ELECTRONICS AND TELEVISION & SHORT-WAVE WORLD

FEBRUARY, 1941

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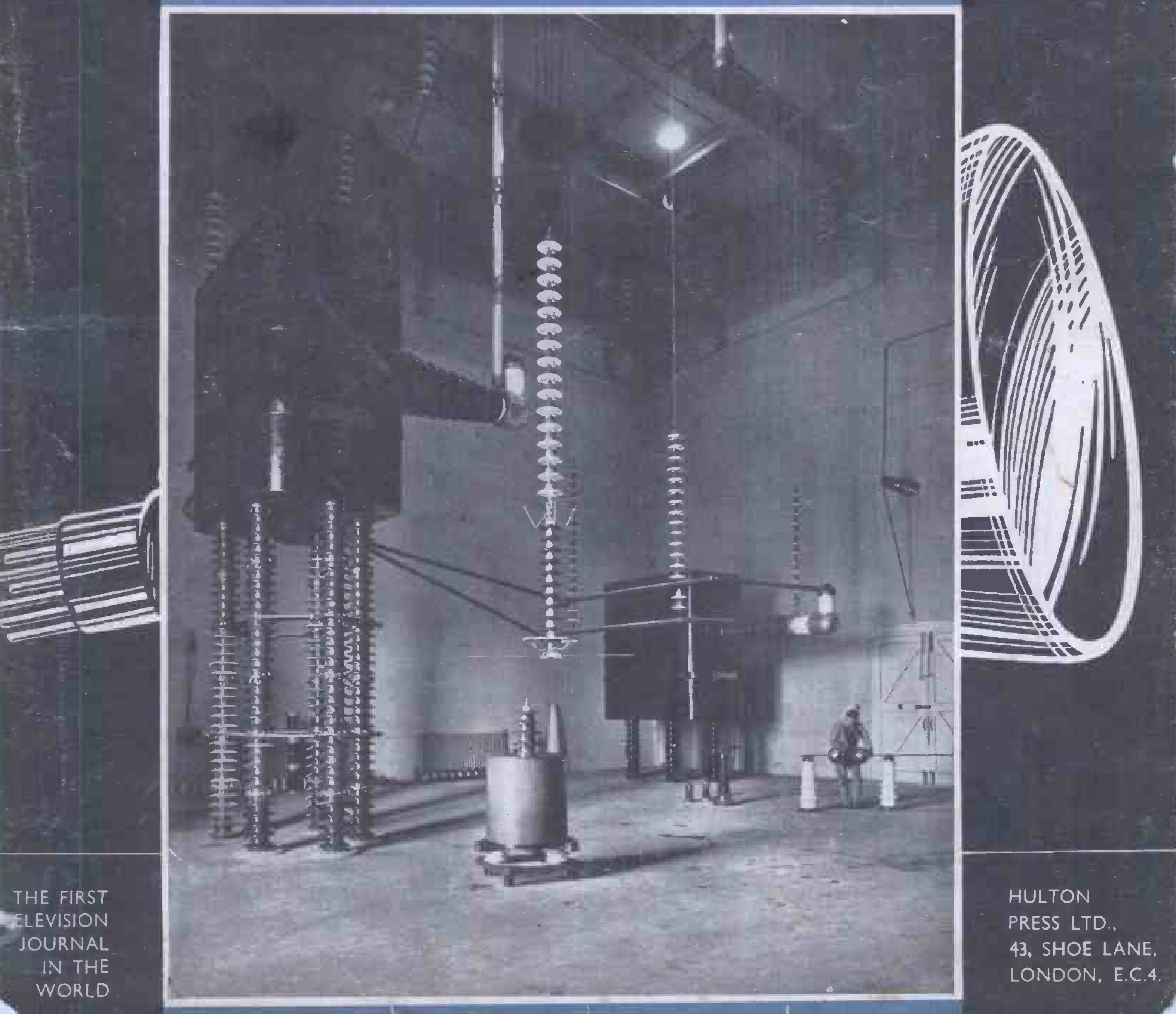

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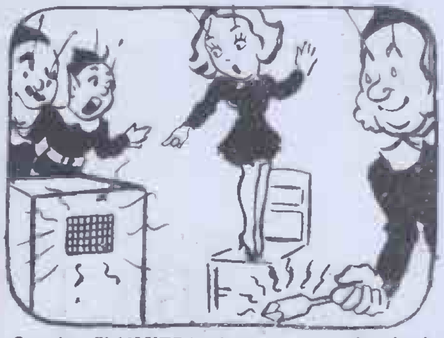

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"It's squealing!"—
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the lads speeded
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I deduce
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broken loose"
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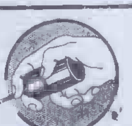

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CURRENT ELECTRONIC LITERATURE

Some Measurements of High Frequency Permeability. (Jackson.) Experiments are described in which the permeability of specimens of mumetal, stalloy, mild steel, and 6% tungsten steel, hardened and unhardened, was measured over the frequency range 10^6-10^7 c.p.s. The permeability was determined by calculation from the measured high-frequency resistance and d.c. resistance. Results shown in graphical form are compared with results obtained by Dannatt and Armour. The author considers whether the variation of permeability with frequency is due only to the frequency effect or whether it depends also on the corresponding variation of H. —*Philosophical Magazine*, September, 1940.

Testing Insulators. (Subak.) The author suggests the substitution of vacuum glow discharge for water as the interior electrode for testing porecelain and other insulators having hollow spaces and a single bottom. Experiment with both d.c. and a.c. are described, the latter producing more complicated phenomena mainly due to the necessity for the discharge to become ignited every time zero current is passed. It is important to determine what share of the total voltage applied is used to sustain the glow column, and a test arrangement is described, which enables the ignition and burning voltages of the glow column to be ascertained. *Electrical Review*, October 9, 1940.

Ceramic Materials.—An outline is presented of regulations issued by a technical committee of German porcelain manufacturers. These regulations are designed to standardise porosity, water absorption, density, tensile strength, compressive strength, impact strength, hardness, thermal expansion, specific heat, thermal conductivity, resistance to sudden temperature change, puncture strength, dielectric constant and losses, insulation resistance, surface resistivity and resistance to tracking and arcing. Numerical values are given of the properties specified, and the standard methods of testing are described.—*Electrician*, October 9, 1940.

Welding Metal to Glass. A description is given of a process used in the making of electric heaters. Metals easily adhering to glass are aluminium or high aluminium alloys which are sprayed on by means of a gun. Questions relating to the design of heaters using this method are discussed, and a specimen design is given. A variety of tests carried out on the completed article are described.—*Electrical Engineer*, November 22, 1940.

A New type of Power-Torque Meter. (Hall.) For instantaneous measurements of power and torque on a propeller shaft something more than an ordinary torsionmeter is needed. A power meter has been developed making use of an electrical micrometer tube which measures mechanical displacement. Constructional details are given and the application of the instrument is described.—*Motor Ship*, December, 1940.

Woven Glass Insulation for Electrical Windings. (Jamieson.) The English Electric Co. have for some time been investigating the application of woven-glass insulation to electrical machines. The author describes how a suitable varnish with good high temperature properties was adopted for impregnating woven-glass material. Some figures are given showing the improved tensile strength, electric strength and insulation resistance of this material.—*English Electric Journal*, November, 1940.

Abstracts by Research Department, Metropolitan-Vickers Electrical Company Ltd.

PRINCIPAL CONTENTS FEBRUARY, 1941

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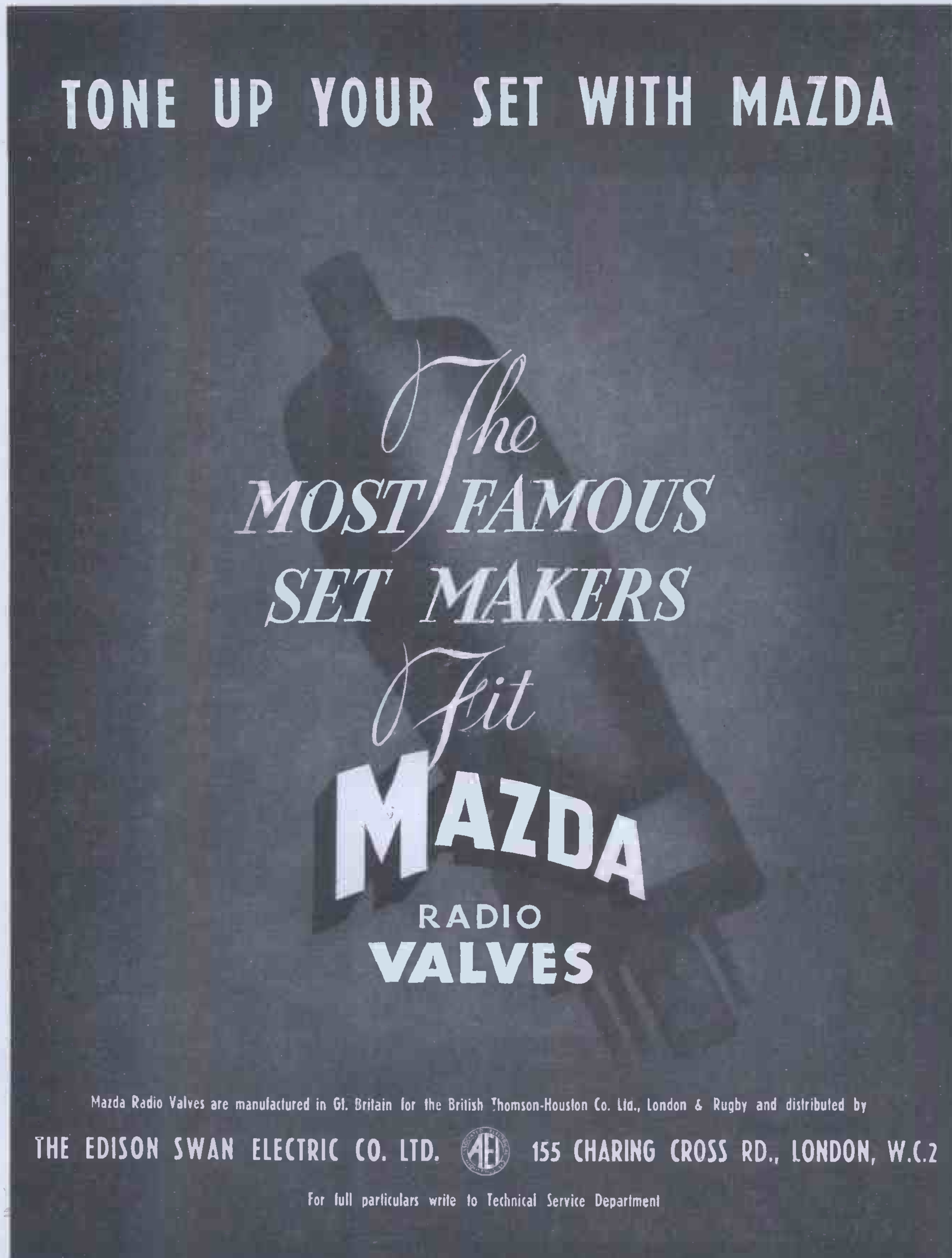
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Electronics AND TELEVISION & SHORT-WAVE WORLD

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News and Views

THE vitally important part played by radio in war-time is emphasised in the annual report of the Executive Council of the Radio Manufacturers' Association. The aims of the Association throughout 1940 have been (a) Direct co-operation in every possible way with the nation's war effort, (b) Utmost possible development of the export or radio apparatus from this country, and (c) Maintenance of the domestic radio industry at a level appropriate to secure the continuance of the home broadcast reception service.

The first has included co-operation with the Government in assisting in the provision of skilled personnel for the Services and to this end a Joint Committee was formed comprising representatives of the Services, the Board of Education, the Ministry of Labour and the Association. The work of this Committee has been the taking of a census of wireless engineers who have joined the Services, or are registered for military service, to ensure their employment in a capacity in which full use is made of their wireless knowledge, the initiation and co-ordination of special wireless courses in technical colleges throughout the country to train wireless mechanics to meet the recurring needs of the Services and the organisation in conjunction with the R.A.F. of refresher courses for civilian instructors to conduct the wireless courses.

For the development of the export and home market trade another Sub-Committee was formed with a suggested production scheme during 1940 of 200,000 sets for export and 900,000 sets for the home market. The scheme was modified about half-way through the year, the revised figures for the second half of the year being 120,000 sets for export and 250,000 sets for the home market. This revised plan was accepted by the Board of Trade. Plans are now being prepared for 1941 and a tentative figure is 230,000 sets for export.

Among the political activities of the R.M.A. was contact with the Television Advisory Committee and a series of meetings was held in which, after full examination of the problem, it became clear that there was no prospect of the reinstatement of a public television service during the war. Methods of continuing television research and development work, both by the Government and in the industry, were, however, explored and this included research in frequency modulation.

Further, refinement and improvement of the Du Mont delay- or memory-screen television tube has resulted in correcting the colour from the original orange to a satisfactory white. The white delay tube, which makes feasible the halving of the usual 30 frames per second to 15, thereby permitting 625-line scanning for greater pictorial detail instead of the 441-line R.M.A. standard, within the allotted television channels, has recently been demonstrated to television engineers studying various systems and standards for their subsequent recommendations to the Federal Communications Commission.

By providing an image-retention or carry-over effect from one electronic impression to the next, the white-delay teletron minimises flicker. Even at 15 frames per second instead of the usual 30 frames necessary for rapid-decay screens, the flicker is not discernible when using the white-delay tube. Whirling disc tests for trailing indicate no objectionable degree of motion blur over a wide range of speeds, while in the handling of film subjects the carry-over feature definitely contributes to smoother action. Comparative tests of pictorial contrasts between the white-delay screen and standard screen have shown the former to be quite satisfactory. Meanwhile, comparative tests of resolution or pictorial detail between 625-line scanning made feasible by the while-delay tube, and the usual 441-line scanning, indicate a marked gain. With the usual rapid-decay tube, half the lines are lost by the eye in following motion, whereas the eye sees this additional detail with the delay tube. Also, the delay tube eliminates interline flicker at 30 frames.

De Mont engineers have also been demonstrating the Du Mont synchromatic system utilising driven receivers which follow line and frame changes automatically and require no oscillator adjustment, thereby eliminating the possibility of obsolescence which has handicapped television commercialisation.

Two Circuits of Interest

Here are two circuit arrangements of practical utility and of a novel character.

Experimental Oscillator Stage

EACH of the various oscillator circuits shown in the diagram (Fig. 1) is well known, but the combination of these oscillators into a composite circuit, due to *Q.S.T.* (U.S.A.), is probably new.

The chief advantage in the arrangement shown in Fig. 1 is its extreme flexibility in adapting itself to purposes for which modern oscillators are generally designed.

By merely selecting the proper coil or plug-in unit for the grid or cathode circuit, it is possible to secure any one of six types of oscillator circuit as follows: straight tetrode or pentode crystal oscillator, tri-tet, regenerative crystal with choke in cathode (the grid-anode oscillator), regenerative crystal with screen-grid feedback, electron coupled oscillator and variable-crystal oscillator.

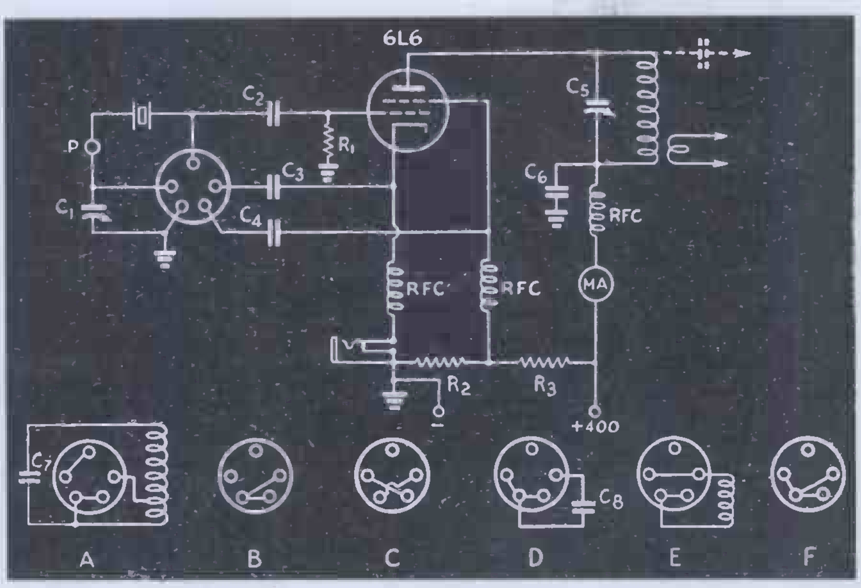

Fig. 1. Circuit diagram of experimental oscillator and details of coil and plug connections.

A—E.c.o.
B—Variable-frequency crystal.
C—Screen feedback crystal.
D—Grid-anode crystal circuit.
E—Tri-tet circuit.
F—Tetrode circuit.
C_1—300 $\mu\mu$fd.
C_2—250 $\mu\mu$fd.
C_3—0.01 μfd.
C_4—0.002 μfd.
C_5—100 $\mu\mu$fd.
C_6—0.01 μfd.
C_7—0.001 μfd.
C_8—250 $\mu\mu$fd.
R_1—20,000 to 50,000 ohms.
R_2—50,000 ohms.
R_3—15,000 ohms.
P—60-ma. pilot lamp.

The condenser C_1 tunes the e.c.o. and tri-tet coils and is used for regeneration control in the screen-grid feedback oscillator, therefore it should be of sufficient size to cover its various uses. A condenser of smaller capacity than that recommended would probably cause erratic operation in regenerative crystal oscillators. It may be as high as 500 $\mu\mu$fd., although some difficulty might be encountered in setting frequency with the e.c.o. while doubling or quadrupling frequency.

A fixed high capacity is connected across the e.c.o. coil for stability and is mounted inside the coil form. The crystal need not be removed when using the e.c.o.

A.C. Operated Ohmmeter

The second diagram (Fig. 2) is the circuit of an A.C.-operated ohmmeter recently published in *Radio* (U.S.A.).

The six ranges of this ohmmeter are 100, 1,000, 10,000, 100,000, 1 megohm, and 10 meghoms full scale, which correspond to 4.5, 45, 450, 4,500, 45,000 and 450,000 ohms at the centre of the scale.

With the low range it is very easy to check filament windings, speech coils, and even soldered joints, while the high range will be useful for testing leakage of condensers, a.v.c. circuits, etc. Voltage ranges of 50, 250 and 1,000 are also included.

The 100-ohm range of the meter operates as a Wheatstone bridge with the meter as a galvanometer and the unknown resistance shunted across one leg of the bridge. With this system a current drain of only 15 milliamperes will suffice for this range.

The maximum voltage applied to the unknown resistance is only 50 or 60 millivolts on the 100-ohm range of this tester. The other ranges merely consist of fixed series resistances with a variable voltage supply to compensate for line voltage variations. The 10-megohm range operates at a potential of 450 volts.

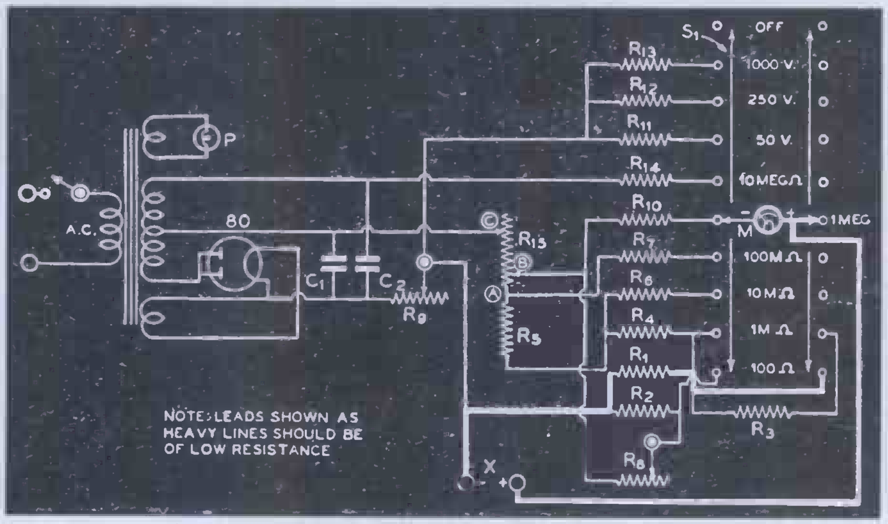

Fig. 2. Circuit diagram of A.C. operated ohmmeter.

C_1—0.5-μfd. 600-volt tubular.
C_2—1.0-μfd. 600-volt tubular.
R_1—5 ohms, ½-watt wire-wound.
R_2—10 ohms, ½-watt wire-wound.
R_3—200 ohms, ½-watt wire-wound.
R_4—30 ohms, ½-watt wire-wound.
R_5—330 ohms (300 and 30 in series) ½-watt wire-wound.
R_6—350 ohms, ½-watt wire-wound.
R_7—4000 ohms, 1 watt.
R_8—10,000 ohm wire-wound rheostat or potentiometer, 10 watt.
R_9—5000 ohms, 4-watt wire-wound potentiometer.
R_{10}—45,000 ohms (40,000 and 5000 in series), ½-watt.
R_{11}—50,000 ohms, 1 watt.
R_{12}—250,000 ohms, 1 watt.
R_{13}—1 megohm, 1 watt.
R_{14}—450,000 ohms, 1 watt.
R_{15}—50,000 ohms, 50 watt adjustable.
S_1—2-circuit, 11-position selector switch.
M—0-1 d.c. milliammeter; 50 ohms resistance.
P—Pilot light.

High-vacuum Pumps and Pumping

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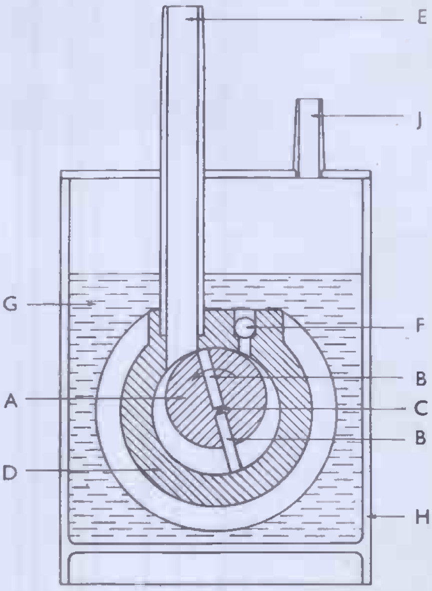


Fig. 1. Diagram showing operating principle of rotary mechanical vacuum pump.

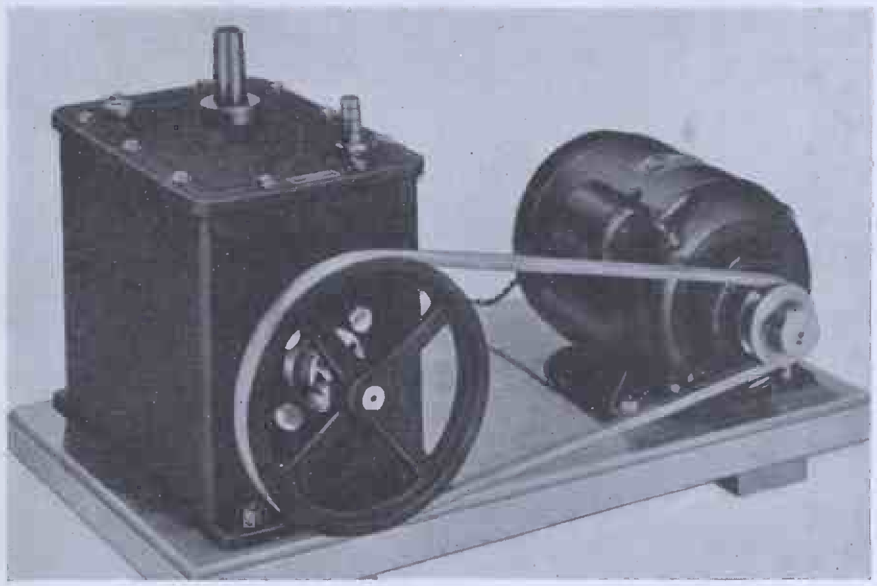


Fig. 2. Complete " Speedivac " mechanical rotary pump.

In the manufacture of valves, cathode-ray tubes, lamps, X-ray tubes, neon tubes and other thermionic apparatus it is essential to obtain the highest possible vacuum and desirable that the pumping speed be high. Although the foregoing are among the better known applications of high vacua, there are very many others employed in industrial processes as, for example, cathodic sputtering in mirror manufacture and deposition of thin metallic films, impregnation and desiccation.

The engineer uses vacuum chucks, the surgeon controlled vacuum to remove fluids, the metallurgist depends on high-vacuum to free dissolved gases from metals, the biologist to evaporate water from organic materials at low temperatures and the chemist to purify substances which decompose when distilled at ordinary pressures.

As fresh applications have arisen new pumps have been developed and to-day there is an extensive selection of models available having a wide range of pump speeds and pressures, though their operating principles are the same. Great advances have been made since the comparatively recent era of piston pumps which are now almost obsolete for the majority of work. The two types of pump which are in general use to-day for the production of high vacua are :—

1. Rotary oil-sealed mechanical pumps.
2. Mercury diffusion pumps.

Rotary Oil Sealed Pumps

Fig. 1 shows diagrammatically the internal construction of a typical rotary oil-sealed mechanical pump. This consists essentially of a rotor A having sliding blades B held apart by springs C. This is arranged to rotate within the stator D and is mounted out of centre so that the rotor and stator are in contact over a part of their diameters between the inlet port E and the outlet valve F. The whole assembly is mounted in an outer tank H and completely submerged in oil G. Air escapes from the outlet valve and leaves the tank by the connection J. Fig. 3 is a photograph of the rotor. A controlled amount of oil is allowed to reach the interior of the pump where it seals the contacting surfaces and also provides the necessary lubrication. As the rotor turns in the direction shown by the arrow, the crescent-shaped space in communication with the inlet is isolated by the blades and the air trapped therein is carried round to the outlet valve and expelled. This operation continues until the pressure at the inlet is reduced to a small fraction of a millimetre (about 0.01 mm. Hg.) the limit being determined by the perfection of the fit of the various parts and the sealing provided by the oil film, which prevents air from passing between the ports as the rotor rotates.

By using two similar sets connected in series and immersed in the same oil tank, extremely low pressures may be reached (0.00001 mm. Hg.). The whole of the working parts are fitted into an outer case and completely submerged in a special low-vapour pressure oil which ensures perfect lubrication, prevents leakage of the air into the high vacuum and assists in efficient cooling of the pump.

Great accuracy is necessary in the manufacture of these pumps which, because of their simplicity and freedom from all complicated devices, will maintain initial efficiency under most exacting conditions. Fig. 2 shows the external appearance of such a pump with its associated motor.

A great advantage of the rotary type of pump is the simplicity with which it can be put into operation. As will be seen the pump is mounted on a base with motor and vee-belt drive. Connection is then made to the electric supply and on closing the switch the unit commences to operate immediately.

The performance of a rotary pump is determined not only by the design but also by a suitable choice of materials for its construction. The main pump castings are made from a special iron alloy, combining suitable hardness and freedom from porosity with a resistance to corrosion.

MERCURY DIFFUSION PUMPS

This is particularly important in industrial applications where acids and similar vapours have to be pumped. Very special attention is paid to lubrication and as the ultimate vacuum is determined largely by the oil in the high vacuum stage, the two-stage pumps are designed so that the oil is freed from gas during its passage from the main tank. Loss of oil as leakage from the shaft sealing gland is eliminated by a special rotary seal.

Vapour sprayed from the exhaust is trapped by a simple baffle cast in the lid. Fig. 4 shows a spray arrestor which may be fitted in place of the outlet spout. The oil employed is a special low-vapour pressure type specially processed for the purpose.

Diffusion Pumps

The mercury diffusion pump is used in conjunction with the rotary type to produce faster pumping speeds and lower pressures than are obtainable with a rotary machine only. They provide the most satisfactory means of reaching very low pressures and even the smallest sizes have pumping speeds at low pressures much greater than can be obtained by rotary pumps. They have no moving parts to wear and can be dismantled for cleaning with a minimum of trouble. The diffusion principle can only be employed efficiently at pressures below 10^{-1} mm. Hg. approximately; these pumps, therefore, must be used in conjunction with a suitable "backing" or "fore-vacuum" pump, which will normally be of the single-stage rotary oil immersed type having an ultimate vacuus of 10^{-1} to 10^{-2} mm. Hg.

Fig. 5 shows the operating principle of the diffusion pump. The liquid used is either mercury or oil which is heated in the boiler S, the vapour passing upwards through the tube A and issuing by the annular jet E. The jet directs the vapour downwards towards the pump walls which are cooled by the water jacket indicated by K.

Gas molecules from the apparatus being exhausted diffuse in the mercury or oil vapour stream and are carried along with the mercury or oil molecules, the mercury or oil is then condensed on the cooled walls and is returned to the boiler by a return tube, while the gas is removed by a mechanical rotary pump, which is connected at V. Fig. 6 shows the external appearance of a single-stage mercury diffusion pump and Fig. 7 a pump of this type in conjunction with a mechanical backing pump.

Oil diffusion pumps operate with very low vapour pressure oils, usually of the Apiezon type.

In order that the high speeds of the diffusion pumps may be fully utilised it is essential that connection to the apparatus being exhausted be as short and wide as possible. For this reason pumps are provided with standard flange fittings on the high vacuum side so that the pump may be bolted directly to the apparatus where this is of metal construction. If a glass tube connection must be used, this may have a standard conical joint and be used in conjunction with the adaptors or the end of the tube may be flanged and joined to the flange of the pump.

Fig. 3. Rotor and blades of single-stage mechanical pump.

The total pressure obtainable with a diffusion pump is limited by the vapour pressure of the working fluid, *i.e.*, mercury, at the cooling water temperature Should total pressures below this be required, it is necessary to interpose a cooling trap between the pump and system to be exhausted, it being essential to trap the vapour which tends to diffuse back from the pump into the exhausted system. This can be achieved by condensing the vapour on a cooled surface, the usual method at one time being to interpose a re-entrant glass trap between the pump and work and to immerse this in liquid air.

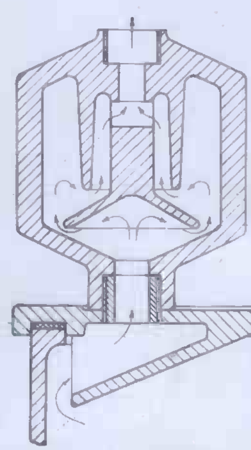


Fig. 4. Diagram of spray arrestor for mechanical rotary pump.

Such traps are fragile and unsuitable for use with metal apparatus and may with advantage be replaced by the steel trap shown in Fig. 7. The inner portion is filled with liquid air through the orifice at the side and as this inner container is surrounded by an evacuated space, the heat flow is restricted and the liquid air only boils off at a comparatively slow speed. Where the very lowest pressures are not essential, a mixture of solid CO_2 in acetone or trichlorethylene may be used. In this connection the following table of vapour pressures will be of interest.

Temperature °C.	*Vapour Pressure of Mercury.*
20	1.1×10^{-3}mm.
10	4.3×10^{-4}mm.
0	1.6×10^{-4}mm.
—76 (CO_2 trap)	1×10^{8}mm.
—183 (liquid air trap)	almost unmeasurable.

If a diffusion pump is to operate at maximum efficiency, it is essential that a "backing" pump shall be chosen with characteristics which are suitable for the proposed work. Where it is required to maintain a certain speed at some fixed pressure, the speed of a suitable "backing" pump is calculated as follows: If the required diffusion pump speed is S_1c.cs. per sec. at a pressure of P_1mm. of Hg. and P_2 is the rated "backing" pressure for the pump, then the "backing" pump must have a minimum speed of $\frac{S_1 \times P_1}{P_2}$ at a pressure of P_2mm. This must not be confused with the free air displacement which will generally be several times greater.

With the larger pumps the required "backing" speed will be so high as to make the cost of the rotary pump prohibitive. In this case a smaller pump may be used to work between the high-speed diffusion and the "backing" pumps. Thus a pump having a speed of 150 litres per second and a backing pressure of 0.05 mm., if operated at its maximum speed at 0.001 mm., would need a fore pump with a speed at 0.05 mm. of 3 litres per second. A rotary oil pump with this displacement would be unduly large, but an equivalent performance can be obtained by interposing a small diffusion pump before the oil pump.

If the work is such that the important factor is the time taken to exhaust a

MERCURY DIFFUSION PUMPS

given volume from atmospheric down to some given pressure, then the problem is rather more complicated. The speed of the diffusion pump is in

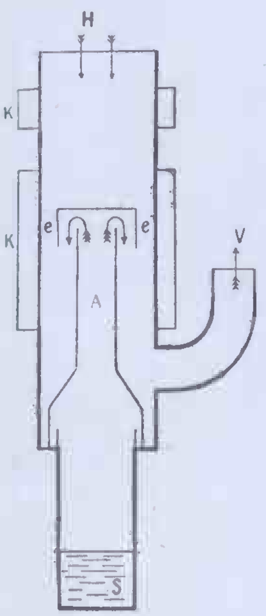


Fig. 5. Diagram showing operating principle of mercury diffusion pump.

general so high compared with that of the "backing" pump that a large percentage of the total time is taken in reaching a pressure of 1 mm. or so. Hence it is important to utilise the full speed of the "backing" pump by using diffusion pumps which have been designed to offer the minimum possible restriction.

All diffusion pumps need a certain heat input to vaporise the mercury and a flow of cooling liquid through the condensing jacket. Electric heating is most desirable, but for laboratory purposes the smaller types may be gas heated. The range of heat input over which the pumps will operate is fairly wide. The characteristics of a pump vary somewhat between the limits of heat input stated and in general the speed at low pressure is a maximum when the heat input is a minimum. The maximum permissible "backing" pressure is, however, increased at the higher inputs and the work in hand determines the best working point.

The speed of a diffusion pump is also influenced by the cooling water temperature and the curve Fig. 9 is a typical example showing how the speed varies with temperature.

The rate of cooling water must be adjusted so that the temperature rise between inlet and outlet does not exceed one or two degrees. This flow may be between 1.5 and 4 litres per minute, according to the size of the pump.

Measurement of High Vacua

Accuracy of measurement of high vacua has become almost as important as its production, and consistent therefore with the development of pumps it has been necessary to devise new measuring instruments. Three types of gauge are in general use, the McLeod, the Pirani and the Philips. The McLeod type is the most popular vacuum measuring gauge. This gauge has undergone important changes in design in recent years and several alternative forms are available. One of these modi-

Fig. 6. Single-stage mercury diffusion pump.

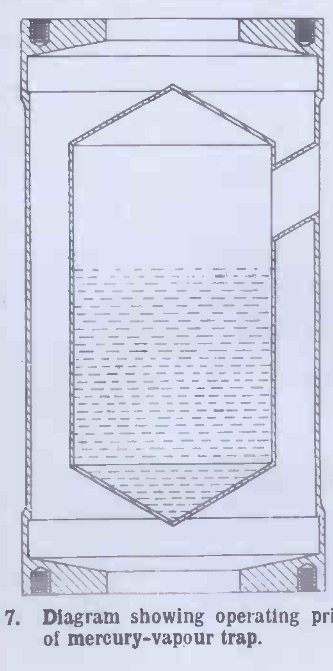


Fig. 7. Diagram showing operating principle of mercury-vapour trap.

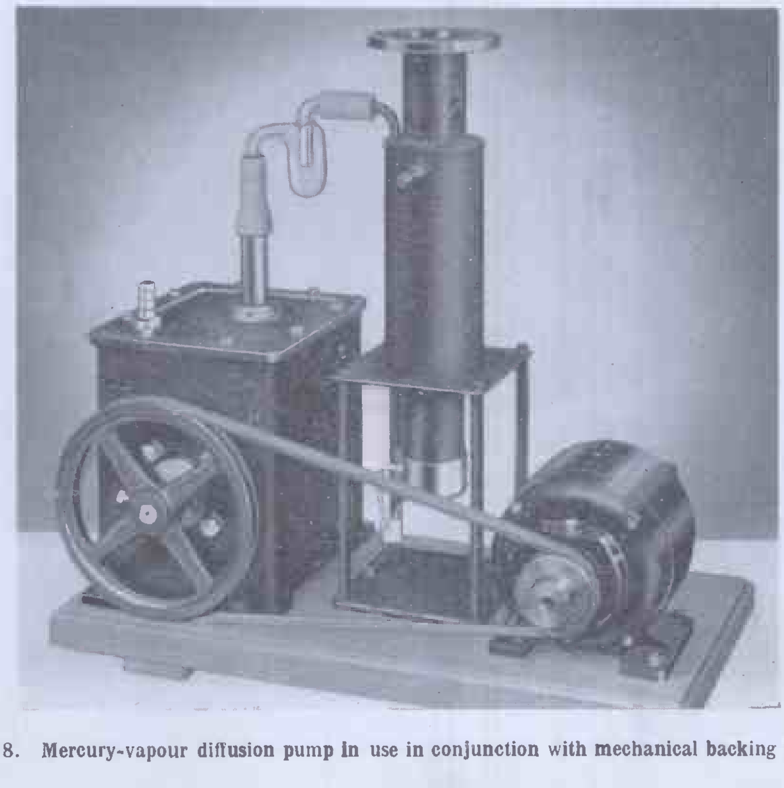


Fig. 8. Mercury-vapour diffusion pump in use in conjunction with mechanical backing pump.

HIGH-VACUUM MEASUREMENT

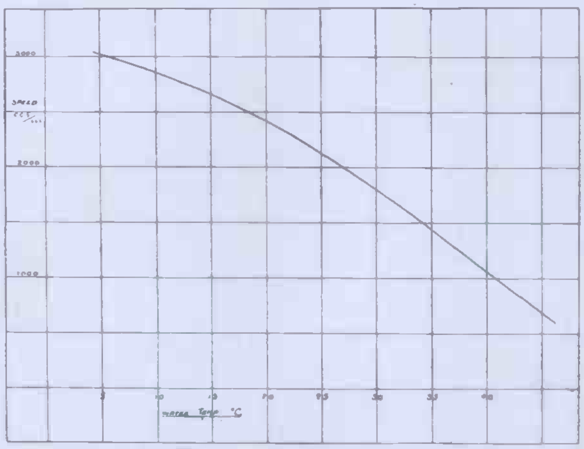


Fig. 9. Curve showing effect of cooling water temperature on speed of diffusion pump.

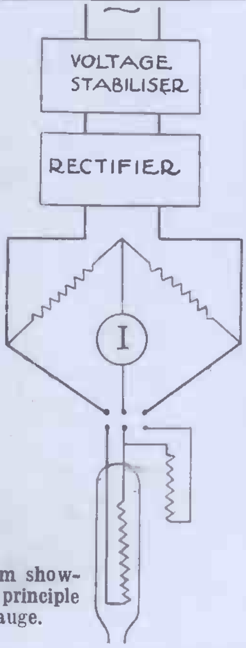


Fig. 11. Diagram showing operating principle of Pirani gauge.

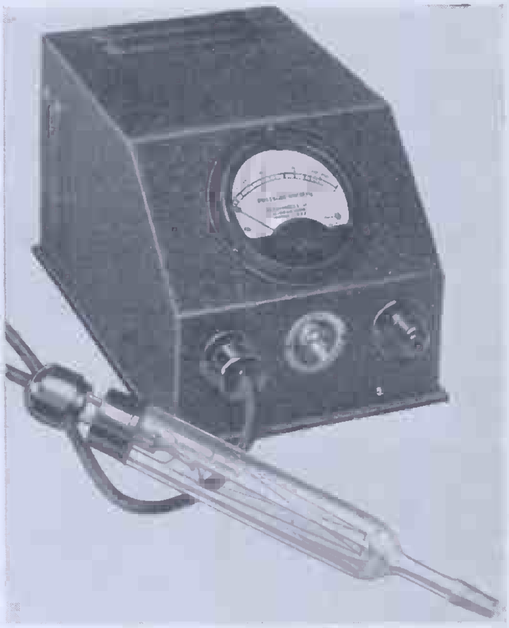


Fig. 12. The complete Pirani gauge.

fications, which is of quite recent introduction, is the Vacustat (Fig. 10). This, while similar in principle to the McLeod gauge, differs considerably in construction and use.

Whereas the normal type of McLeod gauge must have an overall height well in excess of the barometric column, the Vacustat is only 9 in. high and this fact, together with the small quantity of mercury needed (approximately 8 c.cs.) makes the gauge readily portable.

The need for raising the mercury level to compress the gas as in the normal McLeod is obviated by making the Vacustat of such a form that rotation about its centre causes the compression and is the only operation necessary to take a reading. The glass part of the gauge is mounted on a metal stand with direct scale and is provided with a stainless steel outlet. Connection to the vacuum system is made by rubber tubing which also provides the necessary flexibility for rotation through 90°. The gauge is left in the horizontal position during exhaust and simply turned to the vertical position when a reading is desired. The direct reading scale covers the range from 10 mm. to 0.01 mm.

While the McLeod gauge is still the most satisfactory instrument for the accurate measurement of low gas pressures, there are two classes of work for which its use does not meet all requirements.

Firstly, with some industrial processes it is necessary to indicate or even record rapid fluctuations of pressure and secondly it is sometimes more important to know the total pressure rather than the partial pressure of the true gases. Both requirements are met by direct reading gauges of the Pirani and Philips type.

The principle of the Pirani gauge consists of measuring the rate of heat loss from a filament surrounded by the gas whose pressure is to be measured. At low pressures this loss is a function of the pressure and if a constant current is maintained through the filament its temperature and hence its resistance will vary with the pressure. A convenient method is to make the filament one arm of a Wheatstone bridge, the opposite arm being arranged to give

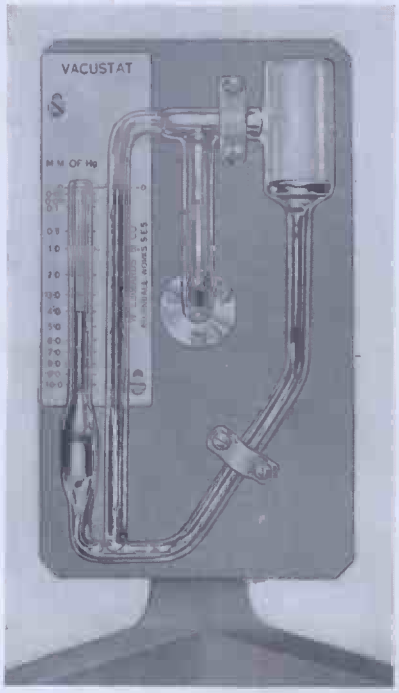


Fig. 10. The Edwards "Vacustat" a modification of McLeod gauge.

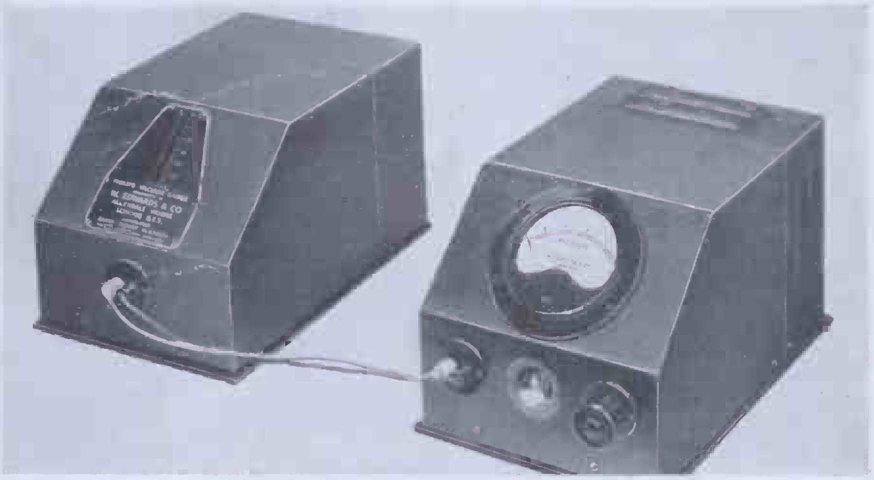


Fig. 13. The Philips direct-reading gauge.

compensation for variations of air temperature. The bridge is supplied from a special circuit giving constant current irrespective of mains fluctuations and a rectifier. An indicating instrument operated by the out-of-balance current is calibrated direitly in pressure units. Fig. II shows a schematic diagram and and a complete gauge of this type is illustrated in Fig. 12. This has a range from 1.0 mm. to 10^{-4} mm.

The standard units are for operation on A.C. 50 cycles or D.C. mains between 200-250 volts, readings being independent of normal mains fluctuations. The indicating instruments may, if desired, be mounted at some distance from the vacuum apparatus.

The Philips gauge (Fig. 13) is another type which gives a continuous indication even with rapidly varying pressures and operates simply by connection to A.C. mains. It measures directly pressures in the range 5×10^{-3} to 10^{-5} mm. Hg.

This instrument has a special discharge tube which is connected to the system of which the pressure is to be measured and this contains two electrodes maintained at a constant potential. The glow discharge current is a function of pressure, but as this would normally be too small to measure at very low pressures a magnetic field is arranged at an angle to the electric field in such a manner that the electron path is lengthened and the probability of ionisation by collision is greatly increased. In this way an appreciable current will flow even at pressures so low that a discharge would normally be impossible.

The instrument consists of two parts—the power and the measuring units. The former is provided with a plug for mains connection and an indicating instrument from the readings of which the pressure is obtained by reference to the calibration curve. The measuring unit is connected to the vacuum system by a standard cone joint and is provided with a glow discharge lamp and scale. The length of the glow discharge gives an alternative approximate indication of the pressure.

This gauge will indicate the pressure of vapours as well as true gases and this fact makes it particularly suitable for controlling the manufacture of all types of discharge devices. If used on systems incorporating mercury pumps or McLeod gauges it must be isolated from these by suitable traps.

The Philips gauge makes possible for industrial purposes the measurement of pressures in the range which otherwise could only be measured with an ionisation gauge. Unlike the latter it requires no skilled adjustments and cannot be damaged by accidental increases of pressure above its normal range. Also it can be arranged for recording or for control purposes with the addition of suitable relays.

A New Frequency Changer

VALVES of low "slope" always tend to give a poor ratio of signal as compared with noise, and on this account, if not for other reasons, frequency-changing valves give a particularly poor performance, for as is well known the conversion conductance of a frequency-changing valve is rarely greater than a quarter of its ordinary mutual conductance. The presence of further grids, common in frequency-changing valves, makes this performance worse by setting up additional noise currents.

In point of fact, it is not the actual value of the slope that matters, but the ratio of the slope to the space current, so that a valve will very often perform best at a value of slope which is by no means its maximum, and it has been discovered that very good results can be obtained when by biasing the control grid very negatively the space current is reduced to a comparatively few microamps. When operated in this way the valve does not function in the usual space-charge-limited manner, but the electron current is determined entirely by the randomness of velocity of the electrons emitted from the cathode. The electron current is then related purely exponentially to the control-grid potential, so that the slope is proportional to the electron current, and it is found that with this state of affairs a much greater ratio of slope to current can be achieved than with operation under space-charge-limited conditions.

An obvious drawback to operation with such small currents is, of course, that with the normal type of valve no amplification of signals is obtainable. The drawback is, however, easily overcome by using a valve employing multiplier action. If a valve is used having three or four stages of electron multiplication subsequent to the control electrode, initial cathode currents of the order of ten micro-amps can be made to yield output currents of the order of ten milliamps. It has been found that in this way with a normal oxide-coated cathode a conversion conductance greater than seven-tenths of the normal mutual conductance is obtainable when using a heterodyning potential as small as only 0.2 volt R.M.S. A radio receiver incorporating such a frequency-changer requires no amplification prior to conversion, and is thus particularly suitable for working at ultra-high frequencies, say, frequencies above 100 mc/s.

Since the cathode current is so small, currents induced in the control-grid circuit by electrons passing the grid are necessarily very small so that grid damping is almost entirely eliminated and a high impedance tuned circuit can be used in the input circuit with its advantage of adding to the overall gain. To make full use of the low grid damping it is desirable to use flat strips or braided wire of thin metal tape for the electrode leads to ensure low high-frequency resistance. Since also the cathode current is so small, the cathode impedance is high and the cathode, therefore, is well suited to be used as a control electrode, and can be used, for example, for applying the local oscillation.

The valve is not suitable as a pure amplifier at very high frequencies on account of the relatively high electron-transit time of a multiplier. This time is likely to be of the order of $^{-8}$ second which is several times the period of an oscillation of 500 mc frequency. The inevitable spreading of the transit times of the electrons in such a case on account of different electron paths, for instance, will result in a corresponding spreading of the output phases and a much reduced slope. In the frequency-changer case there can be no loss of slope in this way unless the beat frequency is very high. It will be evident that the high transit time in no way prevents the valve from functioning well as a detector.

In the use of the valve it may be found that the gain of the valve is liable to wander on account of the various sources of instability in a multiplier type of valve. This can be prevented without any reduction in gain by stabilizing the mean final anode current by the application of pure D.C. feedback to the control-grid circuit.

Some Observations Relating to Reports of Colour Television in America

By P. NAGY, Dipl. Eng., International Television Corporation

*Recently the Columbia Broadcasting System demonstrated a colour television system in New York. Detailed technical reports are available. Based upon this demonstration the future and merits of colour television in general are discussed.**

THE colour television system demonstrated by Dr. Goldmark is simple and practical.[1 2 3]

For those readers who are not acquainted with the details of the system, the essential characteristics are briefly as follows :—

A high-definition black and white picture (484 lines, 60 frames, double interlacing) is transformed into a coloured picture. The number of lines is reduced to 343 and the number of frames per second increased to 120. Each single frame is transmitted in one of the three primary colours, blue, green or red. To the more or less standard film transmitter used is added a three-colour filter rotating between the film and the cathode-ray scanner. The red, green and blue picture components interlaced in the odd and even lines are intermittently scanned in accordance with the succession of the colour segments. On the receiver side a colour filter similar to that of the transmitter rotates in front of a cathode-ray tube and naturally both the transmitter and the receiver filter segments run in synchronism. The red, green and blue picture content appears on the screen of the cathode-ray tube as a partial black and white picture and the colours will only reappear when viewed through the appropriate colour filters. When the colour segments are not used a black and white image of the original appears. It should be emphasised that the main characteristics of the transmission-standard of this colour system are the same as those of a black and white picture : there is no need for separate high frequency channels or an additional synchronising signal ; the frame sync. impulses will synchronise both the frame deflection of the cathode-ray beam and the phonic wheel of the colour filter disc.

Reports of the results obtained with this method are extremely good. The definition of the picture did not seem to suffer due to the " interlaced " transmission of the red, green and blue picture content, but as a matter of fact the definition appeared to be improved. The colour contrast made small details more apparent. The colours were a faithful reproduction of the original. The apparent brightness of the coloured picture was greater than that of the black and white picture in a room which was not darkened.

In the past it has been assumed that to transmit a coloured picture of a certain standard and definition three times the frequency band would be needed than for a black and white picture of the same standard and definition. This assumption was a misconception. Just as the eye is not sufficiently perfect to observe that no two of the elements of a television picture are transmitted at the same time, so it cannot differentiate between two pictures, one viewed in natural colours, or another one which is decomposed in its primary colours and then presented to the eye in quick succession.

The frequency band which is necessary for the transmission of good coloured pictures is best judged by comparing the frequency band of a coloured and of a black and white picture of equal definition, both pictures at the same time lacking any sign of flicker. There are other characteristics which have to be considered, such as the reproduction of fast movements, etc., but these are of minor importance. The basis of comparison is flicker and definition.

The effect of colour on the critical flicker frequency may be reasoned by taking two extreme cases. By the critical flicker frequency is meant that number of changes of brightness per unit time when the eye begins to notice these changes.

Transmission of White Background

Critical flicker frequency of the coloured transmission is presumably the same as the critical flicker frequency of the black and white transmission, because the repetition frequency is the same in both cases. Each filter will transmit an equal amount of light, consecutive frames having different colours ; the sensitivity of the eye for flicker is apparently not affected by any other change, but the repetition frequency, i.e., in this case the number of frames per second.

Transmission of Coloured Background

Repetition frequency of coloured transmission is one-third of the repetition frequency of black and white transmission. This case, in contradistinction to the aforementioned one, represents the worst condition of flicker. Only every third frame is perceptible to the eye and the repetition frequency is equal to one-third of the number of frames per second.

It is reasonable to assume that the average picture content consists of a combination of all the colours, and so it will have a similar effect on the eye to that of the white background when considering the flicker frequency.

The lowest permissible repetition frequency is not only controlled by the number of light intensity changes per unit time, but is also affected by the amount of storage which is present in the received picture, colour, intensity of illumination, background illumination, etc.[4 5] There are very ambitious storage systems, some retain the brightness of every picture element for the period of a whole frame. In this case the critical flicker frequency may be as low as 25 per second and the bandwidth may be reduced as much as 50 per cent.

The frequency band necessary for the transmission of the coloured standard which was demonstrated (System I in table) can be calculated :—

$$\text{Number of frames/sec.}\ \frac{(\text{Number of lines/frame})^2}{\text{Interlacing number}}\ \text{Picture Ratio}\ .\ 1/2 =$$

$$120\ .\ \frac{(343)^2}{2}\ .\ 5/4\ .\ 1/2 =$$

4,400,000 cycles/sec.

The same bandwidth will accommodate a black and white picture of higher definition :—

*Since this article was written Mr. J. L. Baird has demonstrated a colour television system which, it appears, eliminates the only real disadvantage of the CBS demonstration, namely instead of the direct view C.R. tube necessitating a twenty-inch colour filter disc, he is using a small sized projection C.R. tube and thus the diameter of the colour filter disc is reduced to reasonable dimensions ; otherwise the principles of both systems appear to be very similar. As far back as 1923 Mr. Baird made colour television experiments and employed apparatus which was wholly mechanical. In 1939 he demonstrated a colour picture using a projection C.R. tube on the receiver side.

$$60 \cdot \frac{(\text{Number of lines/frame})^2}{2} \cdot 5/4 \cdot 1/2 = 4,400,000.$$

The number of frames per second is halved, therefore the number of lines per frame may be increased with the square root of two.

Number of lines per frame = $343 \cdot \sqrt{2} = 484$.

To quote[1]:—" The immediate effect of increasing the scanning rate (i.e., number of frames per sec.) by a ratio of two-to-one is to reduce the number of lines in the picture, for a given bandwidth, by a factor equal to the square root of two. The coloured picture must have 41 per cent. less resolution than the black and white picture which can be sent over the same channel." Compared with a black and white picture of the same definition the bandwidth necessary for the coloured picture is twice that of the black and white one. Thus the CBS demonstration seems to have established that the bandwidth does not need to be threefold of that of the black-and-white picture.

The important question arises whether a further narrowing of the bandwidth is possible. In the Table on this page the characteristic relations between colour and scan successions, complete period of scanning and the corresponding time intervals of the demonstrated system may be compared with the characteristic relations of other suggested systems.

To narrow the bandwidth for a given detail quadruple interlacing has been suggested by CBS engineers. To quote again.[1] " A field rate (number of frames per second) of 180 per second is employed and the interlacing is four-to-one, the scanning frame rate (number of complete pictures per second composed of all the four groups of the interlacing) is 45 per second. The reduction in detail compared with black and white picture on the same channel is only 22 per cent. Such quadruple interlacing permits adequate rendition of the colour progressions, excepting possibly the effect of interline flicker when a large patch of a solid pure colour is to be reproduced." The black and white standard to which this system (II in Table) is compared is naturally the same black and white standard which was the basis of comparison in system I, i.e., 60 frames per second, double interlacing. The synchronisation of such a quadruple scan must be perfect, otherwise the definition of the picture must suffer seriously and the details of the picture may be muddled appreciably. Line and frame deflection must start dead in time. The lack of perfect interlacing is far less serious in the case of a double interlaced picture. But if such a quadruple interlacing is a practical proposition and there is no interline flicker, then the at present used double interlaced standards should be abolished and quadruple interlacing introduced. It means half the bandwidth and the same definition. The suggested NBC colour system (II in Table) compared with a 60-frame, quadruple-interlaced black and white scan requires three times the bandwidth.

I		P (frames 1–6)											
	Frame No.	1	2	3	4	5	6	1	2	3	4	5	6
CBS standard as demonstrated	Group of lines of interlaced scan.	1, 3, 5, 7, etc.	2, 4, 6, 8, etc.	odd	even	odd	even	odd	even	odd	even	odd	even
$Q=\sqrt{2}=1.41$ $N=120$	Colour of filter	R	G	B	R	G	B	R	G	B	R	G	B
	Time in seconds	$\frac{1}{120}$	$\frac{1}{60}$	$\frac{1}{40}$	$\frac{1}{30}$	$\frac{5}{120}$	$\frac{1}{20}$						
II		P (frames 1–12)											
	Frame No.	1	2	3	4	5	6	7	8	9	10	11	12
CBS standard as recommended	Group of lines of interlaced scan.	1, 5, 9, etc.	2, 6, 10, etc.	3, 7, 11, etc.	4, 8, 12, etc.	1, 5, 9,	2, 6, 10,	3, 7, 11,	4, 8, 12,	1, 5, 9,	2, 6, 10,	3, 7, 11,	4, 8, 12,
$Q=\sqrt{\frac{3}{2}}=1.22$ $N=180$	Colour of filter.	R	G	B	R	G	B	R	G	B	R	G	B
	Time in seconds	$\frac{1}{180}$	$\frac{1}{90}$	$\frac{1}{60}$	$\frac{1}{45}$	$\frac{5}{180}$	$\frac{1}{30}$	$\frac{7}{180}$	$\frac{2}{45}$	$\frac{1}{20}$	$\frac{1}{18}$	$\frac{11}{180}$	$\frac{1}{15}$
III		P (frames 1–9)											
	Frame No.	1	2	3	4	5	6	7	8	9	1	2	3
$Q=1$ $N=90$	Group of lines of interlaced scan.	1, 4, 7, etc.	2, 5, 8, etc.	3, 6, 9, etc.	1, 4, 7,	2, 5, 8,	3, 6, 9,	1, 4, 7,	2, 5, 8,	3, 6, 9,	1, 4, 7,	2, 5, 8,	3, 6, 9,
	Colour of filter.	R	G	B	G	B	R	B	R	G	R	G	B
	Time in seconds.	$\frac{1}{90}$	$\frac{1}{45}$	$\frac{1}{30}$	$\frac{2}{45}$	$\frac{5}{90}$	$\frac{1}{15}$	$\frac{7}{90}$	$\frac{4}{45}$	$\frac{1}{10}$			
IV		P (frames 1–6)											
	Frame No.	1	2	3	4	5	6	1	2	3	4	5	6
$Q=1$ $N=60$	Group of lines of interlaced scan.	1, 3, 5, etc.	2, 4, 6, etc.	odd	even	odd	even	odd	even	odd	even	odd	even
	Colour of filter.	R	G	B	R	G	B	R	G	B	R	G	B
	Time in seconds.	$\frac{1}{60}$	$\frac{1}{30}$	$\frac{1}{20}$	$\frac{1}{15}$	$\frac{1}{12}$	$\frac{1}{10}$						

P= period of complete scan, during which all the lines in all the colours weres canned ones. N=number of frames per second. Q=ratio of the number of lines of the black and white and coloured picture, once where the comparison is based on the 60 frames, double interleaced black and white standard and equal bandwidth. R=red. G=green. B=blue.

Table showing the characteristic relations between colour and scan successions, complete period of scanning and the corresponding time intervals of the demonstrated and other suggested systems.

There are possibly simpler systems which may give good enough results with regard to flicker for the average colour picture content. For example systems III and IV in the Table may be worthy of investigation. It would be interesting to know whether the effect of lower frame frequencies has been investigated during the CBS experiments.

System IV is the simpler of the two. Using double interlacing the number of frames per second is 60. The definition and the bandwidth of both—the black and white and the coloured systems—is the same.

System III compares just as favourably with the double interlaced 60-frame black and white picture regarding bandwidth and definition. Q equals one. The system has 90 frames per second and the interlacing is triple.

Two seemingly undesirable characteristics should be noted:—

(1) The interlacing is triple and there are three primary colours. The colour succession must be therefore staggered, otherwise a particular group of lines of the interlaced scan would always be transmitted in the same colour. The result of such a staggered succession is that the time interval separating the same primary colours is not constant. It may well be possible that due to its inertia the eye will not

notice such irregularity. There is also the additional but small disadvantage that the essential phase adjustment of the colour disc of the receiver must be at least within the range of nine frames, as against three of the demonstrated standard.

(2) The frame frequency does not coincide with the frequency of the supply mains.[6] As we know it has been thought desirable to lock the frame and line frequency to the frequency of the mains on the transmitter side. The chief reason for doing this is the desire to eliminate or reduce the effect of "hum" on the picture. Hum may appear in the deflection voltages, focusing, signal amplitude, etc. When the frame frequency is not locked to the mains the distortion of the scanning pattern or hum band will travel continuously across the picture, and this fault is very apparent and very disturbing. It is possible to eliminate these faults by careful design. We know that the outside transmissions of the Alexandra Palace were occasionally quite good in the above respect and there was a considerable discrepancy between the frame frequency of the transmitter van and the mains in London.

The interlocking of frame and mains frequency has the disadvantage that it requires very careful design of the transmitter; if the follow-up is not smooth and slow the steadiness of the scan and especially the interlacing may suffer.

Colour may be introduced into the picture by changing the colour of the filter after each line and not by scanning the whole frame through a red, green and blue filter. It may be found that interline flicker is less apparent and disturbing to the eye than frame flicker. This type of colour scanning may be especially suitable for certain new television developments combining mechanical and electrical scanners. It does not necessarily mean increased speed of rotation of the colour filter.

Any existing television receiver may be used for colour reception by introducing one major alteration and one major addition :—the brightness of the picture must be increased threefold and a coloured filter must rotate in synchronism with the filter of the transmitter in front of the picture. There are minor alterations, such as adjustment of synchronising circuits, etc., but these are easily met.

The coloured filters absorb two-thirds of the white illumination available and in consequence the brightness of the coloured picture is less than one-third of that of the black and white picture. If the transmission coefficient of an optical surface could be one hundred per cent. it would be exactly one-third.

The brightness of the screen must be increased threefold; it may be that "at the present stage of the art it is rather difficult to construct an electrode system giving a sufficiently large beam current and at the same time a small enough spot size on the screen" using voltages of the order of five to seven thousand volts, but it can be done.

The cathode-ray tube is, however, not the only means of producing television pictures and the ample illumination of the picture should not represent any difficulties in more ambitious television systems using a high intensity light source, such as a tungsten filament or a high-pressure mercury lamp.

Reports have indicated that in a semi-darkened room the apparent brightness of the coloured picture was higher than that of a black and white picture. This is a very precious quality of colour reproduction. "The colour contrasts are not affected so greatly as are simple black and white contrasts, when the picture is flooded with external light." When a black and white picture is viewed, the eye will be only sensitive to the changes of intensity of the white illumination. With colour a new variable is introduced into the picture. The persistence of colour contrasts when flooded with white light is best understood by the realisation that colour is a new and is the second variable in the picture.

The following example may help to visualise matters :—

A television picture consisting of a black and white square, as seen in the

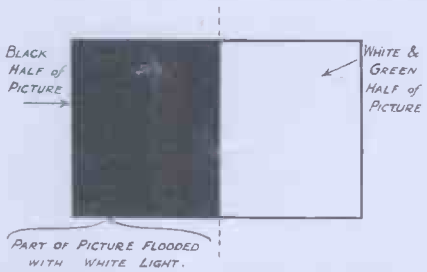


Diagram elucidating the fact that "the colour contrasts are not affected so greatly as are simple black and white contrasts, when the picture is flooded with external light."

figure, is projected on to a white screen. The screen has a reflection coefficient of one hundred per cent. The room itself is illuminated, but only the dark half of the picture is flooded by white light of such intensity that the whole picture appears uniformly white, i.e., the contrast between black square and white square completely disappears.

Colour is introduced. The white half of the picture is now green. The black half of the picture is flooded with white light as before. Whatever the intensity of the green half it will be always visible. We have introduced a new variable :—colour.

Synchronism between the filter discs of the transmitter and receiver up to the present has been maintained by the use of a common alternating-current supply. In commercial practice it will be necessary to synchronise the filter disc of the receiver with the aid of the sync. signals of the transmitter. The disc may be driven by a synchronous induction motor fed by the mains-frequency or any other convenient self-generated frequency and synchronised by a phonic wheel fed with the sync. signals of the transmitter. Or a phonic wheel system may synchronise and also drive the filter disc employing a motor-generator circuit.

The only objectional feature of the CBS system seems to be the size, noise and the difficulties of synchronisation of the colour filter rotating 1200 r.p.m. in front of the receiver. The diameter of the cathode-ray tube was 9 in., giving a picture width of approximately 7½ in. The diameter of the filter disc (six segments) was 20 in. The combination of the number of segments, diameter and speed of the filter disc were apparently chosen in such a way that they represented the best compromise. A picture of reasonable size requires a tube diameter of 12 to 14 in. The corresponding diameter of the colour filter disc will be of the order of 30 in. To synchronise such a disc rotating at 1,200 r.p.m. is not a simple problem, it certainly cannot be done with "a single type 6L6 tube."[1] The speed of the periphery of the thirty inch disc would be 125 miles per hour. The electrical frequencies fed to the phonic wheel and the "mechanical" frequencies generated by the phonic wheel and especially by the disc are well within the audio frequency band. Thus—even if the disc is perfectly streamlined — noiseless operation is unlikely.

There are, however, more ambitious receivers than a directly viewed cathode-ray tube. There is the projection cathode-ray tube which may produce a picture of only two by three inches. There are also other systems combining mechanical and electronic scanning which have also a light source of restricted dimensions. In all these cases colour filter discs may be used having small diameters.

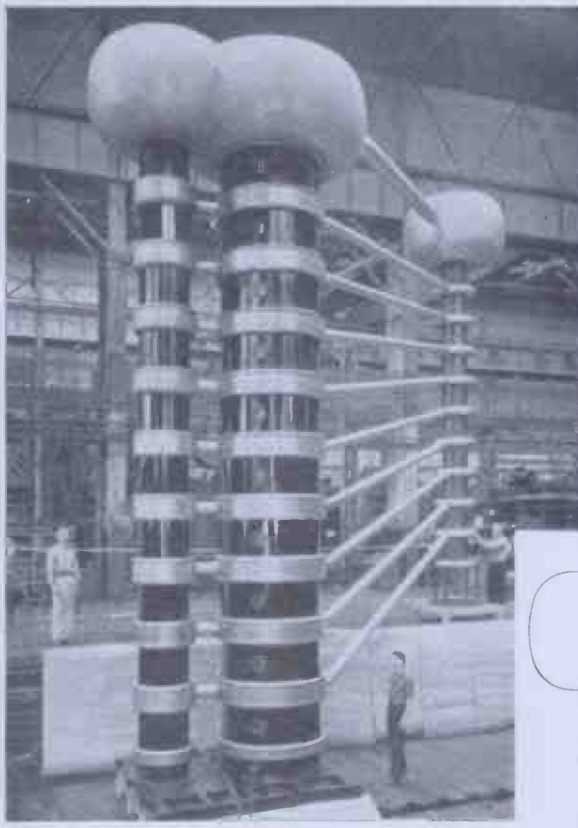
The synchronising of a mechanical scanner is a very much simpler problem than most television engineers believe. Experience gained during the development of mechanical-optical television systems has shown that the power necessary for driving and synchronising a fair sized "slow drum," scanning the frames, or a "high speed drum," scanning the lines, is of the same order as that used for the frame and line scanning of a cathode-ray tube.

The generated sound is proportional to the diameter of the disc.

The power necessary to drive and synchronise the disc is proportional to the inertia of the disc; the inertia is proportional to the third power of the diameter.

The writer is confident that in the near future coloured pictures will be transmitted for the general public using a bandwidth which will be simi-

(Continued on page 95)



1,400,000-volt Constant-potential X-Ray Apparatus

By Dr. E. E. Charlton and H. S. Hubbard,
General Electric Co. (U.S.A.)

Constructional details of the most powerful X-ray equipment in the world built for the U.S.A. Bureau of Standards. We are indebted to the "General Electric Review" (U.S.A.) for the information.

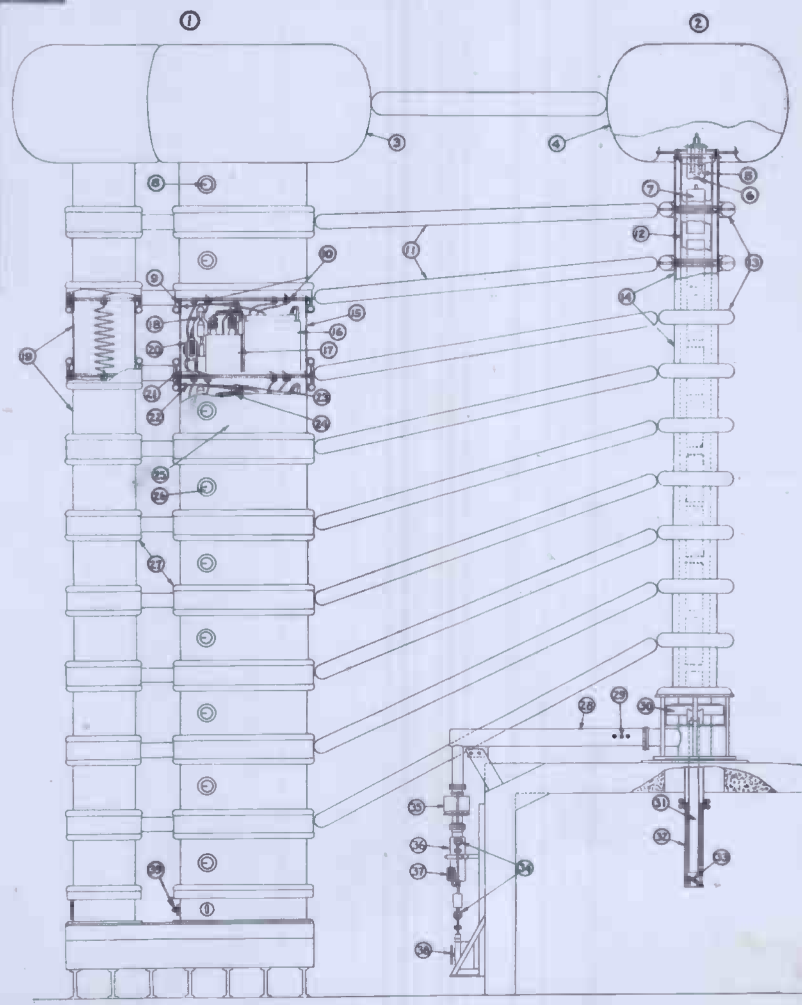


Fig. 1. Assembly of 1,400,000-volt constant-potential X-ray equipment.

THE most powerful and flexible X-ray equipment in the world has been installed by the United States National Bureau of Standards. It is to be used for furthering the work in standardization and methods of measurements of X-radiation over the range from 400 to 1,400 kv., and on this account has many features of design that are quite different from those of other units that have previously been built for the very high-voltage field. Primarily, it consists of a combination of multi-section X-ray tube, D.C. generator, and voltage-measuring resistor, which are shown diagrammatically in Fig. 1.

REFERENCES.

1. Ten-section cascade 1,400-kv d-c generator.
2. Ten-section X-ray tube.
3. Top corona shield of generator.
4. Top corona shield of X-ray tube.
5. Permanent magnet to compensate effect of external magnetic field.
6. Cathode assembly.
7. First intermediate electrode.
8. Oil gauge.
9. Filling plug.
10. Spring contacts
11. Connections to intermediate voltage taps.
12. Cylindrical glass envelope.
13. Tube corona shields on intermediate sections.
14. Herkolite protective shields.
15. Herkolite tank.
16. Plate transformers.
17. Capacitors.
18. Kenotrons.
19. Herkolite stack housing high-voltage resistance potentiometer.
20. Filament transformer.
21. Drain valve.
22. Polarity-switch control.
23. Reversing polarity switch.
24. Plate resistors.
25. 140-kv unit.
26. Viewing window.
27. Corona shields for generator and resistance potentiometer stack.
28. Vacuum line.
29. Ionization gauges.
30. Magnetic focusing coil.
31. Insulated collector electrode.
32. Extension chamber with water jacket.
33. Tungsten target.
34. Vacuum shut-off valve.
35. Charcoal trap.
36. Oil-diffusion pump.
37. Hale-Pironi gauge.
38. Rough vacuum pump.
39. Filament and power-supply terminals.

The D.C. generator is of the cascade type made up of ten individual units with a rated voltage of 140 kc. The circuit is essentially a full-wave voltage-doubling rectifier, each 140-kv. unit comprising a mains transformer, filament transformer, two kenotrons, and two 0.1-uf. condensers assembled in an oil-filled Herkolite tank.

Circuit connections of all the units are made by the cascade principle with each transformer having a tertiary winding which carries power to succeeding units.

The X-rays are generated from a multi-section high-vacuum X-ray tube with the tungsten target mounted in the end of an extension chamber which is at earth potential. The ten sectional glass cylinders comprising the vacuum envelope are surrounded by heavy-wall

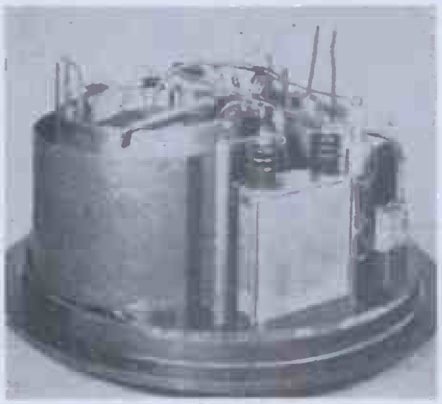


Fig. 2. Interior of generating sectional unit

Herkolite tubes to provide both mechanical strength and safety against possible glass breakage.

High-voltage D.C. Generator

The full-wave voltage-doubling cascade-type generator consists essentially of a number of individual voltage-doubling rectifiers (one of which is shown with the case removed by Fig. 2), the output of which is in series, but with the power supply to each unit in parallel. Such a design has many advantages that are readily apparent. The characteristics of one individual stage represent in general the characteristics of the entire generator, and many of the controlling factors are thus greatly simplified. The design lends itself readily to good regulation, a minimum voltage ripple, and entire stability. Either polarity can be used at will and units may be added to or subtracted from any assembly if more or less total voltage is permanently desired.

For this generator, a unit voltage of 140 kv. was chosen. This offered a convenient potential for which standard kenotron rectifier tubes were available and permitted the use of a small compact transformer design.

The ten units are stacked one above the other (Fig. 1). The entire generator assembly is 30 ft. 6 in. high, including the corona cap and structural base, and occupies a floor space of 8 ft. by 8 ft. 6 in. The total weight is 40,000 lb. Connections between the tanks are of the spring-plunger type and are made automatically as the tanks are assembled in their indexed positions. The base of each unit is securely bolted to the cover of the preceding section in the series, making the entire construction rigid. The vertical construction lends itself to adequate shielding between sections and to shielding the generator as a whole to earth.

The X-ray Tube

The X-ray vacuum-tube envelope consists of ten sections of moulded Pyrex glass joined with wax to cast copper flanges which carry the intermediate accelerating electrodes. The thermionic cathode (Fig. 3) consists of several turns of tungsten wire wound into a spiral and mounted in an electrostatic focusing cup. An exhaust manifold for connection to a vacuum pump is bolted to the tube envelope with metal gaskets. The target of copper-backed tungsten (Fig. 4) is mounted in the lower end of the extension chamber, and both the target and the walls of the extension chamber are water-cooled. The metal flange of the extension chamber is bolted to the exhaust manifold of the tube envelope with metal gaskets.

The X-ray tube is mounted in a vertical position parallel with the generator stack. This simplifies the problem of providing an effective insulating support, the vacuum envelope serving as its own support; it also simplifies the making of the electrical connections between the voltage taps of the generator

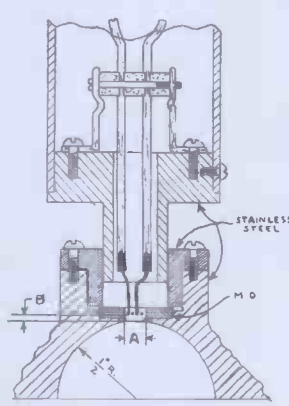


Fig. 3. Thermionic tungsten cathode.

and the different tube electrodes. Surrounding the Pyrex-glass cylinders used for the vacuum envelope, a column of Herkolite cylinders is mounted to serve as a mechanical shield. Suitable corona shields placed outside this Herkolite column provide electrostatic shielding for the electron beam and also serve as a method of connection between the immediate tube electrodes and the voltage taps from the generator.

The diameter of the electron beam is controlled at the emitting source by the design of the spiralled tungsten filament and the electrostatic focusing cup that surrounds it. The direction of the beam as it leaves the hot cathode can be adjusted by a permanent magnet placed in position near the cathode base. The diameter of the beam which impinges on the tungsten target is finally controlled by a magnetic focusing coil which surrounds the tube near the entrance to the anode extension chamber.

The structural support for the tube column is placed directly above the room in which the X-rays are generated and the extension chamber with the X-ray target is extended down through the ceiling into this room. The tube stack occupies a floor space about 3 ft. in diameter, and the insulating column, including the corona cap, extending above the room housing the extension chamber is 24 ft. 6 in. in length.

The exhaust system includes an oil-diffusion pump and a rotary oil pump. A charcoal trap is placed directly over the diffusion pump to keep oil vapour out of the tube. Ionization gauges record the tube vacuum.

Electrical Circuit

The electrical circuit is shown by Fig. 5. From the 220-volt 60-cycle single-phase supply, power is fed to the primary winding of the first rectifier unit. The voltage is controlled by the generator field of the motor-generator set supplying this equipment. The secondary coil of the main plate transformer is so connected with kenotron rectifiers and condensers as to deliver a constant-potential direct-current power supply to the X-ray tube. An insulated third winding in this unit carries the excitation to the succeeding transformer units which follow it in the series.

Cascade-excited filament transformers carry power to the cathode elements of the kenotrons. A third filament winding in the top filament transformer unit supplies power to the X-ray tube filament, and its current is remotely controlled by means of an adjustable resistance.

Each rectifier unit (Fig. 2) consisting of main plate transformer, filament transformer, condensers, kenotrons, reversing switch, and resistors is assembled in a common oil-filled Herkolite tank approximately 50 in. in diameter

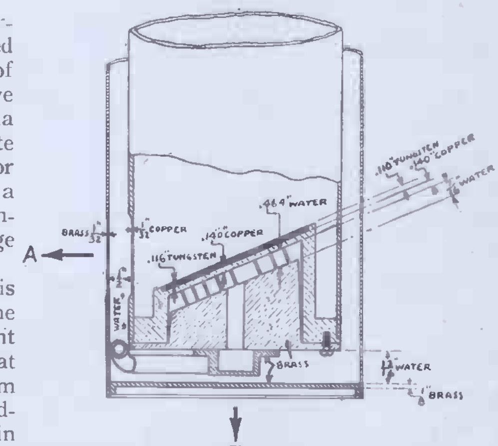


Fig. 4. Tungsten target.

and 28 in. long. Since no insulated terminals are used, full voltage appears across each tank surface; the entire structure is self-supporting, the bottom unit taking the weight of the other nine.

The tank base is likewise of Herkolite to provide additional creepage surface between the various parts, which are assembled on or adjacent to it. A steel cover is used, since at that point additional clearances were obtainable and an electrostatic shield between units to establish definitely the potential at that point is desirable.

The plate transformers are shell type with concentric cylindrical coils symmetrically arranged about the centre core leg. All, with the exception of the top unit, are equipped with an insulated third winding for the excitation of the transformer which follows it in the series. The high-voltage coil is wound for 3 kva. 66,000 volts r.m.s., and is insulated at the condenser end for 70 kv. D.C. and at the tube end for double that value. It is wound in concentric layers, the layers tapering in length towards the high end. Since the excitation is carried through the entire series, these windings in the first transformer are designed for approximately 30/27 kva. respectively and are subsequently reduced in three steps for the remaining nine units. The reactance, an all-important factor in a series circuit of this sort, was kept at a minimum by assembly of the two exciting coils adjacent to one another and by using a relatively large core size. The per cent. reactance between the supply winding and the main high-voltage is moderately low because of the relative reduction in kva. between the two.

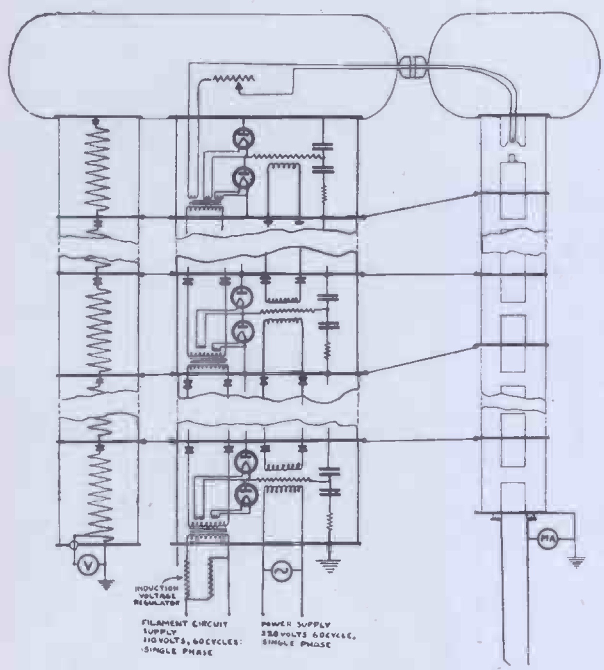


Fig. 5. Electrical circuit.

Because a considerable out-of-phase current component is inherent in a series-excitation circuit involving as many as ten transformer units, the power factor was improved at each stage by the use of a small shunt condenser connected permanently across the supply side and mounted in the unit case. The generator was designed to have a voltage ripple not exceeding 0.1 per cent. per milliampere at 1,400 kv. For additional protection of the X-ray tube a total series resistance of approximately 1 ohm per volt was introduced, divided equally among the ten units and incorporated in the separate tanks.

The filament transformers, like the main units, are arranged for series excitation.

In order that both polarities can be obtained with the generator at will, a reversing switch was incorporated in each unit. As the maximum voltage of the condenser bank (140 kv.) appears across the switch, the problem was one of high insulation in a limited space. This problem was solved by using spherical electrodes $1\frac{1}{2}$ in. in diameter with the stationary and movable contacts mounted in concentric Herkolite cylinders.

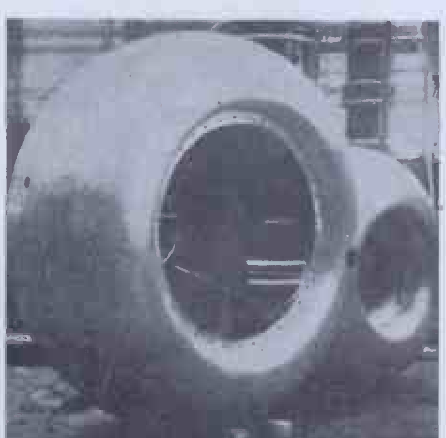


Fig. 6. Corona shield of the high-voltage generator.

Voltage Measurement

Since voltage measurements in practice may be made with a high-resistance leakage-type meter, a shielded enclosure or dummy stack for the divider resistance has been incorporated with the main generator. It is designed to operate at a gas pressure of 15 lb. The casing is made up in four lengths of Herkolite cylinders $24\frac{1}{2}$ in. in diameter with a 5-9th in. wall. In order to establish definite potential gradients along the surface, an electrostatic shield was provided at each corresponding point of the main generator and connected there. No metal appears at the inner surface, additional insulation at the four joints being obtained by a short section of concentric cylinder on the inner and outer wall at this point.

Because of its effect on the voltage and the resulting errors in measurements, every effort was made to minimize corona. How well this was accomplished is indicated by the fact that the total loss current measured on the entire equipment at its rated voltage of 1,400 kv. was only 0.16 milliamp at either polarity. Of this amount a considerable portion is obviously true leakage over the surface.

The main corona shield was made to embrace both the main and divider stacks. It consists of two aluminium spinnings intersected and welded at that point (Fig. 6), the larger of the two having a horizontal diameter of 100 in. and the smaller 73 in. Both have a depth of 48 in., the radius at the equator being about 2 ft.

The bottom ends are made re-entrant and are reinforced with an aluminium ring made to fit the top assemblies of the generator and divider stack. A manhole with a flush cover is provided in the top of each cap so that an operator may be lowered in from a crane and thus have available an entirely safe and adequate working space for making connections or observations if required.

The shields at the connection points of the intermediate tube electrodes are made of spun-aluminium toroids with an outside diameter of 31 in. and a tubular section measuring 6 in. The top corona shield on the X-ray cathode is an aluminium spinning having a depth of 48 in. and a horizontal diameter of 73 in.

Connections between the generator and the X-ray tube, equally important from the standpoint of corona, consist of drawn aluminium tubes about 15 ft. long, the top connector being $10\frac{1}{4}$ in. in diameter, while the others are 6 in. in diameter. Each is equipped with a swivel joint at the generator end and a telescopic adjustment with an open ball-and-socket joint at the other.

Each of the ten sections of the vacuum envelopes is 22 in. long and 12 in. in diameter. The ends of the Pyrex-glass cylinders are ground so as to permit an accurate alignment of all the tube parts, and are joined to cast-brass flanges which support the tube electrodes (Fig. 7). The joints are made vacuum-tight with a special cement. Most of the metal parts of the tubes are made of non-magnetic materials. The intermediate electrodes consist of brass cylinders 7 in. in diameter and 20 in. long. The co-operating ends of these intermediate electrodes are spaced 2 in. apart. This spacing assures freedom from field currents at the gradients employed and provides adequate shielding of the beam from charges on the walls of the insulating envelopes.

The cathode parts housing the tungsten spiral filament are built with copper, brass, molybdenum and stainless steel to avoid magnetic influence on the electron beam. The tungsten filament is mounted in the cathode assembly in a manner to permit ready adjustment of the filament with respect to the electrostatic focusing.

The vacuum envelope is surrounded for its entire length by ten Herkolite cylinders, each having an outside diameter of 18 in. and a length of 22 in. with a ½-in. wall. These Herkolite cylinders are rigidly bolted together and surrounded at the plane of the tube flanges with aluminium toroidal shields which serve as outside electrostatic shields for the electron beam.

The copper-backed tungsten target is enclosed in an extension chamber made of copper with a brass water jacket surrounding it. Both the back of the target and the side walls of the extension chamber are water-cooled. The magnetic focusing coil placed around the upper end of the extension chamber is mounted in gimbals so that it can be used to shift the position of the beam after it enters the extension chamber as well as to control the diameter of the focal spot on the target. The target is mounted at 22 degrees to the tube axis and the reflected beam passes through an inherent filtration of 1-32 in. of brass, 1-32 in. of copper and ½ in. of water.

It was quite apparent in the preliminary design stages that, exclusive of the problems relating to the design of the generator itself, it would be necessary to provide means for testing the completed generator independent of the X-ray tube. Because of the unusual type of equipment, thorough factor tests under load were essential to check calculated characteristics and satisfy design requirements.

Electron Focusing

The electron beam, which travels approximately 24 ft. from the cathode to the anode, must be accurately focused to strike the target.

The tungsten target is 4 in. in diameter and a controlled focal spot size varying from ¼ in. to 1½ in. is desired in the central portion of the target surface. If any portions of this cathode beam were to strike the side walls of the metal accelerating tube or the cylindrical glass walls of the vacuum envelope, instability in the X-ray output or dielectric puncture of the vacuum envelope might result. Electron beam currents of as much as 10 milliamps are desired from a hot-cathode source operating at temperatures sufficiently low to ensure a long-operating filament life. It was also desirable to operate this tube with equal voltages on all sections.

Fig. 7. Construction of individual glass X-ray tube sections.

A cathode gun with low-voltage focusing electrodes could have been used to control the diameter of the electron beam. However, this would have required additional circuit equipment operating 1,400 kv. from earth to provide the voltage adjustments. Also space-charge limitations increase the difficulty of obtaining a 10-milliamp beam sufficiently small from such a source with the cathode operating at a temperature low enough to ensure a long life.

A study of the diameter of the electron beam with the cathode design in Fig. 3 was made. This cathode was mounted in the cathode section with the entrance to the first intermediate electrode built as shown in Fig. 8. This electrode geometry for the entrance to the first intermediate electrode provides a sharper focusing action of the beam and at the same time gives adequate shielding from possible erratic wall-charge effects in the cathode section. A fluorescent screen was placed beyond the end of the third section of the tube, 9 ft. from the tungsten cathode, and the size of the beam measured at this point.

It was found that a change of 4 to 1 in the ratio of the voltage on the second to that on the first section reduced the diameter of the beam to 1-16th of its value for equal voltages on the two sections. It is the ratio of the voltages and not the total which determines the focusing. The voltage on the lower sections below the first and second has much less influence than that on those two.

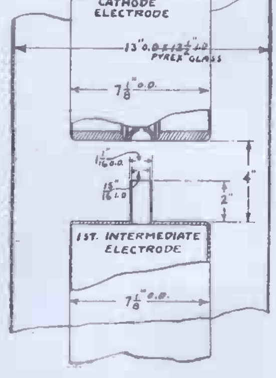


Fig. 8. Cathode section of the X-ray tube.

The British Institution of Radio Engineers—Proposed North-Western Section

THE Council of the B.I.R.E. have had under consideration the formation of a North-Western Section of the Institution. Accordingly on December 8 an informal meeting of responsible members in the North-Western Section was convened in Manchester in order to ascertain whether it would be worth while to proceed with the formation of the Section.

The meeting was well attended and whilst it was resolved that Council permission be sought for the inauguration of a North-Western Section, it was unanimously agreed that a peace-time programme could not be attempted, although members felt that possibly informal meetings would permit of the necessary preliminary detail work being completed before the cessation of hostilities, when the normal activities of a branch could be commenced without delay. For this purpose, a Provisional Committee was elected with Mr. A. G. Egginton, 83 Washway Road, Sale, Manchester, as chairman, and Mr. Alex. V. Simpson, 10 Pullman Street, Deeplish, Rochdale, Lancashire, as honorary local secretary. It is proposed to call a formal inaugural meeting in March.

Readers who are interested should apply to the hon. secretary for the folder entitled "Its purpose" which explains the objects of the Institution.

News Brevities—

Commercial and Technical

IT was recently announced that Broadcasting House has twice been hit during air raids, and serious damage caused. There were a number of casualties among the members of the monitoring staff. Although both attacks occurred during peak hours, transmissions continued without interruption.

* * *

According to *Chemical and Metallurgical Engineering,* the latest synthetic fibre to be made in Germany is called "Perluran," and is made under a process similar to "Nylon." This new plastics will not soften under temperatures about 200° C., and can be boiled and ironed. It is claimed to be considerably tougher and more elastic than silk.

* * *

Several names well known in the scientific world were included in the New Year Honours List. Dr. Edward Victor Appleton, D.Sc., LL.D., F.R.S., Secretary of the Department of Scientific and Industrial Research, has been created a Knight Commander of the Order of the Bath. Another appointment of interest is that of Mr. George Edwin Bailey, M.I.Mech.E., managing director of Metropolitan-Vickers Electrical Co., Ltd., who has been awarded the C.B.E. Mr. R. A. Watson Watt, who until 1936 was Superintendent of the Radio Department of the National Physical Laboratory, and is at present Scientific Adviser on Telecommunications at the Ministry of Aircraft Production is made a Companion of the Order of the Bath.

* * *

A novel device has been developed by an American recording company for cleaning the surface of a disc while recording, and disposing of the shavings cut from the disc so that they cannot tangle under the cutting needle. The unit consists of a blower system which directs a tiny blast of air across the surface of the disc just behind the cutting head; this throws the waste thread to the centre of the disc and prevents it from becoming tangled under the cutting needle.

It is claimed that this new method, which is extremely quiet in operation, is an improvement over the vacuum systems, as the airstream is kept away from the cutting needle where it cannot produce air noise in high-fidelity recordings.

* * *

Engineers of the General Electric X-ray Corporation, Chicago, have found that a special type of X-ray tube in which the target is rotated at high speed, a thin coating of metallic barium is a more efficient lubricant than a lubricating grease or oil. In the high vacuum necessary in X-ray tubes, ordinary lubricants are out of the question since any vaporisation of the lubricant spoils the vacuum and renders the tube useless. The use of barium as a lubricant has made it possible to produce a tube which is not only more quiet in operation, but which also has a much longer bearing life. This would, of course, result in more economical diagnostic work.

In one experiment carried out by the engineers, an anode bearing was observed to have a sound level of 87 db. at a speed of 3,100 r.p.m. and a coasting time of 12 seconds. A barium film was then applied, and in 30 seconds the sound level was reduced to 68 db., the speed increased to 3,560 r.p.m., and the coasting time extended to 8 minutes.

It is believed that the results obtained from these investigations can be applied to other cases in which rotating devices have to be operated in vacuum.

* * *

A large mercury-arc rectifier unit built for electrochemical service in the new reduction plant of the Aluminium Company of America is at present undergoing tests at Schenectady. The first of six such units to be constructed by the General Electric Company, the rectifier comprises two 12-anode ignitron rectifiers, a main rectifier transformer, and two all-welded aluminium-bar air-core reactors. The unit is rated at 10,000 amp. 600 volts D.C.

Among the medal awards of the Royal Society for 1940 is that of the Copley Medal to Prof. Paul Langevin. Prof. Langevin was one of the pioneers engaged in exploring the field opened up by J. J. Thompson's discovery of the electron. There are few branches of contemporary physics which Prof. Langevin has not improved by his writings, and his latest achevement is the foundation of the electron theory of magnetism.

* * *

The sixteenth Annual Convention of the Institute of Radio Engineers took place at the Hotel Pennsylvania, New York City, on January 9, 10 and 11. Among the subjects covered were television, frequency modulation, magnetic recording, valves, telegraphic facsimile, receiver design, measurements, cathode-ray tubes, electron multipliers, etc.

* * *

A vacuum-tube voltmeter capable of operation from either A.C. or D.C. power supply was recently announced by the Measurements Corporation, Boonton, New Jersey. A blocking condenser is employed to separate A.C. from D.C. potentials applied to the probe, and on A.C. the instrument is a peak voltmeter calibrated to read R.M.S. values of a sine wave or 71 per cent. of the peak value of a complex wave.

* * *

Two hundred and fifty thousand volt continuously-evacuated X-ray tubes for deep therapy have been installed in the Christie Hospital at Holt Radium Institute, Manchester, and in the Sheffield Radium Centre at Sheffield.

* * *

It was recently announced that Admiral Henry William Grant, C.B., has been appointed chairman and managing director of Marconi's Wireless Telegraph Company, Limited, and the Marconi International Marine Communication Co., Ltd.

* * *

An ambitious exhibition of radio receivers for export was recently held in London by Ultra Electric, Limited. The exhibition was arranged for the benefit of buyers and overseas shipping agents, and one of the most interesting features of the display was a number of multi-coloured moulded cabinets. A new 6-valve superhet receiver which can be operated entirely from a 6-volt car battery, was also shown.

* * *

An addition to the range of B.T.H. public address equipment was reported in a recent issue of *B.T.H. Activities*. This is a speech amplifying device which does not necessitate a valve amplifier. It comprises a special type of push-pull carbon microphone and requires a polarising supply of 6 or 12 volts, $3\frac{1}{2}$ amp. such as can be obtained from a car accumulator. It is of the hand type, and is fitted with a spring loaded switch which ensures that current is used only when an announcement is being made.

The output from the microphone is fed through a matching transformer unit to a specially designed speaker having a reflex or folded horn and giving an air column of approximately 12 in. to which is attached a high efficiency metal diaphragm moving coil permanent magnet driving unit. The microphone is insensitive to extraneous noise and as there are no valves, trouble due to electrical interference is obviated.

* * *

A booklet issued by the Northmet Power Company sets out the main factors to be watched in order to ensure safety when electricity is used for lighting and heating in air-raid shelters. It is dangerous to use a mains-operated wireless set in a shelter unless it is properly earthed through 3-core flex, or to carry out internal adjustments to the set while connected to the supply.

The booklet is intended to assist members of the public as well as electricians, and copies can be obtained free of charge from the Northmet showroom in London.

* * *

In a series of experiments carried out by G. L. Pearson, of the Bell Telephone Laboratories, and reported in *Bell Laboratories Record* for December, 1940, metallic bridges were formed between gold, steel and carbon electrodes when separated from 2 to 70 $\times 10^{-6}$ cm. As is known, when two electrodes are brought very close together, even under relatively low voltages, particles are torn from the electrodes and may establish a conducting bridge between them. These conducting filaments form at voltages less than the sparking potential and are produced by the large electrical forces which result from the very small separation of the electrodes.

In Mr. Pearson's experiments, the voltage gradients were about ten million volts per centimetre. To determine the point of zero displacement, electrical contact was made between the electrodes. They were then separated a known distance and the voltage between them slowly raised until the bridges formed. This occurred at voltages between 15 and 350 volts, depending on the separation. The resistance dropped permanently to a low value at the same time.

Measurements of the temperature coefficient of resistance of the bridges identified them as consisting of the material of the electrodes and changes of their resistance when the electrodes were separated or brought together slightly showed that they can be pulled out and crushed. The separation of the electrodes was controlled very delicately by attaching one of them to a cantilever bar and adjusting it with a micrometer screw. The other electrode of the apparatus was mounted on a fixed support. To ensure rigidity the whole apparatus was cut from a solid block of steel.

CERAMICS

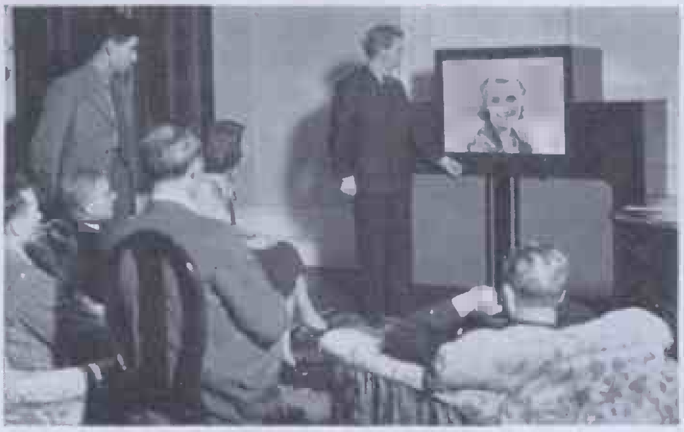
Owing to unforeseen circumstances which have been quite beyond our control, we very much regret that it has been necessary to delay publication of the first article on ceramics, as announced last month, until our March issue.

* * *

A special apparatus was recently set up in the Bell Laboratories to measure the air flow of small ventilating fans. The equipment consisted mainly of a 3-in. anemometer and a stroboscope. The anemometer was mounted 12 in. in front of the fan and measurements made opposite the centre of the fan and at 1 in. intervals in four directions along a vertical and horizontal line which intersects the fan's axis. The anemometer was moved outward until the air velocity became too small to measure accurately. The volume of air propelled by the fan per minute was found from the anemometer readings by dividing the cross-section of the air stream into rings 1 in. wide and concentric with the axis of the fan. The area of each ring multiplied by the average of the four anemometer readings for that ring gave the air flow through it and the sum of these values the total air flow. The rate of rotation of the fan was measured with a stroboscope by determining how many flashes per minute made the blades of the fan appear to stand still. To test for vibration, the fan was mounted on a platform on which rested a vibrometer, and by moving the vibrometer about on the platform the vibration in different directions was found.

* * *

It was reported in a recent issue of the *General Electric Review* (America) that a short time ago General Electric scientists froze light, shipped it, and more than a day later let the light be again born. In producing the frozen light fluorescent plates were submerged in a large vacuum bottle of liquid air, at a temperature of -320 F., and the bottle and plates bombarded with 250,000 volt X-rays. Such plates subjected to X-ray bombardment at room temperature immediately glow. Those immersed in the liquid air did not throw off light, however, until they had been removed from the bottle and allowed to warm up. Then they glowed in successively different hues as the temperature increased.

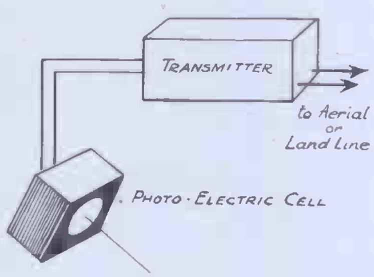


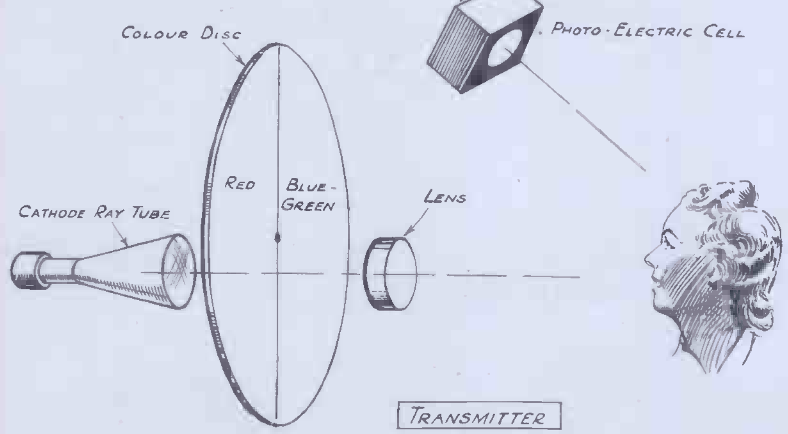
J. L. Baird's New Colour Television System—Employing Electronic Light-Spot Scanning, Direct Pick-up and Electronic Reproduction

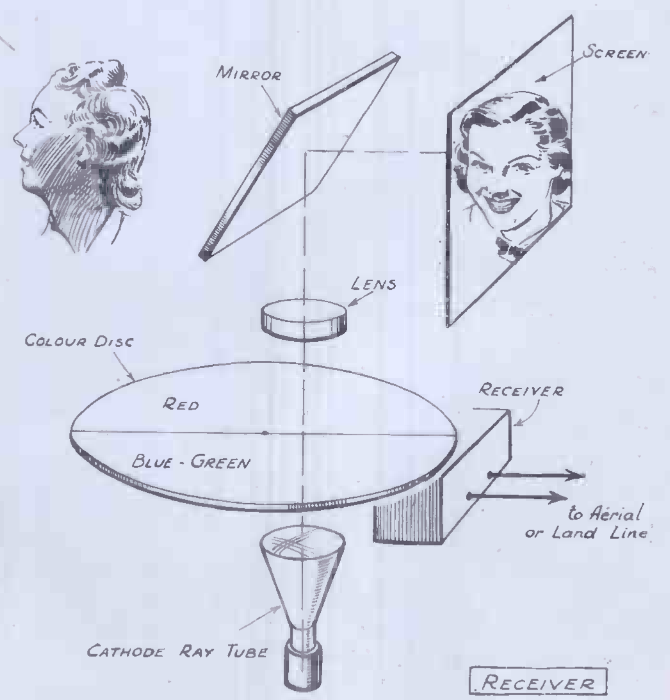
IN the September, 1939, issue of this journal details were published of a colour television system developed by J. L. Baird, and demonstrated just before that date. The following is an abstract from that article, and it is reproduced here to show that the main operating principles were the same as the systems which have recently been demonstrated in an improved form in America and in this country by J. L. Baird. The following is the abstract referred to:—

The method of scanning employed at the transmitter consists of the spot-light system. That is to say, the subject being televised is scanned by a spot of light moving in the correct scanning sequence.

The light source is a high-intensity arc lamp, the rays of which are projected through a stationary slit, behind which revolves a scan-







Schematic diagrams showing the operating principles of the transmitter and receiver. The photographs at the top of the page show the transmitting room and the receiver.

ning disc. This disc has arranged around its axis a series of slots in helical formation toward the centre of the disc. It will be clear that as the disc revolves, the slots passing in turn behind the slit will, in fact, form a scanning spot which moves along the slit. The resulting spot of light is then projected upon a mirror drum, which in turn reflects it on to the subject being televised. The light reflected from the subject is then picked up by special colour sensitive photo-electric cells, the resulting electrical impulses being passed through the amplifiers to the radio transmitter.

Each slot in the scanning disc is covered with a colour filter, the first slot red, the next blue-green and so forth, so that in effect the subject is being scanned with alternate spots of red and blue-green light, so that the special cells transmit a red and blue-green image depending upon which filter is in action. The mirror drum, which has 34 facets, revolves at 6,000 revolutions per minute, while the scanning disc revolves at 500 revolutions per minute. This combination gives a final "raster" of 102 lines, at a monochrome frequency of $33\frac{1}{3}$ per second, being composed of a secondary scan, made up from three scans of 34 lines interlaced, the secondary being displaced three times. . . . This results in a 102-line red picture, superimposed on a 102-line blue-green picture, the final result being a 102-line picture in natural colours at a colour picture frequency of $16\frac{1}{2}$.

The application of the cathode-ray tube at the receiving end, although being the outstanding advance in this system, is quite simple. The incoming picture signal is used to modulate a cathode-ray tube in the usual manner so giving a normal black and white picture on the tube. In front of the tube, there is rotated in synchronism with the scanning disc at the transmitter another disc with colour filters arranged in the same order. The picture on the tube is projected through these filters on to a screen, and since the transmitted signal represents alternately the red and the blue-green component of the subject, then in the same order a red and blue-green picture will be produced.

Recent Progress

This system, first shown by J. L. Baird and characterised by the use of the revolving colour disc and scanning with successive interlacing fields of different colours, the number of fields and colours per picture being odd and even, appears to have provided the fundamental principle with which such considerable success with colour television has now been attained both in America and this country.

For the past eighteen months Mr. Baird has been engaged in the further development of this system, and with the latest apparatus has reached a stage capable of immediate commercial development.

This work of Mr. Baird is entirely personal. The Baird Company's assets have now been taken over by Cinema Television, a company entirely controlled by Gaumont British. Mr. Baird is not connected with this company in any way, but since the outbreak of war has continued his work independently at his private laboratory at Sydenham.

The scanning method now employed remains unaltered, but the number of lines per field has been increased to 200, which, interlaced three times, give a picture of 600 lines (50 per cent. more than used by the B.B.C.) The 200 line fields are transmitted at a rate of 50 per second, so that only the same wave band as that occupied by the B.B.C. is required. The synchronising of the colour disc has been perfected, and a complete home receiver has been produced ready for marketing.

The transmitter employed consists of a cathode-ray tube, the moving spot being projected by means of a lens on to the scene to be transmitted. Between the tube and the lens is interposed a disc with red and blue-green filters so that the scene is scanned by red and blue-green moving spots in succession. The picture consists of a red 200-line field followed by a blue-green 200-line field, three 200-line fields being interlaced so that a complete colour picture of 600 lines is produced every six fields.

Photo-electric cells with a colour response approximating to that of the human eye are used to view the scene. A large aperture lens, F 1.5 is employed, and a cathode-ray tube with a voltage of 20,000 volts, giving a very bright field. This combination provides ample light even after passing through the filters.

At the receiver, the images are reproduced on a small projection tube and then projected through a colour disc run in synchronism with the disc at the transmitter. Synchronisation is achieved by filtering out the usual synchronising pulse from the picture, and amplifying it sufficiently to drive a small synchronous motor carrying the colour disc. The motor drive has been rendered practically silent, and simple and reliable in operation. The picture is projected upon a screen 2 ft. 6 in. by 2 ft., and is of very satisfactory brilliance.

The receiver has been developed as a completely commercial proposition. It includes an automatic record changing radio-gram and an all-wave radio receiver. An automatic device is also provided by which, upon merely pressing a button, the colour disc is moved out of position by means of a small motor, and the receiver can then be used to receive the monochrome transmissions from the B.B.C. Four push buttons are provided. One brings into action the automatic gramophone, the second the all-wave radio set, the third the B.B.C. television programmes, and the fourth the colour programmes. The set has not yet been priced, but will probably be sold round about 200 guineas.

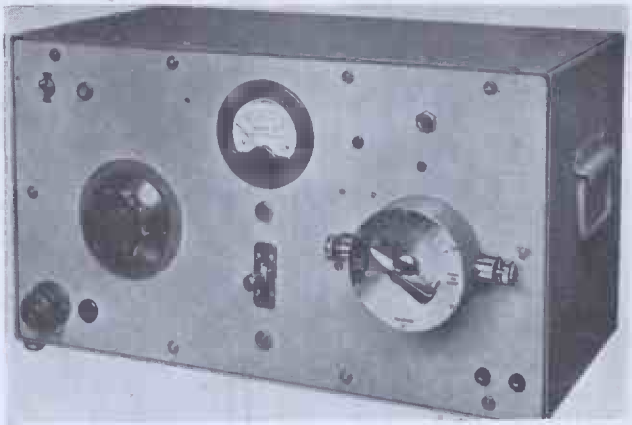
A small colour receiver has also been designed on popular lines to sell at between £20 and £30. The picture in this case is viewed directly and is approximately 5 in. by 4 in.

In the demonstration given, the transmission was by land line as, owing to the war, the use of wireless is prohibited by the Government. The pictures were transmitted from a building in Mr. Baird's grounds, where the transmitter is situated, to the receiver in his drawing room.

Although the picture shown in the heading is not an actual photograph (owing to the difficulty of photographing a television picture, particularly in colour) the reproduction does not fall very far short. Even by close inspection of the screen no signs of the scanning lines can be detected and the detail is excellent. The colour effect approximates that now being obtained with colour films, which are perhaps not quite true to nature but provide a most pleasing effect.

Low-frequency Therapy

A NEW TECHNIQUE IN THE TREATMENT OF MENTAL DISEASES



General view of the apparatus for shock therapy.

IT has been known for a long time that high-frequency currents applied to the body under suitable conditions have a marked effect on the tissues and are of considerable therapeutic value.

The use of audio-frequency currents in the treatment of disease is, on the other hand, a field which has not yet been explored to any extent, although a start has been made in the application of mains-frequency current in cases of mental disorder.

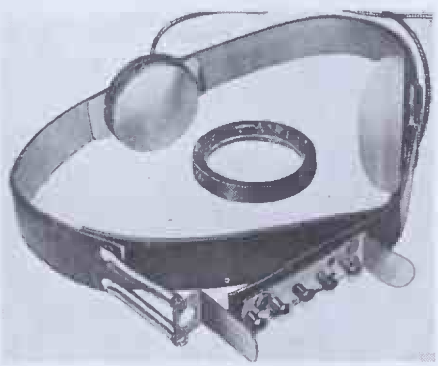
The electrical phenomena occurring in the brain and their relation to disease have already been investigated by means of the Electroencephalograph* and the knowledge so gained has led to the use of alternating voltages at ordinary frequencies to stimulate the cells of the brain where there is evidence that they are not functioning normally.

The original research was undertaken by Cerletti & Bini of Rome, and followed up in this country by the Burden Neurological Institute, Bristol.† As a result, suitable apparatus for administering carefully controlled shocks has been developed and manufactured by the Edison Swan Co. in collaboration with the Institute.

It has been established that the optimum current for stimulus of the brain is about 10 mA., but attempts to pass this current are rendered difficult by the presence of the overlying thicknesses of bone and tissue. If external electrodes are applied to the skull it is found that the attenuation produced by the tissues is such that a current of approximately 1.0 amp. peak is required to give the requisite current in the mid-brain. This current is given by applying a short duration shock of between 80-120 volts lasting for as short a time as 0.2 sec. With 50-cycle mains the brain then receives ten rapid stimuli which are sufficient to galvanise the cells into maximum activity. The effect on the patient is to produce a form of convulsion from which he quickly emerges to pass into a sleepy stage and thence back to normality insofar as his mental condition allows. A remarkable feature of the treatment is the loss of memory on the part of the patient of the circumstances immediately prior to the shock. This is important in that there are no unpleasant associations and hence no objections to the continuation of the treatment. Prior to the discovery of electrical treatment the same stimulation could only be produced by means of drugs, which induced a feeling of terror in some cases and made the patient reluctant to continue with the treatment.

Apparatus

The Ediswan Shock Therapy Apparatus is shown in the photograph above and consists of a steel box weighing about 35 lb. containing the voltage control circuit and special timing switch for shock administration. In the centre of the panel a meter serves for indicating the resistance of the patient and, when switched over, the peak value of the current passed.



View of headband and electrodes for application of the shock to the skull.

An important feature is the provisionally patented switch, by means of which the duration of the shock can be accurately timed and adjusted. It is, moreover, so designed as to prevent the administration of a shock accidentally, or the administration of a second shock without due preparation. The switch is fitted with calibrated dial giving shock durations of 0.1 second to 1.0 second in 1/10th second steps.

On the front panel is also mounted the control knob by which the voltage applied to the patient can be varied, and also the safety and main control switches.

Green and red pilot lights are provided to give indication when the apparatus is ready for shock administration.

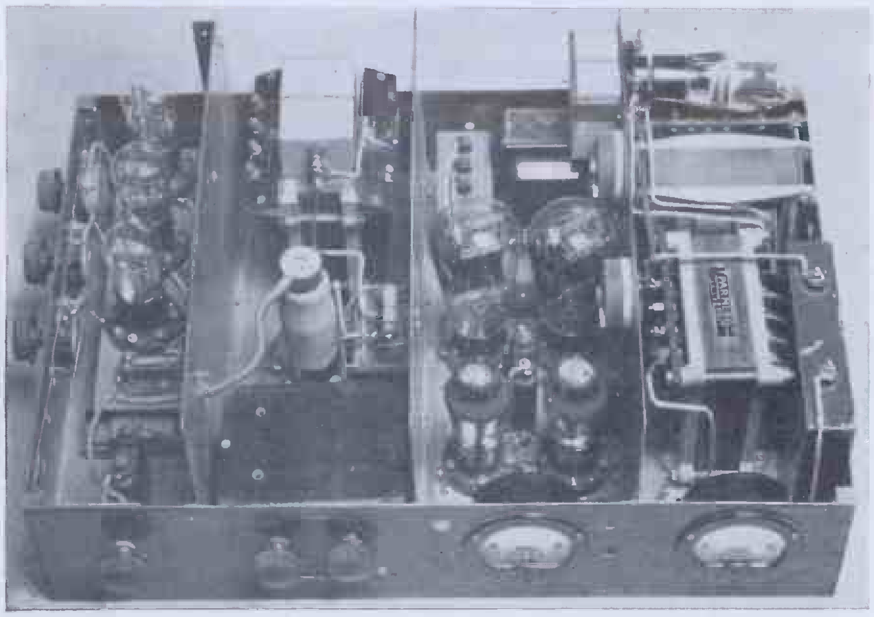
Technique of Administration

A headband with a pair of electrodes shown in Fig. 2 is provided with plug connection to the apparatus. The pads of the electrodes are well moistened with normal saline and the headband is clamped round the patient's head so that the electrodes press firmly on the frontal region. The mains supply is then switched on and the changeover switch on the front panel put into the position marked "Calibrate." This applies a low voltage to the electrodes, and from the reading of the milliameter the patient's resistance is noted. From known data the voltage for the shock is selected by turning the control knob, and the duration of shock is also set by the knob on the main control switch. The scale is calibrated in volts to within 2 per cent. provided that the mains voltage does not fluctuate.

The changeover switch is then moved to the "shock" position, and a red light indicates that the apparatus is ready. To administer the shock the plunger marked "reset" is depressed momentarily and released. The plunger marked "shock" is then depressed and the shock is administered automatically, after which the current is switched off until the switch is re-set.

It should be noted particularly that the apparatus is specially designed to prevent administration of two shocks in succession accidentally. The setting of the switch is a deliberate preliminary to the shock administration and it cannot be set without the knowledge of the operator. The duration of the shock is

(*Continued on page* 95)



Complete amplifier showing the disposition of the components. The L.H. section shows the three input channels ; the second, the tone control stage ; the third the paraphase and output valves, and the fourth the power supply.

Design for a . . . S

By J. C. C.

The A.C. Amplifier described below, radio inputs. By means of a frequer and treble register independently, ove capacity coupling is used throughout.

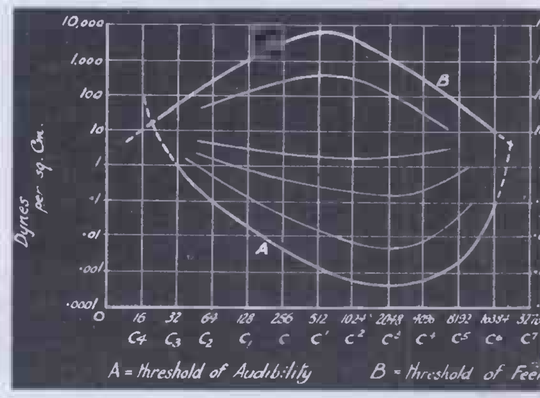


Fig. 1. The aural spectrum curves obtained by the Bell tories in U.S.A.

BEFORE the design of a high-quality gramophone amplifier system can be appreciated, it is necessary to realise the problems that arise—not only in the amplifier and its associated equipment, but also those due to the influence of the ear and the acoustics of the listening-room. It is generally known that the average ear is most sensitive to sounds having frequencies around 1,000 to 2,000 c.p.s., and that at frequencies outside this range the amount of power required to produce equal intensity of signal level rapidly increases. In fact, the intensity of a note at 50 c.p.s. must be 200,000 times that of a note producing equal sensation level at 2,000 c.p.s.

It is noticeable with average radio receivers that as the volume is reduced in level the bass and extremely high notes seem to disappear more rapidly than the medium frequencies. This frequency discrimination is not due to the receiver: actually, the fault is with the ear.

A series of curves taken at the Bell Laboratories in America is shown in Fig. 1, and from these it will be seen that the ear has two limits—the threshold of feeling and the threshold of audibility; the enclosed space between these two limits shows the range of the average human ear and its frequency characteristics with changes in volume level. With increasing age the ear does not convey the very high frequencies to the brain with the same intensity as it did formerly, and many elderly people are quite deaf above 4,000 c.p.s., but to most people below 45 frequencies up to 16,000 c.p.s. are audible. The lowest limit of approximately 16 c.p.s. does not change with age. Below this frequency the individual cycles become noticeable and no longer form a musical note.

Hence it is necessary for the complete equipment to transmit, if frequency distortion is to be completely absent, a range of 16 to 16,000 c.p.s. The curves, however, show that as the volume level is increased above the threshold of audibility the intensity of the signal at both very low and high frequencies does not require to be so great as before, and hence arises the necessity of some form of tone control. It is necessary to stress the fact that the tone control required is not because of any deficiency in any one or more sections of the reproducing apparatus, but because of the frequency characteristics at varying sound levels of the human ear.

Unfortunately, the term "tone control" is usually associated with the knob of a radio receiver which merely reduces the high-frequency sound level, whereas the term "frequency correction circuit" would be more applicable to the case under consideration.

The next problem that confronts the designer is the acoustical properties of the listening-room which can completely make or mar any pre-conceived thoughts on reproduction. Whereas the electrical engineer will do all in his power to produce a straight-line amplifier having as small a deviation as possible from perfect linearity, the room may add or subtract 10 decibels to the output of the loudspeaker over the frequency gamut, and as he has no means of measurement he conveniently forgets it.

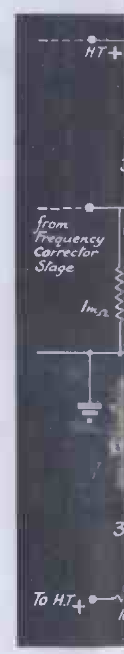
Most reproducing units are used in fairly well-damped rooms having substantial furniture and carpeting, which reduces reverberation but also absorbs the higher frequencies. As the designer has no control over the acoustical properties of the average listening-room, the best he can do is to provide variable frequency correction circuits so that any normal irregularity can be countered.

The loudspeaker system is probably the most difficult matter to approach, as the requirements for any attempt at high-fidelity reproduction necessitates bulky and expensive apparatus. At the low-frequency end it is necessary to displace a large volume of air, and this can be attained by having a large diaphragm, but this will be heavy and have a large inertia. Also it must be very freely suspended so that non-linear distortion of the diaphragm movement is avoided; also the magnetic damping must be very high so that transients do not cause the moving coil to leave the area of uniform flux density.

All these requirements need a large massive field magnet, a large diaphragm and, most important of all, a very large baffle which will prevent the radiated sound waves from each side of the diaphragm interfering with each other before they reach the audience. The size of the necessary baffle can be computed by the following formulæ :—

Length in feet from one side of the diaphragm to the other side $= \frac{1,120}{4F}$ feet.

where F is frequency in c.p.s.



Th

uper-quality 12-watt Amplifier

GILBERT, A.M.I.R.E., A.M.I.W.T., F.R.S.A.
Senior Lecturer in Electro-communications, Northern Polytechnic, Holloway, London.

was designed to give the best quality of reproduction from gramophone and
cy-correction stage, the response curve can be lifted or dropped at the bass
r a wide range. The input channels use electronic coupling and resistance
By means of the frequency-correction stage the amplifier can also be used
for recording both on disc and film.

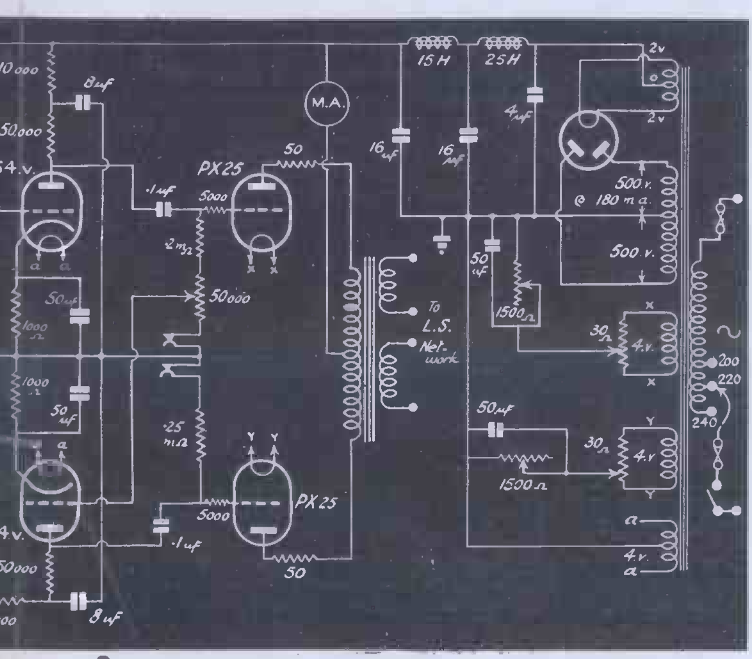
Labora-

Therefore, to reproduce a 50 c.p.s. note at *full* amplitude it is necessary to have a minimum sound path of $5\frac{1}{2}$ ft., and if 20 c.p.s. is sought the sound path must be increased to 14 ft. These figures show that a plain, flat baffle is rather too large for modern flats and houses, although a loudspeaker unit mounted into a wall and having free radiation on both sides approaches to ideal. By adopting what the Americans term an acoustic labyrinth, the low-frequency end can be maintained and in a future article in this journal the writer will describe two successful designs.

The high-frequency end of the audible spectrum presents other difficulties. As the time taken for a whole cycle may be only 1-15,000th of a second, and the diaphragm has to change its direction of travel twice for each cycle, a very small and practically weightless diaphragm is necessary. The volume of air to be displaced is also small and, due to the very short wavelengths of the notes, a baffle is not necessary. The radiation of high frequencies tends to focus rather like a searchlight beam, and it will generally be found that a heterodyne whistle can be heard in a certain position in line with the loudspeaker, but diminishes in intensity on each side of the focus line—always assuming that the room reflections and reverberation periods are very small.

The logical way of overcoming these diverse requirements is in the use of two loudspeaker diaphragms, one large one mounted in a suitable cabinet, and a "tweeter" or high-frequency unit, with some method of diffusing the higher frequencies over a wide angle.

Finally, what are we to reproduce? In its original conception the amplifier was required to be used for radio, gramophone, microphone, sound film and disc-recording purposes, each of which may require special frequency curves; hence the necessity for a very wide range of attenuation and boosting circuits. Also as the input from the microphones, photo-electric cells and moving-coil pickups is very small, a very high-stage gain is necessary.



e circuit diagram of the paraphase stage output valves and power pack.

Close-up of the paraphase and output valves showing the close proximity of the components in order to ensure very short connections.

Fig. 2 shows a schematic arrangement of the amplifier and it is now proposed to deal with each section in turn.

The maximum undistorted power output that is required is dependent on the cubic contents of the listening-room, its furnishing and the efficiency of the loudspeakers. The following table shows the approximate requirements for average and good loudspeakers:—

Size of room.		Loudspeaker. Average watts.	Good watts.
12 × 12 × 10	...	3-4	2-3
15 × 15 × 10	...	7-8	4-5
24 × 24 × 10	...	10-12	6-7

These figures are approximations, as local conditions may vary the final requirements, but if the amplifier is to deal with the maximum potential needs then a 12-watt undistorted output can be obtained by employing either a single output valve or a pair of triodes or pentodes using negative feedback.

As the harmonic distortion with pentodes consists primarily of odd harmonics which are additive in a push-pull stage, the triode valves are preferable. The Mazda PP5/400 or the Marconi-Osram PX25 valves will deliver 12 speech watts when a pair are used in push-pull. Each valve requires an H.T. voltage of 400 and an anode current of 62.5 milliamps, but by slightly overbiasing the valves the current can be reduced to 55 mA. so that the normal 120-mA. rectifier valve can be used without serious overloading. In order to prevent parasitic oscillation a 50-ohm anode stopper and a 5,000-ohm grid stopper are mounted as close as possible to their respective valve holder sockets.

Super-quality 12-watt Amplifier—*Gilbert*

So that the two output valves operate with identical currents, variable resistances are used for the bias resistors, and to cancel accurately the hum signal due to the use of directly heated valves, potentiometers are used across the individual filament windings.

The output transformer must be very accurately designed and manufactured so that the two primary windings induce identical signals into the secondaries. In the case of the triode power valves the effective resistance shunted across the primary of the output transformer is the resultant of the anode resistance and the load resistance in parallel. A moving-coil loudspeaker does not present a resistive load, but tends to behave as an impedance loading with a bass resonance usually between 50 and 80 c.p.s. Hence the reflected impedance at this frequency may rise to as much as ten times the usual impedance figure calculated at 400 c.p.s. In the cases of the two valves quoted, they require a total anode-to-anode load of 7,000 ohms and hence the primary inductance should be approximately 50 henries at 50 c.p.s. so that the response is not more than 1 db. down at the resonant frequency of the loudspeaker and its cabinet.

It is necessary that the leakage inductance of both the primary and secondary windings be kept as low as possible, and this can be done by sectionalising the windings; this also reduces the capacitative losses and keeps down the loss at high frequencies in excess of 10,000 c.p.s.

The transformer used with this amplifier was designed and manufactured by G. A. V. Sowter, B.Sc., A.M.I.E.E. It has two secondaries which drive a large 12-in. diaphragm Baker-Selhurst moving-coil energised loudspeaker and a Voigt unit with an H.C. type corner horn for the reproduction of all frequencies above 250 c.p.s.

A milliameter was placed in the anode circuit of each output valve so that a check could be kept on the valve behaviour; they also provide a guard against valve overloading. By keeping these meters quite steady during a broadcast the minimum of harmonic distortion which may be present is assured. A microgalvanometer can be plugged in the grid circuit of each of the output valves and is used to check grid current and leakage of any D.C. current through the coupling condensers.

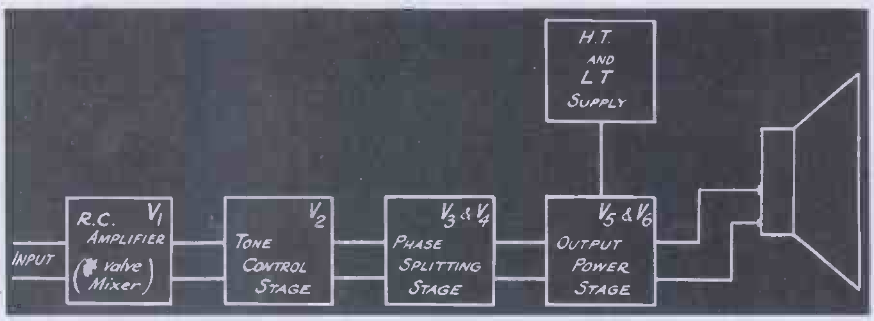


Fig. 2. Schematic diagram of the valve sequence.

The penultimate stage consists of an R.C.-coupled amplifier V3 and the phase-splitting valve V4. A modification of the original Carpenter paraphase circuit has been used, for, although it does not require the minimum of components, the ease of balancing the overall stage gain with the output valve makes its adoption worth the slight additional cost. The paraphase valve obtains its input from the grid load of the output valve V5, and its value can be calculated by

$$R = \frac{R1 + R2}{M} \quad \text{where}$$

R1 = Grid leak.
R2 = Paraphase grid leak.
M = Stage gain of V3.

By making R2 a potentiometer of a suitable value it can be used for accurate balancing of V3 and V5 against V4 and V6. As the output valves are biased to −35 volts, the peak signal required from the penultimate stage in order to load the output valves fully must have an amplitude of 35 volts. This can be obtained by using Mullard 354V valves with a high anode load, and in order that the loss at 20 c.p.s. should not exceed 1 db. a coupling condenser of 1μF with a 250,000-ohm resistance is used.

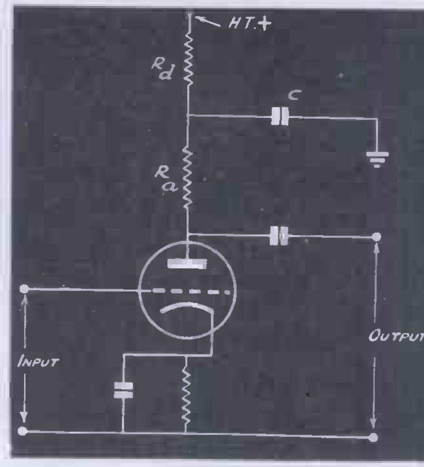
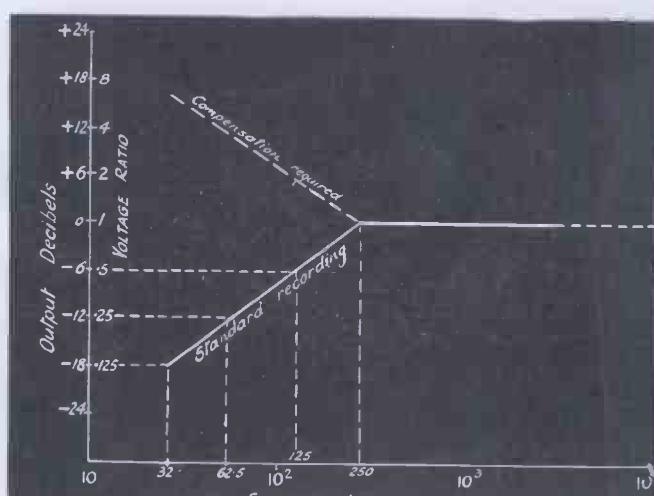


Fig. 3. Conventional resistance-capacity amplifier, showing method of decoupling anode and cathode circuits.

Adequate decoupling in both the anode and cathode circuits prevents attenuation at very low frequencies.

Fig. 3 shows the usual anode decoupling method. It is necessary, in order that the decoupling circuit does not affect the frequency response, that the reactance of the condenser C be not more than one-tenth of the resistance Rd at the lowest audio-frequency that is required. The value of Rd should be about one-fifth of Ra, so that if Ra = 50,000 ohms, suitable value for Rd = 10,000 ohms and taking 20 c.p.s. as the

Fig. 4. The recording cutter curves of the earlier electric recordings. The latest recordings have a rising characteristic in the upper frequency end



lowest frequency, the condenser C = 8 μF. Not only does the decoupling circuit prevent a common impedance across which spurious " motor-boating " voltages are produced, but also reduces the hum level.

The above described amplifier will have practically linear response from 16 to 16,000 c.p.s., but as was stated earlier a wide range of possible inputs is to be used and each of these have various voltage outputs. Therefore, there arises the necessity of a high-stage pre-amplifier, together with a tone-control stage. As one of the major uses of the amplifier is its use for the reproduction of gramophone records, it is desirable to amend the frequency response so that it may be modified to suit most available pick-ups. Latterly two moving-coil pick-ups have been developed in this country. One is known as the " Coil," manufactured by H. H. Jones, of Stourbridge, and the other is designed by P. G. A. H. Voigt, of Voigt Patents, Ltd.

The writer has had the opportunity of trying out an experimental form of the latter pick-up during the past few weeks, and it can undoubtedly produce superb results. During the past fifteen years nearly every pick-up has been reviewed and graphs plotted of the response curves, but only special laboratory instruments have approached the fidelity of reproduction obtainable from these instruments. In a later part of this article a fuller description, together with calibration curve, will be published. The only point of criticism is the relatively low output, it being about -35 db. below zero at 50 c.p.s. (zero taken at 1 volt r.m.s.), so that one extra amplifier valve is necessary.

When standard commercial records are made, the cut is of the " lateral " nature and the velocity of the cutter movement is supposed to be proportional to the input voltage above 250 c.p.s. As the amplitude then increases with decreasing frequency, it becomes necessary below 250 c.p.s. to reduce the amplitude, otherwise one groove might run into the next. In practice, however, the recording companies left the top to help drown the scratch and " iron out " the muddiness of the sudden change at 250 c.p.s.

If a pick-up is used, the output of which depends on the needle-point velocity, the drop in the bass is equivalent to 6 db. per octave, and hence compensation must be provided in order to reproduce the record correctly. Fig. 4 shows the nominal output from a record, and the compensation required to overcome this loss.

Such a loss at the lower frequencies occurs also with sub-standard 16-mm. sound film; therefore such means of tone compensation are again necessary. When a good microphone is used, little compensation is necessary if a room or studio with correct acoustic properties is available but when open-air or close-up work is done a reduction in the bass register is often desirable. With radio reproduction, means of boosting the bass register is useful if the loudspeaker system is lacking in true fundamental bass. In all these cases, control over the upper frequencies above 3,000 c.p.s. is also necessary, either to suppress heterodyne whistles, bad gramophone hiss or accentuation in order to partially overcome side-band cutting.

Hence it is desirable to have separate control of the bass and treble registers and be able to accentuate or attenuate them either by means of variable or step controls. In the next issue full details of the three-way mixer and tone-control stage will be given.

Reducing Phase Shift in Negative Feedback Amplifiers

In a negative feedback amplifier in which the output valves are coupled to the load by a transformer and the feedback is taken off a tertiary winding, phase shift is introduced into the feedback circuit by the potential drop across the primary leakage inductance due to the load on the output or secondary winding so that less feedback is possible than otherwise would be the case, due to the possibility of oscillation.

The purpose of the coupling arrangement to be described is to reduce or eliminate this undesirable phase shift in the feedback voltage. This is achieved by tight coupling and light loading of the feedback winding.

To give tighter coupling, and so to decrease the leakage inductance referred to, the tertiary winding A providing the feedback voltage is sandwiched between two additional primary windings B, C, connected in parallel with the main primary winding D of the output transformer, as shown in Fig. 1.

The loading on the winding A is decreased by connecting a resistance E in series with the cathode resistance F of the valve G across which the feedback voltages are set up.

Figures 2 and 3 show the constructional arrangement of the several transformer windings. The main primary winding D is outermost and the secondary winding H is wound immediately adjacent the main primary winding. The tertiary winding is sandwiched between the sections B and C.

(This development is reported from the laboratories of the Radio Corporation of America).

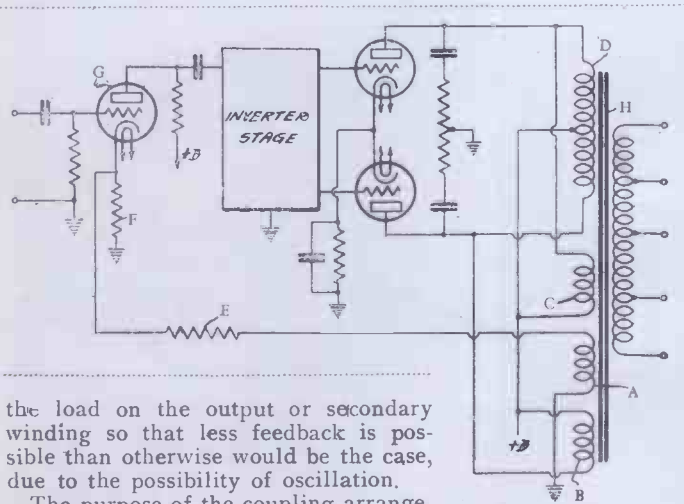
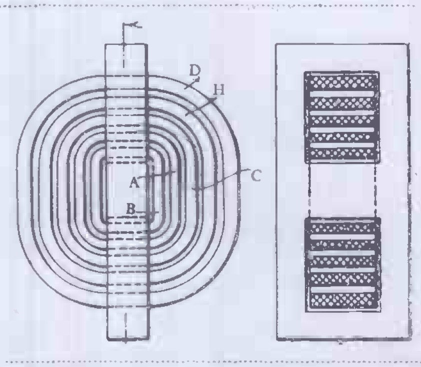


Fig. 1. Circuit arrangement for reduction of phase shift in negative feedback amplifiers.



Figs. 2 and 3. Details of transformer windings.

A RECORD OF PATENTS AND PROGRESS

RECENT DEVELOPMENTS

PATENTEES

L. F. Gardner :: Telefunken Ges fur drahtlose Telegraphie m.b.h. Standard Telephones and Cables Limited :: Soc. Francaise Radio-electrique :: M. Bowman-Manifold and H. Miller.

"Drift" Indicator

(Patent No. 519,698.)

Photo-electric cells are used to make an automatic record of the deviation of a navigable craft, such as a ship or aeroplane, from a set course. As shown by the drawing, a compass-card C, provided with a radial slit S, is mounted above a second card C_1 made of non-magnetic material and provided with a similar radial slit S_1. The slit S_1 is divided into two halves by a vertical partition P. Above the two discs is a lamp L, and below them a pair of photo-electric cells K, K_1 connected to a "graph" recorder R of known type.

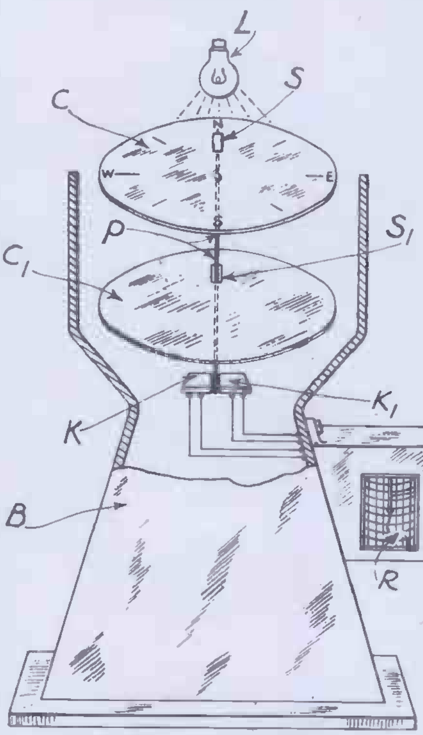


Photo-electric drift indicator. Patent No. 519,698.

When a course is set, the disc C_1 is adjusted so that the slot S_1 is aligned with the slot S in the compass card. So long as that course is maintained, the light from the lamp L will pass through both slits and be divided equally by the partition P, so that it energises both the cells K, K_1 to the same extent. In these circumstances the graph instrument R will record a straight line. Any deviation in the course will, however, move the casing B and lower disc C_1 relatively to the gimbal-mounted compass card. The balance of the light falling on the photo-electric cells is then upset and the line recorded by the "graph" line will be bent to port or starboard accordingly.—*L. F. Gardner.*

Dielectric Guides

(Patent No. 526,719.)

It is known that very short waves can be propagated, without attenuation, through a hollow metal tube, having no inner or central conductor, provided there is a certain definite relation between the wavelength and the radius of the tube. The high-frequency energy travels through the tube in the same way as a wireless wave travels through the ether, except that it is confined inside the tube instead of radiating in all directions. This method of transmission has certain possibilities in the distribution of television programmes from point to point.

It is further known that one such tube, or "dielectric guide," as it is sometimes called, can carry a number of waves simultaneously, each having the same frequency, but each being distinguished from the other by the relative disposition in the tube of the electric and magnetic fields of which they are composed.

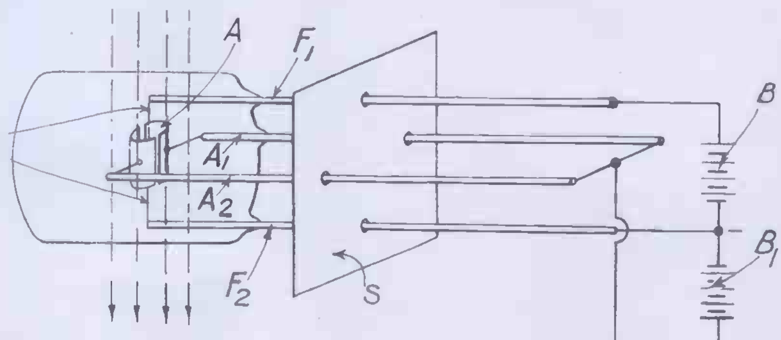
The invention is concerned with the use of a "dielectric guide" for the simultaneous transmission of a number of different messages, each message being carried by a separate wave of characteristic form. More particularly, it describes the means to be used for separating-out each message from the others at the receiving end.—*Telefunken Ges für drahtlose Telegraphie m.b.h.*

Generating Ultra-short Waves

(Patent No. 526,827.)

The Figure shows a Magnetron valve, of the split-anode type, arranged for generating waves only a few centimetres long. The filament F passes centrally through the two halves of the "split" anode A, a magnetic field being applied across the path of the electron stream, as indicated by the arrows.

The main feature of the invention lies in the arrangement of the external leads. The two conductors F_1 and F_2 serve to support and energise the filament from a source B, whilst the conductors A_1 and A_2 similarly support the two halves of the split anode, and also supply



Arrangement of Magnetron valve for generating centimetre waves. Patent No. 526,827.

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it with H.T. voltage from the source B1.

The assembly of conductors forms a Lecher-wire system, which is tuned to the working frequency by sliding a screen S or short-circuiting bridge along them. The screen is insulated from the conductors so far as D.C. voltages are concerned, but its tuning effect prevents the passage of any high-frequency energy from the valve oscillator, over the leads, into the supply batteries B, B1.—*Standard Telephones and Cables, Ltd.*

Cathode-ray Direction-finder

(Patent No. 526,860.)

The direction of a distant wireless transmitter is indicated by the intersection of two luminous curves, which are traced out by the incoming signals on the fluorescent screen of a cathode-ray tube. The deflecting electrodes of the tube are first fed in quadrature with phase-displaced voltages derived from a local oscillator so that, in the absence of any signal, the electron stream marks out a circular trace on the screen.

The signals received from a pair of crossed frame aerials, mounted, say, on an aeroplane, are then superposed on the C.R. tube, the connections from the aerials being continually reversed at the same frequency as the local oscillator. As a result, the original circular trace is converted into two heart-shaped traces, which intersect each other at two points on the screen. The direction of the distant transmitter will then be along a line at right-angles to the one joining the points where the two luminous traces intersect.—*Soc. Francaise Radioelectrique.*

Preventing Distortion

(Patent No. 526,954.)

In scanning the electric charges built up on the mosaic screen of a cathode-ray television transmitter, it is difficult when a magnetic or electrostatic lens is used for focusing the scanning stream to maintain the lens "field" at uniform strength. This results in a spiral distortion of the picture, and also in so-called "barrel" and "pin-cushion" effects.

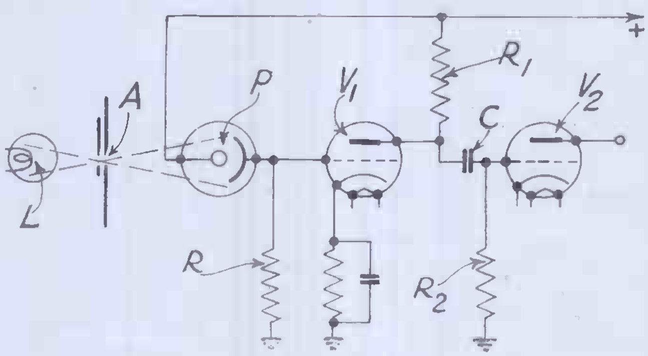
According to the invention, these defects are corrected or compensated by arranging an auxiliary winding between the scanning coils and the screen, and by feeding this winding with a direct current of such strength that the field produced by it deflects the electron stream by the amount necessary to offset the spiral or other deviation due to the irregularity of the focusing field.—*M. Bowman-Manifold and H. Miller.*

Amplifying Photo-electric Currents

(Patent No. 527,103.)

In certain telegraphic systems, particularly for transmitting photographs, it is necessary to transform the uni-directional current produced by a photo-electric cell into trains of alternating current. The transformation should be effected without setting-up undesirable transients, whilst the amplitude of the wave trains should be limited to predetermined values. Also the response of the cell should be confined to impulses above a certain threshold value.

The Figure shows a circuit in which light from a lamp L is flashed on to a P.E. cell P through a variable aperture A at the rate of, say, 800 cycles a second. The output from the cell is applied through a resistance R to the grid of a valve V1, so that corresponding positive impulses are added to the normal anode current of that valve. The impedance of the coupling condenser C and resistance R2 in the grid circuit of the following valve V2 is made so much greater than the impedance of the resistance R1, and the time-constant is made so small by comparison with the 800-cycle working frequency that the current passing through the resistance R1 is but slightly affected, whilst the charging current taken by the condenser C is kept very low and varies as if the condenser were directly connected across the resistance R1.



Circuit for amplification of photo-electric currents. Patent No. 527,103.

The result is that the valve V1 merely converts the input from the cell P into a sinusoidal current, whilst the valve V2 serves to amplify it. An amplitude-limiting device may be applied to the final stage of amplification (not shown). A suitably biased diode valve prevents the passage of any current impulse below a certain threshold value.—*Standard Telephones and Cables, Ltd.*

Summary of Other Electronic Patents

(Patent No. 523,780.)

Time-base circuit giving accurate registration of the saw-toothed voltages used for interlaced scanning.—*C. L. Hirshman and Metropolitan-Vickers Electrical Co., Ltd.*

(Patent No. 524,226.)

Method of arranging the mains-supply unit of a cathode-ray tube so that the total voltage on the anode includes the voltage across the time-base circuit.—*Kolster-Brandes, Ltd., and D. S. B. Shannon.*

(Patent No. 526,875.)

Light-modulating device of the type in which the beam of light is passed through a quartz crystal or similar substance traversed by mechanical pressure waves of supersonic frequency.—*I.M.K. Syndicate, Ltd., P. Nagy and M. J. Goddard.*

(Patent No. 527,009.)

Light-modulating devices of the Kerr cell type with a mosaic electrode on which the modulating process is emphasised by secondary emission.—*I.M.K. Syndicate; P. Nagy and M. J. Goddard.*

(Patent No. 526,982.)

Construction and arrangement of wide-band inter-stage transformer couplings for a television receiver.—*Haseltine Corporation.*

GAS-FILLED TRIODES AND THEIR PRACTICAL USE—VI.

Cathode Protection

By G. Windred, A.M.I.E.E.

Cathode failure is undoubtedly one of the foremost causes of breakdown in gas-filled triodes, and must be carefully guarded against if satisfactory tube life is to be obtained. The factors affecting cathode failure are considered in this article, and means are described for giving protection under normal conditions of operation.

THE necessity for preheating the cathode of the gas-filled triode before passing anode current arises from the destructive conditions which otherwise occur. If the heater and anode circuits are completed at the same time, with the cathode cold, no anode current will flow initially, and the whole of the supply voltage is applied between anode and cathode. As the cathode heats up it produces a feeble but steadily increasing emission, giving rise to a glow discharge through the tube, characterised by a high voltage drop and low current. As the emission increases with rising cathode temperature the voltage drop across the discharge falls and the current increases.

During the comparatively short period occupied by this process it is not possible for all effective parts of the cathode emitting surface to reach the same temperature. The tendency will be for the arc to anchor itself to a restricted region of the cathode surface from which the initial emission occurred, and this region will increase rapidly in temperature owing to the poor thermal and electrical conductivity of the cathode coating. A considerable proportion of the voltage drop from anode to cathode under these conditions will reside in the coating, and the drop will be greater than that corresponding to normal operating conditions. The temperature of the hot spot soon becomes excessive, and in most cases incandescent particles of coating may be seen thrown off from the cathode shortly after switching on. The conditions are less harmful when low values of anode voltage and current are employed, but in general the effect of omitting the preheating time, or unduly restricting it, is to damage the tube so as to shorten its life or even render it unusable.

Methods of Protection

It may be advisable to enumerate at this stage the alternative means which may be employed for overcoming the difficulties due to the necessity for cathode preheating.

1. Some success has been obtained with cathodes designed to withstand the conditions corresponding to simultaneous switching of the heater and anode circuits, so as to eliminate altogether the necessity for preheating. The coating of these cathodes has a high thermal conductivity and low electrical resistance at temperatures well below the normal operating temperature, and is bonded strongly to the core so as to resist as much as possible the stripping action which causes rapid loss of coating. This type of cathode is reported to have given satisfactory service without preheating on low voltage circuits, but has not passed into general use.
2. Use has been made of a circuit in which the negative grid potential is maintained at a high value at starting, by means of a charged condenser. While the cathode is warming up, the condenser charge is allowed to leak away through a high resistance, so that the grid potential does not reach the critical value, as determined by the applied anode voltage, until the cathode has reached a suitable emitting temperature.
3. As an alternative to method 2, the bias preventing conduction may be controlled during the starting period by an auxiliary vacuum tube with a long cathode heating time. This time may be varied to give the required preheating period.
4. Since actual cathode temperature is the criterion for closing the anode circuit, it is possible to incorporate a thermocouple or thermostatic element in the tube to control the closing of an external relay which completes the anode circuit automatically when the cathode has reached its proper working temperature.
5. An auxiliary cathode, acting as a screen to the normal cathode, may be used to prevent striking of the discharge while the cathode proper is heating up. The auxiliary cathode has an emissive inner surface, and is placed very close to the normal cathode. Even with zero bias, the screening action of the auxiliary cathode prevents conduction while the normal cathode is warming up, but when the inner surface temperature of the auxiliary cathode has risen sufficiently to cause emission the shielding property is lost, and the auxiliary cathode becomes virtually a part of the main cathode. The normal discharge then occurs, and the tube operates in the conventional manner.
6. A time delay element may be used to control the closing of the anode circuit. The time delay element is switched on simultaneously with the closing of the heater circuit, and establishes the anode circuit, either directly or through the medium of a relay, after the lapse of a period to suit the particular tube. The time delay may be either fixed or adjustable, according to the type of element employed.

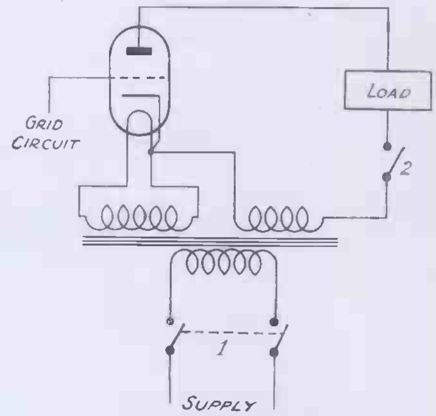


Fig. 1. Basic circuit diagram

Before dealing with the relative advantages of the different methods of operation it will be advisable to consider a further important factor influencing the life of cathodes. This is the effect of heater voltage variation, which requires careful attention in all apparatus employing gas-filled triodes.

Variation of Heater Voltage

If the voltage applied to the heater of a gas-filled triode varies outside definite limits, there is risk of damage to the cathode owing to the following effects:—

1. If the voltage is too low, the emission is reduced and the cathode material is rendered liable to damage by sputtering, as already des-

Gas-filled Triodes—*Windred*

cribed in connection with the simultaneous switching of anode and heater circuits.

2. If the voltage is too high, the cathode temperature becomes excessive, and its material is evaporated at a high rate so as to cause eventual failure of emission.

The permissible limits of voltage variation which avoid both conditions are not often specified by manufacturers, although these limits are of the greatest importance in securing satisfactory tube life. This may be regarded as an unfortunate state of affairs, in view of the fact that in very many practical instances the actual supply voltage differs appreciably from the nominal value. There is the additional consideration that the normal regulation of the supply voltage may cause wide variations from the mean value.

It may be assumed that under normal conditions the supply voltage variation is unlikely to exceed 5 per cent. above and below the nominal value. The heater of the gas-filled triode should operate satisfactorily within this range of voltage variation, since otherwise it will be liable to damage under conditions of working which must be regarded as quite normal.

In terms of heater voltage this means that a tube having a 4 volt heater should operate satisfactorily with a heater voltage of any value between the limits of 3.8 volts and 4.2 volts. The permissible variation must always be agreed to by the manufacturer, who must also decide whether the upper and lower limits are permissible continuously, or only for specified periods.

The problem of how to obtain satisfactory tube life under conditions of abnormal voltage variation requires separate consideration. The use of ballast tubes of the conventional type in series with the heater itself, or with the primary of the power transformer, represents a simple arrangement. In the latter case, the anode voltage, and perhaps also the grid voltage, according to the circuit arrangement will also be controlled.

Alternatively, a constant voltage transformer may be used for the heater circuit. Transformers of this type are often characterised by a poor waveform, so that care should be taken in using them for anode or grid circuits in cases where close control of anode current is required. Otherwise it is likely that the point of conduction may be erratic.

It is important that heater voltage regulation tests should be carried out whenever apparatus employing gas-filled triodes is installed. The highest heater voltage measured at the actual socket, corresponding to the upper limit of line voltage variation and minimum loading of the anode circuit should be compared with the known maximum for the tube. The minimum heater voltage, corresponding to the lower limit of line voltage variation and maximum loading of the anode circuit should likewise be compared with the known minimum. If the actual limits of heater voltage variation determined in this way exceed the limits set by the manufacturer, some means of voltage stabilisation is necessary if satisfactory tube life is to be obtained.

It may be emphasised that the heater voltage should always be measured at the tube socket. Owing to the voltage drop in leads and connections, the voltage measured at the corresponding terminals of the power transformer, for example, may be considerably higher than the voltage actually applied to the heater.

Protective Circuits

When the problems of preheating and voltage regulation are considered collectively it becomes evident that many difficulties would be overcome by the use of cathodes suitable for withstanding the effects of simultaneous switching with the anode circuit and capable of operating under conditions of voltage variation occurring in normal practice. The latter feature is not unusual, and in any case it is generally possible to correct undue variation of voltage by relatively simple means. The problem of suitable switching arrangements to provide the time lag requisite for preheating is, however, a more complex proposition.

Reference to the basic diagram, Fig. 1, will indicate the requirements. It is seen that the primary of the power transformer is connected to the supply mains by switch 1, while switch 2 serves to complete the anode circuit. When switching on, it is essential that switch 2 should be open. Switch 1 is closed first, and the tube heater commences to warm up. The anode voltage appears simultaneously across the appropriate secondary winding. After the lapse of the necessary preheating time, switch 2 is closed, so as to permit the flow of anode current in the load circuit. This current may be interrupted by opening either switch.

The following objections apply to this simple method of operation:

1. Insufficient time may be allowed between the closing of the respective switches.
2. If disconnection is effected by switch 1, the anode switch may be forgotten, so that unless this switch is opened before the supply is reconnected there is risk of damage.
3. There is no protection against the effects of resumption of supply voltage after a failure if the switches are left in the closed position.
4. There is no protection against the effects of the supply voltage falling to an abnormally low value.

Any of these conditions may cause a severe shortening of the tube life, or even result in rendering the tube unusable.

The whole problem of preheating with its attendant complication would be eliminated if suitable cathodes could be employed to withstand direct switching, but since this has not been found generally possible it is necessary for a time delay to be allowed for in practice. This represents an inevitable delay in bringing the gas-filled triode in to the operating condition, and may form an objection in some instances. The objection is lessened when the necessary switching sequence is performed automatically, thus removing the disadvantages applying to manual operation.

The necessary value of time delay, corresponding to the cathode preheating time, depends upon the size and type of tube and whether the cathode is directly or indirectly heated. In the case of mercury-vapour tubes it depends also upon the ambient temperature. In general, it is possible in the case of inert gas-filled triodes to use a fixed time delay, independent of variations in ambient temperature, but in the case of mercury vapour filling some means of varying the time delay is necessary if it is desired to make the delay period as short as possible consistent with the ambient temperature.

Alternatively, it is possible to use a fixed time delay corresponding to the maximum timing required for the lowest ambient temperature. With some types of thermal delay devices it is readily possible to arrange for the delay period to vary in inverse proportion to the ambient temperature, so that with low temperatures a longer time delay is automatically provided.

Automatic Protection

Various types of time delay element are available for use in timing circuits, and some of them are readily applicable to cathode protection arrangements. The time interval generally required in this case is of the order of one minute for tubes of small and medium size, but for the whole range of sizes the necessary time delay may be as short as 15 seconds or as long as 15 minutes. Time lags exceeding 2 or 3 minutes are difficult to obtain automatically without comparatively expensive apparatus.

Gas-filled Triodes—*Windred*

One of the most convenient types of time delay mechanism from the present viewpoint is the thermal element, consisting usually of a bimetal strip which is flexed by the action of a heater element so as to make a contact after a predetermined interval from the time of switching on the heater. In some forms of this arrangement the heater element is wound directly upon the insulated bimetal strip. This practice may be regarded as satisfactory for low voltage circuits, but particular attention is necessary to ensure adequate insulation in cases where the bimetal strip itself forms part of the circuit upon completion of the normal operation. Failure of insulation in this case would result in the interconnection of two independent supplies, and might have very damaging results.

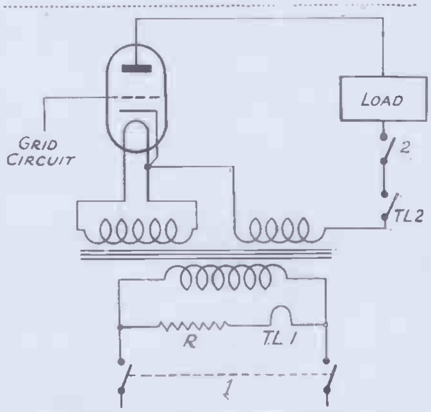


Fig. 2 (left). Simple timing circuit for cathode pre-heating.

The properly designed thermal timer is compact and reliable. It is available in a wide range of types, covering time lags up to about 2 minutes. For longer periods it is usually necessary to employ more expensive types of apparatus, employing some form of air or oil dash-pot, or eddy current retarding device.

A simple form of protective circuit is shown in Fig. 2. In this diagram TL1 and TL2 represent respectively the heater element and contacts of a thermal time delay relay. The resistance R serves to limit the current in the heater to the value required to give the necessary time lag. Switches 1 and 2 perform the same functions as in the case of Fig. 1, but it will be noticed that when switching on, even if switch 2 is already closed, no anode current can flow until the contacts TL2 have operated. The heater TL1 is energised as soon as switch 1 is closed. After the lapse of the predetermined time lag, the contacts TL2 close, so as to complete the anode circuit when switch 2 is closed. This switch is generally necessary to allow of the load being switched off if desired without opening the main switch 1, and thus having to go through the timing process again owing to cooling of the cathode. When switching by means of the main switch, the anode voltage disappears before the cathode commences to cool down. In the event of sudden voltage failure the process is the same; the timer cooling down again ready to operate upon resumption of the supply.

The disadvantages of this simple arrangement may be enumerated as follows:—

1. The time delay element is energised continuously, whereas its action is employed only for the period of time delay when switching on.
2. If a brief failure of voltage occurs, or if the main switch is opened for a short time, and the supply then resumed before the contacts TL2 have been reopened by the cooling of the element, the cathode of the gas-filled triode may sustain damage. This factor depends upon the relative rate of cooling of the cathode and the heater element.
3. There is no protection against the effects of a drop in supply voltage sufficient to cause serious loss of emission. Even if the timer would eventually reopen its contacts under these conditions, the time required for this action would normally be sufficient to introduce risk of cathode damage.

In many cases the contacts of the timing device are unable to deal with the anode current, so that a relay becomes necessary.

A point to be remembered when using this arrangement is that the action of the timing device may be disturbed by vibration or shock. If the relay is mounted on the same panel, the mechanical shock when it closes may cause the contacts of the timing device to jump apart, thus interrupting the circuit. The resulting tendency for the relay to open and close rapidly several times before finally closing may be overcome by suitable circuit arrangements, as will be shown later.

A control circuit developed by the author for overcoming the foregoing difficulties is shown in Fig. 3. In this case the anode current is dealt with by the contacts R1 of an electromagnetic relay under the control of a thermal time delay relay with thermal element TL1 and contacts TL2. The electromagnetic relay has two other sets of contacts, shown at R2 and R3 respectively. The arrangement is such that when the operating coil R4 is energised, contacts R1 and R2 close, and R3 opens. The time

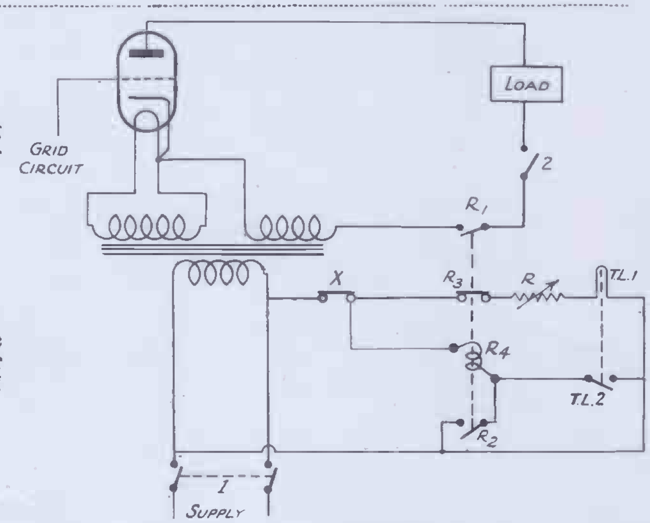


Fig. 3 (right). Schematic diagram of circuit for automatic protection of cathode.

delay in the closing of contacts TL2 of the thermal relay is determined by means of the resistance R, which can be made adjustable if desired so as to suit different types of tubes or different operating conditions.

The operation of the circuit is as follows: When the main switch 1 is open, the positions of the respective contacts are as shown in the diagram, and no current flows in any of the circuits. When switch 1 is closed, the thermal element TL1 is energised, and accordingly commences to warm up. The heater of the gas-filled triode is simultaneously energised from the appropriate secondary winding of the power transformer. The time delay relay is adjusted so that its contacts TL2 close only when the cathode of the gas-filled triode has reached its proper working temperature. When contacts TL2 close, the circuit for operating coil R4 is completed and the electromagnetic relay operates, closing contacts R1 and R2 and opening contact R3. The closing of R2 establishes an independent circuit for R4, so that the closing of the relay continues irrespective of what happens to contacts TL2, thus ensuring that there is no hesitance in this operation.

Gas-filled Triodes—*Windred*

The opening of contact R3 interrupts the timer circuit, and the element accordingly commences to cool down. Contacts TL2 do not reopen until the thermal element has cooled appreciably, so that there is no risk of the opening of contacts R3 causing disconnection of the electromagnetic relay during the change-over process. The closing of contact R1 completes the anode circuit, so that anode current will flow when switch 2 is closed. The use of this switch allows of interruption of the anode current without the necessity for repeating the preheating process before reconnection.

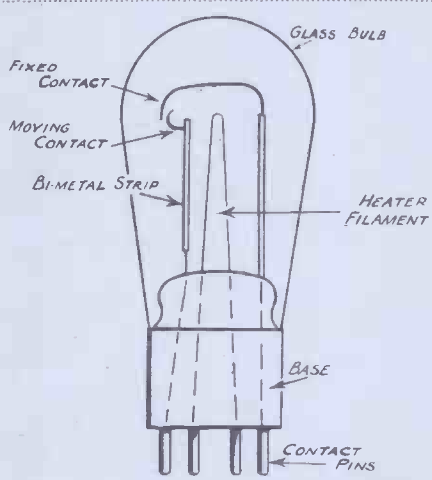


Fig. 4. Vacuum-type thermal delay switch.

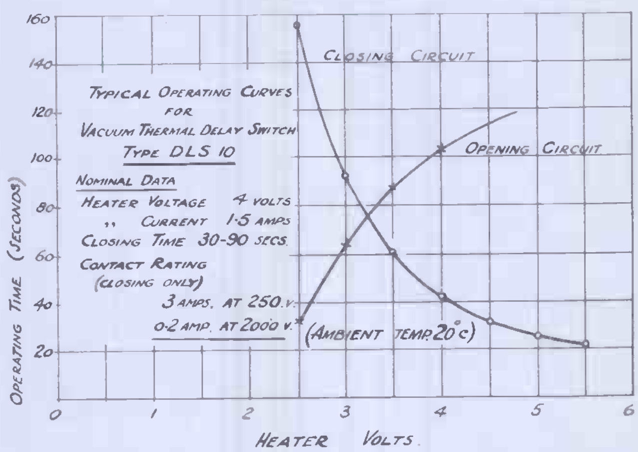


Fig. 5 Characteristics of vacuum-type thermal delay switch.

In the normal running condition, contacts TL2 re-open after the lapse of a definite time interval, and the operating coil R4 is left energised through contact R2 only. This feature allows of the relay being used to perform the additional function of low voltage protection. It is usually possible to obtain A.C. relays of commercial type which can be arranged to release when the operating voltage falls by a relatively small amount from the nominal value. By using such a relay in the present circuits, interruption of anode current will be effected automatically if the applied voltage falls to a predetermined value, thus affording a measure of protection to the cathode of the gas-filled triode. The relay will not reclose, even if contacts TL2 have not opened, until the voltage again approaches the nominal value.

The only type of failure which is not provided for in this circuit is the failure of supply voltage just after completion of the timing process and its sudden resumption just before contacts TL2 reopen. It may be regarded as very unlikely, however, whether a supply failure of precisely the correct duration to introduce risk of cathode damage would be experienced in ordinary circumstances. The most favourable conditions are given by a time delay element with a resetting time which is short in relation to the cathode cooling time. The long resetting time associated with most thermal relays is a disadvantage from this viewpoint. It will be noticed that if the electromagnetic relay has a sufficiently high minimum closing voltage, some measure of protection is also provided against the possibility of closing the anode circuit with an unduly low heater voltage.

Apart from the foregoing advantages of this circuit, there is the consideration that the life of the time delay relay is appreciably lengthened, since it is energised only while performing the actual timing process, instead of continuously during the whole time of operation of the circuit.

There is one possibility in the operation of gas-filled triode circuits for which it is difficult to provide adequate protection in a simple manner. If the tube is withdrawn from its socket while operating normally, and a new tube inserted, anode voltage will be applied before the cathode has heated up. The proper procedure in making such a change is, of course, to open the anode circuit switch before removing the tube and to wait the requisite preheating time after inserting the new tube before reclosing the anode circuit.

It is not always permissible to assume, however, that the correct procedure will be adopted. To overcome the difficulty, use may be made of small auxiliary contacts which are opened when the tube is withdrawn from its socket. If these contacts are connected in to the circuit as shown at X in Fig. 3, the withdrawal of the tube will cause disconnection of the relay circuits, and after insertion of the new tube the timing process will take place automatically in the usual way, unless, as already explained, the change of tubes is effected before the contacts of the time delay relay have had time to reopen, after a previous timing operation. This may be regarded as an unlikely contingency, and the risk can be eliminated by using a timing relay with a short resetting time.

A Typical Time Delay Relay

A very compact and convenient type of thermal delay relay is shown in Fig. 4. In outward appearance the device resembles a conventional valve, and has the same arrangement of base and contact pins. The glass bulb is evacuated, and contains the contact and heater assembly. One contact is fixed and the other attached to a bimetal strip, which is heated by means of a wire filament placed close to it. The base has four pins, and fits the standard 4- or 5- pin radio valve base; the centre pin being omitted. The ends of the heater filament are connected to the usual heater pins, while the two remaining pins correspond to the respective contacts.

In operation, a suitable voltage is applied to the heater circuit. The bimetal strip is accordingly heated, and flexes in a direction which brings its contact closer to the fixed contact. When this movement has continued sufficiently, the moving contact engages with the fixed contact and establishes the external circuit. The time required for the necessary contact movement, representing the time delay period, depends upon the heater current.

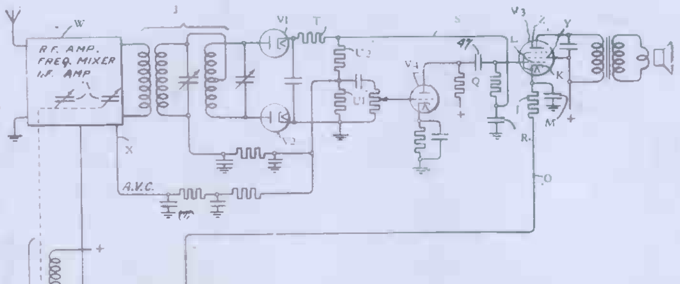
General data and operating curves for this relay are shown in Fig. 5. The curve corresponding to the operation of closing circuit shows the relation between the applied heater voltage and the time required for the contacts to close after switching on the heater. It will be seen that a useful range of timing may be obtained by varying the heater voltage. Owing to variations of characteristic between individual tubes,

(*Continued on page 95*)

Some Novel A.F.C. Circuits

MANY different methods for controlling the frequency of the oscillator of a superhet by means of the bias developed by the discriminator have been proposed. This bias is sometimes applied to the grid of a valve coupled with the oscillating circuit or even to the grid of the oscillator valve itself, while in other circuits the bias is used to control a polarising current through a coil having an iron core of adjustable permeability, the resultant change of inductance of the coil being reflected into the oscillator circuit.

Such substances as Thyrite, which have non-linear resistance and which exhibit an inherent capacity dependent upon the voltage drop developed across them, have useful applications to A.F.C. circuits which do not appear to have been generally realised, and the purpose of the article is to indicate some circuits utilising these substances which are of interest.



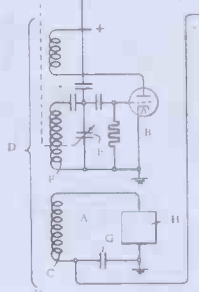


Fig. 1. Typical superhet circuit with A.F.C.

Fig. 1 shows a typical circuit of a superhet receiver with A.F.C. The A.F.C. diodes V1 and V2 will immediately be recognised and also the control circuit A. This automatic frequency control circuit operates to control the frequency of the local oscillator B by virtue of a change in the reactance reflected by the magnetic coupling of a winding C, provided in the transformer D, into the frequency determining oscillatory circuit E, F of the local oscillator. The impedance of the circuit A is comprised by the reactance of the winding B, by the reactance of a by-pass condenser G, and by the resistance at a given moment of a resistor H which has a non-linear resistance characteristic. This resistor may, for example, be Thyrite, and has a terminal resistance dependent upon the current flowing at a given moment. To supply this current, the resistor H and the transformer winding C are connected in series through a resistor J between the cathode K of V3 and earth.

Since the negative terminal of the high-voltage space current supply (not shown) for V3 is also earthed, this connection of the frequency control circuit A in the cathode lead of V3 places the circuit A in the output circuit of V3. The resistor J, in addition to providing a proper operating bias for the grid L of V3, aids the condensers M and G in filtering audio frequencies, appearing in the output circuit of V3 out of the control conductor O so that the current flowing through the resistor H is substantially non-pulsating unidirectional.

The automatic frequency control circuit is completed by connecting the upper terminal of the resistor U2 through resistor Q to the grid of V3. A by-pass condenser R maintains the conductor S at earth potential for oscillations of intermediate and audio frequencies.

It should be noted at this point that the control potential appearing between the conductor S and earth is very greatly amplified, in its effective control over the resistance of the resistor H by the amplifying characteristic of the electron discharge of V3. Thus, very small displacements of the intermediate frequency from a normal value result in large changes in the value of resistance of the resistor H which, when reflected into the oscillatory circuit of the local oscillator B, effect substantial changes in the frequency of the local oscillator in a direction tending to restore the intermediate frequency to its former normal value.

The purpose of the resistor T, in series with diode V1, is to off-balance to a certain extent the equality of the voltages produced across the resistors U1 and U2. This unbalance of voltages is only necessary when a single space current supply source is used for all of the valves in the receiver and the regulation of the space current supply source is very poor. A poor regulation results in an increase in the space current of the electron discharge device V3 upon the tuning of the input circuits by the condensers V to receive a signal oscillation since the automatic volume control operates when a signal is tuned in, to decrease the load on the space current supply source caused by decreasing the space current through the several electron discharge device in the receiving apparatus W to which the automatic volume control circuit X is connected.

Any increase in the space current of V3 in this manner is detrimental to the proper operation of this automatic frequency control and should be avoided. By using the resistor T a greater potential drop appears across the resistor U1 than across the resistor U2 when a signal oscillation is received and this excess voltage, since the ungrounded terminal of the resistor U1 is negative with respect to earth, causes the grid L of V3 thereupon to become biased slightly more negatively than formerly even though the intermediate frequency is at its normal value. Changing the bias of the grid in this manner effectively maintains a constant space current through V3 even though the potential of the screen grid Y and the anode Z rises by virtue of the poor regulation of the space current supply source. The same result may also be accomplished by eliminating the resistor T and by so unbalancing the centre tap of the winding of the intermediate frequency transformer I that a greater voltage is produced across the resistor U1 than is produced across the resistor U2 at times when the intermediate frequency has a normal value.

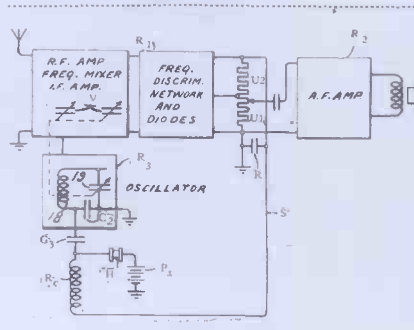


Fig. 2. A modified arrangement

Fig. 2 illustrates a modification of the arrangement in which elements corresponding to elements of Fig. 1 are designated by like reference characters. Rectangle R1 of this figure represents the frequency discriminating network, the diodes, V1 and V2, and their interconnected circuit as shown in Fig. 1; the rectangle R2 represents the audio frequency stages of amplification and

includes the electron discharge devices V4 and V3 of Fig. 1, and the rectangle R3 represents the local oscillator B of the Fig. 1 arrangement.

This modification utilises a characteristic of certain substances, typical of which is Thyrite, which act like capacitors and exhibit an effective terminal capacity which varies with the potential drop across the substance. To utilise the capacitive characteristic exhibited by materials of this class a small condenser C2 is connected in the frequency determining network of the oscillator, comprised by the condenser F and secondary winding E of the oscillator transformer. The Thyrite H, or other substance exhibiting like characteristics, is then connected through a condenser C3 across the terminals of the condenser C2. It will be evident that changes in the terminal capacity of the Thyrite result in corresponding changes in the resonant frequency of the oscillator frequency determining circuit.

A change in terminal capacity of the Thyrite is accomplished by including a source of unidirectional potential Pt in the circuit between the Thyrite and one terminal of the condenser C2 and by connecting the potential drop produced across the resistors U1, U2 through a suitable filter comprised by the condenser R and radio frequency choke Rc across the series connected Thyrite and course of potential Pt. Thus, the potential drop across the resistors U1 and U2 adds to or opposes the potential of the source Pr thereby to increase or decrease the magnitude of the current flowing through the Thyrite resistor. If the potential source has a suitable polarity, the control potential produced across the resistors U1, U2 by the departure of the intermediate frequency oscillations from a normal valve operates to change the terminal capacity of the Thyrite resistor by changing the resistance of the Thyrite, in a direction to change the oscillator frequency to restore the intermediate frequency oscillations substantially to their former value.

The source of potential Pt in this arrangement is necessary in order that an initial biasing current may flow through

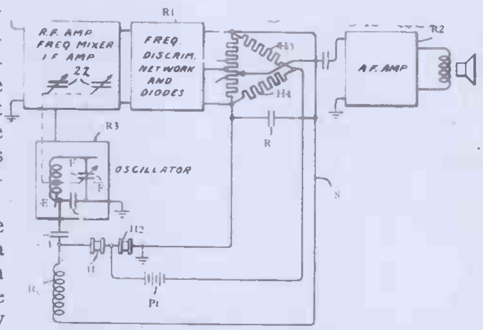


Fig. 3. Another modification using a resistive bridge circuit.

the Thyrite resistor to cause a restoration in the frequency of the automatic frequency oscillations whether these oscillations depart upward or downward in the frequency spectrum from their normal value. The initial biasing voltage across the Thyrite resistor should be at least equal to the peak value of the automatic frequency control voltage likely to be developed across the resistors U1 and U2.

The arrangement of Fig. 2 has the objection that the source of potential Pt produces a unidirectional potential drop across the resistors U1, U2 which places an initial bias on one of the diode rectifiers included in the apparatus R1.

The modification illustrated in Fig. 3 overcomes this objectionable feature of the control circuit of Fig. 2 by the use of a resistive bridge circuit. It will be noted that this modification employs an additional Thyrite resistor H2, the two Thyrite resistors being connected in series with each other and, through the condenser C3, in parallel relation with the condenser C2 of the oscillator frequency determining reactive circuit. An additional pair of resistors H3, H4 are connected across the resistors U1, U2 and form with the Thyrite resistors H, H2, a normally balanced Wheatstone bridge. The source of potential Pt is now connected across opposite arms of the bridge between the junction of the Thyrite resistors H, H2 and the junction of the resistors H3, H4.

This arrangement enables an initial biasing current to flow through the Thyrite resistors H, H2 without producing a potential drop across the resistors U1 U2. The operation of the Fig. 3 arrangement is the same as that of Fig. 2, the terminal capacities of the Thyrite resistors H, H2, being employed in series across the condenser C2 to control the frequency of the local oscillator. The Thyrite resistors should have the same resistive characteristic.

Neutralising Wide-band Amplifiers

THE coupling capacity between the electrodes of a valve can be neutralised by connecting an inductance in series with a D.C. blocking condenser between the control grid and anode, the inductance together with the electrode coupling capacity thus forming a parallel circuit which presents a high resistive impedance at a constant carrier frequency. At other frequencies, however, the impedance will be less and no longer purely resistive, with the consequent possibility of the generation of oscillations due to feedback from the output circuit.

Apart from this possibility it is, of course, always desirable that the phase relation between the input and output currents shall be maintained constant over a wide frequency range so as to obtain uniform amplification over the working range. The compensating networks shown in Figs. 1, 2 and 3, and reported from the R.C.A. Laboratories, have been designed to this end, the networks serving to render the anode-to-grid impedance resistive over a wide range of frequencies.

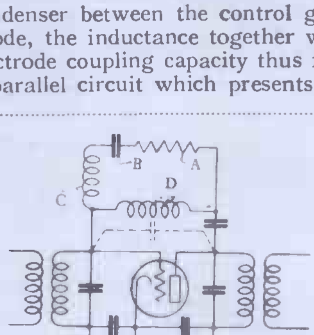
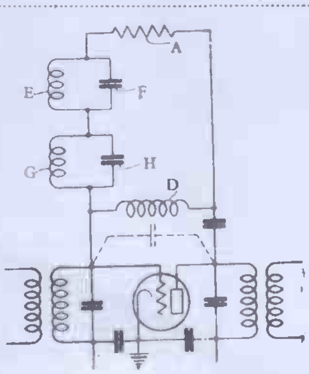


Fig. 1 (left).

Fig. 2 (right).



The pass-band characteristics of an amplifier provided with the usual form of neutralising arrangement referred to are indicated in Fig. 4. The inter-electrode impedance variation represented by the curve A is very considerable within this range, and the phase relation variation between the input and output currents represented by the curve B is also relatively large.

These disadvantages are obviated by the circuit of Fig. 1, in which a resistance A, condenser B and inductance C are series-connected in shunt to an inductance D, coupling the grid and anode of the valve. The condenser and inductance are arranged to be series resonant at the mid-point of the desired frequency pass-band. The effect of this circuit is shown in Fig. 4, the curve C indicating the inter-electrode impedance and the curve D indicating the phase relation, both of which remain substantially constant throughout the desired frequency range.

The amplifier can be made to operate satisfactorily over a still wider frequency range if the series resonant circuit B, C in Fig. 1 is replaced by the parallel resonant circuits E, F and G, H of Fig.

2. The parallel resonant circuits are tuned to frequencies above and below the desired band respectively.

In the arrangement of Fig. 3, which is intended for operation over a still wider frequency band, the resistance A is shunted by parallel resonant circuits K, L and M, N, and is series connected with the series resonant circuits O, P and Q, R, which are shunted by a series resonant circuit S, T. The effective impedance between grid and anode is lower, but can be made uniform over the pass-band instead of varying in the manner shown by the double-peak curve in Fig. 4, the phase angle being substantially zero. The resonant circuits are all tuned to the mid-band frequency and the ratio of the series circuit inductances to the inductance D is dependent upon the width of the desired pass-band.

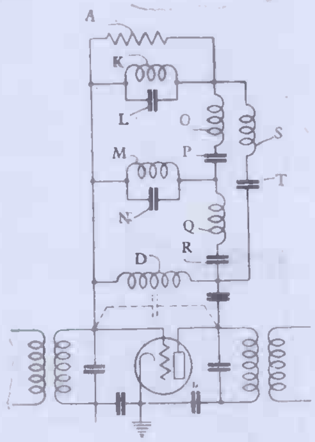


Fig. 3.

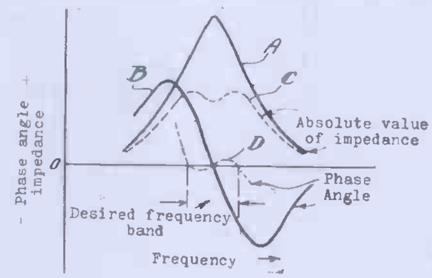


Fig. 4.

The Taylor Model 90 Universal Test Meter

THE Taylor Model 90 meter, of which an illustration is given, is contained in a neat black metal box measuring approximately 8 in. by 4 in. by 5 in., and weighs only $4\frac{1}{4}$ lb.

It has no less than 32 ranges of A.C. and D.C. volts, current and resistance measurement, and has a sensitivity of 1,000 ohms per volt.

Below the meter on the top panel are mounted the range switches and A.C.-D.C. changeover switch, while the ohmmeter range adjustment is on the right. Connection to the meter is by means of plugs and sockets, an extra socket being provided for the 1,000-volt range.

The following ranges are incorporated:

D.C. and A.C. volts: 2.5, 10, 100, 250, 500 and 1,000.

D.C. milliamperes: 1.0, 2.5, 25, 250 and 2,500.

A.C. milliamperes: 1.0, 15, 250 and 2,500.

It is also possible to measure 0.25 volt D.C. by setting the range to 2.5 mA.; in other words, the drop in the meter at 2.5 mA. is 0.25 volt—a useful figure to remember.

Resistance measurements are made by setting the selector switch to 'R' or 'R/10,' depending on the range required. With 'R' the scale covers 0—100,000 ohms. If higher resistances are to be measured an external battery is used in addition to the one in the instrument and the range is then 100 times that of the 'R' range, or 10 megohms max.

The resistance scale is uppermost on the dial and two other scales cover the A.C. and D.C. voltage ranges and the A.C. current ranges.

Test Report

Examination of the interior showed robust and well-finished construction. There is no complicated multi-contact switch to give trouble and the resistances and shunts are mounted securely—an important point in a meter which is intended for hard wear in workshops and test rooms.

The Taylor Model 90 test meter.

The meter is furnished with plugs terminating in sharp needle points, as the user may find to his cost if handled carelessly! An additional refinement would be a pair of crocodile clips, and no doubt Messrs. Taylor will be able to supply these for small extra cost.

The D.C. volt and current ranges were checked at random points against a sub-standard meter and agreed well within the standard of accuracy accepted for meters of this type. The normal resistance range is accurate enough for checking purposes, and it must be borne in mind that everything depends on the initial adjustment of the zero point. It is advisable to check the zero each time the meter is used, particularly when the battery is new.

On the highest range the additional battery of 60 v. must also be checked. The makers recommend the connection of a resistance of 54,000 ohms in series with the high resistance under test, but this value is not critical and a 50,000-ohm commercial resistance did not appreciably affect the accuracy.

On the lowest resistance range the current taken is considerable and the meter leads should not be short-circuited any longer than is necessary to check the zero. This range is particularly useful owing to its open scale between 50 and 1,000 ohms—the average range of bias resistors. Some ohmmeters are cramped over the lower part of the range in an attempt to obtain greater accuracy at the upper end. The battery is replaced without trouble by removing the top panel—a standard 9-v. bias battery is used.

Each meter is guaranteed for six months from date of purchase, provided, of course, that it has not been tampered with.

A book of instructions accompanies each meter, but the operation is so simple that it is unnecessary to refer to this more than once. The price is £9 9s., and the makers' full address is Taylor Electrical Instruments, Ltd., 419, Montrose Avenue, Slough, Bucks.

Catalogues Received

Condensers.—The 1941 issue of the Cornell-Dubilier catalogue contains concise yet very complete information on every condenser the engineer or serviceman is likely to require; the range includes dry electrolytics, wet electrolytics, tubular paper condensers, metal shell cased paper condensers, replacement paper condensers, a special small unit designed for use in car radios and mica transmissing condensers. This company also markets an interference filter and a capacitor test instrument. The Cornell-Dubilier Electric Corporation South Plainfield, New Jersey, America.

HOME INSTRUCTIONAL COURSE

SUPERHETS

THE supersonic heterodyne reciever, called colloquially the "superhet," is not a recent development and in fact dates back to the beginning of the century so far as the fundamental principles are concerned. The first practical superhets were a product of the last war when the need arose for greater amplification of the radio frequencies and the valves available were limited in performance compared with present day products.

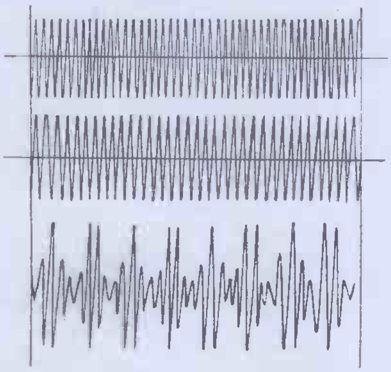


Fig. 1. Showing how two notes of slightly different frequency combine to produce 'beats.'

The amplification of radio frequencies has always been a problem, and the higher the frequency the more difficult the problem becomes. The stray capacities in the wiring and the valve capacities are effectively in parallel with the output of an r.f. amplifier stage and their low impedance to high frequency reduces the gain of the stage considerably. In some television frequency circuits the gain per stage with the best of the modern valves is less than 5, so the difficulty of amplification with the cruder valves of 1917-18 can be imagined.

The development of the superheterodyne method of reception was due to the attempts to overcome the difficulties of high-frequency amplification, and the obvious line of attack was to reduce the frequency as much as possible to overcome the shunting effect of the circuit capacities. It occurred to Armstrong in America, and, independently, to Schottky in Germany, that if the radio frequency from the aerial could be combined with a locally generated oscillation which differed slightly in frequency the resultant "beats" could be amplified more easily than the original signal.

The "beats" would still convey the modulation forming the speech or music and could be rectified after amplification in the usual way. This is the principle on which the superheterodyne is designed, and its operation can be understood by following a signal through the various stages as given in the diagrams.

Beats

The phenomenon known as "beating" occurs whenever two oscillations which are fairly close together in frequency combine to produce an output. The effect is shown in Fig. 1, and can be studied by drawing a series of waves differing slightly in frequency and adding them together graphically.* The resulting wave will be seen to consist of a series of high and low amplitude peaks, the maximum amplitude occurring when the combining waves are in step and the minimum when they are out of step ("phase" would be a more scientific term). If the original frequencies were audible, say C and C sharp, the combined wave would be audible as a series of throbs or beats, each beat corresponding to a rise in amplitude of the resulting wave. Students who have access to a piano which can be tampered with can try the effect of slightly detuning one of the two strings which form each note in the base register. On striking the key the beat between the two frequencies will be heard clearly, its frequency de-

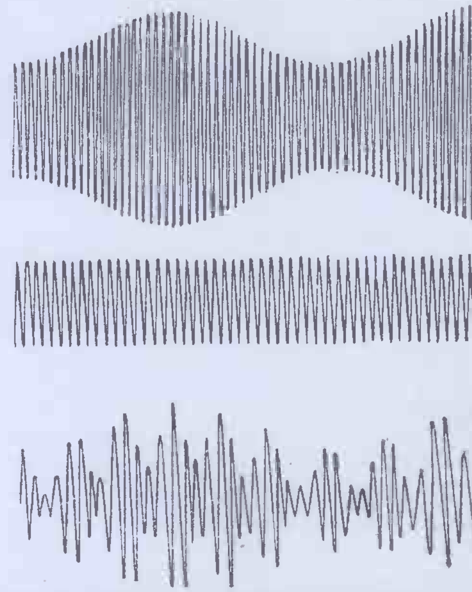


Fig. 2. A modulated carrier wave combined with a local oscillation frequency reproduces the modulation in the beat frequency.

* An early article in this series dealt with the addition of two sine waves.

pending on the difference between the frequencies of the two strings. Lower C is approximately 128 cycles per sec. and if the second string of the pair is detuned to vibrate at 120 cycles per second, a beat note having a frequency of 128-120 or 8 per second can be heard and counted.

The effect is exactly the same if the frequency of the note is raised, or if two oscillatory circuits are used. Suppose one is oscillating at 128,000 cycles per sec. (increasing the original figures a thousandfold) and the other at 120,000. The beat frequency will then be 8,000 cycles which will be audible as a whistle. Increase the frequencies another tenfold and the resultant beat note will be 80,000 cycles which will be inaudible as it is above the range of the human ear. Frequencies above audibility are termed "supersonic." We have now got into the working region of the super-het. 1,280 kilocycles per second corresponds to a frequency in the broadcast band and if it is combined with a wave generated by a local oscillator at 1,200 kc., the resultant beat frequency is 80 kc., which is easier to amplify than the original 1,280 kc. signal.

The incoming frequency in the case of a radio receiver is modulated at audio frequency and instead of being the continuous oscillation of Fig. 1, will be more like the upper curve of Fig. 2. The fluctuations in amplitude produced by the audio frequency modulation appear in the beat waveform, which should be compared with that of Fig. 1.

In combining the incoming signal with a locally generated signal we have not lost the modulation, which is, of course, a most important point.

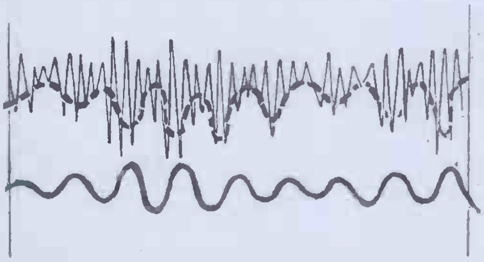


Fig. 3. The modulated beat frequency after rectification showing the anode current fluctuations following the modulation.

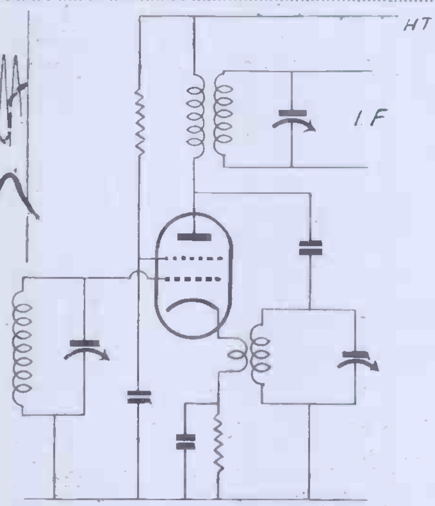


Fig. 5. A simple circuit for injecting an oscillation into the first detector.

Detection

If the modulated beat frequency is passed through a detector in the usual way the anode current of the detector will follow the average height of the complex wave of Fig. 2 and will be of the form of Fig. 3—top. Note that the anode current fluctuation follows two influences: the main fluctuation frequency is that of the beat, the current rising with each pulse of increased amplitude and falling with the troughs of the waves. At the same time the general level of the anode current peaks follows the wave form of the modulating frequency. The fluctuation due to the beats is seen more clearly in the lower diagram of Fig. 3 which has had the high frequency component taken away. This wave is then amplified by successive stages of tuned circuit and valves until it is of sufficient amplitude to be rectified a second time

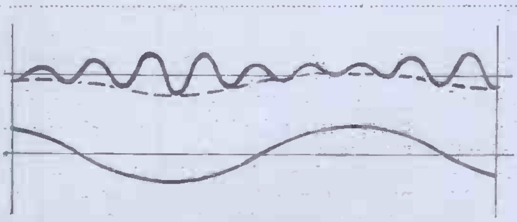


Fig. 4. The modulated beat frequency after detection a second time, leaving the audio frequency component.

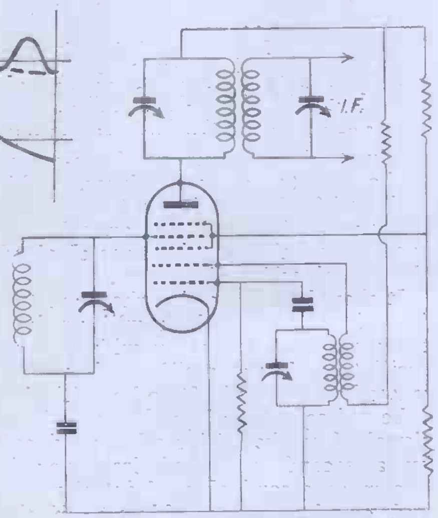


Fig. 6. A valve used as a combined oscillator and detector.

leaving the audio frequency component only. The diagram of Fig. 4 shows the beat frequency modulated by the signal and its rectification to produce the final audio frequency wave which is of the same form as the original modulation.

A superhet, therefore, requires two detector stages—the first immediately following the local oscillator, which rectifies the modulated beat frequency and the second which removed the beat frequency to leave the original modulating frequency.

Instead of the term "beat frequency" we can use the more common one "intermediate frequency," abbreviated to "i.f." denoting the frequency between the original radio frequency and the audio frequency produced after detection for the second time.

The most important difference between the performance of the superhet and that of an ordinary tuned circuit radio frequency amplifier is that in the superhet all the amplification is done at a fixed frequency, that of the beat, while in a "straight" r.f. amplifier the circuits have all to be tuned to the frequency of the incoming signal. Once the tuned circuits of the superhet have been adjusted they need no alteration, and this makes for a neat and reliable form of construction of the amplifying stages.

It is also possible to design the i.f. tuned circuits for maximum efficiency at the frequency chosen, whereas it is impossible to obtain maximum efficiency from tuned circuits over a wide range of frequencies without some adjustment.

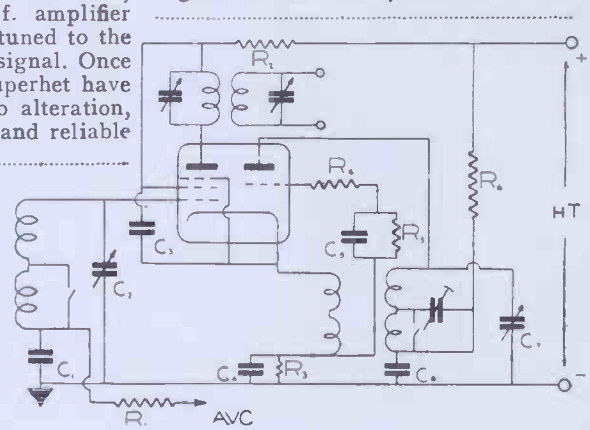


Fig. 7. A heptode valve in which the coupling is by electron stream.

Selectivity

One of the difficulties of present day reception is to keep unwanted stations from interfering with the one to which the receiver is tuned. The higher the frequency to which a circuit is tuned, the more difficult it is to keep out unwanted frequencies as the percentage difference between the two may be very small. As an example, if a circuit is tuned to 120 kc., a frequency of 125 kc. will be passed as the percentage difference is only 5 in 120 or 4 per cent. approximately. Now suppose that the frequency of 120 kc. is combined with an oscillation at 200 kc. to produce an i.f. of 80 kc. The unwanted signal will produce a beat frequency of 200-125 or 75 kc. and the difference between this and the i.f. of 80 kc. is 5 in 80 or nearly 7 per cent. These figures are taken at random and the actual results obtained show much wider differences.

It should be noted that there are two incoming signals which will produce the same beat frequency with a local oscillator. If the oscillator frequency is 450 kc., a signal of 500 kc. will give a beat frequency of 50, but so will a signal of 400 kc. This effect produced by a second unwanted frequency is known as *second channel interference,* and can be very troublesome if the local oscillator frequency is chosen so that there are two stations beating with it at the same time.

The frequency of the local oscillator is always chosen with regard to the frequencies in the broadcast band and is not taken at random. It has been found that the most satisfactory frequencies are round 100 kc. and 450 kc. and most superhets use one or other in this region. The selectivity of the tuned circuits can then be designed so that there is minimum interference from adjacent frequencies in the band.

Superhet Circuits

The circuit of the superhet may be said to be built round the oscillator, as the performance of the receiver depends on the constancy of the oscillator frequency. If this alters, the i.f. alters and the tuned circuits of the i.f. amplifier are thrown out.

Frequency Changing

In early superhets the local oscillations were produced by a separate valve which was inductively coupled to the detector circuit, but later developments simplified the circuit and valves were designed to combine the functions of oscillator and detector. Separate oscillators are still used, however, in television and short-wave receivers.

The incoming signal is usually passed through one stage of radio frequency amplification before being "mixed" with the local oscillation. The valve performing this is often referred to as the "mixer valve."

A simple mixer circuit is shown in the diagram of Fig. 5 in which a screen grid (or tetrode) valve combines the function of detector and oscillator.

The incoming radio signal is applied to the grid in the usual way and the valve is biased by a resistance in the cathode circuit to act as an anode bend detector.* An oscillatory circuit is connected between anode and cathode

* A previous article in this series dealt with detection and with oscillatory circuits.

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C 60/500	60 MA	18-30 H	500 ohms	5/3
C 100/400	100 MA	20-34 H	400 ohms	9/6
C 150/185	150 MA	20-34 H	185 ohms	13/6
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SP. 301	300-300 v. 150 m.a. 4 v. 2-3a, 4 v. 2-3 a, 4 v. 1 a, 4 v. 1a ...	15/-
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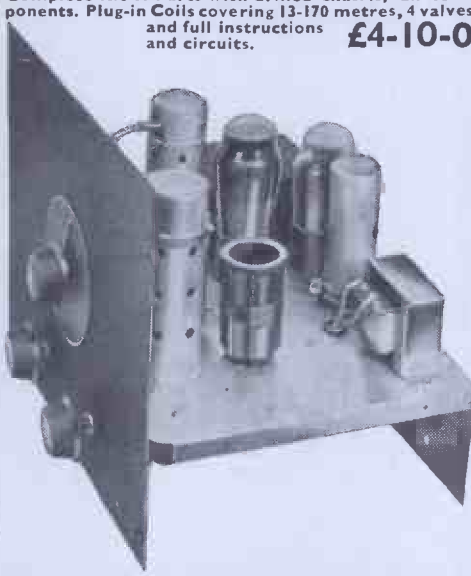

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and coupled back to the grid through the coil in the cathode circuit. The anode circuit thus contains three frequencies—the radio signal and the sum and difference of the oscillator and the radio frequencies. The difference of the frequencies only is required and this is obtained by coupling a tuned circuit to the anode coil as shown. This is the "i.f." transformer and feeds the i.f. to the next valve.

The method of applying the oscillation frequency to the circuit is by coupling in the cathode and for this reason the method is known as *cathode injection.*

Some receivers use a separate valve for the oscillator, but combined with the detector in the same bulb—the triode-pentode.

In these the triode portion is the local oscillator and the pentode the detector, the injection being in the cathode circuit as in Fig. 5.

A more complicated form of combined oscillator and detector which is widely used is the one shown in Fig. 6. The valve has seven electrodes and is therefore a *heptode,* and the coupling between the oscillator portion and the detector is in the electron stream itself. It is as though the oscillations modulated the detector current flowing to the anode and this form of mixing is very efficient and stable owing to the absence of stray coupling between components outside the valve. Fig. 7 shows the circuit arrangement. Note that the signal is not applied to the grid to the first grid (the one nearest the cathode), but the first and second grids form an oscillatory circuit in which the second grid acts as an anode. The electrons pass through this "anode" and are controlled by the fourth grid to which the input signal is applied. The fifth grid acts as the screen in an analagous way to that in a tetrode, while the output is taken from the anode circuit in the usual way. Electrons from the cathode are thus modulated twice on their way to the anode—first by the oscillatory circuit and then by the radio input.

Another variation of the "one man band" type of valve is the triode hexode, in which the pentode portion of Fig. 6 has an extra grid added which is directly connected to the oscillator grid. The principle of most of these multi-electrode mixers is the same—combined modulation of the electron stream and a further diagram is unnecessary here.

The remainder of the superhet circircuit is on standard lines. The i.f. amplifier valves are of the screened pentode type with high mutual conductance and the second detector is usually a diode, which, as will be remembered works well with a high signal input.

Some more details of the circuit will be described later, including the mystic letters A.V.C. and A.F.C.

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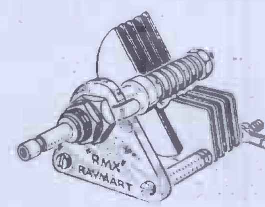

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VC250X	250 mmfd. (.00025 mfd.)	3/0

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Micalex	11.9	18
Porcelain	70	85
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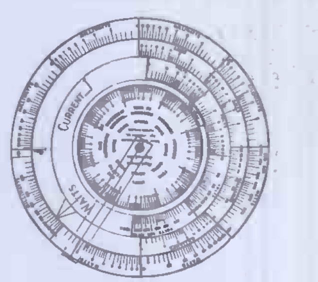

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THE SHORT-WAVE RADIO WORLD

A Review of the Most Important Features of the World's Short-wave Developments

Stabilised $2\frac{1}{2}$-metre Oscillator

Simple Construction of "Pot" Tank Circuits

THE "pot" circuit gives, in effect, a high-C low-L circuit with low losses, which results in a very high-Q tank. Unfortunately, the valve has to be connected across the circuit and thus lowers the Q, and coupling

A Peterson "pot" oscillator for 112 Mc. using two shield cans and a copper rod for the tank circuit. The stability is superior to any other form of U.H.F. self-excited oscillator.

the load into the circuit further reduces the Q, but the net result is still a much better circuit than can be obtained by more conventional means.

The condenser employed is similar to the neutralizing condensers used for lower-frequency circuits, made of two concentric cylinders of slightly different diameters. The inductance is a short length of coaxial line with one end shorted. By using the outer conductor of the coaxial line as the inner cylinder of the condenser, and supporting the outer plate of the condenser by the open end of the inner conductor of the co-axial line, a parallel-tuned circuit is obtained that has no losses except the resistance along the surfaces of the metal, as the only insulator in the circuit is air and there are practically no radiation losses because of the complete shielding. The metallic surfaces have considerable area and so the resistance there is much less than in conventional circuits.

The Circuit

The circuit shown by Fig. 1 is a tuned-anode oscillator using a pot tank and inductive coupling to the grid. The anode of the valve is connected to the open end of the inner cylinder, which corresponds to one end of a conventional coil-condenser parallel circuit, and the grid coupling is obtained by running a wire up through the inner cylinder parallel to the rod. Changing the position of this wire relative to the rod changes the coupling and hence the excitation.

Power is coupled out of the circuit by a hairpin loop of wire running parallel to the rod and in the plane of a radius. Pushing the loop farther down in the pot increases the coupling. The tuning condenser is connected between the anode of the valve and the outer shield can, or in effect, across the tuned circuit. Since the pot is connected to the anode, the whole pot is at the D.C. anode voltage above earth. However, as a safety measure it is easy to give the whole outer surface of the pot several coats of clear lacquer. The rest of the circuit consists simply of by-pass condensers, the grid leak and an R.F. choke, all in conventional locations. The condenser C2 is necessary

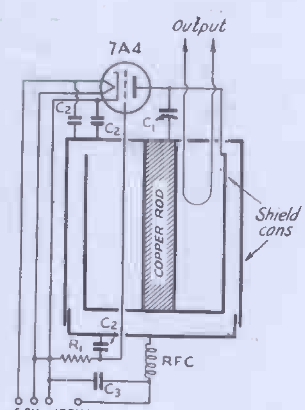

Fig. 1. Circuit diagram of the "pot" oscillator using shield cans for the concentric cylinders.

C_1—20-*uu*fd. midget variable, modified.
C_2—100-*uu*fd. midget mica.
C_3—500-*uu*fd. midget mica.
R_1—10,000 ohms, 2-watt carbon.
RFC—20 turns No. 22 enam. wound on ¼-in. diam. form and stretched to space turns a wire diameter.

to help to remove the R.F. from the power-supply leads.

The outer shield can is 3 in. in diameter, and the inner one $2\frac{1}{2}$ in. in diameter, and both are $3\frac{1}{2}$ in. long. Points are located in the exact centres of the ends of each can and holes drilled to clear 6/32 screws.

A strip 3-16 in. wide is removed from the open end of the smaller shield by first marking it and then cutting through with a sharp knife. A piece of ¾-in. diameter copper rod is cut to exactly $3\frac{1}{2}$ in. in length, and holes drilled in the centre of each end are tapped to receive 6/32 screws for fastening the shields.

The socket is supported by a bracket of ½-in. wide strip brass bent in the

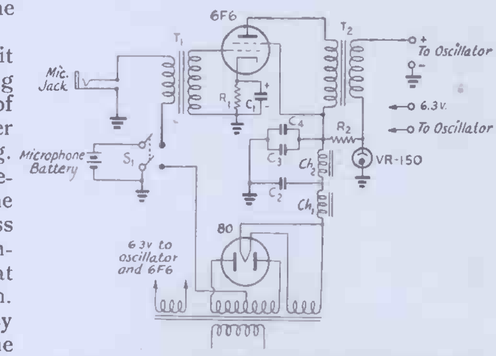

Fig. 2. A modulator and power supply suitable for use with the "pot" oscillator.

C_1—25-*u*fd. 25-volt electrolytic.
C_2, C_3, C_4—8-*u*fd. 450-volt tubular electrolytic.
R_1—350 ohms, 1½-watt.
R_2—3000 ohms, 10-watt wire-wound.
S_1—D.p.s.t. toggle switch.
T_1—S.b. or d.b. microphone to single grid.
T_2—Universal modulation transformer, 12 watts.
Ch_1—9-henry 85-ma. choke (T-13C29).
Ch_2—15-henry 85-ma. choke (T-68C07).

form of a shallow U with lips bending outwards at the ends. Tapped holes on these lips take the screws and fasten the socket. Another piece of the strip brass is used to support the tuning condenser. It is soldered on the under side of the socket bracket at an angle of 45° to the bracket in a position that places the centre mounting hole in the bracket through the centre-line of this strip. Its length is just sufficient to reach the edge of the can by a screw passing through the bracket and centre of the can into the copper rod. The tuning condenser is made a single-support affair by sawing the rotor shaft just past the last plate and sawing the right-hand stator support just past the last plate.

The left-hand stator support is left full length and is easily loosened by applying a hot soldering iron. The tuning condenser is mounted on the end of the brass strip with a flat-headed screw, and the end of the left-hand stator support should come right at the anode connection of the socket.

This condenser and socket assembly is fastened to the large shield can. A ¼-in. hole is drilled 5-16 in. in from the edge of the can to allow the lead from the inner can to come through and be fastened to the tuning condenser stator. A small lug riveted to the top of the inner can furnishes this connection. Opposite the grid terminal of the socket and $\frac{3}{4}$ in. from the edge, a $\frac{1}{4}$-in. hole is drilled to take the grid lead. Directly opposite the strip supporting the tuning condenser and 7-16 in. and $\frac{7}{8}$ in. respectively from the edge, two more $\frac{1}{4}$-in. holes are drilled to take the coupling loop: $\frac{1}{4}$-inch holes are also drilled in the end of the small shield and the bottom of the large one for passing the grid lead, placed so that the grid lead will run parallel to the copper rod.

The grid lead and the coupling loop are insulated from the cans by cementing small strips of $\frac{1}{8}$-in. thick polystyrene to the can, after drilling holes to pass the No. 13 wire grid lead and the No. 18 wire coupling loop.

The bottom cap of the outer shield can is used to support the assembly and, in turn, is mounted on three pillars to raise it above the baseboard and provide room for the grid condenser and leak. It is advisable to fasten the by-pass condensers and the heater and cathode leads at the socket before fastening the socket to the bracket.

"Low frequency Therapy"

(*Continued from page* 71)

positively controlled, and is independent of the setting of the switch, i.e., the plunger is so designed as to prevent it making the circuit for a portion of the timing interval only.

The apparatus is manufactured under the supervision of Mr. W. Grey Walter, of the Burden Neurological Institute, and is normally intended for use on A.C. mains of 200-240 v. If, however, voltage supplies are available an auto-transformer is used. Each instrument is sent out with a booklet of operating instructions and suggestions for technique based on the work already done at various mental hospitals.

REFERENCES.

1. Convulsion Therapy of the Psychoses. Wyllie, *J. Ment. Science*, March, 1940.
2. Cerletti and Bini. Boll. Acad. Med. Rom. 64, 36, 1938.
3. Electric Convulsion Therapy of Schizophrenia. Fleming, Golla & Grey Walter. *Lancet*, December, 1939.
4. Electrically Induced Convulsions. Golla, Grey Walter & Fleming. Proc. R. Soc. Med., Vol. 33, p. 31.

*See "Electrical Activity of the Human Brain" in the Oct. 1939 issue of this Journal, p. 579.
†Golla, Gray Walter & Fleming, *Lancet*, Dec, 1939.

"Cathode Protection"

(*Continued from page* 81)

the safest range of operation lies between the approximate limits of 3 and 4.5 volts. A convenient means of varying the timing is provided by an adjustable resistance in series with the heater circuit.

The curve in Fig. 5 relating to opening circuit shows the time required for the contacts to re-open after the heater has been operated long enough on the specified voltage for a stable temperature to be reached. This time is of the general order of 20 minutes, and if the heater is energised for shorter periods, the reopening time will be less than shown by the curve. In the case of the circuit shown in Fig. 3, the heater is disconnected immediately upon completion of the timing operation, so that the minimum reopening time is ensured. This feature gives a maximum of protection to the cathode of the gas-filled triode.

"Colour Television in America"

(*Continued from page* 62)

lar to that of the present day black and white standards.

The difficulties which have to be overcome on the transmitter side are not great. Even considerable technical complexity of the colour transmitter would not interfere with the final victory of coloured television if the solution of the receiver problems are within easy reach.

The combination of electronic and mechanical scanning seems to be essential for the transmission and reception of coloured pictures.

REFERENCES

[1] Colour Television demonstration by CBS engineers.—*Electronics*, October, 1940.

[2] Columbia Colour Television.—*Electronics and Television & Short-Wave World*, November, 1940.
[3] Colour Television in U.S.A.—*Wireless World*, November, 1940.
[4] Cathodoluminescence as applied in Television. H. W. Leverenz. *RCA Review*. Volume V, Number 2, October 1940, pp. 169-173.
[5] Quality in Television Pictures. P. C. Goldmark, J. N. Dyer.—*Proc. I.R.E.*, Vol. 28, No. 8, August 1940, p. 345.
[6] The Marconi-E.M.I. Television System. Blumlein, Browne, Davis, Green.—*Journal I.E.E.*, Vol. 83, No. 504, December 1938, p. 761.

Revised Prices of Taylor Instruments

In view of the substantial rise in cost of materials, Messrs. Taylor Electrical Instruments, Ltd., state that since the price revision of December, 1939, they are reluctantly compelled to increase the prices of their instruments as from 1st January, 1941, as follows:—

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Model 81C	18	18	0
Model 90	9	9	0
Model 95	7	17	6
Valve Tester—			
Model 40	10	10	0
Model 40P or B/M... ...	11	0	6
Signal Generators—			
Model 60A, B or U ...	12	12	0
Model 60B/M	13	2	6
Valve Tester—			
Model 45	14	3	6
Model 45B/M	14	14	0
Model 45P	14	19	0
Model 47	16	16	0
Model 47B/M	17	6	6
Model 47P	17	11	6
Oscilloscope—			
Model 30	21	0	0

Owing to the unsteadiness of the costs of raw material, the prices above are subject to further alteration at very short notice.

Vibrator Units with U.H.F. Receivers

SIR,—We note with interest your article on the S27 Hallicrafter U.H.F. receiver in the December issue, and in particular your statement that you cannot find a vibrator unit suitable for use with ultra-high frequency receivers.

We would like to point out that our Vibrapacks types 6B200C, 6B250C and 6B300C have been used on communication receivers on the frequencies in question, and given absolutely complete satisfaction.

With reference to the paragraph suggesting that manufacturers should develop units for use with receivers on ultra-high frequencies, we would like you to know that we have been manufacturing a unit for this purpose for a long time; in fact, it is possible to work the most sensitive communication receivers on Masteradio Mallory Vibrapacks over a complete range of frequencies from 50 Kcs. to 50 Mcs. which, we think you will agree, is rather more than the average requirements.

We have also designed Vibrapacks to work high-frequency battery-operated receivers with a sensitivity of one micro-volt using directly heated valves, which we consider to be a far more difficult problem, as the requirements are such that no increase in noise could be tolerated when changing from battery operation to Vibrapack.

In view of the above remarks, we feel sure that you will be prepared to amend your opinion.

S. L. ROBINSON.

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"More Electronic Patents"

(*See page* 76)

(Patent No. 527,104.)

Transmission system for handling a wide band of frequencies as in television, and for equalising the attenuation as between the higher and lower ranges of the frequency band. — *Standard Telephones and Cables, Ltd.*

(Patent No. 527,188.)

Amplifier for a wide band of television signals with an impedance coupling network equivalent to a pure resistance so as to avoid distortion due to phase-shift.—*Marconi's Wireless Telegraph Co., Ltd.*

Synchronising Systems

(Patent No. 526,211.)

In order to simplify the problem of synchronisation, the picture signals are superimposed on one carrier-frequency, whilst the audible signals are superposed on one carrier-frequency, whilst the audible signals are superposed on another carrier frequency, together with two "sweep" frequencies corresponding to the line and frame scanning frequencies used at the transmitter. The two carriers are in turn superposed on a third carrier-wave which is radiated.

No local generator of scanning frequencies is used at the receiver, but the sweep frequencies which form part of the complex radiated wave are first separated out and are converted into saw-toothed oscillations and applied directly to the deflecting plates of the cathode-ray tube. The arrangement "locks" the transmitter to the receiver through the ether, and gives perfect synchronisation, when an interlaced system of scanning is used.—*Standard Telephones and Cables, Ltd.*

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