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Identifying Components

THE method of marking components in circuit diagrams varies in many cases with the draughtsman or manufacturer concerned. Some identify each component with a single figure, some with a suffix figure, as is the practice in this journal.

In some cases the numbering follows some sort of order from left to right and top to bottom throughout the diagram, in others it is more random, and some reference figures may even be duplicated in the diagram if the components are of the same value.

If a series of diagrams is drawn to illustrate an article or instruction book, confusion is often introduced by allocating the same reference number to two different components in successive diagrams, and the fact that a table of values is usually attached does not avoid the difficulties in referring to the items in the text.

A correspondent, Mr. E. Hurran, of Barkingside, has put forward a suggestion for the coding of components in such a way that ambiguity is avoided and reference to them, whether in conversation or in writing, is easily understood by the engineer conversant with the system.

Briefly, his suggestion is that each component in a diagram should be identified by a combination of reference letters and numbers which should indicate its property, (*e.g.* resistance), function, (*e.g.* load resistance), and position in the circuit.

The property of the component is already covered by the accepted reference letters *R*, *L*, *C*, etc., and it will be necessary to attach a code number for the function, based on an agreed table, a second code number for the position—possibly based on the number of valve stages—and a suffix letter for the valve electrode concerned.

As an example, a resistor designated R.1.5.G. would be the load resistor in the grid circuit of No. 5 valve stage ; R.3.4.A would be the decoupling resistor in the anode circuit of No. 4 stage, and so on.

Mr. Hurran points out that such a code avoids all confusion between components in different circuits which bear the same reference number under an existing system, and that, once the code has been established, it would not always be necessary to mark the numbers of well-known components in the diagram. The text of an article could be more easily followed without continual reference to the diagrams.

We might extend the advantages still further and consider whether stock cards and parts lists might not be simplified if the reference number of the part indicated its use at the same time.

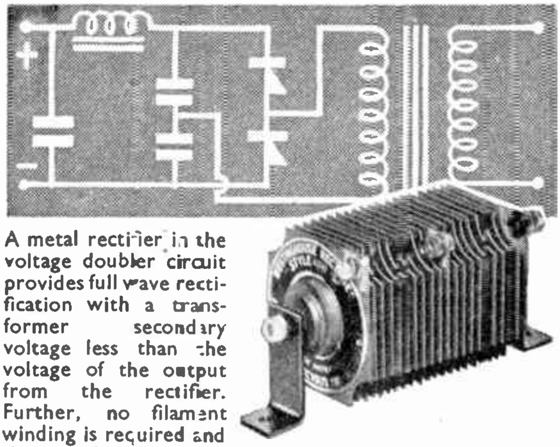
On the whole, such a scheme has many points in its favour and few objections. One of the latter will be the difficulty in coding the function of each component in the many hundreds of circuits which do not follow conventional lines, although the author's draft table has been thoughtfully drawn up to embrace most of the commoner cases.

The objection that the radio engineer is being given yet another table to learn is met by recalling that we already have a similar code in operation for valves. It is no more difficult to remember the function of a 25Z5GT than a similar set of symbols for a resistance.

It is hoped that enough has been given of the outline of Mr. Hurran's scheme to enable readers to follow it and weigh up its pros and cons, and their comments are invited.

Electronic Music Group

The meeting which was arranged for July is postponed. The revised date will be announced in due course.



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Mica quarries in Maine.

Outcrop of mica-bearing permatite, Yicca, Arizona.

Mica

The restriction of imports of mica from the Far East has resulted in a mica boom in America where the demand has risen to record proportions since the outbreak of war.

Owners of mica mines in New England, New Hampshire, Maine, and other Southern States are digging all the available sites and are rebuilding the mica industry to a level higher than has ever been attained.

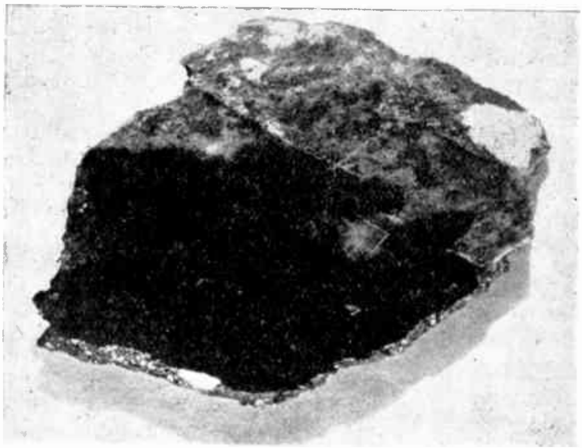
The chemical structure of mica is complex and there are a number of varieties, some containing magnesium and iron oxides in addition to the basic compounds of silicon, aluminium and potassium.

For electrical purposes the principal varieties are *muscovite* (white mica) and *phlogopite* (amber mica), muscovite being harder. Amber mica is largely used in heating appliances owing to its higher resistance to temperature (up to 800°).

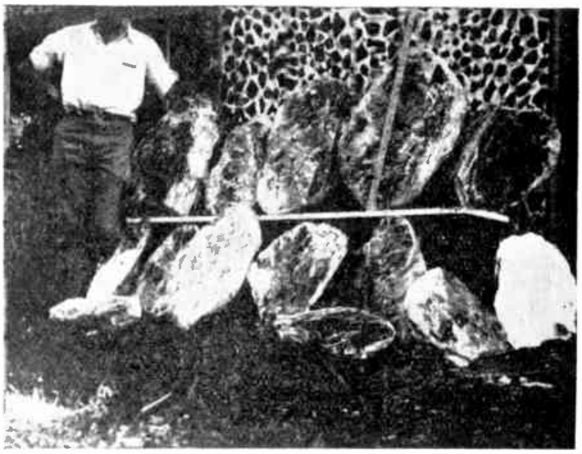
The following are the approximate electrical constants for mica :

Dielectric Constant : 7 - 7.5.
Dielectric Strength : 1,500 - 2,500 kV/cm.
Resistivity : 2×10^{13} - 2×10^{17} ohm-cm.
Power Factor : 0.3 at 50 c/s, 0.2 at 1 kc. - 1 Mc/s.

Specimen of pegmatite and dark mica.



" Books " of mica exhibited at Spruce Pine, North Carolina, Although the "books" are large, they contain very few large sheets.



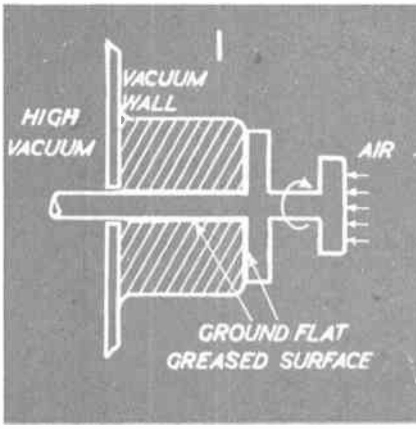


Fig. 1. Simple Cylindrical Joint.

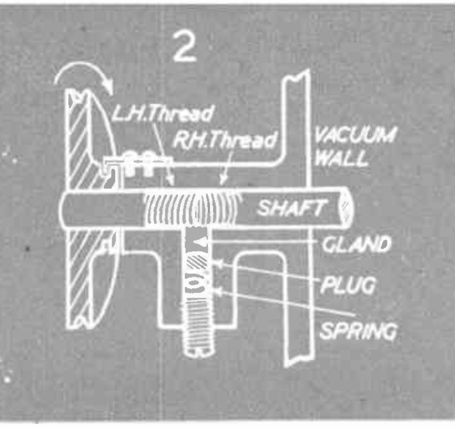


Fig. 2. High Speed Cylindrical Shaft—after von der Groof.

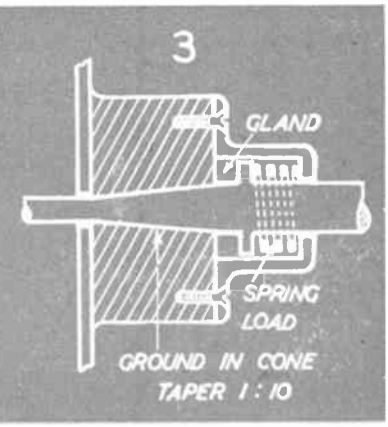


Fig. 3. Cone Joint.

Vacuum-Tight Mechanisms

Methods of Introducing Movement into Evacuated Systems

By E. W. WEBSTER, B.Sc., (Eng.) Hons.*

Introduction

THE field of electronics to-day includes an important class of instrument, an essential feature of which is the maintenance of a kinetic vacuum, which will permit electrons, ions, molecular particles and light quanta to travel freely. By kinetic vacuum system is meant a system (a) not generally vacuum-tight and (b) not outgassed, yet in which a pressure ranging from 10^{-2} to 10^{-7}, but generally about 10^{-5} mms. Hg. is maintained. This is only rendered possible by the advent of very fast pumps and by the application of a specialised vacuum technique.[1] The features (a) and (b) distinguish the kinetic system from the static system, which is exemplified in the familiar sealed-off glass tubes—lamps, radio valves, photocells, ordinary cathode-ray tubes and small mercury arc rectifiers. Generally, too, the kinetic vacuum system is characterised by a sturdy metal construction in which the various sections and components are demountable.

This class of instrument includes the high-speed cathode-ray oscillograph, its off-shoots—the electron diffraction camera and the electron microscope, large high-voltage X-ray tubes, and more recently, physical instruments such as the cyclotron. The kinetic system also finds a use in large mercury arc rectifiers, and in equipment for depositing metals in vacuo by sputtering or evaporation.

In these instruments it is often desirable to adjust the position of components inside the vacuum, without breaking the vacuum, or closing down the plant. For example: in the high-speed cathode-ray oscillograph which records directly on plates or roll film placed inside the vacuum, it is normally necessary to lift a fluorescent screen to expose the photographic material, and to change the plates or wind on the film, all by controls outside the vacuum. The same problem arises in some designs of diffraction camera and electron microscope. In the latter it is additionally necessary to be able to move the irradiating beam of electrons relative to the specimen (*i.e.*, move the electron source) or conversely to move the specimen relative to the beam. Again, in the cathode-ray oscillograph it is sometimes useful to vary the spacing of the deflection plates so as to vary the deflection sensitivity. These examples serve to illustrate why the methods available for controlling the location of targets, screens, photographic materials and other components in continuously evacuated equipment need consideration.

The problem stated then, is: how may translatory and/or rotary motion be transmitted through the vacuum walls with the minimum of leakage? The methods of so doing fall broadly into two classes:

(1) Transmission by relative motion of the constituents of a vacuum joint.

(2) Transmission without such relative motion.

(1) The first category involves direct coupling of an external component with one inside the vacuum. This coupling normally takes the form of a spindle which passes through the vacuum walls and which transmits torque or thrust applied manually or otherwise. Where it passes through the vacuum walls a rigid joint clearly cannot be made; joint design is directed to making the leakage path as highly resistive as possible.

Simple Cylindrical Joint

The obvious form of spindle is a simple cylindrical rod, which fits tightly into a long cylindrical hole. Here, not only is extreme accuracy of workmanship essential, but the grinding together of male and female to ensure the most intimate contact has inherent difficulties, since there must be a leakage path in the clearance between the components, dependent on the coarseness of the grinding

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*High Voltage Laboratory, Queen Mary College, University of London.

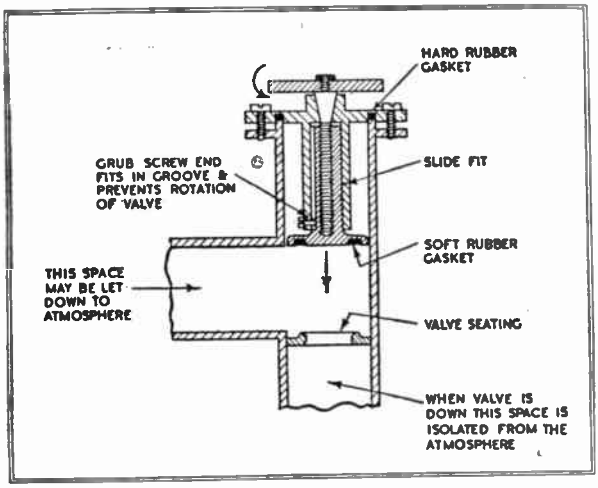

Fig. 4 (left). High Vacuum Large Bore Tap, using Cone Joint.

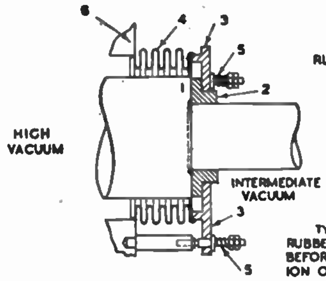

Fig. 5 (lower left). Floating Gland System—*after Whipp*

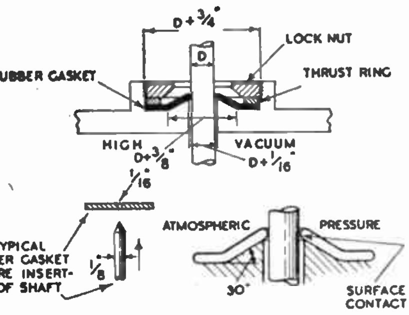

Fig. 6 (below). Wilson's Sliding seal.

material used. Assuming a tight enough fit is obtained initially, and that with the help of grease packing and lubricant the joint is sufficiently vacuum-tight, there would be no means of taking up any wear on the components, with the result that leakage would soon set in. At the expense of losing the advantage of axial motion, the leakage could be sealed by a greased, flat-ground flange joint on the atmospheric side. (Fig. 1.) This would also serve to register the cylindrical component axially. Naturally, a low vapour pressure grease must be used in connexion with all vacuum work; for lower vacua Ramsay or stopcock grease; for high vacua, an "Apiezon" grease, preferably the M type.

High Speed Rotary Motion

With due precaution, a simple cylindrical shaft may be used to transmit such motion. A design due to Van de Graaf is shown in Fig. 2. It was developed in connexion with his electrostatic high voltage generator, high vacua of 10^{-5} mms. being an insulation advantage.

The Van de Graaf type of joint forms a class on its own as distinctive as the cone class. The chief characteristic is an internal packing gland located along the shaft between the atmospheric and low pressure. The packing compound is a viscous material, tenuous in nature, of low vapour pressure (10^{-5} mms. or less). This is maintained at a pressure greater than atmosphere to prevent air forcing capillary paths through it. The shaft itself is a version of the long cylinder already described, fitting as closely as possible. To prevent extrusion of the packing compound various devices are adopted. In Fig. 2 the rotation of oppositely cut threads causes a pumping action, preventing packing leakage from the gland either to atmosphere or high vacuum. The material is Apiezon M grease plus colloidal graphite. Alternatively, an intermediate vacuum gland may be interposed between oil gland and high vacuum. (*See* American Patent, 2,064,703.)

Cone Joint

The most common form of spindle for transmitting manually applied torque is, however, a long cone of small angle (usually 1 in 10) which is fine ground to fit accurately into a corresponding female. A fine smooth layer of grease between the moving components is essential. This grease must contain no trapped air which will keep open a leaking capillary. Some of these joints are spring-loaded, and protected by a packing gland charged with a low vapour pressure grease, often with the addition of graphite, or charged with cotton twine soaked in "Apiezon" Q compound. A simple example is shown in Fig. 3.

The cone joint, which is commonly also used in small bore vacuum cocks, has the advantage over the cylinder of more intimate contact between male and female, which is maintained as the joint wears. Directly, of course, it will only transmit rotary motion, but the use of well-known kinematic devices such as crank systems, levers and long-pitched screw threads, enables linear motion to be obtained. A rotating screw thread operating into a tapped hole in a body which cannot rotate, but is free to move axially, will cause this latter movement. The commonest example of this is the screw-down high vacuum tap (Fig. 4) such as might be used to isolate one part of a vacuum system from its pump (for a "cut-off" test in a search for leaks), or to isolate an oil diffusion pump from equipment which is being opened to the atmosphere.

A conical joint with a stuffing box and packing may also be used to transmit high speed rotary motion, such as the drive to a drum camera, on which recording film rotates at high speed in vacuo, this motion providing a time base. The joint extrudes the packing, and may overheat or wear excessively.

Whipple[2] has developed a novel gland system which is more efficient. It is illustrated in Fig. 5. A shoulder (1) is turned on the shaft and its face is ground flat. A special carbon graphite bushing (2) copper plated except on the bearing face, bears up against this face. It floats from the mounting (3), a triangular plate to which it is soldered. This plate makes a vacuum-tight joint with the rigid housing by means of a metal bellows (4). Thus the carbon bush floats from the housing. Axial pressure is applied to the mounting (and therefore between the bearing faces of bush and shaft shoulder) by the adjustable springs (5). The leakage path will be observed to be along the shaft and between the ground bearing faces. The shaft rotates at 3,000 r.p.m.

Such a single gland system would not work from atmosphere into a desired vacuum of 5×10^{-5} mms. It was necessary to provide two such systems, with an intermediate vacuum of 10^{-3} mms. between them, this being maintained by a fast rotary pump.

Wilson's Sliding Seal

R. R. Wilson[3], in 1941, described an ingeniously simple contribution to the existing types of directly coupled joint. This was a sliding seal in which a rod was able to slide, twist, and if necessary, act as a lever through a specially distorted rubber gasket. With this seal one has a veritable finger inside the vacuum, and yet the leakage is negligible. The writer considers it superior in every way to a cone joint. It is simply made, reliable, shows no noticeable wear during continuous use over a year or more, is easily renewed, and is, in most dimensional respects, non-critical. Wilson used the joint originally for adjusting internal targets in a cyclotron. Fourteen such joints are incorporated in the 60 in. cyclotron at the University of California.

The essentials of the joint are shown in Fig. 6. The hole in the rubber gasket should be small enough to cause the rubber near the rod, when the rod is inserted, to make an angle of about 60° with the rod. The function of the cone is to maintain the rubber in this position. The rod must only be inserted from the high vacuum side of the joint, otherwise it will shear the important part of the rubber round the hole. The tightness is maintained partly by the elasticity of the distorted rubber, but mainly by the atmospheric pressure forcing the rubber against the rod.

The best rubber to use is hard, stiff one-sixteenth in. sheet. The rod need not be uniform, straight or exceptionally smooth. Deep cuts in the metal are, of course, not beneficial! A little low vapour pressure grease lubricates the joint and makes movement much easier.

The seal has been adapted for use as a gland in high vacuum large capacity taps. As an additional safeguard, two seals in cascade may be used, the intervening space being evacuated by a backing pump. This might be more advisable where large rods are concerned.

Intermediate Vacuum

The technique of intermediate vacuum already referred to in connexion with Whipple's gland system, has been used to introduce light-sensitive material in a continuous length through vacuum walls.[4] Incoming gases introduced at the film slit are pumped out by fast rotary pumps at intermediate stages in the progress of the film towards the vacuum as indicated in Fig. 7. This method is obviously inefficient and expensive of plant, because of the necessarily large leaks. In the intermediate vacuum, the mean free path is large compared with the size of the leaking channel with the result that molecular ingress becomes more improbable, obeying Knudsen's laws for rarified gases.

Another method tried in Germany for introducing a continuous length of film into an evacuated system, passes the film through a U-tube of mercury which serves to bridge the difference in head inside and outside the apparatus (760 mms. Hg.).[5] This, again, is complicated and expensive.

(2) The second category of available methods introduces two distinct subsections (a) transmission of motion via flexible components, and (b) transmission by magnetic or electromagnetic means. All methods in this category inherently introduce no leakage, since all joints involved may be rigid. Section (b) is applicable to static systems.

Rubber Tubing

(a) The most obvious flexible material which is vacuum-tight is rubber tubing. By designing the joint in various ways, a rubber tube may be used to transmit reciprocating, rotary or other motion through the vacuum wall.

Fig. 8a illustrates an ingenious device communicated to the author by Dr. G. Voglis. The flexible wire, one end of which is given a rotary motion by tangential pushing communicated by the rubber tube, will tend to twist, transmitting a torque along its length. Actually, the wire, since it is quite free to rotate, does not twist, but rotates in its bearings. The device, using 10 cms. of 1 cm. diameter tubing and a 15 S.W.G. copper wire has been used by the author to transmit a torque of more than 500 gram-cms.

The arrangements depicted in Figs. 8 (b) and (c) are considered as a means of transmitting reciprocating motion. In the first case the air pressure causes leakage along the shaft, and there is a tendency for the shaft to slip through the rubber. In the second case, the air pressure has the opposite effect of forcing the rubber hard against the metal outside cap, providing an air-tight seal. There is, however, one great over-riding objection to the practice of such a device. As the rubber must be bent back on itself, the rubber thickness must be kept small compared with the diameter of the tube. Since, in general one does not wish to use tube diameters greater than a few cms. this means that the thickness of the tubing is limited to a few mms. only; and even then the tube does not double back easily. This means, in practice, that it is impossible to use the stout high-vacuum tubing, in which the rubber is anything up to 1 cm. thick; and yet without such tubing, the vacuum is impaired through porosity

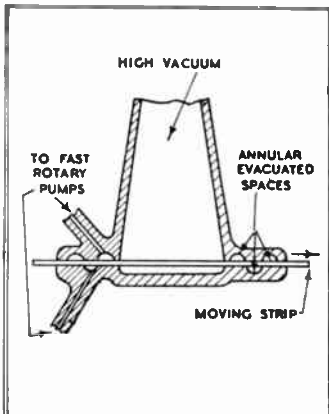

Fig. 7 (left). Gerdien's method of film introduction.

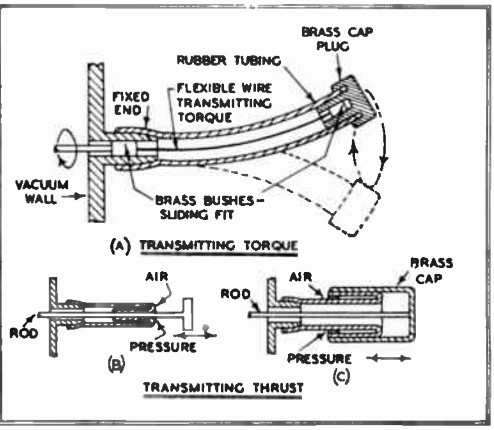

Fig. 8. (right) Transmission of motion by rubber tubing.

of the rubber—especially when it is greatly distorted.

Hence, rubber tubing is relegated to the transmission of torque, as described. For reciprocating motion a compressible bellows is obviously far more suitable.

Metallic Bellows

A flexible metal tube, or one which may be altered in length, such as a metallic bellows, is more satisfactory from the point of view of vacuum tightness and mechanical convenience than a rubber tube. In fact, one is advised against the use, on the high-vacuum side of a kinetic system, of rubber tubing, which may be porous and normally maintains a vapour pressure $\sim 10^{-1}$ mms. Strong[6] has measured the leakage per inch of various types of rubber tubing, and finds that the synthetic Koroseal leaks less than natural rubber.

The metal used, is a copper-zinc alloy normally containing 15 per cent. zinc. One variety is known as "Tombac." A length of such tubing may be compressed or extended 30 per cent. of its natural length, although many workers have reported its safe use beyond the elastic limit.[7]

In 1929, Knoll[8] suggested that the spacing of the deflection plates inside a cathode-ray oscillograph might be varied by external means. A design, due to Whipple,[2] based on this idea of using bellows, is indicated in Fig. 9. The brass plug moves axially along the screw thread when this is turned. The bellows is soldered between the plug and the vacuum wall, so that we have a rigid all-metal joint. The projecting pin serves the dual purpose of taking all rotational strain off the bellows and of locating the position of the plate. The function of the rubber gasket is merely to make the whole arrangement demountable from the vacuum wall.

An obvious sphere for the use of bellows is high vacuum cocks. A screw-down stop valve may be actuated with the bellows replacing a grease or other packing, thus yielding a perfectly vacuum-tight seal. Several workers[9] have described such packless valves and Fig. 10 illustrates one due to Rose. Such valves could be of large aperture and would be ideal as cut-off valves for diffusion pumps.

This bellows technique has been specially extended in the electron microscope for high magnifications. The 1930 edition of the Siemens (von Borries and Ruska) instrument[10] is equipped with an air-lock system by which a specimen may be removed from the vacuum (objective lens) and a new one inserted without breaking the vacuum in the main tube. The R.C.A. instrument[11] described in 1941 uses a similar air-lock technique for introducing both new specimens and new photographic plates. The principle is indicated in Fig. 11, in which a mechanism, not shown, first lifts the specimen out of the objective lens, and then, by further turning of the screw thread indicated on the left-hand side, the specimen is carried into the compartment 1, which is then sealed off from the main body of the tube by the valve gasket. Air is admitted, the specimen removed via the door, a new one inserted, the door is closed, and the compartment evacuated down to the backing pressure before the internal opening is made and this procedure reversed.

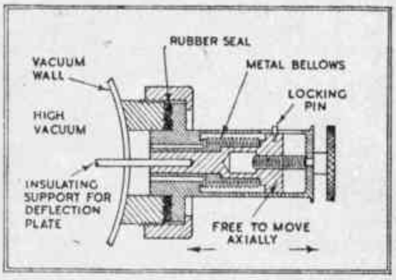

Fig. 9. Use of bellows for varying deflection plate spacing in C.R.O.—*after Whipple.*

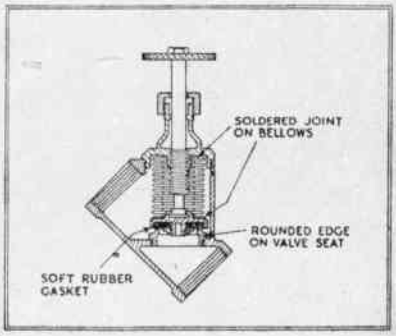

Fig. 10. Packless High Vacuum Valve—*after Rose.*

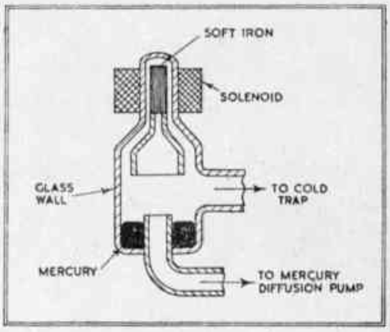

Fig. 14. Mercury cut-off.

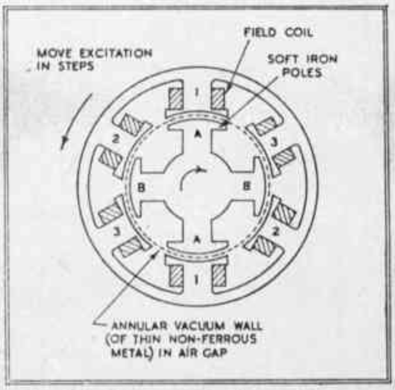

Fig. 15. Electro-magnetic step-by-step motion.

The metallic bellows may be adapted to introducing rotary motion by conversion from an axial thrust, by means of a lever, or by means of a long-pitched screw thread (Fig. 12), on which a nut is free to rotate, but not to move along the thread. The R.C.A. Electron Microscope—several specimens of which are now in this country under Lease-Lend—uses bellows throughout to transmit motion of all kinds, including lateral adjustment of the electron gun.

Another method of introducing torque would be to substitute flexible metal tubing for rubber tubing in the method depicted in Fig. 8a. Such tubing is much used for flexible vacuum connexions, and in this case, all that is required is a flexible, vacuum-tight medium which will carry a given radius of curvature.

Magnetic Transmission

(b) For routine operations in which a precise, automatic movement is to be quickly carried out, for all operations actuated by remote control magnetic or electromagnetic methods are probably best. The essential requirements of magnetic transmission are a magnetic polepiece inside the vacuum, and non-magnetic walls. In a static system the polepiece may be hermetically sealed inside a glass envelope to prevent outgassing.

A good example is Rogowski and Flegler's mechanical method of beam-trapping in the cathode-ray oscillograph[12] (Fig. 13). Normally, the disk A covers the hole in the diaphragm, thus preventing beam passage; beam release is secured in actuating the relay by energising the solenoid. Such

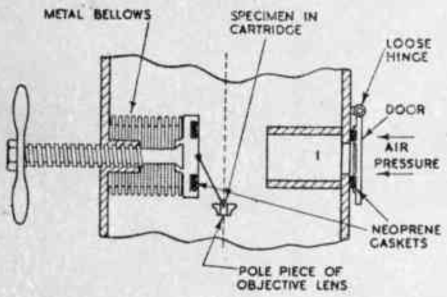

Fig. 11. The principle of the air lock used in recent Electron Microscopes.

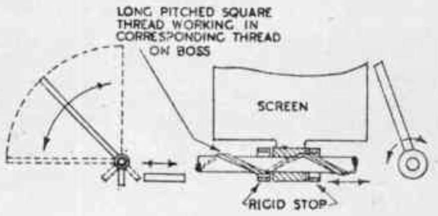

Fig. 12. Converting Linear to Rotary Motion.

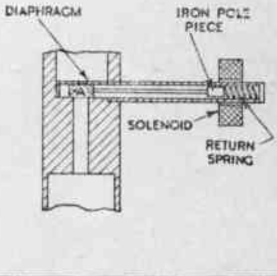

Fig. 13. Rogowski's mechanical beam trap showing magnetic release.

a device may be applied to automatic plate-changing of a magazine plate camera inside a vacuum.[13] The magazine may operate on the lines of a rifle magazine: when a magnetically operated "bolt" pulls the top exposed plate from the magazine, the next plate is elevated into position by a compressed spring. A similar application is the mercury cut-off, which may be used to isolate a mercury diffusion pump. A typical form is shown in Fig. 14, where the duty of the magnet is pure lifting.

High Speed Motion

For driving a dum in vacuo, there is an alternative to the glandular or conical joint previously mentioned. A rotating magnetic field may be transmitted into a vacuum through non-ferrous walls, just as in an induction motor the field crosses the air gap. The walls should be of material with high electrical resistance to minimise eddy current loss and consequent heating. The idea of such a magnetic drive using a disk of magnetic material or a simple drum to form the simplest of rotors inside the vacuum, was introduced by Dufour and Kock.[16] The notion avoiding, as it does, any vacuum troubles has been taken up by more recent workers using a high speed film drum inside a cathode-ray oscillograph for recording short circuit phenomena. Van Sickle and Berkey[14] have driven such a drum at 7,200 r.p.m. through a monel metal cup in the air gap of the driving motor. Whelpton[15] has used a 3-phase induction motor drive through a wall of constantan .015 in. thick, the peripheral film speed approaching 50 metres/second.

A step by step rotary motion—such as would be useful in winding on a film automatically, may be obtained by using a wound stator outside the vacuum and a simple rotor inside as in Fig. 15. The action of the device is as follows: if current flows through the winding 11 the condition shown obtains. If 11 is de-energised, but 22 receives magnetising current, the poles BB being merely soft iron polepieces, will move 30° to a position opposite 22. If then 33 receive field current, the poles AA will move another 30° to a position opposite 33; and so on. A simple drum controller may be used to move the field excitation voltage round the periphery. 12 steps, each one quite stable, are obtained per revolution. If varnished wire is wound on the stator, the whole assemblage may be mounted inside the vacuum, the leads from the external controller being introduced through a sealed insulating bushing.

Internal Relays

Given care in the choice of insulating materials—mica, ceramics and varnishes being most suitable—electric windings may be located inside the vacuum, so that internal relays may be operated. The author has used varnished wire on an iron core in such a relay, the winding surface being covered with "Apiezon" W wax. It is then only necessary to seal conductors through the vacuum walls. Such a relay may control the unwinding in steps of a coiled spring, thus giving another source of automatic step-by-step motion. This is an adaptation of the automatic spring-loaded film winding used in some modern cameras (Leica, Contax, Rolleiflex).

This brings us to the final source of motion inside a vacuum, namely springs, which may be loaded or wound up when the system is opened up and released manually or electrically after evacuation. The simplest example of how a spring may supplement magnetic control is given by the spring load in Fig. 13 which provides the return motion of the trapping disk A.

Conclusion

When a universal method of introducing manual motion is required, the choice should be Wilson's sliding seal. For a given type of motion when no leakage at all and freedom from grease are desired, the metallic bellows may replace it. For high speed rotary motion, induction drive through non-magnetic walls is generally easiest. For push-button automatic devices to control internal repetitive motions, magnetic relays are the obvious choice.

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A Transmitter Drive Unit for F.M. Signals

By F. BUTLER, B.Sc., A.M.I.E.E.

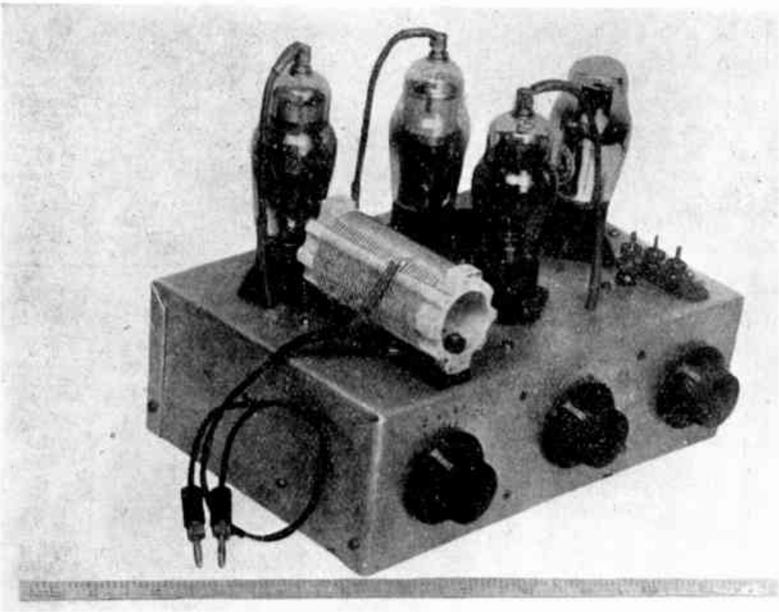


Fig. 4. General view of Drive Unit.

THE recent development and commercial application of frequency-modulated radio transmissions in America have so far had no counterpart in this country.

Besides the requirement for wartime security, it is probable that three main factors have, additionally, been responsible for some lack of interest in F.M. The first is the mathematical difficulty experienced in expressing F.M. currents in terms of the component sidebands as in the case of A.M. The second is because of a common impression that, in order to secure transmissions free from objectionable noise or distortion, excessive band-widths are required in all transfer networks. Finally, the tuning and lining-up adjustments of F.M. transmitters and receivers are in some respects unusual, while there is the additional difficulty that it is not easily possible to apply quartz-crystal stabilisation of the final carrier centre frequency.

Experimental F.M. Drive Unit.

It is proposed to describe a flexible F.M. generator which can form the nucleus of a transmitter or signal generator in which provision has been made for wide variation of radio and deviation frequencies. If used in conjunction with properly designed accessories it is capable of producing signals conforming to the present arbitrary standards for high quality transmissions. These require that audio frequencies up to 15,000 c/s. shall be transmitted without marked attenuation and that the maximum final frequency deviation shall be ± 75 kc/s. from the carrier. The question of the requisite band-width at various stages in the transmitter will be considered later. In the present equipment it is more than adequate to satisfy the foregoing requirements.

Schematic Diagram of F.M. Transmitter

The principles of F.M. will not be recapitulated, beyond remarking that the sequence of stages is commonly as shown in Fig. 1.

In this line-up, the only unusual section is the reactance modulator or quadrature tube, so-called because the anode circuit is back-coupled to the grid through a reactive network in such a way as to cause a 90-degree phase difference between grid and anode voltages. If the valve has a pentode characteristic, the magnitude and phase of the anode current are decided almost entirely by the control-grid voltage. Under these circumstances the valve draws either a lagging or a leading current, the instantaneous value of which depends on the grid potential and on the mutual conductance of the valve. This latter, in turn, is a function of the electrode voltages and so may be varied, if desired, by the modulation voltage.

A reactance valve of this description, shunted across the tuned circuit of a valve oscillator, will alter the primary generated frequency and the extent of the deviation is a function of the amplitude of the audio-frequency modulation voltage.

The remainder of the apparatus consists of frequency multiplier and amplifier stages, comparable with those of an A.M. transmitter.

The equipment to be described is designed to operate over the range 5.5 to 6.5 Mc/s. and to be followed by a frequency multiplication of 18 times, bringing the mid-frequency of the carrier to approximately 110 Mc/s. Since the process of carrier frequency multiplication also raises the frequency deviation by the same factor and because the final maximum deviation is required to be ± 75 kc/s., it is evident that the frequency deviation at the primary oscillator stage is required to be 75 ÷ 18 or 4.2 kc/s. only.

Basic F.M. Theory

Before starting practical work on F.M. apparatus, it is essential to be familiar with the criteria of good engineering design. For this purpose, a number of guiding principles are given below. The justification for some of these statements requires a knowledge of higher mathematics, while others are found to be empirically correct. The tentative standards of ± 75 kc/s. final deviation and 15,000 c/s. (highest desired audio frequency) will be considered.

Transmission Band Width

The ratio of maximum carrier deviation frequency to the modulation frequency is known as the deviation ratio. Its value decides the number and amplitude of *significant* sidebands. In amplitude modulation, we have a constant carrier, accompanied by a pair of side-currents for every modulation tone. The amplitude of these currents depends on the percentage modulation. In the case of F.M., the following statements hold:

(a) The carrier is not constant but varies with the depth of modulation, vanishing at certain critical degrees of modulation.

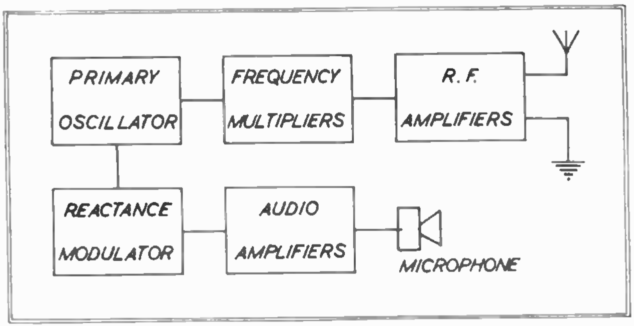


Fig. 1. Schematic diagram of F.M. Transmitter.

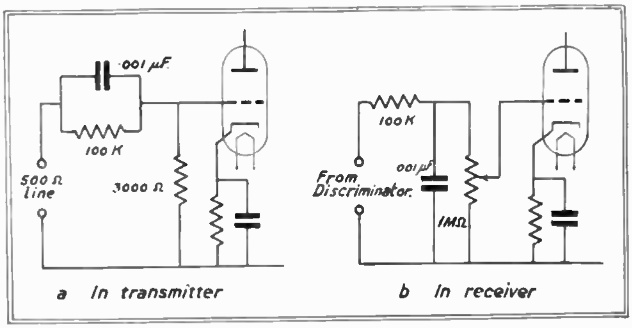


Fig. 2. Typical pre-accentuation circuit.

(b) An infinite number of sidebands exists for each modulation tone. Their amplitudes, absolute and relative, change with the depth of modulation though their frequency spacing remains constant.

(c) Starting from the carrier frequency and counting outwards, odd-numbered side-currents are opposite in polarity while those of even number are of like polarity. It is clearly evident that some such scheme is necessary, for otherwise the vector sum of all the side-currents could not combine with the carrier to maintain that constant amplitude which is actually attained.

(d) For low modulation frequencies (high deviation ratio) a large number of side-currents must be taken into account, because their amplitude is found to fall off slowly as we recede from the carrier.

(e) For high modulation frequencies, the side-current amplitudes fall off quickly and fewer need be taken into account. Because of the wide frequency separation between successive side-currents at high modulation frequencies, it is nevertheless these which determine the requisite band width. In practice, all side currents less in amplitude than one per cent. of the unmodulated carrier can be neglected.

For ± 75 kc/s. deviation with an audio frequency of 15,000 c/s., eight side-current pairs must be taken into account, spreading for a total of 8 × 15 or 120 kc/s. on each side of the carrier. This is the most severe case which is ever encountered in practice, but even here, the band spread on each side of the carrier, *viz*, 120 kc/s., does not greatly exceed the 75 kc/s. frequency deviation.

Before commenting adversely on the large band-width required by F.M., it should be noted that during the transmission of abrupt wave-fronts by A.M., the same wide spectrum is involved; for example, a square wave entails the production of an infinite number of sidebands.

Requirements in Early Stages of Transmitter

These are less stringent as regards absolute band-width but the pass-band required at all stages is the same percentage of the carrier frequency at that stage; in other words, the "Q" value of tuned circuits is required to be the same for all stages of the transmitter. It is essential that all transfer networks should possess a linear phase characteristic over the entire pass band.

The large deviation of ± 75 kc/s. is required in order to secure a high signal to noise ratio. Most noises exhibit amplitude modulation, and their primary effect is removed by the action of saturated amplifiers or limiters. Such interference can, however, cause undesired phase modulation which represents a certain *equivalent* interfering frequency modulation. Its effects are minimised by ensuring that the small unwanted modulation is swamped by the large desired frequency deviation.

Audio Frequency Pre-Accentuation

Most undesired noise lies in the upper audio-frequency range where the amplitude of desired modulation signals is normally low. It is, therefore, of advantage to accentuate these before transmission, immediately following the microphone output. A corresponding de-emphasis is required in the receiver, preferably at the discriminator output. This refinement is not included in the present unit, but can readily be added when required. Typical circuits are shown in **Fig. 2.**

Choice of Experimental Circuit

A good F.M. transmitter is required to handle audio frequencies in the range 30-15,000 c/s., without attenuation or harmonic distortion. This requires that there is a linear relationship between the amplitude of the modulation voltage and the final deviation frequency over the above range of frequencies. High stability of the primary oscillator centre

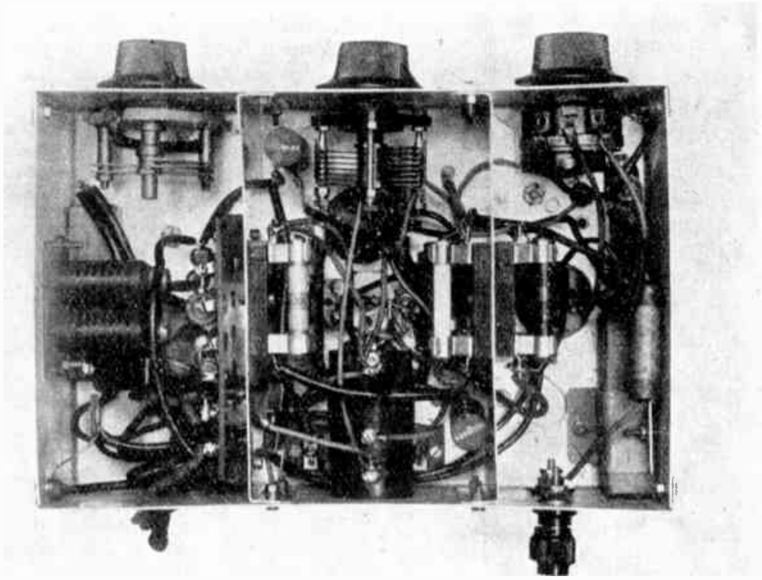


Fig. 5. View of Unit from underneath.

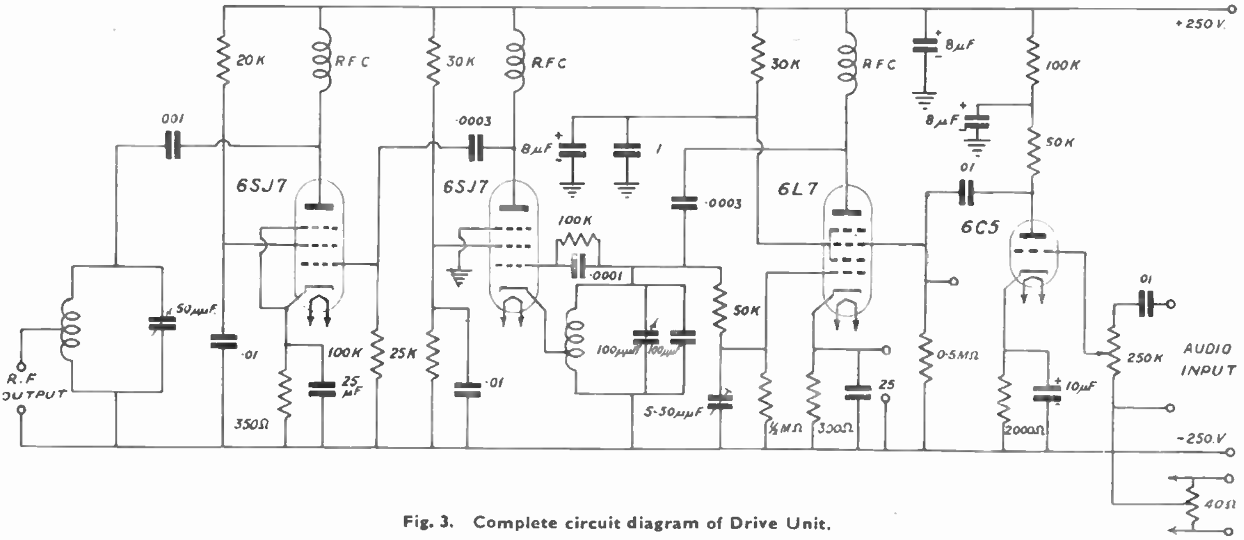


Fig. 3. Complete circuit diagram of Drive Unit.

frequency is also required, together with low hum level and high signal-to-noise ratio. After some consideration the circuit shown in Fig. 3 was selected. No originality is claimed for this as it is a well-tried arrangement, including only the essentials for radiating high-quality transmissions. It will be seen to consist of a resistance-coupled audio amplifier feeding into a reactance tube of the hexode mixer type (actually a 6L7). This is shunted across the tuned circuit of an electron-coupled oscillator, which, in turn, drives a R.F. pentode amplifier having an output tuned circuit tapped down to drive subsequent amplifier and frequency multiplier stages.

The Reactance Modulator

During conditions of full modulation, this stage is required to swing the primary oscillator frequency ± 4.2 kc/s. about the mean carrier value of 6 Mc/s. and this deviation is required at all times to be proportional to the amplitude of the modulating voltage. The 6L7 valve was chosen because the presence of a separate grid for the audio input allowed easy isolation of carrier and modulation voltages. A preferred type would have been the 6SA7, but one was not available when the apparatus was originally constructed. In hexode valves the mutual conductance between the first grid potential and the anode current varies in a linear manner with the voltage applied to the third grid; a similar linear variation of g_m with grid potential is only obtained with single grid valves operating on a square law characteristic. The 6L7 is provided with a feed-back network of series resistance and capacity which causes it to simulate an inductance. Because the fixed element of the primary oscillator tuned circuit is an inductance, constant frequency deviation is secured for all settings of the oscillator tuning condenser (constant audio input being assumed). The feed-back components are selected on the basis that the total series impedance shall not damp excessively the primary tuned circuit, while at the same time the resistance is numerically at least five times the condenser reactance, so that the current drawn is essentially in phase with the applied voltage. The last requirement is satisfied at 6 Mc/s., even if the capacity is merely the tube input capacity. The variable condenser of 5–50μμF. is actually used because it permits a ready control of the reactance valve excitation and so of the primary oscillator deviation frequency. The half-megohm resistance across the grid condenser serves to apply grid-bias. The use of choke-capacity coupling between reactance-tube and oscillator tuned circuit is merely a matter of convenience. At radio frequencies, the oscillator tuned circuit, the reactance tube, feedback network and the R.F. choke in the reactance tube H.T. line are all effectively in parallel. If a Hartley oscillator had been employed, it would have been preferable to use series feed.

Choice of Primary Oscillator Circuit

It is of advantage to choose an oscillator in which one side of the tuned circuit is at earth potential, for then the reactance tube, which necessarily has one side earthed, can act in parallel with the whole tuned circuit. In consequence, two common oscillators are ruled out, the Hartley and the Colpitts. The electron-coupled oscillator (a variation of the Hartley circuit) is very suitable. Its one disadvantage is that the cathode is at a high R.F. potential above earth so that there is some risk that hum frequency modulation may be caused. Two palliatives may be applied. In the first, the cathode-to-earth part of the coil is wound as a bifilar section and the heater fed through this, one side being joined to the cathode. A more drastic method is to supply the heater with D.C. from a rectifier and smoothing unit. These must be considered as refinements, only justified in cases when negligible background noise is essential.

The remainder of the oscillator circuit is of normal design and represents a compromise giving moderately high stability of generated frequency, combined with the ability to accommodate the required frequency deviations. High stability calls for a low ratio of L to C in the tuned circuit, in order that the stray and variable capacities may be swamped by the main tuning capacity. Unfortunately, a low inductance value implies that the reactance tube will only cause small changes of this value; the de-tuning effect is small and it may not be possible to produce the desired deviation frequencies without distortion.

The audio and R.F. amplifier stages follow normal practice and need no special description. The R.F. output from the unit is 25 volts R.M.S., measured across a 10,000 ohm resistance corresponding to the input impedance of the first amplifier stage in the main transmitter.

Requirements for Transmitter Linearity

Wide band F.M. requires that the mutual conductance of the reactance valve varies in a linear manner with the amplitude of the modulation voltage and, additionally, that the primary oscillator frequency deviation is directly proportional to the change of inductance of the quadrature tube. The first requirement is met, in the case of a single-grid valve if the grid-voltage, anode-current characteristic follows a square law. It is also satisfied in the case of a hexode mixer in which modulation voltages are applied to one grid and radio frequency feedback to the other. The injected inductance combines with the main tuning inductance by a reciprocal law of addition and the final frequency is inversely proportional to the square root of the total inductance. It is therefore fortunate that the deviation frequencies required are so small a percentage of the primary oscillator frequency that a linear variation is obtained over sufficient range, no matter what may be the mathematical law connecting them.

Let F = primary oscillator frequency.
C = main tuning capacity.
L_1 = steady state inductance of quadrature tube.
$\pm l$ = variations of quadrature tube inductance during modulation.
L_2 = main tuning inductance.

The equivalent circuit consists of $L_1 \pm l$ in series, connected across the parallel combination of L_2 and C. Considering the case when l is positive, the resonant frequency is given by :—

$$F = \frac{1}{2\pi\sqrt{C}}\sqrt{\frac{L_1+L_2+l}{L_2(L_1+l)}}$$

From this, provided that $L_1 \geqslant L_2$ or l, it can be shown that :—

$$\frac{dF}{dl} = -\frac{1}{4\pi}\sqrt{\frac{L_2}{C}}.\frac{1}{L_1^2}$$

This equation shows clearly the control exercised by the L/C ratio of the main tuned circuit, and also shows that the effect of the quadrature tube inductance enters as an inverse square factor. The theory of the reactance modulator shows that the equivalent inductance is given by $\frac{C_1R}{g_m}$ where C_1 and R are the feedback components and g_m the mutual conductance of the tube. The frequency deviation may thus be written :—

$$\frac{dF}{dl} = -\frac{1}{4\pi}\sqrt{\frac{L_2}{C}.\frac{g_m^2}{C_1^2R^2}}$$

Substituting reasonable values for the various components it will be found that the primary frequency is deviated by about 200 c/s. per microhenry change of quadrature tube inductance. A total change of ± 20 μH is then sufficient to give the necessary frequency swing of 4 kc/s. The total tube inductance may be of the order of 400 μH, under which conditions satisfactory linearity is obtained with the above deviations.

Knowing details of the variation of the mutual conductance of the quadrature tube with modulator grid potential, it is possible to calculate the deviation frequency in kc/s. per volt input from the modulator. A figure likely to be obtained in practice is 10 kc/s. per volt. Only a small driving voltage is necessary for full modulation. The last equation also shows how the setting of the quadrature feedback condenser C_1 controls the deviation frequency.

Constructional Details of Exciter Unit

The entire apparatus is assembled on a chassis 9 in. × 6 in. × 2½ in. A separate power supply unit (250 V 60 mA.) is provided to avoid the risk of hum modulation from a self-contained supply. There are no special difficulties in wiring or construction, standard receiver components are used throughout, and no particular precautions are needed to ensure stability since all stage-gains are kept low. Components are mounted on sub-panels, which, in turn, are bolted to the screening partitions. Sufficient lengths of lead were left for wiring up when the screens were assembled in position. Rigid wiring and construction are required in the primary oscillator compartment. The form of construction which has been adopted is clearly shown in the photographs, Fig. 4 and Fig. 5.

Valves used are not in any way critical, except that straight R.F. pentodes should be used in preference to variable-mu valves. Those employed in the present unit are :—

Audio Amplifier : 6C5.
Reactance Modulator : 6L7.
Primary Oscillator : 6SJ7.
R.F. Amplifier : 6SJ7.

Coil-Winding Data

Primary Oscillator.—28 turns of 20 S.W.G. enamelled copper wire close wound on 1¼ inch diam. former. Cathode tap 6 turns from earthed end. Total tuning capacity 200 $\mu\mu$F. (100 $\mu\mu$F. variable).

R. F. Amplifier.—32 turns of 22 S.W.G. tinned copper wire on 1½ in. diam. former. Auto-transformer output, tapped 10 turns from earthed end. Total tuning capacity 50$\mu\mu$F. (variable). Rough calibration marks have been made, showing the correct tune positions for various frequencies within the primary oscillator range.

Circuit Alignment

The following procedure should be observed. Remove the reactance tube and R.F. amplifier, preferably connecting a dummy load across the power unit to keep the voltage constant. Set the primary oscillator tuning condenser at mid-position and check for oscillation. If possible tune in on an absorption wavemeter or calibrated receiver. Plug in the reactance tube and check that oscillations are still taking place. The frequency will, of course, be raised. Listen to the heterodyne beat note in a receiver and temporarily clip a 250-ohm. resistance across the reactance tube bias resistance. This will change the standing bias and should alter the pitch of the beat note. If these tests are in order, plug in the output amplifier and tune for maximum voltage across the coupling coil using a valve voltmeter or a low-consumption flash-lamp bulb with a pick-up loop held near the tuned circuit.

Three terminals will be seen on the upper surface of the chassis in Fig. 4. These are joined respectively to the reactance tube cathode, modulator grid and to earth. They permit the application of steady or alternating voltages direct to the valve electrodes for testing or calibration purposes.

General Remarks

The apparatus described, feeding into the crystal oscillator stage of a conventional transmitter on 112 Mc/s. will allow all the usual F.M. experiments and measurements to be made. Many refinements can be suggested which may be incorporated at a later stage if desired. Chief among these are carrier frequency stabilisation and audio-frequency pre-accentuation.

Maintenance of Quality in Film-Recorded Sound

II.—Reproduction

By R. HOWARD CRICKS, F.R.P.S.

LAST month I discussed the factors which affect the quality of sound in the recording and duplicating processes. Now let us consider the corresponding factors in the reproduction of films in the kinema.

As previously mentioned, certain of the mechanical and optical factors apply with equal force to the recording and re-recording processes.

I. Mechanical Requirements

In a former article[10] I discussed at some length the essential features of the sound reproducer head. It will be convenient in the present instance to refer chiefly to this equipment.

The principal mechanical requirements of this and of all other sound-on-film equipment is that the film shall be fed at a constant unvarying speed past the scanning point. Failure in this respect, whether in recording, re-recording or reproduction, will cause *wow* or *flutter*, which were previously defined respectively as speed variations heard as pitch variations; and speed variations too rapid to be heard as individual pitch variations, but causing harsh discordant sound due to the production of sum and difference tones.

The nominal speed of 35 mm. sound film is 18 in. per second, and of 16 mm. film, two-fifths of this, or 7.2 in. But the sound head is constructed to run not 18 in. or 7.2 in, per second, but 24 frames per second. The linear speed of the film must therefore depend upon the pitch of the perforations. Since film will normally shrink by about 1/32 in. in the foot during processing, and will thereafter continue to shrink to a maximum of about ⅛ in. in the foot, and since furthermore its degree of shrinkage may vary from day to day, according chiefly to humidity, we are presented with a problem which is in fact responsible for most of the mechanical complications of the modern sound head.

Prevention of Wow

As I mentioned in my earlier article, an obvious cause of wow is variations in the speed of the driving motor. The use of an induction motor and of a heavy flywheel is generally sufficient to overcome this difficulty. In recording and re-recording, it is often necessary to provide an electrically-interlocked drive between various apparatus, *e.g.*, between picture camera and recorder; this is generally effected by means of three-phase synchronous motors, and slight trouble may be experienced due to "hunting."

A particularly interesting device was, however, used by Western Electric in their earlier sets. In this, the induction type driving motor drove also a small 720-cycle alternator; the output from this alternator passed through a tuned circuit, whose impedance naturally varied with slight changes in motor speed. These changes after amplification served to vary an inductance in the motor circuit, so providing very fine speed regulation—claimed to be to within one-fifth of 1 per cent.

Another cause of wow may be bouncing in spring buffers forming part of the driving system. Such faults are, however, fairly easily overcome by suitable damping, and in general it can be stated that wow is not today a major problem.

Prevention of Flutter

The causes of flutter were previously listed as:—

1. Ripple and vibrations imparted to the film by mechanical components.
2. Eccentricity of film driving sprockets, commonly at 6 c/s.
3. Sprocket-tooth ripple due to the difference in pitch between film and sprocket teeth, having a frequency of 96 c/s.
4. Random modulations due to variations in the film itself.

In early sound heads, considerable trouble was taken to eliminate faults (1) and (2). Massive flywheels were employed with quite elaborate mechanical filter systems, ensuring that the sound sprocket ran at an exceedingly constant speed. These precautions were, however, largely nullified by the fact that the sound sprocket was placed immediately below the sound gate, with no means whatever of filtering out sprocket tooth ripple. This ripple was a fruitful source of flutter.

It is improbable that a film will engage accurately with the teeth of a driving sprocket; as each tooth engages or disengages (one or the other, according as to whether the film is short or long in pitch) a slight jerk will be imparted to the film. Thus, if the circular pitch of the sprocket is .186 in. and of the film perforation .184 in., a modulation of .002 in. will be imparted to the film 96 times per second. This will, of course, not be sinusoidal, but may be an almost instantaneous jerk. With the dimensions given, the percentage flutter will be .002 × 100/.184 or roughly 1.1 per cent.

Measurement of Flutter

While the methods adopted to check the sound head for freedom from flutter may be rather outside the scope of this article, brief reference to them will nevertheless be of interest. It has been put forward as an ideal limitation to the permissible degree of flutter that at any moment the position of the film should not vary by more than .0001 in. from its theoretical position.

A method of dynamic measurement described by B.T.-H. employs a stroboscopic light source. A mercury discharge lamp is caused to discharge a current of approximately 1,000 amps. for a period of 10 microseconds, at any desired frequency. The lamp is arranged to fire at the desired frequency, and either the track or the sprocket holes can be examined through a measuring microscope, so providing an actual measurement of the degree of flutter.[11]

RCA have produced a device comprising a Wheatstone bridge circuit, one arm of which consists of an inductance. The output from a constant frequency film is fed, after amplification, through this bridge; any departure from the recorded frequency produces unbalance. By means of a recording meter, both the amplitude and the frequency of the flutter can be plotted.[12]

Elimination of Vibration

Further reference is made in the next section to the need for avoiding vibration in the sound head. The principal sources are of course the intermittent motion, the motor, and the drive gears.

In recent designs, the motor is cushioned on rubber bushes, which also make provision for absorbing the jerk due to the high starting torque; the drive is taken through a rubber coupling. Then the optical system and the scanning drum are mounted

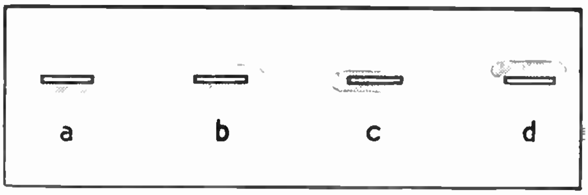


Fig. 7. Exciter Lamp Adjustments in relation to Mechanical Slit : (*a*) Correct, (*b*) incorrectly focused, (*c*) incorrect lateral adjustment, (*d*) lamp too low.

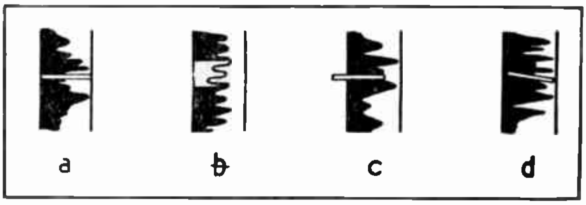


Fig. 8. Adjustments of Optical Unit in relation to Sound Track : (*a*) correct, (*b*) objective out of focus, (*c*) incorrect lateral adjustment of film, (*d*) out of azimuth.

on a bedplate which is again cushioned on rubber supports, insulating it from vibration.[13]

Optical Adjustments

While various makes of sound head differ in regard to the nature of the optical adjustments provided, most designs embody certain corresponding adjustments having similar effects upon reproduction. These adjustments may be classified as follows :

1. *Condenser focus* : Whether the actual condenser is made adjustable, or whether it is the exciter lamp that moves, the effect is identical : if the maximum concentration of light is not obtained on the slit (or in the second type of unit on the film) then obviously light losses will occur, resulting in a lowered volume level of sound. (Fig. 7b).

2. *Vertical adjustment of exciter* : If the exciter is badly out of adjustment vertically, its light may miss the slit altogether, resulting in complete loss of sound. More often, however, the filament image will be merely off-centre with the slit, giving rise to what is known as *vibration pick-up.* The cause of this is that the lamp filament is vibrated by the projector mechanism; the resulting movements of the filament image on the slit cause a corresponding modulation to be imposed upon the sound; thus it is possible for the noise of the projector mechanism to be heard in the speakers. In addition, in the case of the low-wattage lamps, the filament itself, being thin, is capable of resonating at a fairly high frequency, and the combination of this with the 24 c/s. modulation due to the intermittent motion of the projector produces a tinkling sound not unlike bells (*see* Fig. 7d).

3. *Lateral coverage of track* : Two adjustments are necessary to ensure that the track is correctly covered laterally; the exciter lamp must be adjusted laterally (Fig. 7c) and in addition the film path is often adjustable (Fig. 8c).

The effect of incomplete coverage of the track will differ in variable area and variable density tracks. In the latter case, the only effect will be a loss of volume. But in the former case, it is probable that the higher modulations of the track will not be fully covered, resulting in peak chopping, the audible effect of which will naturally be worse with a unilateral track than with bilateral or multilateral. It is also possible for the lateral adjustment to be so badly out that the scanning extends over the perforations, producing a 96 c/s. hum.

4. *Objective focus* : The effect of the objective being out of focus is obvious : in the one type of optical unit the slit is incorrectly focused on the film, and in the other type the film is incorrectly focused on the slit. In either case, the reduced definition results in loss of the finer modulations representing the treble frequencies. (Fig. 8b.)

5. *Azimuth* : This is the term used to indicate the squareness of the scanning slit in relation to the track. The effect is generally a loss of treble, but the effect in a variable area track may be rather complicated, according to the type of track. (Fig. 8d.)

Electrical Requirements

The majority of difficulties of an electrical nature encountered in sound-on-film reproducing equipment differ little from those well known in other types of large-power reproduction. Standards are established in America for the power output of amplifiers commensurate with the size of auditorium, from which the following is an extract :—[14]

Number of Seats	Minimum Power Requirements
Up to 400	10 watts
751—1000	20 ,,
1251—1500	32 ,,
1751—2000	43 ,,
2251—2500	53 ,,
2751—3000	65 ,,
3251—3500	76 ,,
3751—4000	88 ,,

Speech output is defined as follows :—

At its rated output, the amplifier shall not generate more than 2 per cent. total harmonic in the frequency range from 50 to 5,000 c/s. Amplifier output is the average power into the specified resistance load when the amplifier is excited with sinusoidal input signal. The harmonic content is defined in terms of a ratio of currents between the root mean square of all harmonic components and the fundamental.

It will be evident that as the volume range of the recording is increased (and, as previously mentioned, recent developments point to still further increases) so the power of the reproducing amplifier must be correspondingly increased. An extreme case is the RCA installation at the Empire, Leicester Square, where the amplifier is rated at no less than 150 watts output. It is certainly a fact that many kinemas, large and small, have amplifiers of inadequate capacity to cope with modern recordings, with the result that disortion can and does occur.

Frequency Characteristics

An important requirement of the kinema amplifier is that it must be provided with pre-set type tone controls, having a fairly wide range. One type consists of a number of condensers which, according to the manner in which connexions are soldered, are inserted in series or in shunt with the output.

Standards have again been fixed in America for the frequency response of amplifiers.[15] No allowance is made in this standard (shown in Fig. 9) for the varying acoustics of auditoria, which it is recommended should be corrected where this characteristic does not give satisfactory results. Since it is far easier to alter the characteristics of an amplifier than the acoustics of an auditorium, this requirement may be regarded as an ideal unlikely to be often complied with.

A point that must not be overlooked is that the speakers are placed behind the screen, which is perforated to allow the sound to pass. The screen naturally has a certain absorption, rarely constant over the whole frequency range; due allowance for this must therefore be made in the setting of the tone control. In the case of an old screen, the perforations may become clogged, resulting in a severe treble loss.

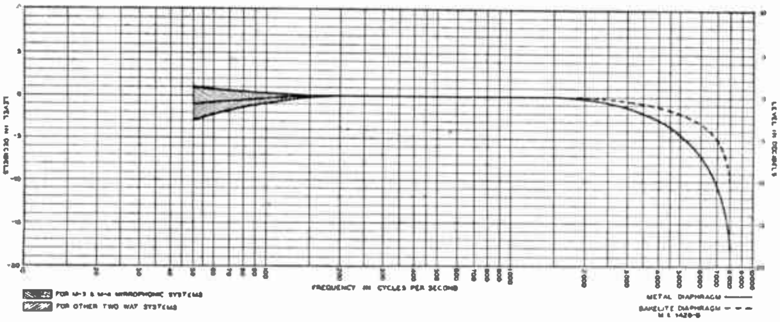


Fig. 9. Standard Electrical Characteristic for Two-way Reproducer Systems.

Research Council, A.M.P.A.S.

Loud Speakers

The type of loud-speaker assembly adopted in modern reproducer equipment consists of one or two bass units of the cone type, mounted on a flared baffle, and handling frequencies up to 300 c/s., and one or two treble units, mounted upon a cellular horn, whose 9, 12, or 15 divisions give high directivity. So directional is this type of assembly that in walking across a gangway outside the seating area, one can detect a noticeable difference in quality of sound.

Specifications laid down for speaker assemblies require that the frequency characteristic shall not vary with angle of listening by more than ±2db from 50 to 8,000 c/s., within the entire angle of distribution within 10 ft. of the mouth of the horn; that the efficiency shall approach 50 per cent.; that the volume range shall be at least 50 db and preferably 60db; and that there shall be an absence of transient distortion.

Accoustic Requirements

It is an accepted fact that any auditorium intended for the reproduction of recorded sound should have a period of reverberation lower than that desirable for direct speech, because of the fact that the recording already contains a degree of reverberation, which is added to that of the auditorium. If the combined period of reverberation is excessive, obviously speech will tend to become unintelligible. The curves of Fig. 10 illustrate the manner in which reverberation in the recording and in the auditorium are added, so that normal exponential decay no longer applies.[16]

Apparent Sound Source

But the kinema has, in addition, a unique requirement in the matter of acoustics. When watching a film, the sound should, of course, appear to emanate from the characters shown on the screen; this effect is known variously as *illusion*, *presence*, or *intimacy*. It is a fact that a kinema in which sound is perfectly intelligible, but is lacking in intimacy, is unpopular with picturegoers (who are, of course, entirely ignorant of the reason for their dislike of that particular theatre, the underlying reason for which is that the personality of the star fails to get across to the audience).

Some interesting researches on the subject were carried out some years ago by Messrs. Moir and Mason, of the B.T.-H. Co. Their equipment consisted of a circuit producing brief pulses of any desired frequency in the theatre speakers, and a microphone which could be carried about the auditorium, and picked up these pulses which, together with the added reverberation, were reproduced on the screen of a cathode-ray tube.[17]

The value of this means of investigation will be evident from the photographed traces of Fig. 11. At a position in a kinema where intelligibility and intimacy were good, a trace shown in (*a*) was recorded. The traces (*b*) and (*c*) show isolated locations with poor sound. The difference between these traces will be evident: in the first, the bulk of the energy is contained in the direct wave, while (*b*) is less good, and (*c*) indicates that the directly-received sound was followed after a considerable period by strong echoes.

The trace (*d*) is of particular interest: in this position intelligibility was good, but intimacy poor; strong echoes follow the initial sound immediately, but, of course, emanating from different points. Both intelligibility and intimacy were poor in the locations in which the traces (*e*) and (*f*) were produced.

(*continued on p. 75.*)

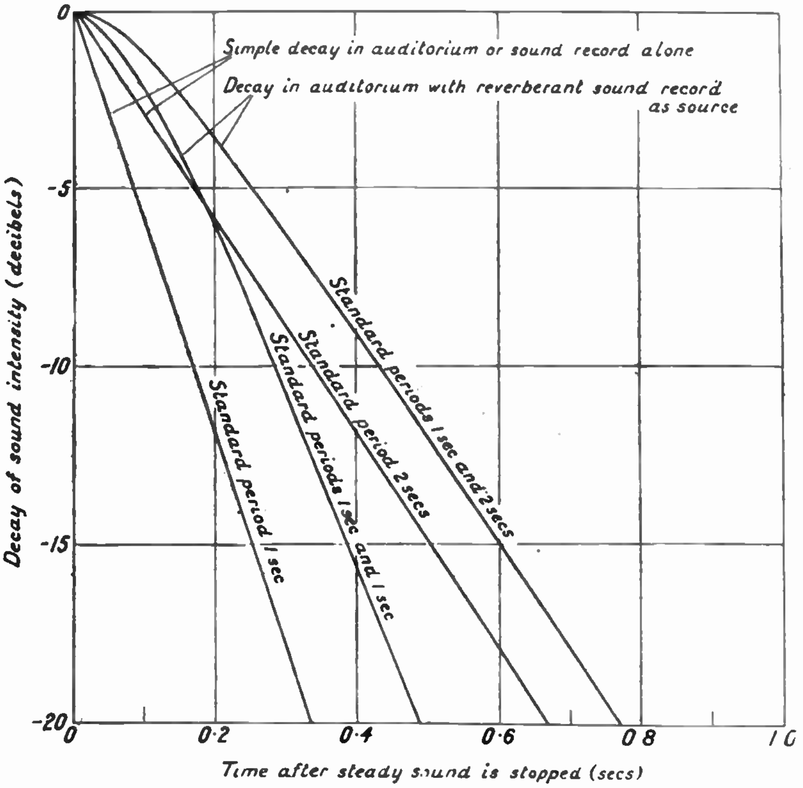


Fig. 10. Simple and Composite Reverberation.

J. Brit. Kine. Soc.

Cathode-Ray Tube Traces

A Series to Illustrate Cathode-Ray Tube Technique

Part I.—Lissajous Figures (continued)

By HILARY MOSS, Ph.D., A.M.I.E.E.

IN the last issue we dealt with the simplest case where each component oscillation consists of a single harmonic term, and in which the ratio between the two component oscillation frequencies is integral. We shall now discuss the case in which the component oscillation frequencies have non-integral ratios.

Case (2). Simple Lissajous Figures with Non-Integral Frequency Ratios

Here the equations (1) degenerate into

$$x = A.\sin m\theta$$

$$\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$y = B.\sin (n\theta + \alpha)$$

in which we shall postulate $n > m$ and n/m reduced to the lowest possible terms by division by any common factor.

To appreciate the essential differences between this system, and that in which the frequency ratios are integral, the first terms of Equations (2) and (3) should be compared. In (3) where the ratio is integral, the spot moves horizontally across the screen and back to its starting point while θ goes from 0 to $2.\pi$. In this same interval, the y term has gone through values corresponding to a variation of θ from α to $2.\pi + \alpha$, and since the sine function has a periodicity of $2.\pi$, and p is integral, it follows that the y displacement is the same at the end of the interval as it was at the beginning. Hence the motion is cyclic, and in one complete cycle the x displacement has moved *once* across the screen and back to its starting point.

In the case where the ratios are non-integral as (2), the x cycle is completed *once* while θ goes from 0 to $2.\pi/m$ and in this interval the y angle has gone through $2.\pi n/m$ radians. Hence since n/m is non-integral, the value of y at the end of the interval does not equal that at the beginning, and the whole cycle is not complete. As before in fact, the whole cycle is completed only when θ has gone through $2.\pi$ radians, and therefore when the x sweep component of the motion has completed the forward and backward screen traverse m times. In the same period of one complete cycle the y sweep will clearly have traversed the screen n times in each direction. From this reasoning we can immediately deduce the rule for determining the frequency ratio.

The frequency ratio is equal to the ratio of the number of intersections between the curve and the lines $y = -B$, $x = +A$ (or between the curve and the lines $y = -B$, $x = -A$).

As in the case where the frequency ratio is integral, there is an exception to this rule for certain values of the phase angle α. This is discussed later (*see* photos Nos. 34, 35 and 36).

Periodicity

The curve is traced once as θ goes through the range 0 to $2.\pi$.

Envelope of the System

Clearly for all values of m, n, and α this is the rectangle defined by $x = \pm A$, $y = \pm B$.

Determination of the Phase Angle*

Setting $\theta = 0$ in (2) immediately defines the point on the curve having coordinates $(0, y_1)$ where $y_1 = B.\sin \alpha$. Hence the phase angle is defined by

$$\alpha = \text{arc sin } y_1/B \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

where y_1 is the intercept of the curve on the " Y " axis. There will be $2m$ numerically distinct solutions for the angle. When $m = 1$, as in the integral ratio case considered in article 1, there are thus two numerically distinct values of phase angle giving rise to the same figure. These can be distinguished when the direction of rotation of the spot is known (as has already been pointed out) but when m is greater than 1 it now follows that knowledge of direction of the spot rotation no longer uniquely defines the phase angle. It merely eliminates half the possible solutions, thus leaving m numerically distinct values which are now quite indistinguishable. This is important in the theory of the complex figures to be discussed in articles 3 and 4.

Determination of the Frequency Ratio

The rule has already been given. It could be more rigorously established by the process of reasoning already given for the case of the integral frequency ratio in the first article.

Miscellaneous Properties

Locus of Intersections

In the case where the frequency ratio is integral we saw that the curve intersects itself for certain values of θ spaced equally on either side of $(2K + 1).\pi/2$ where K is integral. This also occurs in the non-integral ratio case here considered, but there are in addition other intersections for certain values of θ defined by $m.\theta = \beta + 2\pi.K$. For brevity the former class of intersection will be termed " an m intersection," and the latter class " an n intersection."

Locus of " m " Intersections

Setting $m.\theta = \Phi$ in (2) gives:—

$$x = A.\sin \Phi$$

$$y = B.\sin \left(\frac{n}{m}\Phi + \alpha\right)$$

Consider two values of Φ defined by

$$\Phi = (2K_1 + 1).\pi/2 - \lambda$$

$$\ldots\ldots\ldots\ldots\ldots \quad (10)$$

$$\Phi = (2K_1 + 4K_2 + 1).\pi/2 + \lambda$$

where K_1 and K_2 are any integers. The two values of Φ thus defined clearly correspond to equal values of x. The corresponding values of y, from (2) are

$$y = B.\sin\left[\frac{n}{m}\left\{(2K_1+1)\frac{\pi}{2} - \lambda\right\} + \alpha\right]$$

$$\ldots\ldots\ldots\ldots\ldots \quad (11)$$

$$y = B.\sin\left[\frac{n}{m}\left\{(2K_1+4K_2+1)\frac{\pi}{2} + \lambda\right\} + \alpha\right]$$

and are thus equal if

$$\frac{n}{m}\left((2K_1+1)\frac{\pi}{2} - \lambda\right) + \alpha$$

$$= \frac{n}{m}\left\{(2K_1+4K_2+1)\frac{\pi}{2} + \lambda\right\} + \alpha + 2\pi k$$

where k is any integer.

---

[*] See part 1, June, 1944

Lissajous Figures with Non-Integral Frequency Ratios

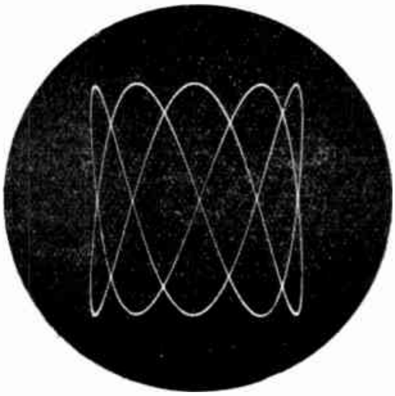
$x = A \sin 2\theta \qquad y = B \sin (3\theta + \alpha)$

19

20

21

$x = A \sin 2\theta \qquad y = B \sin (5\theta + \alpha)$



22

23

24

$x = A \sin 3\theta \qquad y = B \sin (5\theta + \alpha)$

25

26

27

For discussion on absolute values of phase angle refer to text.

Lissajous Figures with Non-Integral Frequency Ratios

$x=A\sin 3\theta$ $y=B\sin(4\theta+\alpha)$

28

29

30

$x=A\sin 4\theta$ $y=B\sin(5\theta+\alpha)$

31

32

33

$x=A\sin 2\theta$ $y=B\sin(3\theta-\alpha)$
$|\alpha|=\frac{1}{4}\pi,\ \frac{3}{4}\pi$, etc.

34

$x=A\sin 3\theta$ $y=B\sin(4\theta+\alpha)$
$|\alpha|=\frac{1}{6}\pi,\ {}^{5}/_{6}\pi,\ \frac{1}{2}\pi$, etc.

35

$x=A\sin 3\theta$ $y=B\sin(5\theta+\alpha)$
$|\alpha|=0,\ \pi,\ \frac{1}{3}\pi,\ \frac{2}{3}\pi$, etc.

36

For discussion on absolute values of phase angle refer to text.

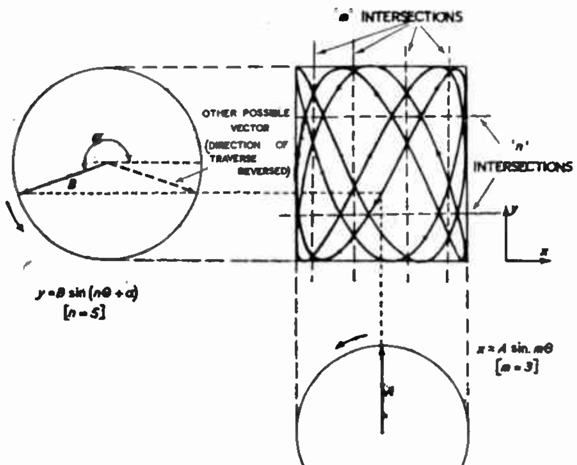


Fig. 3.
The formation of Lissajous figures in the case of non-integral frequency ratios

This condition may be written,

$$2\frac{n}{m}\lambda = -4\frac{n}{m}K_2\frac{\pi}{2} - 2\pi k$$

$$i.e.,\ \lambda = -K_2.\pi - \pi.k.\frac{m}{n} \quad \ldots\ldots\ldots\ldots \quad (12)$$

Substituting back in (10) gives for θ the values

$$\theta = (2K+1).\pi/2m \pm k.\pi/n \quad \ldots\ldots\ldots\ldots \quad (13)$$

where K is any integer.

Ignoring the solutions $k=0$, $k=n$, and $k=2.n$ (which merely represent the ends of the " x " trace), there are $2m\ (n-1)$ distinct solutions for θ in (13), in the complete cycle from $\theta=0$ to $\theta=2.\pi$. At these values the curve intersects itself. Note that θ is independent of the phase angle α, so that the locus of the " m " intersections is parallel to the " Y " axis. This is shown in Fig. 3.

Locus of " n " Intersections

Consider two values of Φ which differ by $2.\pi.K$. Suppose that the two values of Φ are

$$\Phi = \beta$$
$$\Phi = \beta + 2.\pi.K$$

then the corresponding values of y are

$$y = B.\sin\left\{\frac{n}{m}.\beta + \alpha\right\}$$
$$\ldots\ldots\ldots\ldots\ldots \quad (14)$$
$$y = B.\sin\left\{\frac{n}{m}.(\beta + 2\pi K) + \alpha\right\}$$

If n/m is integral these two values of y are obviously equal for all values of α. We have in fact traced the complete figure. Another possible solution occurs when the mean value of the two angles in (14) is equal to an odd multiple of $\pi/2$, *i.e.*, when

$$\frac{n}{m}.\beta + \alpha = (2K+1)\frac{\pi}{2} - \pi K\frac{n}{m}$$

i.e., when

$$\beta = (2K+1)\frac{m}{n}.\frac{\pi}{2} - K.\pi - \alpha.\frac{m}{n} \quad \ldots \quad (15)$$

From (15) we note that the position of the " n " intersection in the direction of the " X " axis, varies with the phase angle α. Substituting the value of β from (15) in (14), however, immediately shows that the value of y at which the intersection occurs is independent of α. Hence the locus of the " n " intersections is parallel to the " X " axis. This is shown in Fig. 3.

Special Case

As in the integral ratio case, an important special case of the figure arises for certain values of the phase angle α. The y deflections become equal over the whole of the forward and backward strokes, about some odd multiple of $\pi/2$. Setting two values of Φ defined therefore by

$$\Phi = (2K+1).\pi/2 - \lambda$$
$$\Phi = (2K+1).\pi/2 + \lambda$$

—where $m.\theta = \Phi$

in equations (2), and writing $\alpha = \gamma.\pi/2$, yields for y the two values

$$y = \mathrm{B}.\sin\left\{\frac{n}{m}\left(2K+1+\gamma\frac{m}{n}\right)\frac{\pi}{2} - \frac{n}{m}\lambda\right\}$$
$$\ldots\ldots\ldots\ldots \quad (16)$$
$$y = \mathrm{B}.\sin\left\{\frac{n}{m}\left(2K+1+\gamma\frac{m}{n}\right)\frac{\pi}{2} + \frac{n}{m}\lambda\right\}$$

whence it is apparent that for *all* values of λ, the two values of y are equal if

$$\frac{n}{m}\left(2K+1+\gamma\frac{m}{n}\right) \text{ is } \mathit{odd} \quad (17)$$

(17) then, defines the phase angles which give rise to this special condition. We have already noted that when n/m is non-integral, there are in general 2.m distinct numerical values of the phase angle α depending on the starting point from which the curve is traced. The relation between the appropriate value of K in (17) and the phase angle is best determined by inspection of a sketch of the curve.

When this special condition is satisfied, the figure degenerates into a line which loops back on itself. This is shown in photographs Nos. 34, 35 and 36. *In this case the rule for frequency comparison breaks down*, as it did in the analogous case when the frequency ratio was integral.

All the photographs are untouched reproductions of the originals. For a brief description of the technique used, refer to the first article in the June issue.

Use of Equations in Parametric Form

It will be observed that the properties of the Lissajous figures have been developed from the parametric form of the relevant equations, x and y being separately defined in terms of a third variable θ. This is by far the easiest method. It is true that it is quite easy to eliminate θ between the two equations (3), when $p = 1$, and so obtain the Cartesian equation of an ellipse, but this process of elimination becomes increasingly difficult as p increases in value. Furthermore, the resulting equations connecting x and y become so complicated that detailed examination is necessary to determine even their most elementary properties. For example, the θ eliminant of the equations

$$x = A.\sin\theta$$
$$y = B.\sin(3.\theta + \alpha)$$

is

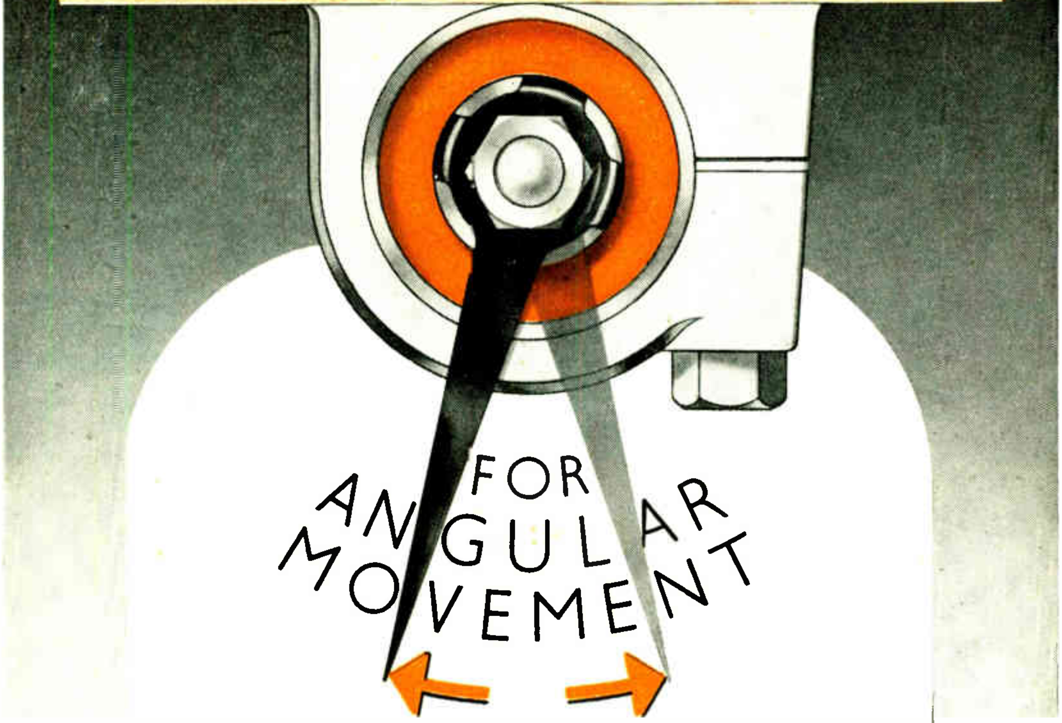
$$y = \frac{B}{A^3}.\left\{x(3.A^2 - 4.x^2)\cos\alpha + (A^2 - 4.x^2)\sqrt{(A^2 - x^2)}\sin\alpha\right\}$$

which is not very helpful. It is quite troublesome, for instance, to show that this Cartesian equation is bounded by the rectangle

$$x = \pm A \quad y = \pm B,$$

a fact which is immediately obvious from the parametric form of the equations. When the ratio between the component oscillation frequencies is non-integral the problem of eliminating θ becomes really serious, and the resulting equations are quite unmanageable.

METALASTIK BUSHES



Metalastik Bushes have an annulus of natural or synthetic rubber which—due to the Metalastik rubber-to-metal weld—is to all intents and purposes integral with the metal, yet permits a valuable extent of angular movement in one plane, without slip, and a limited degree in another.

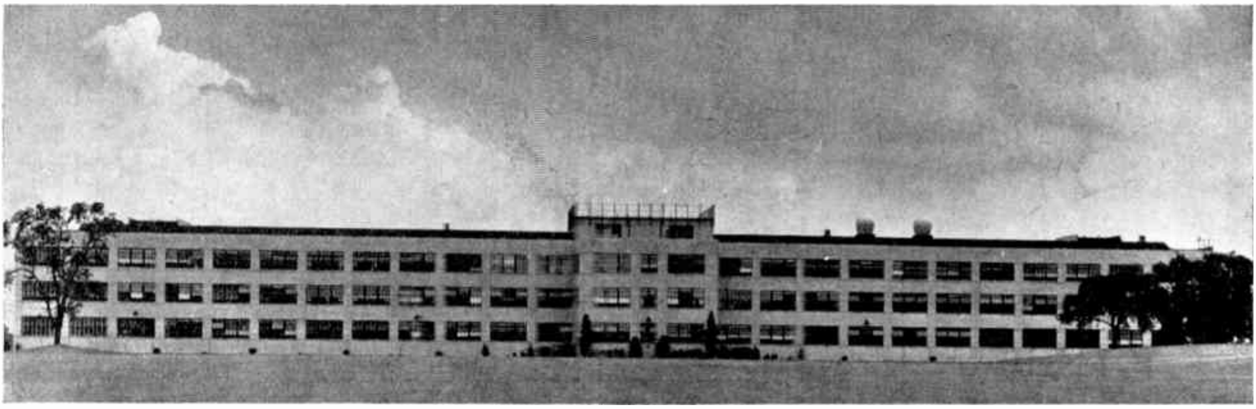
In addition to the obvious load capacity of the rubber in compression, the rubber-to-metal weld also transmits tension and shear stresses, so that the permissible loading is considerably higher than that of the rubber-in-compression type. Furthermore, we have the choice of synthetic or natural rubber over a wide range of moduli, and the characteristics of the bush can be controlled to give any reasonable result.

Used for pivotal and oscillatory movements: as buffers to resist axial shocks: for radial cushioning, etc.: made of steel, light alloys, etc. Need no lubrication, adjustment or attention.

Metalastik Ltd., Leicester.

The Radio Corporation of America

Most readers of this country are aware that the initials " R.C.A." stand for one of the largest radio manufacturing concerns in the world, but few know the details of its organisation and activities. In a recently published brochure "*R.C.A. — What It Is and What It Does,*" an account is given of the origin and growth of the Corporation which is of particular interest at the present time.



The R.C.A. Laboratories at Princetown, New Jersey.

PRIOR to and during the first world war, the United States depended largely on British cables and foreign-owned wireless stations for communication with many important parts of the world.

The war revealed to Americans that radio offered a new and competitive system; a startling opportunity for the dissemination of intelligence.

To develop this system, R.C.A. was formed by the General Electric Company,* as a result of suggestions by officials of the U.S. Navy.

Arrangements were made to acquire the assets of the Marconi W.T. Co. of America, and a charter was granted to the R.C.A. under the corporation laws of the State of Delaware on October 17, 1919.

The business and property of the Marconi Co. were acquired by the R.C.A. on November 21, 1919, and on December 1 the R.C.A. began business as an all-American organisation.

A clause in the charter provides that at least 80% of the stock outstanding shall be held by citizens of the United States, and actually less than 6% of the stock is held by foreign stockholders.

Capital

The working capital (excess of current assets over current liabilities) at December 31, 1942, amounted to \$104,813,081.00. The Corporation's net worth on the same date was \$81,357,902. The total assets were \$212,082,759, divided as follows:—

Current Assets	\$156,555,124
Investments, etc.	\$ 11,187,033
Plant and Equipment	\$ 32,390,284
Patents and Goodwill	\$ 8,941,659
Other Assets	\$ 3,008,659

R.C.A. Building, Radio City, New York, which houses the N.B.C. and W.N.B.T. Television Station.

The total liabilities at the same time were \$130,724,857.

Over the past ten years, the record of earnings has shown a steady increase with the exception of a slight drop in 1938, and in 1943 the gross income was \$197,024,056 as against \$62,333,496 in 1933.

On this income no less than \$19,074,850 was paid in Federal Taxes.

Personnel

At the opening of 1943, R.C.A. and associated companies had a total of 35,587 employees, of whom 54% were men and 46% women.

It is the company's policy to pay as high wages under as favourable hours and working conditions as in similar classes of work as those prevailing in the areas in which the plants are located.

The most modern working conditions are maintained together with a wide variety of educational, training, social and recreational facilities.

The Corporation runs its own training centre—the R.C.A. Institutes, which is claimed to be the oldest radio training school of its kind in America. Classes are held for fifty weeks in the year, both day and evening, and day courses vary from six months to two years, depending on subjects.

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* Of America

Broadcasting

In 1916, David Sarnoff, now the R.C.A. President, proposed in a memorandum to the General Manager a "'radio music box" which would make radio a household utility in the same sense as a piano or phonograph. He wrote: "should this plan materialise, it would seem reasonable to expect sales of 1,000,000 radio music boxes over a period of three years."

The war delayed developments, but in November, 1920, the Westinghouse station KDKA broadcast the Harding-Cox election returns and the "radio music box" became front-page news.

In September, 1926, the National Broadcasting Co. was organised as a service of the R.C.A., and WJZ (New York City) was acquired in 1923, followed by WEAF in 1926.

WEAF became the key station of the "Red Network," and WJZ the key station of the "Blue" network. These were operated by the N.B.C. for 15 years, but the Blue Network was organised as a separate company in 1942, becoming a wholly-owned subsidiary of R.C.A.

The main offices and studios are in R.C.A. Building, N.Y. City, with branch offices in Chicago, Hollywood and Washington.

The six stations now owned by the N.B.C. are WEAF (New York), WRC (Washington), WTAM (Cleveland), WMAQ (Chicago), KOA (Denver), KPO (San Francisco). The Blue Network owns WJZ (New York), WENR (Chicago), and KGO (San Francisco).

Approximately, 42% of the programme hours are sponsored, the remaining 58% being presented by the companies themselves.

On March 12, 1925, WJZ and WRC re-broadcast the chimes of Big Ben for the first time in America.

The pioneer television station is WNBT (New York) with studios in R.C.A. Building and the transmitting aerial on top of the Empire State Building. Commercial operation of television was authorised on July 1, 1941.

Manufacturing

When the R.C.A. was first formed its primary activity was in trans-oceanic communications, but when radio broadcasting began arrangements were made whereby the G.E. and Westinghouse Companies would manufacture radio products and the R.C.A. would sell them.

In 1929 it became necessary for the Corporation to combine manufacture with sales under a common management. It also became evident that the radio and phonograph were complementary in home entertainment. In order to provide manufacturing facilities the R.C.A. accordingly acquired the Victor Talking Machine Co. and also obtained manufacturing rights from the G.E. and Westinghouse companies. In the latter part of 1934 the various units were brought together under the R.C.A. Manufacturing Co., a subsidiary of R.C.A.

The Manufacturing Co. was consolidated with R.C.A. finally in 1942, becoming the R.C.A.-Victor Company.

This company has now six plants, two in New Jersey, two in Indiana, one in Pennsylvania, and one in California.

Other Activities

R.C.A. Communications Inc. was created as a separate company on January 3, 1929, and is engaged primarily in international message (radiogram) communication as a public service. The central office is at 66 Broad Street, N.Y.

RCAC also operates direct radio-photo service between New York and London, Moscow, Cairo, Buenos Aires, and Stockholm.

Radiomarine is a service of the R.C.A. in the marine radio field, producing and installing both radio-telephone and telegraph equipment for ships. It was formed in December, 1927, as a wholly-owned subsidiary of R.C.A. devoted to marine activities. Its headquarters are at 75 Varick Street, N.Y. City, which also houses the R.C.A. Institutes.

The Department of Information of the R.C.A. is at 30 Rockefeller Plaza, New York.

The new stage, band-stand and seating arrangement of N.B.C.'s studio 8-H, largest in the world, at Radio City. *(N.B.C. Photo).*

Valve Hum

By

C. E. COOPER*

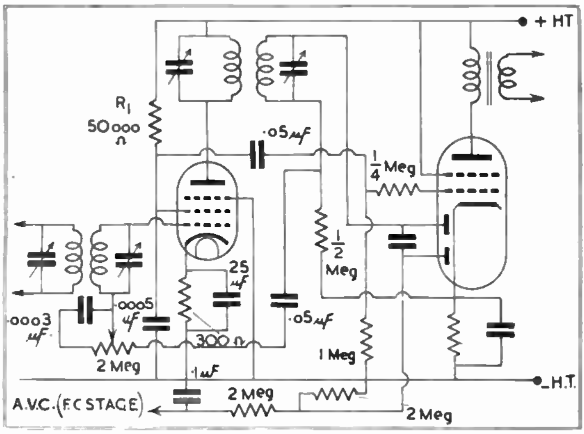

Fig. 1. Reflex circuit. R_1 is the screen load which enables the I.F. amplifier to provide additional A.F. amplification.

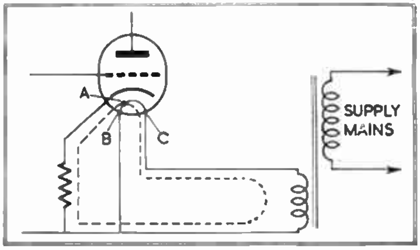

Fig. 2. I_{kh} path for an A.C. valve. If leakage occurs mainly at 'A,' the leakage current is driven by the fraction AB/BC of the heater voltage.

THE limiting factors governing the reduction of hum level in amplifying or receiving equipment are often effects occurring within the valves. This article deals with these effects, to the exclusion of hum produced by, for example, inadequate H.T. smoothing, or stray pick-up by wiring or components other than valves.

Valve hum is classified according to :—

(1) The electrode which modulates the electron stream at hum frequency, *e.g.*, grid hum, and

(2) The method by which the hum voltage reaches that electrode from either the heater voltage or the A.C. heater-to-cathode or heater-to-chassis voltage, *e.g.*, stray capacity hum.

Any electrode whose potential controls the anode current can, of course, produce hum modulation of the electron stream, but those electrodes which apply a hum voltage in series with the grid to cathode circuit of their own, or some previous valve, will have the most serious effect. Thus, only in very low gain stages will such hum as may be picked up by the anode or screen contribute appreciably to the total hum.

The main hum-collecting electrodes are therefore the grid and cathode, in the case of a triode, tetrode or pentode, while in the case of a diode valve, or of an amplifying valve which includes diodes, one or more of the diode anodes can contribute appreciably to the total hum. In almost all receiver circuits using as detector one diode of a D.D.T. or D.D.Pen. type valve, this diode anode will have an A.F. coupling to the grid of the same valve, so that hum picked up by the diode will be transferred to the control grid and so amplified.

A given amount of diode hum will be most serious, however, in those circuits where the diode anode is coupled to the grid of a previous valve, since hum thus transferred will have the additional amplification of this previous valve. This occurs, for example, where the diode forms part of the output valve in a receiver using an A.F. voltage amplifier before the output stage. Such an arrangement is shown in the reflex circuit of Fig. 1, where the I.F. signal is detected in a double diode output pentode and then returned to the I.F. stage for A.F. amplification before finally reaching the grid of the pentode section of the output valve.

Hum may reach an electrode by (1) leakage ; (2) undesired emission ; (3) stray capacity or (4) electromagnetic induction, the nature of the path determining to some extent the character of the hum which may include not only 50 c/s. but also harmonics of this frequency up to or beyond 500 c/s. The amount of any particular harmonic is not always in even approximate inverse proportion to the order of the harmonic. For example, with the distorted heater waveform mentioned later, there will be little or no second or third harmonic, but considerable harmonics of the order of 8 to 10.

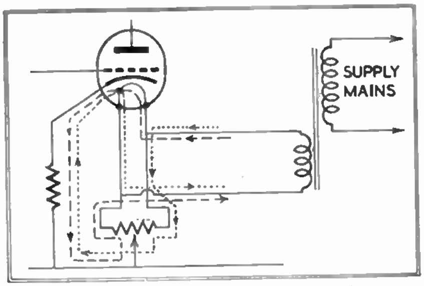

Fig. 3. Humdinger connexions. The two leakage paths are in opposite directions and therefore cancel.

Where the higher frequency harmonics predominate, the unwanted sounds have the character of a buzz rather than a hum, which often provides a clue to the source of the sound. Where the hum is predominantly 100 c/s., its cause is most likely to be due to inadequate smoothing of a full-wave rectifier, since this frequency, though present in valve hum, is rarely predominant.

Leakage most commonly occurs between heater and cathode, largely as a result of the high temperature to which the heater insulating coating is subjected. The amount of this leakage is almost always considerably higher with the heater hot than with it cold.

The circuit of Fig. (2) shows the path of the heater-cathode leakage current (I_{kh}) for an A.C. valve, the current being driven by that part of the heater voltage between the chassis and the point on the heater where the leakage occurs. Where such leakage occurs from the centre of the heater, or where each half of the heater leaks by an equal amount, then centre-tapping the heater winding to chassis will provide two equal and antiphase leakage currents which cancel each other. This cancellation will only be complete where the I_{kh} is a pure leakage, *i.e.*, where there is no emission of electrons from the heater.

The cancellation of leakage I_{kh} can be secured when the leakages from each half of the heater are unequal by the use of a " humdinger " to provide an adjustable tap on the heater winding. This is a potentiometer connected as shown in Fig. (3), its value being negligibly low compared

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* Radio Manufacturers Service.

to the heater-cathode leakage path, but not sufficiently low to add appreciably to the total heater current. Values of 30 to 50 ohms are common, the adjustment being made by aural test.

Due either to local overheating, or to a stray spot of emissive material, as mentioned later, there is often a considerably greater current from one extreme end of the heater than from any other part. I_{kh} will then be a minimum when this end of the heater is connected to chassis, this arrangement often tending to minimise hum due to other causes. Thus it will be seen that the direction of heater connexions is of more importance than is usually considered.

In the case of a universal receiver, where the valve heaters are connected in series, the A.C. potential between heater and chassis may be considerably higher than the heater voltage; often in excess of 100 volts. The sequence of valves in the heater chain should be so chosen that the valves most susceptible to hum come first in the chain, and so have the minimum heater-chassis voltage.

With a valve line-up consisting of (1) frequency-changer, (2) I.F. amplifier and (3) double diode-pentode output, the sequence should be 1—3—2 (*see* Fig. 4a), the frequency-changer being susceptible to modulation hum and so coming first. Where valve No. (3) is a double-diode-triode, followed by a pentode output valve (4), the sequence is likely to be 3—1—2—4 (*see* Fig. 4b), since the additional audio-frequency amplification of the triode section of valve No. 3 will make this valve most susceptible to hum. With some frequency-changers, however, modulation hum is sufficiently serious to merit this valve retaining the first position in the heater chain. The output pentode is now placed after the I.F. amplifier, since hum produced by the pentode is almost certain to be swamped by that of the double-diode-triode.

In all cases the rectifier will come last in the heater chain. It is desirable to avoid including pilot lamps in the beginning of the chain, since the additional 6 volts or so heater-chassis voltage of the first valve may produce an appreciable increase of hum.

Any heater-cathode current which does occur will, in flowing through the cathode bias resistor (if fitted), develop a hum voltage across that resistor. Such voltage is in series with the grid-cathode circuit, and so is amplified. No such hum voltage can occur where the resistor is shunted by a condenser of sufficient capacity to provide a virtual short-circuit at 50 c/s., up to, or beyond 100 microfarads being often necessary for this purpose.

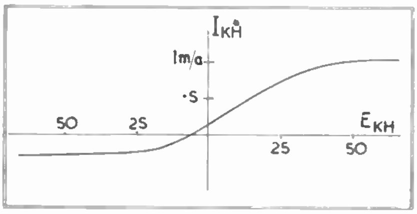


Fig. 5. I_{kh}/E_{kh} curve.

A study of the I_{kh}/E_{kh} curve of Fig. 5, which is typical in shape of most valves, reveals an alternative method of avoiding cathode hum. It will be seen that a saturation effect occurs, where above a certain value of E_{kh}, no further increase of I_{kh} occurs.

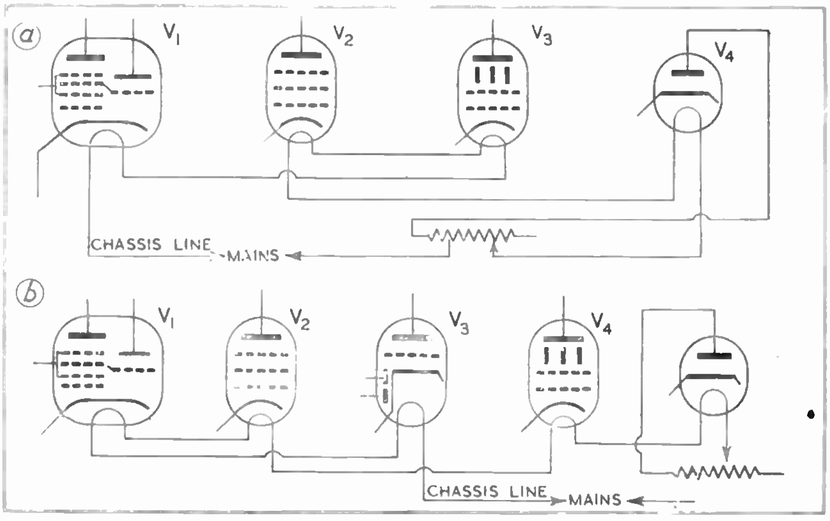
If a D.C. voltage not less than the peak value of E_{kh} plus the saturation voltage is applied between heater and cathode, the I_{kh} will be heavy, but will not fluctuate at mains frequency, and so will produce no hum. Unfortunately, some 50 to 90 volts are often necessary to produce this saturation, but the principle has been found useful at times since it also provides the only method of avoiding electrical and mechanical noise produced by the heater rattling inside the cathode sleeve. This latter valve fault is difficult to avoid during manufacture, since the heater must fit loosely to allow for expansion.

The asymmetry of the I_{kh} curve is due to emission from heater to cathode when the cathode is positive to the heater. This emission is usually due either to impurities in the heater insulating coating, or to a stray spot of emissive material becoming accidentally deposited on the heater. Where the heater extends slightly beyond the end of the cathode sleeve, such a spot may be deposited on the protruding end and produce direct emission to either grid or diode.

Emission from the heater will only occur during the whole, or a part, of one half-cycle of heater voltage, and the hum so produced is therefore rich in harmonics. The amount of hum produced by a given amount of emission to grid or diode will depend on the resistance between these electrodes and the chassis.

Heater emission is almost always extremely critical to heater temperature, an increase of V_f from 4.0 to 4.5 (*i.e.*, 12½%) often causing emission hum to rise by several hundred per cent. This fact is made use of when analysing valve hum with a view to making the design changes necessary to minimise hum.

It is worth remembering that most modern valves will have ample cathode emission with their heaters under-run by 12½%, since such under-running will often eliminate emission hum. The three oscillograms of Fig. 6 show the hum waveform across the anode load of a type 50L6 valve, operated with heater current 10% high, normal, and 10% low respectively. In each case, the valve is operated from a D.C. source of H.T. and has zero cathode impedance, so that the hum is solely that due to heater-grid capacity, leakage or emission. The hum is almost entirely due to emission at the high heater current condition,



Figs. 4a and 4b. Heater sequence for universal receivers.

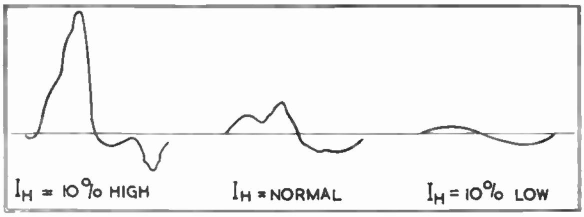


Fig. 6. Hum voltage across anode load of a 50L6 valve, showing the effect of under and over-running the heater.

and is enormously reduced with the heater under-run, the residual hum being mainly due to heater-grid capacity.

Heater-cathode stray capacity may be relied upon to be too small to produce appreciable hum voltage across the cathode bias resistor, which in any event is normally shunted by the cathode bypass condenser. The stray capacity from the heater and its connexions inside the valve to the control grid will, however, be sufficient to produce hum across the high resistance usually found in the grid circuit. In many of the American A.C./D.C. midget receivers, heater-grid capacity and emission would have caused prohibitive hum had the detector grid circuit included appreciable impedance to 50 c/s. This necessitated the use of an anode bend detector in preference to the more sensitive leaky-grid.

Where the valve includes diodes, the heater-diode capacity will cause a hum voltage to appear across the high resistance diode load (R_1 in Fig. 7). This hum will be coupled, via C_1, to the grid of the triode section. There will usually be a higher capacity between heater and one diode than between heater and the other diode. The latter should be the one used for detection, it being usually the one connected to a pin which is separated from the heater pins by an earthed or earthy pin. Fig. 8 gives examples.

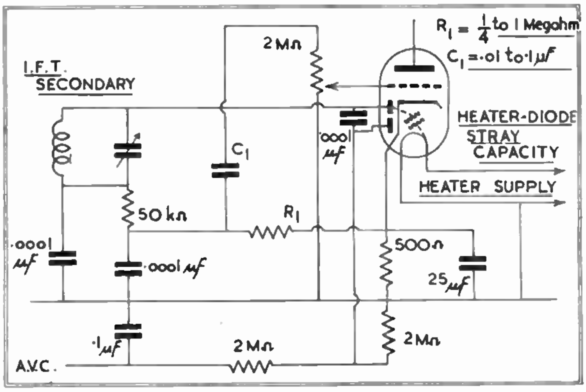


Fig. 7. Diode detector circuit.

Capacity hum can only be combated by the valve designer, by such methods as top cap grid connexions, pin layout and by careful internal screening.

It is often unwittingly increased, however, by distortion of the waveform of heater or heater-chassis voltage. Such distortion occurs when the short, heavy pulses of current drawn by the rectifier pass through an impedance common to the heater circuit. In an A.C. receiver, such common impedance will be the mains transformer, and in a universal receiver it will be the suppression chokes often fitted in series with the mains supply. A particularly bad example is the operation of a 110-volt receiver on 230 volts via a dropping resistance.

In either case, the waveform of heater voltage can be distorted somewhat as shown in Fig. 9, and contains fairly high frequency harmonics. Not only do these harmonics find the heater-grid capacity a lower reactance path than would 50 c/s., but the higher-pitched hum they produce is more annoying to the ear.

The cure is either to restrict the magnitude of the common impedance, or to limit the amplitude of the rectifier pulses by the inclusion of a small resistance in series with the rectifier anode circuit. Alternatively, the rectifier pulses may be reduced in amplitude by using a smaller reservoir condenser, offsetting the effect upon H.T. ripple by either a larger smoothing condenser or a larger choke.

The waveform shown in Fig. 9 is an oscillogram of the heater voltage of a well-known make of receiver. Another make, at a similar price, showed no visible distortion of the heater waveform, presumably due to a less cheap and nasty mains transformer.

The remaining source of valve hum is due to the alternating magnetic field produced by the current through the heater. This field can influence the electron stream directly to produce hum, which, however, is usually quite slight. There is nothing the user can do to minimise this form of hum, though it may almost be eliminated by the valve designer forming the heater into a re-entrant spiral, which produces negligible magnetic field.

The circuit of Fig. 10 shows the arrangement used for the analysis of valve hum, set up for testing a universal-type double-diode-triode.

R_1 sets the heater current, measured by the meter " A," and R_2 sets the

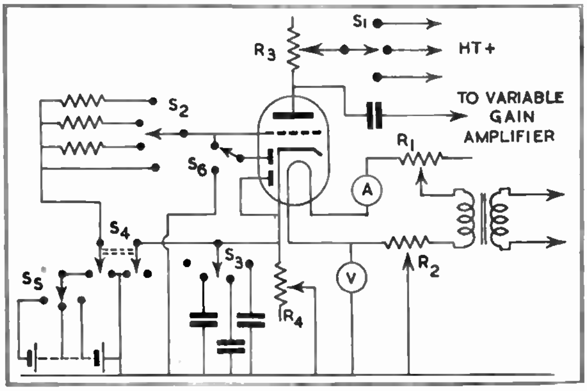
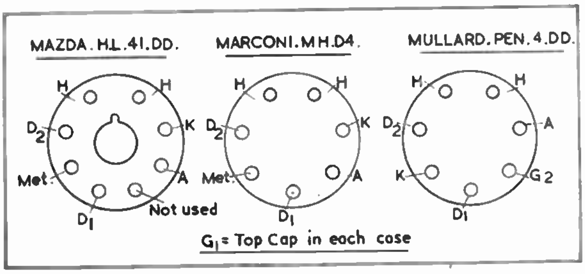


Fig. 10. Circuit used for valve hum analysis.

Fig. 8. Valve base connexions. In each case, the diode marked D1 should be the one used for detection. Unused pins should be earthed.



heater to earth A.C. voltage, measured by meter "V." R_3 and R_4 are calibrated and set to suitable values for anode load and automatic bias resistance respectively for the particular valve type being tested. The switch S_1 selects the appropriate H.T. voltage.

S_2 provides a choice of values for the grid leak, with a position where the grid is short-circuited to the earth line. In this position, only magnetic hum and cathode hum are possible. The cathode bias resistance may be by-passed by a choice of values of condenser, or may be left unbypassed, determined by S_3. The choice will depend upon the circuit in which the valve is expected to be used.

S_4 short-circuits the cathode bias resistance and simultaneously inserts a battery bias in the grid to cathode circuit. S_5 determines the value of this bias, and is set to retain the same biasing conditions as were given by the cathode resistance.

With battery bias, and zero resistance in the grid circuit, the only possible hum is that due to electromagnetic induction. This is usually small enough to be ignored during tests for the other forms of hum.

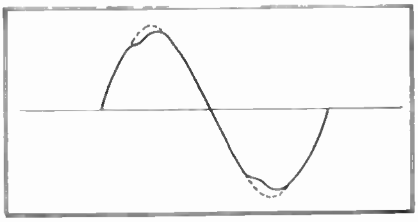


Fig. 9. Distorted heater wave form produced by a poorly designed mains transformer. Dotted line shows an undistorted sine wave.

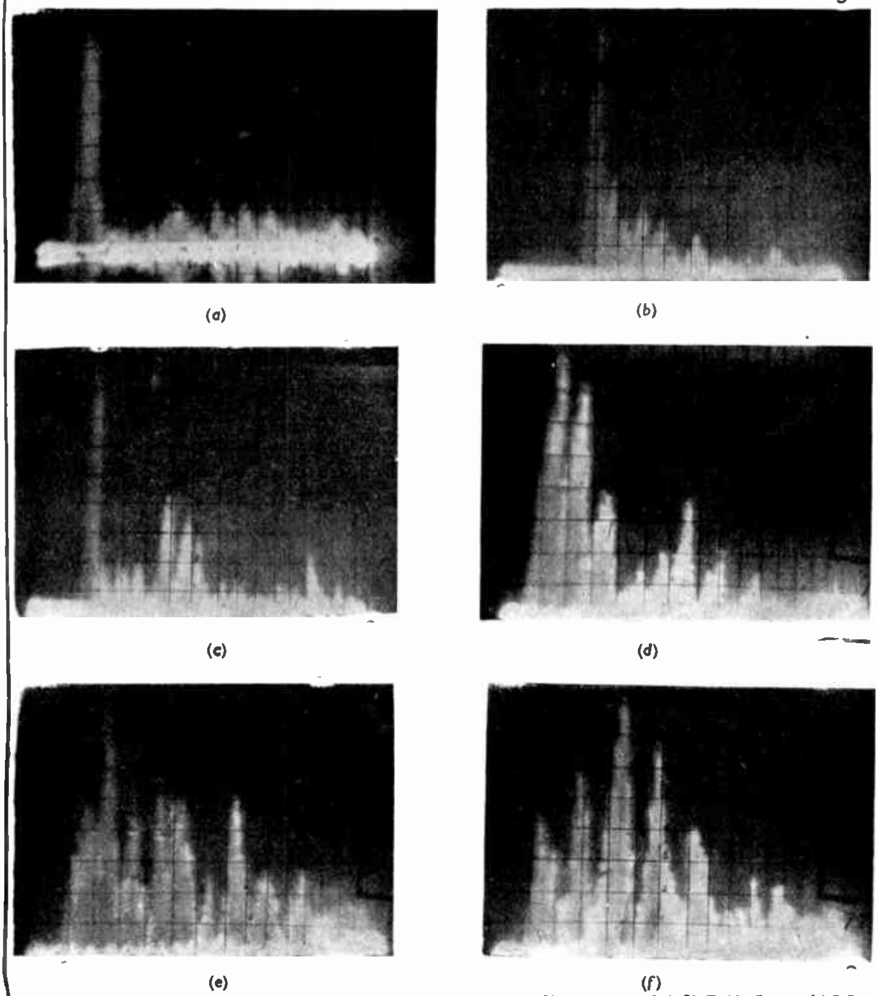
With a suitable value of grid leak switched into circuit, and with S_6 connecting the diode to earth, grid hum will be added to the magnetic hum. If S_6 is then moved to connect the diode to the grid, the additional hum will be due to the diode.

The hum output of the valve under test is taken to an amplifier whose gain is set to represent that which is expected to follow the valve in normal use. Aural measurement of the hum is usual, but sometimes the frequency response of the amplifier is loaded to have "human ear" characteristics, when measurement will be by meter. Incidentally, a given amount of each of the individual types of hum will by no means necessarily add up to a larger total. Considerable cancellation may occur, so that the total hum may be lower than that due to any one electrode.

Maintenance of Quality in Film-Recorded Sound

(Continued from p. 64.)

Fig. 11. Oscillograms of Kinema Acoustics.



(a) (b)

(c) (d)

(e) (f)

[*By courtesy of the B.T.-H. Co., and I.E.E.*

It must be appreciated that many kinemas were built before the sound-film was more than a nine-days' wonder, while others, built in the early days of sound, show little indication of any acoustic knowledge on the part of the architect. Increasing interest is apparently being taken by architects in the acoustical requirements of buildings, but at the present time, it seems doubtful whether acoustics can be regarded as exact science.

Summary

In these two articles, the following factors contributing to the quality of sound in the kinema have been examined:—

Recording and Processing

Studio acoustics.
Microphones.
Studio amplifiers.
Recorders.
Editing, re-recording, duping.
Photographic aspects.

Reproduction

Mechanical and optical requirements of sound head.
Kinema amplifiers.
Loud-speakers.
Kinema acoustics.

Each of these headings represents a link in the chain from the artist to the picturegoer; failure in any one link will mar the quality of entertainment offered to the latter.

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Resonance : *An experimental demonstration of series and parallel resonant circuits for Radio training classes.*

By T. J. REHFISCH, B.Sc.

COMPLEX networks of coils and condensers may be regarded as built up of series and parallel *L-C* combinations. These two are therefore the basic " reactance arms " of filter terminology, and investigation shows that their impedance-frequency characteristics are in " potentially inverse " relationship. This duality is used in theoretical analysis and practical application. (See Appendix.) While the physical nature of dissipation tends to impair the perfection of duality in Resonance, this effect is usually of secondary importance except in measurements on low-loss materials.

The experiments to be described are primarily designed to verify the theory and standard equations of Resonance, with special reference to duality and to the measurement of " Q." Special care was taken to minimise the effects of the source properties from influencing the resonance effects.

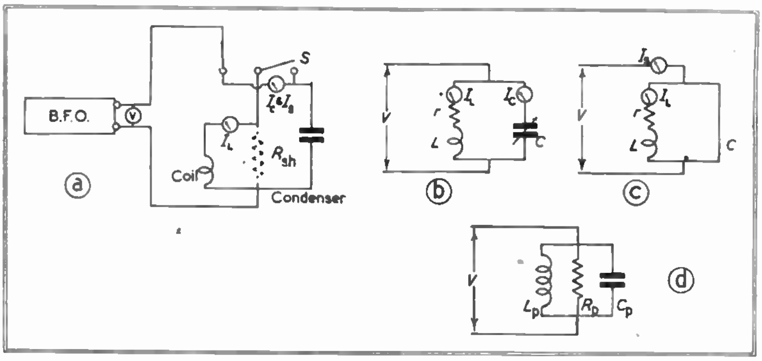


Fig. 1. Parallel *L-C* circuit.

(a) Complete Test Circuit, showing connexion of change-over switch S.

(b) Schematic, S (not shown) set to measure *Ic*; *r* represents losses in the coil and *I*L — meter.

(c) As (b), but S set to measure *Is*.

(d) Equivalent of above; coil represented by its equivalent parallel inductance (*Lp*) and resistance (*Rp*). *Cp* = *C* if condenser loss is zero.

(1) Parallel Resonance

The object of this demonstration is to investigate the properties of a parallel *L-C* circuit fed with a constant a.f. current.

The circuit is shown in Fig. 1(a). The supply is an audio oscillator with provision for varying and measuring both the frequency and the magnitude of the source voltage, V. The parallel circuit is made up of a standard inductor L and capacitor C. The coil was a large standard air-cored variable inductance (Tinsley). It would not be difficult to improvise a coil for this experiment using a former of similar size and with a tap provided for a smaller L value. (Unless compensation is made the series resistance, r, would be affected in this case.) The currents were measured by model 7 Avometers, using the 100 mA. A.C. range (resistance ≑ 2 ohms). With a two-way switch connected as shown a single meter may be used to measure the supply current I_s and the condenser current I_c alternately. Figs. 1b and 1c.

The procedure was to keep the supply current I_s constant throughout at 5 mA. (A) with L and C fixed (L=20mH, C=0.5 μF, say) f was varied from 1.2 to 2 kc/s and V, I_L, I_c observed, special care being taken to obtain readings near the resonant frequency.

(B) The L/C ratio was then halved, keeping the LC product constant (L=14.1 mH, C=0.71μF.). The above was repeated and I_c at resonance was noted.

(C) The circuit of (A) was restored, but a non-inductive resistor R_{SH}, of 3,000Ω was placed across the parallel circuit in the position shown in Fig. 1(a). V was observed when f was varied, I_L at resonance being noted.

(D) With the circuit of Fig. 1(a) f was kept constant at 1,550 c/s and I observed when C was varied. V at resonance was noted.

(E) The d.c. resistance of the coil was measured.

Results and Discussion

The results are plotted in Figs. 2, 3 and 4. The resonant coil current was 94mA. in (A), 0.64mA in (B) and 43 mA in (C). When the branch currents were plotted against frequency, Fig. 3, $I_L > I_C$ below resonance and $I_C > I_L$ above resonance, as was to be expected. Their maximum values differ by only 1 per cent. and occur at practically the same frequency. The latter is also true for the voltage maximum. There is thus no discernible difference here between the resonance criteria by maximum impedance and maximum current step-up (*see* Ref. 1).

The slight reduction in the resonance frequency observed on inserting the shunting resistor R_{SH} (C) must be attributed to frequency drift, as it can be shown that a non-reactive shunt cannot affect the frequency giving maximum impedance. Condenser losses are neglected throughout. The ammeter in (A) need have no effect on these if I_L and V_s are read with the circuit of Fig. 1(c).

Derivations are set out in Table I and Figs. 5 and 6. Most of the calculations in the table required a slight approximation on account of the difference between the series and parallel inductance parameters of a dissipative coil. This is of the order of 100/Q²+1) per cent., *i.e.*, less than 2 per cent. in the worst case here [Q in (c)=8.6]. Somewhat larger errors actually occur, due primarily to frequency drift and meter error. The capacitance variation (IV) method is probably the most reliable in this respect. The resonance curve of Fig. 4 (capacitance variation) should thus be strictly symmetrical. This is verified by Fig. 5 where $\sqrt{p^2 - 1}$ is plotted against δC;

$$p = \frac{(I_L \text{ at resonant capacity } C_0)}{(I_L \text{ at capacity } C)}$$

$$\delta C = C_0 \sim C.$$

The coil Q is obtained from the slope of this straight line. *See* Table 1, last row.

As the circuit is assumed purely resistive at resonance it follows that at any other capacity its impedance Z falls p times and has a phase angle $\emptyset = \cos^{-1}(1/p)$. This is plotted in Fig. 4, which now gives a complete impedance v. capacitance characteristic. ($I_L \propto V_s$ with the coil and frequency fixed. But $|Z| \propto V_s$. Hence I_L represents $|Z|$ in Fig. 4.) Lag is shown positive as the source current is the reference vector in this work. The two curves of Fig. 4 are also represented in the impedance-locus of Fig. 6. This is obtained by drawing a

circle with R_p to scale as diameter, OR_p representing the impedance vector at resonance. The end point of the impedance vector of known magnitude $|Z|$ at any capacity setting is obtained by drawing an arc of length $|Z|$ with O as centre to intersect the circle.

(2) Series Resonance

As it was felt desirable to carry out this experiment at radio frequency, a special instrument was developed to overcome the chief difficulty to be expected, viz., modification (pulling) of the source voltage by the test circuit, which would alter both its magnitude and frequency. In brief, the instrument consists of an r.f. oscillator feeding into a cathode follower using a step-down transformer in its cathode lead. The secondary voltage is thus practically free from regulation effect (10 per cent. down on a 10Ω load), and may be measured directly. The circuit set-up of this experiment is sketched in Fig. 7(a). Two valve-voltmeters are used, but only the one on the condenser had to be of the high-impedance type, the other being calibrated against it. The coil was wave-wound by hand with 30 S.W.G. wire (d.c.c.) on a 2 in. former and varnished. Its inductance $L=141$ μH was obtained by a 1 kc/s bridge measurement. The h.f. resistors used in (c) and (d) below were V-shaped and all of the same length. Their resistance at 1 Mc/s was then expected to coincide substantially with their accurately known d.c. resistance. The condenser was a variable air-dielectric standard fitted with a vernier scale (Sullivan).

The object of this experimental demonstration is to obtain the voltage response curves for a tuned circuit and to derive the coil Q in various ways.

Procedure

In the circuit shown the P.D. applied from the terminals of the r.f. source was maintained constant at 1 v (r.m.s.), being checked throughout the experiment by a valve-voltmeter across the source terminals and

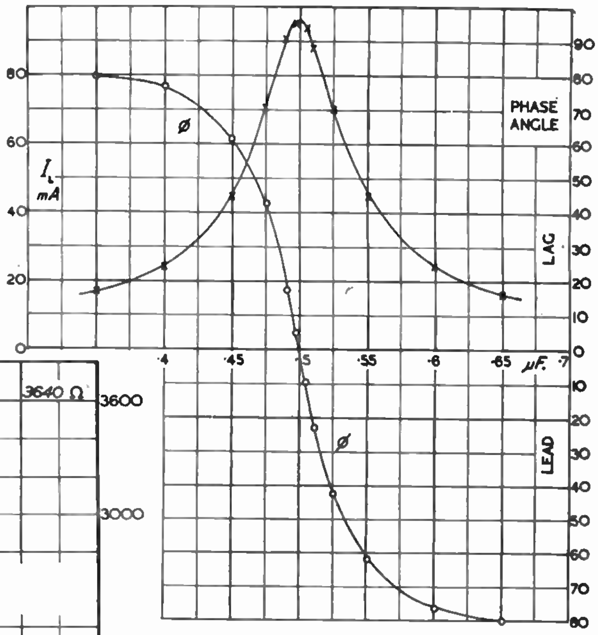


Fig. 4. Coil current I_L ($\alpha/Z/$) and derived phase angle ϕ as function of Capacity, f = 1550 c/s, L=20 mH, r=10.6 Ω (d.c.).

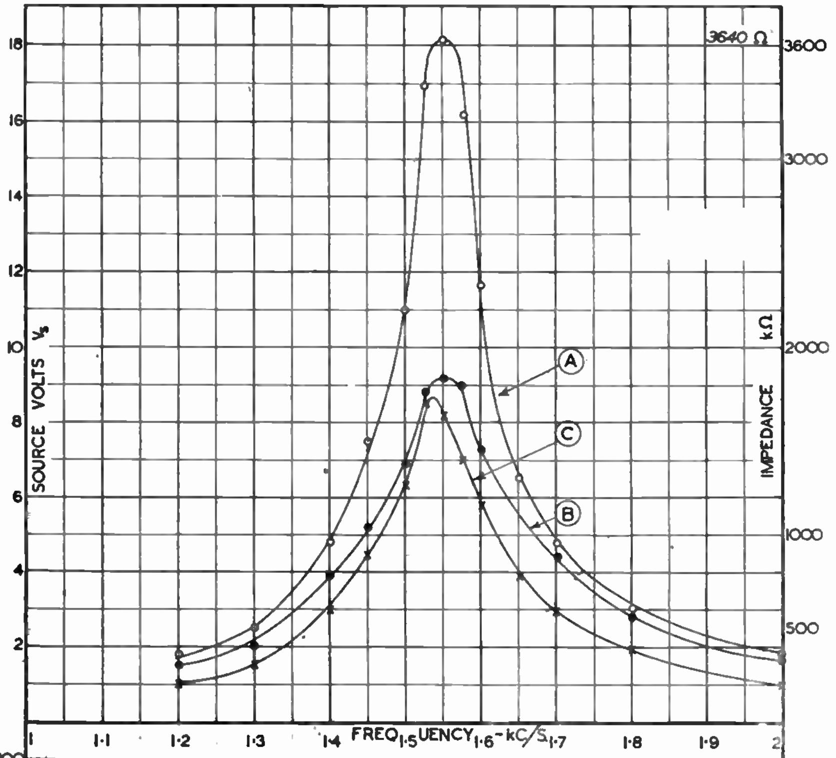


Fig. 2. Source p.d. V_s as function of frequency. Source current=5 mA.

(a) $\left\{\begin{matrix} L=20\text{ mH}, r_{dc}=10.6\ \Omega\text{ in.} \\ C=.50\ \mu F \end{matrix}\right\}$

(b) $L=20/\sqrt{2}$, $C=.5\times\sqrt{2}$, r as (A)

(c) L.C., r as in (a) but shunted by $R_{SH}=3000\ \Omega$

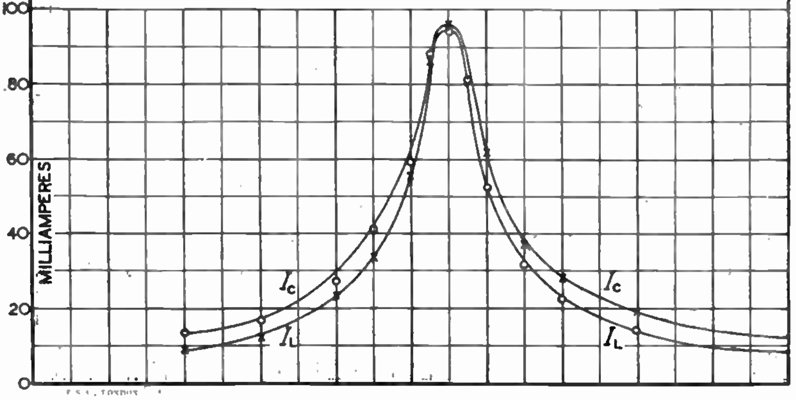


Fig. 3. Branch currents I_L and I_C as functions of frequency. Condition (a) Frequency scale as in (2).

	Method \ Quantity		Frequency of Resonance f_0	Goodness Factor Q	Equivalent parallel Resistance R_p	Equivalent series r Resistance (coil+meter)
A	Calculation from given $L, C, \& r$		From $L=20$ mH $C=0{\cdot}5\,\mu F$ $f_0 = 1/2\pi\sqrt{10^{-8}}$ $= 1590$ c/s.	$\frac{1}{r}\sqrt{\frac{L}{C}} = \frac{\sqrt{4\times10^4}}{10{\cdot}6} = 18{\cdot}9$	By calculation: $\frac{L}{Cr} = \frac{20\times10^{-3}}{\cdot5\times10^{-6}\times10{\cdot}6}$ $= 3770\,\Omega$	$8{\cdot}6+2 = 10{\cdot}6\,\Omega$ dc
A_I	Quotients		$f_0 = 1550$ c/s.	$\left(\frac{I_L}{I_s}\right)_{f_0} = \frac{94}{5} = 18{\cdot}8$		$\left\{\frac{R_p}{Q^2} = \frac{3690}{19^2} = 10{\cdot}4\,\Omega\right.$
A_I'	Volt-ammeter			$\frac{R_p}{\omega_0 L} = \frac{3690\times10^3}{2\pi\times1550\times20} = 19$	$\left(\frac{V_s}{I_s}\right)_{f_0} = \frac{18{\cdot}2}{5\times10^{-3}} = 3640\,\Omega$	
A_{II}	Frequency Variation		As A_I	$\frac{f_0\sqrt{p^2-1}}{\Delta f} = \frac{1550}{80} = 19{\cdot}4$	—	—
B	Circuit "stiffness" (L/C ratio) halved	Calculation from A	No change	As r is constant, Q_A should change by a factor $\frac{(L)_A}{(L)_B} = \frac{20}{14{\cdot}1} = \frac{1}{1{\cdot}41}$, i.e. to $19/1{\cdot}41 = 13{\cdot}5$	Should be halved, i.e. $\frac{3640}{2} = 1820\,\Omega$	No change with this type of coil
		Observation	1550 c/s	$\left(\frac{I_L}{I_s}\right)_{f_0} = \frac{64{\cdot}8}{5} \doteq 13$	$\left(\frac{V}{I_s}\right)_{f_0} = \frac{9{\cdot}2\times10^3}{5} = 1840\,\Omega$	$\frac{R_p}{Q^2+1} = 10{\cdot}9\,\Omega$
C_{III}	Resistance Insertion	Calculation from A	No Change	$(Q)_c = \frac{(Q)_A\, r_A}{r_c} = \frac{19{\cdot}4\times10{\cdot}4}{23} = 8{\cdot}8$	$(R_p)_c = \frac{(R_p)_A\times(R_{sH})}{(R_p)_A+(R_{sH})} = \frac{3640\times3500}{3640+3500} \doteq 1650\,\Omega$	$(r)_c = (r)_A + \frac{\omega^2L^2}{R_{sH}} = 23\,\Omega$
		Observation	1535 c/s.	$\left(\frac{I_c}{I_s}\right)_{f_0} = \frac{43}{5} = 8{\cdot}6$	$(R_p)_c = \left(\frac{V}{I_s}\right)_{f_0} = \frac{8{\cdot}6\times10^3}{5} = 1720\,\Omega$ $(R_p)_A = R_{sH}\left[(V_A/V_c)-1\right]_{f_0} = 3500\left[\frac{18{\cdot}2}{8{\cdot}6}-1\right] \doteq 3900\,\Omega$	—
E_{IV}	Capacitance Variation		—	$\frac{2C}{\Delta C}\sqrt{p^2-1} = \cdot5\times38 = 19$	—	—

NOTE The effect of meter resistance $r_m (=2\,\Omega)$ is to reduce the measured coil Q ($=19$ say) by a factor $1+(1-Q r_m/\omega L) = 1/{\cdot}8$ below the true value Q_0. Hence $Q_0 = 19/{\cdot}8 = 23{\cdot}7$
From given coil data: $Q_0 = 2\pi\times1590\times20\times10^{-3}/8{\cdot}6 = 23{\cdot}2$.

Table 1. Parallel Resonance.

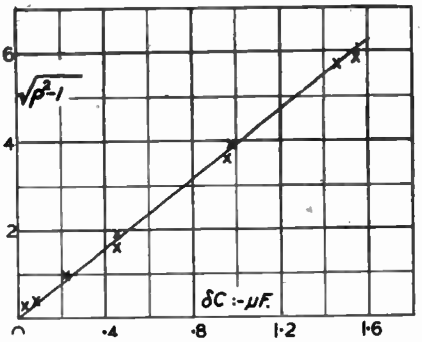


Fig. 5. The derived parameter $\sqrt{p^2-1}$ as function of incremental detuning capacitance δC.

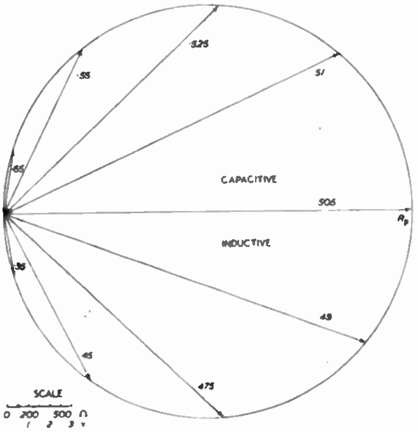


Fig. 6. Impedance-Locus Diagram. C variable.

monitored by the amplitude control where necessary. V_c, the condenser P.D., was observed throughout by a valve voltmeter. The wiring of the circuit was kept as short as possible, and correct zero setting of the voltmeter ensured by frequent checking.

(a) With $f=1$ Mc/s, say, C was adjusted until the condenser P.D., V_c, was a maximum. The value of C was noted, and f was then varied on either side of 1 Mc/s, using the incremental frequency control of the r.f. source to start with, V_c being observed.

(b) A 10Ω h.f. resistor was placed in the series position marked X in Fig. 7a and the above was repeated.

(c) With $f=1$ Mc/s the range of h.f. resistors available was substituted one by one and V_c observed. Slight retuning of f or C was permissible in each case to ensure the corresponding maximum value of V_c.

(d) With $f=1$ Mc/s and no h.f. resistor the capacity of the condenser was varied and V_c observed.

Results

These are shown in Figs. 8, 9, 10, and the derived Q-values in Table II. The condenser reading was appreciably less than would be expected from $f_0 = 1/(2\pi\sqrt{LC})$. As the stray capacities in a laboratory " set-up " of the type used are rather uncontrollable, the larger value obtained from f_0 is considered more reliable and is used in eiv.

The values derived for Q are seen to agree within 2½ per cent. Although it was the soundest method theoretically, capacitance-variation gave the least satisfactory result, no doubt because of the difficulty in reading, the very small capacitance changes involved. In addition, the self-capacitance of the coil was not accounted for, and plays a different role in the various Q-determinations. In contrast with the audio frequency test, the r.f. resistance of the coil (11Ω) is seen to bear no simple relationship to its d.c. resistance (1.8Ω) except that it is higher.

General

The resonance curves of both the series and the parallel circuits are seen to be of the same general shape. In particular the coil current in Fig. 1 corresponds to the condenser P.D. in Fig. 7. In the former case, however, coil current is proportional to source voltage, and hence the I_L curve represents *impedance*. By the same reasoning V_c represents admittance. Also, as the total magnitude of capacitive reactance remains almost constant throughout expt. 2, the V_c curves in this case represent roughly the admittance variation. It should be stressed again that circuit connexions must be kept to a minimum and preferably screened.

Methods

The principle of resonance and the labels of Quotients (I), Frequency Variation (II), Resistance Insertion (III), Resistance Variation (III′), and Capacitance Variation (IV) cover all deflectional methods for measuring coil Q at r.f. They neglect condenser and voltmeter losses, and only the first and last do not involve additional approximations in arriving at Q.

The applied P.D. is usually much less than 1 v. and cannot then be measured directly by a standard valve-voltmeter. The applied P.D. need not be known if it is kept constant, an aim achieved by weak coupling to the oscillator. The exceptions to this are the methods of Quotients (I), and the

	Parameter / Method	Total Circuit Capacitance C	Goodness Factor Q	Equivalent series Resistance r
	Calculation from given L f_0 & r	$C = \frac{1}{(2\pi f_0)^2 L}$ = 179 pF	$Q = \frac{\omega_0 L}{r_{d.c.}} = 490$	1·8 Ω d.c.
	Condenser Reading	149 pF		
a_I	Quotients		$\left(V_c / V_s\right)_{f_0} = 83/1 = 83$	$r = \frac{\omega_0 L}{Q} = \frac{6{\cdot}3 \times 140}{83} \rightarrow = 11\,\Omega$
a_{II}	Frequency Variation		$\frac{f_0}{\Delta f}\sqrt{p^2-1} = \frac{1000 \times 1}{12} = 83{\cdot}2$	
c_{III}	Resistance Insertion		$\frac{\omega_0 L}{R}\left[\left(\frac{V}{V_R}\right)_{f_0} - 1\right] = \frac{6{\cdot}3 \times 140}{10{\cdot}16}\left[\frac{83}{43} - 1\right] = 83$	
d'_{III}	Resistance Variation		$Q = \frac{\omega_0 L}{R} = 83 \leftarrow$	From plot of Fig 9 $r = 11\,\Omega$
e_{IV}	Capacitance Variation		$\frac{2C}{\Delta C}\sqrt{p^2-1} = \frac{2 \times 179 \times 1}{{\cdot}44} = 81{\cdot}4 \rightarrow$	$r = 10{\cdot}8\,\Omega$

Table 2. Series Resonance.

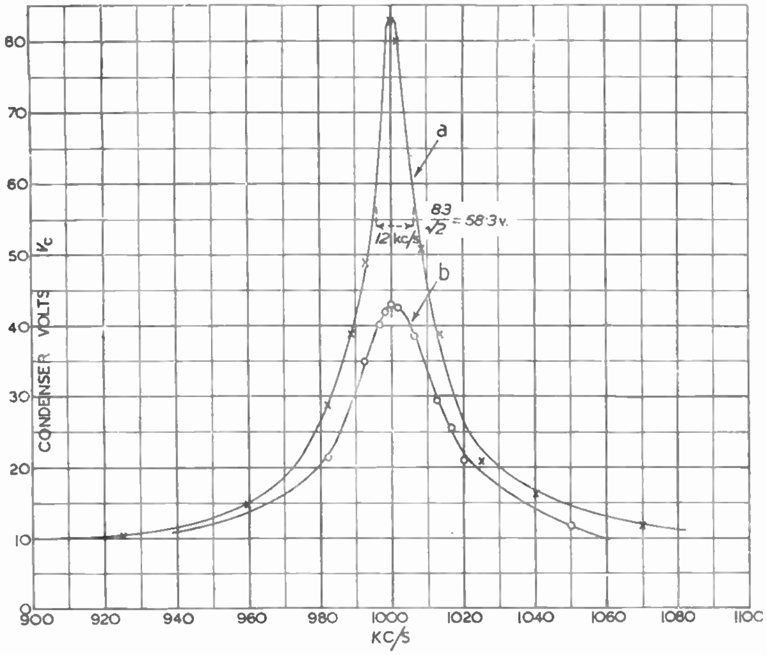


Fig. 8. Series Circuit. Condenser P.D. as Function of Frequency. Source P.D. = 1 v.r.m.s

Fig. 9. $1/V_c$ against R in Series Circuit. V_c = condenser p.d. at resonance. R = added series resistance. Source p.d. = 1 v. at 1 Mc/s throughout.

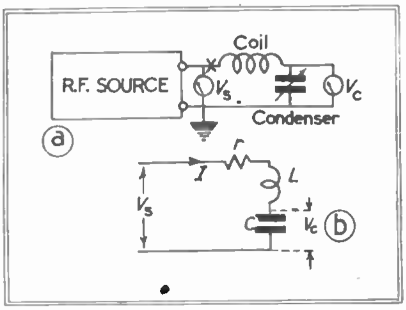


Fig. 7. Series L—C circuit.

(a) Complete Test Circuit, showing connexion of coil.

(b) Equivalent of above, coil represented by its equivalent series inductance (L) and resistance (r). This circuit is the dual of Fig. 1 (d).

Q-meter method derived from it; in the Q-meter method the applied P.D. is calculated from I_sR, where I_s is the source current flowing into the series circuit shunted usually by a 0.04Ω resistor.

A Note on Duality

The impedance of the series circuit of Fig. 7 (b) at frequency $\omega/2\pi$ is given by

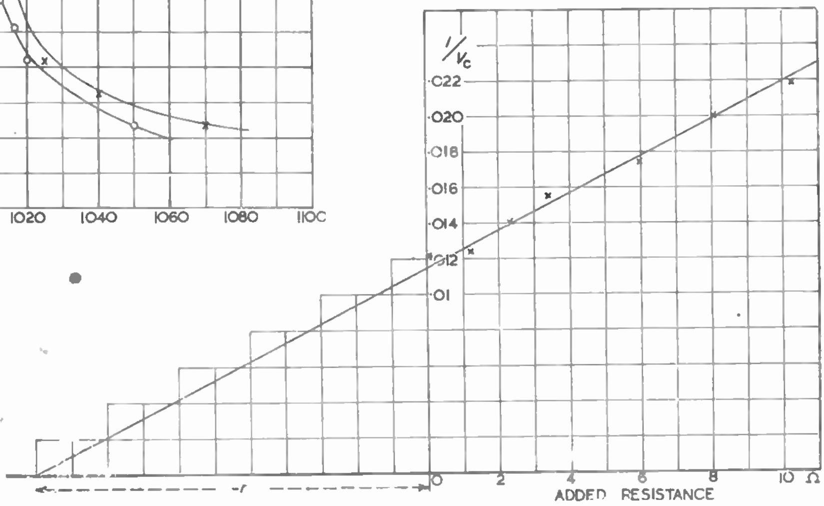
$$Z = \frac{V_s}{I} = r + \text{j}\left(\omega L - \frac{1}{\omega C}\right).$$

The admittance of the parallel circuit of Fig. 1 (d) is given by

$$Y = \frac{I_s}{V} = \frac{1}{R_p} + \text{j}\left(\omega C_p - \frac{1}{\omega L_p}\right)$$

$$= G + \text{j}\left(\omega C_p - \frac{1}{\omega L_p}\right),$$

where conductance $G = \frac{1}{R_p}$.



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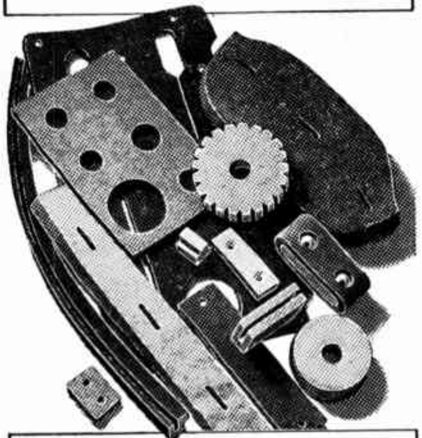

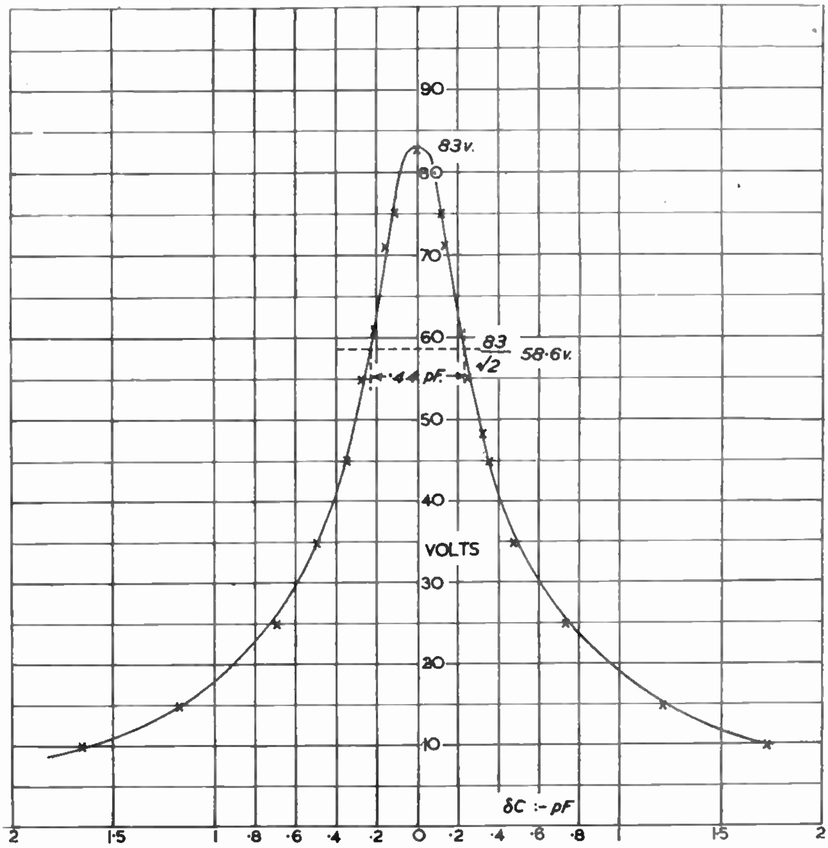

Fig. 10. Series Circuit. Condenser P.D. against Detuning Capacitance Applied P.D.=1 v. at 1 Mc/s.

Hence the ratio

$$Z/Y = \frac{r + j\left(\omega L - \frac{1}{\omega C}\right)}{G + j\left(\omega C_p - \frac{1}{\omega L_p}\right)}.$$

If the parameters of the two circuits are independent of frequency and related by $\frac{r}{G} = \frac{L}{C_p} = \frac{L_p}{C}$ (*i.e.*, $L_pC_p = LC$) then the ratio $\frac{Z}{Y} = \frac{r}{G} = rR_p$ is independent of frequency, i.e., the impedances of the two circuits (Z and $\frac{1}{Y}$) are inverse with regard to rR_p.

The position is summarized in the table below, which indicates the process of forming a circuit which is inverse to the given one.

The rule is to substitute quantities ir one row for corresponding quantitie in the other. As an example, the coi current* in the parallel circuit corresponds to the condenser voltage in th series case.

References

1 Glasgow : " Principles of Radio Engineering, McGraw Hill, 1936. Chapter 11—Resonant Circuits

2 L. Hartshorn : " Radio Frequency Measurements," Chapman & Hall, 1942.

3 D. B. Sinclair : " Parallel and Series Resonanc Methods," *Proc. I.R.E.*, 26th Dec., 1938.

4 A. Russell : " Theory of Alternating Currents, Vol. I, 1914.

5 O'Shea : " Transmission Networks and Wav Filters." Nostrand, 1929. Chapter V. Propertie of Two Terminal Impedance Arms.

Acknowledgments

Thanks are due to the Electrical Engineerin Department of Northampton Polytechnic for assistin in the development of the special r.f. source, and t my colleague Mr. M. Nelkon, B.Sc., A.K.C., for h assistance with the MS.

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* This coil current would be somewhat fictitious in practical case owing to the loss which actually occu in the coil. The loss draws a current which add vectorially to the *Lp* current to give the observed *I* quantity.

SERIES circuit	Frequency	Impedance	Voltage	Current	Resistance	Inductance	Capacitance
PARALLEL circuit	Frequency	Admittance	Current	Voltage	Conductance	Capacitance	Inductance

ABSTRACTS OF ELECTRONIC LITERATURE

INDUSTRY

The Welding of Thermoplastic Materials by means of R.F. Currents

(H. P. Zade)

The historical and theoretical developments of R.F. welding are reviewed and its applications classified as preheating of parts for moulding purposes, the manufacture of resin-bonded plywood and similar articles and the vulcanisation of rubber. Distinction is made between the stationary and continuous methods of welding. The control of the electrostatic fields in the case of butt, lap and seam welding of comparatively heavy sections is discussed and methods are given for welding by the continuous and stationary methods. An interesting application of R.F. heating for the welding of glass is remarked upon and in conclusion the choice of frequency and the problems of R.F. power supply are mentioned.

—*Plastics*, Mar., 1944, p. 100.*

Magnetic Dust Cores

(G. R. Polgreen)

Following a general discussion of the magnetic properties obtainable by various degrees of subdivision of core material, *e.g.*, into laminations, wire or particles), the author reviews the various methods employed for the manufacture of dust cores and gives examples of the uses to which such cores may be put.

—*P.O.E.E. Jour.*, Vol. 37, Part 1, April, 1944, p. 1.

The Rectifying Property of Carborundum

(J. T. Kendall)

A technique is described for obtaining a non-rectifying carbon-carborundum contact. Experimental current-voltage curves are given for single rectifying contacts. These curves show that green and black carborundum are essentially different types of semi-conductor. Experiment also shows that all the rectification takes place at the contact surface, and that any volume rectification, if it exists, is a second-order effect.

—*Proc. Phys. Soc.*, Mar., 1944, p. 123.*

THEORY

On the Currents carried by Electrons of Uniform Initial Velocity

(G. Jaffé)

The following problem is treated: electrons enter the space between two infinite parallel planes with uniform velocity at right angles to the planes. The current is studied for all possible values (positive and negative) of the potential difference between the planes. The complete solution can be obtained if this boundary condition for the current is accepted: The number of electrons entering the discharge space must be equal to or smaller than a given number N_0 per cm^2 per sec., and is for each potential as high as the potential permits. The problem depends on two dimensionless parameters, a reduced plate distance ξ_0 (involving the current) and $\eta_0 = V_0/E_0$, where V_0 is the impressed potential difference and eE_2 the energy of the electrons. For each value of ξ_0 the current is space-charge limited below a critical value of η_0. The limitation, however, is not due to the appearance of a potential minimum low enough to stop the electrons, but is due to the fact that the solution does not exist unless the current is limited. The space-charge limited characteristic is a simple generalisation of Child and Langmuir's well-known formula. The deviations from this formula are very considerable if $E_0 \sim V_0$. The behaviour of the potential distribution is graphed for some typical cases of positive, zero and negative potentials V_0. Currents can pass with zero or negative potentials only below critical values of the reduced plate distance.

—*Phys. Rev.*, Feb. 1 and 15, 1944.

The Cyclotron—2

This is the second of two parts of a comprehensive article on the cyclotron. Various aspects of the subject which are dealt with in detail in this part are: target arrangements, vacuum pumps, vacuum seals and techniques, controls, laboratory design, shielding, cyclotron costs, yield of nuclear reactions and optimum size. The performance of the cyclotron at the Massachusetts Institute of Technology is discussed.

—*Jour. App. Phys.*, Feb., 1944, p. 128.*

ELECTRO-MEDICAL

Medical Electronic Practice and Research

(J. D. Goodell)

Basic principles of bioelectricity, a survey of present techniques, and predictions of future progress, with emphasis on electro-shock therapy, electrical anesthesia, brain-wave recording, determination of ovulation time and measurements on living tissues.

—*Electronics*, Vol. 17, No. 4 (1944) p. 96.

A Simple Variable "Square-Wave" Stimulator for Biological Work

(A. E. Ritchie)

An instrument is described using two standard triode valves to produce impulses independently variable in intensity duration, and frequency over the wide ranges called for in the excitation of nerve and muscle. The impulse wave-form is rectangular. Accurate and reliable operation had been maintained over a year's continuous routine use.

—*Jour. Sci. Inst.*, Vol. 12 (1944), p. 64.

JULY MEETING

Association for Scientific Photography

The summer meeting of the Association will be held on Friday afternoon, July 28, and Saturday, July 29.

Programme: At the Royal Photographic Society's Rooms, 16 Princes Gate, S.W.7.

Friday, July 28, *at* 2.30 *p.m.*: "The Choice of Photographic Materials," by Dr. H. Baines, Assistant Director of Research, Messrs. Kodak, Ltd., and Mr. F. J. Tritton, Research Department, Messrs Ilford, Ltd.

Saturday, July 29, *at* 10.30 *a.m.* —Symposium on "Lighting in Photography." The speakers will include Miss F. Anthony (G.E.C. Research), Mr. Bourne (B.T.-H. Research), Dr. Mandiwall, L.D.S.

Tickets admitting visitors to the lectures can be obtained from the Hon. Secretary, Mr. R. M. Weston, at 34 Twyford Avenue, N.2, or from the Editorial Offices of this journal.

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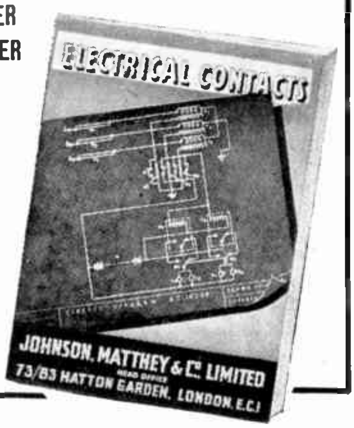

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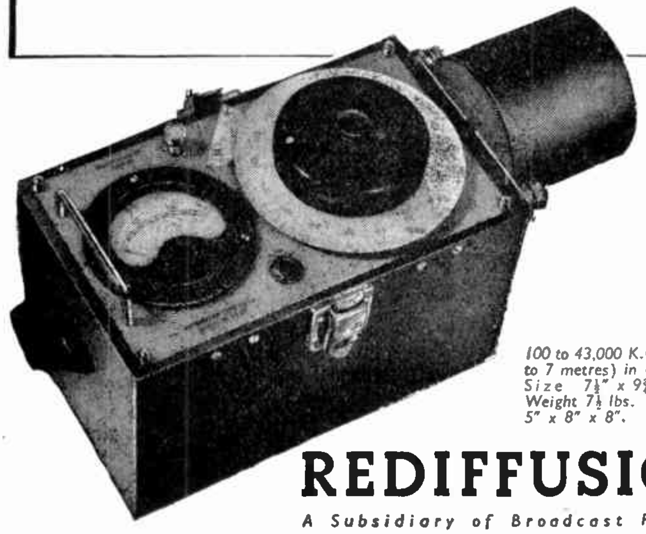

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BOOK REVIEWS

Introduction to Electricity and Radio

T. H. Turney Ph.D 212 pp. 170 figs. (Geo. Newnes Ltd. 7s. 6d. net.)

This book has been evolved from a lecture course which the author has conducted in Liverpool, and is written in semi-colloquial style in order to encourage students to give an understandable explanation of technical terms. The first ten chapters cover the elementary theory of electricity and the generation of currents and the remainder of the book is devoted to radio, from valves and circuits to the complete receiver.

Some miscellaneous chapters at the end deal with the "j" notation, standing waves, power supply units, and experiments and demonstrations.

In writing a book of this type, the author is always faced with the difficulty of avoiding too technical explanations while preserving technical accuracy, and in the main this has been satisfactorily overcome. There is also the problem of packing the equivalent of a three years' course into two hundred odd pages, and here it is suggested that the omission of some of the later subject matter might enable a fuller account to be given of the more common radio applications. For example, justice cannot be done to the cathode ray tube in three-and-a-half pages, but the chapter on "j" notation or A.C. bridges might be omitted from an elementary introduction.

The importance of explanatory figures and diagrams in an elementary book cannot be over-emphasised, and, according to the Chinese proverb, the author could save several thousand words by the use of fully explained diagrams in the text. Unfortunately in many cases the captions are not well-chosen in conjunction with the figures they should clarify; e.g., Fig. 57A shows a "completely" modulated wave (100 per cent. modulation) and Fig. 57B is labelled "A common modulated wave" as though this were something special. In Fig. 66A the circuit is not a simplified time base, as it shows no discharge device nor connexion to the C.R. tube. Fig. 36 is definitely not a sine-wave but two semi-circles, and Fig. 38, showing a triode, is labelled "Curve for a diode."

Other examples could be quoted, and it is hoped that in future editions the author will take the opportunity of elaborating the pictorial side of the book. The reader has not the advantage of hearing him expound with the aid of a blackboard, which, judging from the style on the whole, he does very well.

G.P.

American Midgets

J. Bull (V.E.S. Publications 2s. 7d. post free)

A booklet published by Radio Service Specialities of Melthorne Drive, Ruislip, dealing with midget receivers and their circuits, with suggestions for fault-finding and data on the types of valves used.