation. This is done in the following manner. The hypotenuse side of the smaller prism has a clear space on it, which is placed close to another prism, which carries the light into the eye-piece of the telescope, being suitably focused by a small lens. We have already seen that the light that is lost at the first reflection of the main prism, is passed on to the smaller moving prism. This light is in turn passed on to the eye-piece. The contact surface of the moving prism has a small grid mesh etched on it (not for the purpose of affecting the contact surface) and it is the image of this grid which appeared in the eye-piece As modulation takes place, the image of this grid should become brighter and duller. In practice, it is noted that only on peak modulation does the grid image appreciably change in intensity. It will be observed that this monitoring system is entirely visual, and gives no indication as to the quality of the transmission. In any event, it is complementary to the true modulation, being, as it were, "inside out."

Fig. 4 shows the response curve of the photo cell, and it is noted that the L.F. response is good, but the curve falls off at the H.F. end. In this

(*Concluded on p.* 211.)

An Electronic Stimulator for Use in General Physiology

By ROLAND H. THORP, B.Sc.* and DONALD ROBINSON

SEVERAL instruments have been described for the production of stimuli which are more easily controlled and more consistent than those produced by the ordinary induction coil.

Schmitt & Schmitt[1] described an apparatus using a condenser discharge through a gas-filled triode valve (Thyratron). A potentiometer was included to enable known fractions of the output voltage to be used, but no arrangement was made to provide for variations of output load with the various resistances of the tissue stimulated. This instrument was designed for battery operation and was capable of a limited and discontinuous range of stimuli only. A simple device employing a neon tube was described by Cullen[2], but until the circuits published by Delaunois[3] and later Connerty and Johnson[4] were available little advance was made towards the production of more accurate methods of stimulation.

The requirements to be met in such an apparatus are as follows:—

1. Helmholtz[5] showed that it is preferable that the wave-form of the stimulus should have a steep front corresponding to a very rapid rise in voltage.

2. To avoid the damaging effect of high currents associated with the higher voltage stimuli, it is necessary that the time occupied by the pulse itself should be a small fraction of the interval between the pulses, which means that the peak voltage of the output must be very much higher than the mean voltage.

3. The actual peak voltage applied to the tissues at the time of stimulation must be known, and since the tissues impose very variable loads upon the instrument there must be a device for the approximate matching of this load.

4. The frequency of stimulation should be variable over a wide range without excessive effect upon either the wave-form or the output voltage.

5. A provision should be included for a single pulse and also a visual indication that slow impulses are being delivered. An additional output section is also desirable so that

* Wellcome Physiological Research Laboratories.

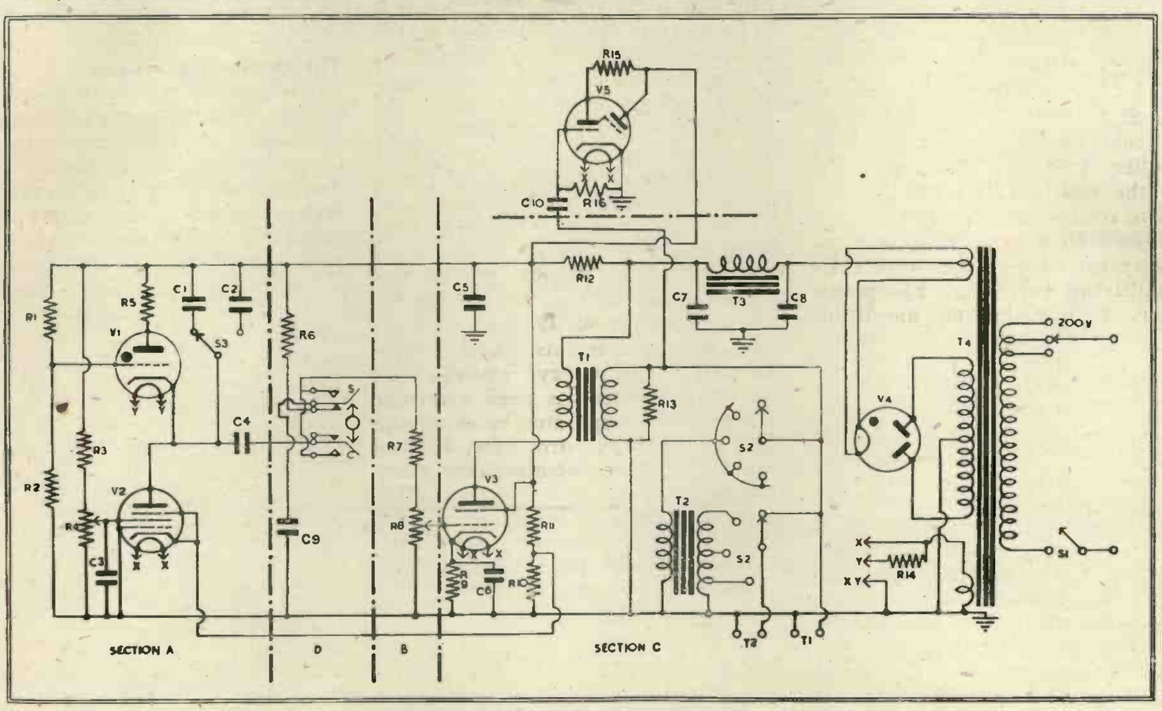


Fig. 1. Circuit diagram of Stimulator.

R_1 500,000 ohms.
R_2 500,000 ohms.
R_3 250,000 ohms.
R_4 1 megohm.
R_5 1,000 ohms.
R_6 500 ohms.
R_7 50,000 ohms.
R_8 25,000 ohms.
R_9 2,000 ohms.
R_{10} 50 ohms.
R_{11} 10,000 ohms.
R_{12} 4,000 ohms.
R_{13} 20,000 ohms.
R_{14} 1.2 ohms. 2 amp.
R_{15} 2 megohms.
R_{16} 1 megohm.
C_1 1 μF.
C_2 0.005 μF.
C_3 0.5 μF.
C_4 0.1 μF.
C_5 8 μF. 300 v. wkg.
C_6 50μF. 50 v.
C_7 8 μF. 500 v. wkg.
C_8 8 μF. 500 v. wkg.
C_9 0.5 μF.
C_{10} 0.01 μF.
T_1 1 :3 output Transformer.
T_2 120, 50, 30 :1 Transformer.
T_3 20 Henry choke 100 mA.
T_4 Mains Transformer supplying 300-0-300 v., 5 v. 2A., 6.3 v. 3A.
V_1 Cossor GDT 4B.
V_2 Mullard EF 36.
V_3 Radiotron 6L6.
V_4 Radiotron 83.
V_5 Mullard E.M.1.

the impulses can also operate a signal marker.

The circuit given in Fig. 1 has been divided by dotted lines for ease of description, and the values of the components and types of valves are given in the table subjoined to the figure. Section A is a conventional cathode-ray time-base relaxation oscillator producing the saw-tooth wave-form shown in Fig. 2a. Its operation is as follows: The valve V_2 is a high impedance pentode which has the characteristic that the anode current is almost independent of the anode voltage and, as a result, the condenser C_1 (or C_2) is charged linearly corresponding to the portion AB of the wave-form shown in the figure. When the voltage of the condenser has reached the point B—the striking voltage of the gas-filled triode valve V_1—the latter discharges the condenser giving the part of the wave BC.

The addition of section B to the circuit alters the wave-form to that shown in Fig. 2b. The steeper part of the curve AB is produced by the current caused by the redistribution of charges between C_1 (or C_2) and C_4 in addition to the normal charging current shown as AB in Fig. 2a. This section also serves to couple the impulse generating circuit to the output and buffer circuit C. Section B embodies the resistance R_7 which is included to reduce the oscillator voltage of 150 volts to the value of approximately 17 volts required to load fully the amplifying valve V_3. The potentiometer R_8 provides an amplitude control at a point where the current is small. The output and power section C is conventional, but the resistance R_{13} imposes a constant load upon the amplifying stage which is low in proportion to the animal load when used for skin surface stimulation. When isolated nerves are being stimulated the resistance load is small, hence the matching transformer T_2 and switch S_2 are included. This provides definite percentages of the measured output voltage for low voltage stimulation or for a recorder, without the power loss of a resistive attenuator used for this purpose.

Section D comprises a switch for disconnecting the continuous pulsations when not required or substituting a single pulse. The key, when depressed in the direction C, connects the oscillator to the amplifying stage. In the central position no output is obtained. A single impulse is obtained each time the key is pushed to the position marked S. Condenser C_9 is charged in the central position through the resistance R_6 and discharges in the S position into section B. The key is locking in the C position and spring loaded in the S position.

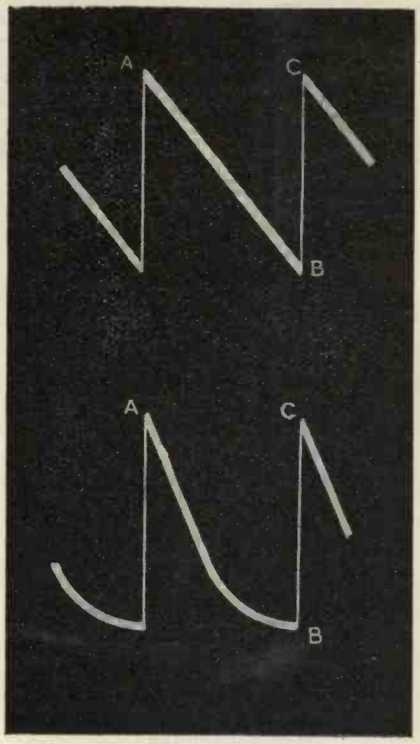


Fig. 2. Diagrams showing (a) Sawtooth waveform of the oscillator section, and (b) the effect of adding Section B to the oscillator.

Section E is a cathode-ray indicator ("magic eye valve") to check the slower stimuli visually.

Previous instruments of this type suffer from frequency instability or "hunting." This has been overcome in the present apparatus by supplying the screen of the control valve V_2 from a high resistance potentiometer which is separate from the grid circuit of the gas-filled triode and also by the addition of the condenser C_3. The cathode of the control valve is maintained at an unvarying potential by the bottom section R_{10} of the heavy potentiometer made up of R_{10}, R_{11}, and R_{12}.

The finished instrument produced the wave-form shown in the oscillograms of Fig. 3. Figures a, b, and c, show the normal wave-form at different frequencies when the amplitude is reduced to retain the peak upon the screen of the cathode-ray oscilloscope. It will be seen that the reverse kick marked CD in the trace diagram (Fig. 3a) was not to be expected on theoretical grounds (cf. Fig. 2b). The explanation of this is considered to be as follows. Although the actual frequency is low, the rate of change of potential, which determines the values of inductive reactances in the circuit, is extremely high and consequently the potential is kept changing in the same direction, and on the charging part of the cycle is carried below the original starting point. This was confirmed by an examination of the wave-form of the pulses at the oscillator stage at the same time, and it was found that the wave-form there was exactly what was expected and identical with the diagram of Fig. 2b. This artefact is probably unimportant, but it is very interesting because it is much more obvious on the cathode-ray oscilloscope when the amplitude of the output is high (Fig. 3d.) and has been mistaken by several workers for the functional wave-form ABC of Fig. 3a, which is so rapid that it is only seen in the dark, and at large amplitudes passes well beyond the limits of the cathode-ray tube screen.

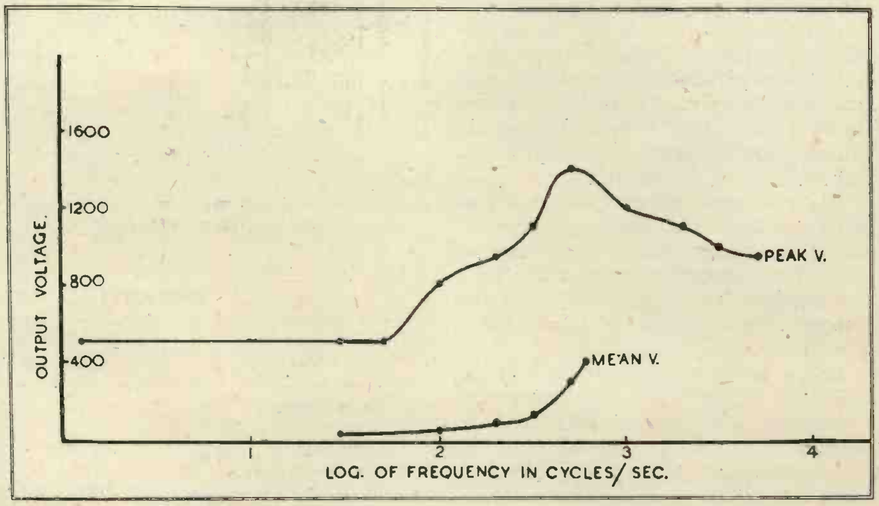


Fig. 4. Graph showing voltage output of stimulator at various frequencies.

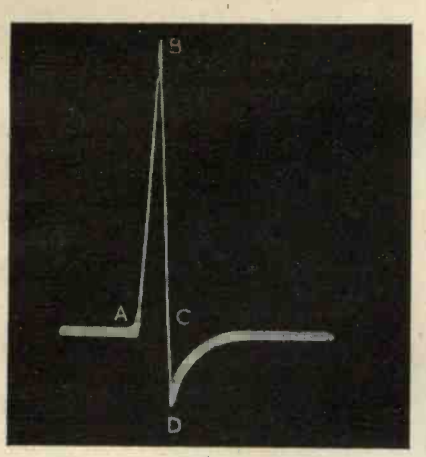
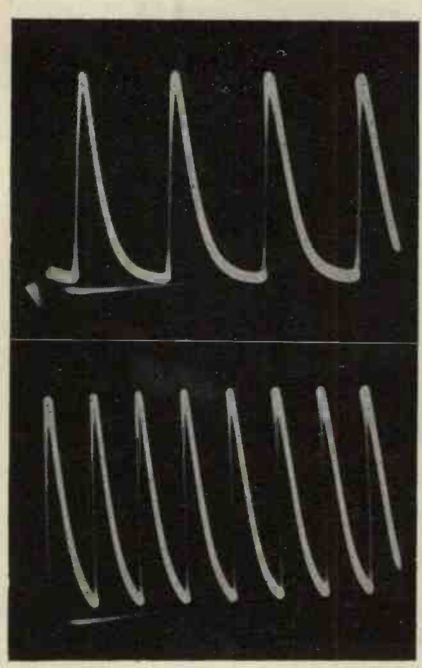
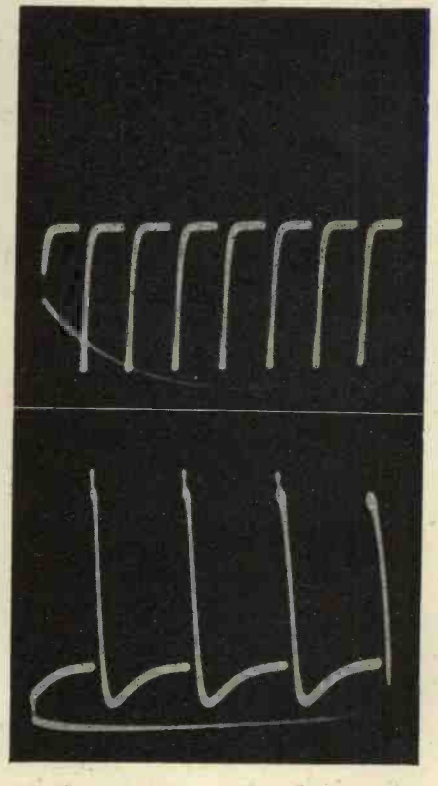


Fig. 3. Waveforms derived from the output stage. (a)—left—Below 200 c/s.; (b) and (c)—centre column—1,500c/s. and 3,000 c/s., respectively; (d) and (e)—right hand column—photograph at large amplitude and low frequency to show reverse kick after condenser discharge. (e) Trace formed when the output valve is overloaded (see text).
(5 secs. exposure at f.8. Mullard GM 3156 Oscilloscope Selo F.P. film).





It will be seen that the waveform becomes less transient above 1,000 cycles per second because the flow of current through the valve V_2 has been increased to a high value compared with that derived from the condenser C_4 which is limited by its time constant with the resistance composed of R_7 plus R_8. This was not thought to be important as these high frequencies are less frequently used, but the desired wave-form could be produced up to any frequency by using smaller condensers in place of C_1 or C_2.

The range of frequencies was restricted in this instrument to from 1 cycle in 10 secs. to 3,250 cycles per second, but can be extended above or below these limits quite simply.

The graph of Fig. 4 shows the effect of variation of frequency upon the peak output voltage and the mean output voltage. The former was read upon a specially designed peak voltmeter intended to be used with the stimulator, and the latter by means of a rectifier moving-coil voltmeter (Avo Model 7). The graph shows that the peak voltage does not fluctuate suddenly and that the mean current is negligible. Above about 500 cycles per sec. the mean voltage readings are quite unreliable with this particular wave-form. If such values are thought important they could be obtained more accurately by means of a thermo-electric voltmeter.

It could with advantage have been permanently incorporated in the instrument, except that any meter at these times needs to serve more than one purpose. The meter is calibrated to read 1,500 volts full-scale and obeys a semi-log. law.

The stimulator was developed from those of Connerty and Johnson and Delaunois, but overcomes certain defects.

In the former the published waveform is similar to that shown in Fig. 3d. in which the top part of the trace runs off the screen and the artefact previously described is prominent. Also the limiting resistance R_7 is omitted and the consequent overloading of the amplifying valve, not only means that it will rapidly fail, but gives rise to the blob on the trace illustrated in Fig. 3e.

This trace was taken with about 50 of the available 150 volts fed into the amplifying valve so that when the whole voltage is fed the overloading is much worse. The method they adopted to bias the control valve is unsatisfactory, but an ingenious method was used to keep a constant wave-form at the higher frequencies, namely, the introduction of resistances R_8 and condenser C_8 in their circuit.

The circuit of Delaunois also shows the omission of the limiting resistance and the direct connexion of the grid of the gas-filled triode valve has been discussed above.

These remarks are not made in any sense of destructive criticism, but merely to point out why this type of instrument has been re-investigated, and the need for the modifications introduced. The table below gives the measured operating conditions of the instrument and the construction was straightforward and followed that of a normal piece of radio equipment.

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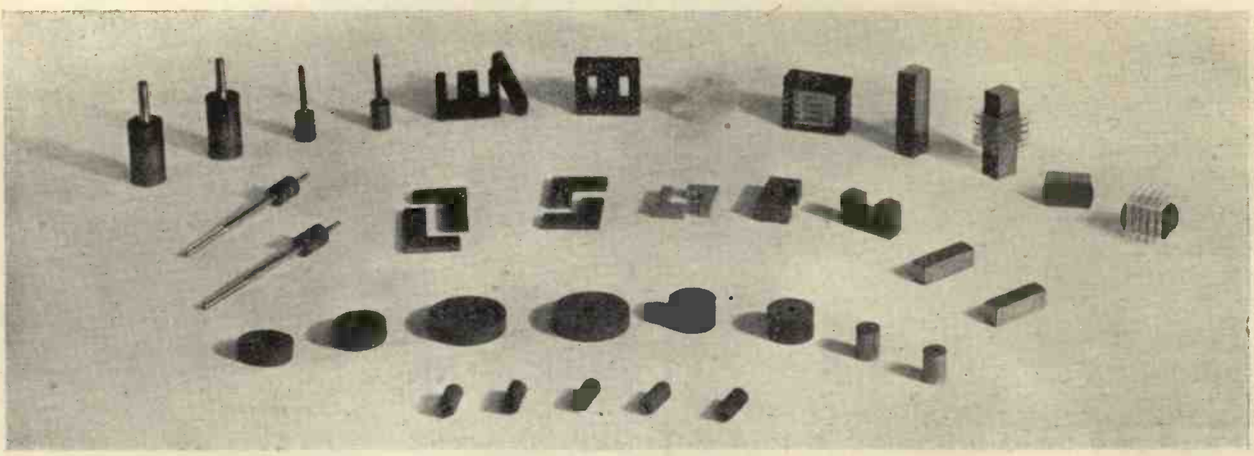
1 Schmitt and Schmitt, *Science*, 1932, 76, 328.
2 Cullen, *Science*, 1941, 94, 219.
3 Delaunois, *J. Physiol.*, 1939, 96, 57P.
4 Connerty and Johnson, *Proc. Soc. Exp. Biol. and Med.*, 1942, 49, 223.
5 Helmholtz, *Poggendorf's Annalen der Physik und Chemie.*, 1851, 83, 505.

OPERATING VOLTAGES AND CURRENTS

Valve		V_1 GDT 4B	V_2 EF 36	V_3 6L6
Anode volts	...	230		350
Screen volts...	...		0—75*	230
Grid bias ...	...	100*	—1.5	—13
Anode current	...			65 m.a.

Total rectified current = 94 m.a. * Measured with 20,000 ohms per volt meter.



Dust Cored Coils

Part III.—Variation of Q with Frequency

By V. G. WELSBY, B.Sc. (Eng.)*

THE magnification of a coil at a frequency f can be expressed as

$$Q = \frac{2\pi f L}{R}\left[1-(f/f_r^2)\right] = Q_o(1-x^2) \quad (1)$$

where f_r is the frequency at which the inductance of the coil resonates with its self capacitance. It is convenient to regard the quantity Q_o as the "true" magnification of the coil, and the factor $(1 - x^2)$ as a correction which has to be applied to obtain the apparent magnification as measured at the coil terminals. It will be noted that at low frequencies, $Q \approx Q_o$, but that as the testing frequency approaches the natural resonant frequency of the coil, the value of Q falls rapidly to zero. It has already been pointed out that, for various reasons, it is usual to design coils so that, even at their highest working frequency, the value of $(1 - x^2)$ is not very much less than unity. As a result, much useful information can be obtained by investigating the properties of Q_o, bearing in mind that Q will always be smaller than Q_o, but that the difference will rarely exceed 10 per cent. even at the top of the working frequency range, and that the correction factor can always be applied when more accurate results are required. As shown in Part 2, the loss resistance R can be expressed as a function of frequency.

$$R = R_{DC} + R_m + R_w$$
$$= R_{DC} + fL[(F_e + k_m + F_d)f + (F_c + F_h I\sqrt{L})] \quad \ldots\ldots (2)$$

where F_e, F_c, F_h are the core eddy current, residual, and hysteresis factors respectively. k_m is the wire eddy current factor and F_d is the dielectric loss factor. Equation (2) can be rewritten as:—

$$R = L[K + f(F_c + F_h I\sqrt{L}) + f^2(F_e + k_m + F_d)] \quad \ldots\ldots (3)$$

$$\text{where } K = \frac{R_{DC}}{L}$$

or

$$\begin{cases} R = L(K + Af + Bf^2) \\ A = (F_c + F_h I\sqrt{L}) \\ B = (F_e + k_m + F_d) \end{cases} \quad \ldots\ldots (4)$$

$$\text{Now } Q_o = \frac{2\pi f L}{R} \quad \ldots\ldots (5)$$

$$= \frac{2\pi f}{K + Af + Bf^2} \quad \ldots\ldots (6)$$

It can be seen by inspection that when f is small, Q_o is nearly proportional to f, and when f is large, Q_o is nearly proportional to $1/f$. Thus it is to be expected that there will be some frequency f_o for which Q_o reaches a maximum value. At this frequency $\frac{dQ_o}{df}$ must be zero.

Differentiating equation (6):—

$$\frac{dQ_o}{df} = \frac{2\pi(K + Af + Bf^2) - 2\pi f(A + 2Bf)}{(K + Af + Bf^2)^2} \quad \ldots\ldots (7)$$

The condition for maximum Q_o is, therefore,

$$2\pi(K + Af + Bf^2) = 2\pi f(A + 2Bf)$$
$$\text{i.e., } Bf^2 = K. \quad \ldots\ldots (8)$$

$$\text{So that } f_o = \sqrt{\frac{K}{B}} \quad \ldots\ldots (9)$$

The maximum value of Q_o is given by:—

$$Q_{max} = \frac{2\pi f_o}{Af_o + 2Bf_o^2} = \frac{2\pi}{A + 2Bf_o} \quad \ldots\ldots (10)$$

Substituting for f_o this becomes

$$Q_{max} = \frac{\pi}{\sqrt{BK} + A/2} \quad \ldots\ldots (11)$$

General Q curve

The first point to be noted is that the frequency of maximum Q_o is not affected by hysteresis and residual losses, the latter merely reducing the value of Q_{max}. This suggests that a convenient way of treating the problem would be to refer the actual curve of Q_o against f to an ideal curve in which hysteresis and residual losses were absent. The actual curve could then be defined completely by three parameters:—

1. Frequency f_o.
2. Peak value of ideal curve.
3. A parameter defining the effect of hysteresis and residual losses.

Denoting the peak value of the ideal curve by Q'_{max} we have from equation (11) putting $A = O$:—

* P.O. Research Station

The photograph at the head of the page shows a collection of typical dust cores manufactured by the Salford Electrical Instrument Co.

$$Q'_{max} = \frac{\pi}{\sqrt{KB}} \quad \ldots\ldots\ldots\ldots\ldots (12)$$

The peak value of the actual curve is by re-arranging eqn. (11):—

$$Q_{max} = \frac{\dfrac{\pi}{\sqrt{KB}.}}{1 + \dfrac{A}{2\sqrt{KB}}} \quad \ldots\ldots (13)$$

$$= \frac{Q'_{max}}{1+p/2} \quad \ldots\ldots\ldots\ldots\ldots (14)$$

where p is the third parameter mentioned above, and $p = A/\sqrt{KB}.$ Thus hysteresis and residual loss reduce the peak Q_o by a factor $\left(\dfrac{1}{1+p/2}\right)$.

Then at any frequency f,

$$Q_o = \frac{2\pi f}{K+Af+Bf^2} \quad \ldots\ldots\ldots\ldots (15)$$

$$= \frac{\dfrac{2\pi}{\sqrt{KB}}}{\sqrt{\dfrac{K}{B}}\cdot\dfrac{1}{f} + \dfrac{A}{\sqrt{KB}} + \sqrt{\dfrac{B}{K}}\cdot f} \quad \ldots\ldots\ldots\ldots\ldots (16)$$

dividing top and bottom by $f\sqrt{KB}$.

$$= \frac{2Q'_{max}}{f_o/f + p + f/f_o} \quad \ldots\ldots\ldots\ldots (17)$$

And, finally, writing $y = f/f_o$, we get

$$Q_o = \frac{2Q'_{max}}{y+(1/y)+p} \quad \ldots\ldots\ldots (18)$$

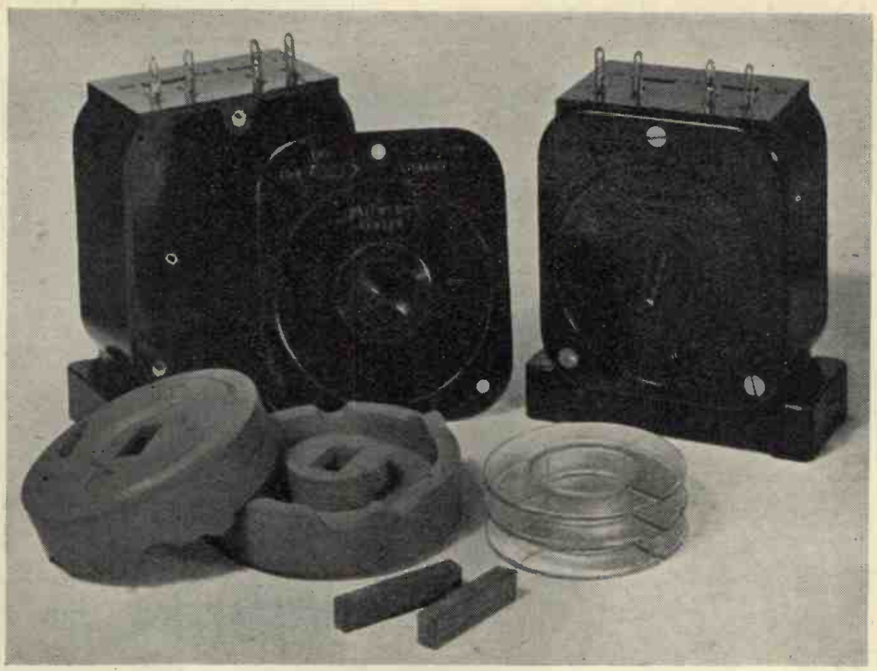
Obviously in the ideal case, Q_o would be equal to $\dfrac{2Q'_{max}}{y+1/y}$, so that the effect of the value of the parameter p on the shape of the curve can be seen. The ratio of the ordinate of the actual curve to that of the ideal at any frequency is $\dfrac{y+1/y}{y+(1/y)+p}$, and at the frequency of maximum Q_o, where $y=1$, this ratio reduces to $\dfrac{1}{1+p/2}$ as already indicated above. The next point to notice is that if Q_o has a given value when $y = y'$, it will reach the same value again when $y = 1/y'$, *i.e.*, the ordinates of any Q_o curve are the same at the two frequencies defined by $\log y = \pm \log y'$.

Thus all such Q_o curves are symmetrical on a logarithmic frequency scale.

Fig. 3.1 shows the shape of the curves of

$$Q_o = \frac{2Q'_{max}}{y+(1/y)+p} \quad \ldots\ldots\ldots\ldots\ldots (19)$$

plotted logarithmically on both axes, with Q'_{max} taken as unity on the Q_o scale.



'Pot-Core' Coils in case, and component parts.
(By courtesy of the Telephone Manufacturing Co.)

Correction for self capacitance

The effect of self capacitance on the Q value can be defined by a fourth parameter f_o/f_r, and the complete expression for Q at any frequency is then

$$Q = Q'_{max} \cdot \frac{2(1-x^2)}{y+(1/y)+p} \quad \ldots\ldots\ldots (20)$$

Fig. 3.2 shows curves of Q/Q'_{max} versus y for various values of f_o/f_r, assuming that p is negligibly small.

These curves show quite clearly how the self capacitance of the coil tends to lower both the peak Q value of the coil and also the frequency at which it occurs. Similar sets of curves can, of course, be drawn for various values of p, but the general effect will be the same.

Applications of Theory

These curves are perfectly general and can be applied to obtain Q curves for any dust cored coil for which the values of the various parameters are

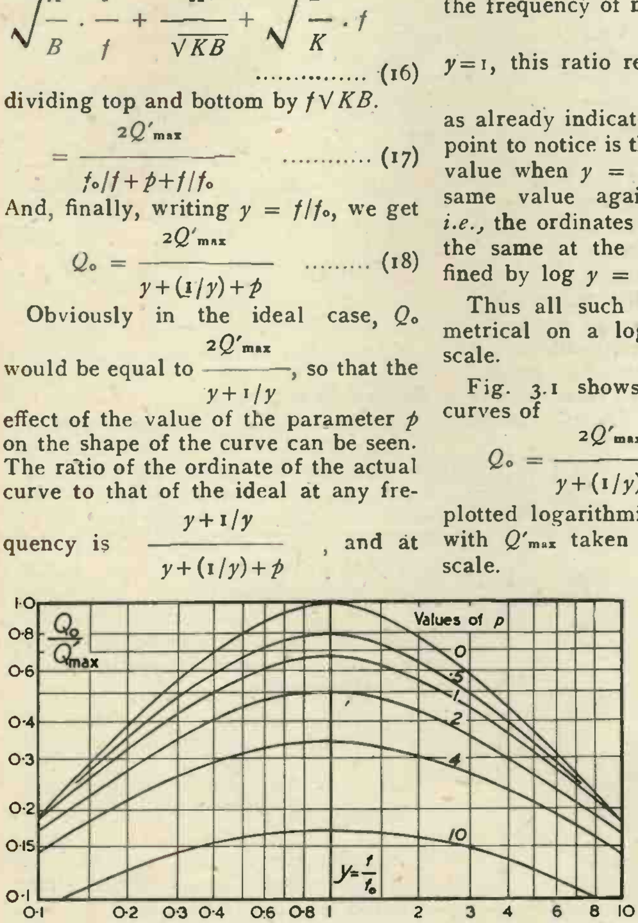


Fig. 3.1. Showing the effect of hysteresis and residual loss on the shape of the general Q° curve.

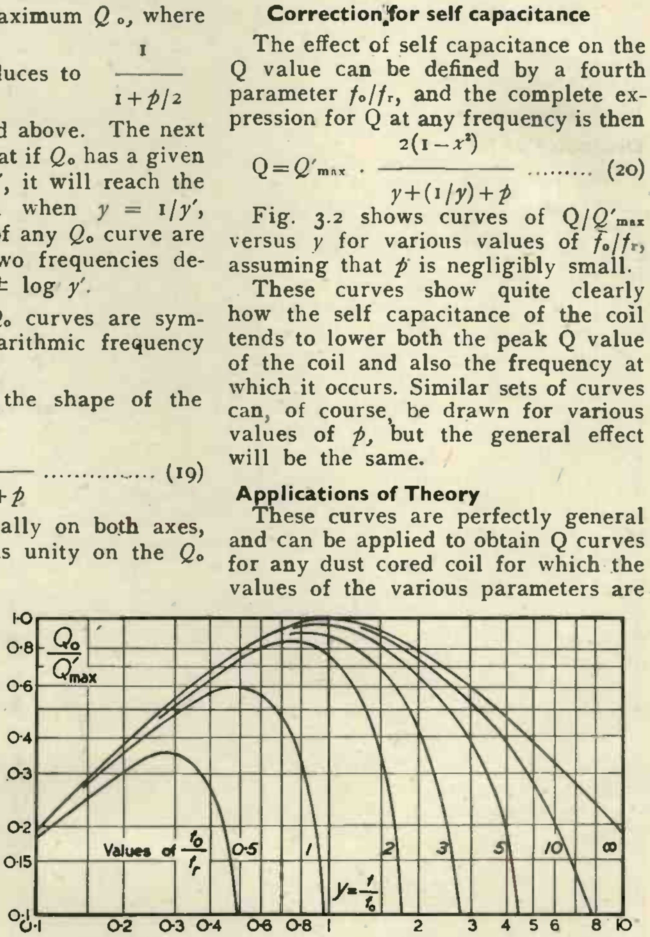


Fig. 3.2. Showing the effect of self capacitance on the shape of the general Q_o curve.

known or can be predicted. This fact has been found of considerable use, for example, when dealing with the design of toroidal coils, of various shapes and sizes, made of materials for which the loss coefficients were known. (In the particular case of a toroidal coil all the parameters can be calculated accurately from a knowledge of its dimensions and the properties of its core material.) The procedure was to calculate f_0 and Q'_{max} for each case and to plot the corresponding point on a log.-log. graph with frequency and Q_0 as abscissa and ordinate respectively. A tracing of Fig. 3.1 to the same scale was then superimposed, and slid parallel to either axis until the peak coincided with the plotted point. The Q curve corresponding to the required value of p could then be pricked through on to the graph underneath. Another application of the theory is to the measurement of the Q of coils. This point will be dealt with in detail in Part 5, but briefly the object is to obtain the Q of a coil, which cannot be measured directly owing to limitations in the accuracy of the measuring device, by carrying out the measurement at a frequency where accurate results can be obtained and then applying the theory to calculate the Q at the required frequency.

Discussion of Results

The physical significance of the various parameters will next be considered. The condition for maximum Q_0 is $Bf^2 = K$. (Eqn. 8.) This means that the maximum Q_0 occurs when the total eddy current loss resistance is equal to the D.C. resistance of the coil (neglecting dielectric losses).

At very low frequencies, with solid or laminated cores, the total loss is made up almost entirely of eddy current loss in the core and D.C. resistance loss in the winding, leading to the well-known rule that, at power frequencies, an inductance coil has maximum efficiency when the iron and copper losses are equal. The same rule can often be used to obtain a rough estimate of the working frequency range of a dust cored coil, but it should be clearly realised that it is only an approximation in this case.

Coils with the same type of wire

If both the core and the type of wire are specified, and the number of turns is varied, the D.C. resistance will be roughly proportional to the number of turns, whilst the inductance can be taken as proportional to the square of the number of turns. From this it follows that K is roughly proportional to the number of turns N.

$$\text{Now } f_0 = \sqrt{\frac{K}{B}} = \sqrt{\frac{K}{(F_e+k_m+F_d)}} \qquad \ldots\ldots\ldots\ldots (21)$$

and

$$Q'_{max} = \frac{\pi}{\sqrt{KB}} = \frac{\pi}{\sqrt{K(F_e+k_m+F_d)}} \qquad \ldots\ldots\ldots\ldots (22)$$

So that, neglecting k_m and F_d for the moment, it can be seen that f_0 is roughly proportional to $\sqrt{N}$ and Q'_{max} to $\frac{1}{\sqrt{N}}$. The value of k_m is proportional to the volume of copper in the winding, and thus increases to a maximum as the winding space is filled. Thus, if k_m is going to have any effect on the result at all, this effect will be greatest when the winding space is filled, in which case it will cause a slight lowering of both f_0 and Q'_{max}. The value of F_d depends on the inductance of the coil, and although usually negligible, it may set a limit to the inductance which can be obtained with a given core design. Where F_d cannot be neglected, it will also tend to reduce both f_0 and Q'_{max}. The parameter p is given by

$$p = \frac{A}{\sqrt{KB}} = \frac{F_e+F_h I\sqrt{L}}{\sqrt{K(F_e+k_m+F_d)}} \qquad \ldots\ldots\ldots\ldots (23)$$

So that p is also approximately proportional to $\frac{1}{\sqrt{N}}$. This indicates that the "flattening" effect of hysteresis* and residual losses on the Q curve (*see* Fig. 3.1) will be least when the coil is fully wound.

The results can be summed up as follows (*see* Figs. 3.3, 3.4):—

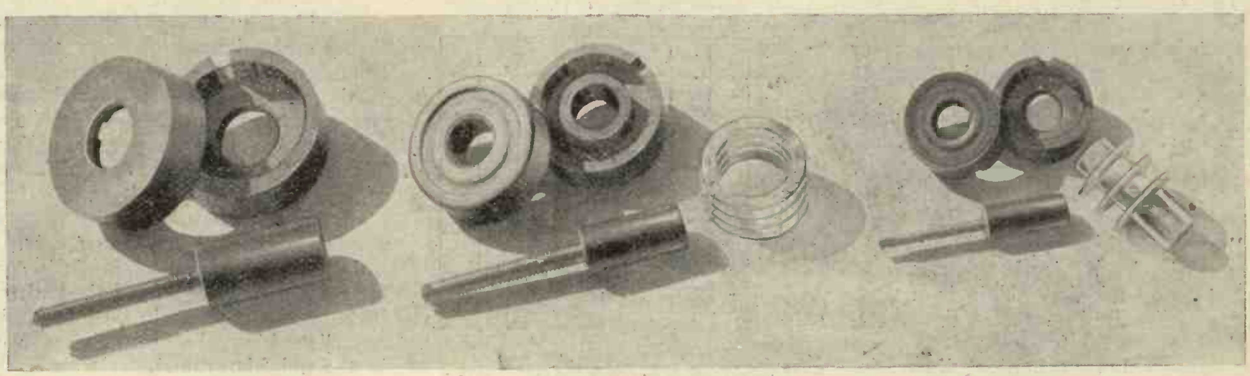
(1) If the wire eddy loss can be made negligible (by suitable stranding of the wire) then the best results will be obtained with the coil fully wound.

(2) In high frequency coils of low effective permeability, where the above condition cannot always be met owing to mechanical limitations of the fineness of wire stranding used, the best results may be obtained with the winding space not quite filled.

Cores with constant winding volume

Having established that the best results will probably be obtained with the available winding space either completely filled, or nearly so, let us now consider what happens if a core is wound with a series of different types of wire, the number of turns being so chosen that the volume of the winding remains constant. Since this is merely intended as a rough approximation, it will be assumed that the space factor of the winding remains constant, so that the number of turns is inversely proportional to the cross-sectional area of the wire. Under these conditions, the D.C. resistance will be proportional to N^2, and therefore, also proportional to the inductance, *i.e.*, K is constant, so that, neglecting k_m and F_d, we obtain the interesting result that the frequency of peak Q_0 is independent of the type of wire used, and depends only on the geometrical design of the coil bobbin and the properties of the core. The value of k_m is proportional to d^2, where d is the diameter of the conduc-

* Although the effect of hysteresis loss has been included, it is usually limited by other considerations to a value which is negligibly small as far as Q_0 is concerned. (See Part 2).



Various sizes of pot core with screw plunger adjustment and distrene coil formers.

tor (or of each strand when stranded wire is used), so that k_m will tend to become important as heavier strands are used, thus lowering both f_o and Q'_{max}. This effect will be most noticeable when solid wire is used, particularly as the use of solid wire usually infers that relatively large inductance values are required, so that the dielectric factor F_d may also cease to be negligible and cause a further reduction in f_o and Q'_{max}. These results can be summed up as follows :—

(1) For a constant volume of winding on the given core, f_o and Q'_{max} tend to be constant.

(2) Both f_o and Q'_{max} may have somewhat lower values for solid than for stranded wire.

(3) Both f_o and Q'_{max} may be reduced still further by dielectric losses when large inductance values are required.

Coils with constant Q'max.

Finally, consider the general case in which the value of Q'_{max} is required to be constant for various values of f_o. To obtain a general idea of the problem, we will neglect all losses except those due to D.C. resistance and core eddy currents. Then the condition for constant Q'_{max} is that the product of K and F_e shall be constant. Now $f_o = \sqrt{\frac{K}{F_e}}$, so that for small values of f_o, K should be small and F_e large. An increase in the volume and effective permeability of the core will increase F_e and at the same time K will be reduced because the increased size allows more winding space, and the increased permeability means that less turns are required for a given inductance. Thus it is clear that coils intended for use at low frequencies should be relatively large and massive, using material of high permeability, whilst the opposite is true for coils for use at high frequencies. This point was mentioned in Part I and will not be considered further here.

Choice of Core

The correct proportioning of the core and bobbin to obtain the best results is a matter for the manufacturer of the cores, and is somewhat outside the scope of the present article. It may be mentioned in passing, however, that although dust-core powders are available which can be pressed into cores having specific permeabilities ranging from 10 to 120, it does not follow that these permeabilities can necessarily be obtained with a core of any shape and size. This is mainly because the high permeability materials have to be formed under great pressure so that mechanical difficulties preclude the use of complicated moulds. As a result, materials with a permeability greater than 50 are usually available only in the form of toroidal cores, whose symmetry simplifies the pressing problem.

Choice of Wire

If a solid conductor is replaced by a bundle of insulated strands having the same cross-sectional area, it appears obvious at first sight that the eddy current losses must be reduced. In reality the problem is complicated by the fact that there are still eddy current paths in the bundle, since eddy currents tend to flow up one strand and down another. This effect can be counteracted by ensuring that the whole bundle is uniformly twisted about its axis, thus transposing all the strands relative to an external field. In addition, it is necessary to transpose inner and outer strands relative to the internal field of the bundle. One method of meeting both these requirements is found in "litzendraht" wire,* which, however, is expensive and has a bad space factor. It is hoped to deal more fully with this problem in a later article on the design of air-cored coils, but at this stage, the following principles will merely be stated without proof.

(1) Stranding without uniform twisting about the axis of the wire is practically useless and must be avoided.

(2) Theoretically, "lizendraht" wire will always be better than simple stranded wire from the point of view of eddy current losses, but it has a worse space factor.

(3) At the frequencies at which dust cores are likely to be used, stranded wire will usually have a smaller eddy current loss than the corresponding solid wire.

Experiment has shown that the use of "litzendraht" wire with dust cores is very rarely worth while, and that the make-up of the wire is usually decided by considerations of mechanical flexibility. In any case the degree of stranding need only be sufficient to make the wire eddy current losses negligible compared with the core eddy current losses, and any further stranding is merely wasted.

(To be continued.)

* See Part 2.

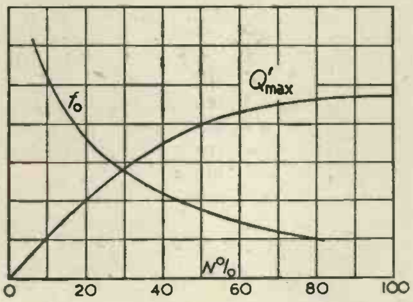


Fig. 3.3. Variation of Q' max and f_o wire eddy losses negligible. (Typical case).

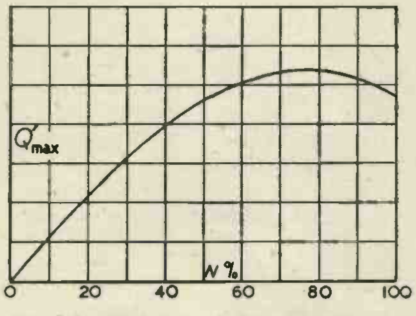


Fig. 3.4. Variation of Q' max and f_o wire eddy losses not negligible. (Typical case).

The Constant Planck

Professor Max Planck, the founder of the quantum theory, has recently celebrated his 85th birthday.

He was born in Kiel in 1858 and came of a scientific family. At the age of 27 he became assistant professor at Kiel and later moved to Berlin. In 1919 he was awarded the Nobel prize for physics.

The whole body of hypotheses, theories, empirical rules and processes of calculation based on the existence of the fundamental quantum of action which has been developed within the last two or three decades owes its origin to Planck.

Among his other investigations are those on thermo-dynamics and the unitary structure of the physical world.

He is a member of most academies of science, and in spite of his great age still takes an active part in the scientific and cultural events of the present day.

Mass Inspection by X-ray

A new mass production X-ray plant capable of inspecting 17,000 castings in 24 hours has been developed by the Westinghouse Company of Pittsburg.

A moving conveyor 40 ft. long by 3 ft. wide is used to transport castings through the inspection, and the unit produces an exposed film of six castings every 30 seconds which passes continuously through the developer.

The tubes operate at 140 and 220 kV. to allow for different thicknesses of casting, and the unit can be operated by one man or eight men depending on the speed of inspection required. The operator is fully protected while at work and the unit can be located anywhere in the plant without disturbing the progress of work in the neighbourhood.

Some Unusual Applications of the Cathode Ray Oscillograph

By G. N. PATCHETT, B.Sc. Grad. I.E.E.*

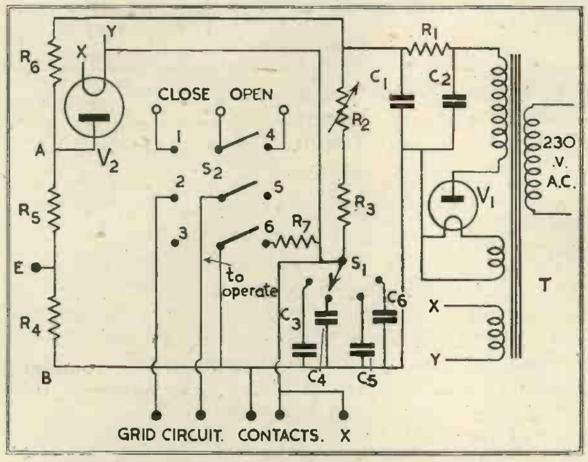


Fig. 1. Circuit of single stroke time base.

R_1 100,000 to 250,000 ohms.	C_1 0.1 μF or larger.
R_2 1 megohm.	C_2 0.1 μF or larger.
R_3 1 megohm.	C_3 0.01 μF.
R_4 40,000 ohms.	C_4 0.1 μF.
R_5 40,000 ohms.	C_5 1 μF.
R_6 500,000 ohms.	C_6 4 μF.
R_7 100 ohms.	

It has been realised by workers in many different fields that the C.R.O. is an instrument which can often solve their problems where no other apparatus could. Its applications seem to be unlimited and a few of the lesser known ones are described in the following article.

Determination of the time of Operation of Controllable non-recurrent phenomena

CONTROLLABLE non-recurrent phenomena are normally photographed either by a moving film camera or by the use of a single stroke time base and a stationary film. The latter method has a number of advantages, one being the small cost of the equipment required. A type of single stroke time base which can also be used as a repeating time base synchronised with the rotation of a shaft is shown in Fig. 1.

The principle of the single stroke time base is to allow a condenser to charge through a resistance, the speed of the sweep being determined by the values of the supply voltage, resistance and capacity. In order to obtain a linear stroke a high voltage must be used so that only the initial part of the charging curve is utilised.

The time base is designed to apply a negative voltage to the oscillograph, this deflecting the spot to the right of the screen.

The transformer T gives 1,000 volts r.m.s. on the H.T. winding which is then rectified by the diode valve V_1, and smoothed by the two smoothing condensers C_1 and C_2, together with the resistance R_1. A switch S_1 selects a condenser to give a suitable time base speed. The condenser is charged through resistances R_2 and R_3, R_2 being variable so giving a fine adjustment of the time base speed.

The voltage required for the traverse of the spot across the screen is approximately 150 volts, and the anode of a diode V_2 is therefore connected to a potential divider, consisting of resistances R_4, R_5 and R_6 arranged so that the anode of V_2 is approximately 150 volts negative. When the condenser potential reaches 150 volts the valve conducts and prevents the condenser charging to a higher voltage. The anode of the cathode-ray tube is connected to point E, 75 volts negative with respect to B which arranges that the spot starts on the left-hand side of the screen without the use of an X shift control.

Before operation the switch S_2 shorts the charging condenser, through resistance R_7. This resistance is necessary to prevent too great a discharge current flowing when discharging the condenser on returning the switch S_2 to the normal position.

When using the time base for photographic work it is necessary to have the spot blacked out except during the actual movement to prevent "fogging." The two contacts marked "grid circuit" are connected to the grid and cathode of the cathode-ray tube to reduce the bias and therefore give maximum brilliancy during the actual movement of the spot. The work circuit is connected to the other contacts of the switch which are arranged to either open or close the circuit. Switch S_2 is constructed so that the contacts operate in the following order:—

a Contacts 6 open.
b Contacts 2 close.
c Contacts 4 open.
d Contacts 1 close.

This ensures that the time base and brilliancy control operate before the phenomena under examination takes place.

When the time base is used with a mechanical contact to produce a time base synchronised with the shaft rotation, the contact is placed across the terminals marked "contacts" and switch S_3 turned to the "operate" position. Switch S_1 and resistance R_2 are adjusted to give a suitable time base speed.

Calibration of the time base scale

A number of methods may be used to calibrate the time base scale:

A. By calculation from the values of the charging condenser and resistance.

Let the value of the charging resistance = r ohms.

Let the value of the charging condenser = c farads.

Let the supply voltage be V volts.

Let the sensitivity of the cathode-ray tube on the X plates = S mm./volt.

Then, the current through $r = V/r$ amperes.

(This may be assumed constant if the voltage across the condenser does not exceed $V/5$.)

The charge (Q) given to the condenser per second = V/r coulombs. Therefore, voltage rise across the con-

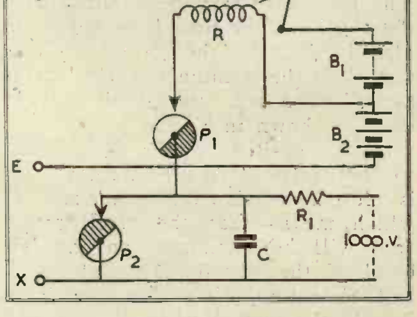


Fig. 2. Circuit for measuring relay timing.

* Bradford Technical College.

denser per second $= Q/c$ volts.
$= V/rc$ volts
One second on the horizontal scale is represented by Vs/rc mm.
Or one millisecond is represented by $Vs/1{,}000rc$ mm.

B. By the use of a calibrating frequency.

This method is most suitable if a double beam tube is used.

A known frequency (*e.g.*, 50 c/s mains) is connected to the other beam producing a waveform which can be used to calibrate the time scale.

If a single beam tube is being used the normal trace is photographed first and then another exposure is made using the calibrating voltage for the Y deflection, the value of r and c being the same in both cases.

Measurement of the operating time of a relay

The apparatus to be described is arranged to show the operation (either opening or closing) of a relay as a steady picture on the cathode-ray oscillograph screen. The time of operation can be measured from the trace on the screen and the nature of the "make" and "break" seen without the need for photography. This is a great saving of time and expense, where the effects of making various alterations to the relay are to be studied.

The principle of the apparatus to show the "making time," is to switch on the current to the operating coil of the relay, and at the same instant, start the time base giving the horizontal deflection to the cathode-ray oscillograph spot. The operation of the relay contacts connects a battery to the Y deflecting plates of the oscillograph, and so gives a vertical deflection to the spot, at the instant when the contacts close. The action is repeated 3 to 5 times per second so giving a stationary trace on the screen.

The circuit of the complete apparatus is shown in Fig. 2. The two contacts P_1 and P_2 are slip rings, one half of each being insulated (the conducting portion is shown shaded). P_1 controls the current to the coil of the relay and P_2 the time base circuit. The time base may be adapted from the single stroke time base apparatus already described by connecting contact P_2 to the terminals marked "contacts," or a separate circuit may be used as shown in Fig. 2.

In the position shown P_1 is open, so that relay R is de-energised. P_2 is closed, so shorting condenser C, which means that the oscillograph spot will be stationary on the left hand of the screen. As contacts P_1 and P_2 rotate, P_1 makes circuit at exactly the instant when P_2 open circuits. Contact P_1 connects the battery B_2 (of suitable voltage for the relay) to the operating coil of the relay, while contact P_2 allows condenser C to charge through resistance R_1, so starting the time base. When the contacts of the relay R operate the battery B_1 (20-40 volts) is connected to the Y deflecting plate of the cathode-ray oscillograph, and gives a vertical deflection to the spot. If the contacts close properly and do not "bounce," a vertical line will be produced at the point of making, while a "bouncing" contact will show as a number of vertical lines. Contacts P_1 and P_2 are driven on a common shaft at about 200 r.p.m. (the maximum speed is determined by the time of operation of the relay) thus repeating the operation 3 times per second. A certain amount of flicker is inevitable, although this can be largely overcome by the use of a cathode-ray tube with a long afterglow screen.

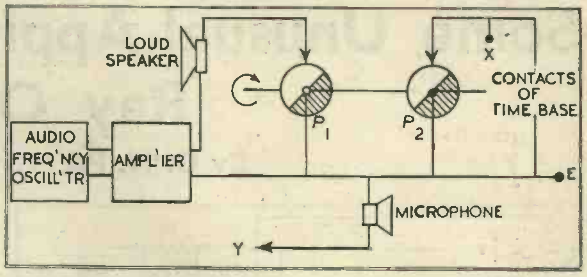


Fig. 3. Circuit for measurement of reverberation characteristics.

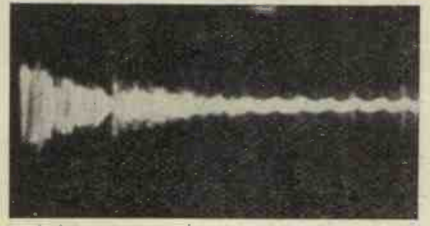


Fig. 4. Reverberation characteristic as recorded.

The opening of the relay may be shown on the screen by simply reversing the contact P_1, so that it disconnects the supply to the relay at the start of the time base.

If a double beam cathode-ray tube is being used, the current in the coil or the voltage across it, may be shown at the same time on the other beam of the tube.

The values of the condenser C and the resistance R_1 must be chosen so that the spot travels a suitable distance across the screen by the time contact P_2 closes again. A high voltage is necessary for the time base supply in order to obtain a linear trace (unless a pentode charging valve is used).

Calibration of the Time Scale:—

The time scale may be determined by:—

(*a*) The constants of the charging circuits.
(*b*) The use of a calibrating frequency.
(*c*) By calculation from the speed of the contacts P_1 and P_2.

(*a*) and (*b*) have already been dealt with fully and we are left with (*c*). Let the speed of P_1 and $P_2 = N$ revolutions per minute. Let the length of the X time scale $= L$ cms. Then, assuming that the contacts P_1 and P_2 are half insulated, the time of the complete X deflection is:—

$$60/2N \text{ seconds.}$$

Therefore, the time represented by 1 cm. of the X axis (assuming a linear time scale) is:—

$$60/2N.L \text{ seconds.}$$

The same device may be used to show other phenomena which can be repeated at speeds above 2 or 3 c/s., *e.g.*, damped oscillations in an oscillatory circuit, the charge and discharge of a condenser, etc.

Determination of the Reverberation Characteristics of a Room

The apparatus is similar to the set up for the measurement of the time of operation of a relay, and the circuit is shown in Fig. 3.

An audio frequency oscillator of the required frequency feeds the amplifier, which, in turn, feeds the loud speaker through the rotating contact P_1. Coupled to the contact P_1 is the contact P_2, which controls the time base to the X plate of the oscillograph. This is shown connected to the two "contact terminals" of the single stroke time base already described, but, contact P_2 may be connected to a time base circuit similar to that used in connexion with the time of operation of a relay. The sound is picked up by a microphone and fed to the Y plates, if necessary, through an amplifier.

The two contacts P_1 and P_2 are driven at a suitable speed and arranged so that they open circuit at the same instant, *i.e.*, as P_1 disconnects the loud speaker contact P_2 starts the X deflection.

The type of result obtained is shown by the photograph of Fig. 4.

(*To be continued.*)

DATA SHEET 53

Aerial Characteristics—II

Radiation Resistance and Polar Characteristics

Radiation Resistance

WHEN considering the power relations of different idealised aerials it is convenient to introduce a fictitious resistance into the aerial system to account for the power radiated. This resistance is known as the Radiation Resistance of the aerial, and is defined as the ratio of the total power radiated by the aerial to the square of the current at some stated reference point in the aerial system. The radiation resistance is usually referred to either (a) current antinode or loop and when referred to this point the resistance is called the Loop Radiation Resistance, or (b) in many instances, particularly in the case of simple vertical grounded wires and dipoles of length other than half wavelength, it is more convenient to refer the radiation resistance to the driving point where the input power is introduced. The resistance is then known as the Base Radiation Resistance or the Radiation Resistance.

Given the base radiation resistance R_B of an aerial and also the r.m.s. aerial current I_o at the base, we have for the power radiated W_r

$$W_r = (I_o)^2 R_B$$

and if E_b is the voltage at the driving point or base of the aerial the power input W_i in the case of an idealised aerial (where the dissipation losses in the wires and ground are neglected) is given by

$$W_i = \frac{(E_b)^2}{R_B}$$

In practice, however, the input power W_i is equal to $W_i = \frac{(E_b)^2}{R_t}$ where R_t is the total resistance of the aerial, that is the radiation resistance plus the dissipation resistance of the aerial plus the earth resistance, all referred to the base or driving point.

We have for sinusoidal distribution of current along the length of the aerial the relation

$$R_B = \frac{R_L}{\sin^2\left(\frac{2\pi l}{\lambda}\right)} = \frac{R_L}{\sin^2(G)} \qquad (11)$$

where G is the electrical length (*see overleaf*).

The expressions for calculating the radiation resistance of even simple aerials are very complex, involving integral-sines and integral-cosines and for this reason they will only be given when curves are not included. Curves of the radiation resistance of certain aerials with finite cross sectional dimensions will be given later in the series, and the present section will be limited to illustrations for infinitely thin idealised aerials.

In Fig. 1 is shown the base radiation resistance of an infinitely thin grounded circular wire aerial up to a quarter of a wavelength long. For aerial lengths not exceeding about $\frac{l}{\lambda} \approx \frac{1}{8}$ or $G \approx \frac{\pi}{4}$ the following simple expressions may be employed

$$R_B \approx 400 \left(\frac{l}{\lambda}\right)^2 \text{ ohms} \quad \ldots\ldots \quad (12)$$

$$\approx 10\, G^2 \text{ ohms}$$

with an error of less than 10 per cent. Equation (12) has been plotted (dotted curve) on Fig. 1.

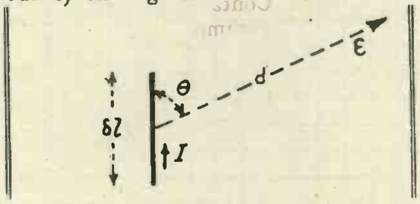


Fig. 4.

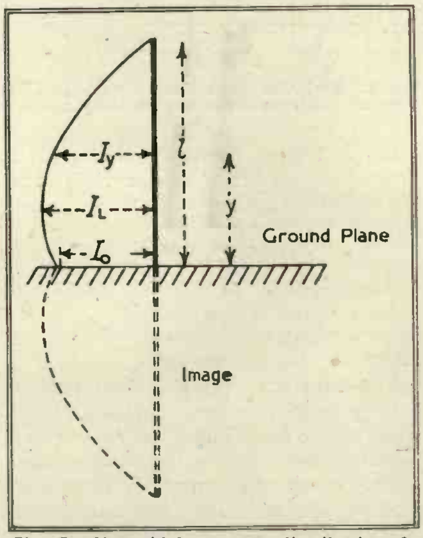


Fig. 5. Sinusoidal current distribution for grounded vertical wire and its image. (Perfect ground assumed).

The above expressions and the curves on Fig. 1 are given for a grounded aerial. In the case of dipole aerials in "free space" the results of Fig. 1 and equation (12) may be employed when the dipole is driven at its centre point. To obtain the radiation resistance for this case the ordinates of Fig. 1 should be doubled and "l" should be made equal to half the total length of the dipole. Thus the radiation resistance of a half wave dipole is equal to approximately 73 ohms.

In the case of both vertical and horizontal dipoles the height of the dipole above even a perfect ground will affect the radiation resistance, and Figs. 2 and 3 illustrate this effect for the case of perfectly conducting ground. From these curves it will be seen that as far as radiation resistance is concerned the vertical dipole is less affected by the proximity of ground.

Field Strength. (With ground of infinite conductivity).

Elemental Doublet.

The electric field intensity produced at a distance "d" of not less than a few wavelengths from an elemental doublet of length δl) in "free space" as shown in Fig. 4 carrying a uniform current $I \cos(\omega t + 90^\circ)$ is given by

$$\varepsilon = \frac{60\pi}{d}\left(\frac{\delta l}{\lambda}\right) I \cos \omega \left(t - \frac{d}{c}\right) \sin \theta$$

volts/metre .... (13)

where c is the velocity of light, i.e., 3×10^8 metres per second. I is in amperes, d in metres. The wavelength λ is measured in the same units as the doublet length ((δl) and θ is the angle formed by a line joining the doublet to the point of measurement and the plane of the dipole.

For simplicity in all the following equations the term $\cos \omega \left(t - \frac{d}{c}\right)$ will not be repeated.

Grounded Vertical Wires

In the case of a vertical grounded wire of length l carrying a uniform current I the field intensity at a distance d ($d \gg l$, $d \gg \lambda$) is approximately given by:—

$$\varepsilon = \frac{120\pi}{d}(l/\lambda)\, I \sin \theta \quad \text{volts/metre} \quad \ldots\ldots \quad (14)$$

While the above expression might be applied to the radiation from the vertical down-lead of an aerial with a very large top capacity, under more normal conditions the current along the wire will not be uniform. As the cross-sectional dimensions of the wire are reduced to infinitesimal dimensions, so the current distribution along an unloaded wire approaches nearer and nearer the sinusoidal law.

Fig. 5 shows this idealised sinusoidal distribution for a vertical grounded wire of length l, if we call

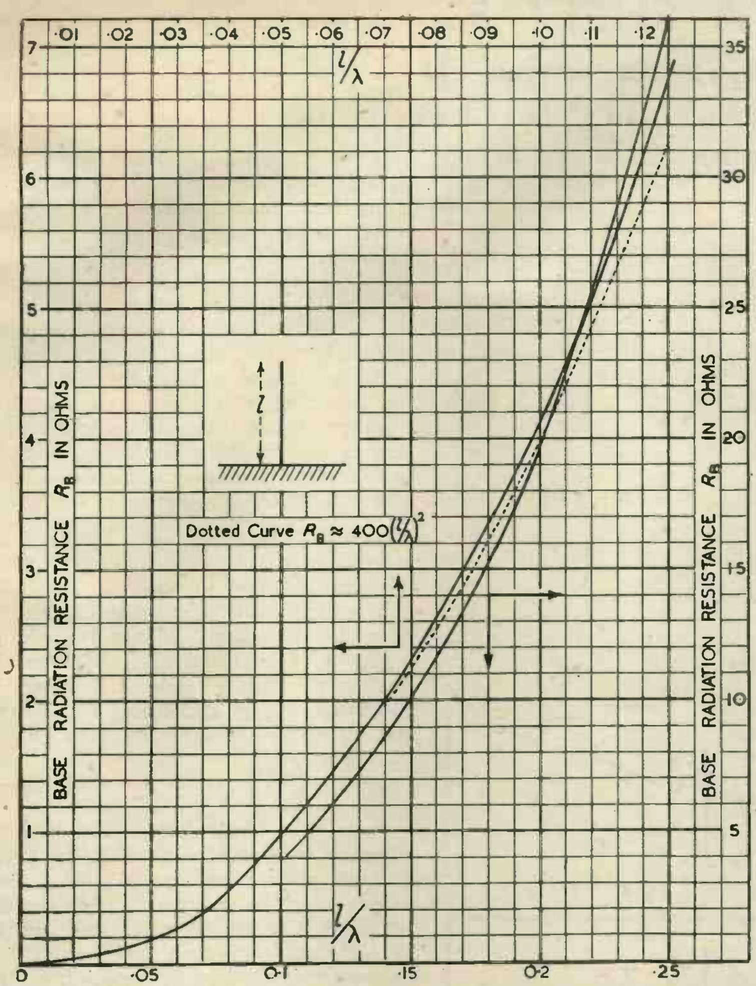


Fig. 1. Radiation Resistance of a thin grounded Vertical Wire over perfect ground.

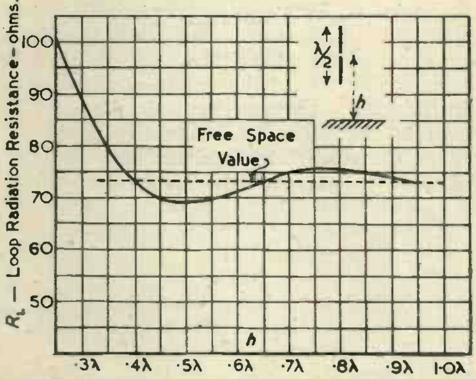


Fig. 2. Variation of Radiation Resistance of Vertical Half-wave Dipole with Height above perfect ground.

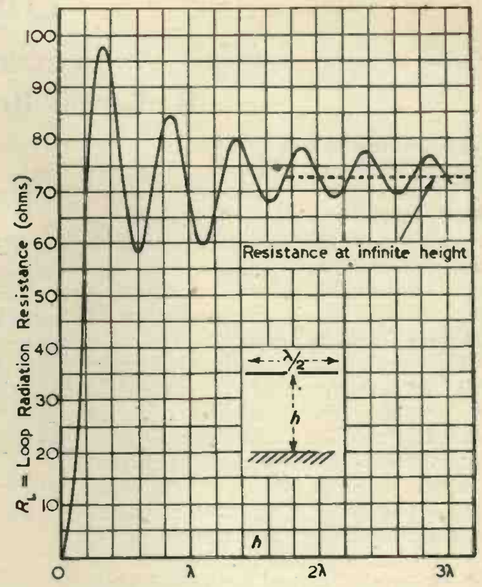


Fig. 3. Variation of Radiation Resistance of Horizontal Half-wave Dipole with Height above ground. (Perfect ground assumed)
(from Carter, Proc. I.R.E., June, 1932)

the value of the current I at the antinode (loop current) I_L and the current at the base I_o then

$$I_y = \frac{I_o \sin \beta (l-y)}{\sin \beta l} = I_L \sin \beta (l-y) \quad \text{............... (15)}$$

where I_y is the value of the current I at a height y from the ground and

$$\beta = \frac{2\pi}{\lambda}$$

The field intensity is given by

$$\varepsilon = \frac{60}{d} I_L K_1 f(\theta)_v \text{ volts/metre} \quad (16a)$$

$$\varepsilon = \frac{60}{d} I_o K_2 f(\theta)_v \text{ volts/metre} \quad (16b)$$

where K is known as the Form Factor of the aerial K_1 being referred to the loop current and K_2 to the current at the base.

$$K_1 = 1 - \cos G \quad \text{..................... (17a)}$$

$$K_2 = \frac{1 - \cos G}{\sin G} \quad \text{..................... (17b)}$$

where $G = \frac{2\pi l}{\lambda}$ radians $= \frac{360 l}{\lambda}$ degrees

(K_1 and K_2 are equal to unity for a grounded quarter-wave aerial) and $f(\theta)$ is the vertical radiation characteristic factor given by

$$f(\theta)_v = \frac{\cos (G \cos \theta) - \cos G}{\sin \theta (1 - \cos G)}$$

$f(\theta)_v$ is always unity in the horizontal direction ($\theta = 90$ degrees).

The function $f(\theta)$ has been plotted in Fig. 6 for several values of l/λ from 0 to 0.64. These curves will be discussed further in a later paragraph.

The value of K_1 and K_2 is plotted against l/λ in Fig. 7. For very small values, of $G = \frac{2\pi l}{\lambda}$, $K_2 \approx G/2$ therefore under these conditions the field strength for a fixed current at the base is directly proportional to the length of the aerial.

Elevated Dipoles

In free space the field strength of a vertical dipole, an integral number "n" of half wavelengths long is given by (16a) with $K_1 = 1$ and

$$f(\theta)_v = \frac{\sin \left(n \frac{\pi}{2} \cos \theta\right)}{\sin \theta} \quad \text{........ (19a)}$$

when n is even and

$$f(\theta)_v = \frac{\cos \left(n \frac{\pi}{2} \cos \theta\right)}{\sin \theta} \quad \text{........ (19b)}$$

when n is odd (n is unity for a half wave dipole). We can also use equations (19a) and (19b) for the horizontal radiation characteristic $f(\phi)_h$ of a horizontal dipole. The angle ϕ is defined by replacing θ by ϕ in Fig. 4.

The horizontal radiation characteristic of a vertical dipole and the vertical radiation characteristic $f(\theta)_v$ of a horizontal dipole are circular, i.e., the polar diagrams in the equatorial plane are circles about the axis of the aerial.

Vertical Dipoles Above Perfect Ground.

Owing to reflexion from the ground (which forms an image of the aerial) the "free space" condition is generally unattainable in practice. For a vertical dipole an integral number n of half waves long $K_1=2$ and

$$f(\theta)_v = \frac{\sin\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\sin(H\cos\theta) \quad \ldots\ldots\ldots\ldots\ldots\ (20a)$$

when n is even and

$$f(\theta)_v = \frac{\cos\left(n\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\cos(H\cos\theta) \quad \ldots\ldots\ldots\ldots\ldots\ (20b)$$

when n is odd. Where $H = \frac{2\pi h}{\lambda}$ and h is the height above ground to the centre of the dipole.

Horizontal Dipoles Above Perfect Ground.

With horizontal dipoles any number of half waves long, $K_1=2$ and the "free space" directional characteristics are modified by multiplying by the factor

$$f(\theta)_v = \sin(H\cos\theta) \quad \ldots\ldots\ldots\ldots\ (21)$$

to take into account the effect of reflexion from a perfect ground on the vertical radiation characteristics in the equatorial plane.

Grounded Vertical Wire with Capacity Top

This case is illustrated in Fig. 9 where the (non-radiating) capacity top enables the current at the end of the wire to have a finite value. The length of wire "b" shown dotted may be considered as the portion of the aerial suppressed by the use of the capacity top.

The field intensity is given as before by equations (16) but K and $f(\theta)_v$ are now given by:—

$$K_1 = \cos B - \cos G' \quad \ldots\ldots\ldots\ldots\ (22a)$$

$$K_2 = \frac{\cos B - \cos G'}{\sin G'} \quad \ldots\ldots\ldots\ (22b)$$

$$f(\theta)_v = \frac{\cos B\cos(G\cos\theta) - \cos\theta\sin B\sin(G\cos\theta) - \cos G'}{\sin\theta(\cos B - \cos G')} \quad \ldots\ldots\ldots\ (23)$$

where $B=\frac{2\pi b}{\lambda}$, $G=\frac{2\pi l}{\lambda}$, $G'=\frac{2\pi(l+b)}{\lambda}$

also
$$R_B = \frac{R_L}{\sin^2 G'} \quad \ldots\ldots\ldots\ldots\ (24)$$

where

$$R_L = 30\left[\sin^2 B\left\{\frac{\sin 2G}{2G} - 1\right\} - \frac{\cos 2G'}{2}\left\{\gamma + \log_e 4G - C_1(4G)\right\} + \left\{1+\cos 2G'\right\}\left\{\gamma + \log_e(2G) - C_1(2G)\right\} + \sin 2G'\left\{\frac{S_1(4G)}{2} - S_1(2G)\right\}\right] \text{ ohms} \quad \ldots\ldots\ldots\ (25)$$

where $\gamma=0.5772$ and $S_1(x)$ and $C_1(x)$ are respectively the integral-sine and integral-cosine for which tables are available.

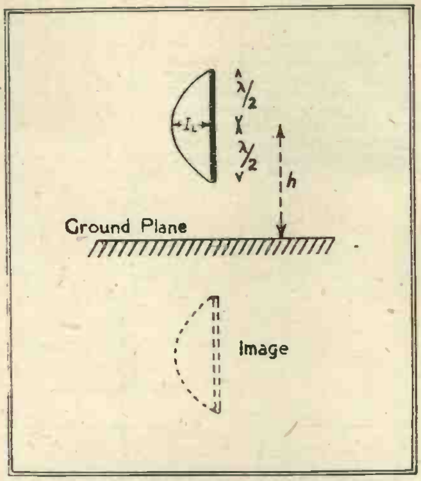


Fig. 8. Sinusoidal current distribution in elevated Half-wave Vertical Dipole and its image. (Perfect ground assumed.)

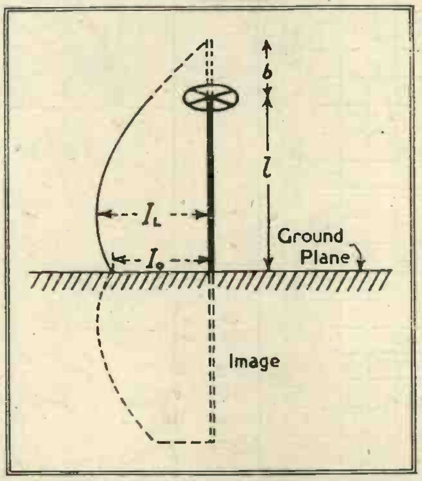


Fig. 9. Sinusoidal current distribution for capacity loaded grounded vertical wire and its image. (Perfect ground assumed).

This system may be employed for shortening the physical length of a half-wave dipole. As before, with dipoles in "free space" with $G' \leqslant \pi/2$ the radiation resistance should be doubled, while l is made equal to half the total length of the dipole.

Inductance Loaded Aerials

In a similar way the aerial can be shortened by inserting an inductance part of the way up the aerial wires so as to still provide a desired current distribution. For further details on both capacity and inductive loading the reader is referred to an article by G. H. Brown, *Proc. I.R.E.*, January, 1936.

Power Relations

It is more informative to compare the field intensity produced by different aerials for a constant input power to the aerials rather than a constant current. If we idealise the conditions by assuming that the aerial resistance is equal to its radiation resistance losses, that is if we neglect all ground losses and dissipative aerial losses, then we can write

$$I_o = \sqrt{\frac{W_i}{R_B}} \text{ or } I_L = \sqrt{\frac{W_i}{R_L}}$$

We can now write the equation for the field intensity at 1 mile for 1 watt input, from (16) as

$$\varepsilon_1 = \frac{37.25}{\sqrt{R_L}} K_1 f(\theta)_v \text{ millivolts/metre} \quad \ldots\ldots\ldots\ldots\ (26a)$$

$$\varepsilon_1 = \frac{37.25}{\sqrt{R_B}} K_2 f(\theta)_v \text{ millivolts/metre} \quad \ldots\ldots\ldots\ (26b)$$

If we consider the field strength at ground level from a grounded aerial $f(\theta)_v=1$; then for very short aerials we have $R_B=10G^2$ and $K_2=G/2$, therefore $\varepsilon_1=5.9$ mV/metre.

From (26b) with a quarter wave aerial $\varepsilon_1=6.15$ mV/metre while a 180° aerial $\varepsilon_1=7.5$ mV/metre.

The values for ε_1 from equation (26a) for l/λ of 0 to 1.0 have been plotted on Fig. 10.

From equations (26) it would appear that for a constant input power, very little advantage is obtained by increasing the length of an aerial from a minute dimension to $l=\frac{1}{4}\lambda$. In practice, however, as was shown in Part 1, short aerials have a high capacitive reactance which has to be compensated by a suitable inductive reactance in the coupling system. The losses in the coupling system together with the ground losses (which can be very appreciable in the case of grounded aerials unless elaborate ground systems are employed), when referred to

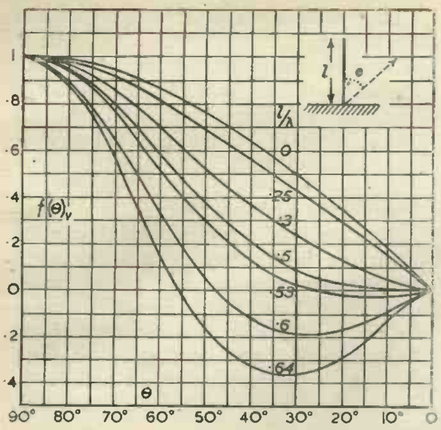


Fig. 6. Vertical Radiation Characteristics of a simple vertical wire connected at one end to a perfectly conducting ground. (Sinusoidal current distribution assumed along wire).

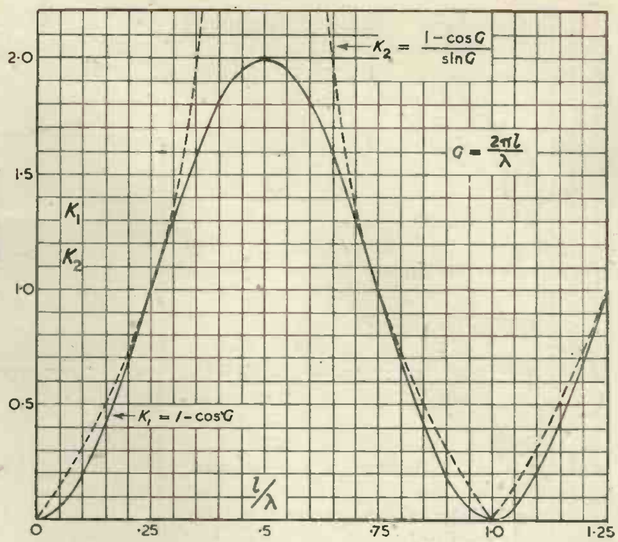


Fig. 7. Form Factor of grounded Aerial Referred to Loop Current (K_1), and Form Factor of grounded Aerial Referred to Base Current (K_2). (Sinusoidal current distribution and perfect ground assumed).

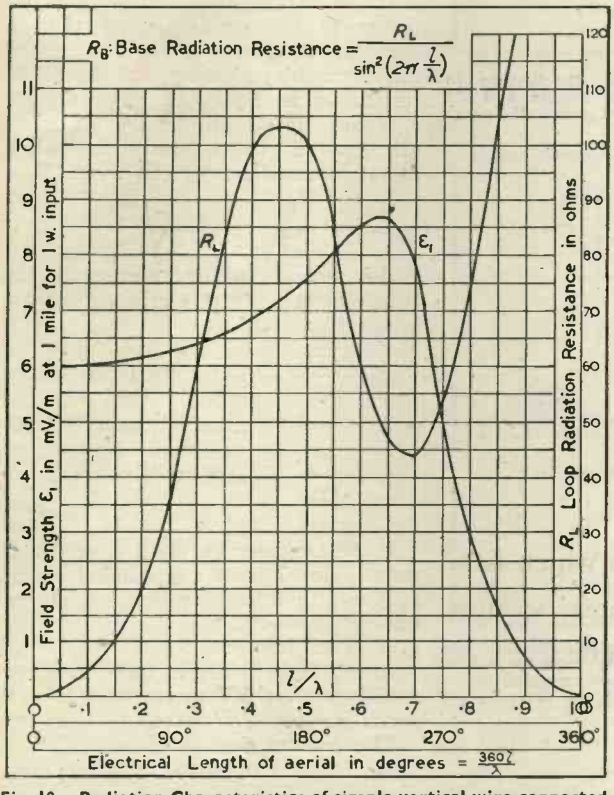


Fig. 10. Radiation Characteristics of simple vertical wire connected at one end to a perfectly conducting ground and with sinusoidal current distribution.

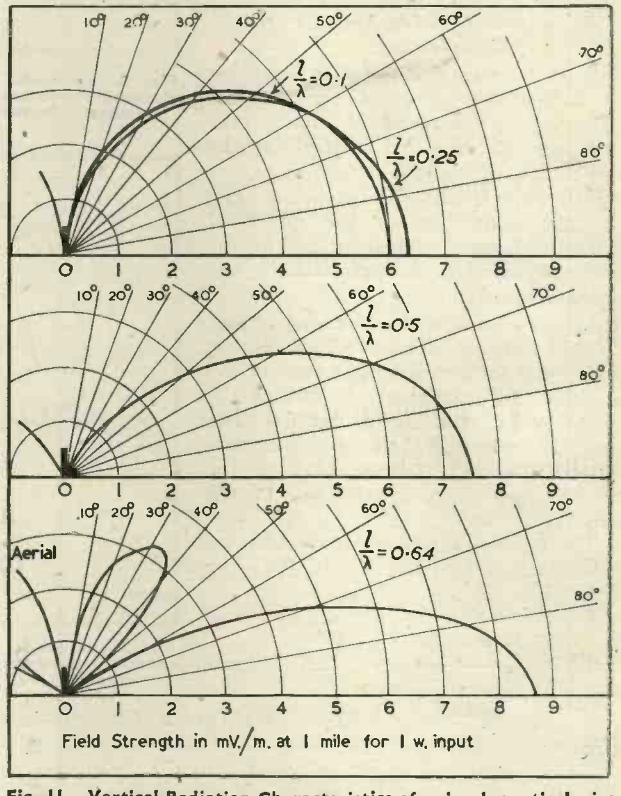


Fig. 11. Vertical Radiation Characteristics of a simple vertical wire connected at one end to a perfectly conducting ground, with sinusoidal current distribution along wire. Aerial length $l = 0.1\lambda$, 0.25λ, 0.5λ, 0.64λ.

the driving point, may be many times the low radiation resistance of a short aerial. For efficient operation with short aerials (i.e., a small value of l/λ) a low loss coupling system together with the use of either a dipole or an efficient ground system is therefore essential. In this connexion the ultra-short waves, requiring aerials of small physical dimensions have a definite advantage.

The physical meaning of the vertical or horizontal radiation characteristics of aerials, such as the $f(\theta)_v$ curves in Fig. 6 are easier to visualise when plotted on polar co-ordinate paper. The field strength at 1 mile as given by equations (26) has been plotted in this way on Fig. 11 for a grounded aerial of length equal to $l/\lambda=0.1$, $l/\lambda=0.25$, $l/\lambda=0.5$, and $l/\lambda=0.64$.

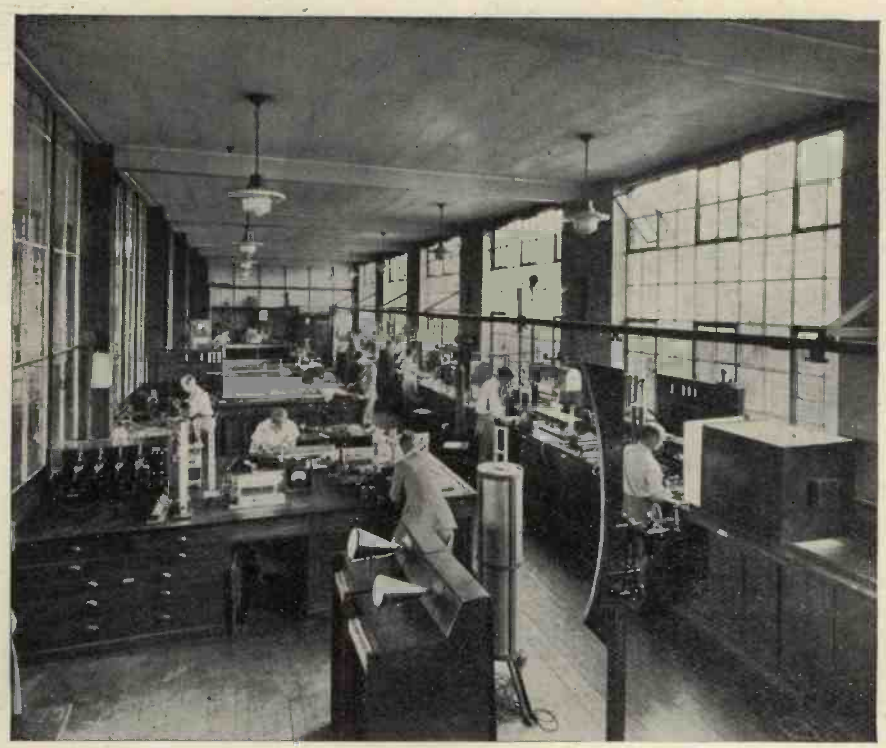
If the directional diagram is viewed in three-dimensional space it consists of a figure of revolution with the aerial as the axis and having a cross-section as shown. In order to save space the cross-section to the left of the aerial has been almost entirely omitted.

It will be seen that for aerial lengths greater than $\lambda/2$ secondary high-angle radiation lobes appear. These can also be seen in Fig. 6 over the range of angles where $f(\theta)_v$ crosses below the zero axis.

Fluorescent Lamps

A Survey of Old and Recent Developments—Part II

By R. NEUMANN, Dipl. Ing.



Part of the Vacuum Physics Dept. at the B T.-H. Research Laboratory, Rugby.
(*By courtesy of the B.T-H.Co.*)

Modern Discharge Lamps

THE more recent development of discharge lamps for general lighting purposes starts with the introduction of the hot cathode, especially of the activated type, and with the admixture of rare gases to the vapours mainly used for light production. Both these measures tend to diminish the voltage required for initiating the discharge. Generally speaking, there are mainly three types of lamps which within the past decade have attained importance from the commercial point of view, each of them having its own field of application in street, workshop, and domestic lighting. These fields of application are closely connected with the special properties of the lamps, especially with the colour of the light they emit, and this is largely dependent on the kind of vapour with which the tube is filled and on the pressure inside the tube.

These three types are: the sodium vapour lamp, the mercury vapour high-pressure lamp, and the mercury vapour low-pressure fluorescent lamp.[6, 13, 14, 15, 16] (*see* p. 205.)

With the sodium vapour lamp most of the light emitted is in the yellow range between 5895 and 5890Å wave length. It is applicable where an intensity of illumination sufficient for the particular purpose and very high sharpness of sight is required, while colour distinction is not of prime importance. Therefore this lamp is specially suitable for high roads, for motor traffic, marshalling yards, storage yards in factories, workshops for intricate work and for illuminated advertising.[8] The molecular density of the monatomic vapour is 10^{12} per cm^3, the current density 0.1-0.3A per cm^2. The intrinsic brightness is comparatively small and amounts to 14 stilb ($candle/cm^2$), therefore the fittings can be simple. Increase of the current density would lead to an increased excitation of the higher spectral lines, which contribute only little to the production of light, and this would result in a decrease of the luminous efficiency. The sodium vapour lamp is specially suitable for smaller units since larger ones would require unwieldy fittings.

One difficulty encountered in the use of sodium vapour lamps for motor-traffic roads was that the signposts along the roads had to undergo a special treatment in order to be legible in spite of the unusual colour qualities of the lamp. They were painted with rhodamine, the same luminescent material that Steinmetz in 1902 proposed for improving the light of the mercury vapour lamp.[12] But a special varnish had to be found which prevented the bleaching out of this paint.

With the mercury vapour high-pressure lamp the intrinsic brightness is more than ten times as large than with the sodium vapour lamp. Brightness and luminosity increase with increasing current density and larger units become therefore more economic. These lamps are working with a molecular density of 10^{17}-$10^{19}/cm^3$ and a current density of 0.5-1A/cm.^{2} The spectral energy distribution of low- and high-pressure mercury discharges is shown in Fig. 1, in which both discharges are referred to the same energy radiation.[14] As will be noticed, the high-pressure lamp produces quite a considerable part of its radiation within the visible range, but the absence of red lines is responsible for the ghastly appearance of human faces with this kind of illumination. On the other hand the predominance of the green lines makes these lamps especially suitable for floodlighting trees and lawns. Other fields of application are the illumination of high traffic squares, large factory halls, streets and highways and the floodlighting of architecture.

One drawback of these light sources must be mentioned: the time lag after being switched on. As may be seen from diagrams published by Francis and Jenkins[6] the 400W sodium and the 125W high-pressure mercury vapour lamps need about 6 and 3 minutes respectively for attaining their full value of luminosity This is due to the fact that the vapour pressure during running conditions is considerably higher than when starting the lamp. The building up of the vapour pressure necessary for efficient working from its low initial value takes a long time.

Due to this feature and to their particular colour qualities[8] neither the sodium nor the high-pressure mercury vapour lamp are suitable for most cases of industrial and domestic lighting. The most remarkable progress for this field of application was brought about by the introduction of the low-pressure mercury vapour fluorescent lamp, and it is this kind of lamp which will be specially dealt with in the following. But before going into details of its design and performance a few words should be said about the part played by the activated cathode and the admixture of rare gases to the metal vapours in reducing the required starting voltage to values compatible with those furnished by ordinary supply mains.

Although all glowing bodies emit smaller or larger amounts of electrons it was found by Wehnelt in 1904 that the electron emission of the oxides of earth-alkali metals is by far the largest, even with comparatively low temperatures. Characteristic for the emission of electrons from a certain metal is its "work function," which measures the work that must be done to extract an electron from the metal. "Owing to the very low value of the work function the emission from wires coated with oxides of calcium, barium, strontium or thorium, or mixtures of these oxides, may be many thousand times greater than that from a bare tungsten wire at the same temperature. Conversely, for the same emission the coated wire may be run at a much lower temperature with a corresponding saving in electrical energy."[5] With cold metal electrodes the cathode drop amounts to 100-300V. With the activated electrode the cathode drop decreases to a few volts,[8] and thus it was possible to produce discharge tubes suitable for being operated directly from ordinary supply mains.

But the activated electrode alone would not be sufficient for accomplishing this result if pure metal vapours were used inside the tube. Their pressure at room temperature is too low for permitting the starting of the discharge. An admixture of some argon or neon of a few mm. pressure is necessary.

Fluorescent Materials

The phenomena of fluorescence and phosphorescence have intrigued many generations of scientists, and in spite of an enormous amount of experimental and theoretical work there remain still considerable gaps in our knowledge concerning them. Luminescent phenomena of the animal and vegetable kingdoms were known to Aristotle and Pliny.* The fluorescence of "lignum nephriticum" was described as early as 1570 in a Spanish treatise cited by Robert Boyle in his "*Experimenta et considerationes de coloribus*" of 1680. The first discovery of phosphorescence is attributed to Vicencio Casciarola, a cobbler and alchemist of Bologna, who about 1602 found a piece of a mineral (barium sulphate or calcium sulphide) which, after calcination, showed that peculiar property of emitting light for some time after having been exposed to irradiation. It may be permitted to quote the neat description given by Otto von Guericke in his "Experimenta Nova" mentioned above, because it gives in a few words in simple Latin the essential facts, and because, in what may be considered the most elaborate history of luminescence,[17] neither the reference nor the name

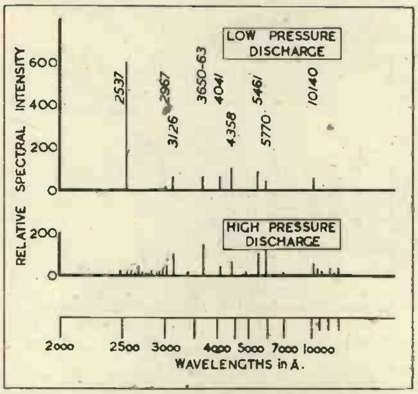


Fig. 1. Spectral energy distribution from high pressure and low pressure discharge lamps.

given to the stone by Guericke is mentioned. Here is the description:

"*Virtus lucens retineri potest in lapide Lucibibo Bononiensi, hic enim cum soli vel etiam igni fuerit aliquando expositus, virtutem Lucentem imbibit, & quando amovetur a sole ac in locum obscurum collocatur, lucem per tempus retinet, ut vivus carbo.*" (Lighting power may be retained for some time in the Bologna Light Drinking Stone, for if that is exposed some time to the sun or else to fire, it drinks the Lighting power, and if removed from the sun and brought into a dark room it retains the light for some time like live coal.)

Only a few names can be given here of scientists who mainly contributed to the research on luminescence: Grimaldi, Boyle, Herschel, Brewster, Stokes, Lommel (regarding fluorescence), Becquerel, Verneuil, Boisbedran, Wiedemann, Lenard, Stark, Wood (regarding phosphorescence). Becquerel must be mentioned specially as the originator of the phosphoroscope which made quantitative measurements possible, and so must Lenard and his collaborators as the principal investigators of the large group of inorganic phosphors and the part played by the so-called activating substances. Both fluorescence and phosphorescence and their history are exhaustively treated by Kayser and his collaborators[17] and—on the base of present views on atomic structure—by P. Pringsheim.[18] It is Stokes to whose experimental research we owe not only the law mentioned above concerning the frequencies of irradiation and re-emission but also the statement that in sunlight there is quite a strong radiation of shorter wave-lengths than those present in visible light and that these ultraviolet rays are most effective in causing fluorescence. Both fluorescence and phosphorescence play their part in the fluorescence lamp. As was already mentioned by Becquerel the stroboscopic effect of the lamp may be lessened by choosing a fluorescent substance with some phosphorescent properties.[12] In recent years much valuable research on luminescent materials has been performed by L. Levy and D. W. West[19] and by the members of the research laboratories of the manufacturing firms, e.g., T. E. Foulke, N. L. Harris, H. W. Leverenz, A. H. McKeag, J. T. Randall and J. H. Shaylor.

As may be seen from Fig. 1, with the mercury vapour high-pressure lamp the line of highest intensity is that of 3650Å. The phosphors most responsive to this line are zinc sulphides and cadmium sulphides, with silver or copper used as activators. For the low-pressure lamp in which the line of 2537Å has the highest intensity zinc silicate, zinc beryllium silicate, cadmium chloro-phosphate, cadmium borate, magnesium tungstate are used and most of them are activated by manganese. These materials cover mostly all the colours of the visible range and are mixed in the coating of the tube in such amounts as to give a beautiful white light, the spectral energy distribution of which is nearly the same as that of daylight (Fig. 2).[6] It should be mentioned that this stepped diagram shows average values for conventional equal ranges of wavelengths. The actual diagram would, of course, show a more or less steady curve.

A brief survey of some of the more important recent patents regarding luminescent materials may not be out

* Dr. Paterson mentions even a Chinese record of about A.D. 980

of place. The principal considerations in the choice of these substances are the colour qualities and the stability against electron and ion impact in the evacuated tube. Thus, for instance, sulphides are not used inside a tube, as they would be destroyed and the tube blackens instead of fluorescing. As to the colour qualities, it must be taken into account that one particular luminescent substance will re-emit the irradiated energy only in a more or less narrow spectral band and that it is therefore necessary to use at least three bands in order to fill the spectrum.

According to Patent 469732 of G.E.C. Ltd. and J. T. Randall (1936) the main constituent of the luminescent substance is magnesium tungstate activated by lead to furnish a blue light. If cadmium silicate or zinc phosphate is added a nearly white light is obtained. The proportion is 1 MgO: 1 WO with lead nitrate sufficient to give 0.1% lead in the final material. The components are ground into a uniform paste with pure water, dried for one hour at 180-200° C., reground and heated to 1000° C. for four hours. Regrinding during half-way in the heat treatment prevents the formation of black spots in the final product.

According to Patent 480356 of G.E.C. Ltd., A. H. McKeag and J. T. Randall (1936) zinc beryllium silicate is used as a matrix instead of willemite (zinc orthosilicate—$2ZnO, SiO_2$), i.e., part of the ZnO is replaced by BeO. Manganese is used as an activator. The spectrum extends from green to red, depending on the proportion of the activator. So with 0.1-0.2% Mn light green, with 0.5-1% Mn green to yellowish green, with 1.5-2% Mn yellowish white to reddish white and with 2-5% Mn orange are obtained. The method of preparation is described in detail in the specification. The current density for interior lighting is 50-250mA/cm.^{2} For improving the red component cadmium silicate activated by Mn is added.

In the luminescent material for producing "warm" colours, i.e., orange-yellow to pink, described in Patent 495706 of G.E.C. Ltd., A. H. McKeag and J. T. Randall (1937), a distinction between matrix and activator cannot be made and the material is therefore described by the form and size of its crystals. It contains cadmium, manganese, chlorine and phosphate.

Patent 521796 of B.T.H. (convention date 1937) describes a luminescent material of the zinc beryllium silicate type activated by manganese and consisting of 60 parts zinc oxide, 40 parts silica, 1.5-2.5 parts beryllium oxide, 3-5 parts manganese dioxide and ½ part lithium chloride. The fluorescent colour of this material is light yellow if 4 parts of manganese dioxide are used, smaller proportions of it giving a green colour and a higher proportion pink. Mixing with other powders, e.g., cadmium borate alone or combined with magnesium tungstate produces white light.

Patent 535897 of B.T.H. (convention date 1938) describes the mixture of three fluorescent powders, viz., 2-60% magnesium tungstate, 10-80% zinc beryllium silicate and 10-50% cadmium borate, the fluorescent energy peaks of these components lying between 4200-5200, 5200-6100 and 6100-7000Å respectively. The preferable composition of the material depends on the character of light to be produced, as is shown in the table below in which I designates the magnesium tungstate, II the zinc beryllium silicate and III the cadmium borate:

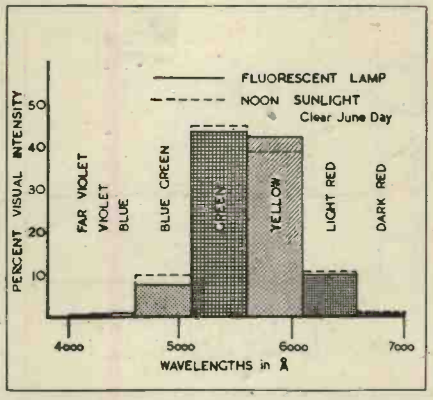


Fig. 2. Luminosity Distribution of Osram Fluorescent Tube compared with that of Sunlight *(after Francis & Jenkins)*

The advantage of using zinc beryllium silicate is that its relative energy/wavelength curve has a comparatively broad peak, so that not such an accurate control is necessary as with zinc silicate, with its high brightness and strong colour quality.

While the materials proposed for use according to Patent 532941 of G.E.C. Ltd., N. L. Harris and J. H. Shaylor (1939) are the same as in Patent 535897, viz., magnesium tungstate, zinc beryllium silicate and cadmium borate with the hint that zinc beryllium silicate may be replaced by the material described in Patent 495706, the composition of the fluorescent layer inside the tube is not determined by the weight of the component parts but by their colour qualities according to the location of their characteristic point within a diagram of mixed colours. The preparation of the different components is described in detail in the specification.

Of these patents, 480356, 535897, and 532941 appear to be the most valuable.

The question of comparing the colour qualities of the fluorescent lamps with other light sources falls outside the scope of this survey. Mention should, however, be made in this connexion of the "figures of merit" proposed by Davies, Ruff and Scott for this purpose.[16]

The fluorescent coating must be inside the tube with the low-pressure lamp, as the 2537Å line is absorbed by glass. It is different with the high-pressure lamp. As the 3650Å line passes through glass the coating of fluorescent material is placed on a second glass globe surrounding the tube proper. As the operating temperature of the low-pressure lamp is much smaller than that of the high-pressure lamp there is no objection against using the material inside the tube. At ambient temperatures below 5° C. the emission of the resonance line decreases rapidly. Therefore the low-pressure lamp is not suitable for outdoor service without being enclosed in a special fixture. Without such an enclosure it operates most efficiently at temperatures slightly above ordinary room temperature.[20] The fact that the 2537Å is absorbed by glass prevents the use of this mercury resonance line from being objectionable from a hygienic point of view.

As was stated above, the proposal to fix the luminescent powder inside the tube was made about 85 years ago. But appropriate methods for accomplishing this task effectively were developed only within the past 15 years. Fixing the powder on the outside of the tube is only feasible if the exciting rays are not absorbed by glass or if quartz is used for the bulb. The powder fixed on the outside of the tube is subjected to the influences of weather and therefore possesses only a short life unless it is protected by a second envelope. For fixing the powder on the inside of the tube, sintering processes are not applicable as the high

Character of light	Black body radiation at°K	I	II	III
Warm white light ...	2800	10%	62%	28%
Natural sunlight ...	5000	32%	66%	12%
Daylight	6500	56%	16%	28%

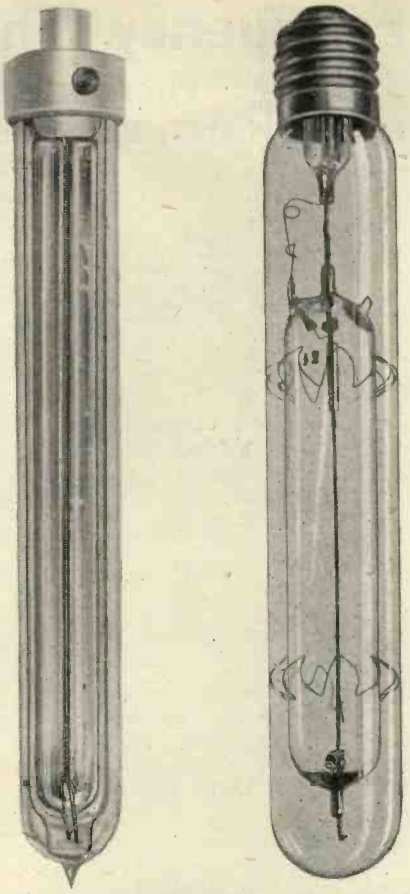
temperature would destroy the luminescent effect. Some kind of a binder must be used which does not impair the vacuum and which allows of producing a continuous layer of even thickness. The binder must be strong enough to stand handling, it must not produce an absorbent compound with the fluorescent powder when struck by electrons and must not oxidise or in any way react with this powder lest the fluorescent properties be destroyed. Therefore a binder is used which by heat and/or evacuation may be expelled afterwards. It must possess a small surface tension and high viscosity, as, for instance, high valent alcohols, especially glycerine, to which boric acid or the like may be added to increase the adhesive properties and to prevent the blackening of the layer. Such a binder forms a varnish-like coating on the luminescent crystals. This method, disclosed in German Patents 536980 (1929) and 583305 (1930) of Gebrüder Koch, Ilmenau, was developed especially for high-voltage discharge lamps for advertising purposes.

According to Patent 441603 of B.T.H. (convention date 1934) boric acid is also used for forming a protective film on ordinary or "Pyrex" glass used in discharge lamps for preventing discolouring and blackening particularly in sodium vapour lamps. To prevent "weathering" of the film, i.e., absorption of moisture accompanied by discolouring, the boric acid glaze is "stabilised" by the addition of barium or strontium oxides or similar substances. The glazing material is either dissolved or suspended in alcohol or a mixture of alcohol and acetone. After coating the glass with the solution or suspension the liquid is drained off, low-pressure air is blown through the part and it is heated to a temperature near the softening point of the glass.

A similar method is also used in connexion with luminiscent materials. In this case the binder is "shot" through the tube on a wetted sponge with compressed air and the luminescent powder is dusted on afterwards.

There may be a stage between the evaporation of the binder and the softening of the glass, when some of the material falls off so that the screen becomes uneven. An improved method combining the two methods just described is disclosed in Patent 460756 of G.E.C. Ltd (convention date 1935). Here a solution of phosphoric acid or one of its analogues is used as a binding material. For preventing the luminescent material being attacked by the acid a substance is added more liable to attack by the acid, e.g., zinc oxide or kaolin if zinc silicate is used as luminescent material.

(To be continued.)



Left: Osram "Osira" Sodium Vapour Lamp. 85 w. rating. The discharge tube is U-shaped and carries oxide-coated cathodes at the open ends, the tube being surrounded by a double-walled vacuum flask. The cap is of ceramic material.
Right: "Osira" 400 w. High Pressure Mercury Vapour Lamp with special hard glass envelope for the discharge tube. This is enclosed in an evacuated outer bulb which absorbs ultra-violet radiation.
(By courtesy of the General Electric Co.)

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October Meetings

Institution of Electrical Engineers

Ordinary Meeting

On Thursday, October 7, at the I.E.E., Savoy Place, the inaugural address as president, will be given by Colonel Sir A. Stanley Angwin, D.S.O., M.C., T.D., B.Sc. (Eng.) The meeting will commence at 5.30 p.m). (Tea at 5 p.m.)

Measurements Section

The inaugural address as chairman will be given on Friday, October 22, at 5.30 p.m., by E. W. Moss, Esq.

Wireless Section

On Wednesday, October 13, T. E. Goldup, Esq., will give his inaugural address as chairman of the section at 5.30 p.m.

Informal Meeting

A meeting to be held on Monday, October 25, at 5.30 p.m., will take the form of a discussion on "How Far is International Standardisation in the National Interest." The discussion will be opened by the President.

London Students' Section

A visit has been arranged for Saturday, October 9, at 2.30 p.m. to the British Electric Transformer Co., Hayes, Middlesex. Details can be obtained from Mr. H. Shorland, 131, Upper Elmers End Road, Beckenham, Kent.

Brit. I.R.E.

The next meeting of the above will be held on October 28 at 6.30 p.m., at the Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1.

At this meeting a paper will be read by Mr. John Logie Baird on "Colour Television."

Association for Scientific Photography

On October 23, at 2.30 p.m., a meeting will be held at the Institution of Mechanical Engineers by kind permission of the Council. The subject will be Mechanical Engineering: The Use of Photographically Sensitised Metal, Wood and Plastics. Papers will be given by A. Hensell Tiltman, B.Sc., F.R.Ae.S., and S. A. Woodward.

The British Kinematograph Society

A meeting of the above will be held on Friday, October 15, at 6 p.m., at the G.B. Theatre, Film House, Wardour Street, W.1. A paper on "Consistency in the Laboratory" will be given by Malcolm V. Hoare, of the School of Kinematography, The Polytechnic.

Institute of Physics

Industrial Radiology Group

A meeting will be held on October 9, at 2.30 p.m., at the Royal Institution, Albemarle Street, Piccadilly, London, W.1, when J. C. Rockley will read a short paper on "The Sensitivity of the Fluoroscopic Method," followed by a short discussion.

High Frequency Therapy

Part II. Dielectric Phenomena at H.F.

by W. D. OLIPHANT, B.Sc., F.Inst.P.*

ALL substances conduct electricity to a greater or lesser extent, the governing factor being termed the conductivity of the substance, which is defined as the ratio of the current density to the potential gradient. A tabulation of the conductivity of a wide variety of substances exposed to varying physical conditions would yield a set of values ranging from practically infinity down to zero. In practice, therefore, it is customary to classify substances under such headings as super-conductors, conductors, semi-conductors and non-conductors or insulators.

Dielectric Constant

A substance capable of withstanding an applied electric stress is called a dielectric and in this class we include, in addition to the non-conductors, certain of the semi-conductors. The physical constant associated with a dielectric is called the dielectric constant. This is generally defined as the ratio of the capacitance of a condenser with the dielectric material between the electrodes to the capacitance of the electrodes alone when placed in vacuo. In problems associated with electro-magnetic wave propagation it is otherwise defined as the square of the ratio of the velocity of propagation in vacuo to the velocity in the material, due attention being given to the fact that the ratio is dependent on the wavelength.

For most known substances the dielectric constant (ϵ) does not exceed about 100, though in experiments with certain colloidal solutions, higher values have been noted. On comparing the values of dielectric constant and conductivity (σ) for various materials it is at once apparent that the values for the former decrease with decreasing values for the latter, but there is no functional relationship between them. The maximum dielectric constant corresponding to the highest conductivity in the semi-conductor class is of the order of 30.

In the particular problem under discussion we are interested primarily in the heating of a dielectric brought about by loss and this is expressed in terms of the so-called loss angle (δ) if the angle be a small one, or more precisely by its tangent if the angle be a large one.

Consider a simple condenser containing a dielectric of constant ϵ whose electrodes are separated by a distance d and are of effective area A. Then the capacitance is given in C.G.S. electrostatic units by

$$C = \frac{\epsilon A}{4\pi d} \quad \ldots\ldots\ldots\ldots (1)$$

When a source of alternating e.m.f. is applied to the condenser, the resulting current which flows can be resolved into two components one of which is in phase with the applied e.m.f. and the other which is in quadrature with it and leading. We shall examine these components in turn.

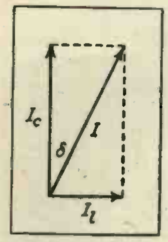


Fig. 1. Vector diagram of current flowing in a condenser, showing the loss component I_l and the charging component I_c differing in phase by 90°.

The in-phase component

This is a loss component and is brought about by dielectric conductivity which in general is not the same as for d.c., being a function of the frequency. Let this be denoted by σ_ω, then, in terms of the condenser dimensions already given, we have that the resistance of the dielectric is

$$R_\upsilon = \frac{d}{A.\sigma_\omega} \quad \ldots\ldots\ldots\ldots (2)$$

and if the applied e.m.f. be of the form $e = E. \cos \omega t$ we get that the loss current is

$$i_l = \frac{E.A.\sigma_\omega}{d} \cos \omega t \quad \ldots\ldots\ldots (3)$$

This is in phase with the e.m.f. applied and will produce heat in accordance with the principles already outlined in part I.

The Quadrature Component

This is the charging current which may readily be shown to be given by the equation

$$i_c = - C\omega E. \sin \omega t \quad \ldots\ldots\ldots\ldots (4)$$

As this component is in quadrature with the applied e.m.f. it does not bring about any heating effect.

In accordance with equation (1), equation (4) may now be rewritten thus

$$i_c = - \frac{\epsilon A}{4\pi d} . \omega.E. \sin \omega t \quad \ldots\ldots\ldots (5)$$

These two current components are shown in Fig. 1.

The loss in the condenser is governed by the so-called "loss angle" (δ) whose tangent is defined as the ratio of the amplitudes of the loss and charging currents. Thus

$$\tan \delta = \frac{I_l}{I_c} = \frac{2\sigma_\omega}{\epsilon.f.} \quad \ldots\ldots\ldots\ldots (6)$$

where σ_ω is in E.S.U.

From Equation (6) we see that, other things remaining constant, tan δ varies inversely with frequency. In practice, however, $\sigma\omega$ to a greater extent and ϵ to a lesser extent, both vary with frequency and so the expression for tan δ is not so simply related to frequency.

Dispersion

Experimental evidence has shown that when ϵ is constant, then tan δ is very small, but when ϵ varies the value of tan δ is always considerably greater, and so a variation in ϵ with frequency is always associated with a greater loss angle. The variation of ϵ with frequency is known as dispersion, but since ϵ decreases with increase in frequency, it is more precisely known as anomalous dispersion. Normal dispersion is encountered at the higher optical frequencies when ϵ increases with increase in frequency.

Within the dispersion range, therefore, we experience greater loss than is accounted for by dielectric conductance alone, and we must now consider the reason. The dispersion range is more generally referred to as the absorption range, and as the name indicates we must be on the look-out for the mechanism of energy absorption.

At low frequencies the effect is accounted for by surface and space charge effects, while at optical frequencies it is accounted for by electronic action in the molecules themselves. At the frequencies which we are most interested in, they are accounted for by the action of polar molecules or dipoles, and the theory based on this concept is due to Debye.

Dipole Theory and Dielectric Absorption

A polar molecule is conceived as being a system having a distribution of electric charges which is characterised by a permanent electric moment. The moment, known as

* University of St. Andrews.

the dipole moment m, is defined as the product of the charge e and the distance r between opposite charges, thus

$$m = e.r. \quad \ldots\ldots\ldots\ldots\ldots (7)$$

In general, molecules may be either polar or non-polar, but as a rule most molecules are endowed with dipole characteristics of finite but widely varying magnitudes depending on the nature of the substance. To gain some idea of the order of magnitude involved, a figure of 10^{-18} E.S.U. may be quoted as a mean value.

Since dipole action assists in the polarisation of a dielectric, it follows that the presence of polar molecules will ensure a higher value of dielectric constant. When we speak of the polarisation of a dielectric, we infer that the application of an electric field causes the dielectric to acquire an electric moment. Thus, in addition to the polarisation brought about by the displacement of orbital electrons already described, we have also to include that due to the orientation of the polar molecules or dipoles themselves.

In a piece of unpolarised dielectric, the dipoles, by virtue of thermal agitation, are lying in all possible positions so that the resultant moment for the dielectric as a whole is zero. When an electric field is applied, the dipoles now try to orientate themselves so that they lie along the lines of force in just the same manner as the elemental magnets in a piece of magnetic material under the familiar theory of magnetisation. By such orientation the dipoles attempt to reduce their potential energy to a minimum. Complete orientation of all the available dipoles into a permanent configuration is not possible due to thermal agitation, but Debye has given the following expression for the resultant moment in the case of a liquid.

$$a_d = \frac{N.m^2.\rho}{3.M.k.T} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

where N = Avogadro's number; = 6.06×10^{23}

ρ = density of liquid at absolute temperature T;

M = molecular weight and

k = Boltzmann's constant = 1.37×10^{-16} ergs per degree.

Thus the resulting moment increases as the square of the polar moment m and inversely as the absolute temperature.

In the above equation complete orientation under the prescribed conditions can only take place at low frequencies since there is a finite interval of time necessary for the complete orientation of a dipole. This time is given by

$$\tau = \frac{4\pi\eta r^3}{k.T.} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

where η = coefficient of viscosity of liquid;

r = effective radius of polar molecule which in general increases with viscosity.

Thus at very high frequencies, when the period of forced oscillation is small compared with τ, even partial orientation may be impossible. There is thus a critical frequency defined by $1/\tau$ above which dipole action becomes impossible and so a_d and therefore ϵ decrease with increase in frequency.

About the critical frequency we experience the phenomenon of resonance in that the dipoles will oscillate in synchronism with the applied field. The amount of dipole motion will thus be a maximum with an attendant maximum heating effect due to friction. The value for tan δ will thus pass through a maximum, and this, along with the variation of ϵ, is shown in Fig. 2.

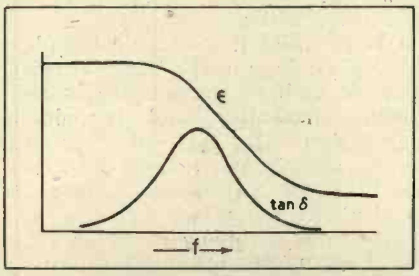


Fig. 2. Curve showing how the dielectric constant and loss angle vary with frequency.

The general expressions for ϵ and tan δ may now be quoted in terms of the dielectric constant (ϵ_0) when the substance is totally polarised by a unidirectional electric stress (that is when both orbital electron displacement and dipole orientation are present) and of the dielectric constant (ϵ_∞) when the dielectric substance is subjected to an alternating stress whose period is much less than the critical period (τ) already defined (that is when orbital electron displacement alone is present) thus

$$\epsilon = \epsilon_\infty + \frac{(\epsilon_0 - \epsilon_\infty)}{1 + \omega^2\tau^2} \quad \ldots\ldots\ldots (10)$$

and

$$\tan\delta = \frac{(\epsilon_0 - \epsilon_\infty)\omega\tau}{(\epsilon_0 + \epsilon_\infty\omega^2\tau^2)} \quad \ldots\ldots\ldots (11)$$

The effect of temperature on the loss of a dielectric exposed to a constant frequency alternating stress can be ascertained from equation (9). As the temperature increases, the viscosity decreases and so the period τ decreases rapidly with consequent increase in the critical frequency. Thus if the exciting frequency is suitably chosen, the losses will be observed to pass through a maximum as the temperature rises.

The Possibility of Specific Action in Biological Materials

At this point it would seem fitting to introduce the controversial topic as to whether or not specific action does in fact take place in a biological substance when exposed to a high frequency electric field. As we shall see in later articles, the biological substance is placed between the electrodes of a specially designed condenser, and it thus fills the rôle of a dielectric. Up to the present all clinical evidence on the curative action of high frequency electric fields has been attributed to the deep-seated heating effect which develops in the substance under treatment, and no definite evidence has been forthcoming of specific action. This is chiefly due to the fact that no accurate quantitative investigation has ever been made, or if it has, then it has not so far come to the notice of the author in published form.

Let us go back to equation (9). Here we have an expression for the critical period of oscillation of a particle in a viscous medium, and in order to get some idea of the magnitudes involved we will take a concrete example. Consider a colloidal particle of radius 10^{-7} cm. and assume that it is present in the blood at a temperature of 38° C., whereat the coefficient of viscosity may be taken as $3{\cdot}4 \times 10^{-2}$. Substitution in equation (9) gives the critical period as of the order of 10^{-8} sec., hence the critical frequency would be 10^{8} cycles per second. Converting into wavelength, we find that we would require an oscillator operating at 3 metres. At this wavelength, therefore, we would expect to get a marked absorption of energy and for specific action to have taken place we would require to test for some chemical reaction, the problem being a purely biochemical one.

Turning to bacteriology, the branch of medical science which would seem best suited to an investigation into the possibility of specific action, we would consider the bacterial cell as our oscillating particle. Here we have a wide assortment of virus particles ranging in size from about 10 mμ for foot-and-mouth disease to about 1μ for staphylococcus. (1 mμ = 10^{-7} cm., and 1μ = 10^{-4} cm.) In order to examine the effect of exposure to the high frequency electric field, it would be necessary to make a very close study of the bacteria themselves.

One might be tempted to stop at a simple morphological study and express one's results in terms of noted structural changes in the form of the organism, but this line of approach would be fraught with grave difficulties. By way of illustration, we will take a very simple case. Certain bacteria possess delicate prolongations of the protoplasm known as flagella which act as locomotary organs and afford the bacteria a high degree of motility. It is possible by simple mechanical means to deprive the organisms of these flagella and thus render them non-motile. Observation of the degree of motility under certain specific conditions would thus seem to afford a ready means of assessing the damage done to the structure, but lack of motility would not necessarily indicate lethal field action, because given time, complete recovery would take place and a fresh flagella would grow. Motility, therefore, cannot be taken as a ready means for studying the effect of short wave action.

It is essential that a critical study of the physiology of the bacterial cell be made embracing such topics as growth, metabolism and reproduction. From the point of view of disease, the virulence of the bacteria would be the all important factor. By virulence we mean the capacity of the bacteria to invade tissue, the rate of reproduction, and the rapidity with which toxic effects are produced. It may very well be found in practice that, while it is not possible to kill-off the bacteria completely, the degree of virulence may be so reduced as to render speedier recovery of the patient possible.

From a purely qualitative point of view, the apparent existence of specific action has been suggested by several investigators. Changes in the osmotic conditions of sedimentation velocity of blood corpuscles have been observed as well as influence on surface tension and phenomena associated with boundary surfaces. Considerable biochemical changes in serum have been experienced, and so on, but in all fairness to the present state of the art it must be recorded that both biopositive and bionegative action has been encountered on micro-organisms. The subject would thus appear to be both a wide and fruitful one for future research.

(*To be continued.*)

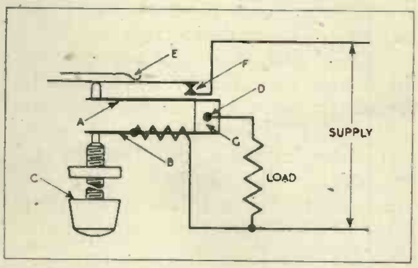
Sunvic Energy Regulator

THE Sunvic Energy Regulator is an alternative to a variable rheostat.

It enables the electrical power input to be adjusted continuously from no load to full load without the loss of energy associated with resistance control. It has moreover the additional advantage that it keeps the input constant at any setting independent of supply voltage fluctuations.

The regulator is thus ideally suited to control the input to hotplate or furnace, or the average output from a motor.

The principle of operation is shown in the attached diagram.



B is a bimetal strip carrying a heat winding. A is a further bimetal strip which serves to compensate for ambient temperature variations. The two strips are fixed to a block G which pivots about the point D.

The assembly is restrained by an adjusting knob C and bears against the snap action switch E. In the normal position current flows through the contact F through the load and also through the winding on the bimetal B.

The bimetal is thus warmed and in bending opens the switch E switching off the heating winding and the load. The bimetal cools and after an interval the switch E remakes and the cycle repeats. The on/off time depends on the position of the adjusting screw. Clearly, if the adjusting screw can be slackened to a point where the maximum bending of the bimetal is insufficient to open the switch, the power is permanently on. Alternatively, if the screw is turned in the opposite direction a point will be reached in which the switch is permanently open with the bimetal cold and the power will be permanently off. Between these limits therefore, the proportion of the total cycle time during which the power is on, and thus the input, will be a direct function of the position of the screw.

Since the same voltage is applied to the load and the bimetal heater, any variation of voltage will affect the two equally so that the combination is independent of supply voltage.

A New Air Raid Warning

To Beat the Sneak Raiders

Fig. 3. One of the spotter's posts, which can be independently wired back to the amplifier.

THE "tip and run" technique of German raiders on the South and South East coast towns though difficult to combat is, nevertheless, being vigorously tackled by both the government and local authorities. The destruction of the raiding craft is, of course, the government's responsibility but the safety of the townspeople is, to a large extent the responsibility of the local government.

An air raid warning system has been developed by the local authorities at Hove to meet the sneak raider menace. It is an electronic system, by which impulses transmitted on a special P.O. danger signal network are amplified and passed on to loudspeakers situated in various parts of the town thus giving local warning of imminent danger. The system is entirely automatic and is supplementary to the normal siren alert. Some idea of the speed of operation (and speed is vital) may be gauged from the fact that there is a time lag of only half a second between the receipt of the control impulse and the broadcast of the warning signal from the loudspeakers!

This electronic equipment consists of a signal generator, control and switchgear mounted in panel form on a 6 ft. rack frame and bolted to this is a similar rack carrying an 800-watt amplifier. Figures 1 and 2 show the front and rear views (covers removed) respectively.

A check on the efficiency of the sixteen valves employed can be immediately carried out by means of a bank of meters on the amplifier panel whilst constant visual and aural checks on the signals being radiated are effected by neon output indicator and monitor loudspeaker panels. On the main control panel a test key is mounted which, when operated, disconnects the loudspeaker network and substitutes an artificial load of equivalent impedance. Coloured lamps on the main control panel indicate the situation as directed by the post office impulses at any given time. The equipment was supplied and installed by Broadcast Amplifiers Ltd., 17, Preston Road, Brighton, in co-operation with the makers, The General Electric Co. Ltd. It is kept at the "ready" twenty four hours a day, seven days a week.

The main amplifier performs three main functions automatically, and in order of priority: (a) the broadcast of an "Imminent Danger" warning signal and the corresponding Imminent Danger release; (b) the normal Home Office "Alert" and "All Clear" siren tones; (c) police announcements by microphone.

The Imminent Danger warning signal is a series of short piercing "beeps" at the rate of forty-eight per minute for thirty seconds whilst the I.D. release is a continuous note of a similar pitch for a like period. The normal siren "Alert" and "All Clear" signals are simulated electronically and are broadcast throughout the speaker network simultaneously with the sirens thus adding considerably to their effectiveness. The police announcements are made through a moving coil microphone installed in the amplifier room.

Although in an emergency the apparatus can be controlled from the amplifier rack or from one or more spotters posts (see fig. 3 above) the entire system is normally operated from a remote control centre by means of impulses transmitted to a tuned relay and thence to the signal control equipment.

The Imminent Danger signal is first in order of priority; the siren signals second, and the microphone announcements are third in priority. This means that if a warning is received during the course of a microphone announcement, either of the two air raid signals automatically takes control and if the Imminent Danger signal is received, even during the time the siren tone is being radiated, the latter will superseded by the short piercing tones of the "beeps" which indicate raiders overhead.

In addition to the check meters, neon indicator and monitor speaker previously mentioned, other aids to quick location of faults and servicing are embodied in the design.

This equipment, unique in many ways, has proved completely satisfactory over a period of time and has on more than one occasion been instrumental in preventing many serious casualties.

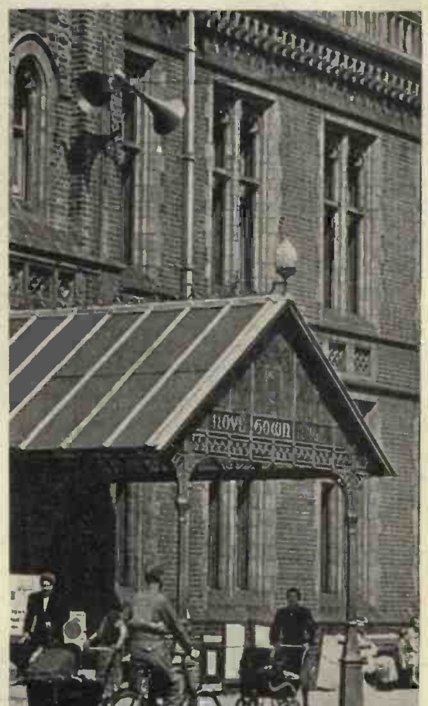


Fig. 4. Two of the loud-speakers by which warning signals and police announcements are radiated.

The G.E.C. Air Raid Warning Equipment

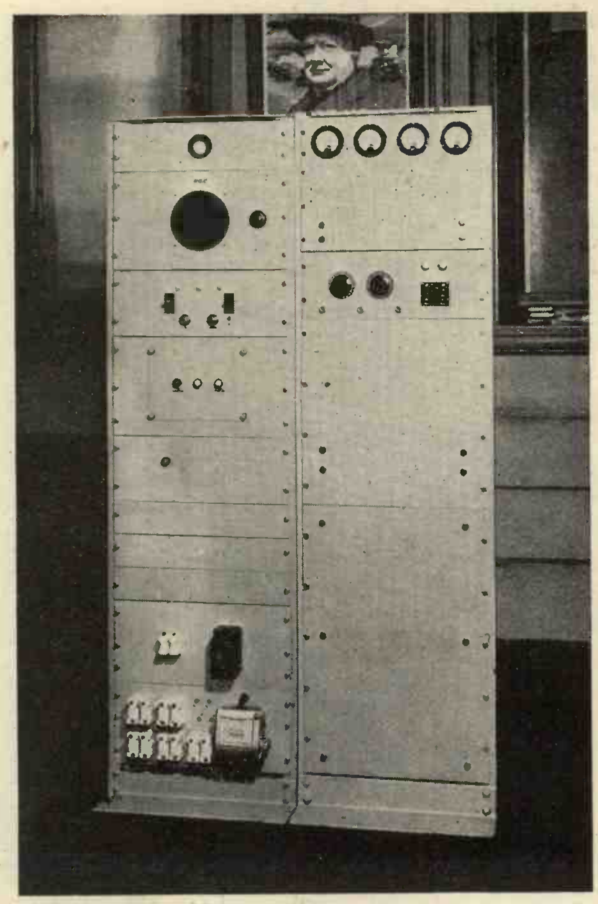


Fig. 1. Front view of the equipment showing meter facilities for checking valve efficiency, monitor speaker, etc.

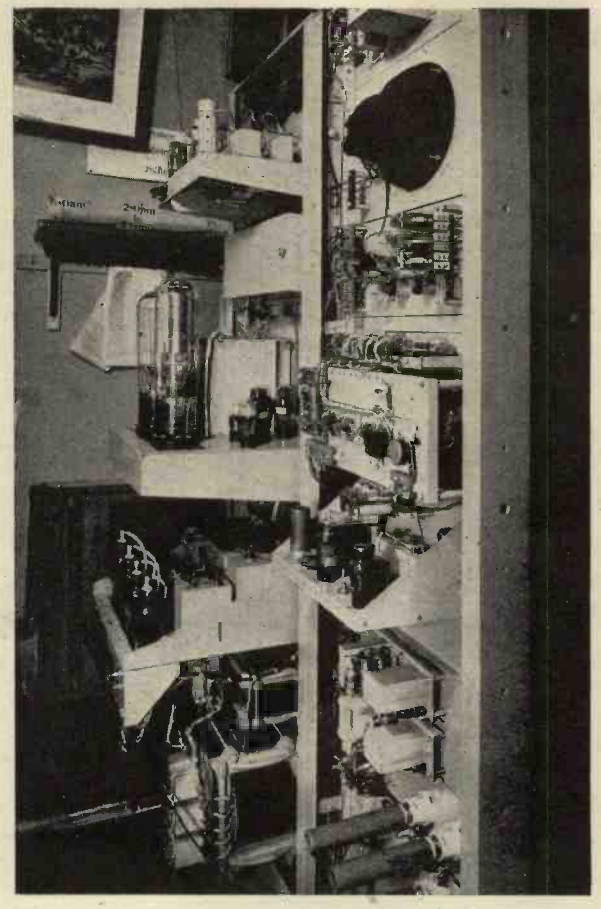


Fig. 2. Rear view (covers removed) of signal generator and amplifier showing accessibility of all components.

German Army "Speech-on-Light" Apparatus — *Concluded from p. 187*

respect, the cell is inferior to a caesium cell, which has a better H.F. response. However, its sensitivity to red and infra-red light is better than that of a caesium cell. The signal-to-noise ratio is 30db.

Fig. 5 shows the response curve of the modulator response whilst it is by no means flat, it is within 5 db. from zero to 2,200 c/s., when the response falls off rapidly.

Fig. 6 shows the overload characteristic of the modulator, plotted for different frequencies. As may be expected, this curve is complementary to the response curve. The effects of overloading, or over-modulating are to make the small moving prism lose all contact with the large one (on alternate half cycles); this makes the area of first reflection one of glass to air boundary. On the other half cycle, overloading causes the prism pressure to be so great that the contact becomes too perfect, and not enough light is reflected within the prism. Both these effects cause non-linearity, and show why, for best results, the modulator should be adjusted to give equal upward and downward modulation for alternate half cycles.

Mechanical Construction

The secret of the success of this instrument depends largely on its good mechanical design and construction. With a device of this sort, mechanical rigidity is of primary importance. The tripod is strongly constructed, and whilst the head is fixed to it by a single universal fixture, it is very rigid.

The head itself is made of aluminium, and optical technique is employed throughout the apparatus, which is made by Carl Zeiss. The lamp-house, whilst being detachable, is firmly held in position, and the modulator is mounted on a slotted platform, so that initially it may be located correctly with respect to the lamp and the transmitting lens. The modulator prism is housed in a heavy machined brass holder, located within the permanent magnet of the armature system. The photo-cell clips into its holder very simply, but perfect positioning is ensured by the holder, since it is necessary that the incoming light is focused dead on the centre of the cell by the 80 mm. receiving lens. The whole apparatus weighs 54 pounds.

It is appreciated that whilst the Speech-on-Light apparatus provides yet another system of communication, its use is strictly limited. Firstly, the range is so small, secondly, it must be used over quasi-optical paths, and thirdly, it cannot be operated on the move. The salient advantages are security as compared to short range radio, its lack of wires as compared to telephones and its provision for speech as compared to ordinary lamp signalling. It will be interesting to observe whether the Allies bring out a corresponding model before the conclusion of the war.

Matrix Algebra

Part II :—The Solution of Electrical Network Problems

Continued from p. 161 of last month's issue

By J. C. SIMMONDS, Ph.D.

As an illustration of the solution of network problems by means of matrix algebra, consider the circuit given in Fig. 1. The matrix equation relating E and I is :—

$$[E]=[R]\times[I], \tag{28}$$

where

$$[R] = \begin{bmatrix}(R+R_1) & -R_1\\ -R_1 & (R_1+R_2)\end{bmatrix} \tag{29}$$

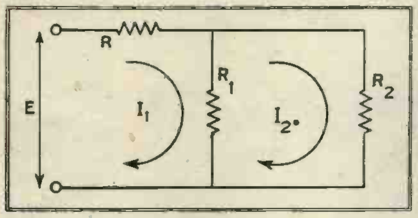


Fig. 1.

The admittance matrix $[A]$ as obtained by the method previously described, is

$$[A] = \frac{\begin{bmatrix}(R_1+R_2) & R_1\\ R_1 & (R+R_1)\end{bmatrix}}{RR_1+RR_2+R_1R_2} \tag{30}$$

Since

$$[I]=[A]\times[E], \tag{31}$$

it follows immediately that—

$$I_1=\frac{(R_1+R_2)\,E}{RR_1+RR_2+R_1R_2} \tag{32}$$

and

$$I_2=\frac{R_1\,E}{RR_1+RR_2+R_1R_2} \tag{33}$$

The same method, of course, would apply had the more general case, in which E is an alternating e.m.f. and R, R_1 and R_2 are replaced by impedances, been considered.

As a further, and possibly more difficult, application of matrix algebra to this type of problem consider the circuit shown in Fig. 2.

In this case the matrix equation relating E and I is :—

$$\begin{bmatrix}E_1\\E_2\\E_3\end{bmatrix}=\begin{bmatrix}(R+R_1) & R & R\\ R & (R+R_2) & R\\ R & R & (R+R_3)\end{bmatrix}\times\begin{bmatrix}I_1\\I_2\\I_3\end{bmatrix} \tag{34}$$

The admittance matrix is easily shown to be :—

$$\frac{\begin{bmatrix}(RR_2+RR_3+R_2R_3) & -RR_3 & -RP_2\\ -RR_3 & (RR_1+RR_3+R_1R_3) & -RK_1\\ -RR_2 & -RR_1 & (RR_1+RR_2+R_1R_2)\end{bmatrix}}{(RR_1R_2+RR_1R_3+RR_2R_3+R_1R_2R_3)}$$

and, therefore,

$$I_1=\frac{E_1(RR_2+RR_3+R_2R_3)-E_2RR_3-E_3RR_2}{(RR_1R_2+RR_1R_3+RR_2R_3+R_1R_2R_3)} \tag{35}$$

$$I_2=\frac{-E_1RR_3+E_2(RR_1+RR_3+R_1R_3)-E_3RR_1}{(RR_1R_2+RR_1R_3+RR_2R_3+R_1R_2R_3)} \tag{36}$$

$$I_3=\frac{-E_1RR_2-E_2RR_1+E_3(RR_1+RR_2+R_1R_2)}{(RR_1R_2+RR_1R_3+RR_2R_3+R_1R_2R_3)} \tag{37}$$

In this problem also the resistances could have been impedances and the phase of the e.m.f.'s could have been taken into account without in the least increasing the difficulty of the solution. If actual numerical values are substituted in equations (35)-(37) the work is, of course, much more laborious when the A.C. case is considered than when the D.C. case is considered.

A different type of problem is associated with the four-terminal network shown in Fig. 3. It is well known that the performance of this type of network can be represented by the equations :—

$$E_1=\mathbf{a}E_2+\mathbf{b}I_2 \tag{38}$$

$$I_1=\mathbf{c}E_2+\mathbf{d}I_2, \tag{39}$$

where a, b, c, and d are constants. In matrix notation these equations are written :—

$$\begin{bmatrix}E_1\\I_1\end{bmatrix}=\begin{bmatrix}\mathbf{a} & \mathbf{b}\\ \mathbf{c} & \mathbf{d}\end{bmatrix}\times\begin{bmatrix}E_2\\I_2\end{bmatrix} \tag{40}$$

The performance of a similar network having constants a^1, b^1, c^1, and d^1 can, of course, be represented by a similar equation. If this second network is connected in cascade with the first, then the input voltage and current will be E_2 and I_2, respectively, and its matrix equation becomes :—

$$\begin{bmatrix}E_2\\I_2\end{bmatrix}=\begin{bmatrix}\mathbf{a}^1 & \mathbf{b}^1\\ \mathbf{c}^1 & \mathbf{d}^1\end{bmatrix}\times\begin{bmatrix}E_3\\I_3\end{bmatrix} \tag{41}$$

The relations between the input and output voltages and currents when the two networks are connected in cascade are very simply obtained from equations (40) and (41) and are given by :—

$$\begin{bmatrix}E_1\\I_1\end{bmatrix}=\begin{bmatrix}\mathbf{a} & \mathbf{b}\\ \mathbf{c} & \mathbf{d}\end{bmatrix}\times\begin{bmatrix}\mathbf{a}^1 & \mathbf{b}^1\\ \mathbf{c}^1 & \mathbf{d}^1\end{bmatrix}\times\begin{bmatrix}E_3\\I_3\end{bmatrix} \tag{42}$$

Thus, it is seen that the two networks in cascade can be replaced by a single network, the constants of which are given by the product of the first two matrices on the right hand side of equation (42). If the two networks are identical $\mathbf{a} = \mathbf{a}^1$, etc., and equation (42) becomes :—

$$\begin{bmatrix}E_1\\I_1\end{bmatrix}=\begin{bmatrix}\mathbf{a} & \mathbf{b}\\ \mathbf{c} & \mathbf{d}\end{bmatrix}^2\times\begin{bmatrix}E_3\\I_3\end{bmatrix} \tag{43}$$

The matrix equation of a four-terminal network can also be put in the form :—

$$\begin{bmatrix}I_1\\I_2\end{bmatrix}=\begin{bmatrix}\mathbf{f} & \mathbf{g}\\ \mathbf{h} & \mathbf{k}\end{bmatrix}\times\begin{bmatrix}E_1\\E_2\end{bmatrix} \tag{44}$$

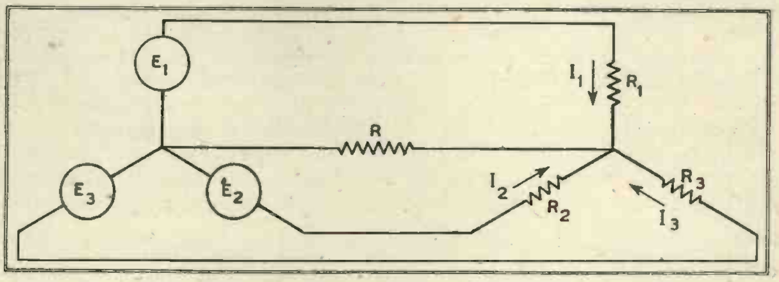


Fig. 2.

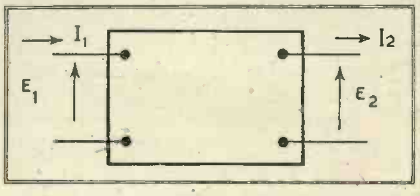


Fig. 3

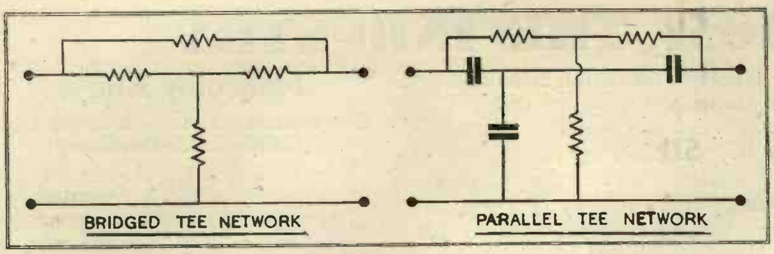


Fig. 4

Thus, if two networks characterised by the following equations :—

$$\begin{bmatrix} I_1' \\ I_2' \end{bmatrix} = \begin{bmatrix} f' & g' \\ h' & k' \end{bmatrix} \times \begin{bmatrix} E_1' \\ E_2' \end{bmatrix} \qquad (45)$$

and

$$\begin{bmatrix} I_1'' \\ I_2'' \end{bmatrix} = \begin{bmatrix} f'' & g'' \\ h'' & k'' \end{bmatrix} \times \begin{bmatrix} E_1'' \\ E_2'' \end{bmatrix} \qquad (46)$$

are connected in parallel, then

$$I_1 = I_1' + I_1'' \ , \ I_2 = I_2' + I_2'' \qquad (47)$$

and $$E_1' = E_1'' = E_1 \ , \ E_2' = E_2'' = E_2 \qquad (48)$$

Therefore, it is seen that

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} f' + f'' & g' + g'' \\ h' + h'' & k' + k'' \end{bmatrix} \times \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} \qquad (49)$$

This equation shows that the two networks when connected in parallel are equivalent to a single network, the constants of which are given by the sum of the corresponding constants of the two networks. (This statement is not always true and details of its failure may be found in chapter iv of *Communication Networks*, Vol. 2, by E. A. Guillemin.) The importance of this conclusion can be seen by considering the bridged tee network shown in Fig. 4. This network can be considered as formed by two simpler networks connected in parallel, one consisting of but a single element and the other of a simple tee section. When regarded in this manner, the bridged tee network is quite easy to analyse, for the constants which determine its behaviour are simply obtained by adding the corresponding constants of the two component networks.

In the same way the parallel tee network, shown in Fig. 4, can be considered as two simple tee sections connected in parallel. Thus, to find the condition that no current shall flow in the output when an e.m.f. of a certain frequency is applied to the input it is only necessary to determine the transfer admittances of the two component networks, add them and equate the sum to zero. From equations (45) and (46) it is easily seen that the transfer admittance (the ratio I_2/E_1) of the component networks are h' and h'' so that the required condition is $h' + h'' = 0$. This also follows directly from equation (49).

The writer is indebted to Mr. C. F. Davidson for reading through the manuscript.

NOTES FROM THE INDUSTRY

Scophony Corporation of America

Dr. A. H. Rosenthal has been appointed "Director of Research and Development" of the Scophony Corporation of America under a three years' contract, according to an announcement by Arthur Levey, President of Scophony, with which are associated Television Productions, Inc. (a Paramount subsidiary) and General Precision Equipment Corporation.

Having been connected with Scophony, Ltd., of London for several years and contributed some of the more important Scophony inventions, Dr. Rosenthal in his present position will head a group of scientists and engineers engaged in research and development of fundamental inventions, not only in television, but also in the ever-widening field of electronics, including various applications of supersonics. These inventions are related to important war problems and, it is anticipated, will help establish new industries and open new horizons to assist in solving the post-war problem of unemployment.

I.E.E. Students Section

The following officers have been elected for the session 1943-44:—

Chairman: Mr. J. D. McNeil, B.Sc.
Vice-Chairman: Mr. C. C. Barnes.
Hon. Secretary: Mr. H. Shorland, B.Sc.
Asst. Hon. Secretary: Mr. B. Rovenblum, B.Sc.

Full information of the activities of the Section can be obtained from the Hon. Asst. Secretary at 145 Cotswold Gardens, London, N.W.2.

Radio Industries Club

It will be recalled that some months ago the membership list of the Club was temporarily closed. However, it became obvious by the rapid growth of the waiting list that there were many more members of the industry who wished to join the Club, and the Committee have been forced to reconsider the matter.

It has now been decided that the membership list will be re-opened, but that the Committee will reserve the right on the occasion of certain luncheons to limit the number of guests to *one per member*. It is still necessary to keep the luncheon attendances down to 200, but the Committee feel that it would be more in the interests of the Club to restrict the number of guests than to continue the ban on new members. Forms of application for membership can be obtained on request from Mr. W. E. Miller, Dorset House, Stamford Street, S.E.1.

Henley's Education Scheme

We have received a copy of an illustrated booklet which is handed to every boy on entering the service of W. T. Henley's Telegraph Works Co., Ltd., and Henley's Tyre and Rubber Co., Ltd. This booklet outlines a scheme which is intended to enable all youths joining the Henley Organisation to see what chances there are open to them and how they can train themselves for their careers.

Every boy is given the option of undertaking a course of training extending over a period of years. On a selected day each week, boys who have shown that they can benefit from such privileges and have been accepted for the course, are released entirely from their normal duties with the company in order that they may attend approved classes at selected educational institutions near to their place of employment. They are expected to devote themselves wholeheartedly to the courses laid down for them during this day, and to attend a recognised educational establishment of their own choosing, at least one other evening in the week, for which purpose wherever practicable, they will be released from shift-work or overtime.

Boys are paid for the time spent at the day establishment, and all fees, both for the day and evening courses, are paid by Henley's.

Mancoloy Alloys

Low Resistance Materials with Low Temperature Coefficient

To meet a demand for copper alloys having low resistance combined with low temperature coefficients of resistance Mallory Metallurgical Products Ltd. have developed two special materials. These alloys are known as Mancoloy 8 and 10 respectively, the number following the name of the alloy denoting their approximate resistivity in microhms. The properties of these alloys are given in the table below, from which it will be seen that their resistivities are appreciably lower than those of other resistance materials, while their temperature coefficients are extremely low. (For comparison the average temperature coefficient of copper is .0039, while that of phosphor bronze usually lies between .0020 and .0025).

These alloys are of great advantage where a low but practically constant resistance is required in instruments and radio apparatus.

For use as drag elements in instruments depending on the eddy current brake principle for their operation, their relatively high conductivities ensure sensitivity, while their low temperature coefficients reduce temperature errors to extremely small proportions.

Both the Mancoloy alloys are available in the usual sizes of strip and wire.

Electrical Properties of Mancoloy Alloys

	Resistivity in microhms per cm³	Electrical Conductivity per cent. I.A.C.S.	Mean Temperature Coefficient of Resistance (0–100°C.)
Mancoloy 8	7.5—8.5	20—22%	.00055—.00065
Mancoloy 10	9.5—10.5	16—18%	.00045—.00055

Mr. E. J. Wyborn

It is reported in the *Wireless and Electrical Trader* that Mr. E. J. Wyborn, M.I.E.E., the deputy managing director of Messrs. E. K. Cole, Ltd., has resigned from the board and is no longer connected with the company.

Lectures

The British Kinematograph Society announce that a course of lectures will be given at the Polytechnic School of Kinematography, Regent Street, W.1, as follows:—

Sensitometry and Laboratory Practice

Lecturer: Mr. M. V. Hoare.

A course of 13 lectures designed to enable laboratory workers to understand the basic principles underlying processing, and studio workers to appreciate the requirements of the photographic process, and to secure the fullest co-operation from the laboratory.

Thursdays at 6 p.m., commencing September 23, 1943.

ABSTRACTS OF ELECTRONIC LITERATURE

MEASUREMENT

Contact Bounce

(*P. H. Estes*)

A description is given of a recorder for the measurement of time intervals, from 0.2 milliseconds to 0.5 seconds, occurring in the various stages of the closing and opening of relay contacts The operating cycle of a typical d.c. relay is given and a set of test traces presented to illustrate and explain the type of record obtained with the instrument. The recording paper used in Teledeltos, a light grey in colour, which undergoes a chemical change and turns black under the stylus whenever a potential is applied to it.

—*G.E. Rev.*, June, 1943, p. 321.*

The Microlineometer

(*E. F. Travis*)

An instrument called the microlineometer was devised for adjusting the time duration of the sweep and for measuring the degree of linearity of the horizontal deflection produced for various settings of the servo sweep generator for a wide band oscilloscope. It consists essentially of a crystal-controlled frequency standard combined with a driven multivibrator having a variable pulse width. The principle and operation of the instrument is described together with a note on the servo sweep generator. Applications of the apparatus for all types of measurements on the servo sweep generator are discussed.

—*G.E. Rev.*, June, 1943, p. 345.*

CIRCUITS

Electrical Transducer Circuit for use with Capacity Pick-up Devices

(*E. V. Potter*)

An electrical circuit suitable for converting changes in capacity into changes in a rectified electrical current has been developed by the Bureau of Mines and has been used in seismic work as well as other studies in which mechanical vibrations are involved. The circuit employs two radio-frequency oscillators and a rectifier can be operated from batteries or 110 volt, 60 cycle a.c. Sensitivities up to 2 mA per $\mu\mu$F, change in capacity and a current range of 5 to 40 mA can be obtained with 25 L6 oscillator tubes.

—*Rev. Sci. Inst.*, Vol. 14, No. 5 (1943), p. 130.

Simple Time Base for a High-speed Cine Camera

(*E. D. Eyles*)

The time base consists of an electrically maintained 1,000 c/s. tuning-fork carrying slit apertures in overlapping plates at the ends of the prongs. Light from a small tungsten filament lamp is concentrated on to the slits by means of an optical system, and an image of them is focused on to the film. As the fork vibrates the slits are displaced relatively one to the other ,and the light beam is interrupted to produce a time base divided into one-thousandth second intervals in the form of a series of dashes photographed along the edge of the film.

—*Jour. Sci. Inst.*, Vol. 20, No. 7 (1943), p. 114.

THEORY

Magnetic Induction Field of Air-Core Coils

(*C. B. Kirkpatrick*)

Expressions are derived for the axial components of the magnetic induction field of both three-dimensional and two-dimensional coils; in particular, the Helix, the Spirals $r = k\theta$ and $r = r_0e^{k}\theta$, and the simple Circular Coil are investigated.

Efficient heating by a high-frequency induction field, and the design of heater coils such as those used in valve manufacture, are discussed in some detail.

—*Wireless Eng.*, Vol. 20, August (1943), p. 372.

Ultrashort Electromagnetic Waves 4. Guided Preparation

(*S. A. Schelkunoff*)

A "non-mathematical" or "engineering" approach to the solution of certain problems involved in the design of wave guides is attempted instead of the more complete equivalent field-theory method. Transverse electromagnetic, magnetic and electric waves in transmission lines are discussed and the field distribution is considered. Impedance and attenuation are also dealt with. A series of optical analogies are presented on the basis of a source of light inside a metal tube. The phenomena occurring in cavity resonators are discussed with reference to several diagrams of wave flow.

—*El. Engg.*, June, 1943, p. 235.*

INDUSTRY

Recent Developments in Organic Plastics for Electrical Insulation

(*T. Hazen*)

Some of the developments that have taken place in the use of plastics for electrical insulation are reviewed. The dielectric absorption of acrylic resins is discussed and the effect of frequency investigated. The general electrical properties of polystyrene, cambric varnishes, synthetic liquid dielectrics and the new wire and cable insulating compounds made from vinyl resins are given. The variation of dielectric properties with plasticiser content is examined for the vinyl resins. The effect of frequency and temperature is illustrated by graphs for many of the compounds used.

—*El. Engg.*, May, 1943, p. 191.*

An Electronic Circuit to control Intensity and Timing of Power for Spot Welding

(*W. B. Nottingham*)

A welder control is described which can deliver currents as high as 200 amperes r.m.s. for any predetermined time from a fraction of half a cycle of the 60 cycle power supply to 60 half cycles. At any specified timing the intensity may be controlled continuously from zero to its maximum value. The operation of the control depends on the co-ordinated application of two electronic circuits which individually or together have many other uses. The one circuit is a regenerative d.c. amplifier which serves as a controlled square-wave generator and the other is a "biased multivibrator." The operation of these circuits is described in considerable detail so that they may be adapted to the solution of other electronic control problems. The construction of pool-type mercury rectifiers and the life tests on these are also presented.

—*Rev. Sci. Inst.*, Vol. 14, No. 6 (1943), p. 161.

THERMIONIC DEVICES

A Two-cycle Flasher

(*S. A. Talbot*)

A light-valve is described for providing single flashes of 3-msec. duration or longer, operated and controlled electronically. It involves disclosure and closure of an aperture by two vanes, whose cycle is commutated automatically. Details are given for a model made mainly from commercial parts, and driven by thyratons. A suitable control circuit is also shown.

—*Rev. Sci. Inst.*, Vol. 14, No. 6 (1943), p. 181.

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