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Classification of Frequencies

Need for a Universal System

PRESENT-DAY trends towards the use of higher and higher frequencies accentuate the need for some system of classification that is explicit and précise and at the same time sufficiently simple and easily memorised to be used by all wireless technicians in their daily work. Such expressions as "very high frequencies" and "ultra-high frequencies" are at best ambiguous and clumsy, and have almost lost what little meaning they ever had. No useful purpose is served by what a correspondent recently described as a hectic search for more "hypers" and "supers."

So far as the nomenclature of wavebands is concerned, it seems hard to improve on the system agreed upon in 1937 by the International Radio Communications Conference (C.C.I.R.). It was advocated by Dr. Smith-Rose, Chairman of the I.E.E. Wireless Section, writing in *Wireless Engineer*, and is given below.

Although some of the metric units employed are not in common use, particularly in this country, the C.C.I.R. system does in most cases divide up the wavebands at those natural boundaries where changes in methods of propagation or transmission and reception technique are known to occur. The table has the additional advantage that it may be extended downwards to embrace the infra-red and visual parts of the spectrum. But most technicians now think, talk and write in terms of frequency, and so any wavelength classification, however good in itself, fails to satisfy their needs completely. The frequency equivalents of the C.C.I.R. wavebands are not particularly difficult to memorise, though they cannot fairly be described as mnemonic.

Designation of waves in terms of wavelengths	Wavelength in metres	Designation of waves in frequencies	Frequency in kilo-cycles per sec.
Myriametre	Above 10,000	Very low	Below 30
Kilometre	10,000–1,000	Low	30–300
Hectometre	1,000–100	Intermediate	300–3,000
Dekametre	100–10	High	3,000–30,000
Metre	10–1	Very high	30,000–300,000
Decimetre	1–0.1	Ultra-high	300,000–3,000,000
Centimetre	0.1–0.01	Super-high	3,000,000–30,000,000

For working in terms of frequency, a useful system of nomenclature is that first suggested by B. C. Fleming-Williams in *Wireless Engineer* for May, 1942. The system, which embraces both audio and radio frequencies, is quite simple. Each band is given a number; that number may be found by expressing a frequency (in cycles per second) as a number between 1 and 10 multiplied by a power of ten. The band number is given by that power of ten. For example, medium frequencies between 10^5 c/s and 10^6 c/s are in Band 5. The complete table of "power of ten" band numbers follows:—

Band No.	Frequency band	Approx. equivalents in present system
0	1–10 c/s.	
1	10–100 c/s.	Bass register } Audio frequencies
2	100–1,000 c/s.	Middle register } Audio frequencies
3	1,000–10,000 c/s.	Top or treble register } Audio frequencies
4	10–100 kc/s	Long-wave band.
5	100–1,000 kc/s.	Medium-wave band.
6	1–10 Mc/s.	Short-wave band.
7	10–100 Mc/s.	VHF
8	100–1,000 Mc/s.	UHF
9	1,000–10,000 Mc/s.	Micro-wave or cm.-wave band.
10	10,000–100,000 Mc/s.	Millimetre-wave band.

It will be seen that the "power of ten" system, like that devised by the C.C.I.R., gives no convenient and easily memorised correspondence between frequency bands and wavebands. That is perhaps no great objection if one ordinarily thinks in terms of frequency. But in dealing with such things as aerials and wave-guides it is often necessary to work in wavelengths.

At first sight it seems almost impossible to devise a universally acceptable classification applying both to frequencies and wavelengths, but it would be well worth while devoting some thought to the task.

Designing a RESISTANCE-CAPACITY OSCILLATOR

Covering Frequencies from 40 to 13,000 c/s in Four Ranges

By

R. C. WHITEHEAD

WHEN an oscillator is required to have a frequency range which will cover the whole of the audio-frequency spectrum, the beat-frequency principle is usually employed. Simple types of BF oscillator are, however, liable to suffer from a number of troubles, and these prompted the writer to design a resistance-capacity oscillator.

The RC oscillator operates on the following principle. If a suitable chain comprising maintaining amplifier and phase shifter be connected with the output fed back to the input, then if the gain of the amplifier exceeds the loss of the phase shifter oscillation will occur at a frequency which produces zero phase shift for the complete chain.

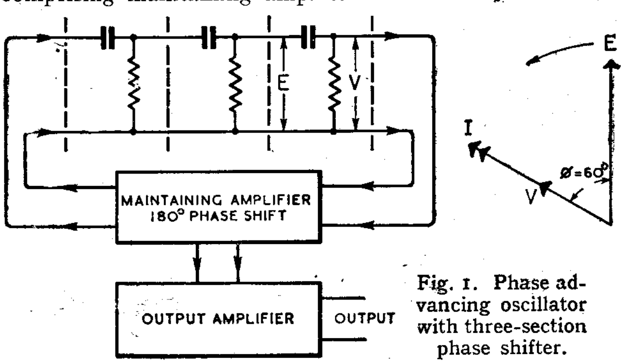


Fig. 1. Phase advancing oscillator with three-section phase shifter.

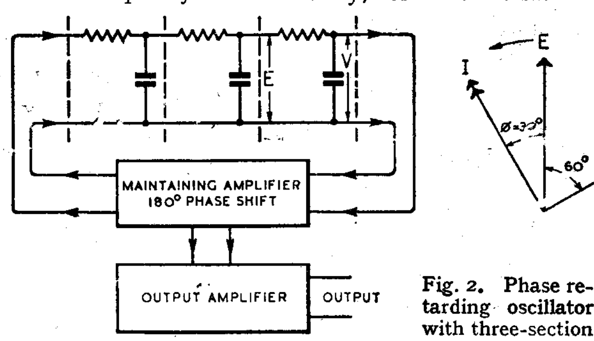


Fig. 2. Phase retarding oscillator with three-section phase shifter.

An RC-coupled amplifier with an odd number of stages produces a phase shift of 180 degrees, so to make it into an oscillator combinations of resistances and reactances (normally condensers) capable of producing a phase shift of 180 degrees are required. An RC-coupled amplifier with an even number of stages produces zero phase shift, so to make this oscillate, combinations are required which will produce a phase shift of zero or 360 degrees.

One cannot quite produce a phase shift of 90 degrees with a single RC combination, so that to produce 180 degrees phase shift, at least three such combinations are required. To produce a phase shift of zero or 360 degrees one may use either a minimum of five such combinations (or sections as it is convenient to call them from now on), or a phase-retarding section and a phase-advancing section, the two effects cancelling out at the operating frequency only. Some suitable basic circuits are shown in Figs. 1, 2 and 3. For various reasons the 180-degree phase shifter was chosen as being the most suitable in the present instance.

To determine how the frequency varies with change in capacity or resistance, let us note that the total of phase shifts in any RC oscillator is fixed at zero for all frequencies of operation. Since in any section of the phase shifter, the phase angle ϕ between the input voltage and the *current* = arc tan (X/R) = arc tan ($1/2\pi f$CR) this value must also be fixed. Therefore, if either C or R is varied, f the oscillation frequency will vary in inverse proportion. Then if R is fixed and C varied the reactance of C will always be the same at the frequency of oscillation. If the total C or R change is 10 to 1, the variation of frequency will be 1 to 10, and *not* 1 to $\sqrt{10}$ as occurs when C or L is varied in an LC oscillator. This frequency variation characteristic necessitates the use of components having very stable circuit values in order to maintain good frequency stability.

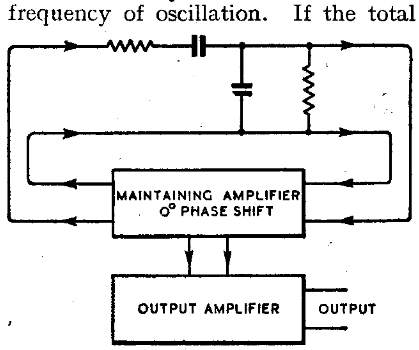


Fig. 3. Phase "advance-retard" oscillator.

The AF spectrum cannot be covered efficiently on one frequency range. It must be decided whether to vary the resistance in steps and the capacity continuously, or vice versa. High quality multiple gang variable resistances are not easily obtainable. Rubbing contact variable resistances are not as reliable as variable condensers. These reasons favour the selection of the first alternative, so a ganged variable condenser is employed, and fixed resistances are selected by means of a Yaxley type switch.

It is generally known that all oscillators produce harmonics, and in an LC oscillator the tuned circuit is made as efficient as possible in order to attenuate them. In the RC oscillator there is no tuned circuit, but the phase shifter can be arranged to produce a similar effect.

Fig. 4 shows the variation of attenuation with frequency for single phase-advancing sections (a), and phase-retarding sections (b). The curves show that the former circuit will attenuate the harmonics less than the fundamental, whilst the latter circuit will attenuate the harmonics more than the fundamental. This led to the adoption of the phase-retarding circuit.

This circuit has been called a phase-retarding circuit because the output *voltage* from any phase shifting section in Fig. 2 or Fig. 4(b) lags behind its input voltage. However, in a circuit containing only resistance and capacity, the *current* must *lead* the input voltage, but because the voltage across a condenser lags behind the current by 90 degrees, the output voltage in a phase-retarding section lags behind the input voltage. This is made clear by the vector in Fig. 2.

It will be seen that the current lead on the input voltage must be the complement of the required voltage lag in the phase-shifter section. Table 1 gives a comparison between three-, four- and five-section 180-degree retarding shifters as regards attenuation, etc. The greater the number of sections used to produce a given phase shift the lower will be the attenuation and the required value of CR.

The CR values should be kept as low as possible, because when generating the lower audio frequencies, if one uses a variable condenser having a maximum capacity of the order of 0.0005 mfd., the value of R will run into several megohms. There is a danger that R may have a value comparable with unavoidable leakage resistances. Also the final section of the phase shifter must be shunted by the input impedance of the maintaining amplifier, which must not be allowed seriously to affect the phase-shifter characteristics.

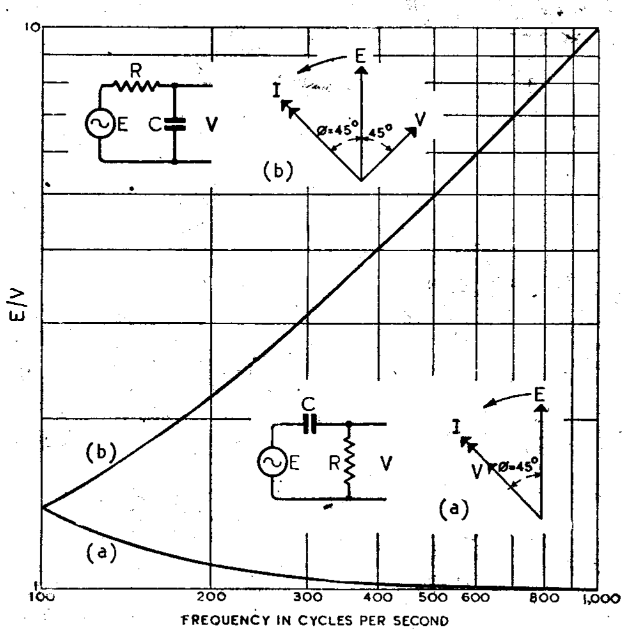


Fig. 4. Variation of attenuation E/v with frequency for single 45 degree phase advancing section (a), and retarding section (b). The vectors apply to the fundamental frequency only — in this case 100 c/s. CR = 0.0016.

A four-section phase shifter is used because this provides a fair compromise between efficiency and complication. It is desirable that the phase shifter should introduce the same attenuation at all frequencies. Unfortunately a simple circuit does not do so for three reasons.

TABLE I
180-DEGREE PHASE-RETARDING SHIFTER

No. of Sections in Phase Shifter	3	4	5
Required voltage lag per section (degrees) ..	60	45	36
Required current lead per section (degrees) ..	30	45	54
Attenuation E/V per section	2	1.4	1.25
Total phase shifter attenuation	8	4	3.1
Required CR product	0.28/f	0.16/f	0.12/f
Required phase shifter resistance in megohms when C=0.00055 μF.	513/f	295/f	218/f

Some of the complications of the phase shifter are beyond the scope of this article. To illustrate basic principles, only basic equations are used. For this reason and for reasons stated in the text, these figures should be taken as general indications only. This applies especially to the figures for attenuation.

The first is that the final section is shunted by the input impedance of the maintaining amplifier, and the lower the frequency range the more troublesome this shunting effect becomes.

The second reason is that there exists across the resistance elements some stray capacity, and when this capacity is an appreciable fraction of the capacity of the condenser (i.e., when the condenser is near its minimum capacity setting) the attenuation increases. This complication constitutes a major controlling factor in the design. To reduce this effect fixed condensers are connected across the variable condensers to raise the minimum capacities. These have the effect of lowering the frequency coverages on all ranges.

The third reason is that there exists across the condensers some unavoidable leakage conductance, and when this becomes comparable with the conductance of the resistance elements of the phase shifter (i.e., when operating on the lowest frequency range) the attenuation again increases. These conditions limit the frequency coverage ratio on the lower frequency ranges to a low value. To avoid switching complications, the fixed capacity shunt condensers are left in circuit on all ranges. It is therefore necessary to employ three or four ranges to cover the AF spectrum.

A three-range phase shifter will conveniently cover 40 to 10,000 c/s, and a four-range phase-shifter 40 to 13,000 c/s. Suitable component values are given in Table 2. Not only does the four-range phase-shifter cover a wider frequency band, but it improves the waveform and frequency stability and the voltage output varies less with frequency.

To reduce the attenuation at the minimum capacity settings of the condenser when operating on the lowest frequency range, a fifth section is added to the phase shifter on this range. Its capacity and resistance values are fixed and are represented by C9 and R17. The resistance should be adjusted to give a constant voltage output over the lowest frequency range. The addition of this section reduces the maximum frequency on this range, without affecting materially the minimum frequency. Additional circuits of this type cannot be used on the other ranges without modification to the switching. The use of the fixed section is a refinement which can be omitted if desired when using the four-range model.

The very high resistances and reactances used in the phase shifter necessitate the use of special precautions in construction. All condensers must have very high insulation dielectrics and must be protected against dust, etc. The trimmers fitted to the ganged condenser must be removed, because their capacity values are not sufficiently stable. No paste or liquid flux should be used when soldering up the range switch. It is desirable to have a blank position on the switch between the lowest frequency range and the adjacent range. The metal framework of the switch must be earthed. The "group board" method of construction should not be used in the phase shifter because of stray leakages and capacities. The resistances should be

Designing a Resistance-Capacity Oscillator—wired up with stout wire directly to the switch tags, and stand-off porcelain insulators used where necessary. The switching can be arranged so that the phase shifter has a switch section either at the input end or at the output end. If the arrangement shown be used, then leakages in the first switch section are unimportant. With this arrangement R1 changes the effective value of R2, so that the final frequency calibration should not be undertaken until all the resistances have been selected to give the correct frequencies on all ranges.

When adjusting the resistances in the phase shifter to secure the required frequencies it is not necessary to make all of the resistances absolutely identical on one range. This would necessitate the use of several standard values to make up one non-standard value. Fine adjustments of frequency can be made by adjusting one resistance only.

Maintaining Amplifier

The following is a brief specification of the maintaining amplifier:—

(a) Its input resistance including the first grid leak must be high compared with 11 megohms. (The highest resistance used in the phase shifter.)

(b) Its input capacity must be either very small or it must be very constant under all conditions.

(c) It must introduce a phase shift of 180 degrees approximately. Whilst it is permissible for the phase shift to deviate slightly from 180 degrees with frequency, it must remain constant with age, warming up, etc.

(d) It must be designed for an input signal of approximately 3·5 volts RMS and must introduce negligible harmonic distortion up to the point where connection is taken off to the output amplifier. Distortion introduced after this point is not so important but should be kept low.

These points will now be dealt with in order:—

(a) The grid leak of a small valve should not normally exceed 2 megohms, except when automatic bias is used, when it may be somewhat higher than this. To raise the total *effective* input resistance, a resistance R19 is connected in the cathode circuit of V1. This causes considerable negative feedback, with the result that the voltage across the grid-leak and grid-cathode space is much smaller than that between grid and earth. This raises the effective input resistance at the cost of a reduction in stage gain. V1 should have a top-cap grid connection. A push-pull connection to the output amplifier may be taken from the cathode and a tapping on the anode load of V1.

TABLE II

THREE-RANGE PHASE SHIFTER

Range	Section 1st R1, 2 & 3	2nd R5, 6 & 7	3rd R9, 10 & 11	4th R13, 14 & 15	Min. Freq.	Max. Freq.
1	11	11	11	11	40	200
2	2	2	2.5	2.5	180	1,500
3	0.2	0.2	0.2	0.2	1,400	10,000

R17 = 0.4 and C9 = 0.002μF. Fixed capacity shunt condensers C5, C6, C7 and C8 = 50μμF.

FOUR-RANGE PHASE SHIFTER

Range	Section 1st R1, 2, 3 & 4	2nd R5, 6, 7 & 8	3rd R9, 10, 11 & 12	4th R13, 14, 15 & 16	Min. Freq.	Max. Freq.
1	10	10	10	10	40	150
2	2	3	3	3	140	600
3	0.2	0.5	1.0	1.0	600	3,000
4	Nil	0.1	0.2	0.25	3,000	13,000

R17 = 0.5 and C9 = 0.001 μF. Fixed capacity shunt condensers C5, C6, C7 and C8 = 100μμF.

All resistance values are in megohms. All resistances may be of ¼-watt rating.

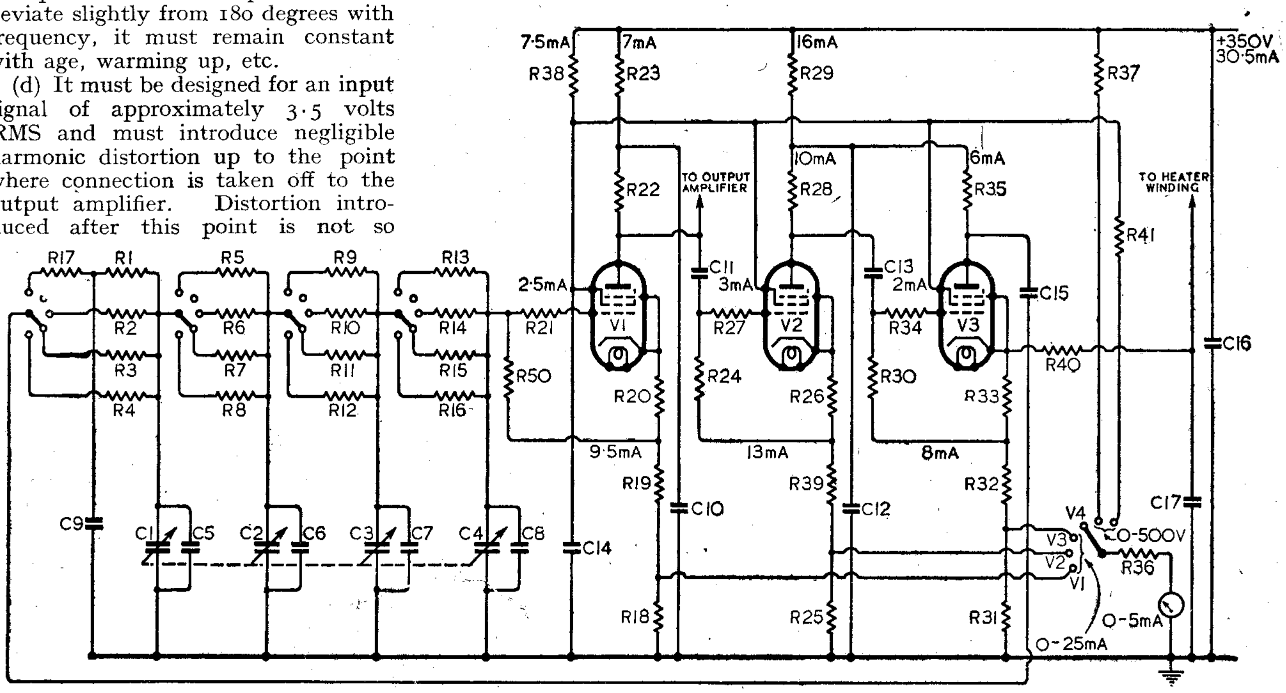


Fig. 5. Circuit diagram of phase shifter and maintaining amplifier. Component values are given in a separate list.

(b) The input capacity is reduced by the action taken to raise the input resistance. The input capacity may be kept to a minimum by making V1 either a cathode follower or a screened pentode. (See "The Cathode Follower," *Wireless World*, July, 1941.)

(c) The CR combinations in the maintaining amplifier should be such as to cause negligible phase shift.

LIST OF COMPONENTS

Resistances

R. No.	Ohms	Watts
18	10*	¼
19	4,000	½
20	250	¼
21	1,000	¼
22	20,000	2
23	2,000	¼
24	2,000,000	¼
25	10*	¼
26	250	¼
27	1,000	¼
28	20,000	2
29	5,000	1
30	2,000,000	¼
31	10*	¼
32	5,000	1
33	200	¼
34	1,000	¼
35	25,000	2
36+res. of meter	40*	
37	100,000*	2
38	10,000	2
39	500	¼
40	1,000,000	¼
41	100,000*	2
42	250,000	¼
43	4.44*	—
44	1,000	1
45	320	¼
46	1,000	¼
47	5,000	3
48	490*	¼
49	50,000	¼
50	5,000,000	¼

* Indicates plus-or minus 1 per cent.

Condensers

C. No.	Capacity (μF)	Volts (Working)	Type
1, 2, 3 and 4	0.0005 max.	—	Variable air
10 ..	32	350	Electrolytic
11 ..	0.02	350	Mica
12 ..	16	350	Electrolytic
13 ..	0.01	350	Mica
14 ..	8	350	Paper
15 ..	0.01	350	Mica
16 ..	24	400	Electrolytic
17 ..	0.05	350	Paper
18 ..	32	350	Electrolytic
19 ..	16	350	Paper
20 ..	0.02	350	Mica

For R1 to R17 and C5 to C9 see Table 2.

Valves.—V1, V2 and V3, Type TSP4; V4, Type 41 MP.

Then, if their values change slightly, the effect on the frequency stability will be *very* slight. For operation at a minimum frequency of *f* c/s no effective CR product should be below 1/*f*. To introduce a phase shift of 180 deg. an odd number of phase-reversing stages is necessary. A single phase-reversing stage, either with or without a cathode follower, could not be used—except at high audio frequencies—because of insufficient gain. It became necessary to use three valves. In an earlier model a cathode follower, an "in-phase amplifier" (see *Wireless World*, February, 1942), and an ordinary stage were used. Finally, a straightforward three-pentode circuit was decided upon.

In cases where there is no phase-shift measuring equipment available, the following test will provide a relative indication of phase shift. Disconnect C9 temporarily. Measure the maximum and minimum frequencies produced on all ranges. Then, if the phase shift in the maintaining amplifier is 180 deg. at all frequencies, the frequency coverage ratios will be approximately equal. If phase advancing occurs at the lower frequency end of a range (due to a low CR product in a coupling circuit), it reduces the frequency coverage ratio. If phase retarding occurs at the lower frequency end of a range (due to a low CR product in a decoupling circuit), the ratio is increased. If phase retarding occurs at the high frequency end of a range (due to a high product of load resistance and stray capacity), the ratio is reduced. Do not forget to reconnect C9.

(d) The negative feedback provided in the first stage is also useful in keeping distortion in V1 at a low level. The resistances R26 and R39 in the cathode circuit of V2 reduce distortion in this stage. Although some distortion is permissible here, grid current in V2 should be avoided, because it will produce distortion at the anode of V1, the point at which connection is made to the output amplifier. For this reason V2 should be given a higher bias than V1. The value of R39 should be determined by experiment. If the amplified "motor-boats," then the gain is too low and R39 should be reduced. However, it should be adjusted to the highest value that will produce reliable oscillation at all frequencies. When making this adjustment, the variable condenser should be set to minimum capacity and the oscillator tested on the two lowest frequency ranges. Oscillation should commence readily when the controls are set to the positions mentioned *and the oscillator is switched on from cold.* These settings are the least favourable for oscillation. If for test purposes a variable resistance is used for R39, it should be noted that the instrument is more willing to continue an oscillation than to initiate one. The resistances R32 and R33 reduce distortion in the third stage. The sum of R32 and R33 should not be so high as to produce excessive heater-cathode potential. The V3 bias resistance R33 has very little effect upon the normal operation of the oscillator, because this stage is biased mainly by grid current passing through the grid-leak R30. However,

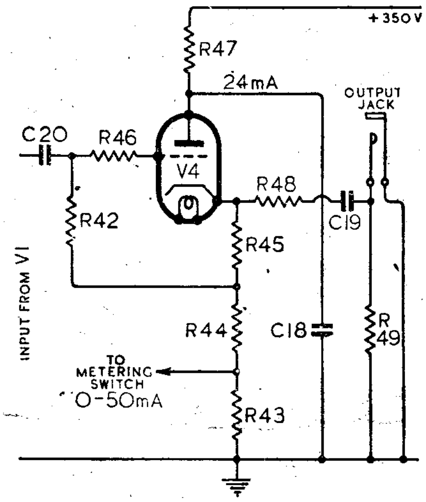


Fig. 6. Output cathode follower stage—with component values listed, the output impedance is 600 ohms.

should oscillation fail, then the anode current of V3 would rise to a high value in the absence of the minimum bias provided by R33.

The output waveform is such that when it is inspected on a small cathode-ray tube it appears as a sine wave at all frequencies. In order to reduce the heater-cathode potentials the heater winding of the transformer is connected via a simple CR filter to the cathode of V3.

A metering circuit is incorporated by means of which the cathode currents and HT and screen voltages may be determined. The switch should not be left in the position for measuring screen voltage, because this has an effect upon the frequency generated. Alternatively, a press button may be connected in series with this lead to the switch.

This should be designed to suit individual requirements. The maximum input available is approximately 18 volts RMS. The impedance input should be high and constant. This

Designing a Resistance-Capacity Oscillator— rules out the use of an ordinary triode voltage amplifier. There must be no transformer or gain control between the maintaining amplifier and the separator. The output amplifier may be connected either to the anode or the cathode of V1, for either a high or a low voltage output.

The first valve consists of a separator, and must be located on the same chassis as the maintaining amplifier and preferably close to V1. The separator should consist of either a screened pentode, preferably of the small transmitter type, or a cathode follower. In the former case a parallel-fed transformer may be used if a low output impedance is required.

Variation of output level by variable cathode negative feedback in the separator stage is inadmissible because of the change in input impedance. A "volume range compressor" is preferable.

For the majority of purposes a separator stage will provide sufficient output without further amplification.

In case a design for an output cathode follower is required, Fig. 6 shows the type used by the writer.

APPENDIX

Attenuation E/V per section of the phase shifter, for a phase retarding circuit

$$= \frac{R + jX}{X} = 1 + j \cot \phi$$

where ϕ = *current* lead.

Gain of pentode stage with anode load R_l and cathode load $R_c = \frac{R_l}{\frac{1}{G} + R_c} = R_l/R_c$ approximately when $1/G$ is small compared with R_c.

(G is the mutual conductance in *amperes* per volt, e.g. G = 0.005 for a TSP4 valve having a mutual conductance of 5 mA/volt.)

Multiplying the effective input resistance of the maintaining amplifier

$$M = R_{19}G + 1 \text{ or } R_{19} = \frac{M - 1}{G}$$

where M = multiplying factor.

Effect of fixed parallel condenser on the frequency coverage ratio N on any range where a fixed phase shifter is *not* used.

$$Cp = \frac{Cv_{max} - Cv_{min}}{N - 1} - (Cv_{min} + Cs)$$

$$\text{or } N = \frac{Cv_{max} + Cp + Cs}{Cv_{min} + Cp + Cs}$$

where Cp = capacity of shunt condenser, Cs = stray capacity and Cv_{max} and Cv_{min} = capacities of variable condenser at maximum and minimum capacity settings respectively. If frequency coverage ratio on each range = N, total frequency coverage ratio = N_T and number of ranges = R

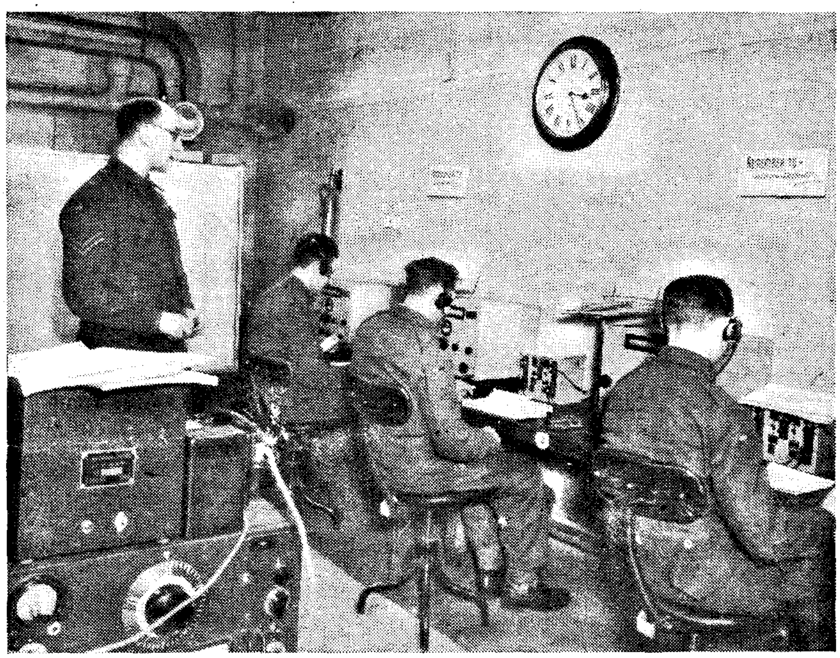
$$N_T = N^R \quad N = N_T^{\frac{1}{R}} \quad \text{and } R = N_T^{\frac{1}{N}}$$

This takes no account of the reduced frequency coverage on any range where a fixed phase shifting section is used.

War Office Communications

Keeping in Touch

THE War Office Signals Office, which is situated deep underground, not far from Whitehall, may fairly be described as the nerve centre of all the British Armies. Through it pass all telegraphic communications between the War Office and the various military units at home or abroad. It is the responsibility of the Royal Corps of Signals to maintain this vital service and to ensure speedy communication with any part of the world where British troops are to be found. Many of the messages handed in for despatch are passed on over wire or wireless circuits actually operated by R. Signals, while others are routed by the Office through civil cable or wireless links.



DEEP UNDERGROUND, not far from Whitehall, is the War Office Signals Office, through which communication is maintained with British troops in all parts of the world. It is operated by the Royal Corps of Signals. This *Wireless World* photograph shows a corner of the Home Wireless Room.

Inland Communications

Naturally, most of the messages to the various Home Commands are normally passed by landline, and in the Office is a large battery of teleprinters, which, incidentally, are mainly operated by A.T.S. girls, who wear the R. Signals badge. For use in emergencies, or in the event of line breakdown, there is a network of hand-keyed wireless transmitting stations which are dispersed at a distance and remotely controlled from the Home Wireless Room of the Office, in which the receivers are installed.

For overseas communication there is a 7½-kW short-wave wireless telegraph station, the transmitting and receiving units of which are situated in the country. The transmitter is keyed by high-speed Wheatstone gear in the War Office Signals Office, where the recording and printing apparatus, actuated by signals from the remote receiving station, is also installed. By means of this station, communication is maintained with our Forces in the Middle East through a corresponding station in Egypt.

Mention of an underground Signals Office may conjure up a picture of extemporised equipment operated under dismal and comfortless conditions. Actually nothing could be farther from the truth. Except for the khaki uniforms, one might imagine oneself in a very busy and smoothly running civilian telegraph station with the most modern equipment. Thanks to air conditioning and fluorescent lighting, the Chief Signalmaster and his staff carry out their vital task of handling some 30,000 messages a week in surroundings that many engaged in communications above ground might envy.

Training

SIGNAL INSTRUCTORS

Interesting Facts About the School of Signals

To give a true picture of the organisation of the Royal Corps of Signals and the chain of communications it maintains throughout the widely dispersed war zones would be impossible in a single article. But, as a result of a recent visit by a member of the "Wireless World" staff to the School of Signals we are able to give some interesting facts about one important, although little known, side of R. Signals organisation.

THE ever-increasing use of wireless in the Army creates a growing demand for signal instructors. This demand is being met by men who have passed through the School of Signals established in the North of England. The School is not concerned with the initial training of signals personnel, which is undertaken by the various Signal Training Centres, but with the training of officers and N.C.O.'s of all arms of the Service who will return to their units as instructors.

The school is divided into two wings, one for Royal Signals and the other for Regimental Signals, for which widely different technical standards are required.

Nine different training courses are conducted in the Royal Signals Wing, for each of which there is a different entrance examination. Only two of these courses are for officers; one being the Advanced Wireless Course and the other the Advanced Lines Course.

Some of the officers entered for the Advanced Wireless Course are selected from Officer Cadet Training Units, whilst others are released from their respective units of R. Signals. Before being accepted for the course they must have a sound knowledge of plane trigonometry; a basic knowledge of two-dimensional vectors; an elementary knowledge of statics and dynamics (such as is required for the School Certificate) and be able to employ the calculus to differentiate any simple expression including products and quotients. Here is a sample question from a recent qualifying examination paper:—" Draw a vector diagram to illustrate the current-voltage relationships in this circuit." (See Fig. 1.)

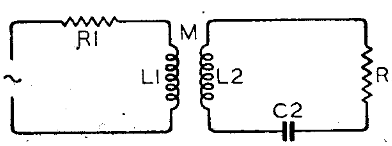


Fig. 1. Prospective officer students of the School of Signals have to draw a vector diagram to illustrate the current-voltage relationships in this circuit.

Another question in a recent qualifying examination relates to a circuit diagram containing "three gross errors" which had to be indicated by the officer students.

The course, which occupies 11 weeks, deals at considerable length with general circuit theory. During the 96 hours spent on this subject the students deal with AF and RF amplifiers, modulation and demodulation, AF, RF and UHF oscillators, filters (including T, Pi and M derived sections), FM, UHF technique, electron optics, television, diversity reception and DF. The students are given every opportunity of putting into practice the theoretical instruction received and for this purpose there is an experimental laboratory.

A great deal of time is spent on test equipment, such as signal generators (including FM types), ocsilloscopes and AF generators. As would be expected, the circuit details of Army transmitters and receivers are studied intensively. A typical, though obsolescent, set still employed in considerable quantities in the Army is the No. 11, which is a transmitter-receiver, mainly used in trucks, which derives its power from a 12-volt accumulator which heats the filaments and supplies HT through a rotary converter. A novel feature of the design is that it incorporates a valve test socket on the panel to facilitate maintenance.

The fundamentals of high-speed telegraphic equipment such as is used in fixed point-to-point stations is also covered by the syllabus for the officers' Advanced Wireless Course. The instructional centre is equipped with a complete transmitter and receiver so that the students go through the complete operation from the perforator to the automatic printer. Although not in regular use an undulator is maintained as a reserve or monitor.

It is noteworthy that a visit to a B.B.C. transmitting station is included in the course. The reason for this is that R. Signals personnel may be called upon to take over and if possible restore to working order a broadcasting station in occupied territory. This actually happened in Abyssinia.

For R. Signals personnel to enter for any one of the seven N.C.O. courses they have to pass a qualifying examination which varies according to the grade or category in which they aspire to act as instructors. One of a set of ten questions for the qualifyng examination for the seven-week N.C.O.'s Wireless and Line Course is "simplify $\frac{x^4-y^4}{(x^2+y^2)\ (x-y)}$." Another question in the paper relates to a network of five resistances (see Fig. 2) and asks, "What is the resistance of the network shown between A and B ?" These questions will suffice to give some idea of the standard required to enter the school for this course. An approximate allotment of the 245 hours available for the course is: elementary mathematics and electricity, 51 hours; wireless theory, 77 hours; wireless schemes, (the modern term for exercises in the field) 32 hours; line instruments, miscellaneous subjects and examinations 55 hours; fault-finding, 18 hours and

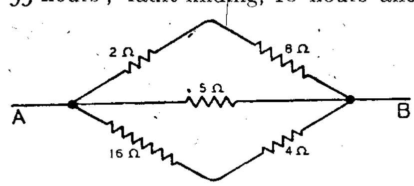
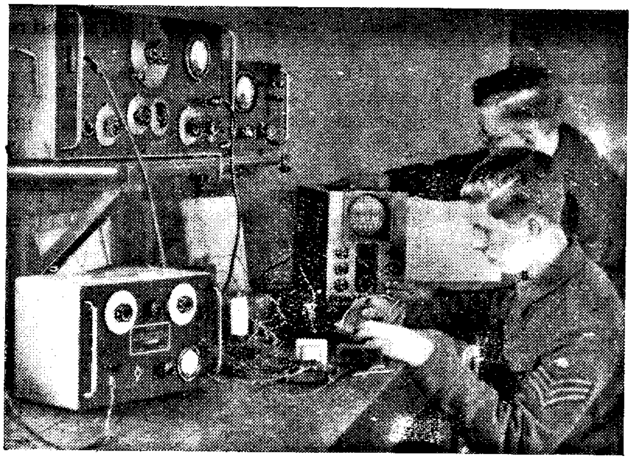


Fig. 2. The resistance between A and B has to be calculated by N.C.O. students during the qualifying examination for the Wireless and Line Course.

12 hours of students' lectures. This latter allotment is very important, for it must be remembered that these N.C.O.'s hope to pass out as instructors.

Training Signal Instructors—

For the Advanced Wireless Course for Operators the entrance examination is more exacting, and the course, which covers 6 weeks, is correspondingly more advanced. There is also an Advanced Wireless Course for Workshop Trades, i.e., instrument mechanics and electricians, which occupies ten weeks and deals mainly with the maintenance of apparatus, and a seven-week course for Foremen Mechanics.



Students in the Laboratory. Each bench position has a set of test apparatus as shown, together with two multi-range meters.

It is not possible to deal adequately with each of the N.C.O. courses in a short article, and we will, therefore, confine ourselves to what are perhaps the most interesting, and certainly the most exacting—those for Foremen of Signals. There are two—the Basic, which runs for 18 weeks, and the Continuation, which occupies 13 weeks. The qualifying examination for entry to the Basic Course is in two parts—mathematics and electricity. It will be seen from the following sample questions that a fairly high standard is required: "Evaluate $\int_{3\pi/4}^{\pi/4} \sec^2 \theta . d\theta$"; "Explain the principles used in the superheterodyne wireless receiver. What is second channel interference and why does it occur?"; "Explain the terms 'carrier wave,' 'modulated wave' and 'side-bands' applied to R/T, taking as an example an R/T transmitter tuned to 3,000 kc/s and emitting a tuning note of 1,000 cycles per second. Assuming the frequency band for speech to be 300 to 2,000 c/s, what is the smallest frequency separation that can be allowed between two R/T stations so that they may work without mutual interference?"

The syllabus for the Basic Course of over 700 hours allows nearly 250 hours for wireless theory and practice, 87 for mathematics, 70 for workshop practice and the remaining time for electricity, magnetism and line communication.

It must be remembered that a Foreman of Signals has to be a really competent fault finder in the field, where he works with a minimum of test gear, and he must be able to effect and supervise repairs. It is essential, therefore, that he should have a very thorough grounding in general circuit theory and be conversant with the apparatus met with in the field, in order that he can make the best use of the testing and repair facilities at his disposal. As in all other courses, the student is taught how to impart to others the knowledge he gains, and for this purpose the students deliver lectures which are criticised by their fellow students.

A few of the students who pass through the Foremen of Signals Basic Course are selected for the 13 week Continuation Course, the title of which is self explanatory. So far as wireless is concerned this course covers transmitting apparatus of relatively high power, aerials, the propagation of electro-magnetic waves, CR equipment, Service sets and high-speed morse equipment.

One of the later and more interesting transmitters on which Foremen of Signals receive instructions during the Continuation Course is the No. 33, which, operated from AC mains or from its own petrol-driven alternator, has an output of 60 watts on 'phone and 250 watts on CW. It has an input of 1·2 kVA and is used mainly in three-ton lorries.

To give Foremen of Signals an opportunity of handling high-powered transmitting apparatus such as might be met with at a captured telegraph or broadcasting station, an obsolete 5-kW transmitter is used for training purposes. A visit to a B.B.C. station is also included. This is, incidentally, the only course for N.C.O.'s which includes instruction in the principles of FM.

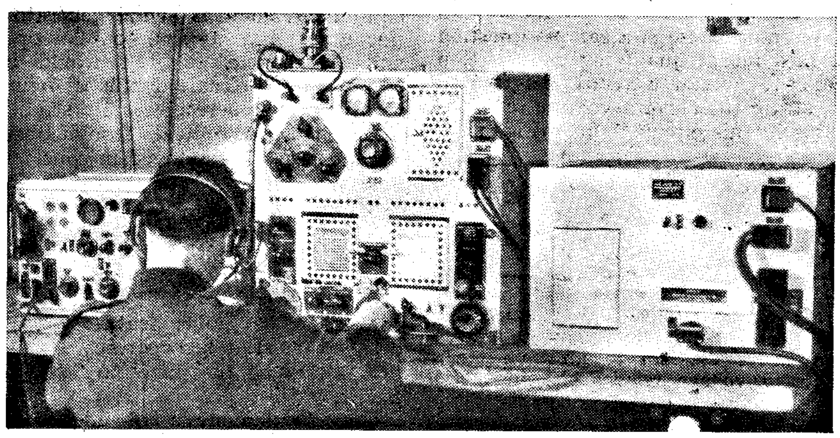
A considerable part of the students' time is spent in the experimental laboratories, where they have to undertake a number of experiments with standard test apparatus, such as would be found in rear areas. Experimenting during spare time is encouraged.

It must be remembered that the job of a Foreman of Signals who has undergone the Continuation Course will be to instruct men normally working in rear areas where the more complicated transmitting, receiving, and test equipment is to be found. He will, of course, also be largely responsible for the maintenance of this and all other signalling equipment in his unit.

It may be of interest to note that in the Signals Wing there are to be seen men from the equivalent branches of the armies of our allies, including American, Belgian, Polish, and Czechoslovakian.

It should be added, that in addition to those already mentioned there are short courses for senior officers (lieut. colonels and majors) and company commanders in the Signals Wing; these comprise a general brush-up in technical and tactical subjects.

Although the Regimental Wing of the school also comes under the command of the Commandant it is very



A semi-mobile medium-power transmitter (No. 33), for telegraphy or telephony, which operates from 230 volts AC. The receiver (R107), is on the left, and the power unit on the right.

much a separate entity from the Signals Wing and is staffed by officers and N.C.O.'s of various regiments. The three distinct sections to the Wing are concerned, respectively, with the training of signals instructors for the Infantry, Royal Artillery and Reconnaissance regiments.

In the Regimental Wing the courses, which occupy eight weeks, differ from those in the Signals Wing in that they include very little theory, the main reason being that the students will not be called upon to give theoretical instruction when they return to their Corps or Division. The qualifying examinations for admission to the courses for officers and N.C.O.'s are very much simpler than those for entry to the Signals Wing. To qualify, an N.C.O. must have an aptitude for imparting knowledge to others, be conversant with the apparatus used in the section of the Army to which he is attached and be a qualified signaller. It should, perhaps, be pointed out that, whereas in R. Signals the term "signalman" is used, in all other arms of the Service "signaller" is employed.

In the Infantry section the course is roughly divided into two four-week periods. The first is confined to instruction and the second to working on schemes as a platoon in which the officers and men combine.

Considerable stress is laid on the use of wireless, for although these students have to be conversant with line work there is seldom opportunity for the use of line communication in the field. Communication procedure, which, incidentally, has recently undergone radical changes, is, of course, an important part of their training. Essential fault finding and maintenance is undertaken in the field by regimental signals personnel but the training is not highly technical as no major fault is rectified in the field. In all the courses in the Regimental Wing theoretical instruction is confined to block schematics.

Different types of transmitters, receivers and transceivers (the official term for apparatus in which some of the components are common to both transmitter and receiver) are used by the three sections. The Infantry (including rifle battalions, airborne troops and machine gunners) mainly use pack transceivers. Of the three or four types in production the most common is the No. 18 which was described in our September issue. A lighter and more compact set—the No. 28—has been produced. This is of the "all-dry" type and is carried in a canvas case little larger than a haversack. Like its predecessor it has a tubular sectional aerial, the socket for which rotates through 90 deg. to allow the aerial to be vertical when the infantryman is lying down.

A later type of pack set is the No. 38 which is intended for the use of officers and is for 'phone only. It is quite

This small infantry pack set (No. 38) employs a throat microphone and is so arranged that it does not interfere with the wearer's fighting efficiency.

small being capable of being worn on the chest next to the respirator. The batteries are carried in a separate case. This set has a three-section 8ft. aerial which, when not in use, is carried in a canvas sling. An interesting feature of this set, the range of which is, for reasons of secrecy, very limited, is the use of laryngaphones so that there is no obstruction to the use of the voice for normal purposes and to leave the hands free.

Students in the section which trains anti-tank and anti-aircraft personnel are trained to the "driver operator" standard in morse, which is twelve words a minute, as they will have to instruct both signallers (10 w.p.m.) and driver operators. Throughout their training in receiving morse they are continually reminded of the prevalence of interference in W/T. For many of their receiving periods they are given an R4 signal with R3 interference superposed. It should be pointed out that the signal strength scale, which used to be graded R1–R9 is now R1–R5.

It may be of interest to give a few brief details of some of the sets more widely used by the men in this section.

The No. 19 transmitter-receiver, which derives its power from an accumulator through a rotary convertor, has some interesting refinements to simplify operation. One of these is push-button tuning to facilitate the process of "netting"—which is the term used for grouping stations into a network. Another refinement makes it possible accurately to tune the transmitter without radiating.

Remote control is provided on the No. 21 transmitter-receiver, which is of the transportable type, so that the set can be erected in an advantageous position for radiation whilst the operator is under cover as much as 120 yards away. Working on 'phone, CW and MCW in the 19–31 and 4·2–7·5 Mc/s bands, the No. 21 is largely used by field artillery. This set, which derives its HT from an accumulator through a vibrator, succeeds the No. 11, mentioned earlier.

Like the infantry and airborne troops, the reconnaissance and motor battalions, or mobile infantry, depend mainly on wireless for communication and their course of instruction therefore stresses this side of the students' training. Tactical training is, of course, of vital importance to reconnaissance troops, and for this reason a large part of the time is devoted to schemes under service conditions. Because of their reliance on their own resources these men are, of course, trained in practical fault-finding.

Most of the maintenance of the training equipment at the school is undertaken on the spot. This is no mean task, for there are some 400 or 500 sets in constant use, and something like a thousand batteries are handled in the charging room.

Although not concerned directly with the training of personnel a branch of the School which is of considerable importance is the Publications Section. All manuals and instruction booklets relating to signals apparatus and procedure are prepared by, or pass through the hands of, the staff. The close co-operation between our own Forces and those of our American Allies has called for a revision of the rules of procedure, and incidentally of the phonetic alphabet.

It is interesting to note that the instructors for both wings of the school are drawn from officers who have passed through the courses. When other Signal Schools, such as those in the Middle East and India, are established the signal instructors are picked from officers who have attended the school, the activities of which have been described.

LAMINATION DESIGN

Influence of Shape on the Cost and Weight of Transformers and Chokes

By
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The fixing of the proportions of a lamination is in reality the first step in transformer design. The author shows the important influence it has upon the economy of the resultant component.

LAMINATIONS manufactured for use in the construction of mains transformers and smoothing chokes have a very definite and specific function to perform. One might reasonably expect, therefore, to find a wide range of sizes all having the same general proportions. But nothing of this sort occurs in real life. Large windows, little windows, tall lean patterns and stocky varieties are (or were) obtainable for the asking.

Two questions at once present themselves. Does the shape matter very much and, if so, why produce anything but the best shape? The former question is capable of logical treatment and will be dealt with in some detail. The latter touches upon the perversity of human nature and is probably unanswerable.

The merit of a lamination can be assessed in a number of ways depending upon the particular purpose for which it is required. In the case of components for radio equipment cost and weight are the principal criteria. The present investigation will therefore be twofold. First, we will discover how the shape of the lamination influences the cost of the materials necessary to produce a component of given performance, and secondly, we will see how the weight of the component is affected thereby.

Mains Transformers

Fig. 1 shows a lamination of typical proportions together with a sectional plan and a side elevation of the complete transformer. As a tentative approach to our problem, consider a square core section ($y = 1$) and examine the effect of varying the height (x). By assigning various values to x it will be possible to calculate the relative costs and weights per watt output for each of the resulting transformers.

The upper portions of Tables 1 and 2 show how this may be done. Column 1 of Table 1 gives the values assigned to x. The second column shows the volume of the space occupied by the winding. This is the area of the window multiplied by the length of the mean turn (see Fig. 1 (b)). For equal performances, the temperature rise must be the same for each transformer, and to take account of this the effective cooling surface of the bobbin must be known. The cheeks of the bobbin dissipate a negligible proportion of the heat and therefore the effective cooling surface of the winding is obtained by multiplying the height of the bobbin ($x - 1$) by the length of that portion of the periphery of the winding which is exposed to the air (see Fig. 1 (b) and (c)).* The results are set down in column 3.

At constant current density, the temperature rise depends upon the available area of cooling surface per unit of volume. This is discovered by dividing the surface by the volume, the result of which is shown in column 4. The ratio of surface to volume is seen to be independent of x, since both the volume and the surface of the bobbin are directly proportional to its height, and therefore constant current density will result in equal temperature rises throughout.

*This treatment is not exact but can be accepted as a first approximation.

Columns 6, 7 and 8 are similar to columns 2, 3 and 4 but relate to the iron core. The effective cooling surface of the iron is that part formed by the edges of the laminations. The conduction of heat across the stack from one lamination to another is relatively small. This time the ratio of surface to volume (column 8) varies with x. It follows that at constant flux density the temperature rise will also vary with x. But the generation of heat within the iron varies approximately as the square of the flux density. Hence to ensure a constant temperature rise throughout, the flux densities must be adjusted in proportion to the square roots of the figures in column 8. These square root values are given in column 9.

The relative outputs for the series of transformers can now be deduced. If both current and flux densities were constant, the output would be proportional to the length of the bobbin ($x - 1$). But to allow for the adjustments to the current and/or flux densities, ($x - 1$) must be multiplied by the figures in columns 5 and 9. In this particular instance column 5 is constant throughout and can be ignored. Column 10 is therefore derived by multiplying ($x - 1$) by the figures in column 9.

Now pass to Table 2. The relative weights of the windings, complete with bobbin, insulation, etc., are obtained by multiplying the volume of the winding space

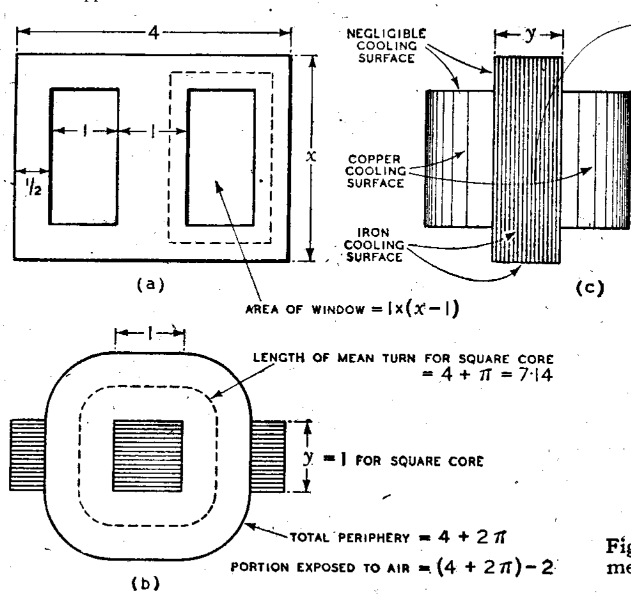


Fig. 1. Relevant dimensions of a typical mains transformer

(column 2, Table 1) by the weight per cu. in. of an average winding. The total weight of a complete winding will, of course, depend upon the size of the transformer to which it belongs. But the weight per cu. in. is appreciably constant over a wide range of sizes for a given type of construction. The figure used for the present purpose is 0.083 lbs. per cu. in. and was obtained from manufacturing experience. Similarly, the relative weights of the cores are discovered by multiplying the core volumes by the weight per cu. in. of core, which is 0.26 lbs. The relative total weights are obviously the sums of columns 2 and 3, and the relative weights per watt output are calculated by dividing column 4 of Table 2 by column 10 of Table 1.

TABLE I

Height x	Copper: Volume V_C	Copper: Surface S_C	$\frac{S_C}{V_C}$	$\sqrt{\frac{S_C}{V_C}}$	Iron: Volume V_F	Iron: Surface S_F	$\frac{S_F}{V_F}$	$\sqrt{\frac{S_F}{V_F}}$	Relative Output
2	7.1	8.3	1.16	1.08	6	12	2.0	1.41	1.41
3	14.3	16.6	1.16	1.08	8	14	1.75	1.32	2.62
4	21.4	24.8	1.16	1.08	10	16	1.6	1.26	3.80
5	28.6	33.1	1.16	1.08	12	18	1.5	1.22	4.9
6	35.7	41.3	1.16	1.08	14	20	1.43	1.19	5.97
Stack y									
0.75	19.9	24.8	1.25	1.12	7.5	12	1.6	1.26	0.84
1.0	21.4	24.8	1.16	1.08	10	16	1.6	1.26	1.08
1.25	22.9	24.8	1.08	1.04	12.5	20	1.6	1.26	1.30
1.5	24.4	24.8	1.02	1.01	15	24	1.6	1.26	1.52
1.75	25.9	24.8	0.96	0.98	17.5	28	1.6	1.26	1.70
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

The relative costs per watt output are worked out in columns 6, 7, 8 and 9. There is one important point to note. The cost of laminations depends upon the gross area and is not altered by the sizes of the window holes. This is because the same amounts of material and labour are expended in their production whatever the size of the window. Hence the price per cu. in. of actual iron will be high when the window is large and low when the window is small. But the price per cu. in. of gross volume i.e., including window space, will be constant. The cost per cu. in. of winding has been taken as 3.02d., and that per cu. in. of gross stack as 3.32d.* As with the weights per cu. in., these costs per cu. in. remain appreciably constant over a wide range of sizes.

Table 2 shows that the weight per watt output continues to improve as x increases, while the cost per watt reaches a minimum value when $x = 4$ and thereafter rises slightly. For practical purposes the minimum values can be regarded as having been attained when the height of the lamination is comparable with its width. There seems little point in making x slightly shorter than the width, or, for that matter, slightly taller. But several advantages accrue from making the lamination precisely square. In particular, the same end plates, the same chassis space and the same fixing holes, will serve for mounting the bobbin either vertically or horizontally. Hence we deduce that transformer laminations for general use might, with a substantial measure of reason, be made square in shape.

Having fixed the value of x at 4 (= width) we can proceed to study the effect of varying the stack (y). The calculations are exactly as before and are set out in the lower portions of Tables 1 and 2. At constant current and flux densities the output would be directly proportional to y. The relative outputs for constant temperature rise are therefore derived by multiplying y by the figures in columns 5 and 9 (Table 1). But column 9 is constant throughout and can therefore be ignored.

Again it will be seen that both the cost and the weight per watt output are reduced by increasing y. However, the stack thickness employed in practice is determined very largely by manufacturing expediency. A square section bobbin is the easiest to wind and is therefore frequently used. Next to this, stacks up to 1½ times the width of the centre limb are satisfactory from the winding point of view, but greater stacks become very difficult to handle. Table 2 indicates that for a given lamination a 1½ stack produces approximately 40 per cent. more total output than a square section. Also the former achieves a small but useful advantage in both the cost and weight per watt output.

Lastly, the width of the centre limb of the lamination has to be determined. (In view of the high flux densities normally employed in transformers, it can be accepted without discussion that the outer limbs shall be precisely one-half the width of the centre limb.) The task is complicated by the fact that the stack cannot be definitely fixed on account of the practical considerations mentioned above. But it is evident from Table 2 that, for a general-purpose lamination to be used in anything from a 1 to a 1½ stack, the limb width should be designed for optimum results in the former case. When the stack is increased the cost and weight per watt automatically improve.

Proceeding on this basis, the height of the lamination has been fixed as being equal to its width, and the stack as being equal to the width of the centre limb. To show that there was no undisclosed subtlety in the selection of 4 as the main dimension in Fig. 1, and to increase the reader's familiarity with the geometry of iron-cored com-

TABLE II

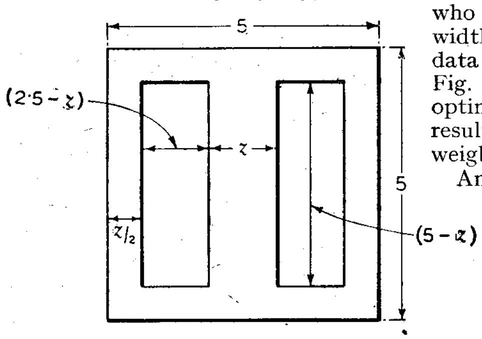
Height x	Relative Weights: Copper	Relative Weights: Iron	Relative Weights: Total	Relative Weights: Per watt	Relative Costs: Copper	Relative Costs: Iron	Relative Costs: Total	Relative Costs: Per watt
2	0.59	1.56	2.15	1.52	21.5	26.6	48.1	34.0
3	1.19	2.08	3.27	1.25	43.2	40.0	83.2	31.8
4	1.78	2.60	4.38	1.15	64.6	53.2	117.8	31.0
5	2.37	3.12	5.49	1.12	86.4	66.4	152.8	31.2
6	2.96	3.64	6.60	1.10	107.6	79.8	187.4	31.3
Stack y								
0.75	1.65	1.95	3.60	4.29	61.0	39.8	100.8	120
1.0	1.78	2.60	4.38	4.07	64.8	53.2	118.0	109.4
1.25	1.90	3.25	5.15	3.96	69.2	66.4	135.6	104.2
1.5	2.03	3.90	5.93	3.91	73.8	79.8	153.6	101.4
1.75	2.15	4.55	6.70	3.95	78.2	93.0	171.2	101.0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

*These manufacturing costs are fictitious. The final results depend only upon the ratio of the winding and core costs. This ratio is correct and therefore the deductions remain valid.

Lamination Design—

ponents, let us now consider a lamination 5 × 5. This is illustrated in Fig. 2 where the width of the centre limb has been called *z*.

Construct two tables similar to Tables 1 and 2 but having *z*, instead of *x* or *y*, in the first column. Assign values to *z* such as 0.25, 0.5, 0.75 . . 2.25.



FOR SQUARE STACK:—

VOLUME OF WINDING = $(2{\cdot}5 - z)(5 - z)[4z + \pi(2{\cdot}5 - z)]$

COOLING SURFACE OF WINDING = $(5 - z)[2z + 2\pi(2{\cdot}5 - z)]$

NET VOLUME OF IRON = $z^2(15 - 2z)$

GROSS VOLUME OF STACK = $25z$

COOLING SURFACE OF IRON = $20z$

OUTPUT AT CONSTANT DENSITY $\propto z^2(5 - z)(2{\cdot}5 - z)$

Fig. 2. Formulæ for surfaces and volumes in relation to the core width for a 5 × 5 lamination.

The figures to be entered in the various columns can now be calculated. To avoid misunderstanding, the required formulae are noted in Fig. 2. It will be found that both the current and the flux densities have to be adjusted for constant temperature rise.

If the costs and weights per watt output obtained as described above be plotted against *z*, a definite minimum point will be found in each case. By giving this point the arbitrary value 100, the other points can be expressed as percentages of the minimum. This has been done in the lower part of Fig. 3 which at once reveals the information we want. When *z* is 1.2 the transformer has the lowest weight per watt output but the cost is about 15 per cent. higher than it need be. For minimum cost, *z* should be 1.6 at which point the weight becomes 15 per cent. up. The most significant spot of all occurs at the intersection of the two curves when $z = 1.4$. This marks the most satisfactory compromise between cost and weight, each being between 3 and 4 per cent. above the lowest possible value.

As a matter of interest it may be noted that the minimum cost per watt output does *not* occur when the cost of the winding is equal to the cost of the core. This fact is contrary to the teaching of several standard textbooks dealing with the design of AC equipment.

The optimum proportions for general purpose transformer laminations as deduced above are shown in Fig. 8. These proportions hold good for the range of outputs from say 30 to 600 watts.

To satisfy the curiosity of those who want to know the optimum limb width for a 1½ stack, the necessary data is shown in the upper part of Fig. 3. It will be observed that the optimum lamination for a square core results in low cost but rather high weight when used in a 1½ stack.

And now a few words of warning addressed to those idealists to whom reference to cost might seem irrelevant. The reference to low cost as employed in the foregoing discussion has no connection with things "cheap and nasty." The finished transformer, be it designed for minimum cost or minimum weight, will employ the same quality materials and will enjoy the same quality workmanship. It will, in fact, have the same performance and reliability. But the low weight transformer will be very wasteful of materials and labour. Fig. 3 shows that a low weight calls for a relatively thin limb and therefore a large window. Thus we start off by creating a large piece of scrap metal —— wasted labour and wasted material. Next we have to buy additional wire to fill the larger window and to spend extra time winding it on to the bobbin —— more wasted labour and wasted material. As a matter of fact, the large bobbin with its greater number of turns per volt, will tend towards poorer regulation. Hence there is an excellent case for taking cost fully into account unless weight is an overriding consideration. Furthermore, cost takes on a new significance as an index of labour and materials instead of being merely money paid out.

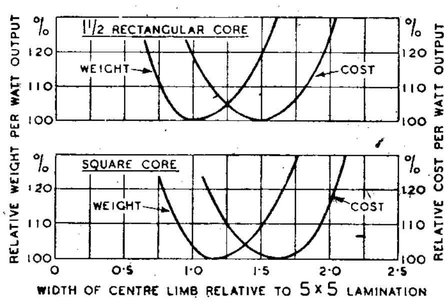


Fig. 3. The width of the limbs has a critical effect upon the weight and the cost of a transformer of given performance.

Smoothing Chokes

Three major parameters are needed for the electrical specification of a smoothing choke:— the inductance (L), the DC resistance (R), and the DC to be carried by the winding.

It is clearly advantageous to have a high value of L together with a low value of R. Thus the ratio L/R should be a maximum. Fortunately, the conditions making for this desirable state of affairs are the same for a non-gapped choke carrying AC alone as for a choke carrying DC and having the optimum air gap in the magnetic circuit. Hence the consideration of DC can be omitted from the present discussion.

Let N be the number of turns on the bobbin, A_F and A_C the cross-sectional area of the iron and the area of the window respectively, l_F and l_C the lengths of the mean flux path and the mean turn. Then, working in terms of the initial permeability:—

$$L \propto \frac{N^2 A_F}{l_F} \text{ and } R \propto \frac{N^2 l_C}{A_C}.$$

$$\text{Therefore } \frac{L}{R} \propto \frac{A_F A_C}{l_F l_C} = C \cdot \frac{A_F A_C}{l_F l_C}$$

where C is the appropriate constant.

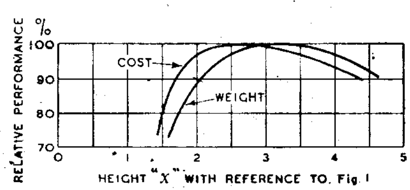


Fig. 4. In the case of a smoothing choke an optimum value exists for the height of the lamination.

Increase the size of this imaginary choke so that all lengths become *k* times longer without upsetting the gemoetrical proportions. The new volume, weight and cost will each increase directly as k^3. The new value of L/R is:—

$$\frac{L'}{R'} = C \cdot \frac{k^2 A_F \cdot k^2 A_C}{k l_F \cdot k l_C} = k^2 \cdot C \cdot \frac{A_F A_C}{l_F l_C}$$

It follows that in a series of chokes of different sizes but having the same geometrical proportions, L/R varies directly as k^2 which is itself directly proportional to $\sqrt[3]{(\text{Volume})^2}$, $\sqrt[3]{(\text{Weight})^2}$ and $\sqrt[3]{(\text{Cost})^2}$. This theorem is going to be very useful a little later.

Now consider a choke of typical proportions. Fig. 1 will serve for this purpose from which it can be seen that:

$$\frac{L}{R} \propto \frac{A_F A_C}{l_F l_C} \propto \frac{(1 \times y)[1 \times (x - 1)]}{[3 + 2(x - \frac{1}{2})](2 + 2y + \pi)} \quad \text{.. .. .. (1)}$$

If the stack be fixed, i.e. y made constant, the effect upon L/R of varying the height (x) can readily be

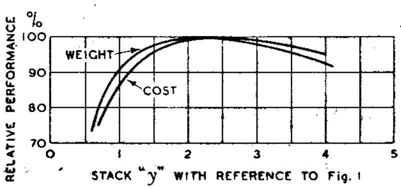


Fig. 5. A choke also has an optimum stack. Practical difficulties prevent it being employed in practice.

deduced. Simplifying the above expression and deleting unnecessary constants we find :—

$$\frac{L}{R} \propto \frac{x - 1}{x + 1}$$

Assign specific values to x and calculate the resultant values of L/R, the weight and the cost.* Our introductory theorem showed that a series of chokes each having the best value of x would produce values of L/R in proportion to $\sqrt[3]{(\text{Weight})^2}$ and/or $\sqrt[3]{(\text{Cost})^2}$. Hence to compare our calculated values for L/R with those given by chokes of optimum design we need only to divide by $\sqrt[3]{(\text{Weight})^2}$ for an equal weight comparison or by $\sqrt[3]{(\text{Cost})^2}$ for an equal cost comparison.

The result of doing this is shown in Fig. 4. A critical ratio exists between the width and the height of the lamination for optimum performance. In the particular instance where the former is 4, as in Fig. 1, the latter should be 2.8.

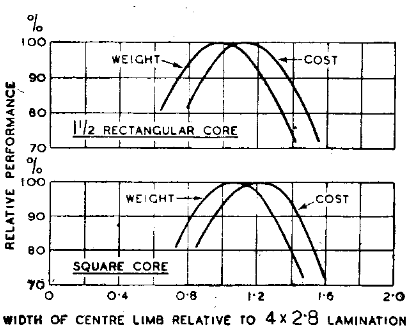


Fig. 6. These curves enable the best widths for the limbs to be determined in the case of a smoothing choke.

In expression (1) above, fix the height (x) at 2.8 and consider the effect of varying the stack (y). It is thus found that :—

$$\frac{L}{R} \propto \frac{y}{2.57 + y}$$

Assign specific values to y and divide the resultant values of L/R by the corresponding values of $\sqrt[3]{(\text{Weight})^2}$ and $\sqrt[3]{(\text{Cost})^2}$. These results are shown in Fig. 5. Again a critical value exists. But for the reasons already discussed only stacks between 1 and 1½ times the width of the centre limb need be regarded as practical. The latter will clearly possess advantages over the former.

To determine the optimum width of the centre limb, fix the height at 2.8, the stack at 1, and call the width of the centre limb z. Assuming the outer limbs to be one-half the width of the centre limb, it can readily be deduced from Fig. 1 that :—

$$\frac{L}{R} \propto \frac{z^2(2 - z)(2.8 - z)}{(9.6 - z)(0.86\,z + 6.28)}$$

$$V_C = (2 - z)(2.8 - z)(0.86\,z + 6.28)$$

$$\text{(net) } V_F = 4\,z^2 + 2(2.8 - z)z^2$$

Assign specific values to z and proceed exactly as before. The resultant curves are shown in the lower part of Fig. 6 from which the optimum width for the centre limb is seen to be 1.12.

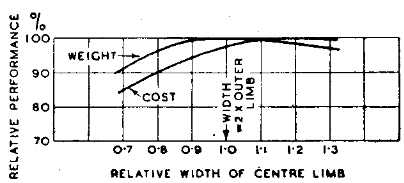


Fig. 7. Showing the effect of varying the centre limb while keeping the outer limbs at a constant width of 0.5.

The above formulae can readily be modified to suit a 1½ stack. Repeating the process on this basis gives the curves in the upper part of Fig. 6. It will be noted that the stack makes very much less difference to the optimum limb width than in the case of mains transformers (see Fig. 3).

Lastly, we have to refute the current superstition that an advantage is gained by making the centre limb less than twice the width of the outer limbs. The argument seems to be as follows : For a given stack of laminations the average value of A_F will be little altered by reducing the centre limb. But more turns can be added as a result, and L varies as N^2 in addition to which these turns, being on the inside, will add little to R. This argument may be plausible but it ignores the most cogent factors. Taking all relevant facts into account the truth is as shown in Fig. 7. If one must meddle with the width of the centre limb it should be made wider and *not* narrower! For many reasons it is altogether undesirable to depart from a 2 to 1 ratio for the widths of the centre and outer limbs.

Unfortunately, we started to design the present choke lamination by assuming "typical proportions" for the very first calculation. The result must therefore be regarded as a first approximation and the whole process repeated substituting this approximation in place of the original guess. The only effect of the repetition is to increase the optimum height to 3 instead of 2.8 relative to a width of 4.

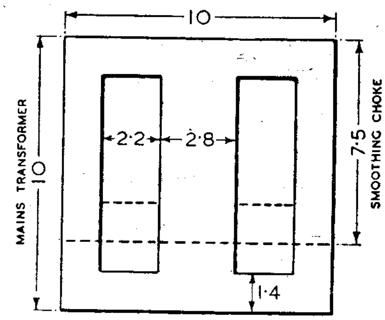


Fig. 8. Showing the optimum proportions deduced in the article. The relative widths of the limbs are the same for both transformers and chokes. But a choke requires to be shorter than a transformer.

The final result is shown in Fig. 8. It is perhaps surprising to see how closely the choke and transformer designs agree in spite of the totally different method of attack. It would appear that a compromise could be reached such that one stamping would serve both purposes without appreciable loss of efficiency in either application.

The foregoing applies specifically to mains transformers and smoothing chokes employing silicon steel. Audio-frequency transformers and components using nickel iron have to be tackled on a different basis, there being nothing to suggest that the optimum proportions will approach those deduced above.

*On account of the better space factor given by chokes and of the smaller average wire gauge, the average bobbin weight per cu. in. is increased to 0.114 lb. and the cost to 3.8d.

"Unique in Technical Literature"

DURING his inaugural address as Chairman of the Wireless Section of the I.E.E., Dr. R. L. Smith-Rose referred to "the comprehensive series of abstracts and references published monthly in *Wireless Engineer*." He said that these abstracts, which have been prepared by the Radio Research Board for the past fourteen years, "are unique in wireless technical literature and are greatly appreciated by radio engineers and research workers in all parts of the world."

This section of our sister journal occupies 27 pages in the November issue, which also includes original articles on reducing the band-width in frequency-modulated receivers, harmonic distortion in audio-frequency transformers, and the "tracking" of tuning circuits. *Wireless Engineer* is published on the first of the month and is obtainable to order through newagents, or direct from our Publishers at Dorset House, Stamford Street, London, S.E.1, at 2s. 8d. (including postage).

Letters to the Editor

Reproduced Music: Transmitter Volume Compression

Player-Piano v. Gramophone

"CATHODE RAY" is quite correct in saying (in your November issue) that the sound of a note on a piano is exactly the same whether it is played by the finger of an expert pianist or by an inanimate object dropped from a suitable height. What he has forgotten, however, is that piano music consists of a sequence of chords or groups of notes, whose individual intensities may differ widely. It is these contrasts which give "expression" to music played by a good pianist, and make it sound better than the same music played at the same speed by a bad pianist.

The player-piano is quite incapable of reproducing these differences in intensity of notes sounding together, and so it destroys the most important part of the music.

The gramophone, on the other hand, although it fails at the extreme frequencies, and has considerable background noise, and may completely upset the transient at the beginning of each note, reproduces practically all the "expression" put into the music by the performer.

Considering the two as musical instruments, therefore, the gramophone wins, in that it sounds like a rather unusual piano played well, while the player-piano sounds like a good piano "played" extremely badly.

Cambridge. R. W. HAIGH.

I WAS surprised and distressed to find anyone of such wide culture as "Cathode Ray" reviving, on p. 271 of your November issue, an appalling statement which I always hoped had been secretly buried in an unhonoured grave: that "pianist's touch" is bunk. At its first appearance (under the auspices, not of Sir James Jeans, but of an American worker), it was, if I remember rightly, definitely *proved*; and I recollect rejecting it on the spot as one of those occasional scientific "facts" which, spurned instinctively by the wise in spite of "proof," are recognised a little later as fiction arising from incomplete knowledge. Such, for instance, was the rigorous mathematical proof, which some of your readers may remember, that wireless communication between Europe and America was fundamentally impossible. I feel convinced that when more is known about "touch" on a piano it will be found to involve some factor, or factors, which were unknown (or unremembered) at the time of that proof; just as the unknown (or unremembered) ionsphere justified Marconi's instinctive and wise rejection of the transatlantic fallacy.

As a matter of fact, I see that the invaluable "Abstracts and References" in your sister journal *Wireless Engineer,* while quoting Weyl's paper in Abstract 1856 of 1936, already seem to question its finality by remarking, "but compare Ferrari, Abstract 1061 of 1936," where I find that apparently opposing results were obtained in Italy. But, in any case, the essential wrongness of the statement is unwittingly brought out by "Cathode Ray" when he uses it to indicate that a player-piano can give results indistinguishable from those given by a first-rate pianist. Now, it is a fact that an expert player-pianist can get much more out of his machine than an inexpert, by various little tricks of technique; but, even so, it is only to himself as he sits playing, that, for some subjective reason, the result sounds equal to a Cyril Smith performance—to a passive listener the difference is only too painfully plain. Hence the well-known fact that no one wants to listen to a player-piano and everyone wants to play it. D'ORSAY BELL.

Chesham Bois.

Post-war Broadcasting

I SHOULD like to put forward a plea for controlled volume compression in post-war broadcasting. The chief arguments in favour of it are:—

1. The range of intensities met with in most musical broadcasts is too wide for the average living room.

2. Most receivers nowadays have diode detectors; it is well known that when the modulation depth expressed as a fraction exceeds the ratio of AC load to DC load harmonic distortion is produced; this sets an upper limit to the depth of modulation for high fidelity.

3. The present system of control by the engineer monitoring the broadcast is unsatisfactory due to its necessarily inexact nature.

With regard to the first argument there are certain exceptions, notably in the case of high-fidelity reproduction, where extraneous noise is negligible and high sound levels can be tolerated. This could adequately be met by controlled volume expansion at the receiver.

The second consideration is of importance to those interested in high fidelity. Owing to the exigencies of wartime service, the maximum depth of modulation employed by the B.B.C. has been considerably increased, and the inevitable result has been deterioration in quality; this has been particularly noticeable in some recent broadcasts of cathedral services, where the normal absence of overtones in the voices renders harmonic distortion more than usually prominent and unpleasant.

The third point hardly requires elaboration; it stands to reason, for instance, that the present system of monitoring cannot deal satisfactorily with transients; an excellent example of its inadequacy was provided in the recording of the Coronation Service (direct from B.B.C. by transmission line) of the anthem "Zadok, the Priest"; the first climax, at the entry of the full chorus, was obliterated by the control engineer's excess of zeal.

This plea is also to be addressed to gramophone record manufacturers, though, perhaps, for somewhat different reasons.

Some time ago I had the opportunity of hearing a large number of records on an electric gramophone which had a total harmonic distortion of less than 1 per cent. at 1,000 c/s, as measured on a Marconi-Ekco Distortion Factor Meter, and a correspondingly good frequency response; this enabled considerably more discrimination than usual to be applied, and the correlation between high quality and low level of recording was astonishingly complete.

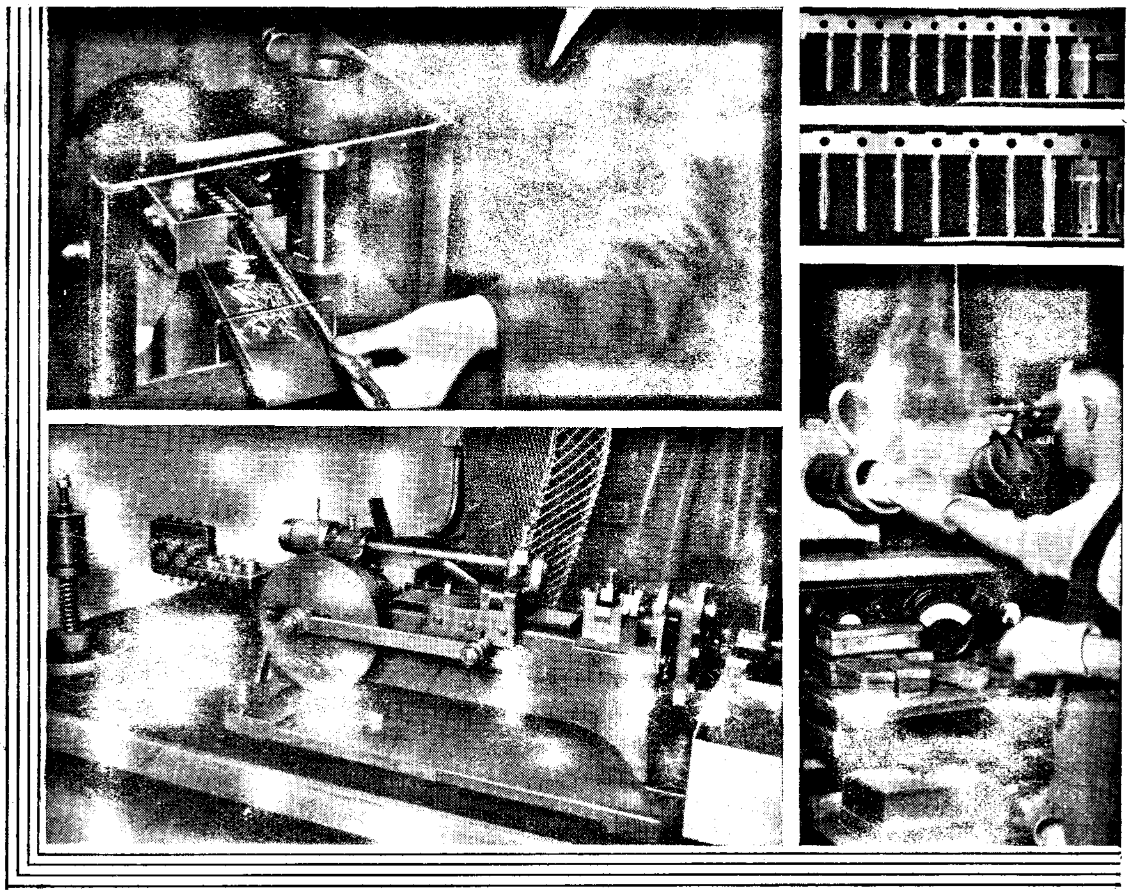
Rugby. A. H. KING.

YOUR leading article in the October issue raises, in good time, the future of broadcasting. One would hesitate on many grounds to welcome the competition due to pure commercialism, but there are many who would welcome more competition in ideas than seems obtainable by the present system. One suggestion I should like to put forward for consideration is that a certain proportion of broadcast time should be sold to advertisers for the benefit of the hospitals. The public at large would be making a contribution, through licences, whilst the profits of the advertisers would come from their sales to a wide public.

If this idea stimulates thought and discussion in relation to the problems of providing a better broadcasting system, some good will come of it.

"HOPEFUL."

Manufacture of piece-parts



MASS production piece-part manufacture and processing are now an essential part of valve making: millions of these items are needed annually.

Our illustration is designed to show some of these manufacturing processes, while the two illustrations (top right) give an idea of the number of operations required on base pins.

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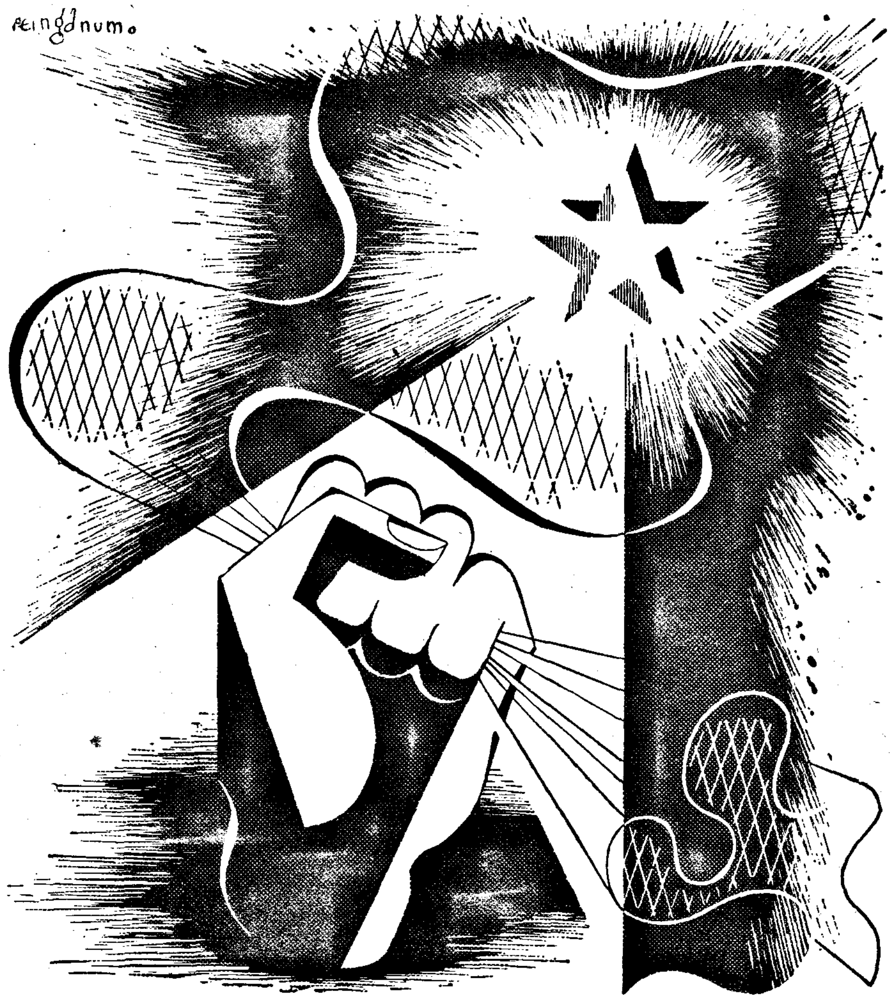

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PHYSICAL FOUNDATIONS OF RADIO

IV.—Composite Cathodes, Photosensitive Surfaces, Cold Emission

By

MARTIN JOHNSON, D.Sc.

IN the last article we emphasised the controlling influence of the work-function over the emission of electrons from a hot cathode, the expression $e^{-\phi/kT}$ in the Richardson equation indicating that for a bright filament at 2,000 degrees a reduction of ϕ from the $4\frac{1}{2}$ electron-volts of pure tungsten to 2 would increase emission about a million-fold. Pure metals refractory enough to stand up to heating all possess work-functions in the neighbourhood of 4, 5, or 6 volts, so that not much is to be hoped for in simple materials. Instead, the dull-emitters required to supply copious anode currents for a low consumption of heating power in small radio valves are often chemical compounds painted or otherwise coated onto a base metal filament or onto the outside of a tiny cylinder which surrounds the actual heating element. Whether thus directly or indirectly heated, the emitting surface is at a much lower stage of incandescence than when the electrons were from the "conduction levels" of the tungsten.

The use of these cooler emitters raises three questions of interest. First, what chemical elements and compounds have work-functions marking them out as suitable emitters. Secondly, why is the reduction of work-function more effective for a very thin coating than if the new material were to replace completely the old refractory material. For instance an alkali film upon nickel or tungsten may be a better emitter than the bulk alkali alone, and not merely better than the nickel or tungsten. Thirdly, there is the practical question of how the coating is to be made and stabilised for long life of a valve.

Alkalis and the "Adsorbed Grid."—On correlating thermionic and chemical properties, it will be found that the alkali metals (sodium, potassium, caesium, etc.) and the alkaline earths (strontium, barium, etc.) have lower work-functions than other elements. The cause involves their crystal structure and atomic size as well as their ease of ionisation or loss of an electron from the individual atomic structure. The crude idea of manufacturing cathodes out of any of these elements is not helpful; among other reasons some have extremely low melting temperature. Their better use as coating a more refractory base such as tungsten depends upon the phenomena of "adsorption," i.e. the adherence of a foreign layer to an underlying surface, the layer clinging with a strength greatly in excess of its attachment to its own kind. For example, an alkali might melt at a low temperature, its atoms easily separating from their own kind, whereas far more drastic heat treatment might be needed to evaporate it from some other metal on which it was "adsorbed." The prefix "ad-" in contrast to absorbed denotes that the attraction is that of a single layer of atoms to a surface, rather than the swallowing up of even a small bulk of the one material in the other.

Imagine the electrical effects of such a thin adsorbed layer of an alkali such as caesium upon tungsten. The layer is electropositive to the underlying material, having an atomic field which facilitates migration of electrons. The layer must not necessarily be regarded as having lost electrons, though in some cases where an alkali vapour is squirted at a hot metal it does rebound in the ionised state as positively charged remnants of atoms whose electrons have been captured by the target metal. But the nature of the field set up by the layer is much as if we could imagine the grid of a valve to be positively charged and moved up to within a ten millionth of a centimetre of the cathode.

We have already utilised potential diagrams to represent how conditions vary from the interior of a cathode to the interelectrode space and then to the anode, and the effects of the "adsorbed positive layer as grid" may be shown similarly. (Fig. 1.)

Thin Potential Barriers.—When discussing in an earlier article the escape of electrons from one equipotential to another inside the metal, we made use of the behaviour associated with their "wave-like" properties. A completely "particle-like" electron would not find the barrier of (b) in Fig. 1 any less of an obstruction than the barrier of (a) to passage from left to right, if the initial height of the step were the same: in each case it would have to acquire kinetic energy equal to the step in order to escape. But the "wave" character of the electron confers a finite probability of a non-zero wave amplitude on the far side of the barrier; this amplitude falls rapidly as the thickness of the barrier increases, and only remains of importance for two or three hundred millionths of a centimetre. The sudden change over the thickness of an adsorbed layer provides one or more very thin walls in any complex potential barrier and the penetration of these plays a large part in emission from coated surfaces.

The "effective" work function is one way of representing the increased facility of electron escape, though it must be remembered that the emission constant "A" in Richardson's equation may also be modified. Observed values of ϕ, compared with 4.54 volts for tungsten and 5.03 for nickel, may be inserted in the equation we used and the increased emission in thou-

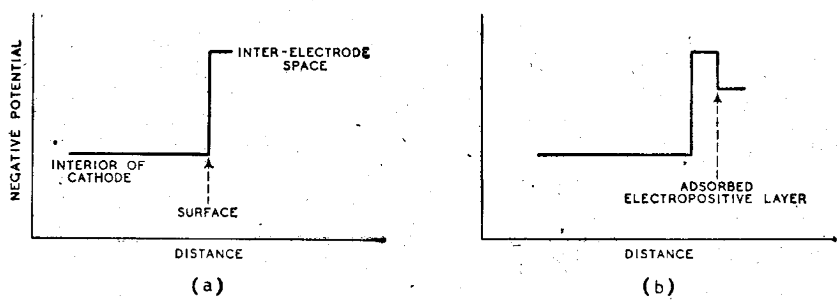


Fig. 1. **Potential** (a) at "clean" and (b) at "coated" cathodes. **The variation of potential will actually be more complex, but has been simplified here to bring out the main feature of difference.**

Physical Foundations of Radio—

sand- or million-fold computed. For barium we have 2.11 volts, caesium 1.81, while for tungsten covered with caesium 1.36 and covered with barium as low as 1.2. Variations depend on whether the layer involves only adsorbed metal or has oxygen in the "sandwich." The latter makes a more complex potential diagram of peaks and valleys, and apart from its electrochemical effects serves to bind the coating against evaporation by introducing a new chemical term into the forces of adsorption.

These composite cathodes could not stand the high temperatures of the bright emitter; but they have no need to. There is both numerator and denominator on the exponential term of our Richardson equation, and if a tungsten emitter yields 8 milliamps anode current for a watt heating at 2,600 degrees, the same with a thorium layer on it may yield 40 at only 1,800 degrees and with barium coating 100 at 1,100 degrees.

"Activating" a Composite Cathode.—These surface layers which are so essential for full emission may arrive by external deposition or by diffusion from an impurity dissolved in the cathode itself. As example of the less refractory and more highly emitting but less easily replenishable layers, a mixture of barium and strontium carbonates is sprayed or painted on to a cathode; the whole is heat-treated until the carbonates break up into

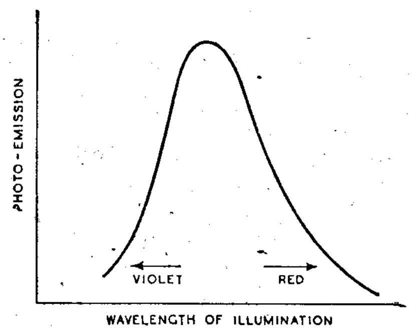


Fig. 2. Selective response of alkali photo-cell. The curve is usually unsymmetrical, and its peak may be in the green, red, or infra-red, according to how the adsorbed surface layers have been treated.

oxides and give off gas, then at another carefully calculated temperature the oxygen atoms arrange themselves into their sandwich with the two or more metals. It is clear that the subtle cookery will be ruined by any subsequent trace of vapour, and such valves need rigorous "degassing" before sealing, if their life is not to be extremely short.

To obtain one's layer from inside instead of outside offers more chance of repairing loss of emission without remaking the valve: thoriated cathodes are worth study as example of this other mode of forming the surface. Early in the development of the tungsten lamp industry, it was found that at incandescence the filament tended to recrystallise into long hair-like crystals, which on AC would "rattle" and lead to rapid "burn-out." To prevent this, about 1 per cent. of thorium oxide was added in manufacture. The work-function of thorium itself is about 3.4 compared with tungsten 4.5, but tungsten coated with thorium shows 2.4, offering enormous increase of emission. To form or activate the thoriated tungsten simply means therefore to spread some of the dissolved impurity over the surface in the correct chemical state. "Flashing" the wire at a preliminary temperature of 2,800 degrees reduces some of the thorium oxide to metallic thorium, and is followed by a longer "activation" at a rather lower temperature which allows a trace to diffuse up to the surface but not to evaporate therefrom. A trace of dissolved carbon assists the reduction of the oxide, and there are other little-understood tricks based upon the physicist's experience that "to fetch out an impurity, send another one in" is sometimes good advice.

Photo-Cathodes.—Hitherto we have only considered thermionics, or the emission of a metal's electrons from a pure or a coated surface by heating. But television and other specialised developments of electronics also require the emission from cathodes which are not heated but are exposed to light or other radiation to which they are sensitive. If we recall that energy had to be supplied to the "gas of free electrons" within a metal in order to evaporate some portion of it into a vacuous space for collection on an anode, it is reasonable to look for other modes of supplying that energy than mere heating of the interior of the whole metal.

A beam of "light," visible or ultra-violet or infra-red, carries electromagnetic energy just as a beam of the much longer wavelengths generated by a valve oscillator and its resonating circuit. The vibration of the electric vector in the radiation communicates energy to the electrons in the metal surface which is absorbing it, and if the frequency is suitable some electrons will escape under this stimulus.

In such a science of "photoelectricity," barriers and work functions are discussed in the same way as in "thermionics," but there is no counterpart of the Richardson equation as the emission is not temperature-controlled. In fact any variation of photo-emission with heating is apt to mean merely that a composite surface is getting altered in structure, and most laws of photoelectricity assume the cathode remains cold.

The energy with which the electron emerges is also quite different from that of thermions, and depends upon the frequency of the light employed. The practical uses of photoelectric emission mostly depend on the property that the anode current or number of electrons emitted is conveniently proportional to the light intensity. Alkali adsorbed layers, however, are as important in photoelectricity as in

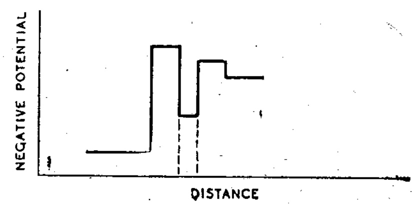


Fig. 3. Idealised shape of possible potential barrier at caesium-silver-oxide photo-cathode.

thermionics, and quite low melting materials can be used as the cathode is not heated. The commoner pure metals are not sensitive to light of lower frequency than ultra-violet, but potassium and the other alkalis do respond to visible light. They also show selectivity, and yield a larger emission over a preferential range of wavelength (Fig. 2) even while the intensity of light remains constant.

It is probable that this selectivity would not occur with a perfectly pure surface: even when this is prepared by driving atomised metal electrolytically through the sealed walls of the photo-cell it is almost impossible to avoid traces of foreign vapour if only from the glass, and the "alkali" is usually a "sandwich." The form of the response curve (Fig. 2) depends on the exact ingredients and seems to smooth out disconcertingly if extreme purity is for once achieved. A favourite sandwich is a layer of caesium only one atom thick separated from a base of silver by an electronegative layer of oxide or hydride. The "activation" sometimes involves flashing a gas discharge in the cell.

The exact form of the most profitable potential barrier has been disputed; it probably includes a valley between two summits somewhat as we have expressed in Fig. 3. Fowler, who has done much to make these processes intelligible, suggested that the selectivity depends on the "valley" allowing formation of stationary electron waves analogous to the stationary electromagnetic waves in a UHF resonator. It is a possible way of accounting for the characteristic property of these alkali sandwiches of showing selective response to illumination of a particular frequency. By ingenious treating of these layers, chemically or thermally or by ionic bombardment in a gas discharge, the peak of the curve of Fig. 2 can be raised or lowered and also shifted sideways until the sensitivity is in the visible or ultra-violet or infra-red region, and the resulting "photo-cell" adapted to television, industrial control devices, gadgets such as burglar alarms, or cinematography.

"Field" Emission.—We have considered emission stimulated by heating a cathode or by illuminating it, but these are not the only ways in which the metal's electrons can be extracted for use in a valve. If a very high anode potential is applied extremely close to the metal surface, the "clean" barrier previously discussed can be reduced to atomic thinness; the sloping line already illustrated in a previous account of the ordinary potential graph becomes so steep that the top of the barrier is a razor-edge. (Fig. 4.) Hence, as in the thinning by adsorbed layers, a finite leak through becomes possible. In this case, however, the emission depends on field and not on temperature. These "field" currents from a cold cathode become important at 10^7 volts per cm., but grids for many kilovolts at interelectrode distances of a small fraction of a millimetre are obviously not easy to design. We

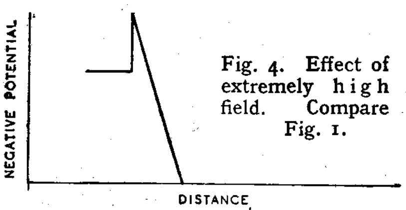


Fig. 4. Effect of extremely high field. Compare Fig. 1.

mention only the X-ray tubes designed by the Philips workers in Holland and the Westinghouse workers in U.S.A. to utilise this phenomena. In one of these, a discharging condenser controlled momentary fields of enormous strength, and the "cold" emission reached 2,000 amps. at 100,000 volts for 10^{-6} second. Obviously, space charge difficulties confine such currents to brief transients, but they were valuable for instantaneous X-ray photography.

Secondary Emission.—In addition to field emission and photo-emission, electrons can be ejected from a cold cathode by bombarding it with another beam of electrons from outside. It is a matter of exchange of momentum between impinging electrons and the first few atomic layers near the target's surface. Reaction with the target atoms causes some of their associated electrons which are in a semi-free state to acquire sufficient backward momentum for ejection right out of the surface. Under favourable conditions each impinging or "primary" electron ejects several such "secondaries." This is used in certain "electron multipliers" which amplify without a thermionic current at all, a photoelectric stream ejecting multiple secondaries at each of several successive anodes. Secondaries also play a large part, of course, in the dynatron characteristic of an oscillating triode. But in many valve applications secondary emission is a nuisance, and the early history of the pentode shows the designer's ingenuity in circumventing its effects.

Thin Film Field Emission.—We mention finally a curious group of effects which may in the future, we think, play a large part in valve practice. Strictly it comes under "cold" and "field" emission, but it is also in a sense a "secondary" emission, and so combines our two last cases. It occurs with the thin and stable oxide film which covers aluminium and some other metals. When bombarded with a primary beam of electrons or with the positive ions from a trace of gas, there is emitted from the aluminium an enormous rush of electrons. The ratio of secondary to primary may reach thousands, so it is clearly not the usual "secondary" exchange of momentum, and suggests a high local field. The best known experiments are those of Malter, whose name is often given to this kind of emission. The enormous local field is probably derived from adjacent layers of opposite charge in the oxide: the "anode volts" are on an "electrode" which is simply the neighbouring atom grossly distorted. Maintenance of the field is probably by adsorption of positive ions from gas traces or by the residual charge left when the first secondaries depart. The emission is therefore subject to uncontrollable time lags, and will need closer study before it can be reliably utilised. That is no excuse for despising it as a mere laboratory freak to amuse the physicist: thirty years ago, O. W. Richardson with no interest whatever in communication engineering, made possible all modern radio by his purely scientific curiosity about why electrons should ever escape from metals. It is such disciplined curiosity which provides the foundation on which the technician is later to build.

INSTRUMENTS : *Test and Measuring Gear and Its Uses*

By W. H. CAZALY

VIII.—*Multivibrators*

THE multivibrator is a device that generates alternating potentials of non-sine-wave form. The value of such a wave-form lies in the fact that it can be analysed into a large number of harmonics of the fundamental frequency, and these harmonics can be selected by tuned circuits. Thus, the multivibrator may be regarded as a kind of generator at the output of which there are simultaneously present many frequencies, each an exact multiple of the fundamental. For example, if the fundamental is 100 kc/s, or 0.1 Mc/s, there may be available for use at the output as many as 500 frequencies, starting with 0.1 Mc/s and going up, at intervals of 0.1 Mc/s—i.e., 0.2, 0·3, 0·4, 0·5 Mc/s, etc.—to as high as 50 Mc/s. Whether they become usable at these high frequencies depends on the design and power of the multivibrator. At the other end of the frequency gamut, it [illegible] to arrange a multivibrator circuit to oscillate at a frequency as low as 1 c/s.

Further, it is possible to lock the fundamental frequency of a multivibrator readily to that of some high-precision generator, so that the multivibrator fundamental and all the harmonics each have precision of frequency of as high an order as that of the primary controlling frequency. One obvious use of such a controlled multivibrator lies in the quick and accurate calibration of receivers, especially when many of them are being so dealt with. The multivibrator is set going at, say, 100 kc/s, or 0·1 Mc/s, and its output fed to the input terminal of the receiver under test. Then by tuning the receiver over the range required to be calibrated—say 6 to 8 Mc/s—signals will be found at every 0.1 Mc/s interval, and these points will give a fairly accurate calibration scale. When once set up, the multivibrator does not have to be touched or retuned; all the required frequencies for calibration present are simultaneously in its output, and each has the same accuracy as that of the primary controlling or triggering frequency.

The multivibrator is a comparatively simple device to construct and may be either battery or mains driven. It consists essentially of two resistance-capacitance coupled amplifiers arranged in a mutual feed-back circuit as shown to the right of the dotted line in Fig. 1, which is a practical circuit as it stands. Such an arrangement—quite apart from the crystal oscillator on the left of the dotted line, which is the accessory triggering source—will oscillate on its own in the manner peculiar to this type of circuit; it is, in fact, a form of "relaxation" oscillator.

Frequency Control

The action of the multivibrator has been the subject of close study, and the sequence of events over a complete cycle of oscillation was described, with the aid of oscillograms in an article by Dr. Edward Hughes in the last issue. In view of this recent exposition we will not devote space here to the basic principles of operation, but pass on to the modifications of the multivibrator necessary for test purposes.

Left entirely to itself, the multivibrator circuit does not perform its reversals at a very constant frequency, since at the moments of equilibrium, any random voltage, however tiny, can set off the change-over of conditions a little before or after it would occur naturally. This leads on to the use of a controlling or triggering voltage that may be injected from an external generator of high precision as regards frequency. A glance at the wave-forms shown in Fig. 2 will indicate the outlines of the effect of applying a controlling voltage to a grid.

An uncontrolled wave-form is shown in Fig. 2 (*b*). On this line, at point A, the potential of the grid is not very far from the "zero" or change-over value—i.e., the value of negative potential at which anode current just begins to flow. It can be easily jolted, as it were, towards the zero line by an injected voltage in the right phase, which is at point A in Fig. 2 (*a*). If it is large enough, this controlling voltage can cause the change-over to take place a little earlier than it would do naturally if solely dependent on the circuit constants of the multivibrator alone.

Once the change-over is started, the grid and anode potentials very soon move well away from the zero line and so can remain unaffected by the comparatively small controlling voltages. This brings out the interesting and valuable fact that a natural multivibrator frequency can be controlled by a voltage of sine-wave form at a much higher frequency—in practice, as much as ten times the frequency. The net effect as shown on an oscilloscope is a wavy line of the shape shown in Fig. 2 (*d*). This wave-form is obviously composed of a very large number of harmonics as well as the fundamental. Whether these harmonic voltages are of sufficient amplitude to be usable depends partly on the power in AC form developed by the

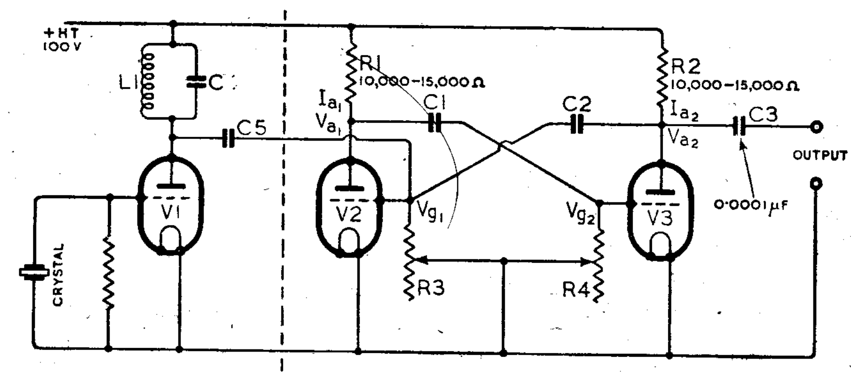


Fig. 1. The multivibrator circuit is shown to the right of the dotted line after C5. The values of C1, C2, R3 and R4 depend on the frequency required, and are calculated from formulæ given in the text.

multivibrator, partly on the order of harmonic, and partly on the overall range of frequencies included by the fundamental and its harmonics.

In a usual type of battery-driven vibrator used for RF work at what are conventionally taken to be the "short waves," up to the 100th harmonic of a 200 kc/s fundamental of whistles that have been counted. For example, let it be supposed that a receiver covers 18 whistles in moving from some one multivibrator harmonic to exactly double the frequency at which the receiver was first tuned. Then it will end up on the 2 × 18th or 36th harmonic. With this as a reference point, other harmonics can be

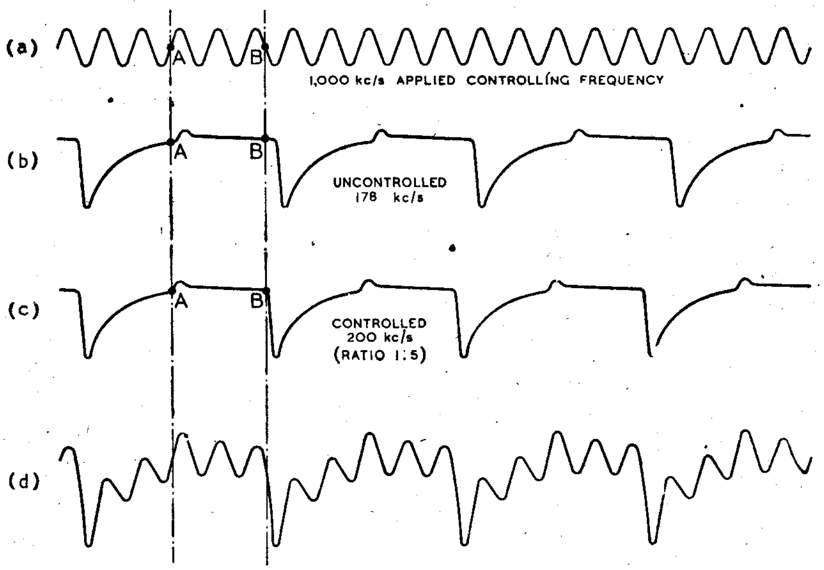


Fig. 2. Diagram showing the action of a triggering sine-wave potential in controlling the frequency of a multivibrator. (a) is the controlling sine-wave voltage. (b) is the uncontrolled multivibrator grid potential. (c) is the grid potential when controlled—without the sine-wave fluctuations superimposed. (d) is the resultant that would appear on the screen of a cathode-ray oscilloscope.

is normally found of practical utility. Beyond that, not only are the harmonics weak, but they are so closely adjacent that it is difficult to distinguish between them.

In this connection, it will be useful to note how the particular harmonic in use can be ascertained when working amongst the high ranges. If it is desired, for example, to ascertain whether one is working on, say, the 34th or the 35th harmonic, the procedure is to tune a CW receiver exactly to any harmonic of that order (using, for instance, the zero-beat-method), and then change the receiver tuning to exactly double the frequency. If this cannot be done with the receiver scale alone, a simple temporary oscillator can be set up to beat with the multivibrator harmonic and the 2nd harmonic of the oscillator used to indicate twice the frequency. While tuning the receiver through to this 2nd oscillator harmonic, the whistle obtained as the *multivibrator* harmonics are passed are counted. Then, when the receiver tuning is halted dead on the oscillator 2nd harmonic (which gives the last whistle) it will then be tuned to the multivibrator harmonic given by 2 × N, where N is the number distinguished by counting whistles up and down the tuning range. Further, if the fundamental is known, the precise frequency involved at any harmonic can be calculated. Thus, if the multivibrator fundamental is 200 kc/s, the 36th harmonic would occur at a frequency of 200 × 36 kc/s, or 7·2 Mc/s.

It will have been noticed in Fig. 2 that it is necessary, if locking is to take place, for a not excessive difference in phase between the controlling and the multivibrator frequencies to be present. When widely asynchronous either locking does not take place, or it may do so at some undesired ratio between the controlling and natural frequencies. Hence, it is necessary that the multivibrator should be designed so that its natural uncontrolled frequency is *approximately* some desired ratio in respect to the controlling frequency chosen.

Frequency Calculations

The natural frequency of a multivibrator is determined mainly by the time-constants of the coupling condensers and grid resistances—C_1, C_2, R_3, and R_4, in Fig. 1—and when

Instruments—
some particular multivibrator fundamental is desired, it can be derived approximately from the formula

$$f = \frac{1}{(R_4C_1) + (R_3C_2)}$$

where R_3 and R_4 are in megohms, C_1 and C_2 are in microfarads, and f is in cycles per sec. If it is assumed that the time constants are to be equal (so that $(R_3C_1) = (R_4C_2)$ the values of the capacitances and resistances can be found as a first rough design approximation from

$$R = \frac{1}{2fC} \text{ and } C = \frac{1}{2fR}$$

These are only approximations to give an idea of the order of resistance or capacitance required, and in making up a multivibrator, it is usual to make the grid resistances variable, the two being ganged on the one controlling shaft. They can then be adjusted in use until locking takes place.

The upper limit of oscillation frequency is set by the amplification obtainable with resistance-capacitance coupling and hence is not very high—only of the order of 200 kc/s or so. If the high-order harmonics are to be preserved at reasonable strength, the whole circuit must be designed as for RF amplification with low losses.

The multivibrator can also be used for the production of audio frequencies and may be triggered by some stable and accurate AF generator such as a magnetostriction bar or electrically driven tuning fork; the main difficulties then arise in designing sharply tuned AF filters for the selection of the desired harmonics in the output, which is not so easy at AF as it is at RF. It is usual to employ tuned bridges for the purpose, or else to start with a comparatively high controlling AF

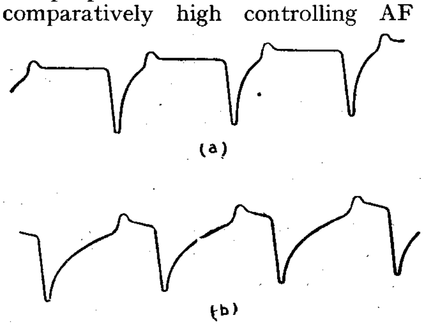
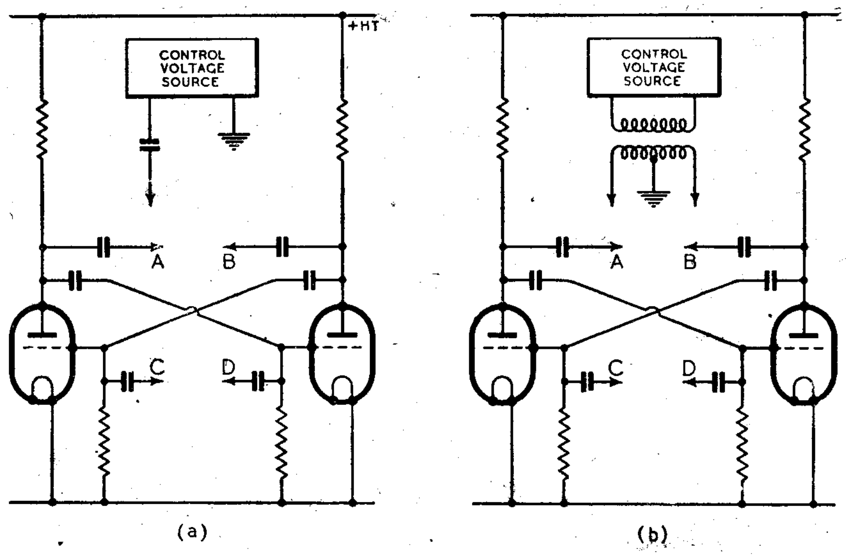


Fig. 3. Diagram showing the effects of differing time-constants on the grid potential wave-form.

(say 10 kc/s) and use a series of vibrators to obtain lower frequencies in multiples of ten. Usually the time constants are made equal in the two amplifiers. If they are unequal, the effect is to make a difference between the duration of the positive and negative part-cycles of grid or anode potential, as shown in Fig. 3. In the upper wave-form (a), the negative part-cycle is of shorter duration than the positive. This indicates that the time constant of the condenser and resistance connected to the grid at which the potential is being observed is larger than that of the other. If the potential were observed at the other grid, it would be found to have the shape shown in the lower wave-form (b).



CIRCUIT	CONTROL APPLIED	RATIOS CONDUCIVE TO OSCILLATION
(a)	A, B, C OR D ONLY	ODD OR EVEN
(a)	A & B SIMULTANEOUSLY OR C & D SIMULTANEOUSLY	EVEN
(b)	A & B IN "PUSH-PULL" OR C & D IN "PUSH-PULL"	ODD

Fig. 4. Table showing the ratios between the controlling and multivibrator fundamental frequencies to be expected with a few common circuit arrangements.

The ratios of the controlling to the natural frequency at which locking tends to take place are determined by factors that are not so much abstruse as rather laborious to study. They will become clearer if several extended representations are made, to show the phase relationships between the natural and controlling frequencies at grids and anodes. In the first place, the ratios obtainable can only be integers, or complete numbers. In the second place, this fact limits the range of frequencies at which a multivibrator can be set up for locking with a given controlling frequency. For example, if the controlling frequency is 1,000 kc/s (a crystal oscillator, for instance), possible ratios are only 5, 8 and 10. At a lower ratio than 5 the multivibrator frequency would be too high to be easily set up; at the higher ratios, only 5, 8, and 10 are exactly divisible into 1,000. Hence, in such a multivibrator, locking could take place only when the fundamental was 200, 125, and 100 kc/s. Which of these possible ratios was selected would depend partly on the relative magnitudes of the controlling and natural potentials, and partly on where the controlling voltage was injected—whether at grid or anode, singly or at both.

The effect of increasing the controlling voltage is to make the multivibrator jump from one locking frequency to the next lower, with increasing uncertainty and instability as the divergence between the natural and the controlling frequencies increases. The effect of the point of application of the controlling frequency is perhaps set out in the simplest practical form of a table referring to Fig. 4, so that whether the output of the controlling generator is applied to one grid or one anode, or to two grids or two anodes depends on whether odd or even ratios are desired.

The multivibrator lends itself to an

The subjects already dealt with in this series of articles on instruments are:

I. Standard Signal Generators and Test Oscillators (March, 1942).
II. Output Meters and Attenuators (April, 1942).
III. Valve Voltmeters (June, 1942).
IV. Testers and Bridges for Inductance and Capacitance (July, 1942).
V. Beat Frequency Oscillators (August, 1942).
VI. Electrolytic Condensers: Inductance and Capacitance at Radio Frequencies (October, 1942).
VII. Valve Testers (November, 1942).

increasing number of practical uses. It has been mentioned earlier as a source of precision signals in a laboratory or workshop for calibration or frequency determination purposes. It is also employed in various types of electronic switching circuit. One of its most interesting uses lies in very high accuracy primary or sub-standard wave- or frequency-meters in which the general arrangement is to control a series of multivibrators by a single extremely high-precision crystal oscillator. The generating of frequencies starts with this temperature-controlled crystal, which is placed in an oven regulated by a gas-discharge valve circuit and a bridge that is unbalanced by changes of temperature. The output of this crystal oscillator is fed, through buffer amplifiers, partly to an output terminal and partly to a multivibrator working at a fundamental 1/10th of the crystal frequency (which is usually 1 Mc/s). The output of this multivibrator is fed partly to an output terminal and partly to another multivibrator which is working at a fundamental of 1/10th that of the first vibrator. This goes on, in a chain of multivibrators, until one at a frequency of 100 c/s ends the gamut of frequencies covered. The output of the 1,000 c/s stage is amplified sufficiently to work an electric clock, the time shown by which to a small fraction of a second may be checked by star transit observations with astronomical instruments or against time signals from some standard transmission. With such costly and elaborate apparatus, an accuracy better than one part in many millions is obtainable with a constancy extending over many months. In fact, frequency can be known to a much higher accuracy than either the velocity of transmission or wavelength.

The Wireless Industry

SIMMONDS AEROCESSORIES, LTD., have been granted the registered trade mark of "Simmonds" for their self-locking nuts.

The latest illustrated list of service components issued by Norman Rose (Electrical), Ltd., 80, St. Mary's Road, London, W.5, includes many additions such as line cord replacement resistances, HF chokes and spindle extension couplings for volume controls. Copies are free to dealers on application.

We have received a copy of "Increased War Production," a comprehensive catalogue of the meters, tools, etc., made by Runbaken Electrical Products, 71-73, Oxford Road, Manchester, 1.

Through an error in repeating old copy, the advertisement of Vortexion, Ltd., in our November issue gave details of an earlier 50-watt amplifier chassis. This has been superseded by an improved version priced at £18 10s. plus 25 per cent. war increase, as announced in the October issue.

"Instruments," Part VI.—A Correction

THE section dealing with the principle of the "Q" meter and starting on line 28 of the first column of page 236 should read:

"Let the applied voltage be V_1, and the voltage across the coil L be V_2. When measured by the valve voltmeter, V_2 will be found much greater than V_1—in fact, it will be $Q \times V_1$.

$V_1 = IR$

and $V_2 = I\omega L$ Where I is the current through the tuned circuit.

$$\therefore \frac{V_2}{V_1} = \frac{I\omega L}{IR} = \frac{\omega L}{R} = Q$$

"If now . . . etc."

Two other points, the balancing resistance mentioned in column 3, page 232, is, of course, R_3 or R_4 and not R_2; and in the circuit of Fig. 5 the live lead of the valve voltmeter should be joined to the junction of R and the circuit LC.

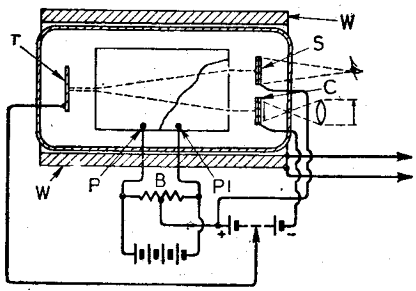
Recent Inventions

A Selection of the More Interesting Radio Developments

LIGHT INTENSIFIER

THE picture to be intensified is first focused upon a photo-electric cathode C, and the resulting stream of electrons is then projected on to a secondary-emission target T at the opposite end of the tube. From here an augmented stream, comprising both primary and secondary electrons is reflected back on to a fluorescent viewing screen S.

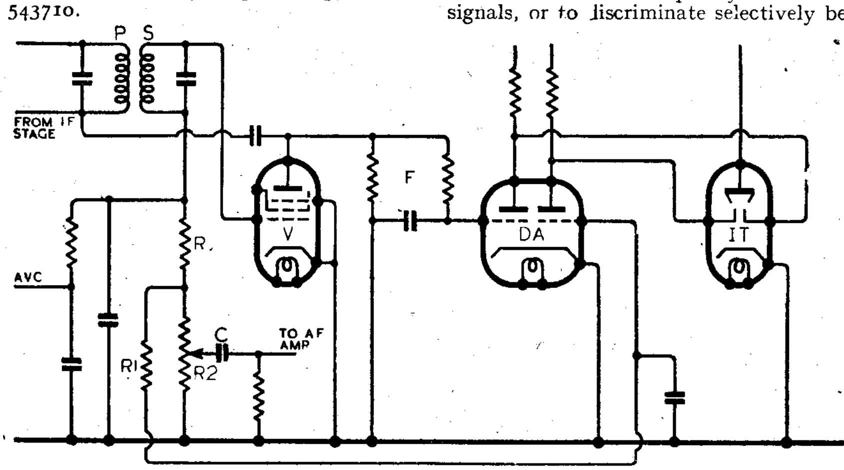
The magnetic field from an external coil W guides the stream in a path which is substantially parallel with the axis of



Light intensification by secondary emission.

the tube at both ends, until the stream passes between two plates P, P_1, which are biased, as shown at B, so as to deflect the stream along the dotted-line path. The deviation from the straight-line path is, of course, reversed by the electrostatic field as the electrons take the return journey towards the viewing screen S. The target carries a fixed biasing potential which is positive with respect to C but negative with respect to S.

Marconi's Wireless Telegraph Co., Ltd. (Assignees of A. Rose). Convention date (U.S.A.) August 31st, 1939. *No.* 543710.



Detector for frequency and amplitude modulation.

FREQUENCY-RESPONSIVE CIRCUITS

THE phase-relation between the primary and secondary voltages of a coupling transformer is used to operate a visual tuning indicator of the cathode ray type. As shown in the figure the primary winding P of the IF output transformer is connected to the anode, and the secondary winding to the control grid of a valve V.

The primary produces an output voltage having an amplitude which is determined by the difference between the signal or carrier-frequency and the frequency to which the IF transformer is tuned; this is applied through a filter circuit F to one of the grids of a duplex amplifier DA.

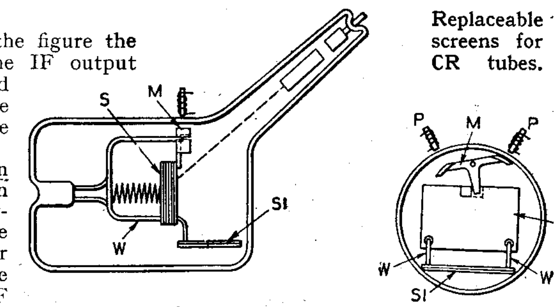
The secondary produces a rectified voltage which is fed through resistances R, R1 to the other grid of the duplex amplifier DA; this voltage will be of a substantially constant value if the AVC control is flat. By suitably adjusting the resistances, the output from the duplex amplifier can be balanced at the carrier frequency, so as to give a corresponding indication at the visual tuning indicator tube IT. The AC component of the AVC voltage is fed to the AF amplifier through a tapping from the resistance R2 and a condenser C.

A similar circuit arrangement can also be used to detect frequency modulated signals, or to discriminate selectively between two amplitude-modulated signals.

Marconi's Wireless Telegraph Co., Ltd. Assignees of W. R. Koch. Convention date (U.S.A.) November 30th, 1939. *No.* 545577.

FLUORESCENT SCREENS

A CATHODE-RAY tube is fitted with a number of "spare" fluorescent screens so that when one burns out or deteriorates, it is replaced by another, thus prolonging the life of the tube. As shown, a pack of thin metal sheets S, coated with fluorescent material, is strung through a pair of lower supporting wires W inside the tube, and is pressed forward by a spring against an upper



Replaceable screens for CR tubes.

three-armed support M. The top of each sheet is recessed, the recesses being alternately staggered, so that when the armature M is swung from one side to the other by a pair of external magnets P the old screen is pushed forward into the discarded position S1 and a fresh one is presented for use.

J. L. Baird. Application date, 7th September, 1940. *No.* 544,413.

AUTOMATIC CALENDAR FOR SHORT-WAVE RECEPTION

AN adjustable chart for indicating the most favourable conditions for short-wave reception at any given time consists of three circular discs arranged so that they can be relatively rotated about a common centre. One disc is marked with the hours of the day, and also with the names of the principal short-wave transmitters spaced according to their geographical longitude. A second disc is marked with a scale of wavelengths. The third disc is formed with cut-out slots shaped in accordance with the seasonal variations of the ionosphere throughout the year.

The discs are set by hand to a given time in order to show which stations can best be heard; or conversely they can be set to show the best time to hear a selected station. The calibrations are valid for a five-year cycle, corresponding to periods of maximum and minimum "sunspot" activity.

N. A. M. McKie. Application date April 22nd, 1941. *No.* 544533.

The British abstracts published here are prepared with the permission of the Controller of H.M. Stationery Office, from specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each.

Random Radiations

By "DIALLIST"

Ducks and D-Xers

THESE notes are being written in Scotland. One thing about life in the Army is that, though you may have long periods in which you may stay put in one place or another, you do, as time marches on, eventually see a good deal of this country of ours. Ever since I arrived at my present northerly station, the rain has pelted down in torrents. That, I fear, appears to be normal for the locality. It is reputed that the village wiseacres say that when you can see the surrounding hills you know it is going to rain, and that when you can't see them you know it is raining! It seems to me to be an ideal place for ducks and medium-wave wireless D-Xers. The heavy, wet soil must make for earth connections of surprising excellence, and the long hours of darkness in autumn and winter should ensure some fine opportunities for long-distance work on the medium waves.

Better Batteries

A DAY or two ago my electric torch glowed only a dimmish red when I switched on, and I realised that it was high time to see about a new battery for it. How long had the old one been in use? I couldn't think for the moment, and then it occurred to me that I'd bought it in Somerset last December. Eleven months' use is pretty good. The cells are of the large type (2¼in. x 1¼in.), but a dozen years or so ago even big cells would have run down in eleven months if they'd stood on the shelf and had no use at all. The advances made in this country in the design and manufacture of dry cells have been striking, as those wireless folk who use battery sets should appreciate. Not so long ago a standard-capacity HTB of 100 volts usually cost a good guinea, and soon threw up the sponge if its load was more than 5 or 6 milliamps. Its shelf life, too, wasn't as a rule much over 3-4 months. Now, even in wartime, batteries cost far less. They stand up to bigger loads, and they can remain on the shelf for long periods without serious deterioration. A good step forward.

But, With a Big B

But may I give one warning about dry batteries of both the flashlamp and HT kinds? You may find some of indifferent make which have either been too long in the shop that offers them or were not too good to begin with. Only the day before this was written, I went forth to get the 3-volt refill battery that my torch needed. Seeing some of the right type in a shop window, I went in and asked for one. The man behind the counter handed it over, but, before calling it a deal, I asked to see what the voltmeter had to say about it. The voltmeter could say nothing better than about 2.3 volts; and so, although I was assured fervently that this was "normal for wartime batteries," I prefer to try my luck elsewhere. A low reading like this from a presumably unused battery is a sure indication that it won't give much service. A few doors away I found one that read a bit over the 3 volts (as it should), thus giving concrete proof of the inaccuracy of shopkeeper No. 1's statement. The moral is that you should always see the battery's voltage read before parting with your money. Not that a full voltage reading under practically no load is any real indication that a battery is in good condition. It isn't; but a low-voltage reading from a new battery shows definitely that there is something very much amiss with it.

One Man's Meat

Some years ago I made a set for high-quality reproduction of Regional and National programmes from the local station, some fifteen miles away as the wireless wave waggles. It was rather an elaborate affair, containing eight or ten valves, and one of its features was that it had separate AF and output circuits yoked to separate loudspeakers, for the low and the high audio frequencies. Each of the two AF circuits had its own volume control. I got the idea from a big American set, and it worked very well indeed. You didn't get more bass by cutting the "top"; you turned up the VC responsible for the lower audio frequencies. The other VC made speech and music more or less brilliant at will. By working the two controls together you could produce what appealed to your ear as the ideal balance. Each VC was given a graduated dial, and I asked every musical friend who came to visit me to adjust the pair until he considered reproduction to be as nearly perfect as possible. I kept a record of the dial readings, and it is interesting to

Random Radiations—
note that no two people agreed exactly in their settings. From this one deduces that it would be impossible to make a high-fidelity receiver that would satisfy the requirements of every musical ear: some kind of tone control, which is, I suppose, really a distortion-producing device, must be provided in order that each listener or group of listeners may be able to arrive at the most pleasing balance of upper and lower audio frequencies. It's a queer business altogether, this matter of the individual human ear.

Preventing Breakdowns

APPARATUS of all kinds in the Services must, of course, always be kept right up to the knocker, so that the possibility of a breakdown is brought to the irreducible minimum. There is a complete system of examination and tests of every accessible part, and this thorough vetting is done at definite intervals of time. I wonder whether, when peace returns, wireless fans who have had a training in almost any branch of the Services won't work out something on the same lines for their own broadcast, short-wave or communication receivers. It would save a vast deal of trouble-hunting if we took methodical steps to prevent breakdowns by drawing up tables of tests to be made, say, once a week. It would help, too, if we kept records of the service life, current readings and so on of all the valves in our sets, taking the latter, perhaps, once a week. Thus any valve that was on the downgrade would plainly be shown up, and we wouldn't have far to look when it finally threw up the sponge.

Wireless World Brains Trust

G.P.O. Control ◆ Is S-W Radiation Harmful?

Question No. 6. — In this country the control of all wireless matters is vested in the Post Office. Would it not be better for this function to be in the hands of an independent body, like the Federal Communications Commission in U.S.A.?

RONALD W. HAMILTON.

P. P. ECKERSLEY, M.I.E.E., formerly Chief Engineer of the B.B.C., replies :—

THE distinction between the Post Office in this country and the Federal Communications Commission in America is, so far as I know, that the Post Office is executive while the Federal Communications Commission is advisory. Both bodies have, of course, the responsibility of taking a detached view of radio problems and giving advice or taking actions which are in the public interest.

There are two ways of examining the relative merits of different public bodies; one by looking into their constitutions, the other by examining the results of their activities. Frequently the constitution of a body is not so rigid as to compel the people who run it to act in the way intended by that constitution.

The constitution of the Post Office would allow it to take a detached view of its problems if it were not for the fact that its policy is to make no mistakes and lots of money. Some people say that the Post Office should be constituted as a "business concern." The chief faults it commits, however, are brought about by its sound business outlook.

I am at the disadvantage of not knowing the exact legal constitution of the Federal Communications Commission. I know enough of it to say that it is constituted to advise legislators as to what actions should or should not be taken concerning public communications, and that it exists to take the detached point of view, regarding the public interest as paramount. I have heard interested American business men become almost lyrical in their condemnation of its activities. Thus, clearly, it has not taken the point of view of the big vested interests. Fairly detached critics, however, have said that while the commission is conscientious, it is timid, and while wholly trustworthy, it can be trusted to be both inexpert and conservative.

It is fairly clear that the modern world demands public control of public services, such as communication, but that the difficulty, because of the legacy of the past, is to constitute such bodies so that they can, in fact, be independent of any interest save that which they serve, and can yet be expert and enthusiastic. The difficulty with the Post Office is that it is answerable in too large a measure to Parliament on questions of financial profit, and that Parliament acts like a majority shareholder with no knowledge of the business. The conditions of service are not such as to attract people who think that informed enthusiasm deserves bigger rewards than are paid to civil servants. All honour, then, to those brilliant people in the Post Office who accept the conditions; there could be more of such people if the pay were more attractive.

One might summarise the answer to the question by saying that it is not only the form of organisation of public bodies which is important; it is more important to know how public bodies interpret or are allowed to interpret their duties. One might get an ideal organisation and staff it with numskulls, or a bad constitution served by a brilliant personnel. It is doubtful which would be worse. Then again, one must look deeper into the political structure of the country which asks the public bodies to serve them. Are the bodies asked to serve the public, or only a section of the public?

Thus the question is obliquely answered, in the best Brains Trust manner, by saying that there seems no good reason for substituting the Post Office by something more American, but that there might be some advantage in freeing the Post Office from a profit-making control and yet making its conditions of service more attractive.

[Other subsidiary issues arise. Should the P.M.G. be ultimately responsible (in normal times) for the B.B.C.'s artistic and cultural activities? Is it right that the G.P.O. should control those with whom it might be more or less in commercial competition? Question No. 6 is still open for discussion.—ED.]

Question No. 7.—It has been observed that the incidence of headaches and tiredness among the technical staff at a certain high-power short-wave station is much above normal.

Is there any foundation for the belief that this is due to the high field-strength in the proximity of the transmitter? And have any other physiological effects due to high-intensity RF radiations been observed?

G. W. SMILES.

This question has been passed to Dr. P. P. DALTON, M.R.C.S., L.R.C.P., who, in addition to being qualified to answer it from the medical point of view, has also studied radio technique in its applications to medicine, and is a Fellow of the Brit. I.R.E. Dr. Dalton writes :—

IT has long been known to medical experts in high-frequency therapy that many susceptible individuals suffer unduly from electro-magnetic radiation. Given a certain minimal exciting power these effects appear to be related more to the frequency than to the power of the transmitter. Exposure to wavelengths of less than about 15 metres produces undesirable effects.

Schliephake, of Jena, states that in working a 400-watt transmitter at a wavelength of 3 m. marked sensations occurred at once, whilst with a 1,500-watt transmitter working close at hand on a 15 m. wavelength no trouble occurred until some hours had passed.

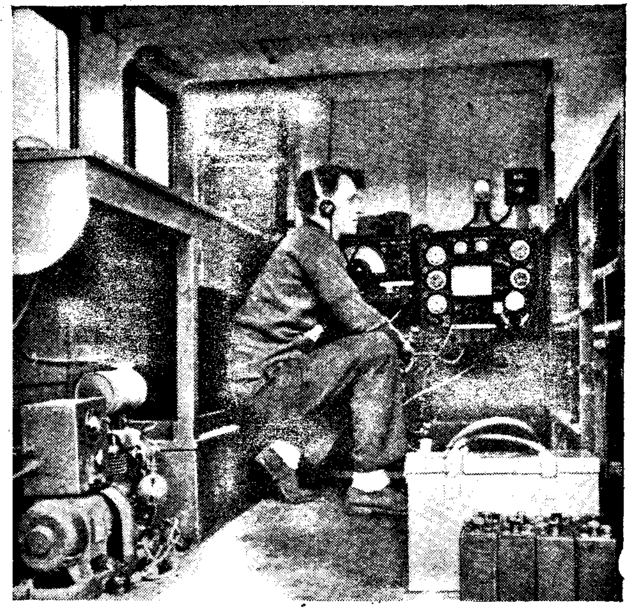
The most marked symptoms noted have been undue fatigue and headaches, irritability and depression extending outside the working day, insomnia and nightmare, lack of confidence in fellow workers, and a "drawing" sensation in the forehead and scalp. It would appear desirable that such ultra-high-frequency transmitters should be screened with an earthed cage of metal. The expense might soon be covered by the increase n the quality of the work done by the station staff.

Medical research, which has led to the development of the modern short-wave radiotherapy, was first initiated when it was noted that workers in the neighbourhood of HF transmitters, who had in the past suffered from neuritic pains such as sciatica, felt a recurrence of these pains when exposed to the HF field.

These facts are all, of course, confirmatory of the existence of a *specific effect* of short-waves—which is strenuously denied by most medical research workers in this country but accepted by those on the Continent and in America. Such specific effects were demonstrated by the writer on frog nerve-muscle preparations in papers read at the first International Congress of Short Waves in Physics, Biology and Medicine held in Vienna in 1937 and are used in medicine by treatment with low-intensity short-ave apparatus.

Other physiological effects which are known to occur through the use of short waves of high or low intensities are markedly a sedative effect on the nerve endings, leading to relief of pain, great increase in the circulation of the blood caused partly by heat and partly by a dilatation of the capillaries, selective killing of bacteria by means of exposure to varying wavelengths, increase in the rate of bloodclotting, local increases in the number of white blood cells and various changes in the blood chemistry. There are definite effects on the vegetative nervous system and the internally secreting glands of the body. The writer has observed, but not yet published, remarkable improvement in diabetes following extremely low-intensity irradiation of the pituitary region.

The World of Wireless



Mobile wireless maintenance van used by R.A.F. Bomber Command. The spaces on the right are for housing test gear and spares.

U.S. INTERNATIONAL STATIONS

FOR some months the policy of operating United States international short-wave stations in war-time has been under consideration. It was at first proposed that the Government should take over the operation of the existing stations but this plan has given place to one of Government "partnership" with existing operating companies.

The proposed scheme provides for the erection of twenty-two new short-wave stations, the power of which will vary from 50 to 100 kW. It is also proposed that the frequencies required for the new stations should be taken from those allocated to other than international broadcasting services.

The Government, through the Board of War Communications, will pay for the erection and operation of the new stations which will be licensed to existing or new operators. It is proposed to offer the transmitters for sale after the war to the companies operating them. Programmes of all short-wave transmitters will continue to be controlled by private operators but with the Government holding a "watching brief."

Commenting on the plan, our American contemporary *Broadcasting* writes: "It seems a pity that so simple a plan should have taken so long to evolve. It will probably take at least six months to get the projected 22 new short-wave transmitters on the air. Meanwhile, the Axis powers, with their own and their seized stations, numbering at least 100, are scattering their propaganda far and wide to the corners of the earth."

R.A.F. WIRELESS MAINTENANCE

TO facilitate the maintenance of the wireless equipment of bomber aircraft at the numerous airfields, mobile wireless testing vans are now being used by R.A.F. Bomber Command. In addition to being used for general maintenance of W/T and R/T airborne equipment, they are also employed for frequency checking of aircraft apparatus.

The van illustrated is equipped with an aircraft-type W/T and R/T transmitting and receiving set to permit of two-way working with aircraft on the ground. A petrol engine generator is included in the equipment so that accumulator charging and servicing can be undertaken when other facilities are not available. To enable the wireless mechanic to reach inaccessible parts of an aircraft, a catwalk is provided on the roof of the vehicle.

EMPIRE COMMUNICATIONS

TO deal with the many Empire communication problems arising out of the war a Commonwealth Telegraph Conference is shortly to be held in Australia. Government representatives from Canada, New Zealand, the Union of South Africa, India, Southern Rhodesia, Australia and the United Kingdom will be taking part. The United Kingdom representative will be Sir Campbell Stuart, chairman of the Imperial Communications Advisory Committee in London, who will also be chairman of the conference. He has left for Canberra accompanied by Colonel Zambra, who is secretary to the Imperial Communications Advisory Committee.

It is understood that, as the conference is being called for Government representation only, Cable and Wireless has not been invited to take a seat at the conference table.

It is also learned on enquiry that the General Post Office will not be represented.

AMERICAN VALVES

AT the time of writing the promised release of the American Lease-Lend valves for replacements in "silent" sets announced last month has not materialised.

It is understood that some difficulty is being experienced in formulating a scheme of distribution to ensure that the valves supplied are for *replacements* in domestic receivers at present out of commission.

WEATHER AND U-S-W

SOME interesting facts regarding the influence of weather on the propagation of ultra-short waves emerge from a study of the records of signal strength variations in the Post Office radio telephone link between Guernsey and England from 1937 to 1939.

The path between stations was about 85 miles in length over sea, of which 36 miles was outside the optical range; the wavelengths employed were 5 and 8 metres. Continuous records taken by the Post Office were analysed by Dr. R. L. Smith Rose and Miss A. C. Strickland, M.Sc., to show correlation between signal strength and atmospheric conditions. The results are given in a paper recently read before the I.E.E.

It is clearly established that weather has an influence on the variations signal intensity. During periods high barometric pressure, often accompanied by temperature inversions, signal strength was at a maximum, but there was much fading of the slow type. Low-pressure conditions with very little temperature inversion gave the steadiest signals though of rather low level. Snowy and foggy weather also gave a steady signal even when the atmospheric pressure was high.

The authors conclude: "It seems clear that the main agencies causing variations in signal intensities on these wavelengths are the variations in refractive index of the air in the lower atmosphere, due notably to changes in moisture content, and in addition the presence or absence of temperature inversion layers from which the waves can be reflected at heights of from a few hundred to a few thousand feet."

NON-FERROUS METAL APPEAL

COPPER, lead, zinc and tin, which are imported from Africa, North and South America and Australia, are urgently needed in our war factories and shipbuilding yards. They are wanted for numerous vitally important uses in their pure form and because they provide in alloyed form brass, bronze and anti-friction bearing metal.

To speed up the supply of non-ferrous metals and to save as much shipping space as possible, the Directorate of Salvage and Recovery of the Ministry of Supply, has issued an urgent appeal to the wireless industry for all unwanted copper, zinc, lead, pewter, white metal, brass, bronze and aluminium.

It is everybody's responsibility to see that these vital metals are rescued from the scrap heap and sent to the local salvage authority.

EMPIRE NEWS

ALTHOUGH short waves are necessarily the medium for the transmissions in the B.B.C. Empire Service, the audience is by no means restricted to listeners with short-wave sets. All over the Empire, as well as in the United States, transmissions of Empire News and other programmes from London are received and are re-broadcast by local stations on medium waves, or, as is the case in a number of West Indian and African colonies, by rediffusion systems. In Nigeria, for instance, the B.B.C. programmes are rediffused for over 14 hours a day, while in the Gold Coast and Sierra Leone transmissions from London are rediffused for 6 hours daily. The rediffusion system in Malta relays London almost continually throughout the day.

In all, the B.B.C. Empire Service is rebroadcast for over 39 per cent. of its transmission time. The figure rises to over 84 per cent. if the rediffusion systems are included. The transmission most rebroadcast, of course, is the news.

The latest schedule of the times (BST) of the transmissions of news in English in the Empire and European Services, and the wave bands in which they are radiated, is given below.

0200	49, 31	1600	31, 25, 19, 16
0345	49	1700	31, 25, 19, 16
0530	49, 41	1900	25, 19
0715	41, 31	2045	31, 25, 19
0900	41, 31, 25	2245	49, 41, 31*, 25*
1000	49, 41, 31, 25	2345	49, 31
1200	25, 19		

* Sundays excepted.

The morse transmissions of news in English, French and German on 261 metres and in the 49-metre band continue to be radiated at 0230, 0300 and 0330 (BST) respectively. For ease of reception each word of the transmission is repeated.

OUR NEXT ISSUE

To conserve paper, and, we hope, to enable more would-be readers to obtain copies of *Wireless World*, we are temporarily adopting a new *format*, with a slightly reduced page area. The January issue will be on sale on December 28th. Succeeding issues will appear on the 25th of the month preceding the nominal month of publication.

IN BRIEF

New "Forces" Transmission

A NEW transmission "For the Forces" was introduced by the B.B.C. on November 1st. It is designed for the men in the Middle East and West Africa. The transmissions beamed to the Middle East are radiated in the 19-metre band from 15.45 to 17.45 and in the 31-metre band from 17.15 to 21.00. The West African transmission is radiated in the 25-metre band from 20.00 to 21.00 and in the 31-metre band from 21.00 to 22.45.

Indian Standard Time

THE introduction in September of the new Indian Standard Time, which advanced clocks one hour, has changed the timing of most of the English news bulletins broadcast from Delhi. These changes are included in the schedule given below. It is interesting to note that no change has been made in the timing

NEWS IN ENGLISH FROM ABROAD

REGULAR SHORT-WAVE TRANSMISSIONS

Country : Station	Mc/s	Metres	Daily Bulletins (BST)
America			
WNBI (Bound Brook)	17.780	16.87	2.0†, 2.45‡, 4.0§‡, 6.0.
WRCA (Bound Brook)	9.670	31.02	7.0 a.m., 9.45 a.m.
WRCA	15.150	19.80	2.0†, 2.45‡, 4.0§‡, 6.0.
WGEO (Schenectady).	9.530	31.48	9.45 a.m., 9.0†, 10.55§‡.
WGEA (Schenectady).	15.330	19.57	2.0, 3.0, 7.45§‡, 11.0.
WBOS (Hull)	11.870	25.27	12.45 a.m.†, 12.0 mdt.
WBOS	15.210	19.72	2.0†, 2.45‡, 4.0§‡, 6.0.
WCAB (Philadelphia).	6.060	49.50	6.0 a.m.
WCBX (Wayne) ..	15.270	19.65	11.30 a.m., 3.30, 7.30‡, 9.30.
WCRC (Wayne) ..	11.860	25.30	11.30 a.m., 3.30, 7.30‡, 9.30.
WCW (New York) ..	15.870	18.90	3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0.
WRUL (Boston) ..	11.790	25.45	9.30‡.
WRUL	15.350	19.54	9.30‡.
WLWO (Cincinnati) ..	6.080	49.34	6.0 a.m., 7.0 a.m.
WLWO	11.710	25.62	7.0, 8.0, 9.0, 10.0.
WLWO	15.250	19.67	3.0, 4.0, 5.0.
Australia			
VLQ6 (Sydney) ..	9.580	31.32	7.0 a.m.
VLQ5 (Sydney) ..	9.680	30.99	8.0 a.m.
VLG3 (Melbourne) ..	11.710	25.62	8.0 a.m.
China			
XGOY (Chungking) ..	11.900	25.21	2.0, 4.0, 5.15, 9.30.
French Equatorial Africa			
FZI (Brazzaville) ..	11.970	25.06	8.45.
India			
VUD4 (Delhi) ..	9.590	31.28	8.0 a.m., 1.0, 3.50.
VUD3	11.830	25.36	3.50.
VUD3	15.290	19.62	8.0 a.m., 1.0.
Spain			
EAQ (Aranjuez) ..	9.860	30.43	6.15.
Sweden			
SBU (Motala) ..	9.535	31.46	10.20.
SBT	15.150	19.80	4.0.
Turkey			
TAP (Ankara) ..	9.465	31.70	7.15.
U.S.S.R.			
Moscow	5.890	50.93	11.0.
	6.970	43.04	11.45.
	7.300	41.10	8.0, 9.0, 10.0, 11.0.
	7.360	40.76	11.0.
	7.560	39.68	11.0.
	9.390	31.95	4.0.
	11.830	25.36	4.0, 6.0.
	15.110	19.85	2.15 a.m., 12.40, 11.45.
	15.180	19.76	12.40, 11.45.
	15.230	19.70	2.15 a.m., 11.45.
	15.270	19.65	12.40.
	15.750	19.05	1.0 a.m., 2.0 a.m., 11.45
Kuibyshev	8.050	37.27	8.30.
	13.010	23.06	6.0 a.m., 2.0, 2.45.
	14.410	20.82	2.0, 2.45.
Vatican City			
HVJ	5.970	50.25	7.15.

MEDIUM-WAVE TRANSMISSIONS

Ireland	kc/s	Metres	
Radio Eireann ..	565	531	1.40‡, 6.45, 10.0.

It should be noted that the times are BST—**one hour** ahead of GMT—and are p.m. unless otherwise stated. The times of the transmission of news in English in the B.B.C. Short-wave Service are given at the top of this page.

* Saturdays only. § Saturdays excepted. † Sundays only. ‡ Sundays excepted.

The World of Wireless—

of the programmes for India's many rural listeners, "whose work and habits are ruled more by the movements of the sun than by the hands of the clock."

New Indian Station

WHEN in 1937 the Government of India, at the request of the Government of the North-Western Frontier Province, took over the 0.25-kW broadcasting station erected by Marconi's at Peshawar five years earlier, there were but a few villages equipped with communal receivers. The situation has changed sufficiently to warrant the erection of a new 10-kW transmitter, which is now working on a wavelengh of 476.9 metres. The station has a 350ft. mast radiator aerial.

Dr. Leonard Klatzow

WE record with regret the death at the early age of thirty-five of Dr. Leonard Klatzow, who since 1934 had been engaged on research work at Electric and Musical Industries. A native of South Africa, he came to this country as a Rhodes Scholar in 1930 and obtained his Ph.D. degree three years later. His work on the Emitron television camera from the photo-electric angle was largely responsible for the success of the transmissions from the London television station. A colleague wrote in *Nature:* "His work, largely unpublished, did not receive the wide recognition it deserved, but there is no doubt that a career of increasing distinction was opening before him."

GOODS FOR EXPORT

The fact that goods made of raw materials in short supply owing to war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export

United States High-power Transmitter

IT is learned from Washington that the United States Government has purchased a new 500-kW short-wave broadcasting transmitter.

School Broadcasting

A TOTAL of 10,429 schools in England and Wales have registered as listening schools with the Central Council for School Broadcasting. This is the highest number recorded at the beginning of a school year, being 469 more than the number registered at the beginning of the previous year, which was itself over 2,400 higher than the figure for any other year.

"Spoils of War"

MENTION is made in the official story of the conquest of Italian East Africa that signal material captured at Addis Ababa was valued at £250,000. This figure, of course, does not include the wireless station, which had been very little damaged and was rapidly repaired by Royal Signals personnel and put to use for propaganda purposes.

I.E.E. Meetings

A DISCUSSION on "The Electronic Control of Industrial and Power Plants" will be opened by S. G. King at the informal meeting of the Institution of Electrical Engineers arranged for Monday, November 23rd, at 5.30. Dr. G. E. Donovan, M.Sc., B.Ch., M.B., will deliver a paper on "The Electrical Amplifying Stethoscope and Phono-Electro Cardioscope," and give a demonstration of the apparatus at the Wireless Section meeting on Wednesday, December 2nd, at 5.30.

Scottish Radio Club

A CLUB conducted on parallel lines to the Radio Industries Club in London has now been formed in Glasgow. The membership of the new Radio Industries Club of Scotland is drawn from all fields of wireless activity, and is already nearing the hundred mark. A. S. Black, Scottish manager of the G.E.C., is chairman; James Robertson, who played a prominent part in forming the club, is vice-chairman; while the secretary is Elliot Macintosh, Principal of the Wireless College. His address is 3, Park Gardens, Clifton Street, Glasgow.

The Ever-growing Need

PROTECTION against the dangers of electrical short-circuit is one of the advantages claimed for the new petrol containers made of specially treated cardboard. This new application of paper stresses the ever-growing need of economy in its use and of salvaging every scrap of waste paper.