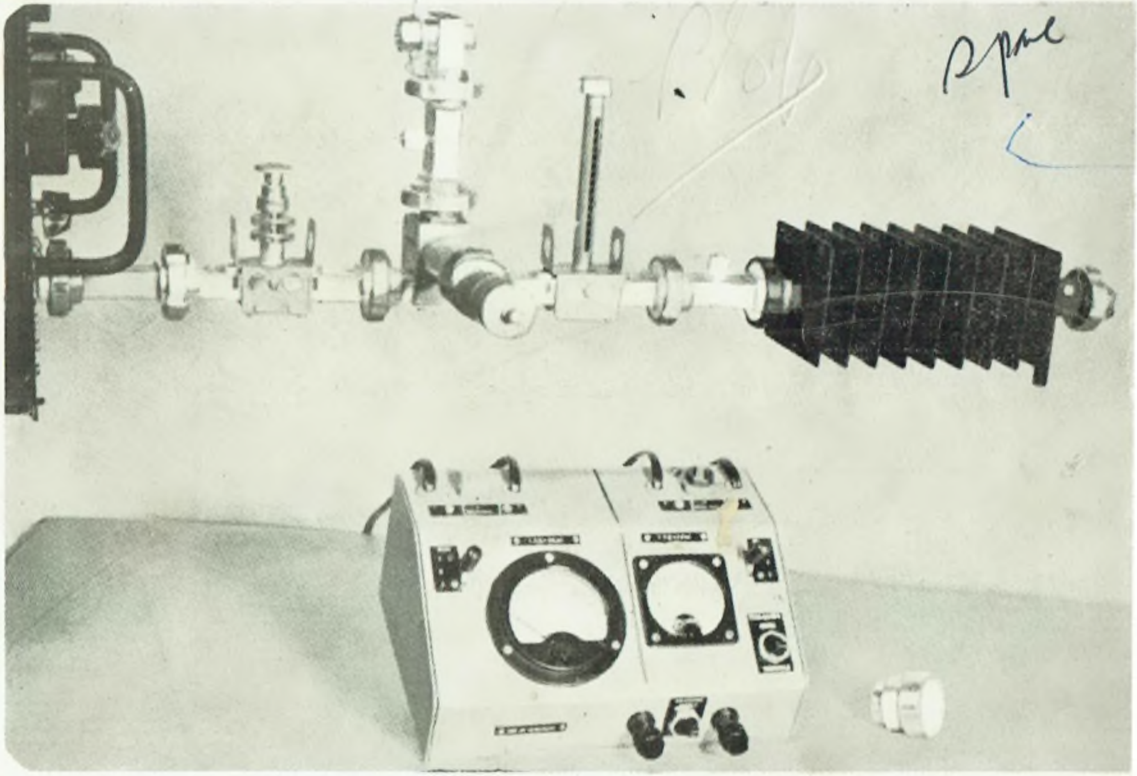
RADIO and ELECTRONICS



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THE BANDSPREAD SIX

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RADIO and ELECTRONICS

Vol. I, No. 7 October 1st, 1946

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OUR COVER this month illustrates some test equipment developed by Messrs. Siemens, of England. This "plumbing" used at centimetre wavelengths has no connection at all with the flow of liquids in pipes. The set-up includes sections of hollow wave-guide, matching stubs, and a "sink" (the radiator-like structure) for absorbing power from a microwave transmitter and for measuring its power output.

CORRESPONDENCE

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Domestic Sets of To-morrow

Since the war ended, a great deal of information has been divulged, both in the technical and popular press, about the outstanding war-time advances in the radio field. News of these achievements has been widely read, and the uninitiated public has been told that the advances in radio technique made during and just prior to the war were undreamed of as little as ten years ago.

All this is perfectly true: it is fitting also that the "back-room boys" should have had their light removed from under the bushel of "security," if only to show the public at large what fine fellows our scientists and engineers are, and to demonstrate just how the technical war was won.

Unfortunately, to the layman, radio is radio, whether at broadcast or super-high frequencies. To him, an advance in the latter argues a probable equal step forward in the former. Only the engineer knows that they are as the poles apart in technique, and that such reasoning is largely fallacious. One result is that the public expects the post-war models of the domestic radio set to incorporate the recent advances in radio engineering which have made possible such wonders as radar.

The fact is, of course, that developments in the ultra-high frequency region can affect hardly at all the design of receivers for broadcast frequencies. It is now many years since domestic receivers underwent any major development in circuit or valve design, and unless some hitherto unsuspected principle of radio reception makes its appearance any hope of vastly improved receivers is quite illusory.

True, it will ultimately be possible, as a result of war-time lessons in production, to turn out more sets in a given time, and therefore more cheaply than was possible in 1938. Standardisation will gradually come about, and "trick" circuits and mechanical design will tend to disappear, as they have done already to a large extent. Certain branches of the radio art will benefit by war-time research, but these will be mostly the ones which at the present time are operated on the ultra-high frequencies, and which can take advantage of our vastly extended knowledge of pulse techniques.

Television and frequency modulated transmission are among the services which can be expected to benefit most, while new developments such as multiplex transmission by means of pulse modulation, and the radio transmission of teletype signals will tend to replace the much more costly cable circuits which before the war carried these services. Here in New Zealand, frequency modulation and television have not yet made their debut, while the two latter examples will make their presence felt by the public only in indirect ways.

Although only a few examples have been presented here, those mentioned are quite typical of the kind of radio advance that will become general, and it is noteworthy that none of them are either desirable or practicable at broadcast frequencies.

While it is necessary for the general public to be kept informed of the rapid strides being made by radio and electronic technology, it is clearly the duty of someone to point out just what will and will not be the results as far as the every-day radio receiver is concerned. Only the technical man can do this, and it is patently to his own advantage to do so lest the impossible be demanded of him and his art.

RADAR

"OBOE"—A High-Precision Radar System

By M. G. Scroggie, B.Sc., A.M.I.E.E., Consulting Radio Engineer; ex-Squadron Leader R.A.F.

Used for precision bombing and target location in war-time, Britain's Oboe system now aids fundamental research. Its many ingenious techniques, of which examples are given here, add to the growing store of electronic capabilities.

The technical details of Oboe are so beautifully ingenious as to be worth studying even if they had no further use. It seems likely, however, that such techniques will be applied in many ways, perhaps far removed from the original intention. The Oboe system as a whole, although an entirely war-time development, is already being turned to peaceful research; and other uses have been proposed.

Oboe is the radar system whereby an installation on the ground can automatically release a bomb from an aircraft hundreds of miles away so that it falls 35,000 feet to land within a few yards of a target spot. Alternatively it can take one or a series of photographs over any desired points, without requiring the air crew to find them. Its accuracy is so great that it is even necessary to allow for the minute variations in the velocity of radio waves through space. It can tell a pilot 300 miles away when he is 18 yards off his course. Of the total error in bombing, only about one-tenth is due to Oboe itself; the accuracy is limited mainly by the difficulty of flying a high-speed aircraft within such a narrow lane.

POSITION-FINDING SYSTEMS

Several systems of position finding using pulse techniques were evolved during the war. In Gee and Loran the navigator observes the differences in time of arrival of synchronised pulses sent from ground stations; the accuracy is moderate, but any number of craft can use the system at once. In Gee-H, the pulses are sent from the aircraft and returned by respondors on the ground, the time for the return journey giving ranges from fixed points. Accuracy is much higher, but the number that can use the system is limited by saturation of the respondors. Oboe is even more limited, as a pair of transmitters can control only one aircraft at a time, but a still higher accuracy is achieved by reversing the Gee-H process so that the high-precision apparatus is installed on the ground, where the actual measurements are made; and all the aircraft has to do is to carry a respondor and follow simple signalled instructions. It is even possible to dispense with a crew!

The reason for the remarkable accuracy of Oboe is that it measures **range**, which is given by the speed of radio waves and the time they take to cover the distance. Time can be measured with greater precision than any other quantity, and the speed of radio waves is known very accurately, and for most purposes can be assumed constant. It does vary, however, mainly with height above ground, between the limits 0.001–0.01 per cent.; and Oboe is now being used to investigate these variations.

Two ground stations are used, marked T and C in Fig. 1. Suppose an aircraft is to be guided to point P. It first flies (aided if necessary by some less precise system such as Gee) to approximately the correct radius from T, the tracking station, but to one side of P, and then approaches P along the line AP at constant radius from T. T sends out pulses,

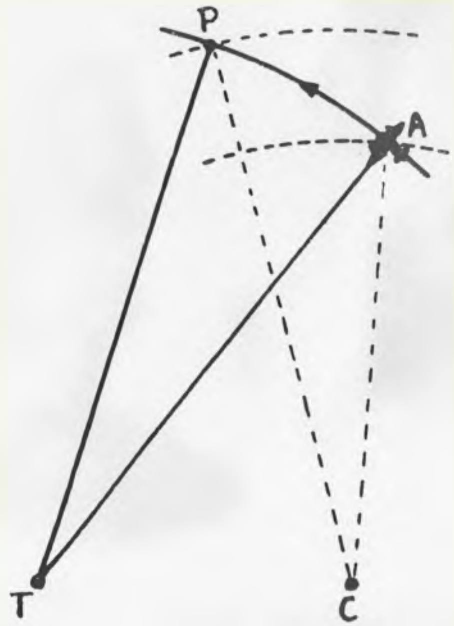


Fig. 1: Diagram of Oboe system, with ground stations at T and C, and aircraft flying along track AP to P.

which are relayed back by the respondor on the aircraft and received by T, which automatically calculates the distance by which the aircraft is off the track AP, and sends a signal which is heard by the pilot—dots if he is too near T and dashes if he is too far.

Meanwhile, C, called the releasing station when bombing was the only aim, but now broadly describable as the control station, is also sending and receiving pulses and measuring the range of the aircraft and hence its decreasing distance from P. Warning signals can be sent to the aircraft at, say, 10, 8, 6 and 3 minutes flying time from P, and finally at P a signal releases a bomb, takes a photograph, or performs any other desired act. One aircraft monopolises the attention of the two ground stations for about 10 minutes, so Oboe was used by the Royal Air Force mainly to drop flares accurately on appointed targets, so that large numbers of other aircraft were relieved from the difficult and uncertain task of finding the target in the dark.

The same principle can be applied to control an automatic pilot over a specified track, measure wind velocities at high altitudes, and so forth.

GROUND EQUIPMENT

Oboe ground equipment is very complex; and short of going into very lengthy detail only a broad outline can be given, to illustrate some of the interesting features. The circuit details are given in a paper shortly to be published in Part IIIA of the Journal of the Institution of Electrical Engineers, London.

The starting point at both T and C stations is a very precise 93,117 c/sec. crystal oscillator. The duration of each cycle is the time taken by a radio wave, travelling at 186,234 miles per sec., to cover one mile and back. These oscillator cycles are distorted into "pips" and displayed along cathode ray tube time base lines as range scales (Fig. 2), each fifth mile pip being lengthened and every 25th mile pip further lengthened. The same oscillator frequency is divided to something in the region of 100 c/sec. to control the start of the C.R.T. time bases and, 50 microseconds later, to trigger the release of pulses from the transmitters. These pulses are sent out on about 10 centimetres wavelength. It is, therefore, necessary for the aircraft to fly high at the extreme ranges—say, 30,000 feet at 300 miles. As the pulses returned by the aircraft are generated by an airborne transmitter triggered by the ground transmitter, they can be received at much greater distances than echoes reflected from a non-co-operating object.

The display at the receivers (both T and C) is in two parts, shown in Fig. 2. Firstly there is a time base covering the whole range from transmitter to aircraft. Only 5-mile and 25-mile pips appear on it. A small section, 1½, 6, or 15 miles in duration, can be selected from the first time base, beginning at any desired mile, and magnified up to give the second, on which 1-mile and 5-mile pips appear. The selected section is marked on the first by a local brightening of the trace.

The two time base displays together can show the range of an aircraft up to 300 miles with an accuracy better than 18 yards. Incidentally, before it was possible to get the benefit of such precision it was necessary to relate the Continental geographical surveys to the British with greater accuracy than hitherto.

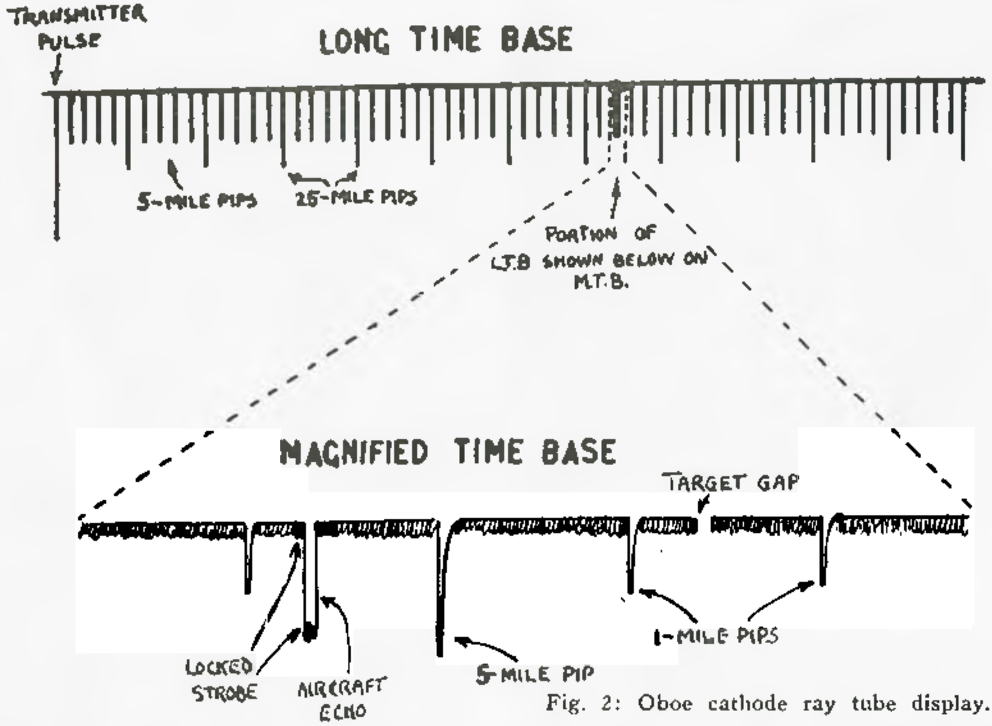


Fig. 2: Oboe cathode ray tube display.

On the magnified time base, the calculated position of the target to which the aircraft is to be guided is marked by a gap in the trace. The "echo" from the aircraft appears as a pip, which approaches the gap. In order to provide the signals from T and C to the aircraft, it is necessary to know the remaining distance to the target, and also the velocity of the aircraft within ½ m.p.h. These are calculated electronically, making use of a brightening marker or "strobe," which is first set by hand on the magnified time base to coincide with the echo, after which it automatically follows the echo wherever it goes. Even if the echo fades out temporarily, the strobe has a "memory" and continues to move at the same rate as it was doing when the fade took place, so that normally it will be close enough to the echo, when it reappears, to be able to relock to it.

From the data provided by the strobe and target gap positions on the base, computor circuits control the signals sent to the aircraft. These signals are conveyed by pulses transmitted in between the range measuring pulses, their exact positions in between forming the means of signalling. Suppose the main pulses occur 100 times per second. When the signal pulses are midway between, the result is a signal of 200 c/sec., to which a filter in the aircraft receiver is tuned. Maximum response therefore results. But when the signal pulses are delayed, the frequency is no longer 200 c/sec. and the response is less. Thus, a loud morse "dot" is transmitted by making the signal pulses occur midway during a period of time corresponding to a dot, and delaying them during the interval between one dot and the next.

As all pulses sent by both ground stations are relayed back by the aircraft, each station can hear what signals the other puts out, and can communicate with one another via the aircraft!

When the bomb-dropping or other operative signal is given, it cuts off the aircraft transpondor, so the fact of release is indicated to the ground, and the exact time and position are recorded there.

TECHNICAL DETAILS

Even though the foregoing description is so very brief, and confined to the main features, it may be enough for the reader to deduce that among other things the circuits must include:

(1) A frequency divider;
(2) A precise and adjustable time delayer;
(3) An extremely linear time base; and
(4) An accurate integrator.

The integrator, due to A. D. Blumlein, of Electrical and Musical Industries, Ltd., England, is shown in simple form in Fig. 3; and forms the basis of circuits performing the other three functions. One

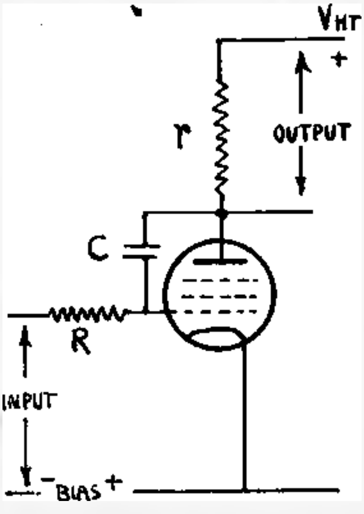


Fig. 3: Essentials of Blumlein integrator circuit.

of these, the phatastron, devised at the British Telecommunications Research Establishment, and used chiefly for functions (1) and (2), occurs over and over again in the Oboe equipment.

Referring first to Fig. 3, suppose a large positive voltage is applied at the input for a period of time. The capacitor C was previously charged by V_{HT}, but now discharges through R and r. The grid voltage starts to rise, which makes the anode potential fall. As the voltage gain of the valve is designed to be very high—at least 100—the grid voltage rise is almost negligible in comparison with the anode fall, and therefore the current through R, and hence the discharge rate of C, and the rate of change of voltage across r, are all practically proportional to the input voltage. If the input voltage is made constant, say, by connecting the input end of R to V_{HT}, the output voltage changes at a constant rate, giving an extremely linear time base.

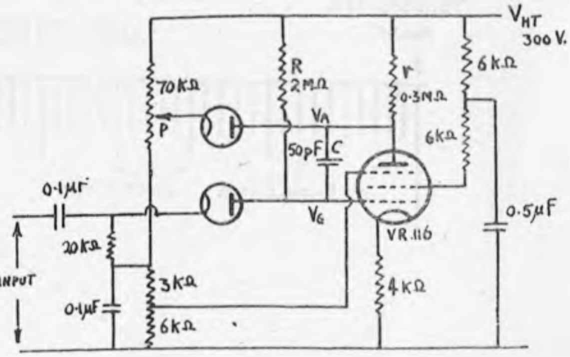


Fig. 4: Phantastron circuit.

In the phantastron, an example of which is shown in Fig. 4, the anode current is initially cut off, because the suppressor grid is held more negative than the control grid or the cathode. The space current is diverted to the screen, which therefore is at a relatively low potential. The two diodes are for setting anode and control grids to desired maximum potentials. When a negative pulse is applied at the input shown (or alternatively a positive pulse to the suppressor grid), this stable state is upset. Anode current starts to flow, making the anode move negative, and (through C) holding the grid negative after the triggering pulse has ended. V_{HT} through R tries to make the grid positive again, and the valve, with R, C and r, acts as described for Fig. 3 until the valve ceases to amplify because the anode potential is as low as it can be. The control grid potential then rises comparatively quickly, and as the suppressor grid fixed potential thereby becomes relatively negative the space current is switched back from anode to screen, and the valve is restored to its initial state. The sequence of events is shown by the potential diagram, Fig. 5.

By selecting the values of C and R and adjusting the potential P, the time T can be set to give a signal (from any of the electrodes) at any desired delay after the triggering pulse. With the values marked in Fig. 4 it is of the order of 50 microseconds, being calculated from

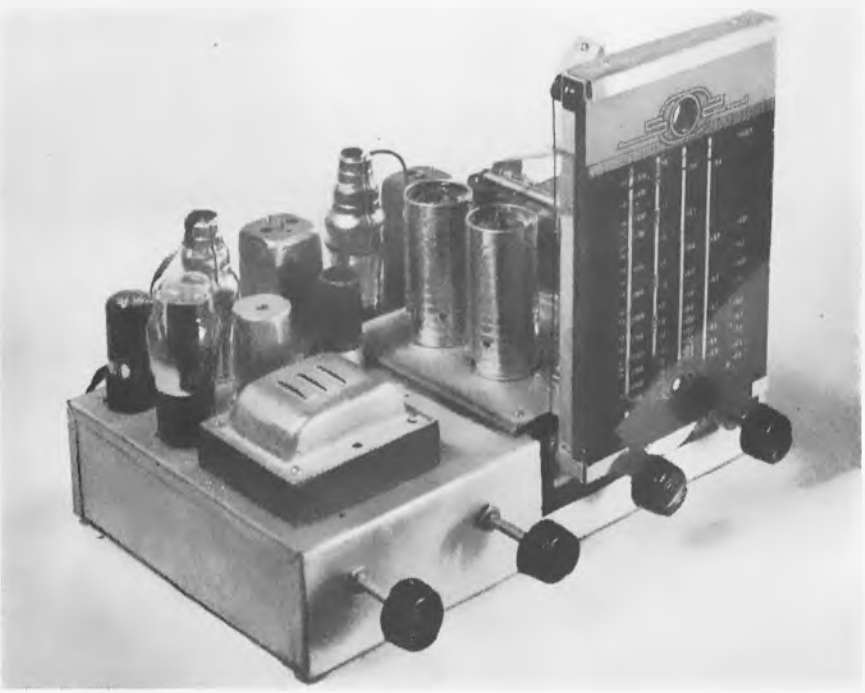
$$T = (V_A - V_G)\, CR/(V_{HT} - V_G).$$

The anode potential provides an extremely linear

(continued on page 40)

THE BANDSPREAD SIX

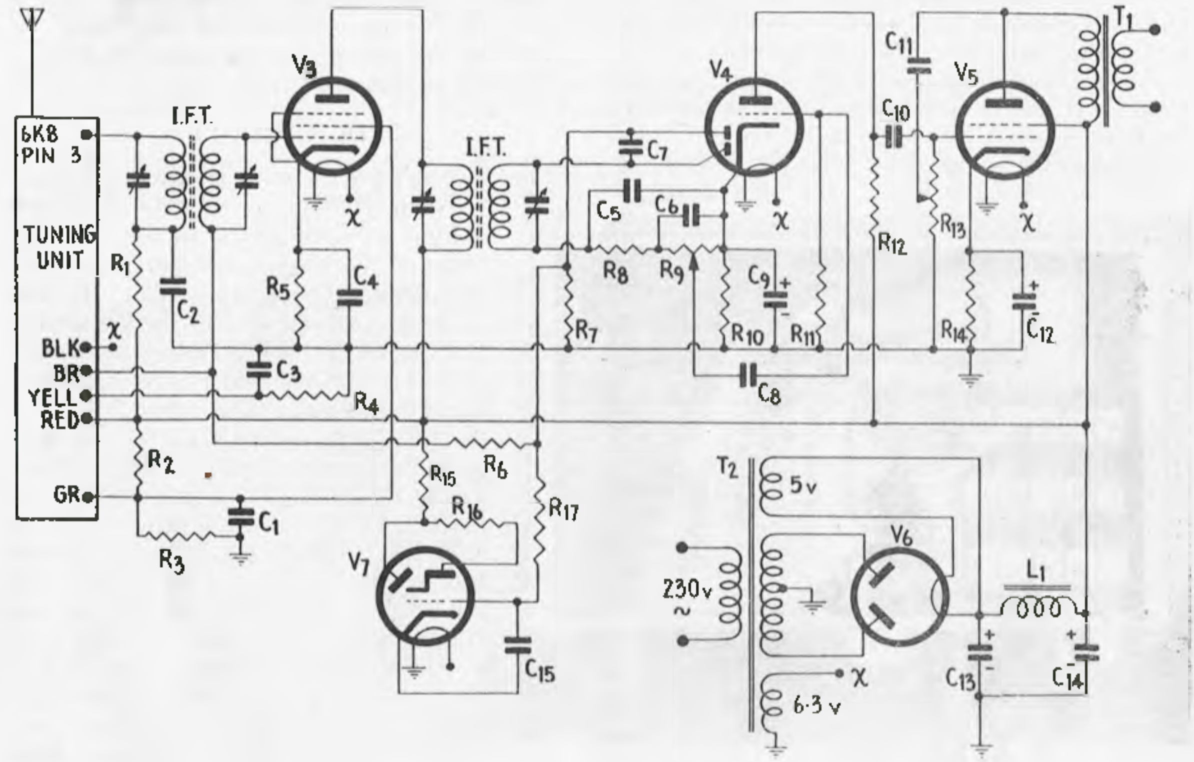
While it is at variance with *Radio and Electronics'* normal policy of publishing constructional articles based solely on equipment designed and constructed by our own staff, the bandspread tuning unit round which this set is built represents such an outstanding development in the kit-set field that we have decided, in this instance, to waive our usual rule and publish a full constructional article describing it.



There should be little necessity here to point out the advantages of a bandspread receiver for shortwave listening. Bandspreading, or the practice of making a very small range of frequencies cover the full 180-degree rotation of the dial is not in itself a new idea. Until the short wavelengths (or higher frequencies) came to be used for radio communication, there was little or no necessity for it, for tuning on the longwave and broadcast bands is quite easily accomplished without recourse to anything more complicated than a simple dial mechanism, which allows four or five rotations of the tuning control to rotate the condensers their full 180 degrees. The necessity for bandspreading on the higher frequencies arises from the fact that dual or allwave receivers must use the large (350 to 500 $\mu\mu f$ max. capacity) tuning condensers, that are necessary for the broadcast band, on the shortwave ranges also. When this is done, only a very small angular rotation of the tuning-knob causes the 20 kc/sec change in frequency necessary to tune right across a single station, making shortwave stations very difficult to tune, and in addition, more and more difficult the shorter the wavelength. Bandspreading by mechanical or electrical means has long been resorted to in the design of communication receivers, in order to overcome this difficulty, but until just before the recent war, it was found much too expensive a process to allow the economical production of domestic receivers incorporating its advantages. However, modern components and production technique have made such sets a payable proposition to the manufacturer and a boon to the average shortwave listener. The technical difficulties are somewhat great for the amateur constructor to be successful in designing and building a bandspread unit for himself, however, so that the firm which has designed the tuning unit used in this set has shown a commendably progressive spirit in making the advantages of bandspread available to home constructors. In turning out this unit, the manufacturer has taken

THE TUNING UNIT

The tuning unit as supplied to the builder consists of R.F. amplifier and oscillator-mixer stages, using the valves 6U7-G and 6K8-G respectively. The complete set of coils, with the gang con-

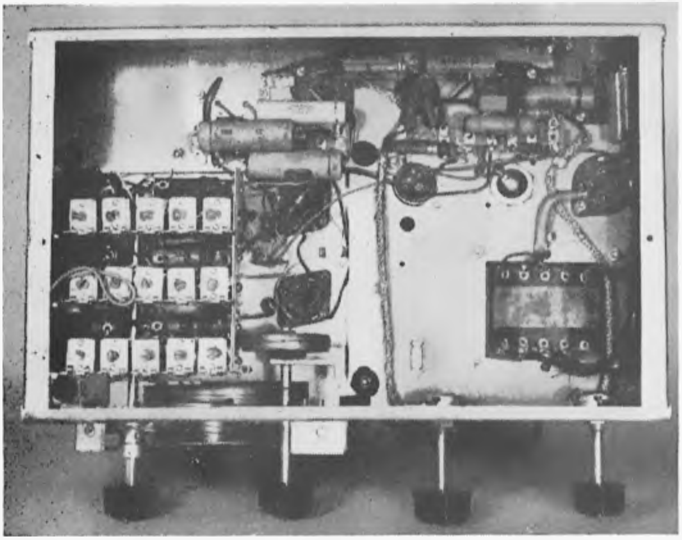


COMPONENT LIST

R_1 = 2k.
R_2 = 10k.
R_3, R_8 = 50k.
R_4 = 150 ω
R_5, R_{14} = 250 ω
R_6, R_7, R_{11}, R_{16}, R_{17} = 1 meg.
R_9, R_{13} = 500k. pot.
R_{10} = 4k.
R_{12} = 250k.
R_{15} = 25k.
T_1 = Output transformer to match single 6V6.
T_2 = Power transformer 385-0-385v. 80 ma. 6.3v. 3 amps., 5v. 2 amps.
C_1 = 0.25μf.
C_2, C_3, C_4 = 0.05μf.
C_5, C_6, C_7 = 0.0001μf.
C_8, C_{10} = 0.02μf.
C_9, C_{12} = 25μf. 25v. electro.
C_{11} = 0.00025μf.
C_{13}, C_{14} = 8μf. 450v. electro.
C_{15} = 0.01μf.
L_1 = 1500ω speaker field.
V_1 = 6U7-G}
V_2 = 6K8-G{
On tuning unit.
V_3 = 6U7-G.
V_4 = 6Q7-G.
V_5 = 6V6-GT.
V_6 = 80.
V_7 = 6G5.

to himself all the technical difficulties, leaving the constructor with, if anything, an easier job in assembling the complete set than he would have with, say, a normal dual or triple-wave kit-set,

denser, dial, trimmers, and all other circuit components, is supplied mounted on a chassis approximately eight inches square. In addition, the unit is completely wired up, with all trimmers adjusted and sealed in place. From the unit emerge seven wires, inclusive of aerial lead, which are soldered during construction to the appropriate points on the circuit. Thus, all the constructor has to do is to assemble the I.F. stage, second detector and A.V.C., and audio stages. This part of the set is quite conventional, and offers no more difficulty to the constructor than the corresponding part of a simple broadcast receiver. It should be mentioned here that the pre-calibrated dial has mounting facilities for a magic-eye tuning indicator, not included in the count of six tubes for the set.



Under-chassis view of the Bandspread Six.

TUNING RANGES

The tuning ranges provided by the bandspread unit are as follows: (1) Broadcast, 550-1600 kc/sec.; (2) a general coverage shortwave band from 6 to 19 mc/sec.; (3) 31-metre band, 9.4 to 10 mc/sec.; (4) 25-metre band, 11.4 to 12.4 mc/sec.; and (5) 19-metre band, 14.875 to 15.8 mc/sec.

This is a very economical arrangement, giving full spread on the three most important shortwave broadcasting bands, while the 16m., 41m., and 49m. bands are available on the general coverage band only. The method of bandspreading is to use condensers in series and parallel with the main gang. Only one set of shortwave coils is used, since all the bands which are spread appear in the range covered by the general shortwave band.

LAYOUT

This can be seen easily from the photographs of the completed set. Directly behind the tuning unit is the first I.F. transformer, after which the layout follows the circuit diagram exactly along the back of the chassis. Behind the 6V6-GT output tube at the extreme left-hand corner is the 80 rectifier, and next to the latter are the two electrolytic condensers C_{13} and C_{14}.

THE CIRCUIT

The circuit used for the complete set is quite conventional, but some parts of it look a little different owing to the fact that some of the components not shown are incorporated in the tuning unit. R_2 and R_3 form a voltage divider for the screen-grids of the first three valves in the set, while C_1 is a common bypass condenser for all of them. The green lead from the unit is the screen feed for the R.F. and mixer stages, and goes to the junction of R_2 and R_3. The yellow lead from the unit comes from the cathodes of the first two valves. R_1 is their common bias resistor, and C_3 a common bypass condenser. The brown lead from the unit is the A.V.C. return for the R.F. and mixer tubes, and so is connected to the A.V.C. line. No bypass condenser appears on the circuit at the "low" end of the first I.F. transformer secondary. This is because the brown A.V.C. lead is already bypassed inside the tuning unit. R_4 and C_2 form a decoupling filter which keeps R.F. from getting into the main H.T. lead and possibly causing instability. Very often such a filter can be dispensed with, but it is a very good and inexpensive insurance against poor performance.

The second detector-A.V.C. circuit is quite normal, the detector diode load being the volume control. It is returned to the 6Q7 cathode so that there is no delay voltage applied to the detector diode, which will work on even the weakest signal. However, the A.V.C. diode load is returned to earth. Thus, this diode has its plate approximately three volts negative with respect to its cathode, so that a signal of three volts peak is required at the A.V.C. diode before it starts to conduct. In this way, the very weakest signals do not operate the A.V.C., and the set sensitivity is at maximum. Tone control is effected by the popular negative feedback method, through C_{11} to

the moving arm of R_{13}. The power supply is quite conventional also, and requires no special mention.

CONSTRUCTION

The layout of small parts can be seen easily from the under-chassis photograph. The terminal strip behind the tuning unit supports R_1, R_2, R_3, R_4, C_1, C_2, and C_3. This makes the leads from the tuning unit as short as possible. In mounting these parts, the best plan is to solder them to the terminal strip first of all. Then the tuning unit is screwed into place and the leads soldered to the terminals. Last of all, the strip is mounted in position on the chassis. In wiring up the second detector and audio sections, two small terminal strips are used. These can be seen in front of the 6Q7 tube socket and the second I.F. transformer respectively. The first of these has five lugs, and is mounted by the centre one between the 6Q7 socket and the electrolytic directly behind the power transformer. On it are mounted R_6, R_7, R_{11}, R_{12}, and C_8. The second strip has three lugs only, and is used to terminate R_8 and the "high" ends of C_5 and C_6. The volume control R_9 is mounted on the front of the chassis, and its three leads run in a piece of shield braid to the detector circuit. The braid is earthed at intervals along its run. Similarly, the tone control R_{13} is mounted on the front of the chassis. This time, only two leads are run inside the shield braid—that to the moving arm from C_{11} and that to the 6V6 grid from the "high" end of R_{13}. The other end of R_{13} is earthed to the chassis and to the shield braid.

LINING UP

Since all the R.F. alignment is performed in the factory, and the adjustments sealed before delivery of the unit, lining up the completed set consists only in adjusting the I.F. transformers correctly to 465 kc/sec. Since it can be assumed that the R.F. unit is correctly aligned, I.F. adjustment should be possible without a signal generator. The procedure is to set the dial to the indicated frequency of a known station, and to bring the I.F. trimmers into line with the R.F. unit. In adjusting the trimmers, start with the one feeding the diode circuits and work backwards, without touching the main tuning dial. While doing this, it is advisable to use as small an aerial as possible. It may be possible to complete the operation using only the aerial lead which is attached to the tuner. If so, so much the better, because the signal used for I.F. alignment should be preferably small enough not to operate the A.V.C. This can be gauged by watching the magic eye, which will not start to close if this condition is fulfilled. The magic eye itself may be used as an indicator of signal strength, and the trimmers adjusted for maximum eye closure, but still the signal used should be as small as possible so as to just operate the eye and no more.

When the I.F. stage has been initially aligned as above, using a broadcast station, it is best to turn to the middle of the 25-metre spread band, and complete the job of lining up by adjusting the I.F. trimmers *on noise only*. The tuning dial should not be set on a station, and the volume control is set to maximum. If now the tuning of the I.F. trimmers is adjusted for maximum noise (but little alteration should be required from the previous setting), the set will be tuned "on the noise," and the best results will be obtained.

When the I.F. stages are properly aligned, no further adjustment should be necessary, and attaching the aerial and twirling the dial should bring in stations from all over the world without any trouble.

AERIALS FOR 10 METRES

In Part 1 of this article the desirability of directional arrays was indicated, and some useful types of non-directional aerials were described. In this section we will describe a few of the lesser-known types of directional aerial, and how they may be fed from the transmitter.

THE RHOMBIC

A comparatively recent development in directional aerial technique is the rhombic aerial. Its name is derived from its shape, for it consists of two wires erected in the shape of a rhombus. The latter is a plane figure whose four sides are all equal in length, but which does not have right-angled corners.

The rhombic aerial is characterised by extremely high directivity and power gain, but has the disadvantage of requiring a good deal of space for its erection, even at wavelengths as short as ten metres. It is entirely unsuitable for installation in the average city section, so that, for many, it will be only a thing to dream about, but for any amateur who lives in the country and has a good flat stretch of ground within reasonable distance of the house or shack where his transmitter is located, it is well worth some serious consideration.

HOW THE RHOMBIC WORKS

There is nothing at all mysterious about the action of the rhombic, in spite of the fact that it is not very well understood by many. It is a special case of the simple "long-wire" aerial. The horizontal directivity of the ordinary half-wave dipole is well known, but not so well known are the directional characteristics of the "long-wire." The latter term means a wire long compared with a wavelength at the frequency of operation, so that, for 10-metre working, any wire of 60 feet or more may be considered a long wire. If energy is fed into such a wire, it radiates with a horizontal directional pattern consisting of four major lobes, each of which makes an acute angle with the wire. As the latter is lengthened, the angle at which the four main lobes leave the wire becomes more acute, and at the same time the lobes become narrower and more directional. Thus, most of the radiation goes out in directions within a few degrees of the direction of the wire itself, though there are nulls in the pattern corresponding with the exact direction of the wire. If now the long wire is fed from one end, and a resistor is connected from the other end of the wire to earth, two of the four main lobes are suppressed. The remaining lobes are those which go out from the sending end towards the end terminated by the resistor. Fig. 4 is a diagram of a complete rhombic aerial, but the pattern which would be obtained from each leg alone were it fed and terminated as a single long wire,

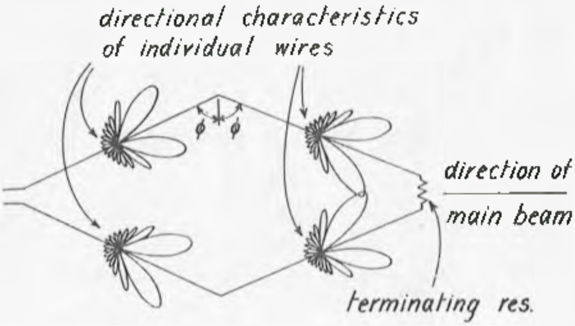


FIG. 4

is drawn on it. It should be noted that the wires are fed from the left-hand end, and are considered to be terminated by a resistor at the right-hand end.

The terminating resistor suppresses the lobes which would normally be present in the reverse direction, because it is adjusted to the correct value to eliminate reflections from the end of the wire to which it is attached.

Now, if the rhombic in Fig. 4 is considered as a whole, it may be thought of as made up of four long wire aerials, each with its own radiation pattern. It can be seen that four of the eight main lobes are shooting exactly along the main diagonal of the rhombus. It so happens that these four lobes are automatically phased in such a way that their radiation adds, producing a single, narrower lobe in the direction away from the end of the rhombic to which the feeders are attached. In addition, the lobes not directed along this line partially cancel each other, since they are out of phase, in pairs, and almost in opposite directions. The total result is a number of very small minor lobes, in addition to the single main lobe. Thus, the rhombic aerial is simply four long-wire aerials, arranged in such a way that some of the lobes add, whilst the remainder tend to cancel each other out.

Since the spacing and width of the lobes of a single long-wire decrease as the wire is made longer, it is apparent that the directivity of a rhombic should also increase as the length of its

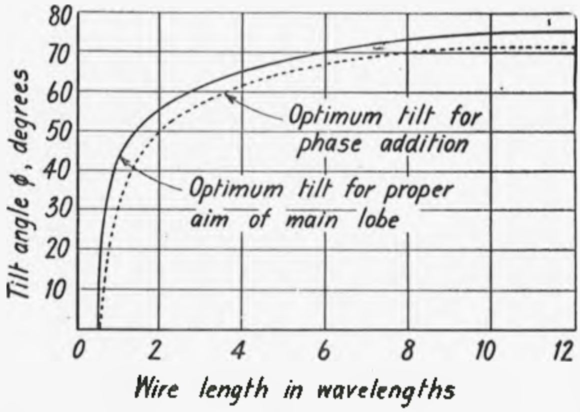


FIG. 5

sides is increased. The first three diagrams of Fig. 6 show how the horizontal directivity of a rhombic increases as the legs are increased from a length of 2λ to 4λ

DESIGN OF RHOMBICS

From the manner in which the rhombic works, it can be seen that not only the size, but also the angles between the legs of the aerial will affect the horizontal pattern obtained. The design of the rhombic from first principles is an exceedingly difficult matter, and has occupied some of the finest aerial engineers for a long time. As a result of their work, the optimum proportions for a rhombic have been found, and are presented in Fig. 5. The best half-angle between the wires at the side corners of the rhombus is shown in Fig. 5 for various lengths of leg, so that if it is desired to erect a rhombic aerial, it is necessary first to decide how much directivity is desired, and what the leg length will be in terms of wavelengths at the lowest desired operating frequency. Then Fig. 5 is referred to, and the optimum half-angle ϕ is found. Any value on or between the two curves will give satisfactory results.

VERTICAL PATTERN

As with all horizontal aerials, its height above ground has a marked effect on the vertical performance of the rhombic aerial. In free space, i.e., if there was no earth to act as a reflecting surface, the directivity in a plane at right angles to that of the wires is very much the same as that in the plane of the wires, which we have called the horizontal pattern. In Fig. 1 in Part I of this article, the vertical radiation patterns of a simple horizontal aerial were shown when erected at heights of $\lambda/2$, $3\lambda/4$ and λ respectively. An idea of the vertical directivity of the rhombic can be obtained by superimposing either of these patterns on the ones given for the *horizontal* pattern of the appropriate rhombic. At angles where a null appears in either pattern, there will be a null in the actual vertical pattern of the rhombic. Roughly speaking, the combined effect can be found by multiplying the two patterns together, i.e., the value of each pattern at a particular angle is taken, and the two values multiplied together. If this is done, and the new values plotted against the angle, a new pattern will be obtained, which gives a fairly accurate idea of the performance of the rhombic. However, all that needs to be done to choose a suitable height for the rhombic is to note whether the nulls in the height patterns of Fig. 1 come at such an angle as to nullify the large amount of radiation from the rhombic. Fig. 5 also shows the actual vertical patterns for three rhombics of differing heights as well as leg lengths. A noteworthy feature of the rhombic is that it does give considerable low-angle radiation as long as its height is suitably chosen. The question of choosing a height for the aerial is not as difficult as might appear, however, for whatever the leg length, a height between $3\lambda/4$ and λ will give good results for long-distance communication.

SUITABLE RHOMBIC FOR 10 METRES

An easily-constructed and very suitable rhombic aerial for 10-metre working could have the following specifications:—

Leg length (2λ, approx.), 75 feet.
Angle of tilt, ϕ, 52 degrees.
Overall length, 118.2 feet.
Overall width, 92.4 feet.
Height ($3\lambda/4$, approx.), 25 feet.

DISADVANTAGES OF THE RHOMBIC

Although this aerial is in considerable use by commercial concerns and by the armed forces, it has some disadvantages for amateur use. First, it is fairly costly to erect, uses four masts, and is definitely non-rotatable. The latter need not be a very great disadvantage if it is desired to erect an aerial to cover, say, the United States, for even with the directivity available, the beam is so broad by the time it reaches its objective that a very wide area indeed is covered. This, though a fairly obvious point, is not usually considered when plans are made to erect rotatable arrays. Of course, if working with Australia and England is desired as well, the rhombic does not become a practicable proposition, unless it is decided to use three of them!

terminating resistor, which should be non-inductive and capable of dissipating approximately one-half of the power delivered by the transmitter. At first sight, throwing away half the available power output seems poor economy, *but there is no advantage in omitting it.* All that happens if the rhombic is not terminated is that it now

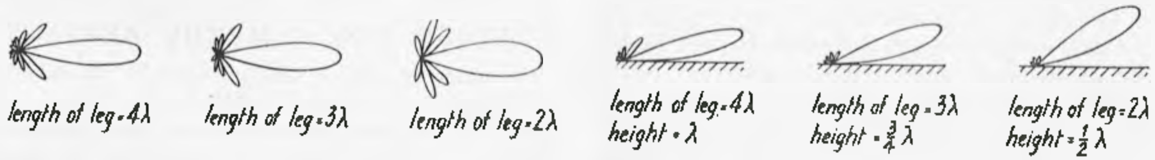


FIG. 6

becomes necessary to cut it exactly to resonant length, and to match the feeders into a virtually unknown impedance. In addition, a back-lobe appears, equal in intensity to the forward one. It is this back-lobe that is suppressed by the terminating resistor, at the same time making the aerial non-critical as to length, and stabilising its input impedance at about 600 ohms. The figure given earlier for the possible gain of a rhombic takes account of the loss in the terminating resistor.

A second disadvantage of the rhombic (and this is not generally known) is that it does not always produce its beam exactly in the desired direction. It is inadvisable to use one over broken ground, for a condition for proper operation is that it should be erected over as flat and conducting a ground as possible. Even if the ground itself is flat, it does not follow that the effective ground used by the aerial is flat also. This is because the portion of the earth which acts as a reflector for radiated energy is usually several feet below the surface. The rhombic is particularly sensitive to the slope of this effective reflecting surface, which cannot be seen, and may cause the main lobe to leave the aerial at some angle not coinciding with the principal diagonal of the system of wires.

In spite of this, the rhombic offers almost unlimited scope to the aerial experimenter who has the space in which to erect it. It is capable of gains of 16db. or so when working properly, which represents an increase of many times in effective transmitter power, and also in receiver sensitivity. Anyone who thinks he may have suitable ground conditions for a rhombic would be well advised to give it a trial, especially as high poles are not required in order to achieve low-angle radiation.

FEEDING THE RHOMBIC

The rhombic aerial is a balanced affair, and so can be fed from a two-wire transmission line. When the terminating resistor of the rhombic is properly adjusted (the correct value is in the region of 600 ohms), the aerial is non-resonant and presents an impedance of about 600 ohms to the feeders. This is very convenient, as a 600-ohm line can then be directly attached to the aerial without any matching devices. Some experimenting should be done with the value of the

THE SLOPING VEE

This type of aerial, illustrated in Fig. 8, is another of the "long-wire" family. Although

FIG. 7

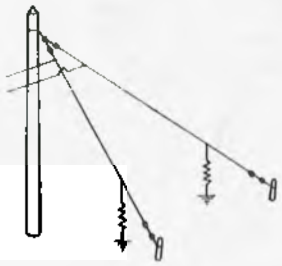


FIG. 8

simpler than the rhombic, it has only recently been brought into use to any extent. As the diagram shows, it consists of the first two wires of the rhombic. At the appex they are supported by a mast, but the far ends slope down to two short poles which need not be more than 6 feet in height. At the lower end of each is a terminating resistor which, in this case, must be taken to a good earth connection. As with the rhombic, the legs are made two wavelengths or more long.

It has been proved that the directive properties of this aerial are hardly at all inferior to those of a rhombic having an equal leg-length, but that the vertical directivity is quite easily controlled by varying the slope of the wires. It has the great advantage of requiring only one mast. Since it is only half as long as its corresponding rhombic, the sloping vee can be made to have almost the directivity of a rhombic twice as large in overall size. Also, it is a very simple matter to swing the wires round in different directions, and to support a number of sloping vees from one mast, using either independent feeders or by switching from a single pair of feeders.

The optimum angle between the wires of the vee for a given wire length can also be estimated from Fig. 5. In the case of the vee, the angle given by the graph is not one-half of the angle between the wires, but 90 degrees minus this angle. Thus, for the vee, an angle of 65 degrees read from the graph means that one-half of the angle between the wires is $(90-65)=25$ degrees, so that the angle between wires should be 50 degrees.

HEIGHT OF MAST

The height of the mast used for the sloping vee is not critical, but should be such that the wires make an angle of between 10 and 20 degrees with the ground, the lower angle for greater leg-length and the higher for shorter legs. This latter fact makes it advisable to use longer leg-lengths if it is desired to keep the height of the mast within reasonable limits. A very suitable design for a sloping vee for 10-metre use would be as follows:—

Length of leg (approx. 4), 150 feet.
Angle between wires, 56 degrees.
Height of mast, 50 feet.
Height of end poles, 6 feet.

NOTE.—Mast heights down to 35 feet could probably be used with quite satisfactory performance.

FEEDING AND TERMINATING IMPEDANCES

The input impedance of the sloping vee aerial is in the vicinity of 800 ohms. Since an 800-ohm line has rather too wide a spacing if constructed of heavy wire, it is preferable to make the line of three or four hundred ohms characteristic impedance, and to use a stub near the aerial to effect an impedance match.

The terminating resistances should each have a value of 400 ohms, and should each be capable of dissipating a quarter of the power output of the transmitter. The sloping vee also is non-resonant when correctly terminated, so that its length is non-critical. It will give a gain approaching that of the corresponding rhombic as closely as 3db. It is worth mentioning in this connection that the aerials used by the National Broadcasting Service for the reception of overseas broadcasts at their new receiving site at Makara are almost exclusively rhombics and sloping vees, directed towards America, Great Britain and Australia.

FEEDERS FOR 10-METRE AERIALS

In amateur circles, the question of whether to use untuned or resonant feeders is always a vexed one. There is no doubt whatever that untuned or non-resonant feeders are more efficient than the tuned variety. For long feeder runs, tuned feeders are so inefficient as to be unusable, but even for short runs the use of untuned feeders is desirable if the utmost in efficiency is desired.

One of the difficulties met by amateurs is the proper matching of untuned feeders to the aerial, but in the cases we have discussed in this article very little trouble should occur. The proper dimensions for the matching portion of a delta-matched dipole can be obtained quite accurately from the data given in the literature. If this information is adhered to, no difficulty will be experienced as long as the aerial itself is cut to the correct length.

However, in using untuned feeders, a check should always be made to ensure that the matching is correct. This is very easily accomplished by a variety of methods, the simplest of which is the use of a neon lamp. This should be a low-wattage lamp, especially for low-power transmitters, and may be mounted on the end of an insulating stick so that the feeders may be reached. With the transmitter on, the lamp should be brought close enough to the feeders for a glow to be seen, and run along them, keeping the distance between lamp and feeders as nearly constant as possible. If the brilliance of the lamp remains constant and exhibits no regular points of maximum or minimum brilliance, the feeders can be assumed properly matched to the aerial. This, of course, is a very rough check, but useful nevertheless, since a standing wave ratio of 2:1 can easily be observed, and the efficiency of untuned lines with this standing wave ratio is very little less than when matching is perfect.

On 10 metres the untuned feeders are frequently long enough, even with amateur installations, to enable proper measurements to be made of standing wave ratio. If the latter is measured, and reference is made to charts which can be found in the literature, the correct length and placement of either open or closed matching stub can be found readily. This process is very simple and requires only a standing-wave indicator for its operation. Although few amateurs seem to go to the trouble of taking even simple aerial or feeder measurements such as this, the process of properly matching feeders can repay manifold the effort expended. As an example of another type of non-directional aerial which can be used on 10 metres and which readily allows the use of non-resonant feeders, we have shown the "J" type in Fig. 7. The double quarter-wave section at the bottom acts both as matching stub and as a means of feeding the unbalanced half-wave vertical aerial from a balanced untuned line.

The proper adjustment of this system is exceedingly simple, and is effected by sliding the feeders along the matching section until an indicator shows that no standing waves remain on the untuned line or, by using a simple field strength indicator at some distance from the aerial, and finding the point at which the feeders must be tapped to give maximum field-strength.

The question of the adjustment of non-resonant feeders could well be the subject of a separate article, as space does not permit further treatment here. As was indicated at the beginning, this article does not pretend to be exhaustive, but it is hoped that a few new ideas may have been presented to some of our readers, and that some, at least, may feel impelled to carry out a little experimental work. The subject of aerials is a fascinating one, and more than repays any time which may be spent on it in improving the performance of both transmitters and receivers.

Letters to the Editor

Sir,—I am writing to express my appreciation of your journal, *Radio and Electronics.* It was badly needed here, as the American magazines, excepting *Q.S.T.*, seem never to use anything new. Some of your circuits are refreshingly different.

I have experimented quite a lot with the high impedance first detector. The signal-to-noise ratio is excellent, but to me it does not seem to have the lift that other combinations have. For instance, a regenerative R.F. stage, plus 6K8, is more sensitive. I have tried a regenerative stage ahead of an infinite impedance mixer with fair results, and also find the 6F5 metal makes quite a good detector. I believe there are possibilities in this circuit, so am going to keep on trying to get it to "perk" par excellence.

The articles on frequency measurement have been a godsend to a lot of us. They fill the bill in simple language. Why did you miss out last month? These articles are worth the price of the magazine alone.

I have also built your Frequency Standard with fair results. The trouble here is getting H.F. components. We also experience difficulty in having metal boxes made, such as the standard 5 in. x 4 in. x 3 in. made in America and used for dozens of things. Perhaps you could suggest that a standard size be made by one of your advertisers. I am sure that they would sell like hot cakes.

Can you give me any information re a meter circuit to measure output voltage of a signal generator, not a ref. level as is often used, as I want to use it for sensitivity measurements? Have used VTVM, but having about six instruments on a bench at one time becomes cumbersome—also hazardous.

So far, there are only two things wrong with your magazine—it should be twice as big and come out oftener!—I am, etc.,

S. J. GOSSLING.

For the Serviceman—H.M.V. MODELS 465 and 465D

The former model is for broadcast only, and the latter is a dual-wave set.

Frequency Ranges:
Broadcast: 540–1750 kc/sec.
Short-wave: 5.5–19 mc/sec.

Intermediate Frequency:
455 kc/sec.

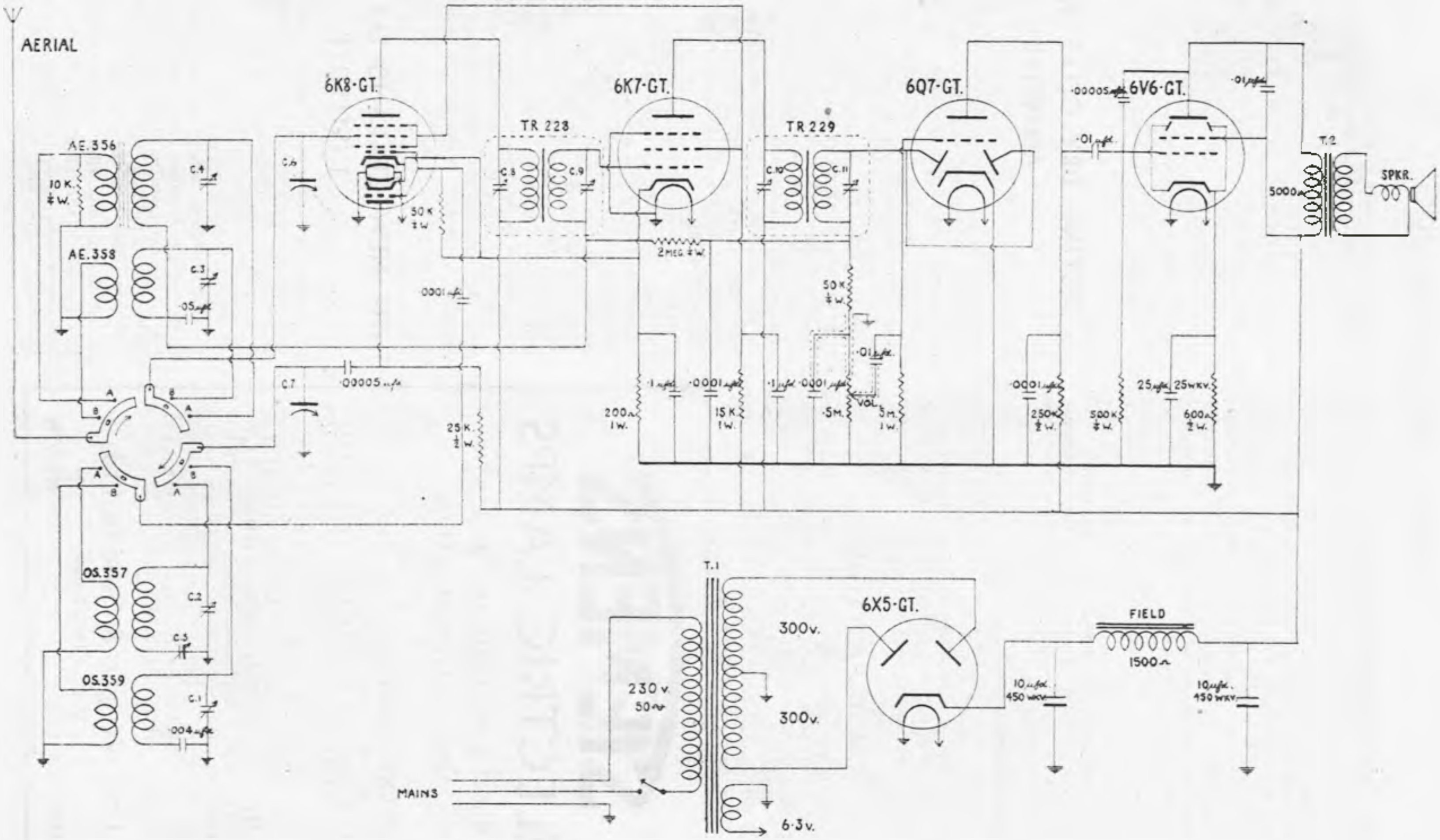


Figure 1-Circuit Diagram

ALIGNMENT DATA

The I.F. trimmers should be aligned with the wave-change switch (on 465D) in the broadcast position, volume control at maximum, and test oscillator connected to the 6K8-GT grid through a 0.05 microfarad condenser. Trimmers should be adjusted from C_{11} backwards. Oscillator output should be as low as possible so that the signal at the 2nd detector produces as little A.V.C. voltage as possible during alignment.

In aligning the R.F. circuits, the padder should be adjusted first with the test oscillator set to 600 kc/sec. The oscillator and 1st detector trimmers should be adjusted at 1400 kc/sec. by setting both test oscillator and receiver dial to this frequency. The signal is then tuned in with the oscillator trimmer and peaked up with the 1st detector trimmer.

Short-wave Alignment (465D only):

The padder on this range is fixed. Alignment of oscillator and aerial trimmers is performed at 18 mc/sec. exactly as described above for the broadcast band. When this has been done, a check should show that 6 mc/sec. is received at the correct point on the dial.

MODIFICATIONS

Owing to the acute shortage of materials, it has been necessary in some cases to use substitute components, but this has been done without any impairment of efficiency. Some of the components affected are valves, ganged and fixed condensers, trimmers, padders and wave-change switches. The following table gives alternative valves which may be found

Original	Substitute
6K8-GT	ECH35
6K7-GT	EF39 or 6U7G
6Q7-GT	EBC33 or 6SQ7
6V6-GT	EL33†
6X5-GT	5Y3-G*

†Bias voltage decreased.
*Separate filament winding required on power transformer.

TESTING DRY CELLS WITH AN AMMETER

For many years dry battery users have been accustomed to connect an ammeter momentarily across the terminals of a dry cell in order to obtain a reading supposedly indicative of its serviceability.

In the past, it has often been assumed that such a reading is indicative of the capacity or serviceability of the cell. This, however, is not the case. The reading given by an ammeter in general has no relation whatever to the output capacity of the cell, as it is dependent largely on the internal resistance of the latter. Worse than this, the practice can undoubtedly damage the cell, especially if it is one of the smaller type. **So unreliable is the ammeter test that a cell giving a low reading often has a capacity in excess of that of a cell which gives a higher reading.**

The ammeter test is injurious to the cell because the low resistance of the meter is a virtual short-circuit across its terminal. If a reliable test is required of the condition of a cell or battery, its voltage should be measured with a 1000 ohm/volt voltmeter **while the cell is under normal load.** For example, the voltage of a cycle battery should be read with the battery normally loaded by the type of lamp that it is intended to work. The reason for this is that, even near the end of its life, the battery may show an open circuit voltage almost equal to its rates voltage when read with a high-resistance voltmeter.

THE NEW ZEALAND ELECTRONICS INSTITUTE

The efforts of the various committees concerned with the promotion of the New Zealand Electronics Institute have culminated in the formation of the institute in Wellington on July 10, 1946.

The committees have given considerable thought to the problems affecting the radio and electronic field in New Zealand, with the object of overcoming them. Consequently, the professional status of the technician should be placed on a sound basis as the institute gains a wider footing.

At the present time the Secretary is preparing a full report of the aims and objects of the institute, and this will be ready for publication in the November issue of "Radio and Electronics."

THE APPLICATION OF MINIATURE TUBES

Part 2

Consideration of Circuit I shows that the value of CN providing best neutralisation depends on the ratio of the amplitude of oscillator voltage on the screen to that on the No. 1 grid. This ratio is determined by the turns ratio between the tickler coil and the No. 1-grid coil. The optimum value of CN, therefore, depends on the number of tickler turns. A good method for adjusting CN and the number of tickler turns for the frequency band between approximately 6 and 18 megacycles is as follows: First, tune to the low-frequency end of the band and adjust the tickler turns to give 20 microamperes No. 1-grid current. Then, tune to the high-frequency end of the band and adjust the capacitance of CN to give maximum receiver sensitivity. In receiver production, it may be desirable to use a value of CN somewhat smaller than the value giving maximum sensitivity so that manufacturing variations will not make CN much larger than the optimum-sensitivity value. If CN becomes much larger than this value, circuit instability is likely to result because of interaction between the oscillator and signal-grid circuits. In the receiver for which the curve of Fig. 2 was plotted, a value of $4\mu\mu f$ for CN gave practically no interaction, $5\mu\mu f$ caused some interaction, and $7\mu\mu f$ made the circuit inoperative. The value of CN selected for use in the 6-18 megacycle band can also be used in the middle- and low-frequency bands. In the middle-frequency band, the optimum value of CN is not at all critical, while in the low-frequency bands the presence of CN in the circuit has very little effect on circuit performance.

In the high-frequency band, the effect of variation in CN on receiver sensitivity and stability depends on the amplitude of oscillation. When this amplitude increases, the value of CN becomes more critical. Hence, this capacitance is generally most critical at the high-frequency end of the band. When it is desired to reduce the effect of variation in CN on receiver sensitivity, this reduction can be made by limiting the amplitude of oscillation at the high-frequency end of the band. A simple method for limiting this amplitude is to connect a resistor in series with the oscillator trimmer condenser.

The method used to vary CN in our laboratory tests consisted of connecting in the circuit different fixed condensers. Each fixed condenser was made by winding a length of bare copper wire tightly on a length of rubber-covered wire. The capacitances of these condensers were measured on a Q-meter.

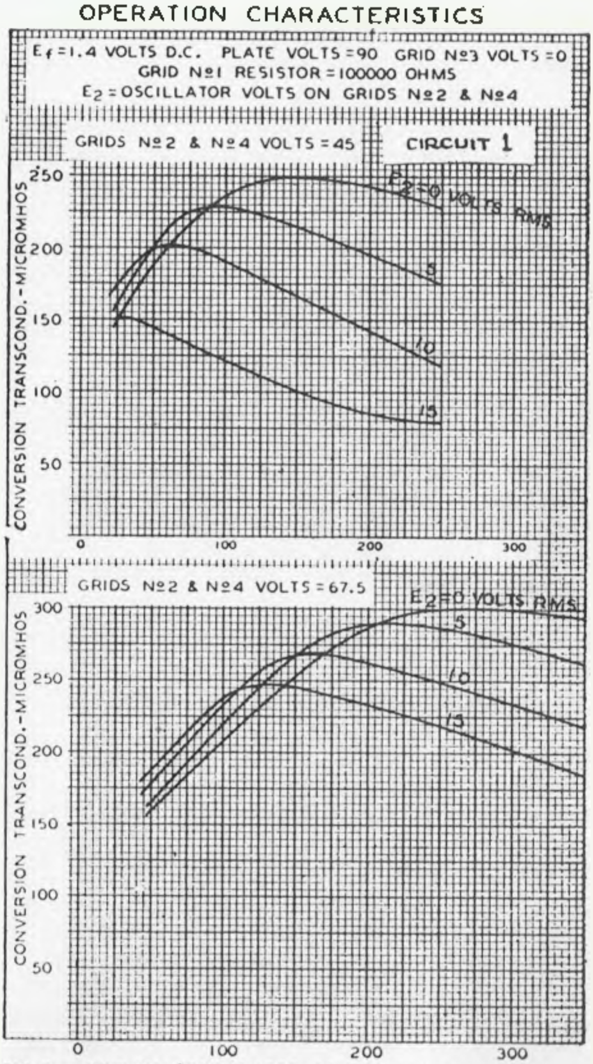


FIG. 3 GRID No1 (OSCILLATOR-GRID) MICROAMPERES

R.F. Choke for Circuit II.

An R.F. choke for Circuit II should meet the following requirements which are not difficult to satisfy. The resistance of the choke should not be so large as to cause excessive drop in the filament voltage supplied to the 1R5. A resistance of 1 ohm, or less, is satisfactory. The inductance of the choke should be large enough to provide effective choking at the lowest frequency to which the oscillator tunes. For operation in the domestic broadcast band, an inductance of 30-40μh is generally satisfactory. The distributed capacitance of the choke should be small enough so that the resonant frequency of the choke is higher than the highest frequency to which the oscillator tunes.

Adjustment of Feedback Turns for Circuits I and II.

In Circuit I, the number of tickler turns should be large enough so that strong oscillation is maintained throughout the tuning range and throughout battery life. However, the number of tickler turns should not be much larger than necessary because an excessive number of tickler turns causes a reduction in conversion transconductance. The reason is that an increase in tickler turns causes an increase in the amplitude of oscillator voltage on the screen. When Circuit I is in normal operation, cathode current flows only during the positive half-cycles of No. 1-grid voltage. During these half-cycles, the oscillator voltage on the screen is negative. Hence, an increase in the amplitude of oscillator voltage on the screen decreases the effective D.C. screen voltage. As a result, an increase in tickler turns above a certain number reduces conversion transconductance. Similar statements are true of Circuit II. The filament tap on the oscillator tank coil should be far enough up the coil for strong oscillation. However, the tap should not be too far up the coil because the oscillator voltage on the filament makes the filament positive with respect to the signal-grid during positive half-cycles of No. 1-grid voltage. Hence, the oscillator voltage on the filament has the effect of increasing the negative bias on the signal-grid and thus reduces transconductance. These statements are illustrated by the curves of Figs. 3 and 4 which show the effect on conversion transconductance of the oscillator voltage on the filament in Circuit II. These curves can be used as a guide when a 1R5 oscillator coil is to be adjusted to give best sensitivity over a tuning band. The curves are convenient to use. A simple vacuum-tube voltmeter adequate for measuring oscillator voltage on the 1R5 screen or filament consists of a diode in series with a 100,000-ohm resistor and a micro-ammeter. *In the domestic broadcast band, best sensitivity is usually obtained when oscillator-grid current ranges between 50 and 150 micro-amperes.*

Modifications of Circuit I for 90-volt Supply.

Modification of Circuit I may be desirable when the B-supply is 90 volts. This supply

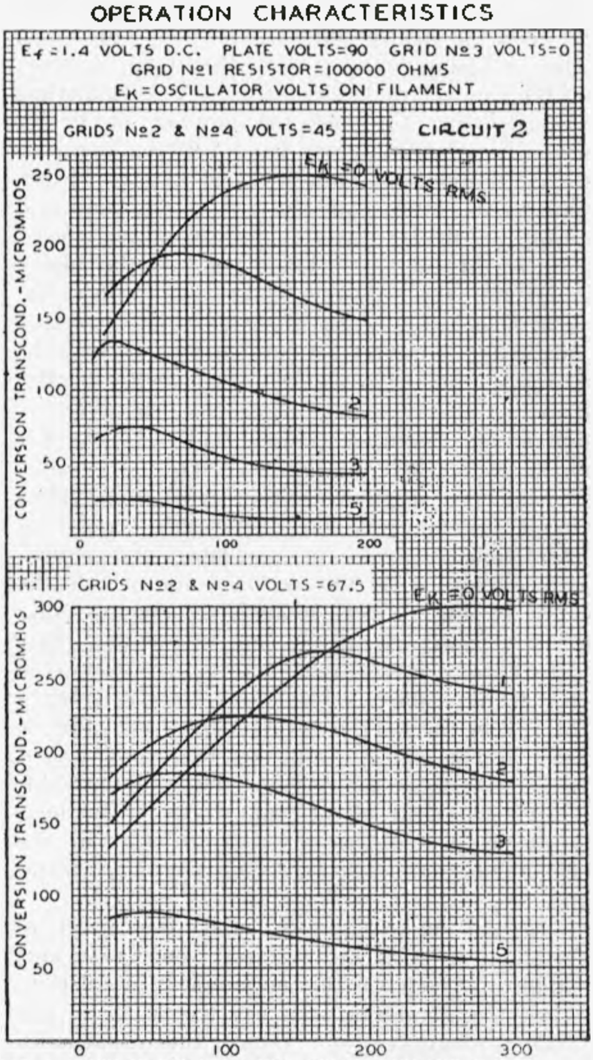


FIG. 4 GRID №1 (OSCILLATOR-GRID) MICROAMPERES

voltage may be used in a receiver where it is desired to obtain more power output than can be provided by a 1S4. For such a receiver, a good tube line-up is a 3Q5-GT operated at 90 volts plate and screen voltage, a 1S5 operated at the 90-volt conditions given below under

Resistance-Coupled Operating Conditions for 1S5 Pentode, a 1T4, and a 1R5. Because the maximum rated screen voltage of the 1R5 and 1T4 is 67.5 volts, a series screen resistor is necessary for these tubes unless a 67.5-volt battery tap is employed. Fig. 5 shows three methods of supplying screen voltage to a 1R5 and 1T4 from a 90-volt battery in a receiver where the 1R5 stage employs tickler feedback. In Circuit A, 1R5 plate current does not flow through the tickler coil; the tickler feedback current is the screen current alone. With this arrangement, the feedback current, and hence the oscillator transconductance, changes with A.V.C. bias. This change may be objectionable in the short-wave bands but is unimportant in the domestic-broadcast and long-wave bands. In Circuit B, the voltage on the 1R5 plate is lower than in Circuit A. As a result, the conversion gain obtainable from Circuit B is somewhat less than that from Circuit A. However, in Circuit B, both the plate current and screen current of the 1R5 contribute to the tickler-feedback current. Because the sum of plate current and screen current changes very little with A.V.C. bias, oscillator transconductance in Circuit B is less affected by A.V.C. bias than in Circuit A. As a result, Circuit B gives better oscillator performance in the short-wave bands than Circuit A. Circuit C gives somewhat more conversion gain than Circuit B because the 1R5 plate voltage is higher in Circuit C. Also, the oscillator performance of Circuit C is good in all bands because the tickler coil carries both the plate current and the screen current of the 1R5. However, Circuit C employs an additional screen resistor for the 1T4.

Remote Cut-off in the 1R5 and 1T4.

Both the 1R5 converter and 1T4 I.F. amplifier have remote cut-off. As a result, a receiver using these tubes can have a better A.V.C. characteristic than a receiver using sharp cut-off types. This statement is illustrated by Fig. 6 which shows A.V.C. curves for a typical battery-operated receiver before and after conversion to the miniature tubes. The curve for the sharp cut-off tubes bends upwards at an antenna input of about 30,000 microvolts. At this value of input, the A.V.C. bias on the converter and I.F. tubes is a large percentage of their cut-off bias. As a result, there is some clipping of negative signal peaks on the I.F. amplifier grid. This clipping produces an increase in the percentage modulation of the I.F. amplifier output, and thus causes the upward bend in the curve for measured audio output. In other words, the upward bend in the curve indicates the signal strength at which modulation distortion starts. The curves show that the range of signal strengths amplified without appreciable modulation distortion is about five times larger for the miniature tubes than for the sharp cut-off types.

MODIFICATIONS OF CIRCUIT I
FOR RECEIVERS WITH 90-VOLT B-SUPPLY

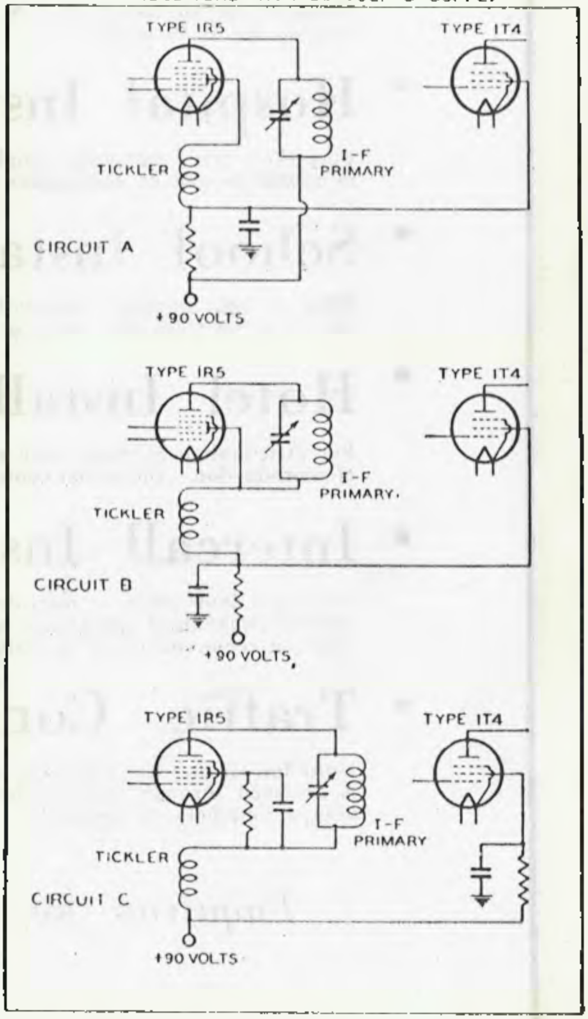


FIG. 5

67.5 Volts on the Screen.

The maximum rated screen voltage of the 1R5, 1T4, and 1S4 has recently been raised from 45 to 67.5 volts. The maximum rated plate and

screen voltages of the 1S5 had been previously set at 90 volts. It should be noted that, in a receiver where part of the B-supply voltage is used to bias the output tube, the values of transconductance and power output will be somewhat less than those shown in the curves.

Resistance-Coupled Operating Conditions for 1S5 Pentode.

Plate Supply Voltage ..	45	67.5	90	volts
Screen Supply Voltage ..	45	67.5	90	volts
Grid Voltage	0	0	0	volts
Load Resistor	1	1	1	megohm
Series Screen Resistor ..	3	3	3	megohms
Grid Resistor	10	10	10	megohms
Grid Resistor for Following Stage	2	2	2	megohms
Voltage Gain (approx.)*	30	40	50	

*Obtained when the grid of the pentode unit is fed from a source having an impedance of 1.0 megohm.

Shielding and Sockets for the Miniature Tubes.

Shielding cans are not usually required for the miniature tubes. The 1T4 I.F. amplifier tube has a shielding electrode which surrounds the plate and is internally connected to the filament. The socket for a 1T4 should have a central metal insert shielding the grid base-pin from the plate base-pin, which is opposite the grid pin. The socket for a 1R5 should be cushioned as a precaution against microphonics. Suitable cushioning can be provided by soft rubber grommets between the socket and chassis. Similar cushioning for the 1T4 may be desirable. It may be necessary to mount a baffle plate or other shielding between the 1S5 and output tube to prevent audio feedback. Also, in a receiver tuning to the long-wave band where signal frequencies are close to the intermediate frequency, it may be necessary to shield the 1S5 and 1T4 from the loop and the R.F. input leads.

When a miniature tube is removed from its socket, the tube should be pulled straight away from the socket without rocking motion. Rocking the tube in its socket produces a transverse pressure on the base pins which may crack the glass base. Likewise, wiring to the sockets should not pull socket terminals out of position because this pull applies transverse pressure to the base pins. Socket contacts should grip the base pins not less than ⅛ inch below the base so that the base pins can bend slightly to make up for misalignment of socket holes or contacts.

AVC CURVES FOR TYPICAL BATTERY RECEIVER
BEFORE AND AFTER CONVERSION TO USE MINIATURE TUBES

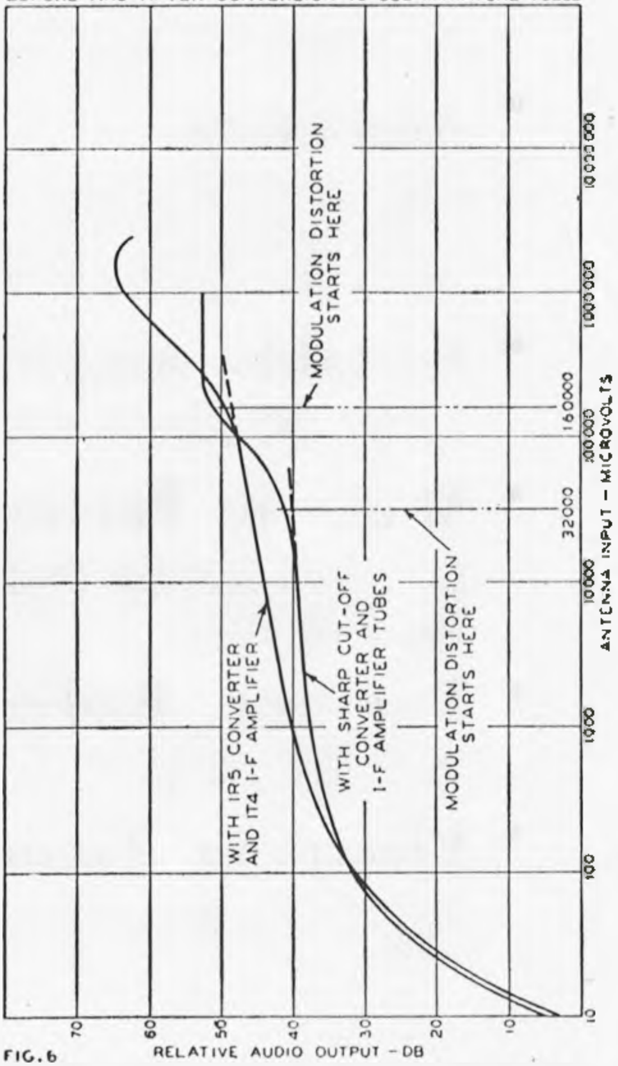


FIG. 6

'Radio and Electronics'

Back numbers of this journal may be obtained from S.O.S. Radio Service, 283 Queen Street, Auckland, and the Te Aro Book Depot, Ltd., 64 Courtenay Place, Wellington, C.3.

This page is contributed monthly by the New Zealand DX Radio Association (Inc.), 20 Marion Street, C.2, Wellington, New Zealand. All "DX" and Club inquiries should be addressed direct to the Association.

THIS "DX-ING"

STATIONS TO BE HEARD

Our sister DX Radio Club in Australia (S.A. Australia DX Radio Club) has made arrangements with the Department of Information (Melbourne) to broadcast weekly DX programmes from Radio Australia on Sundays:

VLC9, 16.82m. 17.84mcs.—Weekly sessions of 20 minutes at 1.10 p.m. to U.S.A. and Canada.

VLA3, 30.99m. 9.69mcs.—Weekly sessions of 12 minutes at 3.45 a.m. to the British Isles.

We request listeners to send reports to Radio Australia on these transmissions. By so doing we can show our appreciation of the efforts of our fellow-DXers in Australia. Good luck for successful broadcasts!

4975kcs.—HJAG, Barranquilla, Colombia. "Emissora Atlantica" relays local dance programme till 6 p.m.; signs with National Anthem.

6030kcs.—CFVP, Calgary, Canada, relays CBC National programme; signs 7 p.m.

6115kcs.—"Radio Polskie," Warsaw, news in English, 8 a.m.; fair sigs.

6147kcs.—HI1G, Ciudad Trujillo, Dominican Republic, signs 6 p.m. Sundays; good sigs.

6160kcs.—CBRX, Vancouver, Canada, is parallel with CFVP, signs 8 p.m.

7290kcs.—AFN, Hamburg, armed forces programme, heard 8 a.m.

9500kcs.—OIX2, Lahti, Finland, English news at 12.30 p.m., broadcasts to North America.

9640kcs.—KZRH, Manila, an old-timer returned; opened on regular schedule July 1st, asking for reports.

11020kcs.—PLP, Bandoeng, Java, "Radio Indonesia," another old-timer returned; heard well 9-9.30 p.m.; excellent sigs.

10070kcs.—Official Dutch Station in Bandoeng, with programmes in English, Dutch, and Indonesian; heard 11.15 p.m.; good sigs.

7120kcs.—"Radio Somali," Hargesia, British Somaliland. We have made tentative arrangements with "Radio Somali" to broadcast a special programme on August 22nd, 6 to 8 a.m. N.Z.D.S.T., 1800-2000 G.M.T. August 21st. Try for this special and send a report; well heard at present.

The following is a complete schedule of the "Voice of the Andes," Quito, Ecuador, South America. English programmes can be heard on all frequencies at these times:—

4107kcs., 6240kcs., 9958kcs., 12455kcs., 15115kcs., 11.30 p.m. to 1.30 a.m., 10-11 a.m., 2-3.30 p.m.

9350kcs.—Madrid, Spain. News at 8 a.m.; good.

9503kcs.—XEWW, Mexico. Heard well 4-6 p.m.

9750kcs.—Russia. News at 8 a.m.

11725kcs.—PCJ, Holland. Good at 9 a.m.

11970kcs.—FZI, Brazzaville. Good, 6 p.m.

17770kcs.—KGEI, San Francisco. Good 2 p.m. onwards.

17800kcs.—KRHO, Honolulu. Good from 11 a.m.

17830kcs.—VUD10, Delhi, India. News at 5 p.m.

11715kcs.—FGA, Dakar, French West Africa. Opens with "Ici Dakar"; news at 7.15 p.m.

9545kcs.—XEFT, Vera Cruz, Mexico. Heard 4-5 p.m. Sigs 5.15 p.m., sometimes later.

STATION ADDRESSES: CENTRAL AND SOUTH AMERICA.

LRX.—Calle Maipu 555, Buenos Aires, Argentina.

PRF6.—"Radio Bare," Caixa Postal 290, Manaus, Brazil.

PRE5.—"Radio Clube Do Para," Edif Bern Av. 15 de Agosta Belem Para, Brazil.

ZFY.—The B.G. United Broadcasting Co., Ltd., P.O. Box 272, Georgetown, British Guiana.

ZNS-2.—Telecommunications Department, P.O. Box 48, Nassau, Bahamas.

HJDE.—"La Voz de Antioquia," C/o L. Ramos, Medellin, Colombia.

HJFH.—"La Voz de Armenia," Canera 13 No. 19-24, Armenia, Caldas, Colombia.

HJGF.—"Radio Bucaramanga," Apartado 47, Bucaramanga, Colombia.

COCX.—Reine 314, Altos, Havana, Cuba.

COCO.—San Miguel 1314, Havana, Cuba.

COBL*.—Apartado 541, Havana, Cuba.

HIT.—"El Hit del Aire," Apartado 1105, Cindad Trujillo, Dominican Republic.

HI2A.—Cafe Del Yaque, Santiago de los Caballeries, Dominican Republic.

HCBS.—"Radio Bolivar," Apartado 49, Quito, Ecuador.

HC2DC.—"Radio Difusora Cenit," Post Office 171, Guayaquil, Ecuador.

YS1.—Radio Inter Continental, Ricardo Ramos y Cia, San Salvador, El Salvador.

——.—"Radio Guadeloupe," Point-o-Pitre, Guadeloupe, French West Indies.

TGOA.—"La Voz de las Americas," Hotel Palace, 12 Calle y Cuarta, Guatemala City, Guatemala.

HHCM.—P.O. Box 118, Port au Prince, Haiti.

PJC-1.—Curacao Radio Vereenging, Willemstad, Curacao, Netherlands West Indies.

OAX1A.—"Radio Delcar," Saenz Pena N.P. 109, Casilla No. 9, Chiclayo, Peru.

HP5K.—Apartado No. 33, Colon, Panama.

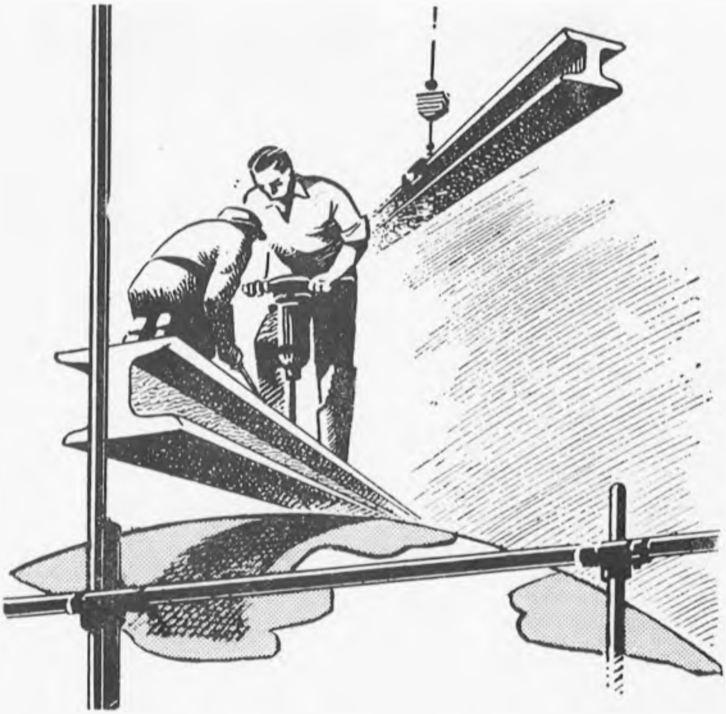
HP5A.—"Radio Teatro," Apartado 954, Panama City, Panama.

CXA-19.—El Expectador, Difusora del Uruguay, 18 del Julio 1393, Montevideo, Uruguay.

CXA-10.—Service Official de Difusion, Radio Electra "Sodre Andes" No. 1465, Montevideo, Uruguay.

YV1RO.—"Radio Trujillo," Calle Independicia, Trujillo, Venezuela.

YV3RS.—"Radio Difusora Occidental," Apartado 76, Barquisimento, Venezuela.



RADIO-FREQUENCY HEATING

By Dr. L. HARTSHORN, National Physical Laboratory.

In the last few years the radio-engineer, using his own special technique, has devised two new heating processes—one for metals and one for non-metals. Few recent technical developments have excited more widespread interest among scientific workers, not because any new principle has been established, but because it is recognised that a new tool has come to hand, which in certain respects gives us a command over the forces of Nature that we have not before enjoyed. It may be true that the poor workman always quarrels with his tools; it is none the less true that the scientific workman is always interested in a new one; and physicists and chemists, biologists and metallurgists, as well as engineers, have shown great zest in trying the new tool on their own special problems, particularly their industrial problems. The processes are too young to make possible a considered judgment of their scientific or industrial value; I shall therefore be content to illustrate their special features by a few examples.

When we speak of a heating process, we imply something more than the mere production of heat. The essence of the matter lies in this: We must be able to impart at will an appreciable amount of thermal energy to some particular body. The problem includes not only the production of the energy, but also its transference to the body to be heated; and this transference must be localised and subject to strict control. Two possibilities lie before us: We can generate the energy in the thermal form and transfer it to the body to be heated in that form by thermal conduction or convection; or, alternatively, we can generate and transfer the energy in some other form, and afterwards convert it into heat in the body to be heated, a process usually described as the absorption of the energy by that body. In the ideal solution of the problem, the heat would appear instantly in the body and nowhere else, in just the amount required and just at the right instant. Both energy and time are involved, and we may say that the process consists essentially in the controlled transference of power—that is, energy per unit time, and its absorption by one particular body, often called by the heating engineer the "work." The methods to be discussed here have this feature in common: The power is transferred to the work in the form of electro-magnetic vibrations of a frequency lying somewhere in the radio range, say, 10 kilocycles to a few hundred megacycles a second, and this is what is implied by the term "radio-frequency heating."

The term "radio" almost inevitably suggests electro-magnetic radiation comprising that portion of the spectrum which the radio engineer has taken for his own, say, a range of wavelengths from a few miles to a few millimetres; to avoid misunderstanding, it must be emphasised that, for the purposes of heating, the power is not employed in the form of radiation; that is to say, in the form of trains of progressive waves such as are employed in broadcasting and television. It is true that such waves are absorbed by both metals and non-metals; and it is because of that very fact that radio-frequency heating is possible; indeed, its peculiar virtues depend very largely on the character and extent of that absorption. But for the purposes of heating, we need to produce a great concentration of power in the "work"; radiation is the reverse of concentration—it is the dispersal or diffusion of electro-magnetic power throughout the universe. When the wavelength becomes short compared with human dimensions, optical technique can be employed for the concentration of radiation, and heating by means of radiation is then possible, provided the work is a reasonably good absorber. The recent developments in "infra-red heating" are of this character, and one day perhaps the radio-engineer may perform the same feat with his micro-waves; but with the long waves we are now considering this is quite out of the question.

The methods of radio-frequency heating as practised to-day are possible because we can produce great concentration of power in the form of electro-magnetic vibrations in the coils and condensers of oscillatory circuits; we must think of these as stationary vibrations rather than progressive waves. But if one remembers that stationary waves arise simply from the multiple reflection of progressive waves in a closed space, and that a vibration is no more than a system of stationary waves, we shall see that there is no essential difference in the nature of the energy in the two cases. Both can be visualised as periodic electric and magnetic fields, concentrated in one case and diffused throughout space in the other. Radio-heating—I now feel justified in using this shorter term—consists of the generation of power in these two forms, periodic electric and magnetic fields, its transference to the work, and its absorption by the work.

GENERATORS.

The generators used for the purpose of radio-heating are in principle the same as those used for radio-transmission, and we need only consider one form—the valve oscillator. Its construction is a job for the radio-engineer. The principle components are, first, an oscillatory circuit consisting of a coil connected to a pair of metal plates constituting an air condenser; secondly, triode valves; and thirdly, an auxiliary unit, which takes power from the ordinary electric supply mains, and transforms it to high-tension direct current suitable for application to the valves.

The condenser, when charged by the high-tension current, discharges through the coil in an oscillatory manner, at a frequency determined by the dimensions of the coil and condenser, the commonest size of coils and condensers giving frequencies in the radio range. Now, what happens in the oscillatory discharge is this: The electro-potential energy of the charged condenser, which we represent as an intense electric field between its plates, is transformed into the electro-kinetic energy of the discharge current, which we represent as the magnetic field of the coil. Strictly speaking, it is the magnetic field of the whole circuit, but we usually regard it as localised in the coil, the contribution of the condenser being negligibly small. The condenser having been drained of its energy, the current ceases, the magnetic field dying away and thereby inducing an E.M.F. in the coil, which again charges the condenser, and so on in the familiar way. There is a periodic transformation of the energy of the circuit from one form to the other, potential to kinetic and vice versa, at the natural frequency of the circuit; and these two forms are to a large extent concentrated, one in the coil and the other between the plates of the condenser. Some of this energy is inevitably absorbed by all solid bodies in the immediate neighbourhood of the circuit, including the coil and condenser themselves, and a little is lost in radiation, so that the oscillation dies down unless additional energy is supplied. This additional energy is supplied by the valves; their control grids and anodes are connected to the oscillatory circuit in such a way that each valve is automatically triggered by its grid to pass into the circuit a pulse of energy at just that part of the cycle, and of just the amount, that is required to maintain the vibration at a steady level. The ratio of the radio-power to the direct current power supplied is the efficiency of the oscillator; this can be brought up to about 50-60 per cent., the remaining power being lost as heat in the valves.

It may be well to note at this stage the scale on which radio-heating is practicable. We have read with some satisfaction that during the war the B.B.C. set up the world's most powerful transmitter, delivering no less than 800kw. of radio-power to the aerial. We have only to express the power transferred in heat units, and divide by the thermal capacity of the "work," the product of its mass and specific heat, in order to find out the rate at which its temperature will rise, apart from heat losses. In this way we find that if the 800kw. of power was concentrated into a cubic yard of water at ordinary temperature, it would take about six minutes to boil; if concentrated into one cubic inch of steel, it would take about one-sixteenth of a second to bring the whole mass to a uniform temperature of 800 degrees Centigrade, say, to a cherry-red heat. But outside the oscillator the power is NOT concentrated; it is very thinly spread by the aerial, so evidently there is no danger in wandering through a powerful broadcast. Compared with the 60,000kw. of an ordinary electric power station, the power is trifling, and it becomes obvious that if quantity and costs are important considerations, radio-power is no competitor of power in the commoner forms; its special virtue lies in its qualities rather than quantity.

We have now to consider the transference of the power to the work and its absorption by the work, and it is here that we find the different treatments for metals and non-metals, a difference that arises from the following facts. First, non-conductors can be permeated by both magnetic and electric fields, but can only absorb power from electric fields. Secondly, good conductors cannot be penetrated by electric fields, but are penetrated to some extent by magnetic fields and absorb power from them very readily. The processes of radio-heating are all developments of these basic experimental facts.

INDUCTION HEATING.

The transference of power to a metal by the magnetic field is a direct consequence of Faraday's law of induction. Power is the quantity we have to transfer to the work, but for the radio-heating of metals, we always picture the process as the induction of currents, and we often speak of the process as induction, or eddy current, heating. The power is transferred by the magnetic field exactly as in a transformer, and one of the chief virtues of the radio-frequency is that it makes possible efficient transformer action in simple systems consisting of a very few turns in air, as against the many turns in iron required at low frequencies. Any metal object provides paths of low resistance for the circulation of eddy-currents, and these paths may be regarded as short-circuited turns of a transformer, the coil producing the magnetic field being the primary coil. Very heavy currents are induced by the rapidly-fluctuating magnetic field in these short-circuited turns, and the heat is generated by these currents in overcoming the resistance of the metal.

It is a well-known fact that electric currents of radio-frequency are very largely confined to the surface skin of the metal, and the result is that in the radio-heating of metals nearly all the heat is produced in the surface layers of the "work," the interior remaining cool except in so far as it is heated by thermal conduction from the surface. The concentration of current in the surface can be deduced mathematically from Faraday's law, but we may also describe the whole process as follows. The power is transferred from the generator coil to the metal in the form of the electrokinetic energy of the magnetic field, which freely crosses any space either in air or vacuum. The metal is, however, such a very good absorber that all the energy is absorbed at the surface on which it is incident. The actual depth of penetration can be worked out from a knowledge of the frequency, the resistivity of the metal, and its magnetic permeability, so that we can find out what frequency must be used in order to get the energy to penetrate to any desired depth.

The phenomenon has important applications in the case-hardening of steel tools, gear wheels, etc. Since all the heat appears in an extremely thin layer at the nearest surface to the inducing coil, the volume of metal that is heated can be made almost as small as we please; by a suitable disposition of inducing coil, we can transfer all the power available to one portion of the surface, so that the heated portion can be controlled in both area and depth. The concentration of the absorbed power can therefore be made exceremely high, even with a generator of moderate power. Thus power concentration of, say, 20,000 kw/cu.in. are obtainable with no more than, say, 20kw. of total power. It is therefore possible with such a generator to heat the surface of a steel tool to a white heat in a second or less, and then by immediate quenching to harden the surface without affecting the main bulk of the material in any way, the whole process being very rapid, subject to precise control, and obviously not in the least likely to cause any distortion of the tool.

Induction heating has also been applied with success to soldering and brazing, the melting and general heat treatment of metals in vacuo, and to many other processes where controlled surface heating is necessary. There are, of course, many technical details to be considered: The form of inducing coil and the method of keeping it reasonably cool (water-cooling is usually necessary), the method of coupling the inducing coil to the oscillator in order to ensure the transference of all the power available, or the match-

(continued from page 48)

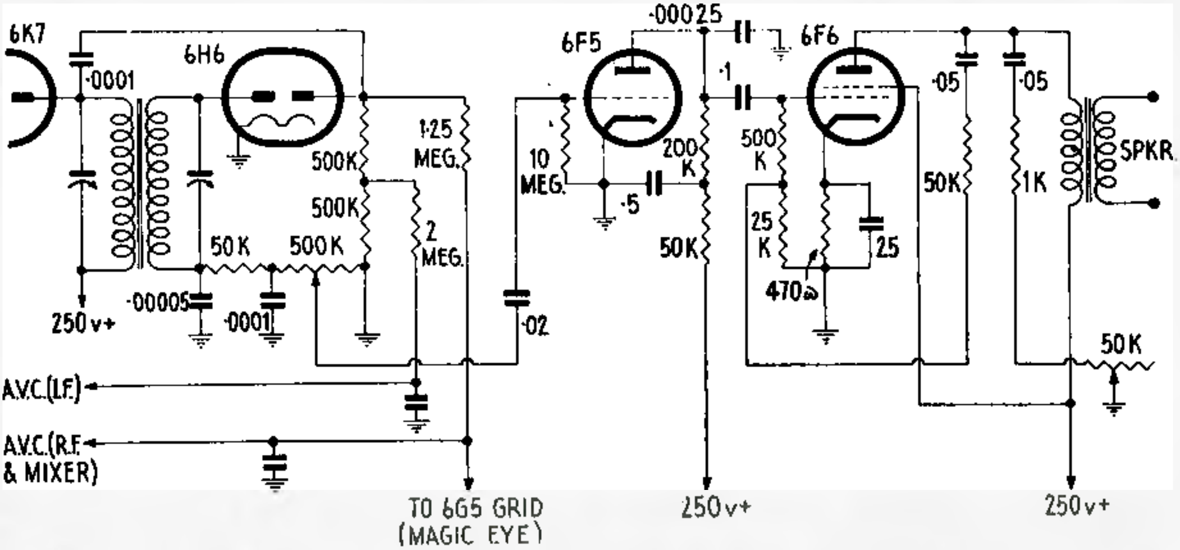
QUESTIONS and ANSWERS

Mr. W. Adams, Takapuna, writes as follows: "Attached is part of the circuit diagram of a 1938 Ultimate all-wave receiver, as modified by myself to improve the fidelity of the audio channel. The improvement is quite noticeable, but I am in doubt as to whether I have done the best possible. Here, then, are my questions:—

(1) Does the grid leak bias shown introduce any more distortion than self bias, or back bias?

(2) Is the inverse feed-back circuit efficient?

With regard to the first question, I realise that value of grid leak will reduce A.C. shunting on the diode load, and will therefore reduce distortion, but I do not know whether it introduces some form of non-linearity in the operation of the 6F5.



With reference to the second question, I realise that the percentage of feedback is small. What I really want to know is whether the circuit is efficient at all audio frequencies. The percentage of feedback can, I take it, be increased by increasing the value of the resistor at the ground end of the network."

The circuit given by Mr. Adams has several very good points which can well be recommended to the notice of readers. First, the use of the diode load resistor as volume control tends to reduce the A.C. shunting as mentioned in the question. The use of a high grid leak value for the 6F5 also aids in this respect, so that detector distortion should be very low. Secondly, feeding the A.V.C. diode from the plate of the I.F. tube is good practice, since it reduces the distortion which tends to occur at the point when the A.V.C. diode just commences to function. The third good point about the 6H6 circuit is the use of one-half of the total A.V.C. voltage on the I.F. tube. This reduces what is known as modulation rise which is a form of distortion encountered on large signals passing through a variable-mu tube. Since the greatest fidelity is usually required on the largest, i.e., local, signals, this point is well worth incorporating.

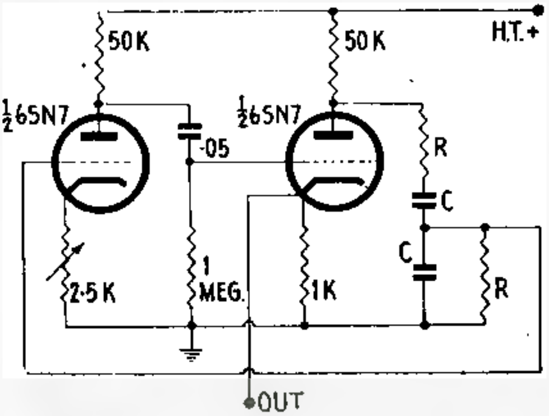
Coming now to Mr. Adams' questions, we have first of all that of whether normal biassing methods are superior to grid leak bias for a high-mu triode. First, it should be mentioned that grid leak bias is advisable only on high-mu tubes, since it does introduce a certain amount of distortion—usually about 2 per cent., but much more if used with low-mu tubes. Grid leak biassing may be termed standard practice with high-mu battery triodes. With these it is used because 1.5 volts is too high, and because, in a battery set, bias voltages lower than this are inconvenient to obtain. However, with heater cathode type tubes, there is no necessity to resort to this means. In spite of the reduction of diode shunting, it would be preferable in this case to use cathode bias and a normal grid leak of 1 meg.

In regard to question (2), Mr. Adams' statement that the percentage negative feedback is small, is not correct. Calculation shows that his circuit gives a gain reduction factor of 4.03, which is quite large. As far as the 6F6 is concerned, there would be little advantage, if any, in increasing the amount of negative feedback, but the effect on the 6F5 of so doing would undoubtedly be bad. The reason for this is as follows: With no negative feedback a peak audio signal of 16.5 volts is required fully to swing the 6F6. In the circuit shown this figure has been increased to $16.5 \times 4.03 = 66.5$ volts. Reference to resistance coupled data for the 6F5 shows that, under the conditions shown, its maximum output is only 47 volts peak. This means that, in the circuit shown, the 6F5 has to be overloaded to fully excite the 6F6. Further increase in the negative feedback would aggravate this condition, and would mean a reduction in the maximum undistorted power output of the amplifier. An improvement would be to substitute for the 6F5 a 6SJ7, pentode-connected. This has a maximum output of 80 volts assuming a 250-volt power supply and a load resistor of 100k., so that the 66.5 volts required by the 6F6 would be easily supplied at low distortion. Although the 6SJ7 would need a grid leak of not greater than 1 meg., shunting of the diode load would actually be decreased, because the greater gain of the pentode would necessitate a lower setting of the volume control potentiometer for full output, so that for a given output level, the grid leak is shunted across a smaller portion of the diode load.

* * *

Mr. N. R. White, Whangarei, writes:—

"I am about to build a test oscillator modulated at 400 c/sec., and require a suitable simple audio oscillator for the modulator." Mr. White then goes on to give the circuit of the well-known single valve phase shift oscillator, and asks whether we can supply him with the necessary circuit details.



Although the circuit given by Mr. White has frequently been used in radar applications, we consider it inferior to the circuit given below for amateur use. The single valve circuit requires a gain of 30 or more to make it operate at all, and obtaining good wave-form with it is more difficult than with the circuit shown. Although the latter uses two valves, these may be combined into one by the use of a 6SN7. The required values are shown on the circuit diagram. Output is taken from the unbypassed cathode resistor of V_2. The variable cathode resistor of V_1 is a preset control and is used to adjust the output level. Very pure wave-form may be obtained by adjusting this until oscillation just starts. It should be remembered that all types of phase shift oscillator can give highly distorted wave-form, and will do so unless adjusted in this way. The overall gain in the circuit shown need not be greater than about three times for oscillation to take place, so that most of the available gain may be purposely thrown away by means of negative feedback as used here, with resulting improvement in wave-form and stability.

NOTE: C and R for a frequency of 400 c/sec. should be 0.008 and 1 meg. respectively. It is suggested that C be made up to .009 with condensers in parallel, and that the lower R be made a 1 Meg. Pot. with which exact frequency adjustment may be made.

Classified Advertisements

Rates are 3d. a word, with a minimum charge of 2/-. Advertisements must be to hand in this office not later than the fifteenth day of the month in order to be published in the issue appearing about the middle of the following month.

While all care will be taken, no responsibility can be accepted for errors. Advertisements should therefore be submitted either typed or printed in block letters.

TRADE WINDS

Mr. P. C. Collier, principal of Collier & Beale, Ltd., Wellington, has returned to New Zealand after a very busy time in England and America. Mr. Collier, in an interview, made some extremely interesting statements, and the following is a brief account of his impressions of the overseas radio industry:—

Mr. P. C. COLLIER

"My trip was mainly in connection with general business and supply problems, but nevertheless I was able to study the present trend in domestic radio design. From my observation, it is apparent that those who expect major changes in broadcast receiver design as a result of wartime electronic research will be disappointed. The peace-time application of the colossal effort put into war research will be limited to specialised equipment such as pulse transmission for communications, navigational aids, telecommunications, and all systems involving transmission and reception on very high frequencies. There is no doubt whatever that experience gained by the radio industry in production methods of components and completed receivers must reflect in methods employed in future domestic set manufacture, but from the technical point of view, equipment used on broadcast frequencies will be essentially the same as pre-war design.

The supply problem has the greatest retarding effect on radio production, and in both England and America supplies of raw material are critical—for a different reason in each country. In England, the domestic and export market can absorb materials in excess of present production, and this is not surprising when it is realised that there has been an entire absence of domestic radio manufacture during the six years of war. The most critical materials at the moment are electrical steel and copper wire, and as the producing industry cannot keep pace with the demand, some indication is given of the vast strain placed on the industry in radio and electrical production alone.

In America, materials are in extremely short supply, but this can be attributed to labour troubles. The production capacity of American industry is so great that, when normal production commences, outstanding requirements can be rapidly fulfilled.

In Chicago I visited the retail store of one of the largest manufacturers of radios in America. The store was well stocked with new models, but it was impossible to purchase one except for delivery in five months' time. In New York, one store representing several well-known manufacturers had a complete range of new models, but the store display consisted of cabinets and dummy dials. As in Chicago, orders could be accepted only for delivery some months ahead.

It was with some pride that I could come back to New Zealand and realise how well off we are in the radio field. Although the radio industry is experiencing difficulties never known before, we are at least able to supply sufficient receivers to satisfy public demand. The fact that domestic radios are in production has been greatly facilitated by the prompt action taken by the War Assets Realisation Board in making available to the industry all surplus Government stocks.

Many pages could be filled in describing travel difficulties in and from America, but these, like many existing problems, can be straightened out eventually."

[**Editors' Note.**—In view of Mr. Collier's remarks with reference to the War Assets Realisation Board, the Editors asked the Board for a statement of the amount of radio material disposed of. We have been advised by the Secretary that the value of radio components and material disposed of by the Board from January, 1945, to the end of July, 1946, is approximately £326,800.]

* * *

Another world tourist now back in New Zealand is Mr. William J. Blackwell, General Manager of the Dominion Radio and Electrical Corporation. His visit to England and America was devoted to a study

Joseph Gillies, Vice-President in charge of production at the Philco plant in Philadelphia, explains the working of final radio test assemblies to William J. Blackwell, New Zealand Philco Representative.

of general conditions and production methods. As Mr. Blackwell's organisation is the manufacturer of Philco in New Zealand, the greatest amount of his time was spent with Philco in Philadelphia. As a result of this visit, many of Philco's modern production methods are to be adopted by the Dominion Radio and Electrical Corporation. Mr. Blackwell was very impressed by the attention paid by Philco to the training of their own technical specialists within the organisation. As a part of the immense war programme, the company undertook the responsibility of training 12,000 men in radio and radar for the Armed Forces. This undertaking was so successful that Philco retained the schools for the training of their own staff.

* * *

Owing to circumstances beyond their control, the Swan Electric Company are vacating their premises in Christchurch. We all know that office accommodation is extremely difficult, but it is possible that some of our readers may know of office space which is or is about to become vacant. If any person should be able to assist in this matter, it would be appreciated if they would advise the Managing-Director of Swan Electric Co., Ltd., Wellington.

* * *

The National Electrical and Engineering Co., Ltd., advise that they now have available a catalogue containing complete information on all types of insulators manufactured by New Zealand Insulators, Ltd., Temuka. The range is very complete, the types covering almost every need from small radio egg insulators to those required for high-tension heavy electrical engineering. In addition, procelains for electrical appliances and special insulator bushings are also described.

These useful booklets are available on application to the National Electrical and Engineering Co., Ltd., Wellington.

* * *

Swan Electric Co. advise us that they have received a limited supply of sapphire reproducing needles for use in normal gramophone pick-ups.

SOME NOTES ON THE DESIGN OF AMATEUR-BAND RECEIVERS

In the earlier days of amateur radio, receivers were not nearly the problem they are to-day. In short, the number of types of receiver that could be built was limited, and the builder's main problem was one of designing a set to suit his pocket. Regenerative receivers were the rule rather than the exception.

Now, with the greatly extended resources in valves and components which are available to amateurs, the question is not so much one of expense, but rather one of electrical and mechanical design proper. A formidable array of tubes and circuits confronts the receiver constructor—so formidable as to be almost bewildering! In addition, most types of circuit are found published in reputable sources; but these publications simply present the circuits with very little attempt, if any, to weigh their pros and cons. It is a case of "Yer pays yer money and yer takes yer pick."

As a result, many receivers are built according to published specifications, only to be found wanting in some respect by the constructor after his time and effort has been expended. If the amateur constructor has sufficient engineering knowledge to analyse critically the published designs, he is unlikely to fall into such a trap, but this is not always the case, and such a man is able to perform his own design work in any event. For the constructor who must rely implicitly on other people's designs, there is only one way out, and that is for design information to include accurate statements of the equipments' limitations as well as of their virtues. These notes are intended to indicate some of the main points which should be given consideration when choosing a design for an amateur receiver, and to act in some measure as a yardstick with which to gauge the suitability, or otherwise, of a given design to the fulfilment of the builder's own requirements.

SPECIFICATIONS

The first step in choosing a design should be to draw up a list, as comprehensive as possible, of requirements that must be met by the receiver once constructed. The specifications need not be accurate from the engineering point of view, but broad classification should be aimed at. This prevents time and money being spent in producing a set with unnecessary features which may even be detrimental. For instance, though not the most important factor, that of selectivity must be considered. It is quite unnecessary to state what the selectivity must be in terms of decibels down at a given bandwidth, but it certainly should be decided quite early in the deliberations whether normal, high or super-selectivity is required, or a combination of the three by means of selectivity control. This is an excellent example of the manner in which the completed design may be controlled in the initial stages.

Once the list of specifications has been fixed, then, and then only, is the time to consider what are really details—such things as mechanical layout and the circuits to be used for individual stages. Finally comes the very detailed work of deciding whether the chosen stage circuits will work harmoniously together, and of fixing the values of individual components. If the problem is tackled in this way, there is very little chance of ending up with an unsatisfactory receiver, and every possibility of producing one which will serve until such time as altered conditions necessitate a different type altogether.

MAIN RECEIVER FEATURES

What then are the fundamental features which must be specified before detailed design work can proceed? A suggested list of questions to be answered is as follows:—

(1) Is the greatest possible signal-to-noise ratio essential?

(2) Does selectivity need to be low, medium, high or ultra-high?

(3) Would variable selectivity be an advantage?

(4) Is the set primarily for 'phone or C.W. operation?

(5) Is the set for headphone or loudspeaker operation?

(6) Is the receiver for portable, mobile or fixed use?

(7) What wave-bands must it cover?

(8) Is it desired to use the receiver for approximate signal-strength measurements?

(9) Must the receiver be exceptionally stable as to calibration and adjustment?

(10) Must a minimum or a particular number of tubes be used?

(11) Is A.V.C. required at all? If so, is it to be operative on 'phone only, or on both 'phone and C.W.?

When all these questions have been answered, it is possible to say whether the receiver is to be a T.R.F. with regeneration, a super-regenerative receiver, or a superheterodyne. It is not possible here to go into this question at all fully, but it should be pointed out that, under some conditions, the simple regenerative receiver, with or without R.F. amplification, is not surpassed by even the best superhet. In fact, from one point of view, namely signal-to-noise ratio, the regenerative receiver can, and very often does, outperform the latter. Thus, if conditions are such that the minor disadvantages of a regenerative set are unimportant, it will give better DX reception than any superhet which is not designed for the best possible signal-to-noise ratio. This fact explains why so many amateurs have been very disappointed in the performance of expensive communications-type receivers, by comparison with well built T.R.F. sets using regeneration.

The above is not a plea for a general return to regenerative receivers, but merely an attempt to give the regenerative its due. For example, if an amateur is situated in the country, far from man-made noise, and many miles from the nearest amateur transmitter, and if at the same time he is not interested in working under difficult conditions in the congested bands, there is very little reason why he should go to any more trouble than to build himself a really good regenerative receiver. If, on the other hand, he is interested not only in DX reception, but also in reception under any conditions of band crowding, the only possible answer is a superheterodyne with crystal or other means of obtaining very high adjacent channel selectivity.

MAIN DESIGN FEATURES

Having decided on the type of receiver to be built, it is necessary to fix the major design features, without bothering at this stage to decide just how each is to be achieved.

Signal-to-Noise Ratio:

Perhaps the most important question is that of signal-to-noise ratio. This has been stressed many times already in the pages of *Radio and Electronics*, because, in addition to its extreme importance, there is an almost equally extreme disregard of it in the whole of the present amateur literature. It should be striven for in any superhet. intended for DX working on QRP transmissions. If the ultimate in signal-to-noise ratio is required, the oscillator-mixer section is automatically fixed as an infinite-impedance mixer, either with separate oscillator tube or using a double triode.

The success attained by New Zealand amateurs with this circuit—mostly by way of modification of existing receivers—brings up some very interesting possibilities for the design of entirely new receivers built round it. In fact, to realise fully the potentialities of the infinite-impedance mixer, demands that the rest of the receiver be designed with it in view, simply because its inherent noise is so low—lower even than that of the conventional R.F. or I.F. stage.

The most startling conclusion that may be drawn from this is the fact that the conventional 6K7 or 6J7 type of R.F. stage will then degrade the signal-to-noise ratio rather than improve it, so that, purely from noise point of view, it might well be expedient to omit the R.F. stage altogether! Since this is a logical step, let us see where it leads. In the first place, omitting the R.F. stage leads to loss of gain. Secondly, the infinite-impedance mixer at the lower amateur frequencies does not have as much gain as the conventional mixer tubes. But, since the new mixer has reduced the set-noise, a *higher* overall gain than normal can be used advantageously. Thus, the usual single I.F. stage becomes inadequate. Two stages of I.F. have more gain than a single stage of I.F. plus one of R.F. so that, by replacing the lost R.F. stage with a second stage of I.F., the gain is more than made up. In this way could be provided the extra usable gain made possible by the use of the infinite-impedance mixer.

However, this problem does not end at this point, for, assuming we have a receiver using an infinite-impedance mixer and two stages of I.F., the signal-to-noise ratio will be determined by the noise characteristics of the first I.F. stage.

It therefore becomes imperative to use a low-noise tube in this position. The best tubes to use would be the Philips EF38, or the American type 6AC7/1852, both of which have very low noise characteristics. The 6AC7 is somewhat better in this respect than the EF38, but both are far ahead of the "ordinary" R.F. pentodes. The EF38 is a remote-cut-off tube, and so may be controlled by A.V.C., but the 6AC7 is a sharp-cut-off valve and introduces difficulties if A.V.C. is to be used with it.

(to be continued)

OUR GOSSIP COLUMN

Mr. L. W. Field, Managing-Director of Wilkins & Field, Ltd., Nelson, was in Wellington recently and called at our office. Bill has been an enthusiastic radio man since the early "twenties," when Wilkins & Field became one of New Zealand's first really active radio dealers—in those days they were operating their own broadcast station. Although Bill is now Managing-Director of the firm, he still casts a very interested eye on his old favourite—the radio department.

* * *

Mr. Wallace Clarke, of H. W. Clarke, Ltd., Wellington, is at present in America on business connected with his organisation. He is not expected to return to New Zealand until the end of the year.

Another caller at the office of "Radio and Electronics" was Mr. H. I. Forsman, who is commencing a business as a radio and electrical dealer in Pukekohe. He has recently returned from overseas after having spent three and a half years in England with the R.N.Z.A.F. Whilst in England he worked on radar equipment at operational sites and at the Telecommunications Research Establishment. We wish him all the best in his new business venture.

Seen at the Waldorf lunching with Ken Stevens, of H. W. Clarke, Ltd., was Joe Hunter, of Hunter's Radio Service, Otahuhu. They appeared to be engaged in deep conversation—our guess is radio or refrigeration.

Another of our visitors was Mr. Hillier, of M. J. Hillier, Ltd., Morrinsville. He was in Wellington on general business, but found time to call on us. During the war, Mr. Hillier served in England with the R.A.F., and specialised on A.I. radar in Beaufighter and Mosquito aircraft. He is now back in business, which is mainly Philips Radioplayers and general radio service.

* * *

Fred Noad, of Photo Engravers, Auckland, was in Wellington recently, and while here contacted most of the radio manufacturers.

* * *

Mr. J. R. Howard, of Marton Junction, paid a visit to Wellington recently. As he is Courtenay Representative in Marton, he spent some time with Doug. Billing, Radio Chief of Turnbull & Jones.

Another Courtenay dealer enjoying the bracing weather of the Capital City was Mr. C. H. Terry, of Waipukurau. We believe that he is maintaining close liaison with the Railways Department.

* * *

Mr. H. C. Weir, Dominion Manager for the Allum Electrical Co. Radio Department, spent a few minutes with us during a trip made by air to Dunedin, Christchurch, and Wellington.

* * *

Mr. A. Wyness, Managing-Director of His Master's Voice (N.Z.), Ltd., is at present in England discussing H.M.V. activities with the parent firm.

Mr. Barker, Swan Electric salesman in Auckland, has been in Wellington attending a sales conference. While here he met many members of the radio industry.

* * *

One of the fortunate ones chosen to represent New Zealand in London's Victory Parade was Mr. Ferguson, of Ferguson's Radio Service, Huntly. After serving as a commissioned officer in the army in the Middle East, Mr. Ferguson is now back in his business, which, we understand, is a flourishing one.

Recently returned to New Zealand from Australia is Mr. P. W. Humphries, of Standard Telephones and Cables Pty., Ltd. While there he spent 18 months in the S.T.C. Sydney factory studying modern production methods, specialising in high-frequency heating and Selenium Rectifier design.

A graduate from Canterbury University in 1943 with a B.E. degree, Mr. Humphries has since taken a post-graduate course in electronics.

Now busily engaged as Equipment Designer, he has relieved Mr. Martin Byron, of S.T.C., Sydney, who will be crossing the Tasman in the near future to rejoin the Rectifier Section in Sydney.

RADAR *(continued from page 6)*

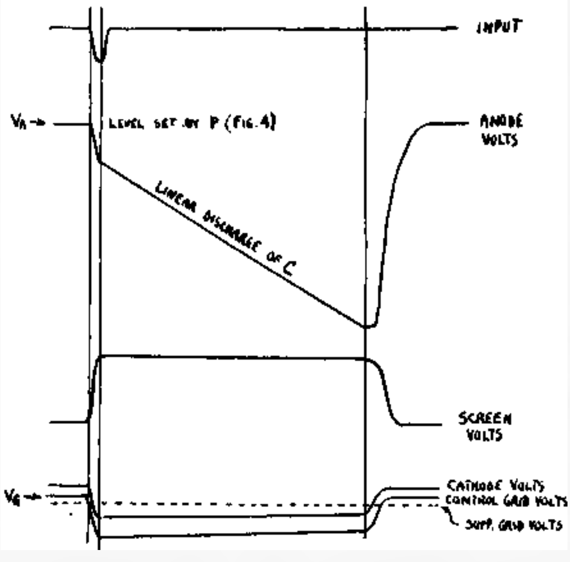


Fig. 5: Potential diagram for phantastron.

time base; and if T is set so that n of the input pulses occur during the time anode current is passing, the phantastron goes through one of its cycles to every (n + 1) of the input, giving a frequency reduction of 1:(n + 1). In the Oboe circuits a second phantastron frequency divider stage feeds back pulses to the first in a way that delays its action every so many cycles, so that if n and m are the two divider ratios the obtainable transmitter pulse frequencies are not confined simply to

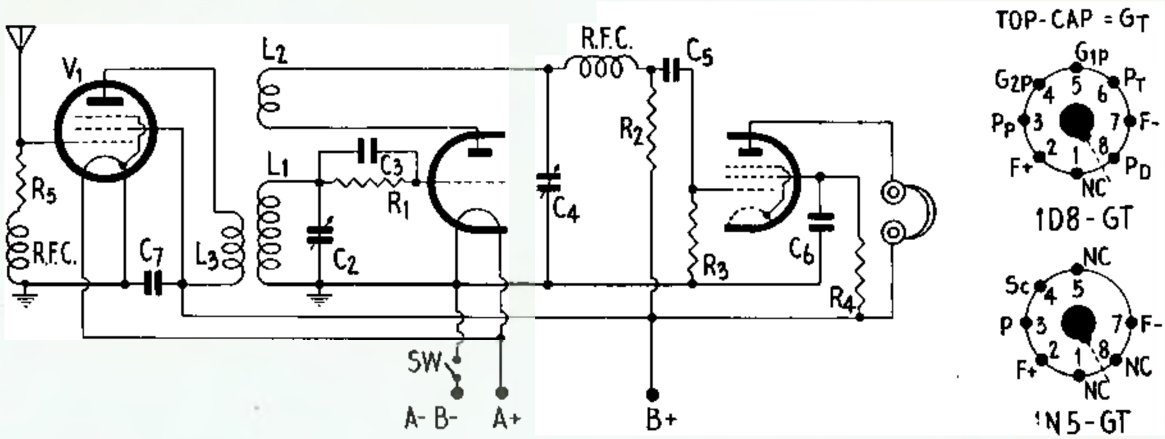
$$93,117/(n + m),$$

but can be given intermediate values.

THE RADEL "PROGRESSIVE" BATTERY THREE

PART II.—ADDING THE UNTUNED R.F. STAGE.

The plan of the Progressive Battery Three was outlined in the last issue of *Radio and Electronics*, where we indicated that, after the initial building of the Radel One circuit into the specially-designed metal chassis, the next step was to add a stage of untuned R.F. amplification.



$C_1 = 30\mu\mu f.$ max. trimmer.
$C_2 = 0.00035\mu f.$ max. variable.
$C_3 = 0.0001\mu f.$ mixed.
$C_4 = 0.0003\mu f.$ max. variable.
$C_5, C_6, C_7 = 0.1\mu f.$
V_1 = 1N5-GT.

R_1 = 2 Megs.
$R_2 = 50{,}000\,\omega$
R_3 = 5 Megs.
$R_4 = 20{,}000\,\omega$
$R_5 = 10{,}000\,\omega$
R.F.C. = 2.5 mh. choke.

ADVANTAGES OF UNTUNED STAGE

The untuned R.F. stage is a scheme that has not received nearly enough attention from home constructors in the past, mainly because such a stage is no longer used commercially. Nevertheless, it has a number of decided advantages when attached to a simple regenerative detector circuit.

The regenerative detector has some serious disadvantages when fed directly from the aerial, as is often the case. First, only loose coupling is possible between aerial and the detector circuit, because, if the coupling is made too tight, the detector circuit is so highly loaded that it cannot be made to oscillate at all. As the coupling is reduced, it is found that oscillation is obtained at some places on the dial, but not at others, while, in order to obtain oscillation and therefore proper operation over the whole dial, it is possible to use only very loose coupling of the aerial, with consequent loss in signal strength. The cause of this behaviour is the fact that most aerials act as though they have a very low resistance, which, when the aerial is attached, is shunted across the detector circuit. The actual resistance represented by the aerial varies over a wide range according to the frequency that is being received, so that, when the detector is tuned to widely-different frequencies, the loading effect of the aerial changes considerably, and necessitates wide variation in the setting of the reaction control.

This effect, though annoying to the operator, is not serious as long as the aerial coupling is so adjusted that oscillation can be obtained over the whole band covered by the tuning condenser. However, a much more serious effect is that of swinging of an aerial due to wind. When the aerial swings, its characteristics change because it varies its position with respect to nearby objects. This can have a disastrous effect on the operation of a straight regenerative detector, since movement of the aerial causes sufficient change in the loading on the detector circuit to cause the latter to lose the critical adjustment that has to be made in receiving a weak station. Thus, a weak signal

that has been tuned in by careful and laborious adjustment can be lost altogether, or the set brought into squealing oscillation, simply by the swinging of the aerial.

A third effect, which is annoying not to the set user but to other listeners, is that the simple regenerative receiver itself radiates a signal when it is oscillating, and the user is either searching for carriers or reading a morse station.

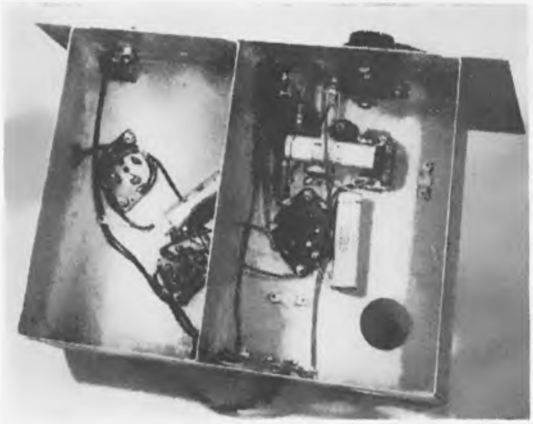
The advantages of the untuned R.F. stage are such that all three of these drawbacks to the simpler set are removed.

The point now arises as to whether or not the untuned stage is difficult to get going, and whether it is too costly to make its use worth while. The answer to both these questions is an emphatic "No!" A glance at the circuit diagram, and a comparison with that of the first stage of the set, shows that, apart from the valve used, the only other parts required are one R.F. choke, one resistor, one condenser, and a primary winding on the detector coil in place of the original aerial coupling condenser. No extra set controls are called for, and the operation of the set is exactly as it was before the untuned R.F. stage was added, with the exception that aerial coupling adjustments are no longer necessary. Besides, in addition to the advantages we have outlined above, the new stage gives appreciable gain at all frequencies, and will enable weaker stations to be copied than could be read before, and therefore gives better DX reception. When the set was built in *Radio and Electronics'* laboratory and first turned on, using only about 10 feet of wire inside the building as an aerial, the first stations heard were American shortwave broadcasts on the 19-metre band.

CONSTRUCTION

The photographs clearly show how the R.F. stage is added on the already prepared chassis. In order to facilitate the next step in the development of the set—namely, the conversion of the untuned stage to a tuned stage of R.F., the resistor-choke combination in the grid circuit of the untuned stage has been built as a plug-in unit, in the following manner.

A four-pin valve-socket type of plug is used, similar to those which will be used for the plug-in R.F. coils. One of the leads from the choke is passed through pin No. 4 on the plug, so that the choke stands up vertically on top of the plug, and the lead is then soldered to the pin. Next, one lead from the 10k. resistor is passed through and soldered to pin No. 1. The free ends of the choke and resistor are now soldered together. Next, a piece of push-back or other hook-up wire is soldered to pin No. 2, and the other end soldered to the resistor lead which passed through



pin No. 1. The plug-in unit is now complete. Reference to the under-chassis photograph shows that, on the socket of the R.F. unit, connections are made as follows: Lugs Nos. 3 and 4 are connected together and to earth. Lug No. 1 is connected by a piece of hook-up wire passing through a small hole in the chassis to the top-cap grid of the R.F. amplifier tube. The aerial wire is soldered to lug No. 2, and the earth wire to lug No. 3.

If the plug-in unit and its socket are wired up in this way, no alteration of the set wiring will be necessary when the R.F. stage is tuned.

UNDER-CHASSIS SHIELDING

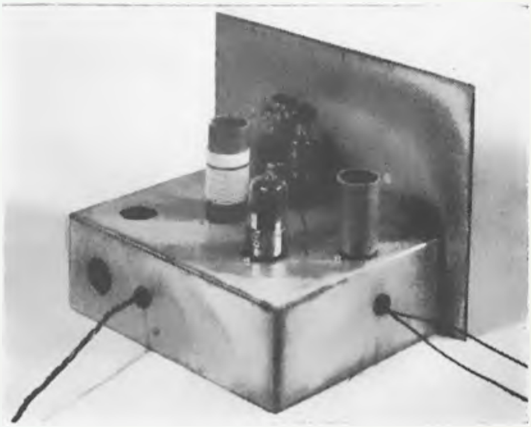
Although, strictly speaking, an untuned R.F. stage does not require any shielding, a baffle shield has been inserted at this stage. It consists simply of a piece of the chassis-steel (or aluminium if preferred) seven inches by three, with a quarter-inch flange along the two short sides and one of the long sides to enable it to be fixed to the chassis. Apart from filament and B+ leads, which are taken through the shield by two small holes at the top front corner (in the photograph), the only lead going through the shield is that from the R.F. stage plate pin to the primary of the detector coil. The small hole for this purpose is placed so as to make this lead as short and direct as possible, but about an inch from the bottom of the chassis, since it carries R.F. and should not be run closer than this to the iron chassis. It will be noted that the shielding partition divides the chassis into two compartments, the left-hand one containing only the parts associated with the R.F. stage, and the larger right-hand one all the small parts belonging to the detector and audio stages. Battery leads are twisted together and taken through the small hole in the back of the chassis, after which each is connected to one of the insulated lugs on the small terminal strip mounted on the back of the chassis. From this point, the lead carrying A— and B— is taken through the shield to the on/off switch. A lead is taken from the other terminal of the switch to the Fil.— terminals of the valves, while the Fil.+ terminals are connected together and to the lug on the strip which terminates the A+ battery lead.

THE COILS

The detector coils for this and subsequent stages of the set are identical with those used in the first stage of the set, except for the addition of the primary windings which couple the R.F. stage to the detector. These windings have been called L_3 on the wiring diagram. In the case of the two shortwave coils which have spaced turns for L_1, the primaries L_3 are wound between the turns of L_1 with 36-gauge enamelled wire. Since the detector coil consists now of three separate windings, a six-pin plug will have to be used for it. All windings are wound in the same direction and terminated as follows: Pin 1, top of L_1; pin 6, bottom of L_1; pin 2, top of L_2; pin 5, bottom of L_2; pin 3, bottom of L_3; pin 4, top of L_3. The correct direction in which the various windings should be connected is exactly as shown in the circuit diagram. The bottom of L_1 is earthed, and the top goes to the tuning condenser. The bottom of L_2 goes to the detector plate, while the top of L_2 goes to the R.F. tube plate. If one of the windings is reversed, the detector will not work at all, so great care should be taken to ensure that the coils and set wiring are arranged so as to bring about the connections given. Since the wire for L_3 is so fine, it may be slipped through the same hole as is used for the bottom of L_1, and only a small hole made with a needle for the other end, without disturbing the secondary turns.

THE BROADCAST COIL

The construction of this coil is more difficult, since the turns are close wound. Here, the primary is put on over the top of the turns of L_1. First, a piece of thin paper is glued round the bottom third of the secondary with celluloid



BRITAIN MAINTAINING WORLD LEAD IN RADAR

(By Radio.)

London, 2nd September, 1946.

Britain will be able to produce an "almost perfect" radar set within two years.

This was stated recently by Sir Robert Watson Watt, Deputy-Chairman of the Radio Board of the British Cabinet.

Sir Robert, who was speaking at Liverpool, paid a tribute to the way in which this great British port is leading the world in matters of marine radar. Liverpool, he declared, was using inventions to-day which every other port would be using two years hence. Radar at sea was vital to successful navigation by ships when entering port during poor visibility. He added that Britain was still ahead of the rest of the world in most fields of radar development.

Sir Robert revealed that Britain had offered to all liberated European countries the use of radar equipment used by the R.A.F. "We must achieve standard national equipment," he said. "It is no use equipping our planes and airports with British radar if foreign aircraft flying to this country do not understand our signals. Our aim is to create a common system of traffic control in Europe."

cement and allowed to dry. The bottom end of L_2 is started by using the same hole as for the bottom end of L_1, and the required number of turns wound on over the paper. The turns are close-wound. When all the turns are on, the winding is cemented down with celluloid cement and allowed to dry before attempting to fix the finishing end. When the winding is firm, the free end is bent down outside the winding and taken through a hole drilled below the bottom of the windings and opposite to pin No. 4. This procedure has to be resorted to as it is impossible to take the end of L_2 through the close-spaced winding of L_1.

COIL SPECIFICATIONS

The coil specifications are as follows. It will be noted that, with the exception of the primaries, numbers of turns are identical with those used previously.

BROADCAST:

L_1 ...... 105 turns 36-gauge en. close-wound.
L_2 ...... 30 turns same wire, close-wound ⅛in. from top of L_1.
L_3 ...... 40 turns same wire, wound over bottom end of L_1.

SHORT-WAVE A (approx. 30-90m):

L_1 ...... 16 turns 24-gauge en. or D.C.C. double-spaced.
L_2 ...... 10 turns same wire, close-wound ⅛in. from top of L_1.
L_3 ...... 6 turns 36-gauge en. inter-wound at bottom of L_1.

SHORT-WAVE B (approx. 19-60m.):

L_1 ...... 6 turns 24-gauge en. or D.C.C. double-spaced.
L_2 ...... 10 turns same wire, close-wound ⅛in. from top of L_1.
L_3 ...... 4 turns 36-gauge en. inter-wound at bottom of L_1.

Note.—All coils wound on 1¼in. diam. tubing.

A Practical Beginners' Course

Part 3

Last month's instalment of the Beginners' Course concluded with some tips on operating the crystal set in order to obtain the best results, and even with a hint that our first circuit by no means represents all that may be desired in the way of crystal sets. However, to understand properly the necessity for circuits different from the one shown in Fig. 2, it is essential for us to realise what the limitations of this simple circuit are, and why they occur. So, before going on to see how the circuit of Fig. 2 can be improved, let us see if we can find what there is about it which requires improvement.

HOW THE SET WORKS

Now, in describing how to wind the coil for Fig. 2, we specified 70 turns to be wound on the former. It will, no doubt, have occurred to some to wonder how this number of turns is arrived at, and why 60 or 80 turns would not have done equally well. This question is bound up with the much more general one of how the set works, so that, before going on to describe the limitations of the circuit as an efficient receiving set, it is advisable to say a few words on this subject.

If we look through the pages of "Radio and Electronics" we will find circuits of much more complicated sets than our crystal set, but if these circuits are examined we can find portions of them which are very much like the crystal set circuit to look at. For instance, on page 34 of the September issue is the circuit of the first part of the "Progressive Three." Now, this is quite a simple valve set, but, even so, it is a good deal more complex than anything we have yet seen in the "Beginners' Course." In spite of this, however, there are components which can be recognised on the diagram as being of the same kind as those used in the crystal set. These parts are L_1 and C_2, which are not at all new to us since they are connected together in exactly the same way as are the coil and condenser in our crystal set. That is to say, each end of the coil is connected to one set of plates of the condenser. This is really the only point of similarity between the two circuits, but it is very important. C_2 in the larger set has exactly the same purpose as the variable condenser we have used in the crystal set, and so has L_1 when compared with the coil in the latter. When connected together in this way, they form what is known as a **tuned circuit.** This is a fundamental part of any set, and can be found in all of them. If a five-valve set is examined, it is possible to find a number of such tuned circuits all working together, and it is this that gives the bigger sets most of their desirable operating characteristics.

The way in which a tuned circuit works is not easy to describe at this stage, because we have said so little about the nature of the radio currents which the set picks up, but it is interesting to see just what the tuned circuit does, even if we cannot yet know just how it acts.

The tuned circuit does two things, both of which are quite important. In the first place, it has the remarkable property of selecting some radio currents and rejecting others. Secondly, it is able to amplify, or make bigger, the radio currents fed to it from the aerial, so that we receive a much stronger signal in the headphones than we would had we not used such a circuit. Its name of "tuned circuit" calls to mind musical instruments rather than electrical things, but there is good reason for this in that there is a distinct similarity in action between a tuned circuit and, say, the string of a piano, which is tuned to a certain note.

First of all, let us think for a moment just how a piano string is tuned, so that, when struck, it gives out a particular note and not any other. Sounds are caused by any object that is made to vibrate. When the piano string is struck, it vibrates and sets in vibration the particles of air which are in contact with it. These air vibrations travel outward in all directions, just like the ripples on a pond when a stone is thrown into it, and ultimately strike our ears, when we hear what we call the **sound** of the vibrating string. As you all know, the string is tightly stretched across the frame of the piano, and the tuner alters the pitch of its vibration (or the pitch of its sound) by turning a key. This key either tightens or loosens the string. When the latter is tightened, the pitch of its sound rises, and when loosened the pitch falls, giving a lower note. When the string is left at a certain tension, it produces the same note every time it is struck. In fact, it is said to be **tuned** to that note. But there is another way of looking at the tuning of a piano. In this instrument, it is so arranged that all the strings are stretched to about the same tightness, but if you examine the strings, you will find that the higher notes use short strings, and the lower notes use longer and longer ones as we go down the scale.

Now, in exactly the same way as a stretched wire is tuned to a certain musical note, so is a tuned circuit **tuned** to a particular radio wavelength. Just as a piano string gives a lower note if it is made longer and a higher one if it is made shorter, so does varying the capacity of the tuning condenser allow the tuned circuit to respond to longer or shorter wavelengths. The reason for this is that the currents picked up by the aerial are what may be called **electrical** vibrations. That is to say, these radio currents flow first in one direction and then in the opposite direction along the wire which carries them. In electrical language, they are called **alternating** currents, because they flow **alternately in opposite directions**. Now, a current that behaves in this manner may do so at either a fast or a slow rate. In this it is again very similar to our piano string, which, if a long one, vibrates at a slow rate to produce a low-pitched note; if it is short, it vibrates faster and gives a higher note.

We have said that a tuned circuit is able to respond to radio currents of different wavelengths at different settings of the tuning condenser. We are now in a position to see why. The rate at which a vibrating (or alternating) current performs these alternations is called the **frequency** of the current. This is the proper electrical term, and is simply the name for **the number of times a second that the**

alternations occur. With radio currents, the actual figures are very high. For example, the currents received from 2YA alternate 570,000 times a second—which is quite rapid! Now, when we talk about wavelengths of radio waves, all we are doing is expressing their frequency in another way. In fact, now that we have explained what frequency is, there is no necessity for the term wavelength at all, so we will in future refer only to frequency.

We have already discussed a tuned circuit **responding** to different radio frequencies. In acting thus, the tuned circuit is again very similar to a vibrating string. For example, if one note of a piano is held down until the sound of the note has died away, and the same note is then sung or whistled, the vibration of the string can be heard once more. However, should any other note be sung, the string will not vibrate. In other words, that string selects only the note to which it is tuned.

In the case of the tuned circuit, if the latter is tuned with the tuning condenser so that it responds to radio currents of one frequency, it will not respond to currents of other frequencies. Or, at a particular setting of the condenser, **the circuit selects only that frequency to which it is tuned.**

With our piano string, the things which make it tune or resonate to a particular note are its length and tightness. **But with the tuned circuit, the factors which decide the frequency to which it tunes are the electrical sizes of the coil and condenser.** Here at last is the answer to the original question: "Why do we have just so many turns on the coil?" As explained earlier, we vary the tuning of the circuit with a variable condenser. It might have been possible to use a fixed condenser and vary the tuning by having a variable coil, and in the early days of radio this scheme was much used. However, it has been found that variable condensers are much easier and cheaper to make than variable coils, so that the latter (except in a few special cases) have gone out of use almost entirely.

Just as the electrical size of a condenser has a special name—capacity—so has the electrical size of a coil been given the name of **inductance.** Now, the inductance of a coil depends on the number of turns, the diameter of the former, and a number of other factors which we need not go into here. However, by this time it should be plain that, if we have a particular variable condenser and we wish to tune in 2YA at the closed end of the condenser rotation, there is a particular electrical size of coil which will enable us to do this. If the inductance of the coil is too great, we might find 2YA about half-way out on the condenser. This would mean that other stations we may want to hear cannot now be covered by the variation we have available in our condenser, and thus will be off the dial. If the inductance of the coil was too small, we might not be able to tune in 2YA, even with the condenser leaves fully closed. For this reason, we have chosen 70 turns on the coil, which, with the size of wire and former specified, gives the coil just the right inductance to tune over the range of frequencies we need in order to receive any of our broadcasting stations.

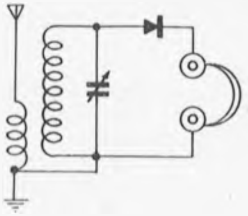


FIG. 3

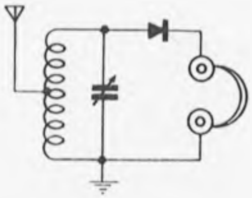


FIG. 4

ADDING AN AERIAL COIL

A very great improvement in the performance of the set may be obtained by the addition of an aerial coil. This consists of a second winding on the coil former, close to the winding of 70 turns which forms part of the tuned circuit. One end of this new winding is connected to earth, and the aerial is joined to its other end. Fig. 3 is the circuit diagram of the set with the aerial coil added. It will be noted that the new winding is drawn close to the **original** one to indicate that the two are **coupled** together. This is a term which is frequently found in **reference** to coils, and merely means that the coils are placed close enough together to enable currents in one of them to cause currents to flow in the other. If the two coils are very close together, they are said to be **closely** or **tightly coupled.** If they are not very close to one another, they are said to be **loosely** coupled.

Since the radio frequency currents from the aerial flow in the aerial coil, coupled to the tuned circuit in the manner described, currents are induced or caused to flow in the tuned circuit, and are detected as before. This time, however, the aerial is not directly connected to the tuned circuit, so that the de-tuning effect is almost removed. In addition, the selectivity, though still not very good, is improved. Thus, by the simple addition of an aerial coil, the performance of the set is much improved from several points of view, and the main limitations of the simple circuit are removed.

CONSTRUCTION

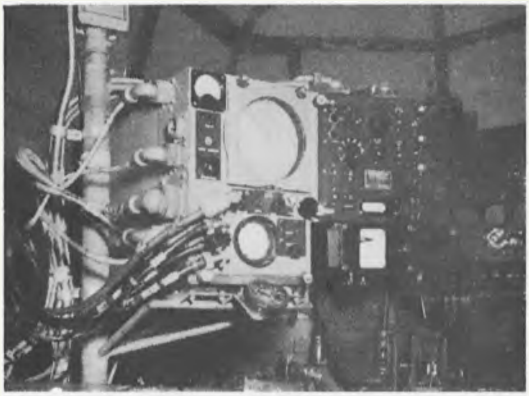
The construction of the aerial winding may be carried out exactly as for the original one. The new winding should be commenced a quarter of an inch from the top of the old winding, and 30 turns wound on exactly as before. Of course, it will be necessary to unsolder the coil and remove it from the base board in order to put on the new winding. When this modification has been made, re-solder the coil and make the connections as in the new circuit diagram, Fig. 3. The end of the aerial coil nearest the old winding should be the one connected to the earth terminal, leaving the other end to connect to the aerial terminal. Of course, the wire that used to connect the aerial terminal to the tuned circuit is now removed, for, if this is not done, the aerial coil would be short-circuited and we would be no better off than before.

This is not the only method of reducing the undesirable effects we have discussed, so that, in our next instalment, we will have something to say about other methods of increasing selectivity and reducing aerial de-tuning.

R.F. Heating (*continued from page 31*)

ing of the load to the generator; but since both the transference and absorption of the power are governed by laws that are well understood, the conditions required for success can usually be predicted from the results of a few trials and a knowledge of the appropriate data for the material to be treated and for the oscillator.

(To be concluded.)



The second picture shown in last month's radar story was printed in error. Above are the H.S P.P.I., range tube and height indicators.

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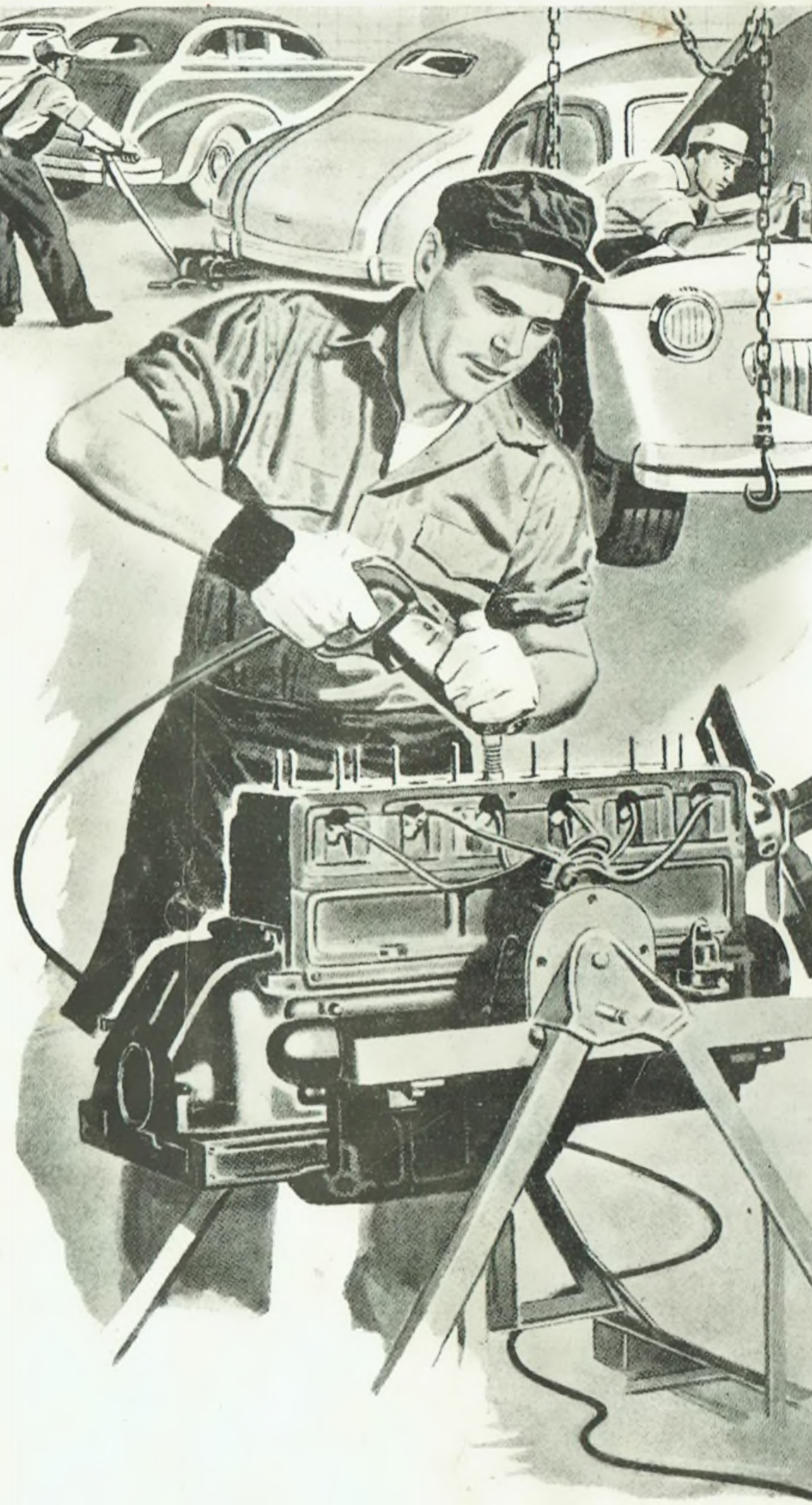

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