THE PRACTICAL RADIO REFERENCE BOOK

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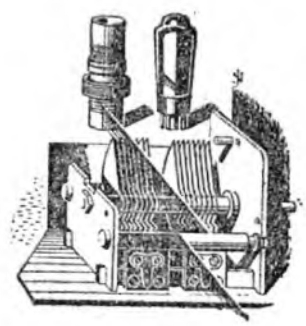
COMPLETE GUIDE IN
QUICK REFERENCE FORM FOR
ALL RADIO TECHNICIANS, STUDENTS
AND AMATEURS

Edited by ROY C. NORRIS
Technical Editor, "Electrical and Radio Trading"



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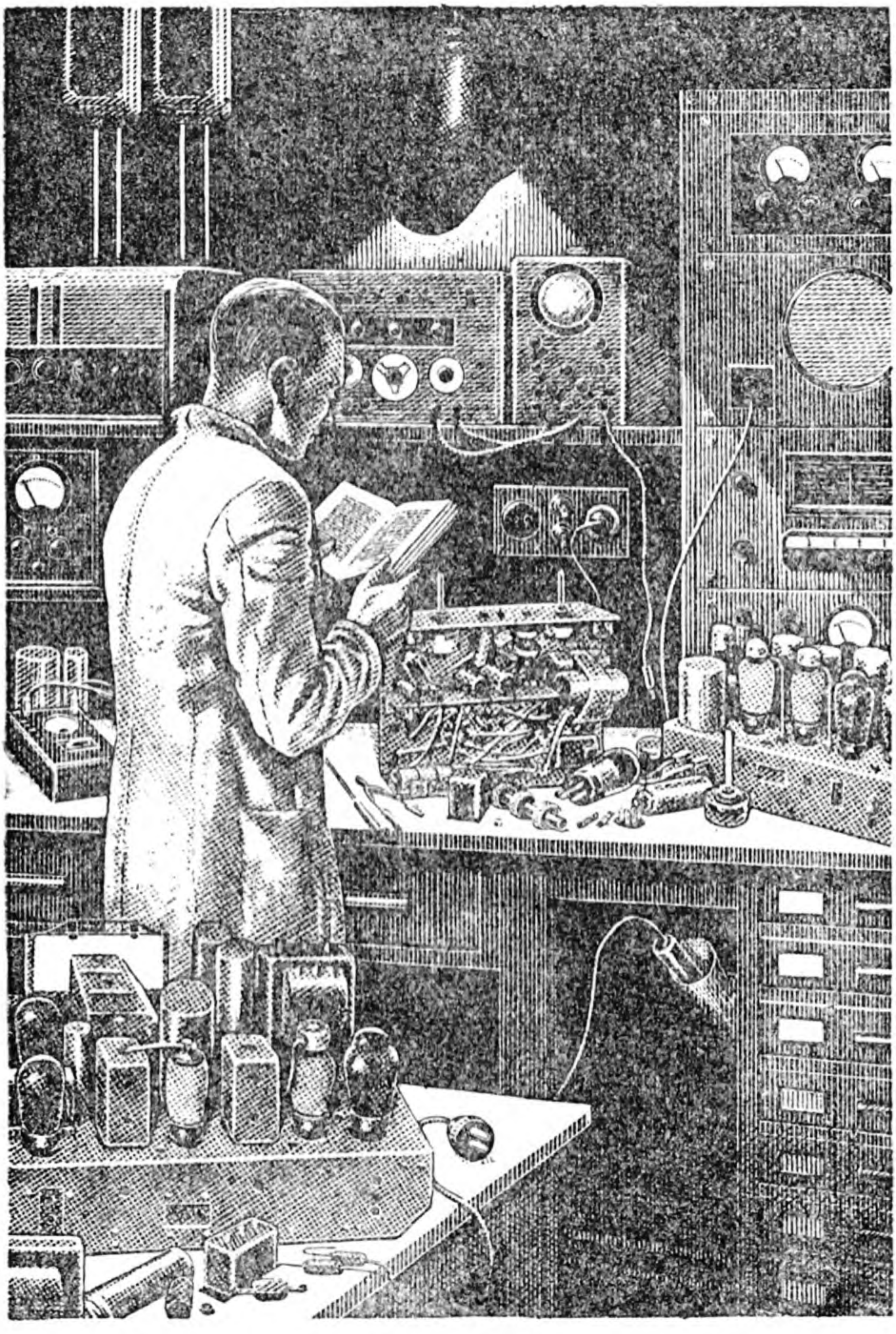

WELL-EQUIPPED RADIO WORKSHOP

Instruments essential to radio repair and design work include multi-range meters, a service oscillator and a components tester. Other valuable aids are a cathode-ray oscillograph, a frequency-modulated signal generator, a stabilized power supply and various substitution speakers and components of modern design.

THE PRACTICAL
RADIO REFERENCE BOOK

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HOW TO USE THIS BOOK

PROPERLY used, this book can be a big time-saver for the practical radio engineer and student alike. It presents a mass of practical and theoretical data in as concise a manner as compatible with intelligibility. Within these covers can quickly be found information which otherwise might be elicited only after thumbing through a whole shelf-full of books on theory, circuit practice, valves, components, sound amplification, instruments, interference suppression, and so forth.

The reader should first familiarize himself with the general 'shape' of the book. It will be seen from the Contents that the volume is divided into numerous sections, each devoted to a department of practice or theory.

A little acquaintance with the volume will enable the reader to turn, in most cases, straight to the section containing the information he requires.

Within each section, data are presented in appropriate sequence—technical or otherwise. This gives each item its logical place, thus aiding reference and at the same time ensuring, in many instances, that the item is explained by what precedes it.

When the reader has no clear conception of the category in which a required fact may be located, he should refer to the detailed index in the end pages. Every effort has been made to ensure that the index is comprehensive but, on occasion, it may be necessary to recollect that some information does not readily lend itself to itemized listing.

While essentially a reference book, the reader will find several features which can be read through. In fact, while full explanation is outside its scope, the volume is more than a plain reference work.

This approach is exemplified in the Valve section. There you will find definitions of terms and brief descriptions of valve types, in addition to the formulæ for understanding and utilizing valve circuits. The diagrams form, in themselves, a pictorial outline of theory as well as a reference guide to the numerous circuit arrangements which are the practical man's concern.

The Component Design section not only contains the necessary data in particularly compact tables and helpful curves, but also explains how the material should be used. It is, in fact, a potted design manual.

The section on Instruments is not concerned with how they work as much as with how their ranges may be modified for particular purposes or with what is conveyed by the patterns on cathode-ray oscillographs. Sound Amplification begins with basic terms and useful reference charts and goes on to such practical matters as the characteristics of microphones and loudspeakers.

The needs of the television installation engineer, as well as of the short-wave enthusiast, have been borne in mind.

A summary of AC theory and of the algebra necessary for its application will be valuable equally to the student and to the older man who needs a refresher. Abacs and charts are given to speed everyday calculations.

It is hoped to revise and extend the book from time to time and suggestions for its improvement from readers will be welcomed.

Thanks are extended to contributors, among them D. H. Smith, B.Sc., Ph.D., E. J. G. Lewis, A.M.Brit.I.R.E., W. B. Hunt, and J. de Gruchy, M.Brit.I.R.E.

ROY C. NORRIS.

SECTION 1

FUNDAMENTALS

WHILE all the information set out in the following brief introduction to the principles of electricity and magnetism can be found in the tables which follow it, nevertheless the introduction may help to explain the tables more completely.

The several distinct aspects of electrical phenomena may be related to the behaviour of electricity when stationary, classified as *static electricity*; to electricity flowing in one direction, namely, *direct current*; to electricity flowing this way and that, which is described as *alternating current*. A subdivision of the classification of direct current is that of *unidirectional current*.

Electromagnetism

Associated with the flow of electricity, whether in one direction continuously or alternating this way and that, are the magnetic effects in the neighbourhood of the conductors carrying the electricity, thus introducing the subject of *electromagnetism*.

Static Electricity. A body is said to be *charged* when it has an excess of positive or negative electricity. We thus speak of a *charge of electricity* as meaning an excess of it. When a body is charged it is said to have an electrical potential. It is always assumed that the earth cannot have an excess of electricity, so that the earth is at zero potential and charged bodies have a potential with respect to earth, or a potential difference from earth potential. Thus, the electricity in charged bodies tends to flow to earth if a conductive path is provided. Two bodies with unequal charges of a like kind, or charges of an unlike kind (i.e., different positive or different negative charges or positive and negative charges respectively) have a difference of potential.

When a body is charged it exercises an *electric force* in the space around it. This force is such as to attract or repel other charged bodies, or to attract bodies which are not charged. Bodies with like charges repel one another.

A concept which aids the understanding of the action of forces around a charged body is that of postulating the existence of an *electric field* composed of *lines of electric force*, a line of electric force being a line drawn in the field which gives at all points the direction of the electric force.

When a body is charged, then an uncharged body brought near it is raised in potential; the field, in fact, represents a state of strain and a body in the field attains a potential representing this strain.

Imagine a body charged with positive electricity and consider that another conductive body, not originally charged, is brought near the charged body. It is then found that that part of the body nearer the positively charged body has a negative charge, and that part of the body farther away from the charged body has a positive charge. These charges are *induced charges* but, since they are equal and opposite, there is, in fact, no total charge on the body, although the body, influenced, of course, as it is by the electric field, has a potential.

Displaced Electricity

To describe this effect, we say that electricity has been *displaced* in the body, some excess being represented as a charge of positive electricity in one part of the body, some being an excess of negative electricity in another part of the body. The body as a whole has no excess of electricity because the charges cancel.

If the charged body creating the induced charges on the other body had a negative charge, displacement would also occur in the body which was introduced in the field, but the displacement would be the opposite way round from where the charged body had a positive charge.

A *dielectric* is the name given to a medium through which electricity may be displaced, but which does not conduct electricity as do metallic conductors. We may consider that the molecular structure of the dielectric helps to cause induction. *Insulating material* has this property but is not by definition a dielectric; it is material which has a very high resistance.

Displacement Current

Electricity may be said to be displaced across a dielectric when the electric forces responsible for the state of strain are varying, because a quantity of electricity changing in the charged body causes the induced charges to vary; anticipating future description, we may say that a current of electricity may seem to flow through a capacitor when the potential is applied to an uncharged capacitor, even though there is no conductive path between the plates of a capacitor, the plates being separated by a dielectric. Such a current represents a displacement of electricity, or a *displacement current*.

Electric flux associated with all varying charges is measured as the quantity of electricity displaced across a dielectric, and the intensity of an electric field is a measure of the electric flux.

The ratio of the electric flux density produced in a dielectric, to that produced by the same electric force in a vacuum, is called the *relative permittivity* of the dielectric.

A dielectric concentrates the electric field much as a ferro-magnetic material concentrates a magnetic field, and permittivity can be associated with permeability.

Air has a relative permittivity so close to unity that it is sufficient in most cases to assess relative permittivity of dielectrics in relation to the electric flux-density produced by a given electric force in air. The permittivity of dielectrics is greater than unity, showing that dielectrics have the property of concentrating the electric field; this property has practical use in the construction of capacitors, a point that has now to be dealt with.

Capacitance

Given a certain charge on a body, the body has a certain potential. Consider that the body is conductive and that other bodies in its neighbourhood are at zero potential; the *capacitance* of the body is then defined as the ratio of the charge on the body to the potential of the body. This property, namely, capacitance, depends upon the physical shape of the body and its position relative to other bodies. The capacitance of the body is also determined by the permittivity of the medium which separates the charged body from other bodies, increasing with increasing permittivity. A *capacitor* is a component designed, in a practical form, to have the property of capacitance and, ideally, no other electrical property.

What have been referred to previously as 'bodies' are, in a capacitor, essentially two conductive systems insulated from one another by a substance which has, consistent with other properties, a large relative permittivity.

Direct Current. A source of electricity capable of maintaining a steady and continuous flow of electricity in a conductive circuit established across its terminals, must succeed in maintaining a steady difference of potential across its terminals while the conductive circuit is connected between them. This difference of potential will have different values, according to the magnitude of the flow of electricity in the conductive circuit, but, in order to establish the flow, the difference of potential across the conductive circuit must be maintained whatever its value.

The term *electromotive force* describes the force associated with the source of electricity which urges the flow of electricity round the circuit in one direction. The flow of electricity in the circuit is called an *electric current* or current; the difference of potential causing the current may be described as a *voltage*. When the flow of current is in one direction round a circuit and is of uniform value, this current is described as a *direct current*.

Ohm discovered that the metallic conductors of electricity with which he experimented had a property he called *resistance*, the value of which resistance is given by the ratio of the difference of potential acting across the conductor and the consequent current flowing in the conductor, this value (of resistance) being independent of the value of the potential acting and the current flowing provided the conductor is kept at a constant temperature. This discovery constitutes a natural law and is described as Ohm's law.

Rectifiers and Ohm's Law

Certain conductors do not obey Ohm's law, e.g., certain compositions, or the contact between dissimilar materials or, notably, the contact between bright and oxidized contacts of the same material. What are called 'rectifiers' do not obey Ohm's law because they conduct more strongly when the potential acts one way across them than when it acts in the other, and even when the rectifier conducts relatively strongly the apparent resistance varies with current and voltage.

Conductance is the reciprocal of resistance; the greater the resistance of a conductor the less its conductance, and vice versa.

A *resistor* is a component designed to have ideally the property of resistance and no other electrical property.

As a direct consequence of Ohm's law, the voltage across a resistor (or a conductor having a given resistance) is given by the product of the resistance of the resistor (or conductor) and the current flowing in it. This is called a *voltage drop*.

If several resistors having different values of resistance are connected in series and a difference of potential acts continuously across all the resistors in series (producing the same current in all of them), then the sum of the several voltage drops developed across each resistance is equal to the total voltage acting across them all in series.

Internal Resistance

A source of electricity capable of producing a direct current in a circuit connected across its terminals can be considered as consisting of a constant electromotive force (commonly symbolized by the abbreviation EMF) and an *internal resistance*, the EMF and the resistance being in series across the terminals of the source. This internal resistance must not be confused with the existence of the physical object called a resistor, it is, in fact, part of a conception which conveniently explains the fact that the voltage across the terminals of the source is reduced as the current taken from the source is increased.

The internal resistance causes a voltage drop to be developed across it when a current flows in it, so that the voltage at the terminals of the source is equal to the voltage of the EMF minus the voltage drop in that resistance. If the external circuit has infinite resistance, this is the sole condition when the voltage on the terminals of the source is equal to the EMF of the source, because there is no voltage drop in the internal resistance—since no current flows.

If the terminal voltage of the source is reduced by half, by connecting an external circuit of the required resistance to halve the open-circuit voltage, then this external resistance must measure the value of the internal resistance of the source. If the external circuit has zero resistance, then the terminal voltage is zero and the voltage drop in the internal resistance is equal to the EMF. All sources of electricity have internal resistance, whether they be small dry cells or high-powered electrical machines; a change of terminal voltage, however large or small, takes place directly the current is drawn from the source.

When a direct current flows in a conductor, *a quantity of electricity* flows through that conductor. This quantity is given by multiplying the steady rate of flow (current) by the time it flows uniformly.

It is observed that when a current flows in a conductor the conductor gains heat, showing that energy conversion takes place when a current flows in a conductor; electrical energy being transformed or converted into heat.

Joule's law states that the heat generated in a certain time by the passage of a uniform current through a conductor having a given resistance is equal to the product of the current squared times the time it flows uniformly times the resistance of the conductor in which it flows.

Using what are called practical units, current flow is measured in amperes, difference of potential in volts, and resistance in ohms.

Power is the rate of doing work. Power is measured, in a direct-current circuit, by the constant volts acting multiplied by the constant current flowing. A *watt* is thus given when one ampere flows due to the potential of one volt. *Watt-hours* is a measure of energy; it requires, let us say, an energy of x watt-hours to bring a quantity of water from 0° Centigrade to boiling point, but provided no radiation takes place, this might be 10 watts acting for 50 hours or 500 watts acting for one hour or 30,000 watts acting for one minute; the energy is the same in each case.

As electric power depends upon a voltage times a current, namely, EI, it follows that, since $E = RI$ (Ohm's law), that power is also given by RI^2, the product of resistance and current squared. Furthermore, since $I = \frac{E}{R}$, power, namely, EI, is $\frac{E^2}{R}$, i.e., the square of the voltage divided by resistance.

Electromagnetism. The passage of a current through a conductor causes a *magnetic field* to be set up in the neighbourhood of the conductor. The field may be pictured as consisting of *lines of magnetic force* which give, at every point in the field, the direction of the magnetic force. The density of the lines of force is a measure of the strength of the magnetic field.

When a conductor is moved in a magnetic field so that it cuts the lines of force, an EMF is induced in the conductor, the value of the EMF being determined by the rate at which the lines are cut through. If the moving conductor forms part of a closed circuit, then the EMF induced in it will cause a current to flow in the conductor, always supposing that the resultant EMF is not zero, due to opposing induced EMF's in other parts of the circuit.

Magnetic flux is an attribute of the field produced in the medium in the neighbourhood of a magnet or electric current. The amount of magnetic flux through any area is measured by the quantity of electricity caused to flow in an electric circuit of given resistance bounding the area when the circuit is removed from the magnetic field. This quantity is independent of the time taken in removing the circuit; if the removal is relatively slow, the induced EMF is less, and so the current less, but the time is relatively longer than if a more rapid removal were made. Thus, however slowly or rapidly the circuit is removed from the field, the product of resulting current and time, being the quantity of electricity, remains the same; therefore, the magnetic flux is given by the product of the quantity of the electricity and the resistance of the circuit when the circuit is removed from the magnetic field.

The measure of flux is related to *magnetic flux density*.

The *magnetizing force* at a point is the force associated with the flux density at that point. A *magnetic circuit* is a closed path throughout which a magnetic field is established by a magnetizing force.

The sum of the magnetic forces at all points around a magnetic circuit is said to equal the *magnetomotive force* acting to create the magnetic forces. There is here a similarity to current flowing in a conductive circuit, and caused to flow by an electromotive force, because the sum of the voltage drops (including that in the internal resistance of the source) around the circuit is equal to the electromotive force, just as the sum of the magnetic forces around the magnetic circuit is equal to the magnetomotive force.

Relative Permeability

The magnetic flux density produced by a given magnetizing force in a medium will vary according to a property of the medium. This property is called the *permeability* of the medium. The *relative permeability* of a material or medium is defined as the ratio of the magnetic flux density produced in the material or medium to that produced in a vacuum by the same magnetizing force. Certain ferro-magnetic materials have a relative permeability which is several thousand times that of a vacuum. The relative permeability of air is very nearly unity. Some materials have a relative permeability less than unity.

Electromagnetic induction is the term describing the fact that an EMF is produced in a conductor when lines of magnetic force cut that conductor. Electromagnetic induction may take place in two different ways. The magnetic lines of force may be stationary and the conductor may be in suitable motion, relative to the lines of force, or the conductor may be stationary while the lines of force are in suitable motion relative to the conductor. The latter condition may be established by causing currents to vary in one conductor when the consequently varying magnetic field created by the varying currents cuts another nearby conductor, thus inducing varying EMF's in it. In this condition *mutual induction* is said to take place.

Self-Induction

If, however, only one conductor is in question, forming part of an electrical circuit, then if variable currents are passed through this conductor the varying lines of magnetic flux cut the conductor itself and induce EMF's in it. This process is called *self-induction*, and the property of a conductor, associated with the effects of self-induction, is called its *self-inductance*. This term is commonly abbreviated as *inductance*. Associated with *mutual induction* is the property of *mutual inductance*.

A component designed to have the property of inductance is called an *inductor*. It is inevitable that an inductor has some resistance, but an ideal inductor has the property of inductance and no other electrical property. The more nearly 'ideal' an inductor, the greater the ratio of its inductance to its resistance.

Unidirectional Currents in Capacitors and Inductors. A *unidirectional current* is one which flows in one direction round a circuit but which does not flow at a constant rate.

Suppose a potential difference exists at the terminals of a unidirectional source of electricity and that these terminals are connected, at a given instant, to the terminals of a capacitor. If one terminal of the source is positive and the other negative, then one plate of the capacitor receives a positive charge and the other a negative charge. In order to establish these charges, a quantity of electricity must flow from the source to charge the plates of the capacitor and in so flowing must establish a current in the conductors joining source and capacitor.

After a lapse of time and when the charges are established, i.e. when the plates are at the same potential as the terminals of the source, no more current can flow because a steady current cannot pass through the material insulating the plates of the capacitor. At the instant of connection, the flow of current will be determined by the ratio of the EMF of the source and its internal resistance (assuming the conductors connecting source and capacitor to have negligible resistance), because nothing else exists to limit the current flowing into the capacitor plates to charge them. After a certain lapse of time there is only electric strain in the dielectric in the capacitor which opposes any further flow of electricity from source to capacitor.

These effects can be explained by the assumption that the flow of current is opposed by a back-EMF in the capacitor, this back-EMF being zero at the instant the capacitor is joined and equal to the EMF of the source when the capacitor plates are fully charged.

If an inductor substitutes the capacitor, then at the instant of its connection the rate of change of current in it is maximum, resulting in an induced EMF which has its maximum value owing to the effects of self-induction. This is a back-EMF because it opposes the rise of current. After some lapse of time the current becomes steady, its value being determined by the EMF of the source divided by the internal resistance of the source (assuming the inductor to have negligible resistance).

These effects can be explained by assuming that the inductor, at the moment the circuit is joined, exerts an EMF equal and opposite to the EMF of the source, which back-EMF reduces as time passes until, when a steady current flows, it is zero.

It is to be noted that the relationship between the time of action of the back-EMF in capacitor and inductor is an inverse one, the capacitor back-EMF starts by being zero and builds up in time to a value equal to the EMF of the source; the inductor EMF starts by being equal to the EMF of the source and dies down in time to zero.

Alternating Current. An *alternating current* is one which alternately reverses its direction of flow in a circuit in a periodic manner. An alternating current which executes a period of alternation in the same time continuously can be said to have zero value at one instant, to rise to a maximum in one direction, to fall again to zero, to rise to a maximum value in the other direction, and to come to zero once more. The time taken for the execution of this total process (zero to, say, positive maximum, from positive maximum to zero, from zero to negative maximum, from negative maximum to zero) is called the *period* and is measured as a time.

The complete series of changes just described is called a *cycle of alternation*, or, briefly, a *cycle*.

The term *frequency* describes the number of cycles per given time; it is expressed in practice as a number, giving the number of cycles per second.

In a simple conception, a source of alternating current may be considered to consist of an EMF which acts alternately in one direction and the other through an internal resistance.

If a capacitor be connected across the terminals of a source producing alternating potentials at its terminals, a current will flow, first this way, then that, into the capacitor, because the plates will be charged this way, then that. A limitation of the current, apart from that given by the internal resistance of the source, will be due to the back-EMF produced by the capacitor, because the current flowing into it cannot pass conductively through it and can only be represented as a current which is altering the charge on the capacitor plates, i.e. a *displacement current*.

If an inductor be connected across the terminals of the source of alternating current, then because this current exhibits a rate of change as it rises and falls, so it will create a back-EMF due to the self-induction of the inductor. This back-EMF opposes the alternating EMF of the source and so, in common with the internal resistance of the source, limits the current.

The term *reactance* describes the property of a capacitor or an inductor, which property limits the value of alternating current passing through them in virtue of the back-EMF each produces. Neither a capacitor nor an inductor, if 'pure', has resistance, and so does not absorb power when the alternating current passes through it, whereas a resistance does.

It has been seen that the back-EMF of inductor and capacitor act oppositely in similar circumstances (*see* unidirectional currents) and so their reactances are of opposite sign when added together. This means that the *inductive reactance* and *capacitive reactance* of an inductor and a capacitor, when these components are connected in series, produce back-EMF's which tend to cancel each other; the alternating current flowing in a circuit containing a capacitor and inductor in series may be greater, other things being equal, than when either capacitor or inductor exist in the circuit alone.

When a circuit contains components having reactance and resistance, the combination is said to have *impedance*.

Further and more comprehensive discussion of the behaviour of alternating currents is given in a later section, dealing notably with those important practical questions of phase, power, and the relationships of reactance and frequency.

SYSTEMS OF UNITS

Units. Measurement is essential alike in science and technology. As a means to measure, the units of measurement must be the same when relating one quantity with another; the results of calculation can only be expressed in a useful form when a related system of units is used. It is useless, for example, to express areas in terms of the multiplication of lengths, some of which are measured in centimetres, some in inches; all lengths must be expressed, in this example, in the same units—be they inches, centimetres or yards.

Fundamental units are units of physical quantities that are regarded as fundamental concepts, such as length, mass and time, and *derived units* are units other than fundamental units. *Absolute units* are defined by reference to fundamental units, these being usually length, mass and time. The *centimetre-gramme-second* (abbreviated c.g.s.) system is a system of physical units in which the centimetre, gramme and second are the fundamental units.

Electrical units used in practice, and called *practical units*, are based upon the c.g.s. system, but are numerically adjusted because the c.g.s. units are inconveniently large or small.

There are two systems of absolute units, the *electrostatic system of units* and the *electromagnetic system of units*. Both are based on the c.g.s. system, but the electrostatic system has as its primary electrical unit a unit charge, while the electromagnetic system is based on the definition of unit magnetic pole. Both systems make an arbitrary assumption about the permittivity or permeability of air respectively.

Derived from the c.g.s. system, is the *metre-kilogramme-second system*, the metre being 100 centimetres and the kilogramme 1,000 grammes. The *metre-kilogramme-second electromagnetic system of units* (*M-K-S units*) includes many of the practical units, i.e. ampere, ohm, volt, joule, henry, and farad, and makes an arbitrary assumption about the numerical value of the permeability of free space.

AIDS TO NUMERICAL CALCULATION

Powers of Ten. Although practical units have values which in practice are mostly numerically manageable, some must be expressed in multiples or fractions of the basic practical unit.

The use of 'powers of ten' greatly helps in making numerical calculations, and the use of prefixes such as mega, micro, milli, etc., are conveniently used in describing units which are multiples of ten times or the reciprocal of multiples of ten times the basic practical unit.

The number 1,000,000 may be written 10^6, meaning that a million is 10 multiplied by itself six times, and meaning that a million has six noughts after the initial figure of one. Thus, the number 1,000 is 10^3, the number 10 is 10^1, while the number 1 is 10^0. In fact, neither 10 nor unity is written as 10^1 and 10^0, respectively, although it would be logical, if clumsy, to do so.

The convenience of the power of ten method of expressing numbers is that in multiplication of numbers the 'powers' are simply added, e.g. 1,050,000 multiplied by 300,000 comes to $1{\cdot}05 \times 10^6 \times 3 \times 10^5 = 3{\cdot}15 \times 10^{11}$; the 1·05 and the 3 are multiplied, the power figures, 6 and 5, are added.

The further convenience is that $\frac{1}{10} = {\cdot}1 = 10^{-1}$, while, for another example, $\frac{1}{1{,}000{,}000} = 0{\cdot}000001 = 10^{-6}$.

Thus, because the positive powers of ten are added, $0{\cdot}003 \times 470{,}000 \times 620$ is $3 \times 10^{-3} \times 4{\cdot}7 \times 10^5 \times 6{\cdot}2 \times 10^2 = 3 \times 4{\cdot}7 \times 6{\cdot}2 \times 10^4 = 87{\cdot}42 \times 10^4 = 8{\cdot}742 \times 10^5 = 874{,}200$.

The use of the mega, milli, and micro prefixes is described in Table IV. The foregoing brief introduction concerning fundamental concepts and their quantitative expression, both in terms of units and numerically, is summarized in the following tables.

Symbols commonly used in algebraic expressions are:

$=$	meaning equal to
$\doteqdot$ or $\approx$	,, approximately equal to
$>$	,, greater than
$\gg$	,, much greater than
$<$	,, less than
$\ll$	,, much less than
$\ngtr$	,, not greater than
$\nless$	,, not less than
Σ	,, sum of
$\lvert A \rvert$	where A is any symbol meaning the magnitude but not the direction and magnitude of A.
$\frac{dy}{dx}$	meaning the rate of change of y with x.

TABLE I

Term	Brief description	Letter symbol
Static electricity ..	Electricity at rest and existing in excess in charged bodies	
Direct current ..	Electricity flowing uniformly in a conductor in one direction	DC
Alternating current ..	Electricity flowing alternately in reverse directions in a periodic manner	AC
Unidirectional current	Electricity flowing in one direction but not at a constant rate of flow	
Electromagnetism ..	Magnetic effects produced in the neighbourhood of a conductor in which electricity is flowing in any manner	
Charge of electricity	The excess of positive or negative electricity on a body or in space	
Potential difference (abbreviated P.D.)	A difference between the electrical states existing at two points, tending to cause a movement of electricity from one point to another	V
Electric force ..	A force exerted in the neighbourhood of a charged body on other charged or uncharged bodies	
Electric field	The space in the neighbourhood of a charged body throughout which an electric charge experiences a mechanical force. (An electric force is exerted by a *varying* magnetic field.)	
Line of electric force ..	A line drawn in an electric field which gives at all points in the field the direction of the electric force at these points	
Displacement ..	The displacement of electricity in a conductor or a dielectric due to the action of electric forces	
Dielectric	A medium across which a quantity of electricity may be displaced but which is incapable of conducting electricity through it	
Insulating material ..	Material which offers a relatively high resistance to the passage of an electric current	
Electric flux	A phenomenon produced in the medium in the neighbourhood of a charged body and related to the conception of lines of electric force	
Relative permittivity ..	Referred to a dielectric. The property of a dielectric in relation to its effect in concentrating electric flux in it when acted upon by an electric force	K
Capacitance	The property of a conductive body by virtue of which a quantity of electricity has to be contained in it to produce a difference of potential between the body and surrounding bodies	C
Capacitor	A component capable of storing electrical energy in the form of electrical stress in insulating material placed between conductive surfaces which are electrically separated by the insulating material	

TABLE I—*continued*

Term	Brief description	Letter symbol
Electromotive force (abbreviated EMF)	Of a source of electricity—that force which tends to cause a movement of electricity in a circuit	E
Electric current ..	The flow of electricity along any path or round any circuit	I
Resistance	That property of a body by virtue of which it resists the flow of electricity through it	R
Ohm's law	The resistance of the majority of metallic conductors is independent of the potential acting across them and the consequent current flowing in them, provided the conductor is kept at a constant temperature	
Conductance ..	The reciprocal of resistance	G
Voltage drop ..	The voltage between any two points on a conductor with current flowing in it. The voltage across a resistor with current flowing in it	
Internal resistance ..	Of a source. Resistance concealed in a source and existing between physically inaccessible terminals	
Quantity of electricity	The term is self-explanatory, but see Table II	
Electric power ..	The rate at which energy is converted from electrical to other forms	W
Magnetic field ..	The space in the neighbourhood of an electric current or a permanent magnet throughout which magnetic forces can be detected	
Line of magnetic force	A line drawn in a magnetic field such that its direction at every point is the direction of magnetic force at that point	
Magnetic flux ..	A phenomenon produced in the medium in the neighbourhood of electric currents or magnets and associated with lines of magnetic force	Φ
Magnetic flux density	At a point. The amount of magnetic flux per unit area, the area being in a position which gives a maximum value for the flux	
Magnetizing force ..	The force at a point which produces or is associated with the flux at that point	H
Magnetic circuit	A closed path in a magnetic field	
Magnetomotive force	Around a magnetic circuit. The force which establishes the magnetic forces around a magnetic circuit	F
Permeability ..	The property of a medium described in relation to its effect of concentrating magnetic flux in it when acted upon by a magnetizing force	μ
Electromagnetic induction	The production of an electromotive force in a circuit by a change of magnetic flux in the circuit	
Mutual induction ..	The production of an EMF in one circuit by electromagnetic induction caused by varying currents in another circuit	

TABLE I—*continued*

Term	Brief description	Letter symbol
Self-induction	The production of an EMF in a circuit due to the varying currents in that circuit	
Self-inductance (abbreviated inductance)	The property of a circuit by virtue of which self-induction occurs	L
Mutual inductance ..	The property of a circuit by virtue of which mutual induction occurs	M
Inductor	A component designed to have principally the property of inductance	
Back-electromotive force (abbreviated back-EMF)	An induced electromotive force which opposes the normal flow of current	
Period	The minimum time interval at which similar characteristics of an alternating current or voltage are repeated, the alternations being such as to make this time always the same	
Cycle	The complete series of changes executed by an alternating current or voltage during a period	
Frequency	The number of cycles (of alternation) occurring in a defined time	f
Reactance	A property associated both with capacitance and inductance which causes a back-EMF tending to oppose the flow of an alternating current	X
Impedance	A property associated with a circuit containing both resistance and reactance which limits the value of alternating current flowing in the circuit according to the value of the impedance	Z

TABLE II

Term	Definition (practical units)	Practical unit (unless otherwise stated)	Letter symbol of unit
Unit charge. Unit quantity of electricity	That quantity of electricity which passes through a conductor in one second when the mean current is one ampere	Coulomb	C
Potential difference. Electromotive force	That electromotive force or potential difference which applied steadily to a conductor the resistance of which is one ohm produces a current of one ampere	Volt	V

TABLE II—*continued*

Term	Definition (practical units)	Practical unit (unless otherwise stated)	Letter symbol of unit
Electric force	Measured in magnitude and direction at any point by the mechanical force per unit charge experienced by a very small body placed at that point	Volt per unit length	**E**
Relative permittivity	Of a medium. The ratio of the electric flux density produced in the medium to that produced in free space by the same electric force		
Electric flux	The quantity of electricity displaced across a given area in a dielectric. The total flux displaced across a surface enclosing a charge equals the charge		
Electric flux density	The electric flux per unit area normal to the direction of the flux		**D**
Capacitance	The ratio of a charge on a conductor to its potential when all neighbouring conductors are at zero potential. The ratio of the charge of a capacitor, i.e. the total flux between its electrodes to the potential difference between them	Farad	**F**
Electric current	Unit current is that which deposits 1·11800 milligramme of silver per second from a solution of silver nitrate	Ampere	**A**
Resistance	Of a body. Given by the constant difference of potential applied to the ends of the body divided by the current which it produces, no EMF being assumed to act in the body. The *international ohm* is the resistance offered at the temperature of melting ice to an unvarying electrical current by a column of mercury 14·4521 grammes in mass of uniform cross-sectional area and 106·300 centimetres in length	Ohm	Ω
Conductance ..	Unit conductance is the conductance of a body having a resistance of one ohm	mho	
Power	Unit power is the energy expended in one second by an unvarying current of one ampere produced by a voltage of one volt. (For consideration of power and alternating current, see later sections.)	Watt	**W**

TABLE II—*continued*

Term	Definition (practical units)	Practical unit (unless otherwise stated)	Letter symbol of unit
Energy	Unit of energy, the energy expended in one hour when the power is one watt. One watt-hour = 3,600 joules	Watt-hour	Wh
Magnetizing force	The mechanical force experienced by unit magnetic pole placed at the point where the force is measured. In EM units the force in dynes exercised on unit pole	Oersted (EM unit)	
Magnetomotive force	Along any path. The sum of the magnetic forces around the path. If the path is closed, this is 0·4 π times the ampere-turn	Gilbert (EM unit)	
	The ampere-turns is the multiplication of the turns on a coil and the current in amperes flowing in the coil	Ampere-turn	AT
Amount of magnetic flux	Through any area, measured by the quantity of electricity caused to flow in a circuit bounding the area when the circuit is removed from the area. Unit magnetic flux (EM units) is that flux the removal of which from a circuit of unit resistance causes one electromagnetic unit of electricity to flow	Maxwell (EM unit)	
Magnetic flux density	The amount of magnetic flux per square centimetre over a small area	Gauss (EM unit) (1 gauss = 1 maxwell per square centimetre)	B
Relative permeability	Of a medium. The ratio of the magnetic flux density produced in the medium to that produced in space by the same magnetizing force		
Inductance (self-inductance)	The practical unit of inductance (the henry) is equal to 10^8 flux linkages per ampere	Henry	H
Frequency ..	Measured in cycles per second ..	Cycle/Sec.	c/s
Reactance ..	Of a capacitor: has a numerical value given by the reciprocal of the product of 2 π times the frequency in cycles per second and the capacitance in farads Of an inductor: has a numerical value given by the product of 2 π times the frequency in cycles per second and the inductance in henries	Ohm	Ω

TABLE III

Term	Symbol	Principal relationship with other quantities expressed algebraically
Potential	V	$V = \frac{Q}{C}$
Capacitance	C	$C = \frac{Q}{V}$
Charge	Q	$Q = CV$
Electromotive force, potential difference	E	$E = RI = \frac{I}{G}$
Resistance	R	$R = \frac{E}{I}$
Current	I	$I = \frac{E}{R} = EG$
Conductance	G	$G = \frac{I}{E} = \frac{1}{R}$
Power	W	$W = EI = \frac{E^2}{R} = RI^2$
Magnetic flux density ..	B	$B = \mu H$
Magnetizing force ..	H	$H = \frac{B}{\mu}$
Permeability	μ	$\mu = \frac{B}{H}$
Frequency	f	
Angular frequency ..	ω	$\omega = 2\pi f$
Reactance	X	
Reactance (of a capacitor)	X_C	$X_C = \frac{1}{\omega C}$
Reactance (of an inductor)	X_L	$X_L = \omega L$
Impedance (of a circuit containing resistance and reactance)	Z	$Z = \sqrt{R^2 + X^2}$

TABLE IV: PREFIXES

Prefix	Letter symbol	Interpretation	Example
Mega or meg	M	Millions of	1 megohm $= 10^6$ ohms
Kilo	k	Thousands of	1 kilocycle per second $= 10^3$ cycles per second
Deci	d	Tenths of	1 decibel $= 10^{-1}$ bel
Milli	m	Thousandths of	1 milliamp $= 10^{-3}$ amp
Micro	μ	Millionths of	1 microfarad $= 10^{-6}$ farad
Pico or micro-micro	p or $\mu\mu$	Million-millionths of	1 pico-farad, 1 micro-microfarad $\} = 10^{-12}$ farad

TABLE V: ABBREVIATIONS SOMETIMES USED IN TABLES, TEXT AND DIAGRAMS

A	=	Ampere
A, or AE	=	Aerial
A battery	=	Low-tension battery (American)
AC	=	Alternating current
AC-DC	=	All mains
Acc	=	Accumulator
AF	=	Audio frequency
AFC	=	Automatic frequency control
AG	=	Auxiliary grid
Ah	=	Ampere-hour
Amps	=	Amperes
AM	=	Amplitude modulation
AT	=	Ampere-turn
AVC	=	Automatic volume control
B	=	Magnetic flux density, or Press button
B battery	=	High-tension battery (American)
B/D, or Brd	=	Braided wire
BF	=	Beat frequency
B and S	=	Brown and Sharpe gauge
Batt	=	Battery
BT	=	Bellini-Tosi system of direction finding
BWG	=	Birmingham wire gauge
C	=	Capacitance, capacitor, or coulomb
C battery	=	Grid-bias battery (American)
CB	=	Circuit-breaker
Cm	=	Centimetre. Used on Continental capacitors to indicate capacitance. 1 cm = 1·1 μμF
Cp	=	Counterpoise
cps, or c/s	=	Cycles per second
CR	=	Cathode ray
CW	=	Continuous wave
D	=	Electric flux density
dB	=	Decibel
DC	=	Direct current
DCC	=	Double cotton-covered wire
Det	=	Detector
DF	=	Direction finding
DIR	=	Double rubber-covered wire
DPC	=	Double paper-covered wire
DPR	=	Double-lapped pure rubber-covered wire
DSC	=	Double silk-covered wire
DX	=	Distant (reception)
E	=	Earth, or electromotive force
EHT	=	Extra-high tension
EM	=	Electromagnetic
EMF	=	Electromotive force
Enam	=	Enamelled wire
ES, or EX	=	Extension speaker
f	=	Frequency
F	=	Farad, or fuse, or magnetomotive force
FC	=	Frequency-changer valve
FM	=	Frequency modulation
ω	=	Frequency × 2π
G	=	Generator, or grid, or conductance
GB	=	Grid bias
H	=	Henry, or magnetizing force
HC	=	High-conductivity wire
HD	=	Hard-drawn copper

Het	= Heterodyne
HF	= High frequency
HMT	= Hand micro-telephone
HT	= High tension
I	= Current
IC	= Intercommunication
ICW	= Interrupted continuous wave
IF	= Intermediate frequency
IFT	= Intermediate frequency transformer
Int	= Interrupter
J	= Jack
K	= Permittivity (relative), or Morse key
Kc/s	= Kilocycles per second
kVA	= Kilovolt amperes
kW	= Kilowatt
kWh	= Kilowatt-hours
λ	= Wavelength
L	= Inductance, or inductor
La	= Lamp
Lam	= Laminated
LF	= Low (audio) frequency
LS	= Loudspeaker
LT	= Low tension
LW	= Long wave
M	= Meter, or mutual inductance
m	= Metre
MA	= Mains aerial
mA	= Milliamperes
mA/V	= Milliamperes per volt
Mc/s	= Megacycles per second
MC	= Moving coil
MCW	= Modulated continuous wave
meg	= Megohm
MF	= Medium frequency
mFd, or μF	= Microfarad
MG	= Motor generator
μH	= Microhenry
Mic	= Microphone
mmFd, or $\mu\mu$F	= Micro-microfarad
MO	= Master oscillator
mH	= Millihenry
μ	= Permeability, or amplification factor
mV	= Millivolt
MW	= Medium wave
N	= Neon tube
Ω	= Ohm
Osc	= Oscillator
P	= Padding condenser, or plug
PA	= Public address
PB	= Pushbutton
PC	= Photo-electric cell
Pen	= Pentode
pF	= Pico-farad (one mmFd)
Φ	= Magnetic flux
PL	= Lamp signal, or pilot lamp
PM	= Permanent magnet
Pot	= Potentiometer
PU	= Pick-up
PUC	= Polyvinyl chloride (plastic) covered cable
QPP	= Quiescent push-pull
R	= Resistance, or resistor
RC	= Remote control
RCC	= Resistance-capacitance coupled
Rec	= Rectifier, or receiver
Rel	= Relay
RF	= Radio frequency
RT	= Radio-telephony
S, or Sw	= Switch
SCC	= Single cotton-covered wire
SD	= Soft drawn copper wire

SG	= Screen grid	TRF	= Tuned radio-frequency
S/het	= Superheterodyne receiver		
SIR	= Wire with single rubber lapping	USW	= Ultra-short wave
Spk	= Loudspeaker		
SR	= Starting relay	V	= Potential difference, volt, valve
SSC	= Single silk-covered wire	VA	= Volt-ampere
SW	= Short wave	VF	= Video frequency
SWC	= Single white silk-covered wire	Vib	= Vibrator
		VIR	= Vulcanized india-rubber cable
SWG	= Standard wire gauge		
Sync	= Synchronizing	Vol	= Volume control
T	= Trimming condenser, transformer, transmitter	W	= Power, or watt; rectifier
		W/C	= Wave-change switch
TCC	= Triple cotton-covered wire	Wh	= Watt-hour
		WT	= Wireless telegraphy
Tel	= Telephone		
TI	= Tuning indicator	X	= Reactance, or crystal
TPC	= Triple paper-covered wire	X's	= Atmospherics
TR	= Transmitter-receiver		
Trans	= Transformer	Z	= Impedance

RADIATION OF WAVES

An aerial is a structure capable of radiating waves when it is successively charged, this way and then that, which process results in alternating currents flowing in the aerial.

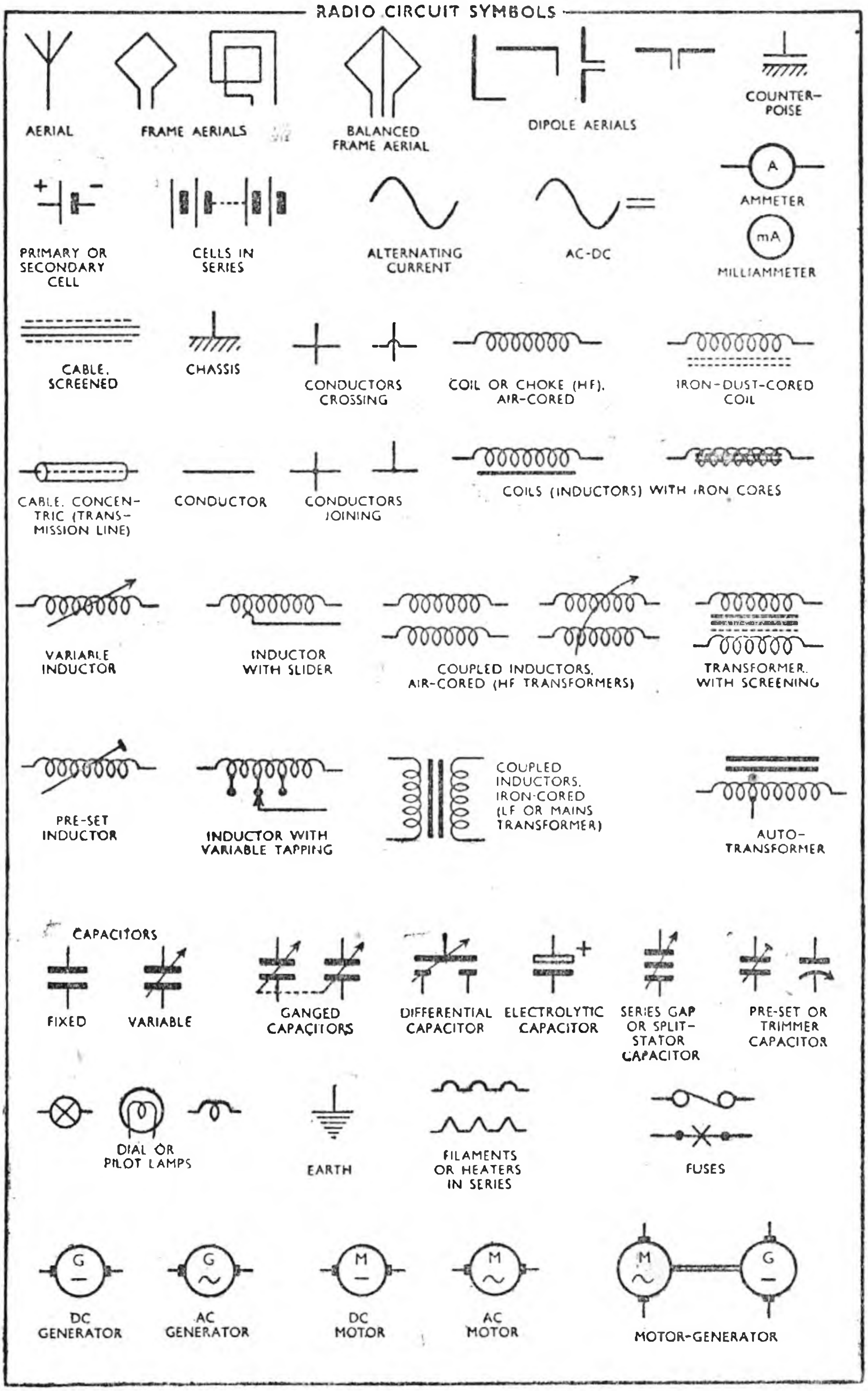
The relationship between the length of the wave radiated from the aerial and the frequency of the currents flowing in the aerial is that the product of these two quantities is equal to a constant; therefore, the higher the frequency of the currents causing waves to be radiated, the shorter the length of the wave. If the waves are radiated into space, then the product of the frequency of the aerial currents, expressed as cycles per second, and the length of waves in centimetres, is very nearly equal to 3×10^{10} cms per sec., which is the assumed velocity of light. This velocity is approximately 186,000 miles per sec.

Waves are classified both as to their length and, as it is called, their frequency, meaning basically the frequency of the alternating currents flowing in the sending aerial.

Some qualitative descriptions are attempted, such as short waves, long waves, ultra-short waves, and so forth. (See Fig. 2.)

The British Standards Institution publishes information, set out in tabular form on page 26, which attempts to standardize usage.

Note that the product of wave-length in metres and frequency in kilocycles per second is the number 300,000, but also note that this



RADIO CIRCUIT SYMBOLS
AERIAL
FRAME AERIALS
BALANCED FRAME AERIAL
DIPOLE AERIALS
COUNTER-POISE
+ −
PRIMARY OR SECONDARY CELL
CELLS IN SERIES
ALTERNATING CURRENT
AC-DC
A
AMMETER
mA
MILLIAMMETER
CABLE, SCREENED
CHASSIS
CONDUCTORS CROSSING
COIL OR CHOKE (HF), AIR-CORED
IRON-DUST-CORED COIL
CABLE, CONCENTRIC (TRANSMISSION LINE)
CONDUCTOR
CONDUCTORS JOINING
COILS (INDUCTORS) WITH IRON CORES
VARIABLE INDUCTOR
INDUCTOR WITH SLIDER
COUPLED INDUCTORS, AIR-CORED (HF TRANSFORMERS)
TRANSFORMER, WITH SCREENING
PRE-SET INDUCTOR
INDUCTOR WITH VARIABLE TAPPING
COUPLED INDUCTORS, IRON-CORED (LF OR MAINS TRANSFORMER)
AUTO-TRANSFORMER
CAPACITORS
FIXED
VARIABLE
GANGED CAPACITORS
DIFFERENTIAL CAPACITOR
+
ELECTROLYTIC CAPACITOR
SERIES GAP OR SPLIT-STATOR CAPACITOR
PRE-SET OR TRIMMER CAPACITOR
DIAL OR PILOT LAMPS
EARTH
FILAMENTS OR HEATERS IN SERIES
FUSES
G
DC GENERATOR
G
AC GENERATOR
M
DC MOTOR
M
AC MOTOR
M G
MOTOR-GENERATOR

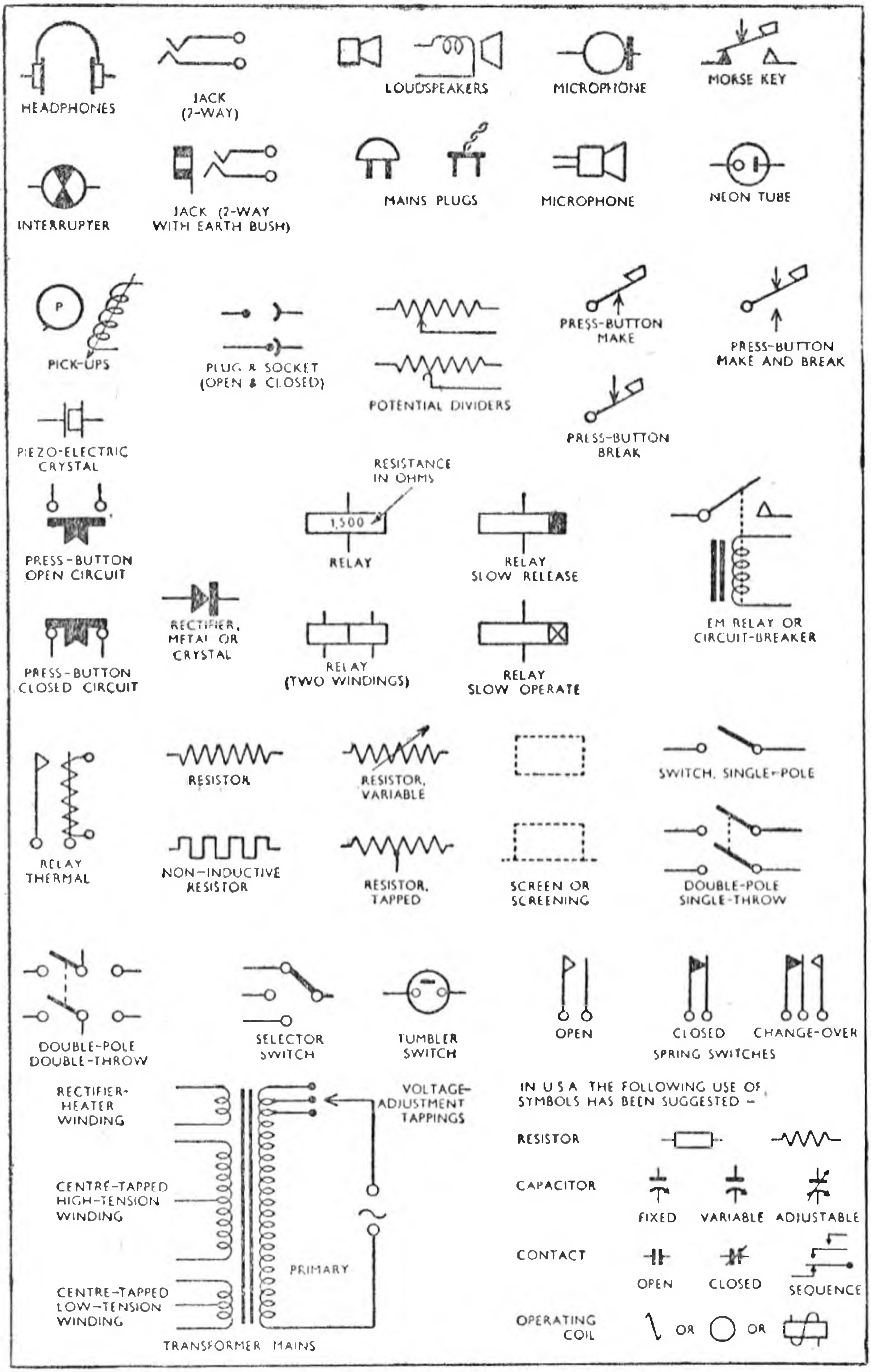

HEADPHONES
JACK (2-WAY)
LOUDSPEAKERS
MICROPHONE
MORSE KEY
INTERRUPTER
JACK (2-WAY WITH EARTH BUSH)
MAINS PLUGS
MICROPHONE
NEON TUBE
PICK-UPS
PLUG & SOCKET (OPEN & CLOSED)
POTENTIAL DIVIDERS
PRESS-BUTTON MAKE
PRESS-BUTTON MAKE AND BREAK
PRESS-BUTTON BREAK
PIEZO-ELECTRIC CRYSTAL
RESISTANCE IN OHMS
1,500
RELAY
RELAY SLOW RELEASE
EM RELAY OR CIRCUIT-BREAKER
PRESS-BUTTON OPEN CIRCUIT
RECTIFIER, METAL OR CRYSTAL
RELAY (TWO WINDINGS)
RELAY SLOW OPERATE
PRESS-BUTTON CLOSED CIRCUIT
RELAY THERMAL
RESISTOR
RESISTOR, VARIABLE
SWITCH, SINGLE-POLE
NON-INDUCTIVE RESISTOR
RESISTOR, TAPPED
SCREEN OR SCREENING
DOUBLE-POLE SINGLE-THROW
DOUBLE-POLE DOUBLE-THROW
SELECTOR SWITCH
TUMBLER SWITCH
OPEN
CLOSED
CHANGE-OVER
SPRING SWITCHES
RECTIFIER-HEATER WINDING
VOLTAGE-ADJUSTMENT TAPPINGS
CENTRE-TAPPED HIGH-TENSION WINDING
PRIMARY
CENTRE-TAPPED LOW-TENSION WINDING
TRANSFORMER MAINS
IN U S A THE FOLLOWING USE OF SYMBOLS HAS BEEN SUGGESTED –
RESISTOR
CAPACITOR
FIXED
VARIABLE
ADJUSTABLE
CONTACT
OPEN
CLOSED
SEQUENCE
OPERATING COIL
OR
OR

TABLE VI

According to Wavelength	
Description	**Length in metres**
Myriametric	Above 10,000
Kilometric	10,000 to 1,000
Hectometric	1,000 to 100
Decametric	100 to 10
Metric	10 to 1
Decimetric	1 to 0·1
Centimetric	0·1 to 0·01

According to Frequency	
Description	**Frequency in kilocycles per second**
Very-low frequency	Below 30
Low frequency	30 to 300
Medium frequency	300 to 3,000
High frequency	3,000 to 30,000
Very-high frequency	30,000 to 300,000
Ultra-high frequency	300,000 to 3,000,000
Super-frequency	3,000,000 to 30,000,000

assumes that the velocity of light is 3×10^{10} cms per sec. Since the measurement of the velocity of light depends upon experimental results, and because different experimenters have not found exactly the same result, therefore the figure for the velocity of light is an approximation, though a very near one.

It is not possible to give the range of senders in accordance with the wavelength used, because this depends upon many factors, such as the power of the sender, its location (with the higher frequencies, particularly as regards its elevation above the earth's surface), the signal-to-noise ratio at the receiver and the relevance of this ratio to the requirements of signalling.

Waves radiated from sending aerials follow different ray paths, some which run parallel to the earth's surface but leave this approximately tangentially when the earth's curvature becomes a relevant factor. Other waves are radiated skywards along paths making an angle to the earth's surface.

Consistent reception is the more possible as the receiver is better located to pick up the waves passing over the earth's surface. Nevertheless, the sky-seeking waves may be turned earthwards again by effects produced in the electrified layers in the upper atmosphere, called the ionosphere.

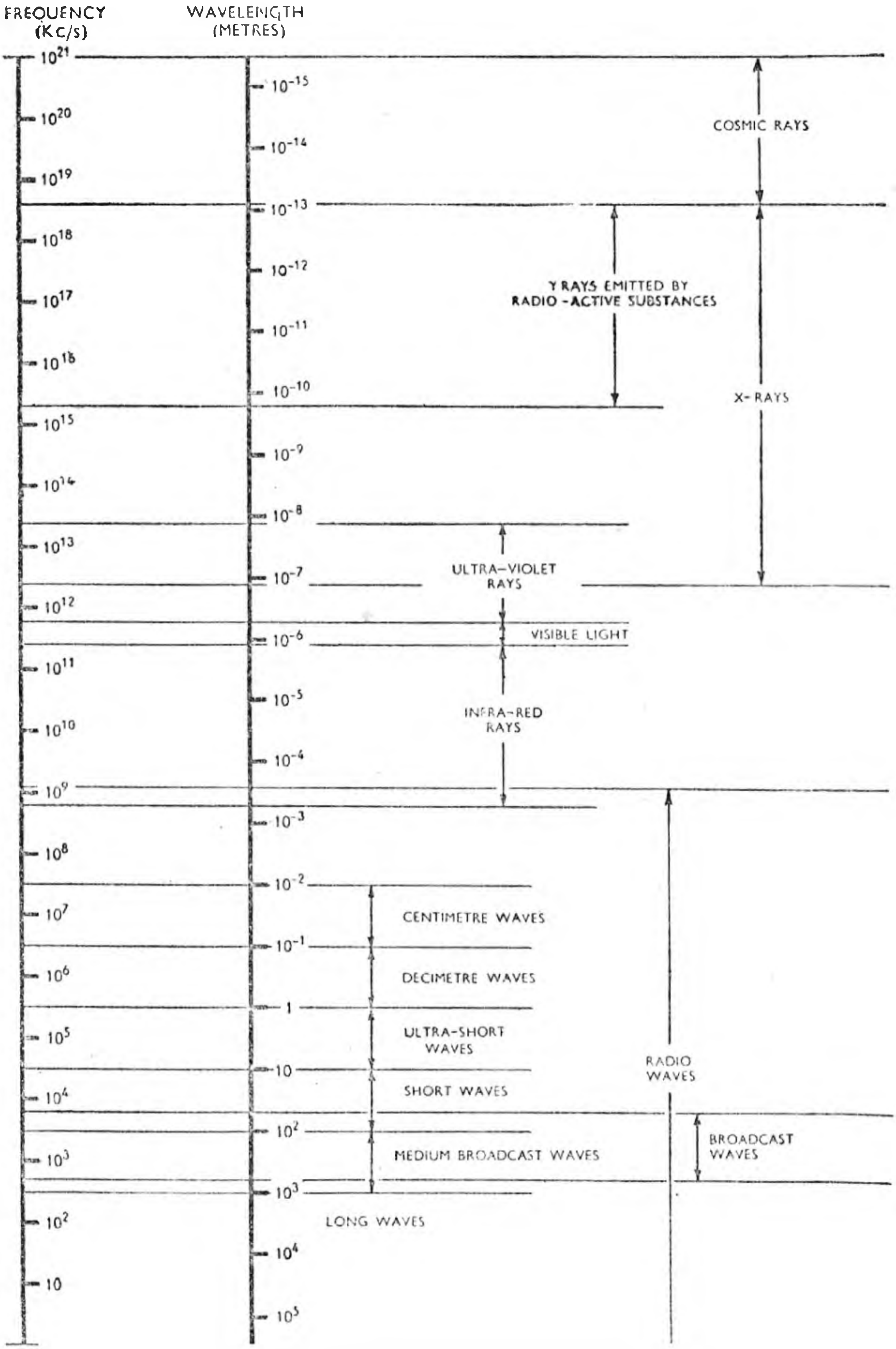
Electrical changes in the atmosphere cause noise to be reproduced in receivers, and such noise may interfere with reception. This noise is referred to as *atmospherics*. The longer the wave, other things being equal, the greater the liability to noise from atmospherics.

The longer the wave, however, the greater the strength of the ground waves, at a given distance, for senders of the same power and with equally efficient aerial systems.

Decametric waves may be bent earthwards at the ionosphere in spite of the effect of the sun's rays on it; hectometric, kilometric and myriametric waves are more strongly received when sun's rays no longer impinge on the upper atmosphere.

All these factors lead to a choice of waves for different services, in which the decametric waves are used for signalling over world distances, with a certain unreliability in reception, because of the variable effects of ionospheric behaviour. Hectometric waves are used for broadcasting, where great reliability is essential, and where ground-ray reception gives this; while the longer waves are used for signalling over continental distances.

The use of metric, decimetric and centimetric waves is being explored and yielding satisfactory results for signalling over distances of the order 10 to 100 miles; range of the senders being greatly enhanced as they are elevated above the earth's surface.



ELECTROMAGNETIC WAVE SPECTRUM

Fig. 2. Depending on frequency and wavelength, ether waves have many different characteristics and uses, and these are clearly explained in this layout and text.

SECTION 2

CALCULATIONS CONCERNING DIRECT CURRENT

Relationships between Voltage, Current and Resistance. It is known from Ohm's law that $E = RI$; put into words, this means that the voltage acting across a conductor of resistance R is equal to that resistance multiplied by the current flowing in that resistance, care being taken to use the appropriate units.

Since $E = RI$, therefore, $I = \frac{E}{R}$ and $R = \frac{E}{I}$, showing that if two quantities are known the third may be calculated. A way to remember the equivalences is to put the symbols in this form, namely, $\frac{E}{RI}$, when the blotting out of any one of the symbols gives the expression for the remaining two. Blot out E and get RI (which E is equal to), blot out I and get $\frac{E}{R}$ (which I is equal to), blot out R and get $\frac{E}{I}$ (which R is equal to).

A further point of practical importance, particularly when doing mental arithmetic, is that E comes out in volts if I is expressed in milliamps and R in k/ohms (thousands of ohms). For instance, if R is 5,000 ohms, that is, 5×10^3 ohms, or 5 k/ohms, and I is ·003 amp, that is, 3×10^{-3} amps, or 3 milliamps, then E is $3 \times 10^3 \times 5 \times 10^{-3} = 15$ volts. In other words, k/ohms times milliamps is volts.

Equally, when a ratio is involved, e.g., $R = \frac{E}{I}$, R will come out in ohms if E is expressed in microvolts and I in microamps or E is expressed in millivolts and I in milliamps; in general, any, but always the same, units may be used for the ratios $\frac{E}{I}$ or $\frac{E}{R}$. Therefore, with 250 millivolts acting and a current of 5 milliamps flowing, the resistance acted upon is, $\frac{250 \times 10^{-3}}{5 \times 10^{-3}} = \frac{250}{5} = 50$ ohms.

To give some examples, in which the results derived from Ohm's law are relevant, we may want to know what is the voltage drop across the fixed winding of a motor if the winding has a resistance of 1,500 ohms and passes a current of 50 milliamps. Since $E = RI$, therefore, the voltage dropped is $1{\cdot}5 \times 10^3 \times 50 \times 10^{-3} = 75$ volts.

Suppose, for another example, that a potential divider has a total resistance of 1·25 megohm and 1,500 volts act across it, what is the current through it? (This is a case in which the current is often called a bleeder current, because current is 'wasted' with the object of obtaining at the slider of the potential divider a voltage less than the total voltage.) Given $I = \frac{E}{R}$, then, in the example, $I = \frac{1{\cdot}5 \times 10^3}{1{\cdot}25 \times 10^6} = 1{\cdot}2 \times 10^{-3} = 1{\cdot}2$ milliamp $= 0{\cdot}0012$ amp.

Let the voltage applied to a heater circuit be 250 volts and the resulting current 0·3 amp, what is the total resistance of the circuit?

Since $R = \frac{E}{I}$, therefore, in this case, $R = \frac{250}{0{\cdot}3} = 833{\cdot}\dot{3}$ ohms.

This last example, in which the 3 after the decimal point is written $\dot{3}$, to show that 3 goes on recurring (i.e. it is 833·3333, and so on), introduces the idea of significant figures.

We could say that the resistance was approximately 833 ohms. Since three figures are used, the approximation is expressed in three significant figures. If the number were written 833·3, four significant figures would be used; therefore, 0·007352 is a number with four significant figures. Incidentally, if a result comes to, say, 845·7, its expression in three significant figures is 846, because the ·7 brings it nearer to 846 than 845. In expressing numerical values in practical radio work, three significant figures are usually enough because the accuracy of measurement is not often so great as to justify the use of more.

Power. The practical unit of electrical power is the watt and it is expended when one ampere flows due to a voltage of one volt. The electrical power W, expended in any way, may be measured, in a DC system, by the steady current flowing in the circuit in which the power is expended multiplied by the volts acting, or $W = EI$.

But since $E = RI$, therefore, $W = RI^2$.

Also, since $I = \frac{E}{R}$, $W = \frac{E^2}{R}$.

Table VII gives these equivalences in convenient form.

When a current flows in a resistor, electrical energy is converted into heat in the resistor. If the current be excessive in relation to the ability of the resistor to carry it, the resistor gets very hot and may be destroyed. Resistors are rated in terms of the watts that can be dissipated in them without danger to their life, and without unduly affecting the resistance of the resistor, permanently or temporarily.

A problem might arise in which it was necessary to obtain a voltage drop of 100 volts in a resistor when 25 milliamps were passed through it. How many watts would be required to be dissipated in the resistor? The answer, from $W = EI$, is $W = 10^2 \times 25 \times 10^{-3} = 25 \times 10^{-1} = 2{\cdot}5$ watts. Therefore, a 2·5-watt rating is the minimum rating to be chosen for the resistor; it is better practice to choose a higher rating, say, 3·0 watts.

TABLE VII : EQUIVALENCES IN DC CIRCUITS

I = current, E = voltage, R = resistance, W = power.
$I = \frac{E}{R} = \sqrt{\frac{W}{R}} = \frac{W}{E}$.
$E = RI = \sqrt{WR} = \frac{W}{I}$.
$R = \frac{E}{I} = \frac{E^2}{W} = \frac{W}{I^2}$.
$W = EI = I^2R = \frac{E^2}{R}$.
Units: I in amps, E in volts, R in ohms, W in watts.

Running Costs. Electricity is sold to the public in accordance with a stated cost of electrical energy. The so-called 'unit' is one kilowatt-hour; it is the energy expended in one hour when the power is one thousand watts. Given certain known values of voltage, currents, resistances, etc., it is possible to calculate the units of energy and the cost of using this energy.

For example, suppose a radio receiver energized from 250-volt DC mains takes a total current of 0·5 amp, then the power is 125 watts. Suppose a unit (of energy) costs 2d., what is the cost per hour of running the receiver? The power is 125 watts, or 0·125 kilowatt, so that in one hour 0·125 unit is used. Since the cost is assumed to be 2d. a unit, the cost per hour is $2 \times 0{\cdot}125$ pence, or ·250 pence, i.e. a farthing an hour.

The question of the cost has been specifically referred to a DC circuit. Provided certain questions of power factor and the method of measuring the current are taken into account, the expressions are applicable equally to the case where the mains supply is of alternating current form.

SECTION 3

SERIES AND PARALLEL CONNECTIONS

Resistors in series. The total resistance of any number of resistors connected in series, and having various values of resistance, is the sum of the values of all the resistances. Thus, in Fig. 3,

$$R = R_1 + R_2 + R_3.$$

Resistors in parallel. The total conductance of any number of resistors connected in parallel and having various values of resistance is the sum of the conductances of all the resistors so connected. Thus, in Fig. 4,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

This gives R.

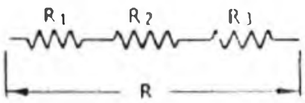


Fig. 3. (Above) Three resistors in series.

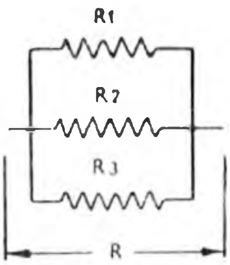


Fig. 4. (Right) Three resistors in parallel.

Resistance networks. The total resistance of some forms of resistance networks can be found by calculating the resistance of groups of resistors forming the network, until the network is resolved into the simplest form containing what are effectively a number of single resistors in series or one resistor. This method cannot be used in all cases (e.g. certain bridges), and the use of Kirchhoff's laws is then convenient.

Numerical examples. The *series connection* of resistors of value 10,000 ohms, 35,000 ohms, and 50,000 ohms is 95,000 ohms. The *parallel connection* of resistors of 10,000 ohms, 50,000 ohms, and 100,000 ohms gives a conductance of $\frac{1}{10{,}000} + \frac{1}{50{,}000} + \frac{1}{100{,}000} = 1 \times 10^{-4} + 0{\cdot}2 \times 10^{-4} + 0{\cdot}1 \times 10^{-4} = 1{\cdot}3 \times 10^{-4}$ mhos, or $\frac{1}{1{\cdot}3} \times 10^4$ ohms, or 7,692 ohms, using four significant figures.

The resistance of the network of Fig. 5 is given by first adding the

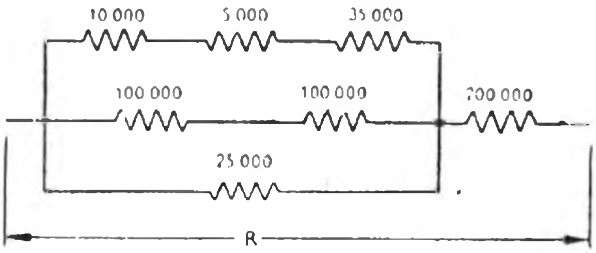
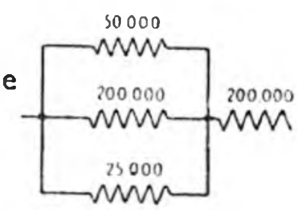


Fig. 5. A network of resistors consisting of both series and parallel arrangements.

values of the resistors which are in series in each arm and so deriving Fig. 6. It is then possible to add the conductances $\frac{1}{50{,}000}$, $\frac{1}{200{,}000}$ and $\frac{1}{25{,}000}$ to make a resistance of 15,380 (four significant figures), which is added to 200,000 to make 215,400 ohms (four significant figures).

Laborious calculation gives 215,384·6 ohms, and if the figure were thus written the implication would be that the resistances themselves could be measured to one part in ten million. This is, of course, quite impracticable, in ordinary everyday work, and even if it were feasible with the finest instruments to measure to this accuracy the resistors would, unless of very special construction and kept in constant conditions, never maintain a value deserving such close measurement.

Fig. 6. What is the total resistance ?



Inductors in series. The total inductance of a number of inductors connected in series and having various values (it being assumed that the inductors are not coupled to one another to add or subtract mutual inductance) is the sum of the inductances of all the inductors so connected. In Fig. 7,

$$L = L_1 + L_2 + L_3.$$

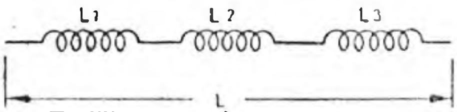


Fig. 7. Three inductors in series.

Inductors in parallel. There is no term relative either to inductance or capacitance to describe the reciprocals of these quantities, and so we must say that the reciprocal of the total inductance of a number of inductors in parallel is the sum of the reciprocals of the several inductances so connected, or, as in Fig. 8,

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}.$$

This gives L.

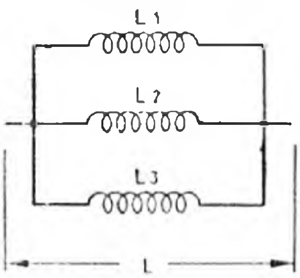


Fig. 8. Three inductors in parallel.

Inductors are treated as resistors; when in series their values are added, when in parallel the reciprocal of the total inductance is given by the sum of the reciprocals of the individual inductors.

Capacitors in parallel. The total capacitance of a number of capacitors in parallel is the sum of the capacitances of all the capacitors, or, as in Fig. 9,

$$C = C_1 + C_2 + C_3.$$

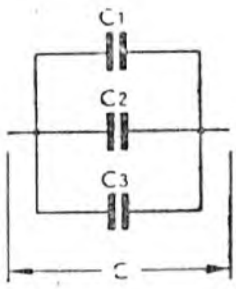
Capacitors in series. The reciprocal of the total capacitance of a number of capacitors in series is the sum of the reciprocals of all the capacitors so connected. Thus, in Fig. 10,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3},$$

which gives C.

No good object is served by giving numerical examples concerning inductors, since the treatment is exactly the same as for resistors, but, so as to make the principles clear, we may consider, without using numerical values, how to calculate the total capacitance of the combination shown in Fig. 11.

First, we should tackle that part of the network containing C_1, C_2 and C_3. The capacitance of C_1 and C_2 in series, which we might call C_a, would be given by $\frac{1}{C_a} = \frac{1}{C_1} + \frac{1}{C_2}$. Having got C_a, we add it to the (parallel) value of C_3. Let C_a and $C_3 = C_b$. Then the total capacitance



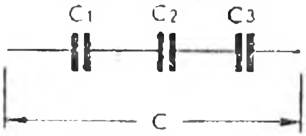


Fig. 9 (Left). Three capacitors in parallel.

Fig. 10 (Above) Three capacitors in series.

C of the combination is given by $\frac{1}{C} = \frac{1}{C_b} + \frac{1}{C_4}$. This gives C. If this process were done algebraically, the value of C would be,

$$C = \frac{C_4\ [C_1C_2 + C_3\ (C_1 + C_2)]}{C_1C_2 + (C_3 + C_4)\ (C_1 + C_2)}.$$

If only the numerical value of the combination is required, it is best to work out each step arithmetically. Note that $\frac{1}{C_1} + \frac{1}{C_2} = \frac{C_1 + C_2}{C_1C_2}$, or that $\frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1R_2}$, showing that the total value of two capacitors in series, of value C_1 and C_2, or two resistors in parallel, of value R_1 and R_2, or two inductors in parallel, of value L_1 and L_2, are, respectively,

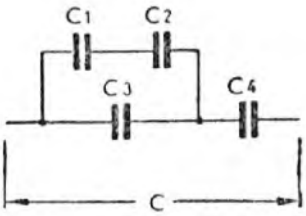


Fig. 11. How is the total capacitance calculated?

$$C = \frac{C_1C_2}{C_1 + C_2};\ R = \frac{R_1\ R_2}{R_1 + R_2};$$

$$L = \frac{L_1L_2}{L_1 + L_2}.$$

SECTION 4

EXPLANATION OF ABACS

THE abacs on the following pages enable various quantities to be ascertained simply by the use of a ruler or straight-edge, preferably of the transparent variety. In most instances, three related quantities are represented by three scales. When any two are known, the third can be ascertained as follows: Lay the straight-edge so that it passes through the appropriate points on the scales representing the known quantities. The third quantity can then be read off on the third scale.

When the scales do not extend to the values required, it is sometimes possible to multiply or divide the quantities and bring them within the ranges. Figs. 12-17 give certain useful abacs.

The abacs can be read with sufficient accuracy for most practical purposes, but where greater precision is necessary, answers should be calculated from the formulæ.

Resistors in parallel, Capacitors in series. The chart of reciprocals (Fig. 12) simplifies the calculation of the effective value of resistors in series, and capacitors in parallel.

The formula giving the total resistance R of a number of resistors in parallel is:

$$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}, \text{ etc.}$$

The value of $\frac{1}{R}$, and so on, is a reciprocal, and can be read from the chart.

For example, what is the total resistance value when resistors of 20, 15, and 9 ohms are connected in parallel?

The reciprocals are ·05, ·067 and ·11 respectively. Their sum is ·227, and this is the reciprocal of 4·4, which gives R as 4·4 ohms.

Similarly, the formula for capacitors in series is:

$$\frac{1}{C}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}, \text{ etc.,}$$

where C is the total capacitance of three capacitors, C_1, C_2 and C_3, in series. Therefore, if capacitors of ·01 mFd and ·03 mFd are in series, their total capacitance is: Reciprocals 100 and $33{\cdot}\dot{3} = 133{\cdot}\dot{3}$. $133{\cdot}\dot{3}$ is the reciprocal of ·0075, so that C = ·0075 mFd.

Note that, in this case, to find the reciprocal of $133{\cdot}\dot{3}$, the whole number side of the chart (right-hand side) is extended by 'multiplying' by 10 and the reciprocals are 'divided' by 10.

Therefore, 13·33 on the chart is read as 133·3, and ·75 on the chart is read as ·0075.

Abac 1. This chart relates inductance, capacitance and wavelength for parallel- and series-tuned circuits. Place a rule through two known values and read the third on the remaining scale. Range may be extended by multiplying inductance, capacitance and wavelength, but *not* frequency, simultaneously by the same factor.

Examples: (A) What inductance is tuned by ·0005 mFd to 600 m? The answer is, as read on the abac, 200 mH. (B) With this coil tuned by 30 mmFd, what is the wavelength? The answer is 140 m.

Fig. 12. Short cut for calculating resistors in parallel and capacitors in series.

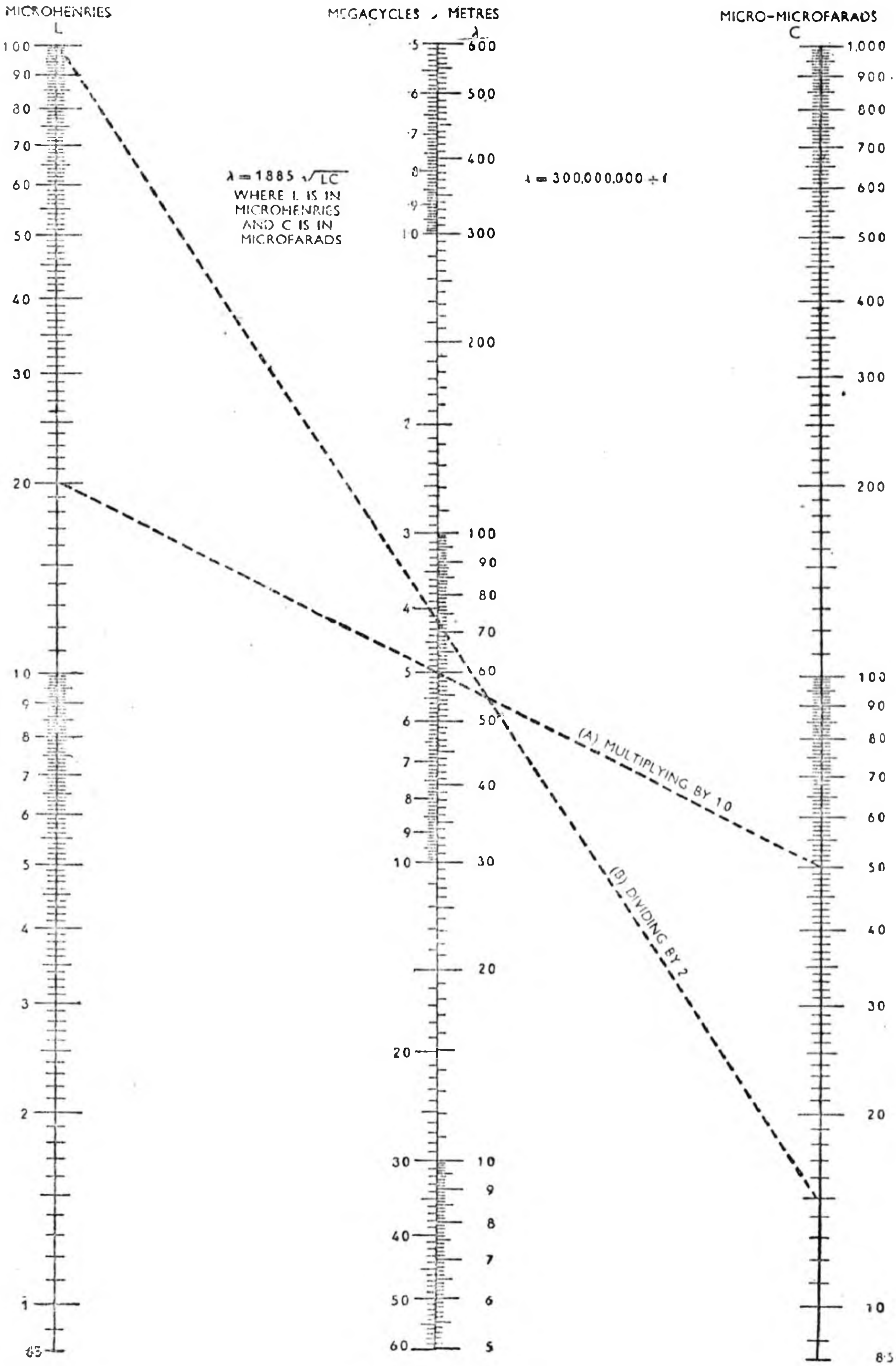


Fig. 13. ABAC I: INDUCTANCE, CAPACITANCE, FREQUENCY, WAVELENGTH

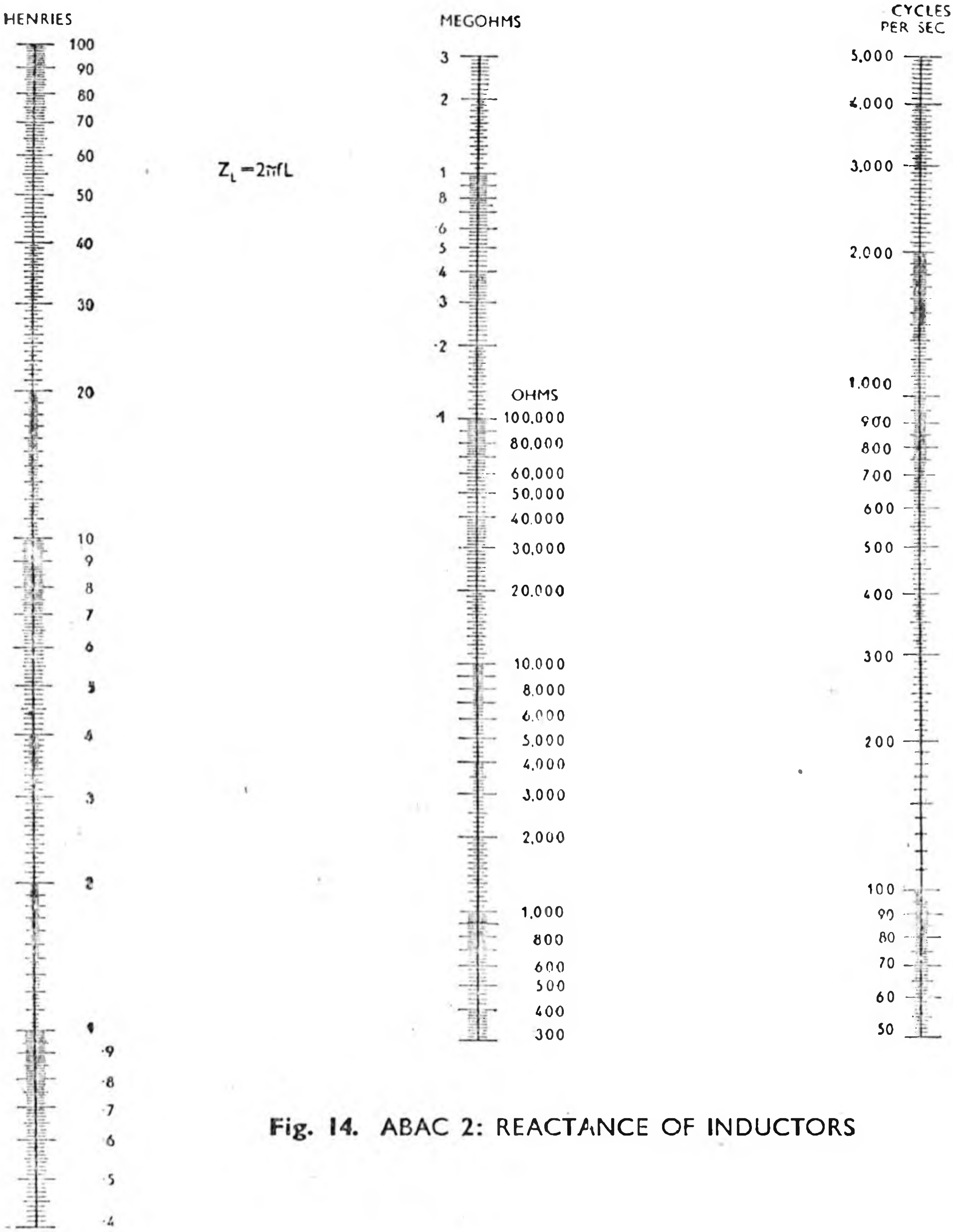


Fig. 14. ABAC 2: REACTANCE OF INDUCTORS

Abac 1 also provides a wavelength-frequency conversion scale. Read one side of the centre scale against the other side. To extend, divide one side and multiply the other side by the same factor.

Example: A frequency of 450 Kc/s (·45 Mc) corresponds to a wavelength of 666 m. (Divide frequency scale, multiply wavelength.)

Abac 2. As drawn, the scales are for low frequencies. For high frequencies, read henries as micro-henries, cycles as kilocycles and divide ohms by 1,000. Other extensions are simple, because inductive reactance is proportional to frequency and inductance, e.g., doubling frequency doubles inductive reactance, doubling inductance

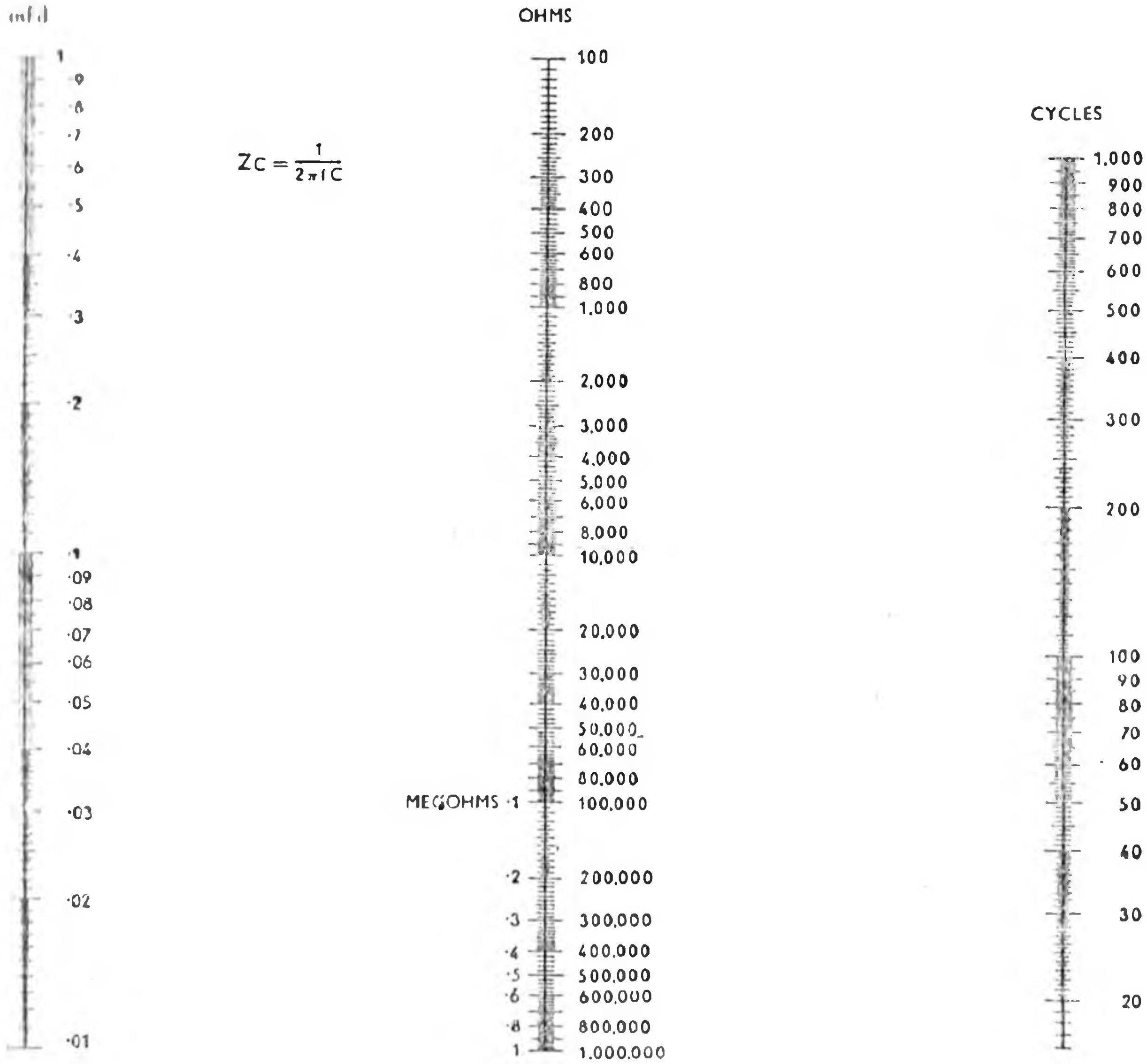


Fig. 15. ABAC 3: REACTANCE OF CAPACITORS

doubles the inductive reactance.

Abac 3. As drawn, the scales are for low frequencies. For high frequencies, read cycles as kilocycles, and divide ohms readings by 1,000; alternatively, read cycles as kilocycles and divide capacitance readings by 1,000. Other extensions are simple, because capacitive reactance is inversely proportional to frequency and to capacitance, e.g., doubling the frequency halves the reactance, doubling the capacitance halves the reactance.

Abac 4. For larger currents, the milliampere scale can be read as amperes, and then either volts must be multiplied by 1,000 or, alternatively, ohms divided by 1,000.

Abac 5. If the volts scale be divided by 1,000 (making it read millivolts), the watts scale must be divided by 1,000 (making it read milliwatts). Similarly, if the amperes scale be divided by 1,000 (making it read milliamps), the watts scale must be divided by 1,000 (making it again read milliwatts). If both volts and amperes scales be divided by 1,000 (making them read millivolts and milliamps) the answer on the watts scale is in microwatts (e.g. 1 volt multiplied by $\frac{10}{1,000} = 10^{-2}$ amps $= 10$ milliamps, makes 10 milliwatts $= 10,000$ microwatts, which is the scale reading on the abac for these).

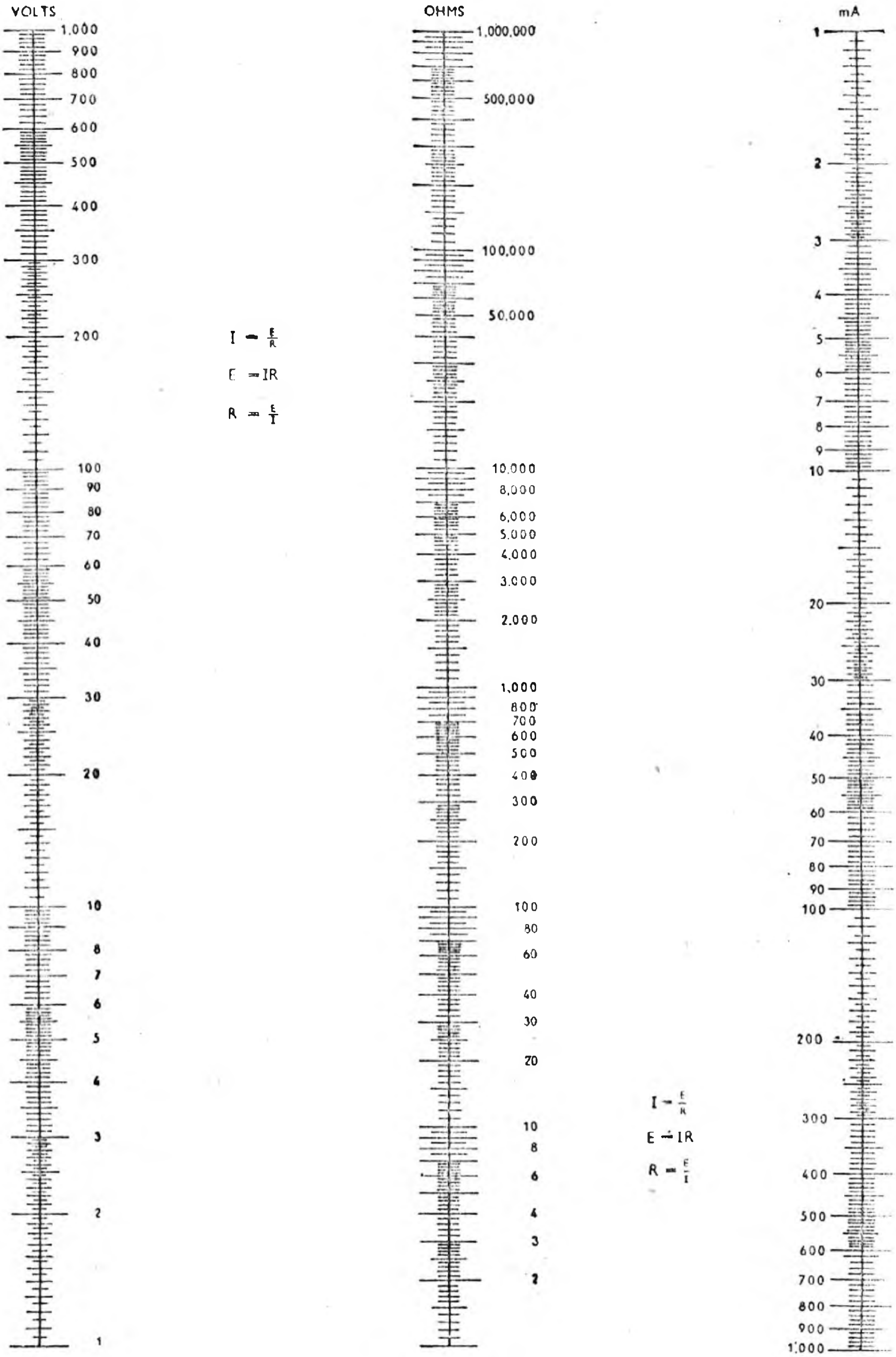


Fig. 16. ABAC 4: OHM'S LAW—VOLTS, OHMS, AMPERES

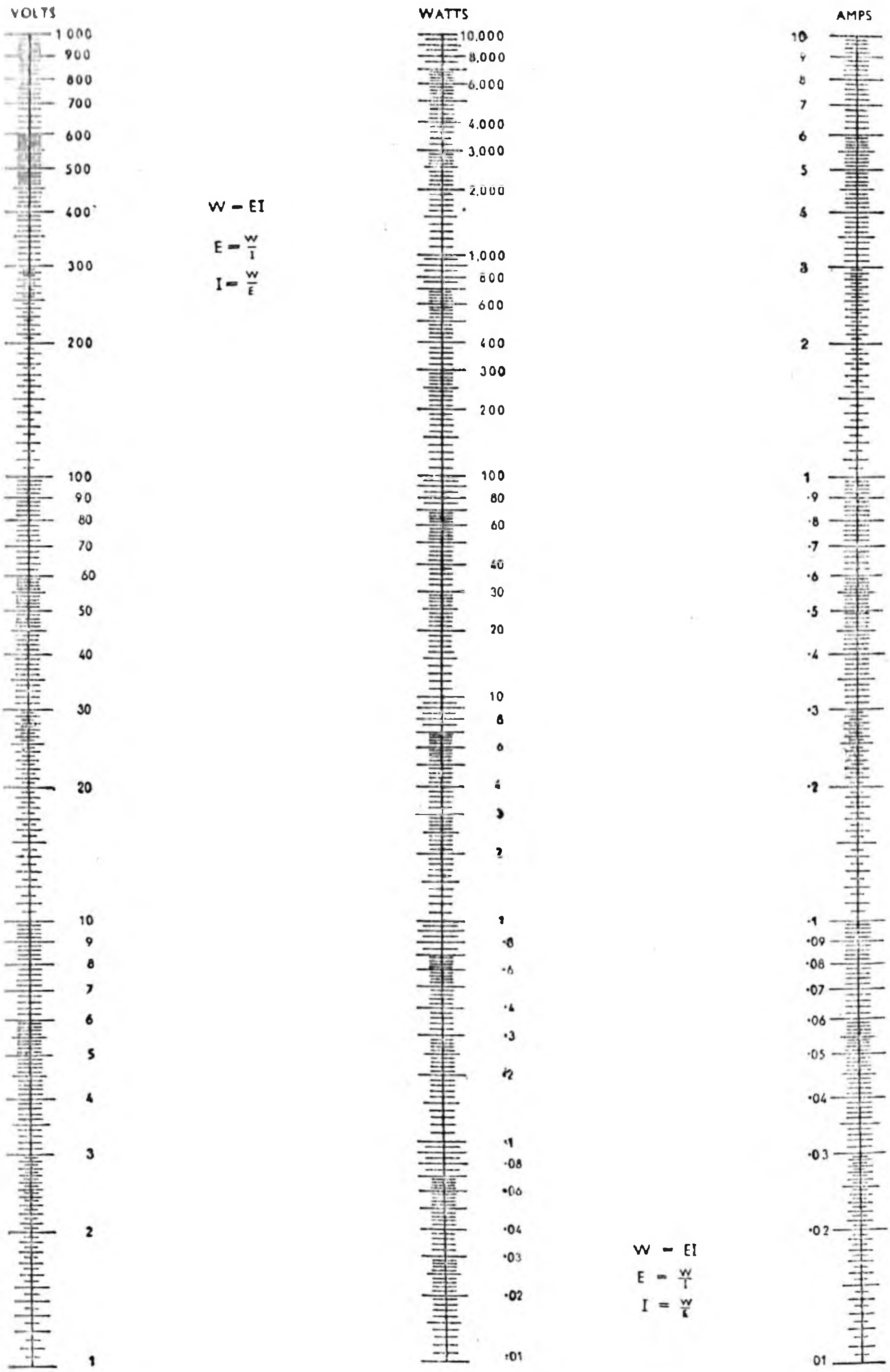


Fig. 17. ABAC 5: POWER—VOLTS, WATTS, AMPERES

SECTION 5

ALTERNATING CURRENT

THE practice of radio signalling is based upon the use of alternating currents, so that a proper understanding of the behaviour of such currents is essential to the radio engineer.

In Section 1, the terms period, cycle and frequency were defined, the next step is to consider the relationship between the intensity of the current and time. So far we have spoken of alternating current; obviously, this cannot exist without an alternating voltage.

Our first step is to relate the intensity of current or voltage and the instant of time at which a given intensity exists. Thus, over a period of alternation, the current or voltage has an intensity which is different at different times during the period; we require to know how intensity is related with time.

Sinusoidal Graphs

Proof can be given that, always provided a cyclic variation is maintained, any graph, however irregular, plotting intensity of current or voltage against time, is the result of adding together a number of graphs which are referred to as sinusoidal graphs. The first step is to consider the nature of a so-called *sine curve* or sine graph.

Consider Fig. 18. The line OP_1 is a line of certain length and direction. The direction can be defined by saying it makes an angle θ with a horizontal line drawn through OQ_1P. A vector has both magnitude and direction, so that OP_1 is a *vector*.

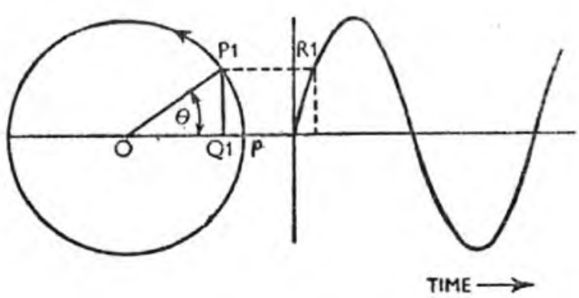


Fig. 18. Derivation of a sine curve.

If the vector OP_1 is considered to rotate about O, its tip traces a circle. If the rotation is uniform in a counter-clockwise direction, the angle θ increases uniformly with time. Therefore, we can say that the uniform rotation of OP_1 represents the rotation of a vector with a constant *angular velocity*, because θ increases uniformly with time.

The sine of the angle θ is defined as the ratio of the vertical line Q_1P_1 to the line of constant length OP_1 or, referring to Fig. 18, $\sin\theta = \dfrac{Q_1P_1}{OP_1}$.

OP_1 is a constant, and so $\sin\theta$ is proportional to Q_1P_1. If we plot time along the horizontal (or x axis), and the length Q_1P_1 on the vertical (or y axis), the resulting graph is that shown to the right in Fig. 18. Since the y axis of the graph is proportional to Q_1P_1, and since Q_1P_1 is proportional to $\sin\theta$, therefore the curve is called a sine curve.

A *radian* is an angle, and θ in Fig. 18 is equal to one radian when $PP_1 = OP_1$. There are 2π radians in a circle; in other words, there are 2π radians in 360°; π is the ratio of the circumference of a circle to its diameter. Expressed to five significant figures, $\pi = 3{\cdot}1416$. Therefore, to look at it another way, 360° is the same thing as 6·2832 radians.

If the vector OP_1 rotates f times a second (f being a frequency of rotation), the angular velocity of rotation (assumed uniform) is $2\pi f$. In any time t, measured from some zero time when, say, the vector OP_1 is horizontal and $\theta = 0$, the vector will have rotated through $2\pi ft$ radians. Therefore, suppose f were

1,500 rotations per second, then if $t = \frac{1}{3,000}$th second, the angle swept through by the vector in this time would be $2\pi 1,500 \times \frac{1}{3,000} = \pi$ radians $= 180°$.

If $t = 1{\cdot}5$ sec., the angle swept through would be $2\pi\ 1,500 \times 1{\cdot}5$, or about 14,200 radians.

If we cared to express the angles in degrees, we could say that the angular velocity was $360°f$ and the angle rotated through in t seconds would be, in degrees, $360°ft$, and if f were fifteen times a second and t were $\frac{1}{7}$th second, the angle swept through would be $\frac{360 \times 15}{7}$, about 771°, or about eight right angles and 50°, i.e., twice right round and 50° more.

Cycles per Second

From all this it is clear that, if we go back to radian measure of angles, then the function of the wavy curve to the right of Fig. 18 is given by $y = OP_1 \sin \omega t$, where y is the instantaneous intensity, measured above or below the horizontal line, as delineated by the curve, and t is time plotted uniformly along the horizontal, while $\omega = 2\pi f$, where f is the frequency of rotation of the vector. Since f is the frequency of rotation of the vector, it is, therefore, the number of complete cycles of variation of the sine curve in a second. This means that f is the frequency, expressed in cycles per second, of the alternation.

If the sine curve represents an alternating voltage, the peak value of which is E_{max} and if E is the intensity of this voltage at any time t, then $E = E_{max} \sin \omega t$, and expressed in terms of an alternating current I, of peak value I_{max}, $I = I_{max} \sin \omega t$.

The expression ωt represents an angle. Tables are published giving the sines of angles. From these, and from a study of Fig. 18, it is clear, or

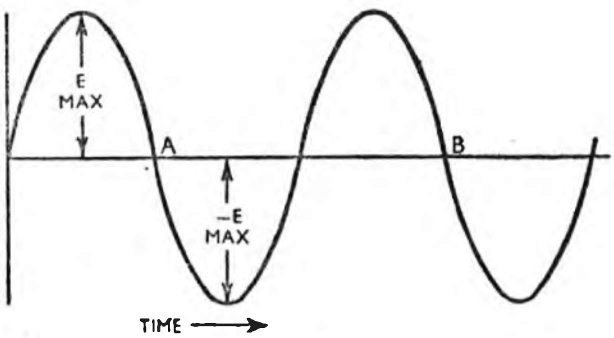


Fig. 19. Sine curve showing variation of a voltage with time.

can be shown, that $\sin 0° = 0$, $\sin 45° = \frac{1}{\sqrt{2}} = 0{\cdot}707$, $\sin 90° = 1$, $\sin 135° = {\cdot}707$, $\sin 180° = 0$, $\sin 225° = -{\cdot}707$, $\sin 270° = -1$, $\sin 315° = -{\cdot}707$ and $\sin 360° = 0$ again.

Also, $\sin 30° = \frac{1}{2} = \sin 150°$ and $\sin 210° = -\frac{1}{2} = \sin 330°$, and these figures indicate the function of the curve, provided we know $\omega = 2\pi f$ and t the time. Note, as in Fig. 19, shown as an alternating voltage obeying a sine law, that E_{max} has the same magnitude as $-E_{max}$, because $\sin 90° = 1$ and $\sin 270° = -1$.

Consider now Fig. 20, which represents an ideal alternator. An alternator is a machine for producing an alternating EMF and hence an alternating current in a circuit. A uniform magnetic field, shown by the horizontal lines between N and S, these being the poles of a magnet system, is formed in a cylindrical space between the magnets. The dots, labelled a and c, are supposed to be conductors having their lengths extended at right angles to the surface of the paper.

Induced EMF

Suppose these conductors are secured in an armature, free to rotate about an axis passing through O at right angles to the paper. As this armature rotates, the conductors move so that a comes to b and c to d. Suppose the armature rotates at a uniform angular velocity $2\pi f$. As it rotates, so the conductors cut the magnetic lines and an EMF is

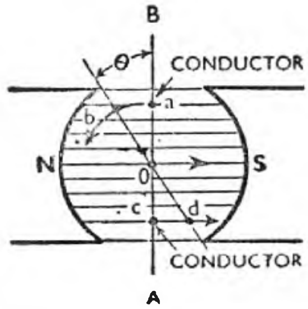


Fig. 20. Diagrammatic explanation of an alternator.

induced in the conductors. It can be shown that this EMF is proportional to the sine of the angle θ. When $\theta = 0$, the conductors are moving so that no lines are cut; when $\theta = 90°$, the conductors cut the lines at maximum velocity and so have a maximum EMF induced in them. The angle θ is measured by ωt, where t is the time measured from the instant when $\theta = 0$. Thus the induced EMF is $E = E_{max} \sin \omega t$, which is the function of an alternating voltage of unique frequency $f = \frac{\omega}{2\pi}$ and peak magnitude E_{max}.

Alternating currents may be produced by all sorts of means, notably by associating circuits containing inductance and capacitance with a negative resistance, but the alternator is used when mechanical forces are not too large to prevent an armature rotation frequency giving the required frequency of alternation of the currents and voltages generated by the alternators.

Always remembering that ωt is an angle, consider the expressions,

$$E = E_{max} \sin (\omega t \pm \varphi),$$

or, $$I = I_{max} \sin (\omega t \pm \varphi),$$

where φ is any angle added to or subtracted from ωt, according as it is plus or minus.

All that these expressions mean is that if we compare $E = E_{max} \sin \omega t$, $I = I_{max} \sin (\omega t \pm \varphi)$, is that the voltage E and the current I do not exhibit their maxima or their minima, or any value relative to their maxima, say, at the same time. For suppose, given some values of t, so that $\omega t = \frac{\pi}{2}$, then $E = E_{max} \sin \frac{\pi}{2}$, or since $\sin \frac{\pi}{2} = 1$, $E = E_{max}$.

But since $I = I_{max} \sin \left(\frac{\pi}{2} \pm \varphi\right)$, and if $\varphi = \frac{\pi}{4}$, then $I = I_{max} \sin \frac{\pi}{4}$, or $I = 0{\cdot}707\, I_{max}$; E is a maximum, I has not yet attained its maximum.

This point is brought out in Fig. 21. The terms '*in phase*' and '*out of phase*' are used to say whether two alternating quantities attain the same value relative to their maxima at the same time or not, respectively. The angle φ, used in the foregoing, is a *phase angle*. The two sine curves in the lower diagram are derived from rotating vectors which, according to the symbolism of Fig. 18, make, at any instant, an angle θ and an angle $\theta - \varphi$ with a horizontal; since $\theta - \varphi$ is less than θ, the current is said to lag the voltage because the rotating current vector is always lagging behind the rotating voltage vector. If φ were positive, the current would lead the voltage. We talk of leading and lagging voltages or currents.

It is not necessary to refer the phase of current to voltage, or vice versa, we may also compare the phase of one current with another, or one voltage with another.

A particular case occurs when φ,

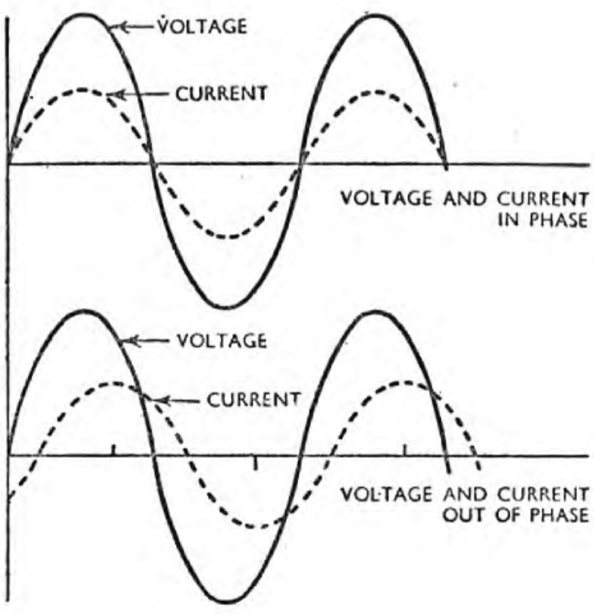


Fig. 21. Curves representing voltage and current in phase and out of phase.

in sin $(\omega t + \varphi)$, is 90°, i.e. $\frac{\pi}{2}$ radians. The resulting graph or curve is called a cosine curve or cosine graph (the term curve being generally used).

Clearly, when $\sin \theta = 0$, then $\cos \theta = 1$; θ being 0°. Fig. 22 summarizes some useful information relating radian measure and degrees and sine and cosine functions.

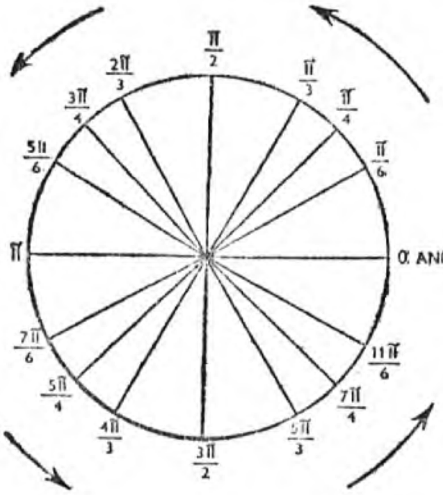
Root-Mean-Square

The *root-mean-square* value of an alternating current is the value which gives the same heating effect in a conductor as that caused by a direct current of that value. The term root-mean-square is used because it can be shown that the alternating current which gives the equivalent heating of a direct current, has a value given by taking the square root of the mean value of the sum of the squares of all the values of the current over a period of alternation.

At least to show the method and to get an approximate value of R.M.S. current, consider a peak value of 1 amp, then the currents at every $\frac{1}{8}$th cycle are 0, 0·707, 1, 0·707, 0, –·707, –1, –·707, 0, and the squares are 0, 0·5, 1·0, 0·5, 0, 0·5, 1, 0·5, 0; the sum of the squares being 4 and the mean $\frac{4}{9}$, making the square root of the mean $\frac{2}{3}$, showing a very approximate R.M.S. value of about 0·67 amp. As more and more points are taken, it can be shown that the R.M.S. value is $\frac{1}{\sqrt{2}} = 0{\cdot}707$ of the peak value. We may also apply the same reasoning for alternating voltage and have an R.M.S. voltage.

Most instruments for measuring AC voltages and currents read R.M.S. values.

An AC generator can be considered to be composed of an alternating EMF and, in many cases, an internal resistance. Provided R.M.S. values are taken, the same laws apply when the circuit is composed entirely of resistance, for alternating as for direct current; that is to say, E being R.M.S. voltage, I being R.M.S. current, and R being resistance, $E = RI$; while power is EI, or $\frac{E^2}{R}$, or RI^2.



DEGREES	0	30	45	60	90	120	135	150	180
SINE	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0
COSINE	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0	$-\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$-\frac{\sqrt{3}}{2}$	–1
DEGREES	0	210	225	240	270	300	315	330	360
SINE	0	$-\frac{1}{2}$	$-\frac{1}{\sqrt{2}}$	$-\frac{\sqrt{3}}{2}$	–1	$-\frac{\sqrt{3}}{2}$	$-\frac{1}{\sqrt{2}}$	$-\frac{1}{2}$	0
COSINE	–1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$-\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1

ANGULAR MEASUREMENT

Fig. 22. Information covering radian measure and sine and cosine functions.

Reactance. In Section 3 it was shown that if a current flowing in an inductor exhibited rate of change (i.e. was not constant), then a back-EMF, opposing the flow of current, was generated across the terminals of the inductor, this back-EMF being greater as the rate of change of current was greater, and the inductance value of the inductor the greater. This may be expressed by saying that the back-EMF is given by $L\frac{di}{dt}$, L

being the inductance and the ratio $\frac{di}{dt}$ meaning the slope of the curve plotting current against time; in other words, $\frac{di}{di}$ being the rate of change of the current over a very small interval of time dt.

In Section 1 the relationship between capacitance, charge and potential was shown to be the $Q = CV$, Q being the charge, C the capacitance and V the voltage. From $V = \frac{Q}{C}$, the back-EMF across a capacitor when a displacement current is flowing in it will be $\frac{1}{C}\int idt$,

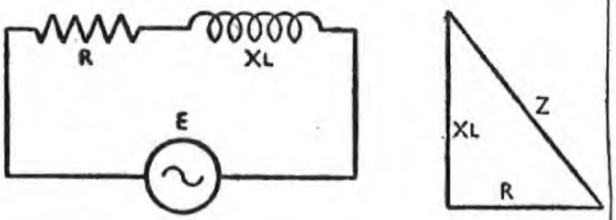


Fig. 23. Alternating voltage applied to inductance and resistance in series and, right, the impedance triangle.

where C is the current and where the $\int idt$ means, in effect, the charge on the capacitor when the current i varies as some function of time t and dt is a very small interval of time.

Using Calculus Methods

Expressing the value of the back-EMF's as $L\frac{di}{dt}$ and $\frac{1}{C}\int idt$, uses the methods of the differential and integral calculus. From a knowledge of the calculus, and knowing that $i = I_{max} \sin \omega t$, we derive that $E_{Lmax} = I_{max} L\omega \cos \omega t$ and $E_{Cmax} = I_{max} \frac{1}{\omega C}(-\cos \omega t)$, where E_{Lmax} and E_{Cmax} are the values of the back-EMF

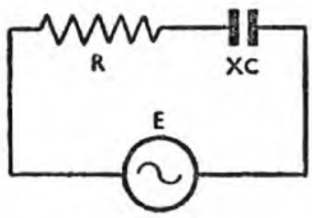


Fig. 24. Resistance and capacitance in series.

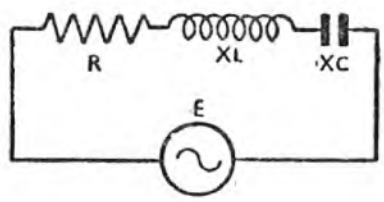


Fig. 25. Resistance, inductance and capacitance in series.

existing across an inductor and a capacitor when an alternating current of sine form flows through them.

These expressions may be written, $E_L = I\,X_L \sin(\omega t + \frac{\pi}{2})$; $E_C = I\,X_C \sin(\omega t - \frac{\pi}{2})$; E_L and E_C and I being R.M.S. values, because a cosine function is also a sine function, with $\frac{\pi}{2}$ radians (90°), added or subtracted, and because we have chosen to write,

$$X_L = \omega L$$

$$\text{and } X_C = \frac{1}{\omega C}.$$

The term X is frequently used to denote *reactance*, and X_L is an inductive and X_C a capacitive reactance. Clearly, the voltages across the reactances are 90° out of phase with the current, but the two voltages E_L and E_C are 180° out of phase with one another; their difference is, in fact, π radians = 180°.

Impedance. Consider Fig. 23. The current will flow through both R and the inductive reactance X_L. We cannot simply say that $E = RI + X_L I$, as if the voltages were

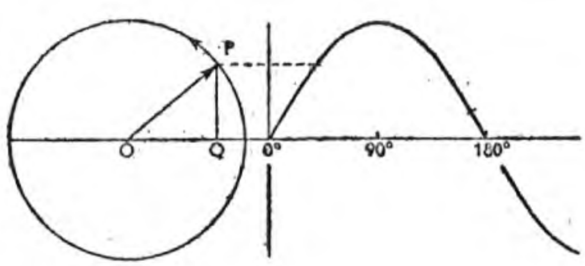


Fig. 26. Showing how a sine curve is developed by using basic principles.

steady as in DC conditions, because the voltage RI is 90° out of phase with $X_L I$ and because the voltages are varying with time. The magnitude of one voltage RI is proportional to R and the magnitude of the other to X_L, but the resultant voltage must be expressed in terms of a vector addition, not an arithmetical addition, since $X_L I$ and RI are voltages 90° out of phase.

The triangle on the right of Fig. 23 shows the vectors of length proportional to R and length proportional to X_L at right angles to one another producing a resultant proportional to Z in the sketch. From our knowledge of the relationships between the lengths of the sides of a right-angle triangle, we get, $Z_L = \sqrt{R^2 + X_L^2}$.

Using the same principles (Fig. 25), we get $Z_C = \sqrt{R^2 + X_C^2}$, where X_C is the reactance of the capacitor of capacitance C.

Since the back-EMF's $X_L I_{max}$ and $X_C I_{max}$ are 180° out of phase, then for Fig. 26 we get, $Z_S = \sqrt{R^2 + (X_L - X_C)^2}$.

The letter Z denotes what is called an *impedance*, and it is the back-EMF ZI which acts to limit the value of the current.

We may thus write, as a generality for all the circuits shown in Figs. 23, 24 and 25, $I = \frac{E}{Z}$, where I and E are R.M.S. values of current and voltage and $Z = \sqrt{R^2 + X^2}$.

X is $X_L = \omega L$ in Fig. 23, $X_C = \frac{1}{\omega C}$ in Fig. 24, and $X_S = (X_L - X_C)$ in Fig. 25.

Power Factor. The statement has been made that when an alternating current flows in a resistance connected to a source of alternating current having internal resistance, then the same relationships between E, I, and R exist as for DC, provided E and I are expressed in R.M.S. values.

When the circuit connected across an alternating current source contains resistance and reactance, then the power in the circuit is not obtained by a simple multiplication of voltage and current, because voltage and current are not in phase. The multiplication of R.M.S. volts and R.M.S. amps gives the volt-amperes acting, but the power is $EI \cos \varphi$, where φ is the phase angle between volts and amperes. If the circuit is purely reactive, $\varphi = 90° = \frac{\pi}{2}$ radians and $\cos \varphi = 0$, so $EI \cos \varphi = 0$ and no power is developed in a pure reactance.

If the circuit is purely resistive, $\varphi = 0$ $\cos \varphi = 1$, and the power is EI = volt-amps. The power factor, so called, is the ratio of watts to volt-amps, and in the case of sine functions it is equal to $\cos \varphi$.

Vector Algebra. In order to revise what has gone before, Fig. 26 once more underlines the basic principles for deriving a sine curve; the vector OP rotates at a uniform angular velocity and the instantaneous value of PQ is plotted against time to the right of the diagram. Now, consider Fig. 27, in which two sinusoids, derived from the rotating vectors OP_1 and OP_2, both rotating at the same angular velocity, are plotted as shown.

What is the resultant curve?

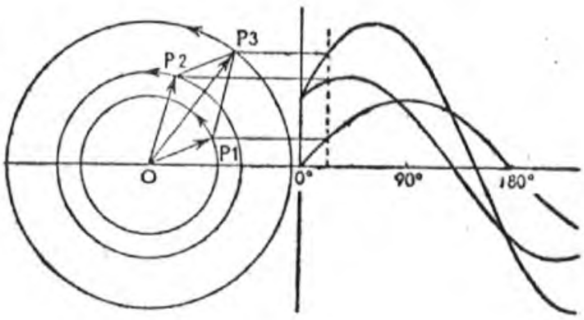


Fig. 27. Result of addition of sine curves shown by vector addition.

This could be found without further recourse to vectors by adding and subtracting the vertical heights of the two sine curves and so getting the third.

But the resultant vector obtained by the vector addition of OP_1 and OP_2 gives OP_3, and the resulting curve, derived from OP_3, is also a sinusoid as shown. It has the same frequency as those derived from

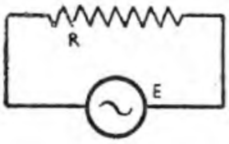


Fig. 28. Alternating voltage applied to resistance.

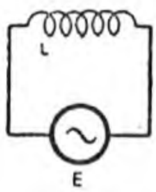
OP_1 and OP_2, which are also of equal frequency.

Going back over past ground, but giving vector representation of the voltages and currents, we see in

Fig. 29. Voltage and current vectors in phase.

Fig. 28 and Fig. 29 this representation where current and voltage are in phase in a pure resistance and where pure arithmetic addition gives the resultant.

In Figs. 30, 31, 32 and 33 it is seen that the quantities involved cannot be added arithmetically be-



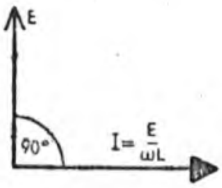
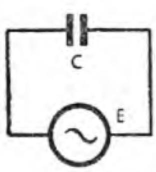


Fig. 30. (Left) Alternating voltage applied to inductance. **Fig. 31.** (Right) Voltage vector leading current vector by 90°.

cause vector quantities, having both magnitude and direction, are involved. Note, comparing Figs. 31 and 33, the 180° relationship between the reactance voltages obtained from inductor and capacitor. Fig. 35, being the vector diagram applicable to Fig. 34, shows the resultant of adding the vector quantities ωLI and RI and the same process in Fig. 37 applicable to Fig. 36.

Consider the three vectors E, jE and $j\,(jE)$ of Fig. 38. It would be legitimate to say that the vector addition of the two vectors E and that labelled $j\,(jE)$ could be an arithmetical one, namely, $E - E$.



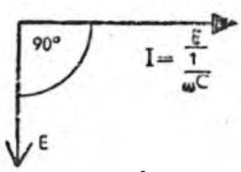


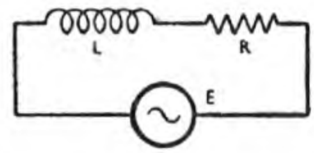
Fig. 32. (Left) Alternating voltage applied to capacitance. **Fig. 33.** (Right) Voltage vector lagging current by 90°.

Thus, if $j \times j = -1$, then j^2 means an operator turning a vector through two right angles in an anti-clockwise direction. If j^2 turns a vector through two right angles in an anti-clockwise direction, then legitimately the operator j turns the vector through one right angle in an anti-clockwise direction. Logically, $j = \sqrt{-1}$.

Using the Operator

Since no number exists which, multiplied by itself, equals -1, the letter j is called an imaginary; it is, in fact, not a quantity, but an

Fig. 34. Alternating voltage applied to combination of resistance and inductance in series.



operator. It gives the instruction, when written jE, to turn the vector of magnitude E through one right angle in an anti-clockwise direction.

Fig. 39 illustrates the conclusion that $-j$ as a multiplier means turn through one right angle in a clockwise direction. Thus, $a + jb$ means add together two vectors of length a

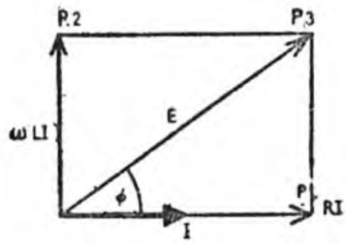
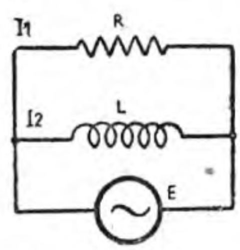


Fig. 35. Voltage and current phase difference is less than 90°.

and b, the vector b is considered to be horizontal and pointing to the right and vector a considered to be vertical and pointing upwards. The magnitude of the resultant must be, from our knowledge of the relationships of a right-angled triangle, $\sqrt{a^2 + b^2}$.

$a - jb$ is only different from $a + jb$ in that the vector b is vertical but

Fig. 36. Alternating voltage applied to resistance and inductance in parallel.



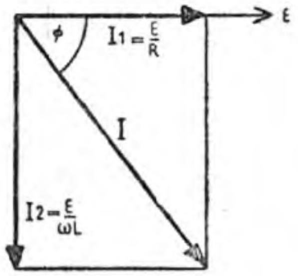


Fig. 37. (Left) Current lags voltage by less than 90°.

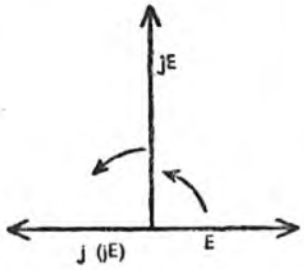


Fig. 38. (Right) Operator j turns a vector through 90 degrees in an anti-clockwise direction.

pointing downwards, while the magnitude (not the direction) of the resultant is $\sqrt{a^2 + b^2}$.

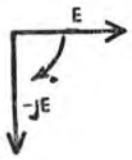
All vectors with j before them can be added arithmetically, because they all have the same direction.

Thus, $a + jb - jc - jd + je = a + j(b + e - c - d)$, and the resultant is $\sqrt{a^2 + \{(b + e) - (c + d)\}^2}$.

All vectors not having j in front can be added arithmetically. $a + b + c - d - e + jf$ has a resultant $\sqrt{\{(a + b + c) - (d + e)\}^2 + f^2}$.

Applying this to previous analyses, currents and voltages can be expressed in terms of j and reactances. In Fig. 40, a vector diagram applicable to a voltage acting on an inductor, we can write $I = -j\frac{E}{\omega L}$, or multiplying top and bottom of the ratio $\frac{E}{\omega L}$ by $+j$, as $I = \frac{-j^2 E}{+j\omega L} = \frac{-(\sqrt{-1})\quad(\sqrt{-1})E}{j\omega L} = \frac{E}{j\omega L}$.

Similarly, in Fig. 41, we can derive $I = j\omega CE = \frac{E}{\frac{1}{j\omega C}}$, where $\frac{1}{j\omega C}$ is the



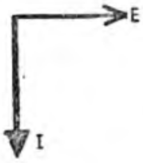


Fig. 39 (Left) and **Fig. 40** (Right) show phase relations in an inductor.

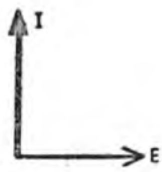
capacitive reactance, as was $j\omega L$ previously the inductive reactance.

In Fig. 42, two vectors, which might represent voltages RI and XI, are shown, using the operator j, as R and jX, and the resultant is $R + jX$, which can be expressed as a magnitude $\sqrt{R^2 + X^2}$, according to previous conclusions.

Other Uses

Another valuable use of the j nomenclature is that the value of the angle φ in Fig. 42 can be obtained by writing $\tan \varphi = \frac{jX}{R}$, where $\tan \varphi$ means the tangent of the angle φ, being the vertical side of the right-angle triangle divided by its base.

The phase angle of an impedance



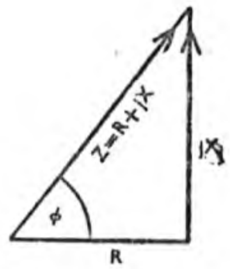


Fig. 41. (Left) Shows voltage and current in a capacitor, and **Fig. 42** (Right) the appropriate impedance triangle.

may always be obtained from the ratio of the j terms to terms not multiplied by j, or using usual terminology in vector algebra by dividing the imaginary terms by the real terms, real terms being those not multiplied by j and associated with resistance.

Impedance of Series Circuit. Using the j nomenclature, consider a circuit containing resistance R, capacitance C, and inductance L in series. We can find the resultant impedance by writing, $Z = R + j\omega L + \frac{1}{j\omega C}$,

$$\text{or, } Z = R + j\left(\omega L - \frac{1}{\omega C}\right),$$

$$\text{while } |Z| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2},$$

where $|Z|$ is the magnitude of the

impedance, while Z is expressed as a vector quantity.

Moreover, $\tan\varphi = \dfrac{\omega L - \dfrac{1}{\omega C}}{R} = \dfrac{\omega L\left(1 - \dfrac{1}{\omega^2 LC}\right)}{R}.$

Note that when $\omega L = \dfrac{1}{\omega C}$, $Z =$

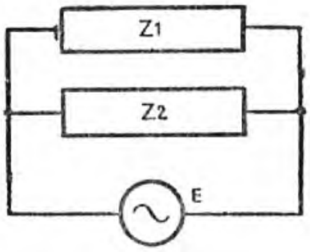


Fig. 43. Alternating voltage applied to impedances in parallel.

$|Z| = R$ and $\tan\varphi = 0$, meaning $\varphi = 0$. This is the condition of resonance.

Impedance of Parallel Circuit. In Fig. 43 there are two impedances in parallel. The term *admittance* means the reciprocal of impedance, just as conductance is the reciprocal of resistance. Thus the admittance of Z_1 and Z_2 in Fig. 43 is,

$$\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2}, \text{ or}$$

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}.$$

Applying this to Fig. 44, and using the j operator, we have,

$$\frac{1}{Z} = \frac{1}{R} + \frac{1}{\dfrac{1}{j\omega C}}$$

$$= \frac{1}{R} + j\omega C$$

$$= \frac{j\omega CR + 1}{R}, \text{ or}$$

$$Z = \frac{R}{1 + j\omega CR}.$$

This is not always a useful form of the expression, because the j term comes in the denominator. We may write, $Z = \dfrac{R\,(1 - j\omega CR)}{(1 + j\omega\, CR)\,(1 - j\omega CR)}$ $= \dfrac{R - j\omega\, CR^2}{1 + \omega^2 C^2 R^2}$, giving a real term, $\dfrac{R}{1 + \omega^2 C^2 R^2}$, and an imaginary term, $= \dfrac{j\omega CR^2}{1 + \omega^2 C^2 R^2}$, and so deriving $\tan\varphi = -\,\omega CR$, showing a negative angle for φ, because the j vector is pointing downwards. From any of the above equivalences,

$$|Z| = \frac{R}{\sqrt{1 + \omega^2 C^2 R^2}}.$$

Note, if ωC is very small (C very small or frequency very 'low' or both frequency small and C small, so that $\omega^2 C^2 R^2 \ll 1$), then $\tan\varphi$ = very small or $\varphi \approx 0$ and $|Z| = R$, i.e., the circuit 'looks like' a pure resistance. If ωC is very large (frequency very high or C very large or both), φ approaches a right angle and

$$Z = \frac{R}{\omega CR} = \frac{1}{\omega C},$$

and the circuit 'looks like' a pure capacitance.

It is as well to remember that it is often valuable, especially to determine φ, to separate real and imaginary terms so that when a result comes in the form $\dfrac{a + jb}{c + jd}$ we may multiply

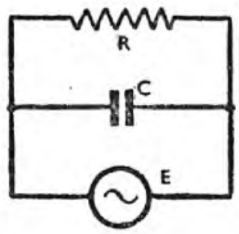


Fig. 44. Alternating voltage applied to resistance and capacitance in parallel.

numerator and denominator by $c - jd$, getting

$$\frac{(a + jb)\,(c - jd)}{c^2 + d^2}$$

$$= \frac{ac - jad + jbc + bd}{c^2 + d^2}$$

$$= \frac{ac + bd}{c^2 + d^2} \text{ and}$$

$$j\,\frac{bc - ad}{c^2 + d^2}.$$

If $(c - jd)$ comes in the denominator, then multiply the numerator and the denominator by $(c + jd)$.

SECTION 6

TUNED CIRCUITS AND CIRCUITS USED FOR SELECTIVE RESPONSE

Resonance. We have seen that capacitors and inductors passing an alternating current develop EMF's across them. A capacitor and an inductor are said to possess the property of reactance, the former having a capacitive reactance and the latter an inductive reactance. The value of these reactances is given as a vector quantity, being $\frac{1}{j\omega C} = -j\frac{1}{\omega C}$ for a capacitor and $j\omega L$ for an inductor. The EMF's developed across capacitor and inductor when a current I flows in them are $\frac{-jI}{\omega C}$ and $j\omega LI$ respectively. They act oppositely and tend to cancel, since one is multiplied by $+j$ and the other by $-j$. We are concerned in this section with conditions when capacitive and inductive reactances are equal, or nearly so. When these reactances are connected in a circuit and have equal values, then a condition of *resonance* is said to exist.

Associated with a condition of resonance, a voltage or a current or a voltage and a current attain their maximum values.

Tuned Circuit

A circuit in which the condition of resonance may be exhibited is called a *tuned circuit*, and the properties of resonance are made use of in receivers to make circuits highly responsive to certain narrow bands of frequency and as unresponsive as possible to others. Thus a tuned circuit is described as being *frequency-selective*, or *selective*, or as possessing the property of *selectivity*. Tuned circuits can be described as series-tuned or parallel-tuned, depending upon whether the nearly equal or equal inductive and capacitive reactances act in series or in parallel with one another in the circuit.

Series Tuned Circuit. A series tuned circuit is shown in Fig. 45.

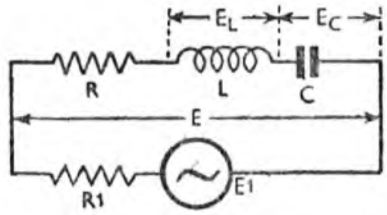


Fig. 45. Alternating voltage applied to series tuned circuit.

This circuit has been analysed previously and it has been shown that its impedance is given by,

$$Z_S = R + j\omega L - j\frac{1}{\omega C}.$$

When, by adjusting the values of C and L, or C or L, or by changing the frequency $f = \frac{\omega}{2\pi}$, we make $\omega L = \frac{1}{\omega C}$, then $Z = R$, and the current $I = \frac{E}{R}$ has its maximum value. This condition occurs at a unique frequency f_0, such that $2\pi f_0 L = \frac{1}{2\pi f_0 C}$; so that $f_0 = \frac{1}{2\pi\sqrt{LC}}$.

We may transform the expression for Z_S as, $Z_S = R + j\omega L\left(1 - \frac{1}{\omega^2 LC}\right)$ $= \omega L\left\{\frac{R}{\omega L} + j\left(1 - \frac{\omega_0^2}{\omega^2}\right)\right\}$, because $\frac{1}{LC} = \omega_0^2 = 4\pi^2 f_0^2$.

The effects of resonance are clearly the more marked as R is smaller; therefore, if R were zero and $\omega = \omega_0$, then $Z = 0$ and, given a generator capable of supplying an infinite current, the current at resonance would be infinite. It is desirable, as the circuit is to be made more selective, that R should be as small as possible. Thus no resistor, of value R, is added and the resistance R in Fig. 45 is shown to represent the resistance of the inductor and capacitor, while R_1 is the internal resistance of the source of alternating voltage energising the resonant circuit.

Effect of Resistance

The resistance R, so far as the external circuit is concerned, is, in practice, almost entirely the resistance of the inductor, the resistance of the capacitor being relatively negligible.

The term $1 - \frac{\omega_0^2}{\omega^2}$ is $\frac{\omega^2 - \omega_0^2}{\omega^2}$.

If we write $\omega = \omega_0 \pm \Delta\omega$, where $\Delta\omega = 2\pi\Delta f$, Δf being a frequency $\ll f_0$, then $\frac{\omega^2-\omega_0^2}{\omega^2} = \frac{(\omega_0 \pm \Delta\omega)^2-\omega_0^2}{(\omega_0 \pm \Delta\omega)^2}$ $= \frac{\pm 2\Delta\omega\ \omega_0 + \Delta\omega^2}{(\omega_0 \pm \Delta\omega)^2}$. We may neglect $\Delta\omega$ compared with ω_0 in the denominator and we may neglect $\Delta\omega^2$ compared with $2\Delta\omega\omega_0$ and get $1 - \frac{\omega_0^2}{\omega^2} \approx \pm \frac{2\Delta\omega}{\omega_0} = \pm \frac{2\Delta f}{f_0}$.

Thus, $Z_{s0} = \omega_0 L \left\{ \frac{1}{Q_0} \pm j \frac{2\Delta\omega}{\omega_0} \right\}$,

provided we express $\frac{\omega_0 L}{R_0}$ as Q_0. Thus, Q_0 is the ratio of the reactance to the resistance of the inductor at, or nearly at, resonance.

The voltage across the inductive reactance is $\omega_0 L I = E_L$. The current, $I = \frac{E}{Z_s}$, where E is the voltage acting across the series tuned circuit (see Fig. 45). Therefore,

$$\frac{E_L}{E} = \frac{1}{\frac{1}{Q_0} \pm j \frac{2\Delta\omega}{\omega_0}}$$

$$= \frac{1}{\sqrt{\frac{1}{Q_0^2} + \frac{4\Delta\omega^2}{\omega_0^2}}}.$$

When $f = f_0$, so $\Delta\omega = 0$, then

$$\frac{E_{L0}}{E} = Q_0 = \frac{\omega_0 L}{R}.$$

Since the voltages across capacitor and inductor have very nearly equal values at resonance, so $\frac{E_c}{E_L}$, where E_c is the voltage acting across the capacitor, is virtually,

$$\frac{E_{c0}}{E} = Q_0 = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR}.$$

These expressions are approximate and apply only when the frequency is close to f_0, and when $\frac{\omega_0 L}{R_0} = Q_0$ is at least 5 or more in value. Note that if $\frac{1}{Q_0} = \frac{2\Delta\omega}{\omega_0}$, then $\frac{E_L}{E} = \frac{E_c}{E} = \frac{1}{\sqrt{2}} =$ 0·707 of its maximum value. If ω_0 were $2\pi \times 10^6$ c/s and Q_0 were 100, $2\Delta f = \frac{f_0}{Q_0}$ would give $2\Delta f = \frac{10^6}{10^2}$, or Δf would be 5,000 c/s.

This means that at 5,000 cycles off resonance the ratio of the response to a maximum response would be 0·707 times with a Q value of 100 and a resonance frequency of one million cycles.

A typical resonance curve plotting $\frac{E_L}{E}$ against frequency is shown in Fig. 46, the maximum value of $\frac{E_L}{E}$ being $Q_0 = \frac{\omega_0 L}{R_0}$, and in the case cited being 100, E being considered to remain constant.

Parallel Tuned Circuit. The commoner type of tuned circuit, so far as radio practice is concerned, is the parallel tuned circuit of Fig. 47.

The first step is to find its impedance. This is most easily done by adding the admittances (*admittance* being the reciprocal of impedance) of the two branches. That containing the capacitor is assumed to have zero resistance and so we want to know its susceptance (*susceptance* being the reciprocal of reactance). Writing Y as the sum of admittance of the inductive branch and the susceptance of the capacitive branch, gives, $Y = \dfrac{1}{j\omega L + R} + j\omega C$

$$= \frac{1 - \omega^2 LC + j\omega CR}{j\omega L + R}.$$

Writing $\omega^2 LC$ as $\dfrac{\omega^2}{\omega_0^2}$ and C as $\dfrac{1}{\omega_0^2 L}$, we can write,

$$Y = \frac{\dfrac{f}{f_0} + jQ\left(\dfrac{f}{f_0} - \dfrac{f_0}{f}\right)}{\omega_0 L\,(Q - j)}.$$

Assuming $Q \gg j \times 1$, the impedance of the parallel tuned circuit is $Zp = \dfrac{\omega_0 LQ}{\dfrac{f}{f_0} + jQ\left(\dfrac{f}{f_0} - \dfrac{f_0}{f}\right)}$ and

$$|Zp| = \frac{\omega_0 LQ}{\sqrt{\left(\dfrac{f}{f_0}\right)^2 + Q^2\left(\dfrac{f}{f_0} - \dfrac{f_0}{f}\right)^2}}.$$

At frequencies very close to resonance, the term $\dfrac{f}{f_0} - \dfrac{f_0}{f}$, by putting $f = f_0 \pm \Delta f$, as previously explained, when considering the series tuned

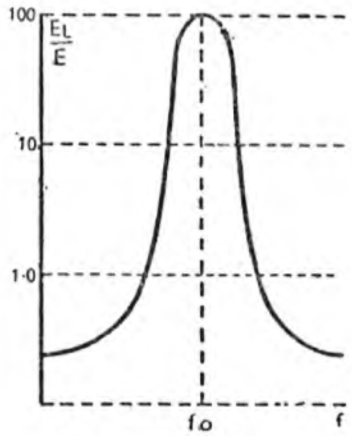


Fig. 46. How voltage across a series tuned circuit varies with applied frequency; f_0 is the resonant frequency of the circuit.

circuit, is $\approx \pm \dfrac{2\Delta f}{f_0}$, so that

$$Z_{po} = \frac{\omega_0 L Q_0}{1 \pm j\dfrac{2\Delta f}{f_0} Q_0}$$

$$= \frac{\omega_0 L}{\dfrac{1}{Q_0} \pm j\dfrac{2\Delta f}{f_0}}.$$

The denominator of this expression is the same as that which multiplies the inductive reactance in a series tuned circuit.

We see that when $\Delta f = 0$, $Z_{po} = \omega_0 L Q_0$, showing a maximum value of impedance. Thus, provided a resistance R_1, which may well be the internal resistance of the source,

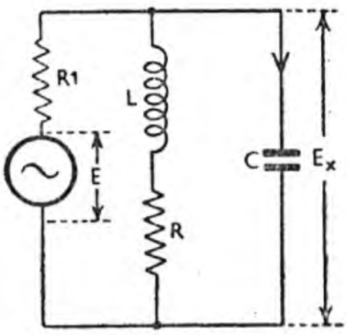


Fig. 47. Parallel tuned circuit, the voltage E_x is maximum at resonance and nearly equals E.

exists (as it must, since all sources have some internal resistance), the voltage across the parallel tuned circuit, which we might call E_x (Fig. 47), rises to a maximum at resonance and $\dfrac{E_x}{E} = \dfrac{Z_{po}}{R_1 + Z_{po}}$

$$= \frac{1}{\dfrac{R_1}{Z_{po}} + 1}.$$

At frequencies far from resonance, $\dfrac{R_1}{Z_p}$ should be large compared with unity and $\dfrac{E_x}{E} \approx \dfrac{Z_p}{R_1}$ and is small.

At resonance, or a frequency very close to resonance, $\dfrac{R_1}{Z_{po}}$ may be $\ll 1$ and $\dfrac{E_x}{E} \approx 1$, or $E_x \approx E$. There is, in a parallel tuned circuit, no magnification of voltage, the frequency selective properties depend essentially upon the rising impedance of the circuit, which may rise to values sufficient to cause a sharp increase of voltage, E_x, across the circuit at resonance.

Dynamic Impedance

The impedance at resonance of the parallel tuned circuit is $Z_{po} = \omega_0 L Q_0$, and is sometimes called the dynamic impedance of the circuit. Its phase angle equals 0. A parallel tuned circuit at resonance 'looks like' a high resistance, a series tuned circuit 'looks like' a low resistance.

Since, $Q_o = \dfrac{\omega_o L}{R_o}$, so $Z_{po} = \dfrac{\omega_o{}^2 L^2}{R_o}$,

and because $L = \dfrac{1}{\omega_o{}^2 C}$, $Z_{po} = \dfrac{L}{CR_o}$.

Coupled Circuits. The transfer of energy (between, for instance, stages of a receiver) by means of coupled circuits allows greater flexibility to be obtained in the shape of the resonance curve, while, at the same time, the loading on the preceding valve is of the high impedance associated with the parallel tuned circuit. It also permits the use of variable selectivity. The chief types are :

(1) Mutual inductance coupling (tuned transformer). (Fig. 48.)

$$k = \frac{M}{\sqrt{L_1 L_2}}.$$

Either primary, or secondary, or both may be tuned.

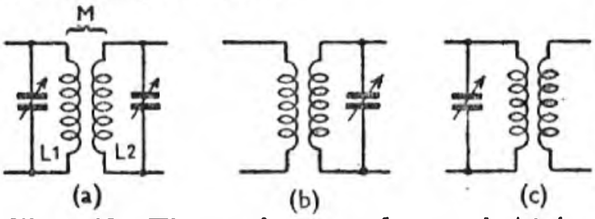


Fig. 48. Three forms of tuned high-frequency transformer.

(2) Common inductance coupling. (Fig. 49.)

$$k = \frac{L_m}{L_1 L_2}.$$

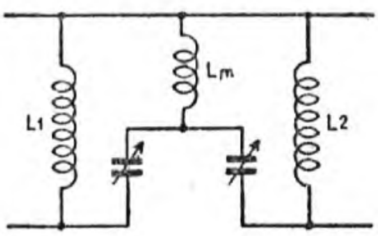


Fig. 49. Band-pass circuit consisting of two tuned circuits with common inductance L_m.

(3) Common capacitance coupling. (Fig. 50.)

$$k = \frac{\sqrt{C_1 C_2}}{C_m}.$$

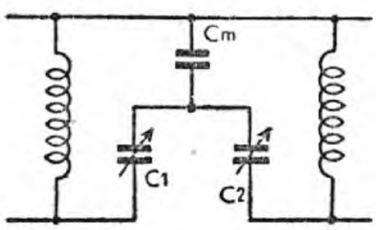


Fig. 50. Band-pass circuit with common capacitance C_m for transference of signal.

(4) 'Top-capacitance' coupling. (Fig. 51.)

$$k = \frac{C_m}{\sqrt{C_1 C_2}}.$$

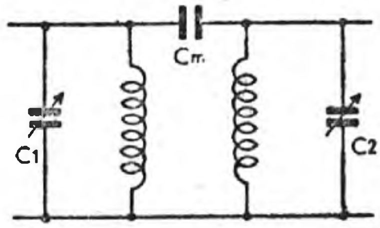


Fig. 51. Band-pass circuit with 'top capacitance' coupling.

Types (1) are most commonly used for coupling between valve stages; for example, in the IF amplifiers of super-heterodyne receivers, while the remaining types are met with more usually in the aerial coupling circuits of the pre-selector stage.

Resonance Curves. The shape of the resonance curve, expressed as the impedance offered to the source of voltage, depends on the closeness of

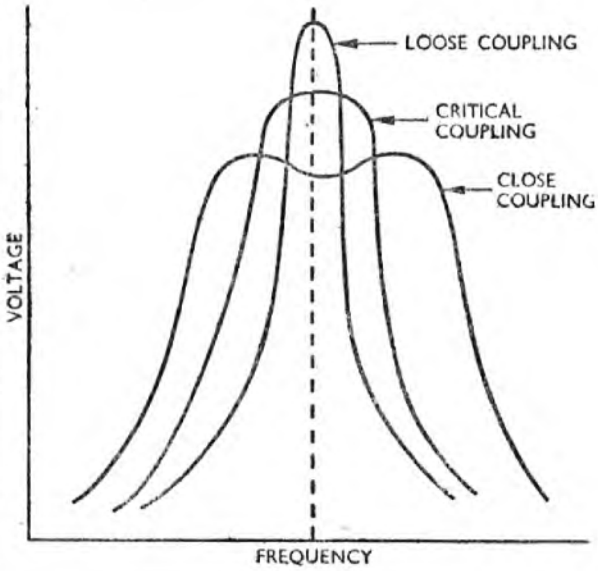


Fig. 52. How the response of coupled tuned circuits varies with degree of coupling.

coupling between the circuits. (Fig. 52.)

Loose Coupling. The resonance curve is similar to that of a single parallel tuned circuit.

Critical Coupling. For a certain closeness of coupling, the resonance curve becomes flat-topped.

Close Coupling. For coupling closer than the critical coupling, a double-hump peak appears in the resonance curve.

Cœfficient of Coupling. The cœfficient of coupling is defined as: $k = \frac{M}{\sqrt{L_1 L_2}}$, where M is the mutual inductance between the inductors, and $L_1 L_2$ are in the inductances of the two inductors. (The values of k in the other cases are given above.)

Also, $k = \frac{1}{\sqrt{Q_1 Q_2}}$, where Q_1 and Q_2 are the Q factors of the two circuits.

With identical circuits, $k = \frac{1}{Q}$.

The mutual inductance for critical coupling is, then,

$$M = \sqrt{\frac{L_1 L_2}{Q_1 Q_2}}$$
$$= \frac{\sqrt{R_1 R_2}}{\omega}.$$

With coupling exceeding the critical coupling, the frequency difference between the peaks is,

$$\Delta f = f_0 \sqrt{k^2 - \tfrac{1}{2}\left(\frac{1}{Q_1^2} + \frac{1}{Q_2^2}\right)}.$$

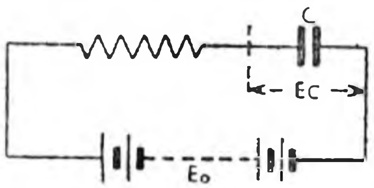


Fig. 53. Capacitor C is charged through the resistor by the battery.

With identical circuits, $\Delta f = f_0 \sqrt{k^2 - \frac{1}{Q^2}}$, where f_0 is the common frequency to which the circuits are tuned.

With the other types of coupling,

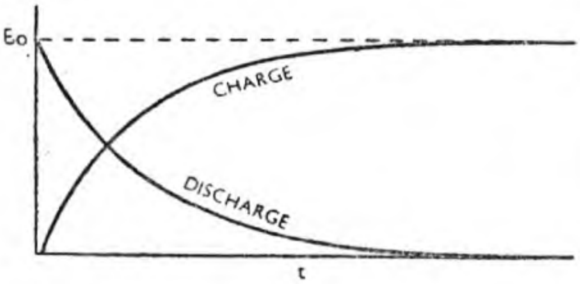


Fig. 54. How voltage across a capacitor varies during charge and discharge.

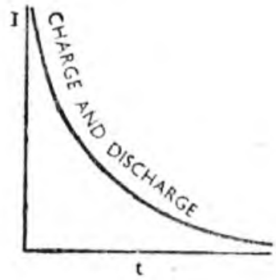


Fig. 55. Current against time for charge and discharge of capacitor.

the resonance curve does not open symmetrically when the coupling is increased beyond the critical value.

Time-constant (Figs. 53-55). While circuits associating resistance and capacitance do not come into the category of tuned circuits, they are used for various purposes in receivers which must give selective response and, therefore, merit some mention.

Voltage Rise

When a capacitor is charged through a resistor from a battery or other steady voltage source, the rate at which the voltage across the capacitor rises depends upon the product of the resistance and the capacitance ($R \times C$). The relevant formulæ are:

Let E_0 be the voltage of the source, and let E_c be the voltage across the capacitor t secs. after the circuit is closed. Let Q be the charge on the capacitor at time t, and let Q_0 be the final charge when the capacitor is charged to the voltage E_0.

Then, $E_c = E_0 \left(1 - \varepsilon^{\frac{-t}{RC}}\right)$, where $\varepsilon = 2{\cdot}718$; $Q = Q_0 \left(1 - \varepsilon^{\frac{-t}{RC}}\right)$.

The charging current at time t is,

$$I = \frac{E_0 - E_c}{R}$$
$$= \frac{E_0}{R} \varepsilon^{\frac{-t}{RC}}$$
$$= I_0 \varepsilon^{\frac{-t}{RC}},$$

where $I_0 = \frac{E_0}{R}$ is the initial current.

The product $R \times C$ is called the time-constant of the circuit. It will be a time in seconds if R is in ohms and C in farads.

With the values occurring in practical circuits, R is more usually expressed in megohms and C in microfarads, and the product is again in seconds.

t sec. $= R$ (megohms) $\times$ C (microfarads).

Thus, if $R = 2\text{M}\Omega$, $C = 0{\cdot}1\ \mu\text{F}$, $t = 0{\cdot}2$ sec.

Charging Time

Calculating from the above formulæ shows that the time constant measures the time taken for the voltage across the capacitor to rise to 0·632 of the charging voltage.

The time-constant also governs the rate at which the capacitor discharges through the same resistor. (Fig. 56.)

If E_0 now represents the voltage to which the capacitor is initially

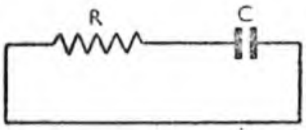


Fig. 56. Capacitor discharging through resistor.

charged, E the voltage after time t, then,

$$E = E_0 . \varepsilon^{\frac{-t}{RC}};$$

$$Q = Q_0 . \varepsilon^{\frac{-t}{RC}};$$

$$I = \frac{E_0}{R} . \varepsilon^{\frac{-t}{RC}}.$$

Applications. (1) Any capacitor has a natural leakage resistance R, and the product RC is a measure of its quality. The Post Office specification for paper capacitors is that the natural time-constant should not be less than 300 secs.

(2) Numerous circuits occur in which a capacitor and a resistor are associated in this way, and where the correct choice of the time-constant is important.

In the simple AVC circuit shown (Fig. 57), the voltage drop across the diode load, which is composed of primarily R_2 and C_2 in parallel, includes a DC component proportional to the carrier strength, and this is used to bias the earlier valves. The resistor R_1 and capacitor C_1 act as a filter to prevent the audio-frequency component of voltage across the load from being applied to these valves.

We may imagine that when the signal first arrives, C_1 becomes charged through R_1, to a voltage equal to the DC voltage across R_2C_2, and this voltage across C_1 is actually the control voltage for the earlier stages. The voltage across R_2C_2 will rise and fall with fluctuations in carrier strength, owing, for example, to fading, and it is important that the voltage across C_1 should follow these fluctuations quickly enough.

This it can do only if the time constant R_1C_1 is correctly chosen. Suitable values are: Telegraphy, 1 sec. or more, so that the control voltage diminishes slowly when a signal ceases. This prevents noise between signals. Telephony, 0·1 – 0·2 sec. This ensures that the AVC will not follow modulation on low notes.

Another use of time constant is in synchronizing pulse separator circuits in television receivers. There are short and long signal pulses to trigger the line and frame time-bases respectively. They are sorted by a *differentiating* circuit of, say, 50-$\mu\mu$F series capacitor and 50,000-ohm shunt resistor for the line pulses and an *integrating* circuit of 20,000-ohm series resistor and ·001-μF shunt capacitor for the frame pulses.

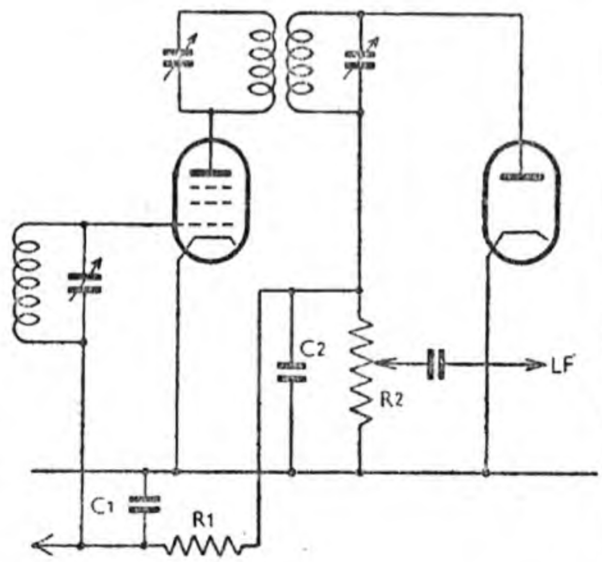


Fig. 57. Two examples of the use of time constant found in AVC circuits.

SECTION 7

FILTERS AND EQUALIZERS

A FILTER is essentially an electrical network designed to allow the free passage between its input and output terminals of currents having frequencies within one or more frequency bands and to prevent the passage of currents having frequencies outside these frequency bands.

In one sense, a tuned circuit can be considered as a filter and the two basic forms are shown in Fig. 58. The point to be realized, however, is that these circuits do not have selective properties unless associated with other impedances.

The term 'pass' is used to convey the idea of the free passage of currents. The term 'transmit' is used in the same sense. Pass bands of frequencies and transmission bands mean the bands of frequencies which define the frequency of currents freely transmitted through a filter.

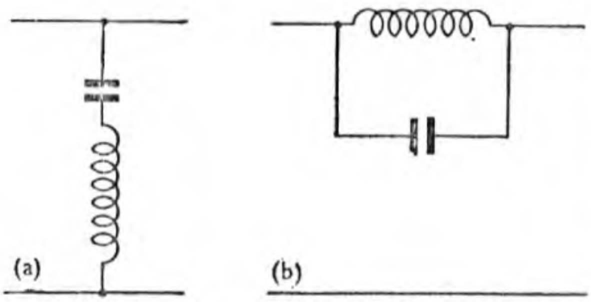


Fig. 58. Basic forms of tuned circuit. (a) Series and (b) parallel.

The term 'stop' may be used to define the condition when the filter acts to prevent or tend to prevent currents of certain frequencies passing between input and output terminals. A more general term, 'attenuation', is used to convey the idea of the prevention of a free passage of currents through a filter.

Filters are classified as (*a*) low pass; (*b*) high pass; (*c*) band pass. These terms describe filters which (1) pass currents of frequencies lower than a so-called *cut-off frequency*, and attenuate currents of frequencies greater than the cut-off frequency; (2) which pass currents of frequency higher than a cut-off frequency and attenuate those of frequencies lower than the cut-off frequency.

In the simpler forms of band-pass filter (3), there are two cut-off frequencies and the filter passes frequencies lying within a band of frequencies bounded by the lower and higher cut-off frequencies, while attenuating currents of frequencies outside the pass band.

A band-stop filter has two cut-off frequencies and the filter attenuates frequencies lying in the band between these frequencies, passing currents of other frequencies.

A filter contains elements which have, ideally, the nature of reactance and no resistance. In an ideal case, in which the filter elements were pure reactances and the terminations of the filter had impedances varying with frequency, exactly matching what is called the filter *image impedance*, there would be no loss at all in the transmission band and attenuation would become finite at frequencies infinitesimally greater or less than the cut-off frequency.

Such conditions cannot be realized in practice, but, using good elements and careful design, the approximation to an ideal performance is reasonably good.

Equalizers

In structures in which elements having the property almost entirely of resistance are associated in the filter proper with elements having chiefly the property of reactance, the action will be such as to give greater attenuation to currents of one frequency than to another. There is no case where resistance is embodied in the filter proper that a sharply defined cut-off frequency exists, and these structures are more properly described as *equalizers*.

This term is used because, in a large number of cases, equalizers are used to compensate for some gradual falling away or increase of response with frequency in some part of a transmission system, which is subsequently equalized.

Referring to Fig. 59, the structures properly described as filters are the high-pass T, π and L sections, the low-pass T, π and L sections, and that labelled 'coupled circuit', because these are structures containing, in themselves, essentially, reactances.

The structures properly described as equalizers are the high-pass $R — C$, the low-pass $R — C$ and $L — R$, and the band-pass single-tuned circuit and the band-stop rejector.

It will be noted that the response curves, which are purely diagrammatic and not to scale, show much sharper rate of change of response with frequency for the filters than for the equalizers.

The load resistances can vary according to requirements. In some of the equalizers shown, the resistance elements of the equalizer are in parallel with the load resistances, and so, to all intents and purposes, the load resistance may be infinite.

Choosing Values

It is extremely important, in the filter structures, to choose the values of the reactances in relation to the terminating or load resistance.

If R be the value of the load resistance, and C and L the values for the capacitors and inductors respectively (where two capacitors or inductors are shown for the filters in Fig. 59 they have equal values), while f is the cut-off frequency (C being in farads, L in henries, f_c in c/s, and R in ohms), we have, for the sections:

Filter	Section	C (farads)	L (henries)
High pass	T	$\frac{1}{2\pi f_c R}$	$\frac{R}{4\pi f_c}$
	π	$\frac{1}{4\pi f_c R}$	$\frac{R}{2\pi f_c}$
	L	$\frac{1}{2\pi f_c R}$	$\frac{R}{2\pi f_c}$
Low pass	T	$\frac{1}{\pi f_c R}$	$\frac{R}{2\pi f_c}$
	π	$\frac{1}{2\pi f_c R}$	$\frac{R}{\pi f_c}$
	L	$\frac{1}{2\pi f_c R}$	$\frac{R}{2\pi f_c}$

Tone Control. We now turn from filters (typically used in radio in the IF circuit of a super-heterodyne receiver) to a consideration of equalizers, particularly in their application to radio receivers, for altering the 'tone' of the reproduced sounds as it is affected by a greater or lesser gradual relative attenuation of bands of frequencies within the audio spectrum.

In Fig. 60, a capacitor C_1 is connected across the primary of the transformer supplying audio-frequency currents to a loudspeaker. As the frequency of the voltages applied from the valve to the network containing the capacitance and the transformer in parallel increases, so the impedance of the combination gets lower.

Considering the valve as a source of voltage having an internal resistance, clearly the voltage across the transformer drops, owing to the increasing voltage drop in the internal resistance, as the frequency gets higher. The internal resistance of the source varies with the type of valve-source used.

The capacitance value found suitable, if the valve is a pentode, to eliminate what is described as 'shrillness of tone' (in fact, the poor performance of the circuit and

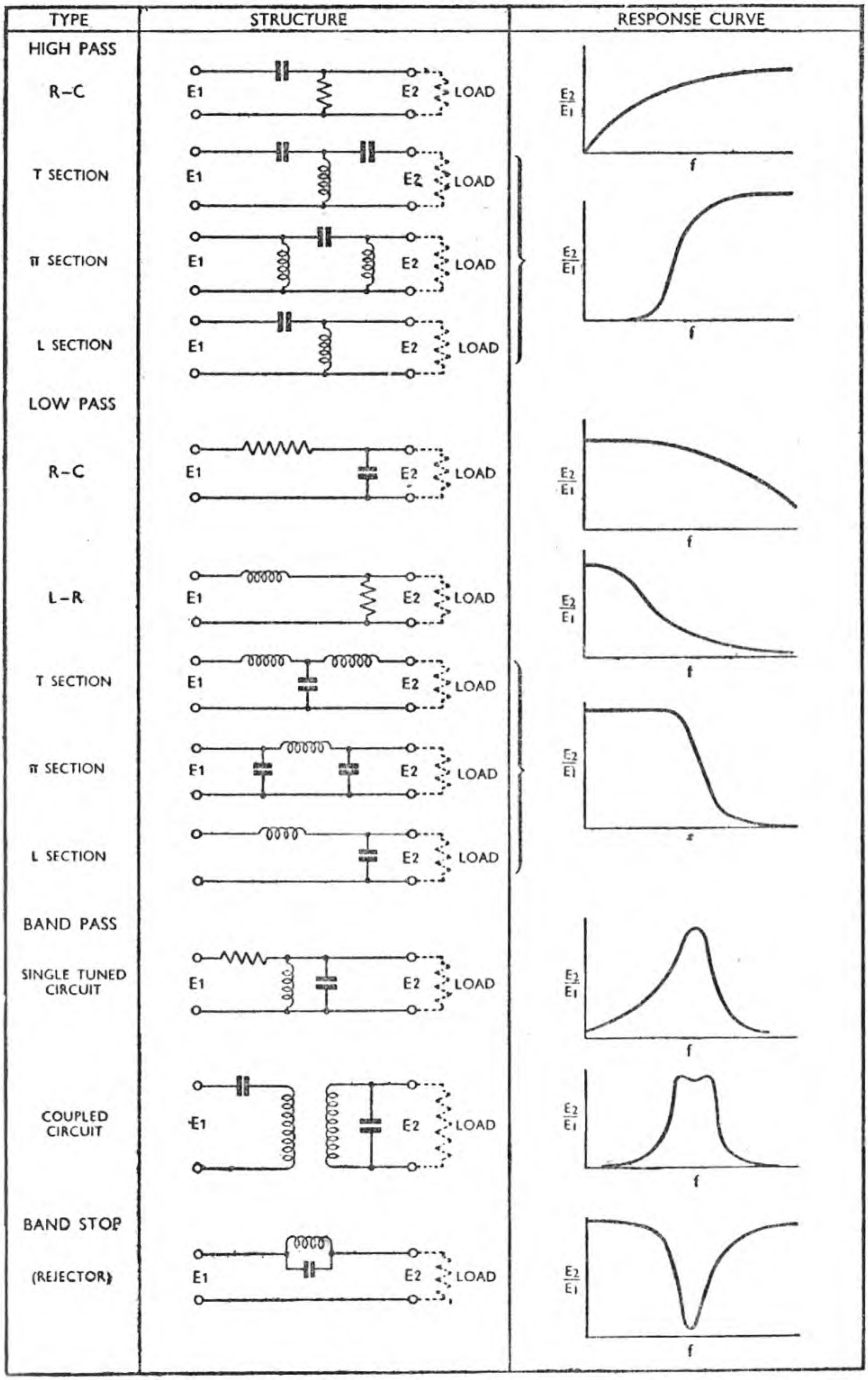


Fig. 59. FILTER CIRCUITS AND THEIR CHARACTERISTICS

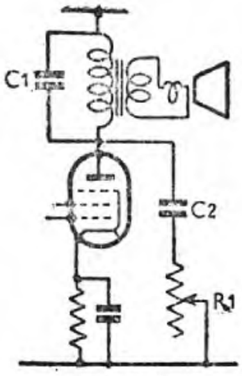


Fig. 60

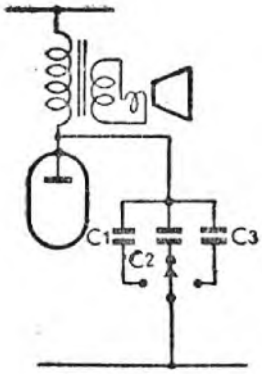


Fig. 61

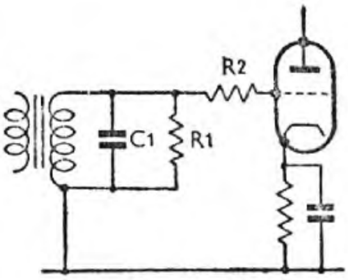


Fig. 62

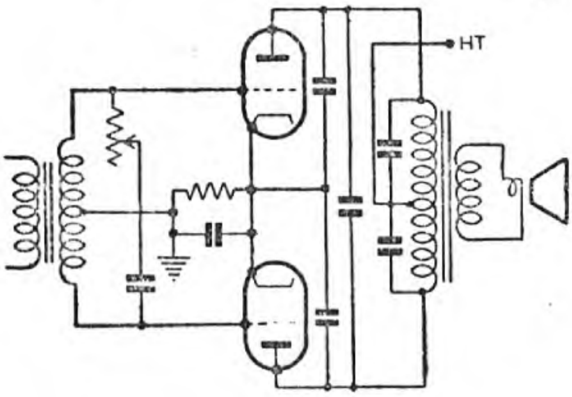


Fig. 63

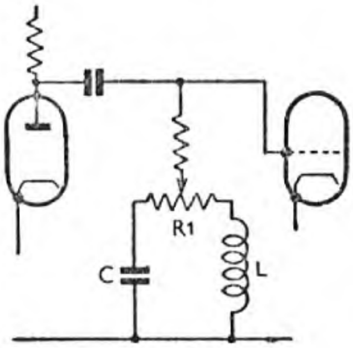


Fig 64

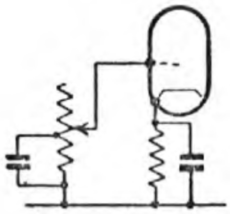


Fig. 66

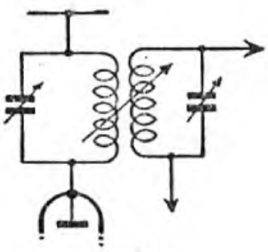


Fig. 67

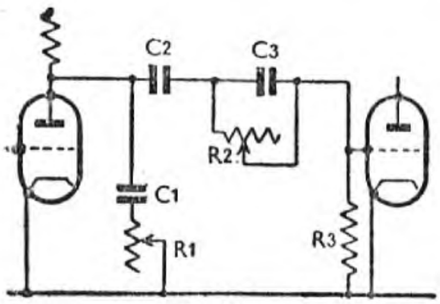


Fig. 65

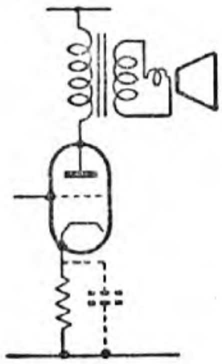


Fig 69

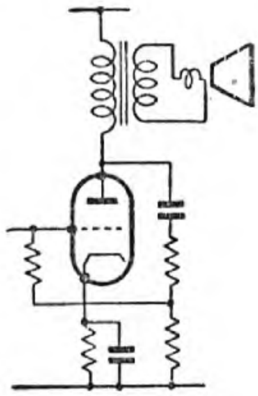


Fig. 70

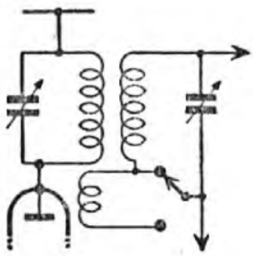


Fig. 68

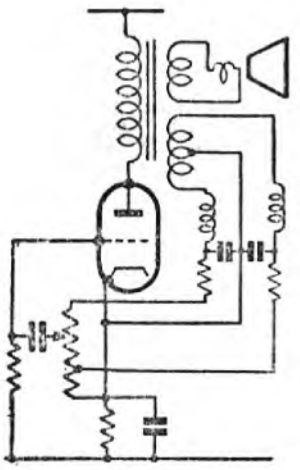


Fig. 71

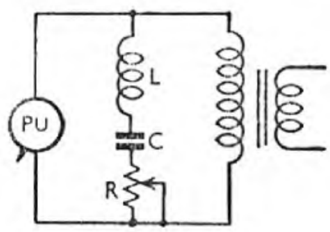


Fig. 72

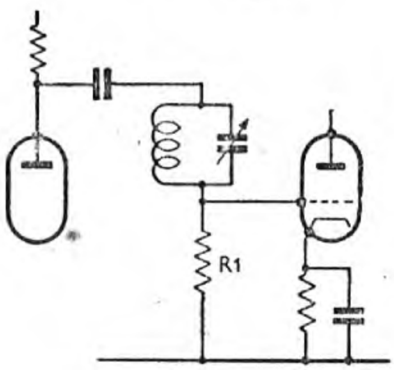


Fig. 73

CIRCUITS THAT CONTROL AUDIO-FREQUENCY RESPONSE

Figs. 60-73. This representative batch of tone-control circuits affords much scope for experiment, and includes methods to prevent shrillness.

loudspeaker at the higher audio frequencies), is 0·05 to 0·001 μF.

Variable control of tone may be provided by C_2 in series with R_1, which is, so far as the alternating currents are concerned, in parallel with C_1, because + HT and earth (or frame or chassis) are virtually at the same zero alternating potential.

A maximum value of between 25 and 50 k/ohms does for R_1 if C_2 is 0·01 to 0·05 μF. As R_1 is decreased, the equalizer attenuates the higher frequencies to a greater degree and the tone becomes more 'mellow'.

Fig. 61 shows a stepped system for different degrees of attenuation of the higher frequencies. Suitable values of the capacitors for pentode valves are 0·001, 0·005, and 0·02 μF.

In Fig. 62, depending upon the choice of values, and the design of the transformer, the performance may be made that of an equalizer or a low-pass filter. The transformer will have leakage inductance and this forms the series arm of a low-pass filter, while C_1 is the shunt arm and R_1 the load or terminating resistance.

If a low-pass filter effect is required (with an abrupt cut-off after a cut-off frequency), C_1 may be varied until, at a chosen frequency, the voltage across it rises to a maximum, R_1 being infinite. R_1 may then be chosen so that the voltage at this tuned frequency is made approximately equal to the voltage appearing at lower frequencies. The circuit will then give a very rapid attenuation of voltages of higher frequency than the cut-off frequency.

To make the attenuator vary more slowly with frequency, R_1 may be reduced more and more. (R_2 has no functional significance as regards the filter or equalizer action, its use is to stop parasitic oscillations if these are prone to occur.)

In Fig. 63 we get an equalizer effect and variable control.

In Fig. 64, moving the slider along R_1 so that the impedance of the network is chiefly capacitive, gives a greater attenuation of the higher frequencies, and moving it to the other end, to make the impedance chiefly inductive, gives a greater attenuation of the lower frequencies so that intermediate settings of R_1 give intermediate results.

Fig. 65 permits control of both high- and low-frequency attenuation by operation of two controls. R_1 and C_1 correspond to C_2 and R_1 in Fig. 60. C_2 is the normal coupling capacitor of sufficient capacitance to pass the low frequencies with little loss. At low values of R_2, C_3 has little effect, but at high values C_3 is in series with C_2. By making C_3 of small capacitance, the effective coupling capacitance is made small and the proportion of low-note response appearing across R_3 correspondingly reduced.

The principle of tone-compensated volume control is shown in Fig. 66. To preserve apparent tonal balance, a greater proportion of low-frequency energy is required at low volumes. By a tapping on the volume control, it can be arranged for high frequencies to be by-passed at low settings of the control.

Tone Control by Negative Feed-back. (Figs. 67 and 68.) The principle of negative feed-back is used in its more general application to reduce distortion in valve amplifiers; it can, however, be used to alter the response of amplifiers as a function of the frequency of the currents amplified.

Negative feed-back implies that the signal voltage applied at the input to a valve amplifier, be it a single or multi-stage amplifier, is opposed by another voltage, of less amplitude, derived from the input voltage but secured as an output voltage and, therefore, proportional to, but of less amplitude than, the input voltage.

Put more concisely, negative feed-back means that a voltage, derived from the output of the amplifier, is fed back in phase opposition to the voltage input to the amplifier. If, by design or fortuitously, the phase of the feed-back voltage, or its magnitude, or both, varies with frequency, then the input voltage will be more or less opposed, according to the frequency of the voltage, and so the apparent gain of the amplifier will vary with frequency and so give a measure of tone control.

If A is the gain of an amplifier and β is the proportion of the output voltage fed back in anti-phase, then the net gain of the amplifier is, in voltage feed-back, $\frac{A}{1 + \beta A}$.

Feed-back also has the effect of altering the anode slope resistance of the output valve, an alteration given in voltage feed-back by, approximately, $\frac{1}{\beta g_m}$, where g_m is the mutual conductance of the valve.

Thus, if β, in either of these expressions, varies with frequency, so the response varies with frequency and so the anode slope resistance, which may also have an effect upon response, varies with frequency.

In Fig. 69, suppose the capacitor, shown dotted, is in fact connected across the cathode resistance, then the impedance of the combination of resistor and capacitor will vary with frequency.

At the higher frequencies, this impedance may be substantially zero, so the grid cathode alternating voltage is that of the grid to earth alternating voltage. As the frequency gets lower, the AC, passing through R and C in parallel, may establish potentials on the cathode because the impedance of the RC combination is no longer negligible in its relationship to the alternating voltages established across it.

In this condition, if the grid goes positive (say) with respect to earth, so the cathode goes positive too, and the net grid cathode potential diminishes, making the ratio of anode current to grid voltage (the effective g_m of the valve) less, and so its effective magnification becomes less.

At higher frequencies, reactance of capacitor may be negligible compared with resistance of parallel resistor and valve gives a maximum magnification. At lower frequencies, reactance of capacitor may, if it has a suitable value, increase, so introducing feed-back and lowering magnification.

In Fig. 70 the feed-back is obtained from the anode circuit. If the cathode circuit exerts no feed-back, and if the capacitor is large and if no reactance plays any part (a quite unrealizable condition up to very high frequencies), then the system behaves independently of frequency. The difficulty with such circuits is that, at some high frequency, reactance does play a part and the whole set-up oscillates.

In Fig. 71 the scheme illustrated is designed to prevent oscillation by attenuating any high frequency in the feed-back circuit which might get fed back to the input.

Scratch Filters and Heterodyne Filters. The scratch noise appearing at the output of a gramophone pick-up has chief components in the region of 5,000 c/s. The heterodyne whistle set up by broadcasting stations is of the order 8 to 9 Kc/s.

The noise can be eliminated by filters of the band-stop type. The series tuned circuit of Fig. 72 presents its lowest impedance at resonance, and if L and C are suitably chosen, the low impedance presented to the voltage source PU causes a large voltage drop in its internal resistance and so, at and around the resonance frequency, a low voltage to the output transformer. The resistor R adjusts the maximum voltage attenuation.

The band-stop filter of Fig. 73 works because the parallel combination of L and C becomes a very high impedance at frequencies near resonance, thus reducing the voltage across R_1.

In both cases, L and C are chosen to be resonant either at the 'scratch' or 'heterodyne' frequencies.

SECTION 8

WIRE TABLES

TABLE VIII: BARE COPPER

SWG	Diam. (in.)	Section area (sq. in.)	Ohms per 1,000 yds.	Length per ohm	Weight per 1,000 yds.	Ohms per lb.
				ins.	ozs.	
50	0·001	0·00000079	30,570	1·18	0·145	3,365,000
49	0·0012	0·00000113	21,230	1·7	0·209	1,623,000
48	0·0016	0·00000201	11,941	3·02	0·372	513,500
47	0·002	0·00000314	7,642	4·71	0·581	210,300
46	0·0024	0·00000452	5,307	6·78	0·834	101,440
45	0·0028	0·00000616	3,899	9·24	1·14	54,750
44	0·0032	0·00000804	2,985	10·77	1·49	32,090
43	0·0036	0·0000102	2,359	15·26	1·88	20,040
42	0·004	0·0000126	1,910	18·87	2·32	13,146
41	0·0044	0·0000152	1,578	22·81	2·81	8, 978
40	0·0048	0·0000181	1,326	27·15	3·35	6,340
				yards	lbs.	
38	0·006	0·0000283	849	1·18	0·327	2,597
36	0·0076	0·0000454	529	1·89	0·525	1,008
34	0·0092	0·0000665	361	2·77	0·769	469·8
32	0·0108	0·0000916	262	3·82	1·06	247·4
30	0·0124	0·000121	199	5·03	1·40	142·85
28	0·0148	0·000172	139·5	7·18	1·99	70·14
26	0·018	0·000254	94·3	10·6	2·94	32·06
24	0·022	0·000380	63·2	15·8	4·4	14·366
22	0·028	0·000616	39	25·6	7·12	5·475
20	0·036	0·00102	23·6	42·4	11·8	2·004
18	0·048	0·00181	13·27	75·4	20·9	0·684
16	0·064	0·00322	7·46	134·6	37·2	0·2
14	0·08	0·00503	4·78	208	58·1	0·08216
12	0·104	0·0085	2·83	353	92·8	0·02877
10	0·128	0·013	1·87	535	148·8	0·012537

TABLE IX: FLEXIBLE CORDS

Conductor		Current Rating	Resistance per 1,000 yds. at 60° F. for straight single cores, no allowance being made for twisting
Nominal cross-sectional area	Number and diameter (in.) of wires		
sq. in.		amps	ohms
0·0006	14/0·0076	2	39·7
0·001	23/0·0076	3	24·2
0·0017	40/0·0076	5	13·9
0·003	70/0·0076	10	7·94
0·0048	110/0·0076	15	5·05
0·007	162/0·0076	20	3·43

TABLE X:

COTTON-COVERED AND SILK-COVERED

SINGLE COTTON-COVERED					DOUBLE COTTON-COVERED				
SWG	Total thickness of covering in mils.	Turns per in.	Turns per sq. in.	Yards per lb.	SWG	Total thickness of covering in mils.	Turns per in.	Turns per sq. in.	Yards per lb.
40	4	112·5	26,600	3,910	40	7/9	78	6,080	3,456
38	4	100	10,000	2,550	38	7/9	71·5	5,110	2,287
36	4	86·2	7,430	1,610	36	7/9	64	4,010	1,477
34	5	70·5	4,970	1,280	34	8/10	55	3,020	1,024
32	5	63·3	4,010	835	32	8/10	50·5	2,550	755
30	5	57·5	3,300	634	30	8/10	47	2,210	587
28	5	50·5	2,550	452	28	8/10	42	1,790	422
26	5	43·4	1,892	311	26	8/10	37	1,400	294
24	5	37	1,369	219	24	8/10	32·3	1,043	203
22	5/6	29·8	888	134	22	9/11	26·3	692	129
20	5/6	24·1	581	81·7	20	9/11	21·7	473	79·4
18	6/7	18·3	335	46·3	18	9/11	17·3	299	45·4
16	7	14·1	198	26·1	16	10/12	13·3	177	25·6
14	7/8	11·4	130	16·9	14	12/14	10·75	115	16·6
12	7/8	9	81	10·3	12	12/14	8·5	72	9·09
10	7/8	7·4	54	6·63	10	12/14	7·1	50·3	6·58

SINGLE SILK-COVERED					DOUBLE SILK-COVERED				
				yds. per oz.					yds. per oz.
47	1·2	312	97,300	1,375	47	2·2	238	56,600	1,190
46	1·2	278	77,300	1,000	46	2·2	217	47,100	871
45	1·2	250	62,500	752	45	2·2	200	40,000	675
44	1·2	227	51,530	599	44	2·2	185	34,200	536
42	1·2	192	36,860	387	42	2·2	161	25,000	358
40	1·3	164	26,900	276	40	2·5	137	18,800	258
				per lb.					per lb.
38	1·3	137	18,770	2,871	38	2·5	118	13,900	3,760
36	1·3	112	12,540	1,815	36	2·5	90·1	8,120	1,750
34	1·3	95·2	9,060	1,250	34	2·5	85·5	7,310	1,220
32	1·3	82·6	6,820	912	32	2·5	75·2	5,650	887
30	1·3	73	5,330	695	30	2·5	67·1	4,500	675
28	1·3	62·1	3,860	488	28	2·5	57·8	3,340	478
26	1·3	51·8	2,680	332	26	2·5	48·8	2,380	325
24	1·5	42·5	1,810	222	24	3	40	1,600	218
22	2	33·3	1,090	137	22	3	32·2	1,040	134
20	2	26·3	692	83·3	20	3	25·6	655	82·5
18	2	20	400	46·8	18	3	19·6	384	46·3
16	3	15	222	26·4	16	4	14·7	216	26·1

TABLE XI: ENAMELLED

SWG	Total thickness of covering in mils.	Turns per in.	Turns per sq. in.	Yards per oz.
50	0·2	833	694,000	6,480
49	0·2	714	510,000	4,510
48	0·3	526	277,000	2,500
47	0·3	435	189,000	1,630
46	0·4	357	127,500	1,128
45	0·5	303	91,800	835
44	0·5	270	72,900	642
42	0·6	217	47,100	411
40	0·7	182	33,100	286
				per lb.
38	1·0	143	20,450	2,810
36	1·0	116	13,450	1,840
34	1·0	98	9,600	1,202
32	1·2	83·3	6,940	915
30	1·2	73·5	5,400	694
28	1·6	60·1	3,610	488
26	1·8	50·5	2,550	330
24	2·3	41·1	1,690	221
22	2·5	32·8	1,080	137
20	2·7	25·8	666	83·3
18	2·7	19·7	388	46·9
16	3·5	14·8	219	26·4

TABLE XII: CURRENT RATING

Maximum current in amps at 1,000 amps per sq. in. In practice, the safe current depends on heat dissipation, and in amateur-made transformers—for example, where windings are less compact—the figures below may be doubled.

SWG	Amps	SWG	Amps
12	8·5	28	·172
14	5	30	·12
16	3·2	32	·092
18	1·8	34	·0665
20	1·02	36	·0454
22	·615	38	·0283
24	·38	40	·0181
26	·25		

TABLE XIII: EUREKA RESISTANCE WIRE

SWG	Diameter (in.)	Ohms per yard	Yards per lb.	Current (amps) for temperature rise of 100° C.
8	0·160	0·0335	4·2	29·0
9	0·144	0·0413	5·3	24·0
10	0·128	0·0523	6·7	20·1
11	0·116	0·0637	8·1	18·5
12	0·104	0·0793	10·0	14·8
13	0·092	0·1013	13·0	12·6
14	0·080	0·1339	17·1	10·5
15	0·072	0·1653	21·1	9·3
16	0·064	0·2094	26·7	8·1
17	0·056	0·2733	34·9	7·0
18	0·048	0·3718	47·6	5·75
19	0·040	0·5356	68·4	4·6
20	0·036	0·6613	84·6	4·1
21	0·032	0·8372	106·9	3·6
22	0·028	1·093	139·8	3·1
23	0·024	1·487	190·8	2·7
24	0·022	1·770	226·7	2·4
25	0·020	2·142	274·6	2·18
26	0·018	2·645	337·8	2·0
27	0·0164	3·186	406·5	1·82
28	0·0148	3·914	500·0	1·66
29	0·0136	4·634	592·3	1·54
30	0·0124	5·575	714·2	1·4
31	0·0116	6·370	813·0	1·3
32	0·0108	7·350	943·4	1·2
33	0·010	8·571	1,093·2	1·08

TABLE XIV: KANTHAL RESISTANCE WIRE

SWG	Ohms per ft. at 20 deg. C		Ft. per lb.		Current (amps) for temperature of 200 deg. C. Types A and D
	Type A	Type D	Type A	Type D	
8	·03266	·03172	16·04	15·83	21·5
9	·04032	·03916	19·80	19·54	18·7
10	·05103	·04956	25·07	24·73	16
11	·06214	·06035	30·53	30·11	13·95
12	·07731	·07508	37·97	37·45	12·10
13	·09879	·09594	48·53	47·87	10·17
14	·1306	·1269	64·15	63·29	9·14
15	·1613	·1566	79·23	78·13	7·25
16	·2041	·1983	100·3	98·91	6·20
17	·2666	·2590	131·0	129·2	5·18
18	·3629	·3524	178·2	175·8	4·46
19	·5226	·5075	256·6	253·2	3·29
20	·6452	·6266	316·9	312·6	2·86
21	·8166	·7930	401·2	395·6	2·46

TABLE XIV: KANTHAL RESISTANCE WIRE—*continued*

SWG	Ohms per ft. at 20 deg. C		Ft. per lb.		Current (amps) for temperature of 200 deg. C. Types A and D
	Type A	Type D	Type A	Type D	
22	1·067	1·036	523·9	516·8	2·10
23	1·452	1·410	713·0	703·2	1·67
24	1·728	1·678	848·8	836·8	1·48
25	2·090	2·030	1027	1013	1·30
26	2·581	2·506	1267	1250	1·15
27	3·109	3·019	1526	1506	·995
28	3·817	3·707	1875	1849	·870
29	4·535	4·390	2220	2190	·775
30	5·338	5·281	2671	2634	·685
31	6·214	6·035	3052	3010	·625
32	7·169	6·962	3504	3473	·565
33	8·362	8·121	4108	4050	·510

TABLE XV: COMPARATIVE TABLE OF WIRE GAUGES

No.	British standard gauge SWG	American gauge AWG or BS	No.	British standard gauge SWG	American gauge AWG or BS
	Diam. (in.)	Diam. (in.)		Diam. (in.)	Diam. (in.)
7/0	·500	—	23	·024	·0226
6/0	·464	—	24	·022	·0201
5/0	·432	—	25	·020	·0179
4/0	·400	·4600	26	·018	·0159
3/0	·372	·4096	27	·0164	·0142
2/0	·348	·3648	28	·0148	·0126
0	·324	·3249	29	·0136	·0113
1	·300	·2893	30	·0124	·0100
2	·276	·2576	31	·0116	·0089
3	·252	·2294	32	·0108	·0080
4	·232	·2043	33	·0100	·0071
5	·212	·1819	34	·0092	·0063
6	·192	·1620	35	·0084	·0056
7	·176	·1443	36	·0076	·0050
8	·160	·1285	37	·0068	·0045
9	·144	·1144	38	·0060	·0040
10	·128	·1019	39	·0052	·0035
11	·116	·0907	40	·0048	·0031
12	·104	·0808	41	·0044	—
13	·092	·0720	42	·0040	—
14	·080	·0641	43	·0036	—
15	·072	·0571	44	·0032	—
16	·064	·0508	45	·0028	—
17	·056	·0453	46	·0024	—
18	·048	·0403	47	·0020	—
19	·040	·0359	48	·0016	—
20	·036	·0320	49	·0012	—
21	·032	·0285	50	·0010	—
22	·028	·0253			

TABLE XVIA: FUSE ELEMENTS

IEE Current rating of semi-enclosed fuse	Tinned copper wire		Standard alloy wire (63% tin, 37% lead)	
	Diameter (in.)	SWG	Diameter (in.)	SWG
amps				
1·8	—	—	0·0164	27
3·0	0·006	38	0·024	23
5·0	0·0084	35	0·032	21
8·5	0·0124	30	—	—
10·0	0·0136	29	—	—
15·0	0·020	25	—	—
17	0·022	24	—	—
20	0·024	23	—	—
24	0·028	22	—	—
30	0·032	21	—	—
37	0·040	19	—	—
46	0·048	18	—	—
53	0·048	18	—	—
60	0·056	17	—	—
64	0·056	17	—	—
83	0·072	15	—	—
100	0·080	14	—	—

The ratings given in Table XVIA are the normal maximum current of the circuit, and not the overload at which the fuse will operate. Fusing currents are given in Table XVIB, below.

TABLE XVIB: FUSING CURRENTS

SWG	Approximate fusing currents—amperes				
	Copper (plain)	Standard alloy 63% tin 37% lead	Lead	Tin	Aluminium
12	344		46·5	55	260
14	232		31·5	37	170
16	166		22·5	26·6	120
18	110		14·5	17·3	80
20	70		9·5	11·3	50
21		7·5			
22	50		6·5	7·7	35
23		4·5			
24	35		4·5	5·4	25
26	25		3·5	4·0	18
27		2·7			
28	17		2·5	3·0	14
30	15		1·9	2·3	10
32	12		1·6	1·9	8
34	9		1·2	1·5	7·5
36	7		0·9	1·1	5·0
38	5		0·75	0·8	4
40	3		0·5	0·6	2·5

COMPONENT DESIGN

Air-cored Coils. The simplest method of calculating the inductance of a coil is the formula given by Terman: $L\,(\mu H) = N^2dF$, where N is the number of turns, d the diameter of the coil in inches and the term F is a variable, depending upon the ratio of coil diameter to length of winding. F is given in Table XVII for ratios of ·1 to 10, to cover all normal constructions.

TABLE XVII

Factor F in inductance formula $L=N^2dF$, in terms of the length 'l' and diameter 'd' of the winding; l and d in inches.

$\frac{l}{d}$	F	$\frac{l}{d}$	F
·1	·05	1·5	·013
·2	·04	2	·01
·3	·034	2·5	·0085
·4	·029	3	·0072
·5	·026	4	·0056
·6	·023	5	·0047
·7	·021	6	·0039
·8	·019	7	·0033
·9	·018	8	·0029
1	·017	10	·0024

For example, a 50-turn coil of diameter 2 in. and length 1 in., has a ratio $\frac{l}{d}$ of ·5, for which F is obtained from the chart as ·026, and so the inductance becomes: $L = 2{,}500 \times 2 \times {\cdot}026 = 130\ \mu H$.

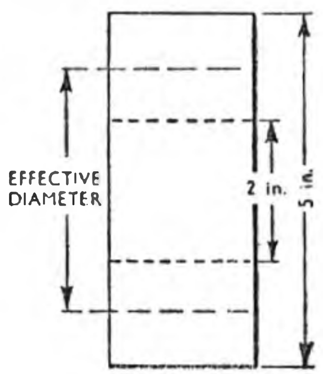


Fig. 74. Effective diameter is used to calculate inductance of a multi-layer coil.

When dealing with a multi-layer coil, d is mean diameter, that is, the inside diameter of the coil plus half the difference of the inside and outside diameters. The inside diameter of the coil shown in Fig. 74 is 2 in., and the outside diameter 5 in., so that the effective value of d to be used in finding the inductance is:

$$2 + \left(\frac{5-2}{2}\right) = 3\tfrac{1}{2}\ \text{in.}$$

The charts shown in Figs. 79 and 80 have been compiled from the above information and indicate the number of turns required for a given inductance from ·1 μH to 10 μH with a single layer on different-size formers, but with a constant ratio of $\frac{l}{d}$ of ·5. The gauge of wire to be employed is marked along each graph.

Iron-dust Cores. Where an iron or iron-dust core is employed, the inductance of the coil will be increased by a factor which is the effective permeability of the magnetic circuit. When the iron core forms a complete magnetic circuit around the coil with a negligible air-gap, as for instance in the case of G.E.C. Ironclad, illustrated in Fig.75, or the NeoSid cup or pot type, the inductance of the coil will be increased by a factor nearly equal to the permeability of the iron core, that is, from 2 to 4 in the radio-frequency bands.

Where, however, the iron core is in the form of a slug inside the coil, the net increase of inductance will be less than the permeability factor, owing to the effective air-gap.

Iron-dust cores having a permeability of 1·3 are made for use at 50 Mc/s and higher permeabilities, up to 15, for use in the IF band at 450-500 Kc/s. The makers' literature should be consulted in choosing a particular core for a given frequency range and purpose.

Advantages of iron-dust core inductances are :

(1) Inductance value can be adjusted.

(2) Lower R loss with the possibility of higher Q for a given coil.

(3) Possibility of achieving constant Q over a band of frequencies.

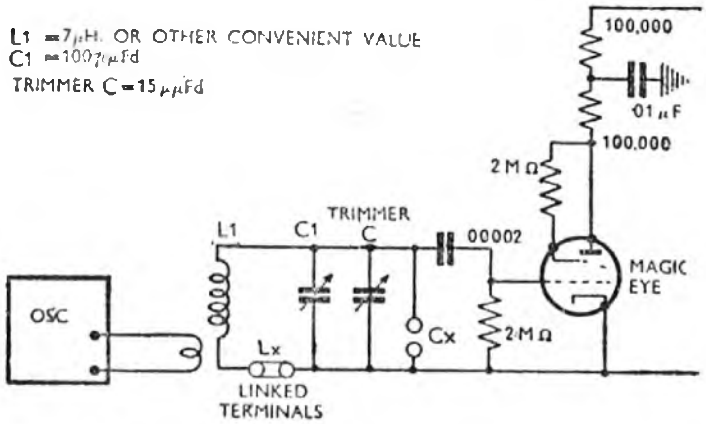


Fig. 76. Circuit for measuring values of inductors and capacitors. Oscillator frequency is set at 6 Mc/s.

Low-frequency Chokes. The design of LF chokes is complicated by the fact that, in addition to the ripple component, there is often a direct current flowing through the winding. This necessitates an air-gap in the magnetic circuit.

Since the actual inductance of an iron-cored choke coil is a variable depending upon the DC and upon the ripple voltage applied to it, some simplifying assumptions are made which reduce somewhat the accuracy of the method.

L is taken as equal to $\dfrac{1{\cdot}45\,AN^2}{\sqrt{a}\times 10^7}$,

where

A = cross-sectional area of iron circuit in square inches.

N = number of turns.

a = air-gap in inches. This is assumed to be never less than ·002 in.

In Figs. 81-84, the graphs denote the inductance for a given number of turns on the core shown in the caption. The different curves are for different lengths of air-gap, indicated by the figures at the end of the curve.

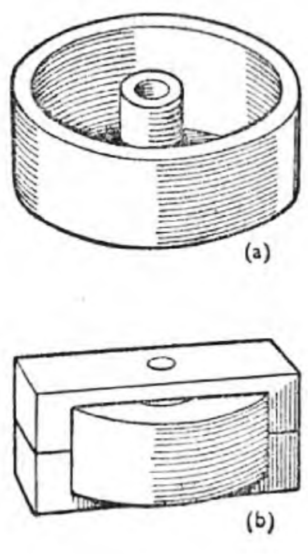


Fig. 75. Forms of iron-dust core for radio-frequency inductors. (a) Totally enclosed pattern, and (b) semi-enclosed.

The figures along each curve are the limiting values of current, DC plus AC, from the viewpoint of non-saturation. Below each chart is the gauge of wire which may be employed for different numbers of turns, and the resistance.

Measurement of Inductance. For the measurement of small inductances, ·1 – 150 μH, the resonance method is to be preferred on the score of simplicity and accuracy. It is shown in Fig. 76. The oscillator is set to about 6 Mc/s and feeds into the tuned circuit L_1C_1, having two terminals normally connected by a short link.

With the link in position, C_1, the calibrated capacitor, is set to maximum capacitance, and the oscillator tuning is adjusted for maximum reading on the valve voltmeter or magic-eye indicator. The unknown inductance is now connected to the terminals in place of the link and C_1 is adjusted for resonance. L_x, the unknown inductance, is then given by:

$L_x = L_1\dfrac{C_3}{C_1 - C_3}$, where L_1 is the original inductance, C_1 is the total capacitance, C_3 is the reduction in capacitance to reproduce the resonant condition with L_x in circuit.

For a carefully constructed standard of 7 μH employed with a frequency of 6 Mc/s, the capacitance to inductance ratio for L_x in terms of

C_3 is as shown in the chart (Fig. 85).

For the measurement of larger inductances the impedance bridge of Fig. 78 is to be preferred. In this case, inductances can be read off a resistance scale once the standard inductance is brought into circuit.

Capacitors are grouped according to their dielectric—the insulating material between their plates. These are air, mica and mica substitutes, paper, ceramics and electrolyte.

The capacitance is given by: $C = \frac{A \times SIC}{4{\cdot}45t}$, where A is the area of the opposing plates in square inches, t is the thickness of the dielectric in inches, SIC is the permittivity (specific inductive capacitance) of the dielectric, and C is expressed in micro-microfarads.

Table XVIII gives the *SIC* for a number of materials used as dielectrics. It also shows the range of power factors and the breakdown voltage in volts per thousandth of an inch.

Use of Capacitors. In choosing a capacitor for a particular service, consideration must be given to the following points:

(1) The dielectric must be capable of withstanding the peak voltage that will be impressed upon it.

(2) The terminals and plate configuration must be suitable for the peak voltage to be applied, under the worst conditions of atmospheric pollution, or the low pressures of high altitude, that may be encountered.

(3) The lugs joining the plates to the terminals must have sufficient cross-section to carry the capacitance current without undue overheating.

(4) The portion of the total current represented by the loss component must not cause a dangerous rise in temperature.

A rise in dielectric temperature in

TABLE XVIII: DIELECTRIC QUALITIES

Material	SIC	Power factor, tan θ	Breakdown strength in volts per thousandth of an inch
Air, normal pressure	1	0	20
Air, five times normal pressure	1	0	80
Air, at altitude of 20,000 ft. ..	1	0	10
Mica	3 — 8	·0001 — ·001	500 — 1,000
Micalex	8	·002	200 — 300
Polystyrene (Distrene, Trolitol, etc.)	2·2 — 2·5	·0002	500
Frequentite, Calit	6	·0003 — ·002	100 — 300
Alsimag, Isolantite	6	·0005 — ·002	100 — 300
Faradex, Condensa	80	—	—
Porcelain	5 — 6	·001 — ·005	50 — 150
Paper	2 — 2·5	·02 — ·05	100 — 500
Glass (Electrical)	4 — 6	·005 — ·01	1,000 — 1,500
Glass (other grades)	3 — 9	·005 — ·05	200 — 500
Ebonite	3 — 5	·005 — ·01	400 — 500
Bakelite (Phenolaldehyde) ..	4 — 7	·02 — ·1	100 — 600
Wood	3 — 5	·002 — ·05	100 — 200

practically every instance causes a lowering of the dielectric strength, and also an increase in the dielectric loss. Therefore, overheating effects can be cumulative, and breakdowns sometimes occur after prolonged use at a small overload. For this reason, it is imperative that the capacitor manufacturer's rating should not be exceeded.

At high frequencies, the limiting factor becomes the current that may be passed, and whilst a general figure cannot be given, it could be said that the maximum current passed by a small mica capacitor of the 'postage stamp' variety should not exceed one ampere. The following figures are quoted by Maloff for a ·01 mica capacitor (*Proceedings I.R.E.*, Vol. 20, p. 647, April, 1932):

Frequency Kc/s	*Rated Voltage*
Direct Current	10 kV
1	10 kV
100	3 kV
300	3 kV
1,000	1·78 kV
3,000	605 volts
10,000	178 volts

Electrolytic Capacitors. Electrolytic capacitors are formed for a given voltage, and have a plate area and dielectric thickness suitable for use at that voltage. To avoid risk of permanent damage to the dielectric film, the rated voltage, and current, where stated, should not be exceeded.

Capacitors should not be employed at maximum ratings at a temperature in excess of 40 deg. C, and most types are not satisfactory at temperatures below –10 deg. C.

When employed as reservoir capacitors, the capacitance should be chosen so that $\frac{I^2}{C}$ is less than 900 for capacitors having plain anodes, and less than 450 for etched anode types. I is the DC current in milliamperes, and C the capacitance in microfarads.

Measurement of Capacitance and Power Factor. The simplest method of measuring the capacitance and power factor is the impedance bridge shown in Fig. 77. This employs the 100 c/s rectified ripple for energizing the bridge, and also a simple power pack to supply the magic-eye tuning indicator, which is connected as a grid rectifier across the galvo terminals of the bridge, to indicate the balance position.

The simple type is not capable of measuring very small capacitances, of the order of 10 mmFd or less, and cannot detect the small changes of unbalance caused by power factors in the range ·0001 to ·01.

Where these latter measurements are of importance, the more elaborate design of Fig. 78 is required.

In this, a valve oscillator feeds the bridge network, preferably via a cathode follower stage. An amplifier is interposed between the bridge and the detector, and it is essential that the screening and decoupling of oscillator and amplifier be of a high order if stable and accurate results are required.

In both types, the circuit employed does not allow the power factor of capacitors having a lower loss

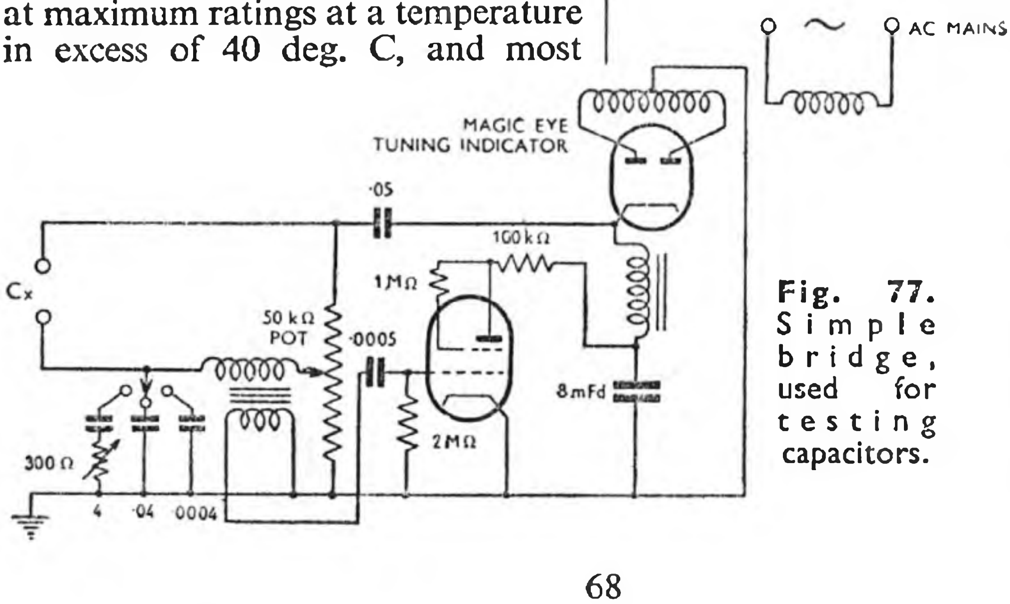
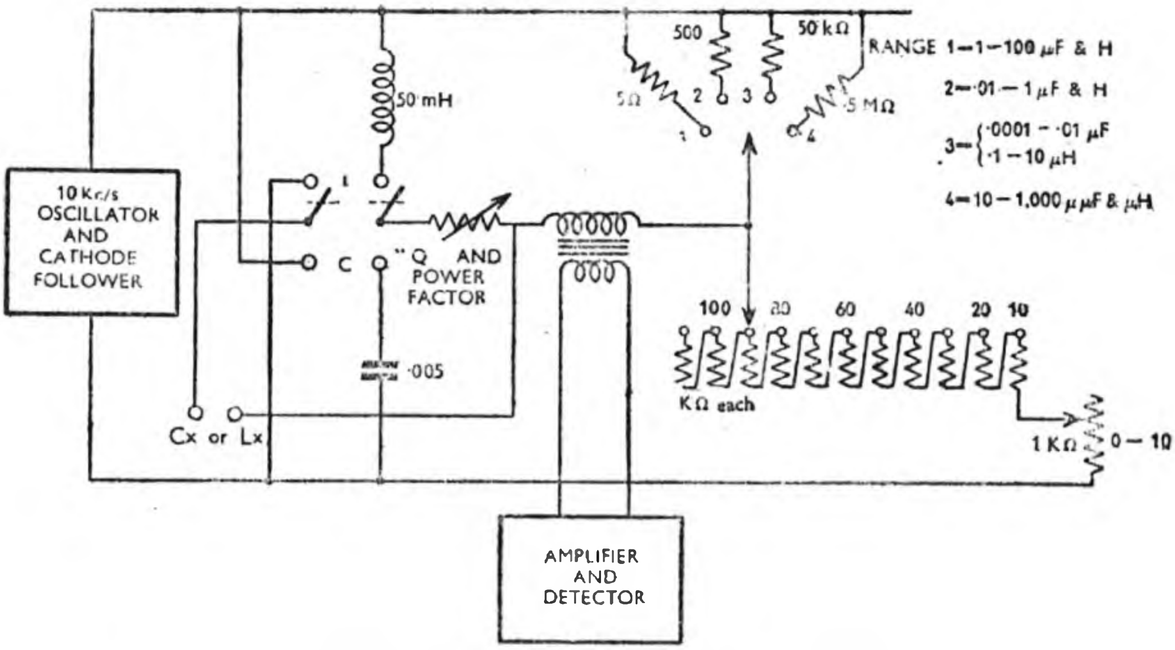


Fig. 77. Simple bridge, used for testing capacitors.



DIRECT-READING IMPEDANCE BRIDGE

Fig. 78. Gives direct readings of impedance of a capacitor or an inductor.

than the standard capacitor employed to be measured. In such a case, it is necessary to connect a resistance in series with the unknown capacitor, set the resistor in series with the standard capacitor to zero and find the value of added resistance that balances the bridge.

As long as the power factor of the standard capacitor is known, the power factor of the unknown capacitor can be calculated, since at the balance point the phase difference in the two reactive arms of the bridge is zero.

For precise results, the readings of the lowest ranges must be reduced by a figure representing the effective capacitance of the terminals and wiring.

For the measurement of very small capacitances, the resonance method is widely employed. The circuit of Fig. 76 may be employed, and the trimmer capacitor calibrated in micro-microfarads.

The trimmer is set to maximum capacitance, and C_1 used to obtain resonance at the detector. The unknown capacitor is then connected at the terminals marked C_x and the trimmer capacitor is set to obtain resonance once more. The difference in its settings is equal to the unknown capacitor connected at C_x.

This method will be found satisfactory for measuring the input capacitance of a valve and its valve holder, also the variation of its capacitance with changes of anode current.

Power Transformers. Because it operates at a constant frequency, and usually with a constant load, the power transformer is a much simpler affair to design than the other transformers employed in radio engineering.

The design tables appended are for 50-cycle input frequency (Table XIX). Transformers based on this data will operate satisfactorily at 60 c/s, but must not be connected to a 25-c/s supply.

The laminations chosen are silicon steel, ·014 in. thick. The sizes are the types most commonly used and the stacks arranged for bobbins that are commercially available.

A flux density of 60,000 lines per sq. in. is provided when the core area A, multiplied by the turns per volt (TPV), equals 7·5.

The required core area is given approximately by $A = \frac{\sqrt{W_p}}{5{\cdot}7}$, where

TABLE XIX: DESIGN DATA FOR

W_s Total secondary load (watts)	Approx. efficiency (per cent)	W_p Primary watts $= \frac{W_s \times 100}{\text{Efficiency}}$	Core area (A) $= \frac{\sqrt{W_p}}{5{\cdot}7}$	Turns per volt, TPV $= \frac{7{\cdot}5}{A}$	Primary gauges for 200-250 volt (SWG)	Primary current for 230 volts (amps)	Suitable lamination
50	75	67 watts	1·5	5	26	·3	4A
75	80	94 ,,	1·76	4·5	24	·41	4A
100	85	117 ,,	2·1	4	23	·51	75A
150	90	166 ,,	2·35	3·5	22	·72	75A
200	90	222 ,,	2·7	3	20	1	28A
300	93	323 ,,	3·25	2·5	18	1·4	35A
500	94	530 ,,	4·15	2	16 or 2 × 19	2·4	37A

W_p is the primary power, that is, $\frac{W_s \times 100}{\text{Efficiency per cent}}$, and W_s is the power drawn from the secondaries.

Usual efficiencies that are obtained in small transformer designs are shown in column 2 of Table XIX.

To commence a transformer design, it is first necessary to know W_s, the secondary power. A radio transformer usually carries a centre-tapped HT secondary with two or more LT secondaries. For example :

(1) HT secondary: 350—0—350 volts at 120 mA.

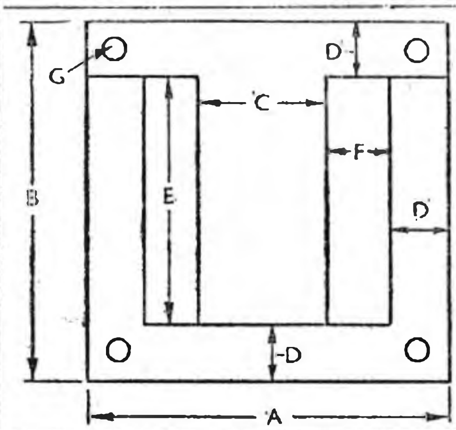
Since only half of the secondary is in use at one time, $W_s = \frac{350 \times 120}{1{,}000} =$ 42 watts.

(2) Rectifier LT=5 volts, 3 amps =15 watts.

(3) Normal LT = 6·3 volts, 5 amps = 31·5 watts.

Total secondary power, W_s=88·5.

TABLE XX: DETAILS OF LAMINATIONS

Diagram showing dimensions A, B, C, D, E and F.	Type No.	A	B	C	D	E	F
	4A	3·563	3·188	0·938	0·439	2·313	0·87
	75A	4·000	3·375	1·000	0·500	2·375	1·00
	28A	5·000	4·250	1·219	0·625	3·000	1·26
	35A	6·250	5·250	1·500	0·750	3·750	1·62
	37A	6·750	6·750	1·750	0·875	5·000	1·62
	41A	8·500	7·250	2·500	1·250	4·750	1·75

TYPICAL SMALL POWER TRANSFORMERS

Size of stack (in.)	Window area (sq. in.)	Compensated primary turns			Secondary compensation: to TPV × E_s add	Approx. magnetizing current at 230 volts
		200	230	250		
1·5	2	920	1,060	1,140	6 per cent TPV × E_s	83 mA
2¼	2	850	985	1,060	4 „ TPV × E_s	86 „
2¼	2·375	770	880	960	4 „ TPV × E_s	103 „
2¼	2·375	680	775	845	3 „ TPV × E_s	150 „
2¼	3·8	580	670	725	2 „ TPV × E_s	170 „
1¾	6·1	490	560	610	2 „ TPV × E_s	240 „
2	8·1	395	455	495	1 „ TPV × E_s (where E_s is the secondary voltage)	350 „

From column 2, Table XIX, we see that the efficiency will be of the order of 85 per cent, so that,

$$W_p = \frac{88 \cdot 5 \times 100}{85} = 104 \text{ watts.}$$

The core area A is now fixed by $\frac{\sqrt{104}}{5 \cdot 7} = 1 \cdot 8$ sq. in. and the turns per volt as $\frac{7 \cdot 5}{1 \cdot 8} = 4 \cdot 15$, say 4.

We now choose a suitable lamination size. Table XX lists the widely employed laminations together with suitable bobbins. Values of A for each bobbin are given.

Since the primary power is 104 watts, we can calculate the primary current from $I = \frac{W}{E} = \frac{104}{230}$ for a 230-volt supply, that is, 450 mA.

From the Wire Tables (Section 8), we see that for a conservative rating of 1,000 amps per sq. in. we should employ 23 SWG wire, but that

FOR CHOKE AND TRANSFORMER COILS

STANDARD BOBBINS

Thickness of lamination stack (*t*) and area of iron path (*A*), sq. in.

t	*A* sq. in.	*t*	*A* sq. in.	*t*	*A* sq. in.
1 in.	·938	1½ in.	1·4	2¼ in.	1·88
1 „	1	1½ „	1·5	2¼ „	2·25
1¼ „	1·5	2¼ „	2·7	2¾ „	3·35
1½ „	2·25	2¼ „	3·4	2¾ „	4·1
1¾ „	3·05	2¼ „	3·95	—	—
2½ „	6·25	3¾ „	9·4	5 „	12·5

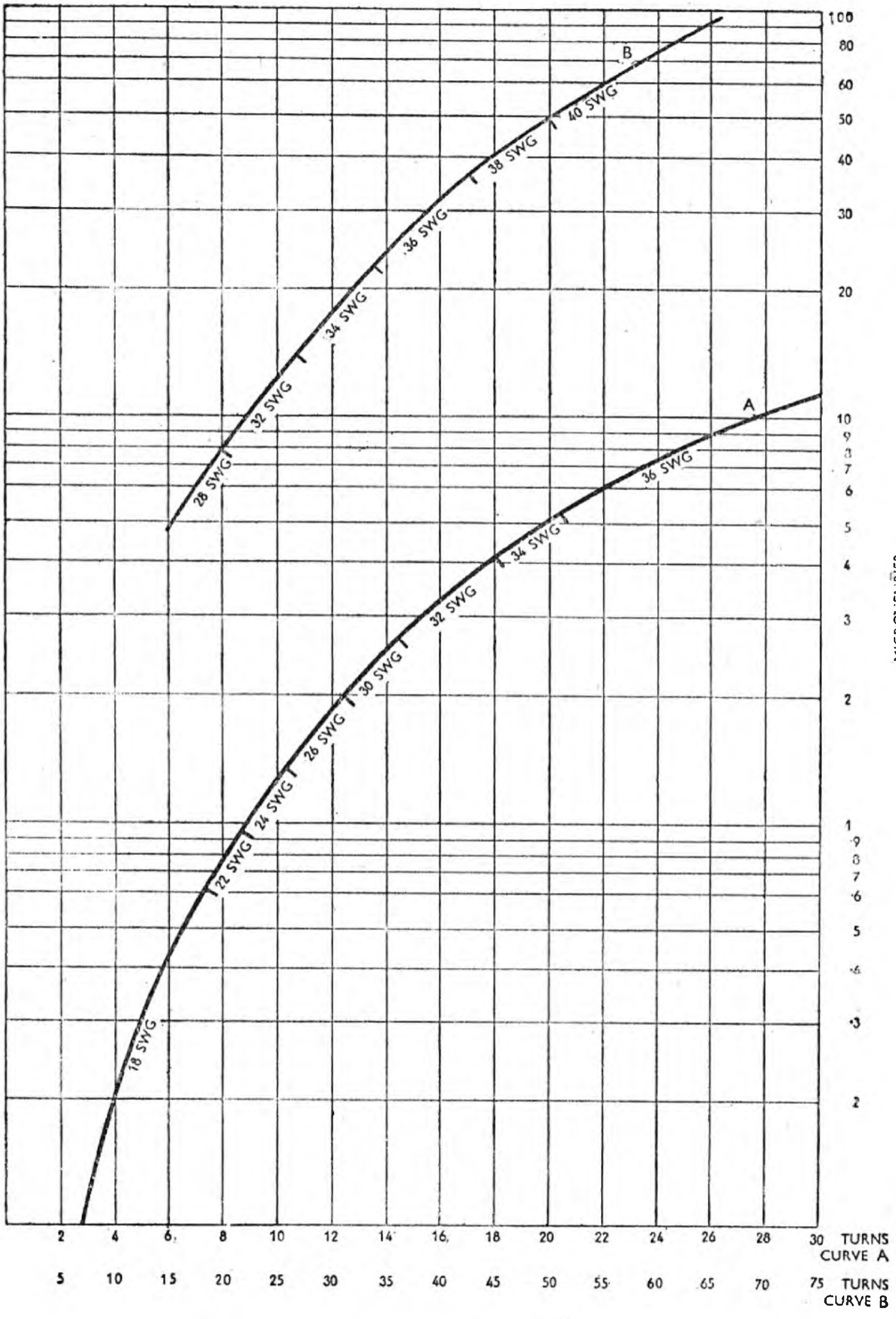


Fig. 79. INDUCTANCE OF AIR-CORED COILS (I)

CURVE A—DIAMETER ½ IN., LENGTH OF WINDING ¼ IN.

CURVE B—DIAMETER ¾ IN., LENGTH OF WINDING ⅜ IN.

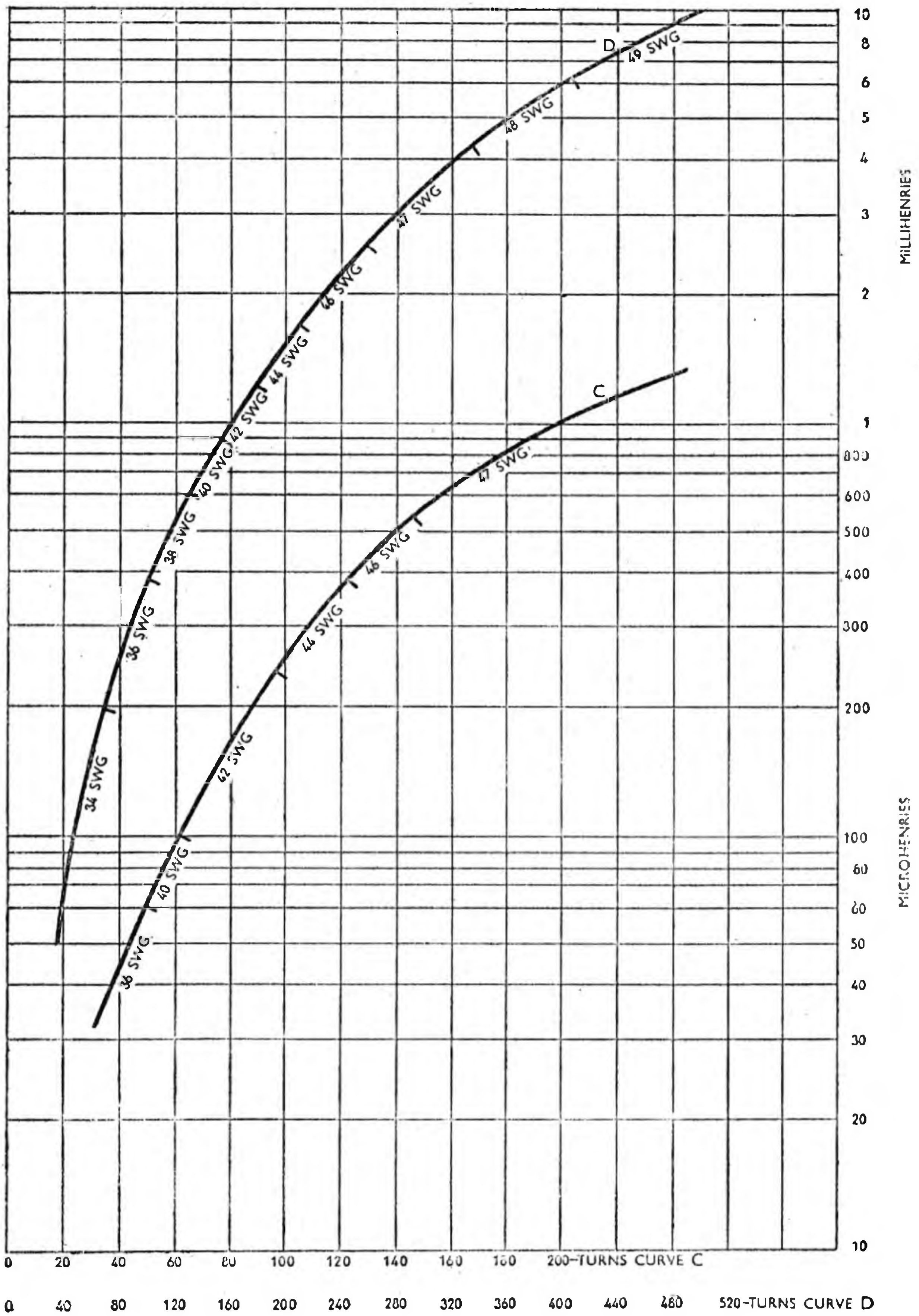


Fig. 80. INDUCTANCE OF AIR-CORED COILS (2)

CURVE C—DIAMETER 1 IN., LENGTH OF WINDING ¼ IN.

CURVE D—DIAMETER 1½ IN., LENGTH OF WINDING ¼ IN.

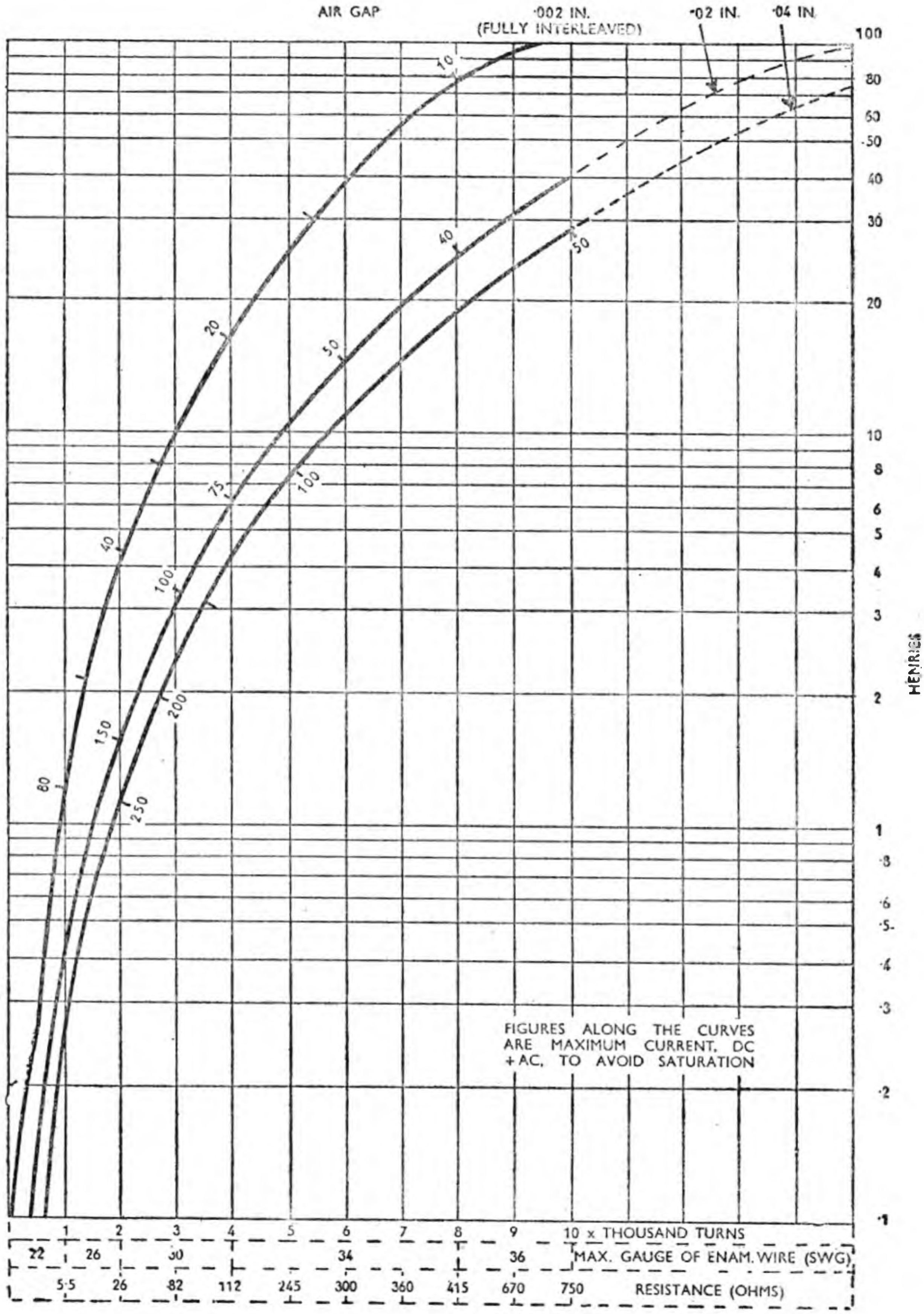


Fig. 81. INDUCTANCE OF IRON-CORED LF CHOKES

No. 15 LAMINATIONS (STALLOY)

CORE ·625 IN. THICK (40 PAIRS)

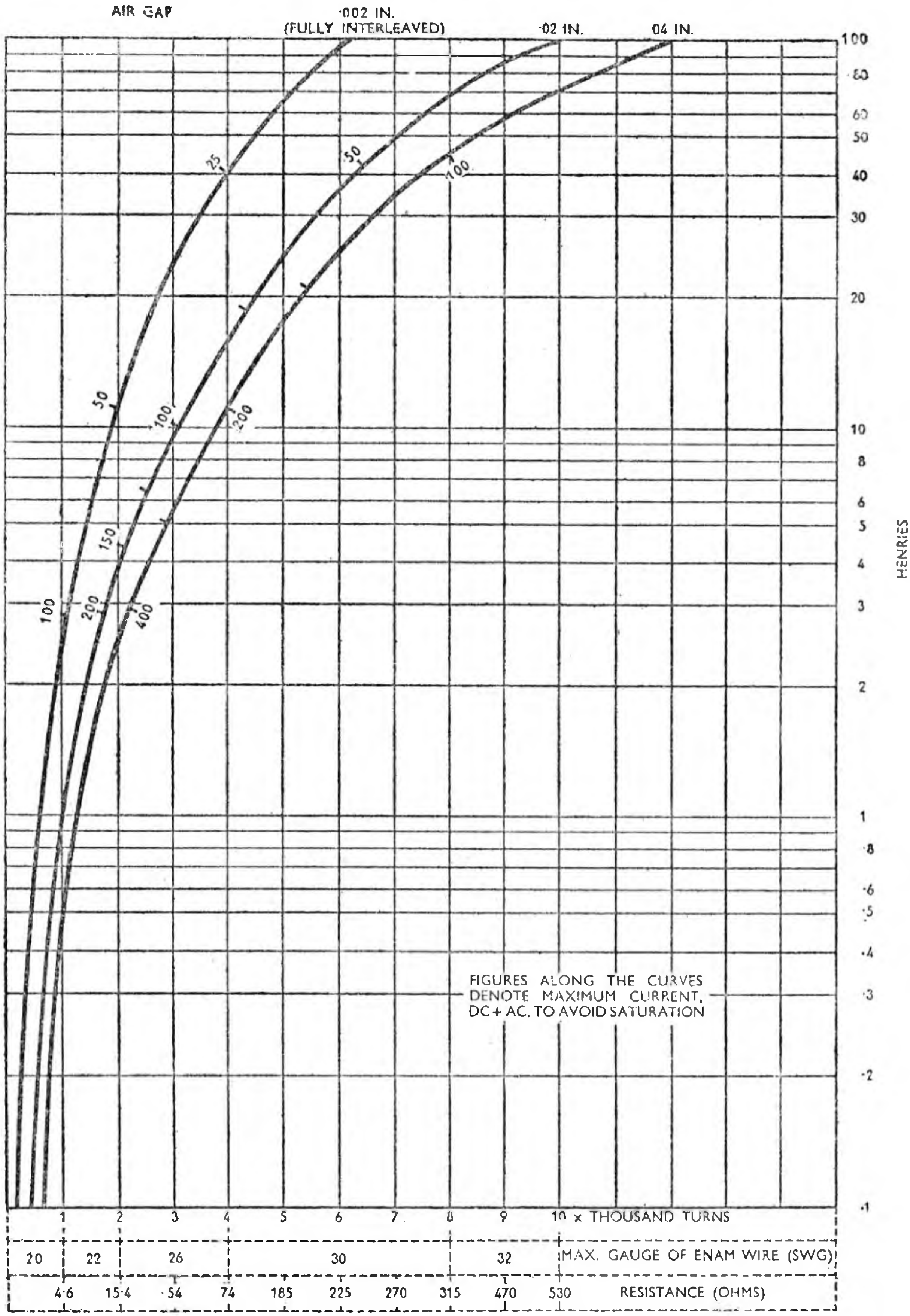


Fig. 82. INDUCTANCE OF IRON-CORED CHOKES

No. 75 LAMINATIONS (STALLOY)

CORE 1 IN. THICK (66 PAIRS ·014 IN.)

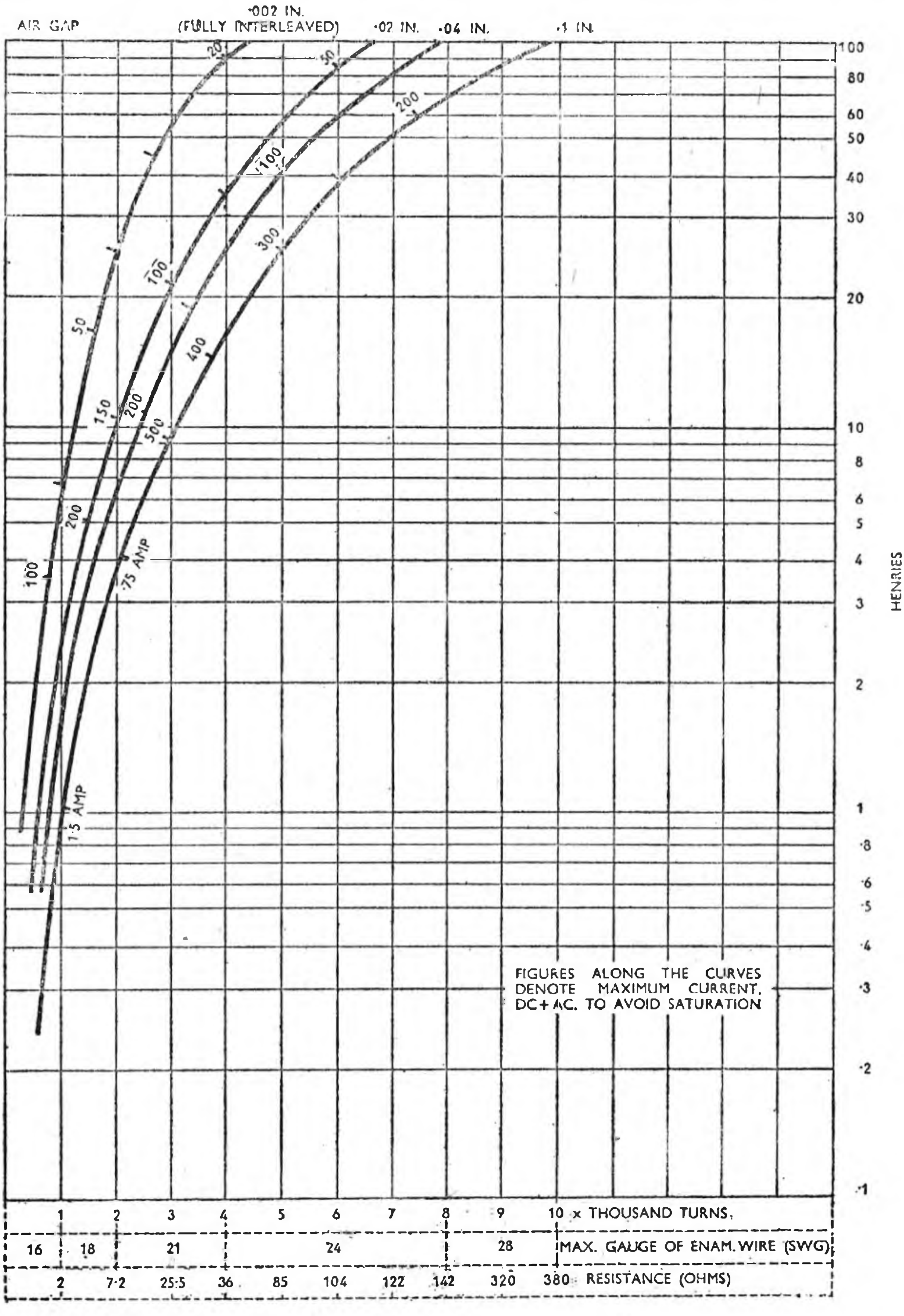


Fig. 83. INDUCTANCE OF IRON-CORED CHOKES

No. 35 LAMINATIONS (STALLOY) 1·5 IN. STACK (98 PAIRS ·014 IN.)

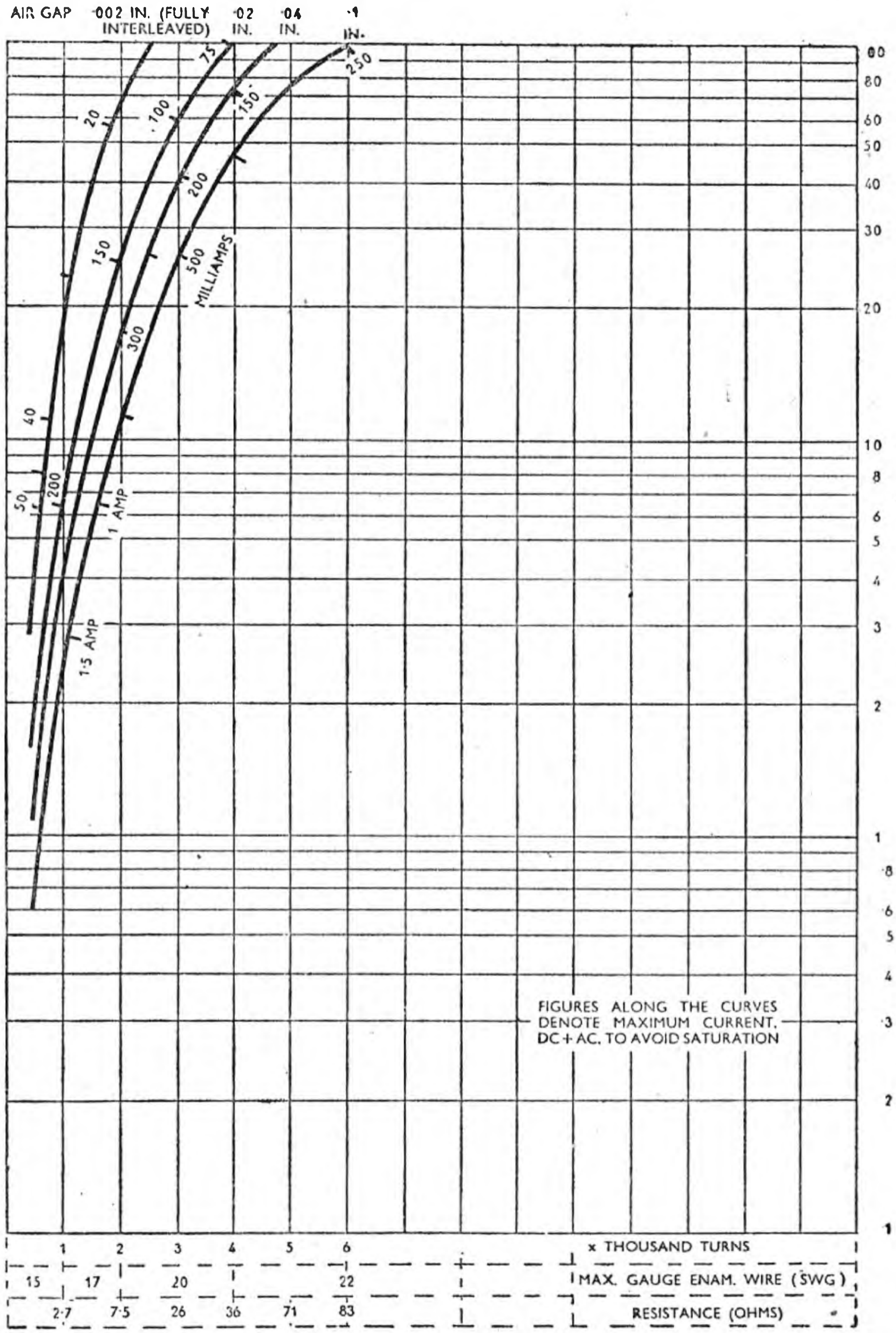
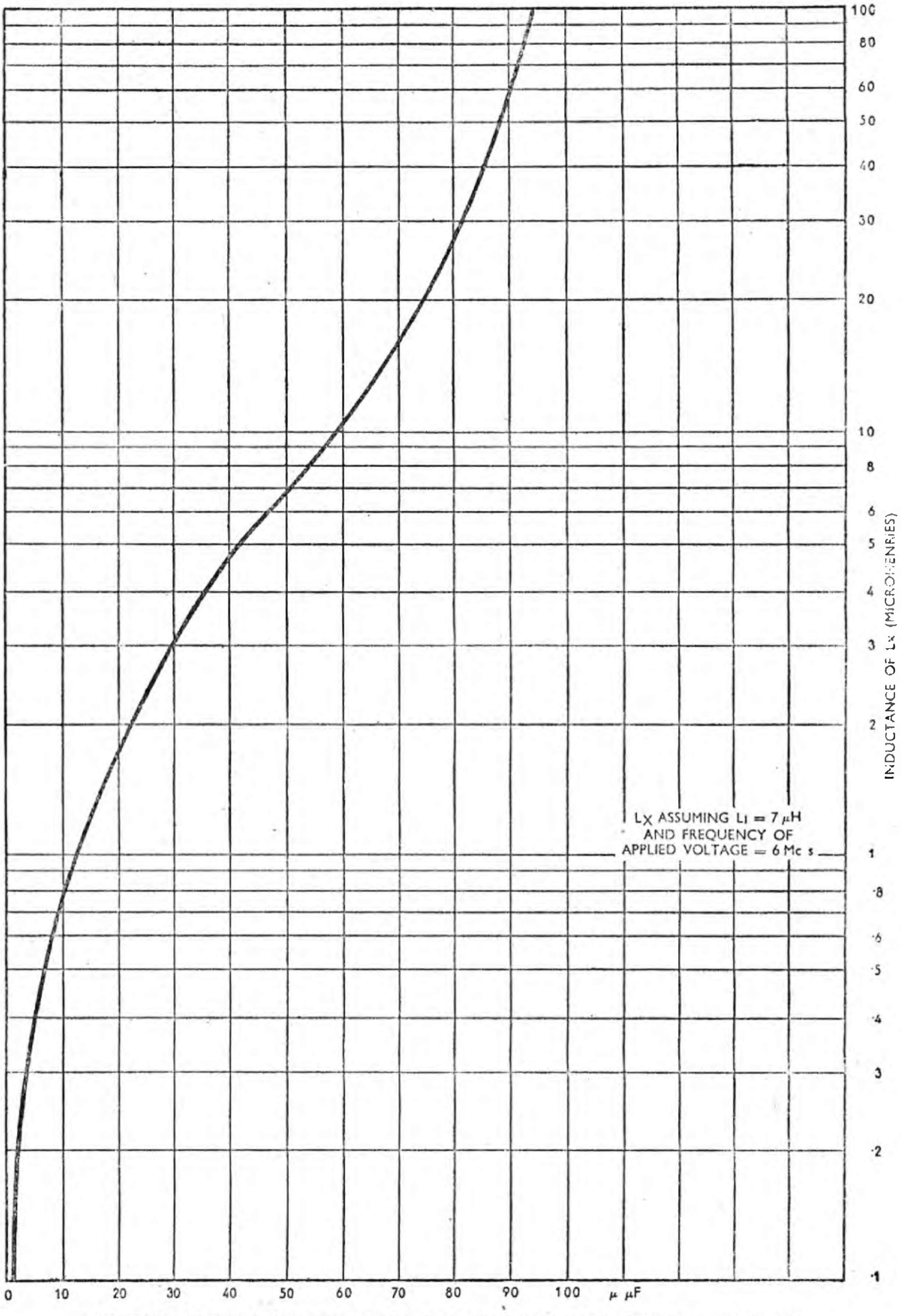


Fig. 84. INDUCTANCE OF IRON-CORED CHOKES

No. 41 LAMINATIONS (STALLOY)

2·5 IN. STACK (166 PAIRS ·014 IN.)



CONVERSION GRAPH FOR INDUCTANCE TESTER

Fig. 85. This chart is for use with the inductance measuring circuit shown in Fig. 76. The inductance of the coil under test is read off against the capacitance change necessary to produce resonance with the 6 Mc/s signal.

since the current density is only 1,200 amps per sq. in. for 24 SWG, this latter gauge can be used.

The total primary winding consists of primary volts (E_p) $\times$ TPV = 230 $\times$ 4 = 920 turns, and these in 24 SWG require 0·55 sq. in. for machine winding, and a generous allowance, say 0·8 sq. in., for hand winding.

It is usual to allow about 35 per cent of the total window area for the primary winding, and this fixes the window area at between 1·5 and 2·3 sq. in. The 4A size lamination has a window area of 2 sq. in., or the 75A a window area of 2·375 sq. in.

The thickness of stack required will be 1·9 in. in the case of the 4A, or 1·8 in. in the case of the 75A. We choose a 2¼-in. stack of 4A size.

Taping Windings

There must be a layer of insulating tape between the primary and the secondary, with ample dielectric strength to withstand the normal or fault stresses. Normal stress is 1·4 $\times$ ($E_p + E_{HT}$). For the transformer in question this will be 1·4 $\times$ (230+350) =820 volts peak. It is well to allow for at least double this stress and wind on three thicknesses of Empire tape 0·004 in. thick.

The secondary winding of 350$\times$2$\times$4=2,800 turns + 300 turns, to compensate for losses, will be wound with 34 SWG. Since each half of the winding is only conducting for approximately half of the total period, it is only necessary to use a gauge of wire to carry 60 mA continuously.

The LT windings will each have an extra turn to compensate for the IR drop in the winding and other losses. Thus the 5-volt winding will consist of 21 turns of 16 SWG, whilst for convenience the 6·3-volt secondary could be wound with two parallel windings, each of 26 turns of 16 SWG, instead of the single winding of 14 SWG, which is more awkward to handle.

Between the HT secondary and the LT secondaries, a further layer of insulating cloth or tape must be employed, and also between the two LT windings.

Design data of a number of typical transformer sizes for use on 200-250-volt supplies is set out in Table XIX.

To simplify design, compensation for losses can be split, as in the above example, between primary and secondary, the primary being reduced by a small percentage and the secondary increased by a similar amount.

In choosing the gauge of wire for the LT secondaries, the effect on voltage of reducing the load must be considered. Voltage regulation is equal to $I \times R_s$, where I is the full-load current and R_s is the resistance of the LT secondary winding. A safe rule is to ensure that at full load the current density is less than 1,000 amps per sq. in. (see Wire Tables, pages 59-64).

The data given above assumes that the winding is carried out with enamelled or silk- and enamel-covered wire. There will be room for double-silk covering, but in some instances there would not be sufficient room for double-cotton-covered wire.

Auto-Transformers. The power transformers so far described are of the double-wound variety, that is, the primary and secondary are insulated electrically. Where it is desired to change the available voltage to some other value, e.g. operate a 230-volt appliance from 105-volt mains, a simpler form of transformer, called an auto-transformer, can be employed.

This is shown diagrammatically in Fig. 86 and it is seen that the section of the winding from the 'common' terminal is connected to the low-voltage supply, whilst the required voltage appears across the whole winding. Conversely, of course, the 230-volt supply could be connected to the ends of the winding, when

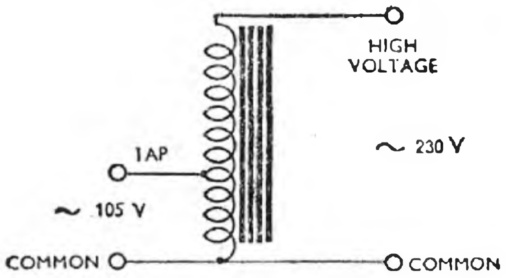


Fig. 86. An auto-transformer has a single tapped winding, as shown in this diagram.

105 volts would appear between the tap and the common terminal.

Since the secondary current flows through the primary turns, it has the effect of reducing the primary current. Therefore, a smaller gauge of wire can be employed for the section between the common terminal and the tap, the reduction being greater as the ratio of input to output voltage approaches unity.

The remaining calculations are as for the double-wound transformer. Find, first, W_s, then W_p, then A and TPV. Calculate I_p from $I_p=\frac{W_p}{E\,(\text{input})}$, and effective I_p from I_p-I_s, where $I_s=\frac{W_s}{E\,(\text{output})}$. Now select a suitable gauge of wire for the primary, in terms of the effective current (see Wire Tables, pages 59-64).

For an example, take an auto-transformer for operating a 230-volt receiver, requiring 120 watts from 105-volt AC supply at 50 c/s.

W_s=120 watts; efficiency=85 per cent.

$$W_p=\frac{120\times 100}{85}=140 \text{ watts.}$$

$$I_p=\frac{140}{105}=1{\cdot}33 \text{ amp.}$$

$$I_s=\frac{120}{230}=0{\cdot}53 \text{ amp.}$$

Approximate current from COMMON terminal to TAP$=I_p-I_s=0{\cdot}8$ amp, requiring 21 SWG.

Approximate current from TAP to high-voltage terminal$=I_s=0{\cdot}53$ amp, requiring 23 SWG.

$$A=\frac{140}{5{\cdot}7}=2{\cdot}0 \text{ sq. in.}$$

$TPV=3{\cdot}5$.

Primary turns=380, requiring ·45 sq. in.

Secondary turns=440, requiring ·35 sq. in.

These turns could be accommodated on a 15-size lamination, having a core width of ·625, but this would require a stack of 3·25 in. In this instance, a better design would incorporate a 2-in. stack of No. 4A laminations, and the larger window area would permit the two windings to be carried out in 19 and 21 SWG respectively.

Construction and Testing. When assembling the core, the 'T' laminations should be placed in pairs from each end of the former alternately, and the 'U' pieces likewise.

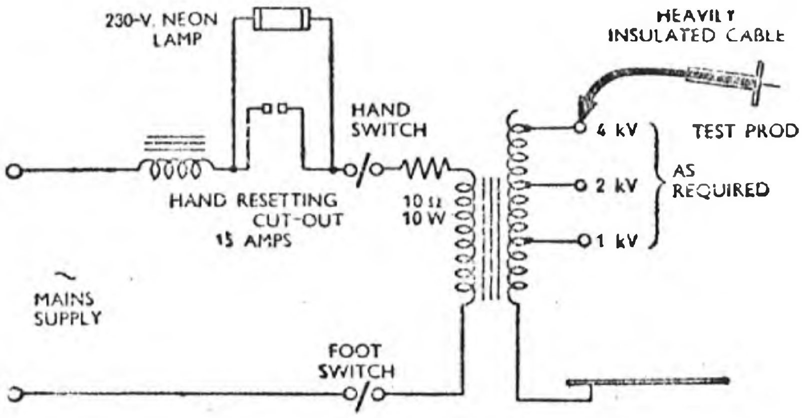


Fig. 87. Circuit for a high-voltage flash tester.

After the transformer has been assembled and bolted up, the magnetizing current should be measured. Approximate figures for this are given in Table XIX, but a variation of at least ± 25 per cent may be encountered, due to variation of stacking, depending upon whether a good magnetic joint has been made, also upon the quality of the iron, which varies from different manufacturers, and sometimes even between one maker's samples.

Assuming that the results of this test are satisfactory, the secondary voltages should be measured when giving their rated load. A half-hour run at least should be made at full load to see that the core and windings do not overheat. Both should be about the same temperature, 40—50 deg. C (104—122 deg. F).

A further test that should be imposed is a 'flash' test, employing a suitable voltage of about twice the normal voltage appearing between windings. This voltage is applied between windings and also between all windings and core.

A diagram of a suitable flash tester is shown in Fig. 87. It employs a tapped transformer to give a range of suitable test voltages, a pair of heavily insulated test prods and a foot-switch to close the primary circuit. Great care must be exercised.

In the case of high-voltage transformers, such as are used for cathode-ray tube power supplies in television sets and oscilloscopes, the transformer should be placed in an earthed 'cage', and clips used in place of the test prods for applying the test voltage. The primary switch is arranged in series with a door switch on the cage so that the circuit cannot be completed unless the door is closed.

Audio-frequency Transformers are of two types, voltage transformers and LF power transformers. The former type work into a large secondary resistance, such as the grid circuit of a Class A amplifier, and the second type is used where the secondary circuit consumes power.

Voltage Transformers. The design of voltage transformers is controlled by the amount of DC in the primary. Where this is zero, as in the case of the resistance-capacitance transformer circuit of Fig. 88, a compact design is possible, using Mu-metal stampings. Mu-metal, with its high incremental permeability at low values of magnetization, allows an efficient design in small space, with high primary inductance and low self-capacitance.

High primary inductance ensures

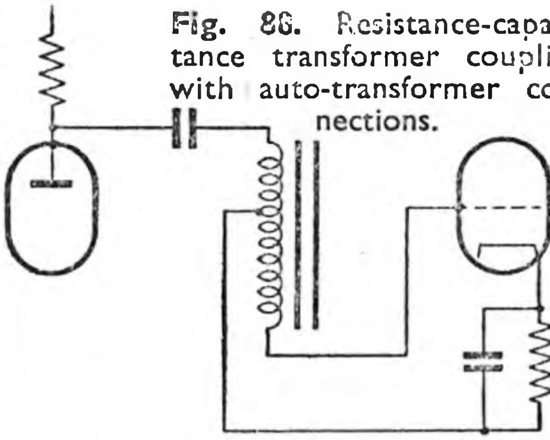


Fig. 88. Resistance-capacitance transformer coupling with auto-transformer connections.

a level response well into the bass register, while low leakage inductance and self-capacitance permit efficient high-frequency response.

Although its advantage is most marked when there is no DC, Fig. 91 shows that it is possible to obtain satisfactory results with the miniature core, even with small direct currents in the primary.

This chart also indicates the primary inductance of windings of 3,000, 4,000 and 5,000 turns on a stack of twelve pairs of 31T Mu-metal stampings, both with and without DC in the primary.

With the auto-transformer connections of Fig. 88, step-up ratios of 5 to 1, 4 to 1 and 2·4 to 1 are possible, if total winding of 12,000 turns of 44 SWG enamel wire is used in each case.

If double-wound coils are employed, as shown in Fig. 89, the step-up ratios are 3 to 1, 2 to 1 and 1·4 to 1 respectively.

Fig. 90 shows the primary inductance necessary to limit the lower cut-off to 1, 2 and 3 dB at various frequencies up to 150 c/s with an anode resistance of 10,000 ohms. For other values of anode resistance, the figure obtained from the chart should be multiplied by the anode resistance of the valve in thousands of ohms and divided by 10.

Thus, if the value obtained from the chart is 90 henries and the anode resistance of the valve is 6,000 ohms, the required inductance will be 90 multiplied by 6 and divided by 10; that is, 54 henries.

Where the DC component is too

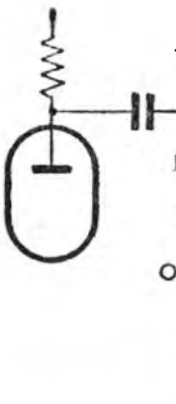


Fig. 89. Parallel-fed transformer intervalve coupling.

large for a Mu-metal core, the use of Radiometal is recommended. Fig. 92 gives the primary inductance for different windings on a core of 60 pairs of 24T Radiometal stampings.

Having chosen the core and the primary winding to give the necessary primary inductance and step-up ratio, the degree of interleaving of the windings can be decided. Usually, it is sufficient to wind on one-half of the secondary, then the primary winding, and lastly the remainder of the secondary. Care must be given to the interwinding insulation in view of the fact that the voltage between them may exceed the sum of the HT and the GB supplies.

From the foregoing it is seen that the step-up ratio of the normal intervalve transformer is largely controlled by the number of turns needed to obtain the specified primary inductance. For impedance matching, such as connecting a 600-ohm line, or a microphone to the grid circuit of a Class A amplifier, it is necessary to arrange the number of turns so that a correct match is obtained on both sides of the transformer. This is achieved when the ratio of the turns is the square root of the ratio of the impedances connected to the two windings.

Typical ratios are : carbon microphone to grid of Class A amplifier, 25 to 1 ; 600-ohm line to grid of Class A amplifier, 10 to 1.

Low-frequency Power Transformers. With low-frequency power transformers, in addition to the design requirements detailed above, to take into account the losses it is necessary to make an adjustment to the actual turns ratio.

First, the core dimensions are settled by reference to the charts to be found in the low-frequency choke section. The DC flowing controls the core size and gap, the required inductance being obtained as before from chart in Fig. 90. Since a secondary winding has to be wound in part of the space, it is necessary to limit the gauge of wire used for the primary, so that it occupies just less than one half of the total winding space.

Table XXI shows the maximum gauge of wire that may be employed.

Transformers of this type having an output of 5-20 watts, usually have an efficiency of 70 to 80 per cent. This implies that the secondary must be increased above the number of turns required for impedance matching. For the smallest transformers, this increase should be 20 per cent, but for the larger types, handling 20

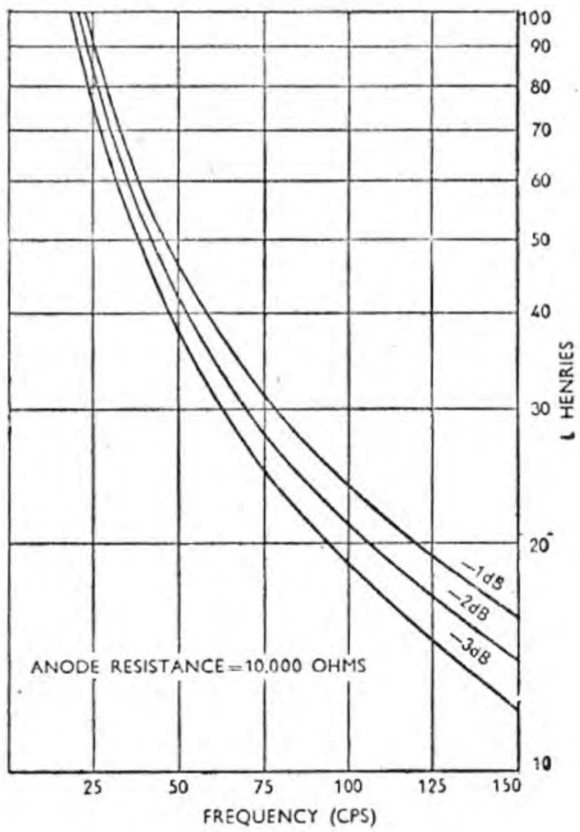


Fig. 90. This chart indicates the inductance necessary in an anode circuit to limit the loss at bass frequencies, as shown, to values indicated by the curves.

watts or more, the increase necessary will be about 12 per cent.

Push-pull Transformers. Push-pull transformers are fundamentally similar to the single-circuit types just described. The input voltage transformer must provide two equal secondaries, and this precludes the use of the miniature core, unless a step-up ratio as low as 1·5 to 1 can be tolerated. Otherwise, the Radiometal core should be employed; alternatively, a larger Mu-metal assembly.

The push-pull output transformer has the advantage that the DC component in the two primary windings are in opposition magnetically. For production work with unmatched valves, it is usual to assume that the residual DC is 15 per cent of the normal DC component of one of the valves.

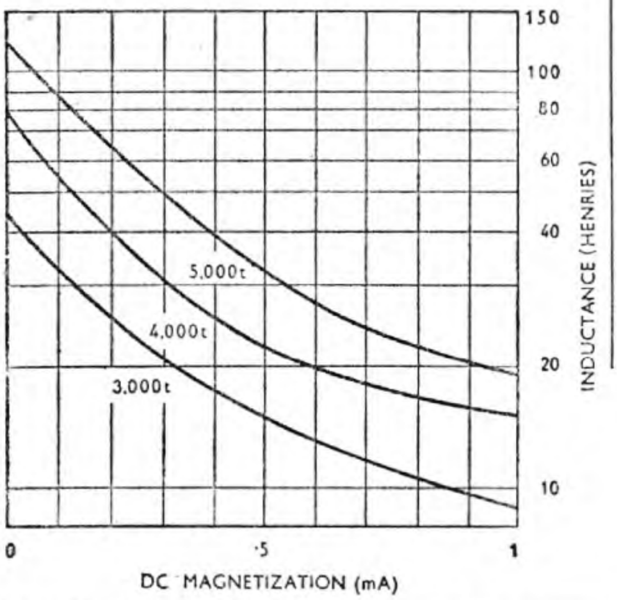
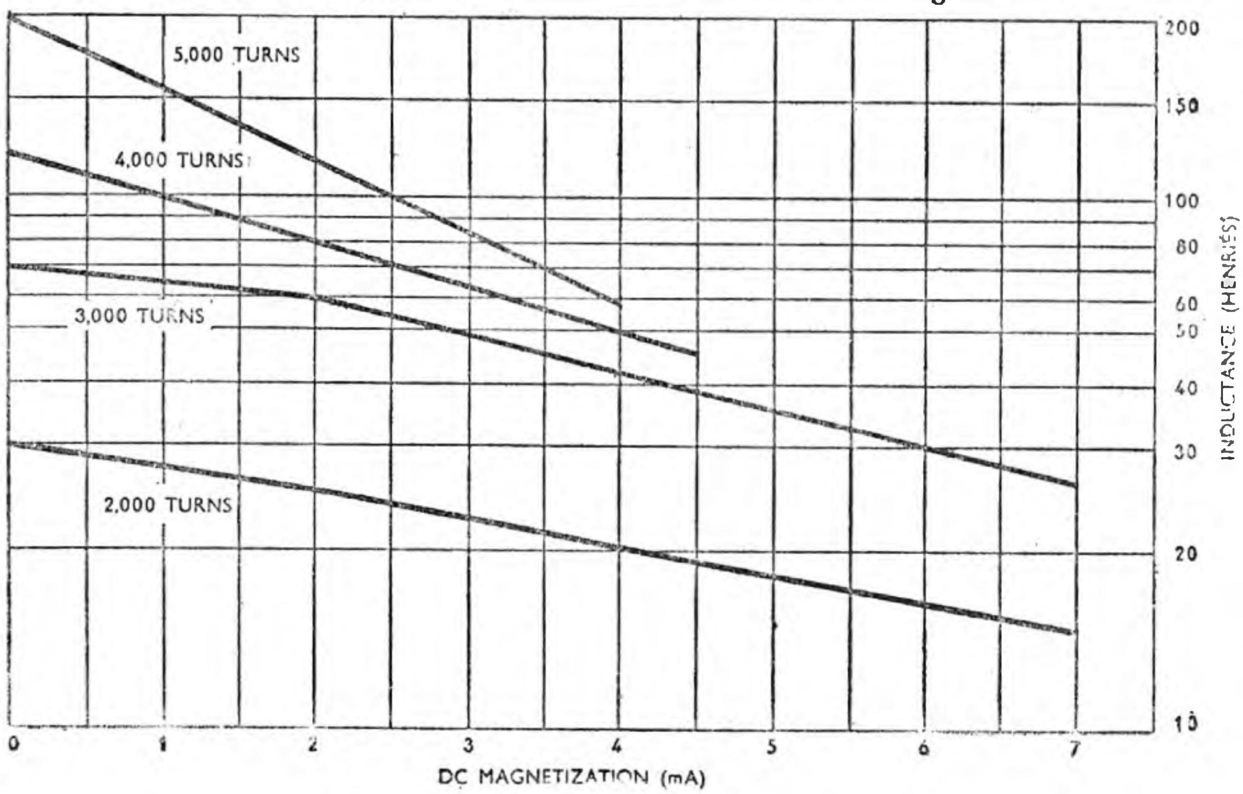


TABLE XXI

Gauge of wire (SWG) shown at foot of choke charts	Equivalent gauge SWG of wire for transformer use	Current-carrying capacity. DC-AC
20	22	1 A
22	26	370 mA
24	28	250 mA
26	30	180 mA
28	32	130 mA
30	34	100 mA
32	36	75 mA
34	38	45 mA
36	40	27 mA
38	42	18 mA
40	44	12 mA

Fig. 91. (Left) How the primary inductance of three coils, all on 12 pairs of 31T Mu-metal stampings, varies with DC magnetization. **Fig. 92.** (Below) How the primary inductance of four coils, on 60 pairs of 24T Radiometal stampings, varies with DC magnetization.



SECTION 10

MATCHING

Principles of Matching. If a source of voltage, direct or alternating, is applied to an external circuit having only resistance, and if the internal impedance of the source is also resistive, then *the maximum power is developed in the external resistance when its value is equal to the internal resistance of the source.* Therefore, if the EMF of the source be E and its internal resistance R_I, and if the resistance of the external circuit be R_X, then the current flowing is, $I = \frac{E}{R_I + R_X}$.

The power in the resistance R_X is $R \times I^2$, or $W = E^2 \frac{R_X}{(R_I + R_X)^2}$.

This value of W may be transformed as,

$$W = \frac{E^2}{R_I} \frac{1}{\left\{ \frac{R_I}{R_X} + 2 + \frac{R_X}{R_I} \right\}}.$$

R_I is a constant and so we want to know the maximum value of an expression of the form $\frac{1}{x + 2 + \frac{1}{x}}$, where $x = \frac{R_I}{R_X}$, and has values varying between zero and infinity. Obviously, neither of these limiting values fits, because in both cases the ratio is 0 and, in the absence of mathematical proof (given by differentiating the function and equating to 0), trial and error reveals a maximum value of $\frac{1}{4}$, when $x = 1$.

The point italicized above is an important principle and applies whether the source be a microphone, a valve, an alternator, or a battery, always provided the nature of the internal and external impedances is wholly resistive.

If the internal impedance is of the nature $R_I \pm jX_I$, and the external impedance be of the nature of $R_X \pm jX_X$, then all reactance can be eliminated at one frequency by realizing that the current will be given by, $\frac{E}{R_X + R_I + j(\pm X_I \pm X_X)}$, when the connection of another reactance X_C may be used to make $\pm X_I \pm X_X \pm X_C = 0$. This correction, can, however, only be effective at one frequency and so some loss is inevitable when the impedances, internal and external, do not match. Obviously, with varying frequency, unless the impedances are the same, mismatching is inevitable.

The Transformer. In many cases a source of voltage may have a constant internal resistance R_I, while it has to feed a load with fixed resistance R_X which also cannot be changed. In this case, provided AC is in question, the transformer is used to secure matching.

In an ideal transformer, the output power equals the input power. If a voltage E_1 be applied to the primary of a transformer across which is connected a resistance R_1, the primary power W_1 is, $W_1 = \frac{E_1^2}{R_1}$.

Let the voltage on the unloaded secondary of the transformer be E_2. Then, if R_1 be disconnected and a new resistance R_2 be connected across the secondary, the secondary power, also equal to W_1, is, $W_2 = \frac{E_2^2}{R_2} = \frac{E_1^2}{R_1}$. Thus, $\frac{R_1}{R_2} = \frac{E_1^2}{E_2^2}$.

$\frac{R_1}{R_2}$ is the impedance transformation ratio and $\frac{E_1}{E_2}$ the voltage transformation of the transformer, and if T_Z be the former and T_E be the latter, $T_Z = T_E^2$, or $T_E = \sqrt{T_Z}$.

If a generator having an internal

resistance of 2,000 ohms has to feed a load of 200 ohms, then, for correct matching, a transformer is required with an impedance transformation ratio primary to secondary of 10 and a voltage transformation giving $\sqrt{10}$; that is to say, if 15 volts were applied to the primary, $\frac{15}{\sqrt{10}} \approx 5$ volts would be applied to the secondary.

Put in another way, the 200 ohms at the secondary 'reflects' 2,000 ohms to the primary, and this reflected load is in series with the 2,000 ohms of the source, so that maximum power is generated in the load; albeit, without the transformer, mis-matching would occur.

A method exists to find the internal resistance of any source directly, wherein the voltage of the source is found first with the load connected across the terminals and then a load is found which reduces the source voltage to half its open-circuit value. This load resistance then equals the internal resistance.

If a transformer be used and the load connected across the secondary to reduce the open-circuit secondary volts to half, then the internal impedance is given by multiplying the value of the experimentally determined load resistance (to reduce open-circuit volts to half) by the impedance ratio of the transformer (primary to secondary), or by the square root of the voltage transformation ratio.

For example, in a 10 to 1 impedance ratio (primary to secondary) transformer, if the secondary load were 100 ohms to reduce the open-circuit voltage by half, the internal impedance of the source would be 10 times 100 ohms = 1,000 ohms.

Matching with Valves. Provided reactance effects associated with inter-electrode capacitance may be neglected, then a valve, considered as a source of electric power, can be simulated by an EMF, of value μE_g, in series with an internal resistance R_A, where μ is the amplification factor, E_g the grid cathode voltage, and R_A the anode slope resistance of the valve.

With triodes or with feed-back arranged to reduce the effective anode slope resistance of pentodes and where maximum power output is required, it is legitimate to match the external load with the actual or effective value of R_A, using, if necessary, a transformer to do so.

Where voltage amplification is required, the largest practicable value of external resistance is used.

As an important rider to these generalized statements, it should be appreciated that in many cases a mis-match is preferable in order to minimize harmonic distortion.

A pentode used without feed-back to lower its anode slope resistance has a very high value of R_A and it is impracticable to attempt to secure a load resistance of comparable value. Thus a pentode is like a constant current generator, the value of the external load makes little difference to the current in that load, since it is $\frac{\mu E_g}{R_A + R_L}$, and since $R_L \ll R_A \approx \frac{\mu E_g}{R_A}$, which is a constant.

Any anode impedance, conducting the anode current, is part of the load resistance. In a resistance-capacitance amplifier the valve load is $\frac{R_K R_g}{R_K + R_g}$, where R_K is the value of the anode resistor and R_g the following grid resistor, the latter being blocked off by a capacitor.

The best advice to the designer is to consult makers' catalogues to find optimum load values for particular valves arranged in different ways.

Loudspeaker Matching. The impedance of a loudspeaker, whatever its type, is neither wholly resistive, nor is it constant with frequency.

Certain empirical rules about loudspeaker impedance may be used, or the makers consulted. The impedance of low-resistance speech coils may be taken as that of their DC resistance when this has a value of the order 2 to 5 ohms. Above these values, and up to 15 ohms DC resistance for the coils, their impedance at 1,000 cycles is of the order 20 – 25 ohms.

In practically all instances the use of modern low-impedance loudspeakers calls for the use of a transformer to secure 'matching' with the relatively high impedance of the output valve. As explained above, the transformer ratio is given by

$$\sqrt{\frac{\text{Valve optimum load}}{\text{Speech coil impedance}}}$$

Mis-Matching

Some 'tone correction' may be achieved by mis-matching, with consequent risk of distortion due to such mis-matching. The generally accepted practice is to match to the impedance at 1,000 c/s, but if a lower figure than this be taken there will be a greater attenuation of the higher frequency than if matching at 1,000 c/s were done. Vice versa, low-note attenuation, preventing 'boominess', may be obtained by matching to a higher impedance than that given at 1,000 c/s, always remembering that distortion may also be introduced by these expedients.

If similar loudspeakers are connected in parallel, then their impedance is the impedance of one divided by the number energized in parallel. This rule does not apply in rediffusion practice, where the impedance of the lines, notably at the higher audio-frequencies, is an important factor, as well as their loading.

Whatever the resulting impedance for whatever type of load, the use of feed-back on the one hand, and a matching to the lowest impedance on the other, assures that the applied voltage cannot vary by more than 2 to 1 over the frequency range, and, if the load be constant (i.e. always the same number of speakers), an equalizer can be used to secure an equal input voltage at all frequencies, or a shaping of a response curve, by equalizers, to get the most pleasing effect.

Loudspeakers are seldom connected in series, but if they are the total impedance is the sum of all the impedances of all the loudspeakers.

Microphone Matching. The impedance of microphones may vary from fractions of an ohm to megohms, depending on their type. A microphone is usually connected directly to the input of a valve amplifier, the impedance of which, between grid and cathode, is virtually infinity. The maximum gain of the system, microphone-cum-first valve, is obtained when the voltage applied to the valve grid is maximum.

If the microphone is of low impedance, its terminals may be connected to the primary of a transformer having a large step-up ratio, a suitable load for the microphone being connected either across primary or secondary of the transformer.

Mechanical considerations forbid the manufacture of transformers giving a step-up of voltage when the primary impedance is very high, in which case the microphone (typically of the capacitive type) is connected directly to the grid cathode circuit of the input valve.

To obviate long leads, this valve is sometimes embodied in the microphone housing and a transformer steps down the impedance from valve anode to leads, thereby making a low-impedance connection between microphone and subsequent amplifier.

Pick-up Matching. The pick-up may be treated as a microphone; if it is of low impedance, a transformer may be used; if high, it cannot.

Sometimes the isolation of one circuit from another given by a transformer is useful and so a transformer may be used more from circuit consideration than because it gives a voltage gain.

SECTION 11

VALVES

FILAMENT, BIAS, SCREEN AND ANODE SUPPLIES

Battery Types. The filaments of 2-volt battery valves are normally operated in parallel from a 2-volt accumulator. The current ratings of the valves may be different. To find length of operation after one charge of the battery, add all the valve currents, and divide this into the ampere-hour capacity of the accumulator.

Valves with 1·4-volt filaments are run in parallel from a single dry cell, or dry cells in parallel. If operated from a 2-volt accumulator, series resistance is necessary to reduce the voltage. The value in ohms is:

$$R = \frac{V_B - V_V}{I_V},$$

where V_B is battery voltage, V_V is rated voltage of valve filaments, and I_V is total filament current in amps.

Mains valves may be operated from batteries or accumulators if the necessary voltage and current are available. The 6·3 range of valves may be operated from a 6-volt battery.

AC Mains Valves are normally operated in parallel from a low-voltage winding on the mains transformer. Voltage ratings of the valves must be the same, but current consumptions may differ.

AC-DC Mains Valves. In sets for operation from DC as well as AC mains supplies, the valve heaters are connected in series, so that the total voltage necessary to energize the heaters is increased and, therefore, less has to be reduced in a series resistor. The specified voltages of valve heaters may differ when heaters are connected in series, but their specified current consumption must be the same.

Value of the series or 'ballast' resistor is: $R = \frac{V_M - V_V}{I_V}$,

where V_M is mains voltage, V_V is the sum of the valve voltages, and I_V is the rated current through the heaters.

Suppose an American receiver contains the following valves: S6A7, 6SK7, 6B8, 25A6 and 25Z6. The heater current will be ·3 amp, and the total of voltages will be 6·3 + 6·3 + 6·3 + 25 + 25 = 69. In America, the standard mains voltage is taken as 117·5. Therefore,

$$\text{Ballast} = \frac{117 - 69}{\cdot 3} = 160 \text{ ohms.}$$

To operate this set from a supply of, say, 230 volts, an additional ballast resistor, or line cord resistor, will be necessary, as indicated in Fig. 93, the value being

$$\frac{230 - 117}{\cdot 3} = 380 \text{ ohms, approx.}$$

The series resistor must be capable of dissipating the heat developed, which is IE watts; for example, (230 – 117) × ·3 = 34 watts.

Line cords require, in most cases, to be cooled by air circulation, and must not be hidden under carpets unless designed to be so used.

To ensure the same current for series operation, combined series-parallel connections of heaters may be arranged. Where a valve takes less than the circuit current, a resistor may be connected in parallel with the valve, the value being:

$$\text{Parallel resistance} = \frac{\text{Valve heater volts}}{\text{Circuit current} - \text{Valve current}}.$$

For example, suppose a ·15-amp 12·6-volt valve is to be used in series with ·3-amp valves.

$$\frac{12 \cdot 6}{\cdot 3 - \cdot 15} = 84 \text{ ohms.}$$

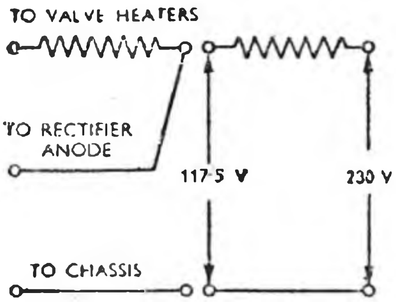


Fig. 93. An extra line cord is needed when U.S. midget sets are used on mains of over 117·5 volts.

To minimize 'noise' in AC-DC sets, heaters should be connected in the following order: Voltage-dropping resistor, rectifier, output, RF and IF valves, frequency changer, first LF valve, demodulator, chassis.

Cathode Connections. In valves with indirectly heated cathodes, the heater has no part in the anode circuit; but to prevent noise and reduce likelihood of heater-cathode insulation breakdown, the voltage difference should be kept low (less than 150 volts). The heater circuit is usually connected to HT negative, either from a centre-tap on the heater energizing winding or from the centre-tap of a 40/50-ohm 'hum-dinger' resistor across the winding. With rectifier valves, the heater circuit is connected to HT positive.

In high-gain circuits, the heater may be made 10 volts positive to the cathode to prevent emission from heater to cathode causing hum.

Bias Resistors. When automatic bias is provided by a resistor between cathode and HT negative, the resistance in ohms is:

$$R = \frac{V_B \times 1{,}000}{I_C},$$

where V_B is required bias volts and I_C is cathode current in milliamps.

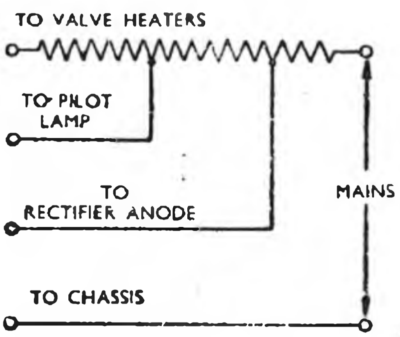


Fig. 94. Sometimes line cord resistors are tapped.

Bias and cathode current are obtained from valve data. Cathode current comprises anode current plus current to other electrodes, such as screens, and is that given for the rated working voltages.

The power in the resistor must be: Bias volts × cathode current (amps).

Where bias is derived from resistance between chassis and HT negative, the total bias available is: E (volts) = Total receiver HT current (amps) × Bias resistance (ohms).

The bias resistance may be the DC resistance of the speaker field coil. Where the actual bias to the valve is taken from a potential divider across the total bias volts, the proportion is: $\frac{R_1}{R_1 + R_2}$, where R_1 and R_2 are the values of the resistors across the main bias resistor (or choke), with R_1 as the one nearer the chassis.

Bias resistors should have a parallel decoupling capacitor to prevent voltage changes due to the cathode current being introduced to the grid circuit and causing negative feed-back and loss of gain. Reactance of the capacitor should be ·3 to ·2 times bias resistance at lowest frequency to be fully reproduced.

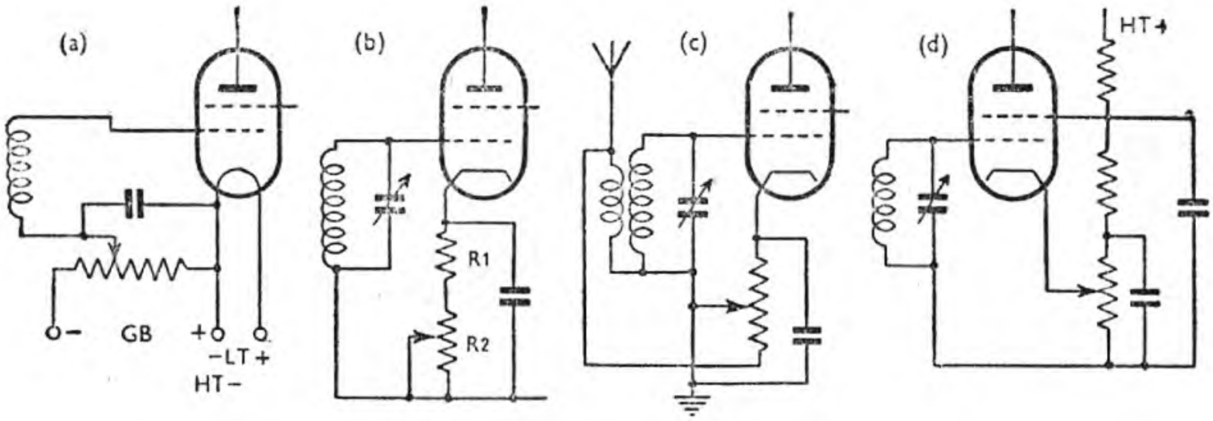
Representative values in receivers are:

Stage	*Capacitance*	*Type and Working Voltage*
RF and IF	·1 μF	Non-inductive paper (only low applied voltage)
LF	8-50 μF	Electrolytic, 10 volts upward
Output	50 μF upward	Electrolytic, 10 volts upward

Positive electrode of electrolytic capacitor goes to cathode, and negative to chassis.

In LF stages, the decoupling capacitor may be omitted where negative feed-back is required.

With power output valves of high mutual conductance, it may be necessary to shunt the decoupling electrolytic capacitor by a mica



FOUR MANUAL VOLUME-CONTROL CIRCUITS FOR HF STAGES

Fig. 95. (a) Variation of the battery grid bias; (b) variation of the cathode bias; (c) simultaneous regulation of aerial input and cathode bias; (d) an improved cathode bias control circuit.

capacitor of about ·001 μF to prevent oscillation.

Bias Control of Volume. With the variable-mu type of valve, an increase of bias results in reduction of amplification. Therefore, the output volume can be regulated by control of bias. Fig. 95a shows a method for battery valves, R being 10,000-50,000 ohms, with a view to discharging the bias battery during the 'life' of the HT battery. In Fig. 95b, R_1 and R_2 together give the maximum bias (calculated from above formulæ) at minimum cathode current, and R_1 gives minimum bias, again calculated at the appropriate current.

The bias resistor may be combined with the aerial circuit (Fig. 95c), so that signal input is reduced simultaneously with reduction in gain. In Fig. 95d, a potentiometer system is employed; this also acts as a bleeder and gives voltages less dependent of the current through the valve.

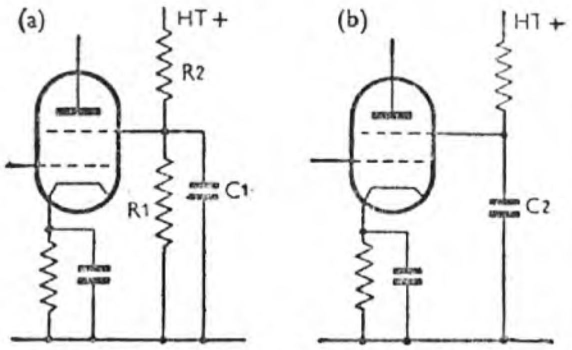


Fig. 96. Screen-grid voltage may be applied by using (a) a potential divider, or (b) a series resistor.

Screen Voltages. The screen of a screen-grid valve should not be fed from a series resistor, because the screen current varies during operation, and a varying screen voltage would alter the gain of the valve. A feed from a potential divider should be employed (Fig. 95d or Fig. 96a). The larger the drain through R_1 and R_2 with respect to the screen current, the steadier the voltage. A total resistance of 50,000 to 100,000 ohms is satisfactory.

The voltage at the screen is: $E_s = E \times \frac{R_1}{R_1 + R_2}$, where E is the total HT voltage.

With the pentode, screen current is sufficiently steady to permit the use of a series resistance only (Fig. 96b). Value is: $\frac{E - E_s}{\text{Screen current (amps)}}$.

In the 'sliding screen' pentode, the screen current does vary, and the voltage on the screen rises as the total cathode current decreases. This characteristic is used to achieve anode current economy at low bias.

The screen decoupling capacitor C_1 (Fig. 96) is usually of ·1 μF, and should be a paper non-inductive type, or should, at least, have the outer foil as the one connected to chassis.

In early sets, adjustment of screen voltage was sometimes employed for volume control.

Anode Voltage and Load. The maker's stated anode voltage must not be exceeded, and at times a series voltage-dropping resistance is necessary. For example, in an RF or IF stage, the DC resistance of the anode load is negligible. If the available HT is 270 volts and the maximum permissible anode voltage is 200 with a current (at normal bias) of 10 mA, the voltage-dropping resistance is $\frac{270-200}{\cdot 01} = 7{,}000$ ohms.

In choke- or transformer-coupled LF stages, again the DC resistance of the coupling may be negligible.

With resistance-capacitance coupling, the anode load is a resistor which causes considerable HT drop. The larger the resistance value of the decoupling resistor R_1 (Fig. 97), the lower must be R_2 the anode load, if

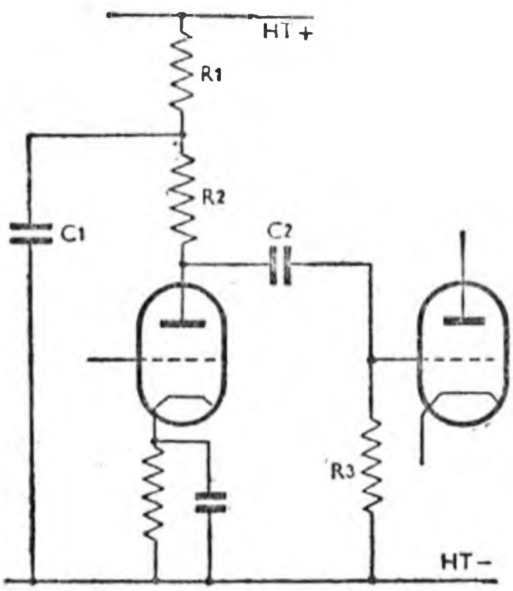


Fig. 97. Resistance-capacitance audio-frequency intervalve coupling. R_1C_1 form anode decoupling circuit.

the HT at the anode is not to be too low.

The maximum permissible anode load resistance may be calculated, and then the smallest possible part of this allocated to the decoupling resistor. Experiment may be necessary.

$R = \frac{E_1 - E_2}{I}$, where R is total anode resistance, E_1 is HT, E_2 is working anode voltage, and I anode current (in amps), at the working anode voltage and corresponding bias.

Anode decoupling will probably be adequate if, at the lowest frequency, the reactance of the capacitor C_1 is one-tenth the resistance of the decoupling resistor. Normally, it is sufficient for C_1 to have a reactance one-fifth of this resistance. Suitable values are given in Table XXII.

TABLE XXII:

DECOUPLING CAPACITANCE
(μF)

Decoupling resistance (ohms)	Reactance at 50 c/s, ·2 of decoupling resistance	Reactance at 50 c/s, ·1 of decoupling resistance
5,000	6	3
10,000	3	1·5
15,000	1	·5

The capacitor must have a working voltage at least as high as that applied, and preferably higher.

Decoupling is not generally necessary unless there are more than two stages. In modern sets with electrolytic capacitors of small reactance providing excellent HT regulation, decoupling may not be needed even for five- and six-stage sets. The smoothing choke and capacitor can be regarded as decoupling all the stages. A voltage-regulated mains unit greatly decreases the effects of common coupling of stages in an amplifier.

The anode load resistance R_2 should be at least twice the AC resistance of the valve. Generally speaking, the higher the load the better, until the point is reached where the anode voltage becomes so low on increases of current due to the signal that amplification is lost.

The grid resistance of the valve R_3 (Fig. 97) must be high, as it is in parallel with R_2. The upper limit, however, is usually stated by the makers of the valve which forms the next stage of amplification.

Capacitance of the grid capacitor C_2 must be large to pass low frequencies, but a limit is set by the 'time constant' determined by $R_3 C_2$.

In older sets, the anode load for a triode used as the first LF amplifier was 10,000-75,000 ohms; 50,000 being an average figure where HT permitted. The modern practice is to employ anode loads of 100,000-500,000 ohms, the anode current being extremely low (Table XXIII).

TABLE XXIII: REPRESENTATIVE COUPLING VALUES

Anode load (ohms)	Coupling capacitor (mFd)	Following grid resistor (ohms)
50,000	·025 –·05	100,000
100,000	·01	250,000
250,000	·005	500,000
500,000	·003	1,000,000

CODE OF PRACTICE FOR RADIO VALVES

So that the optimum performance and life of valves can be secured, the British Standards Institution issue a Code of Practice as a general guide to designers of receivers and users of valve equipment. The Code BS1106, 1945, was drafted by the British Radio Valve Manufacturers' Association.

Valve ratings in the makers' specification must not be exceeded. Heater voltages should not vary by more than plus or minus 7 per cent of the rated value.

Care should be taken to determine whether the valves have a constant current, or a constant voltage heater rating. It is, in general, undesirable to wire constant-voltage heaters in series as in AC-DC receivers.

Mounting Valves

Valves should be mounted base down, and with the axis vertical. The only provision for alternative mountings is in the case of directly heated valves and with certain high-mu indirectly heated types, where the filament, or the major axis of No. 1 grid, can be vertical.

Layouts must afford sufficient ventilation. For most receiving valves, the maximum safe running temperature is 20° C above the temperature attained in free air. Special care is needed with regard to valves using powers in excess of 25 watts.

It is desirable to avoid large heater-cathode potential differences in the case of indirectly-heated valves not designed for AC-DC operation. The general maximum is 150 volts.

In no circumstances should valves be operated without a DC connection between each electrode and the cathode. The resistance of this connection should be the minimum practicable, and it is emphasized that the apparent advantage of an open-circuited electrode, or of a high-resistance path, may be defeated by the valve's secondary emission characteristics.

Where grid bias is obtained by means of grid rectification, sufficient cathode bias should be provided to avoid damage in the event of loss of drive. High resistance in series with the control grid should be avoided, and, with receiving valves, the series resistor should not exceed 1 meg for auto-bias, and ·5 meg with fixed bias.

Where valves have an anode dissipation of over 10 watts, the series resistor should be ·5 meg for auto-bias (cathode resistor), and ·1 meg with fixed bias. These figures do not apply when resistance is common to more than one control-grid circuit.

Resistors in the voltage supply network to the screen grids of multi-electrode valves should have as low a value as possible. Aligned grid valves, operating with the screen voltage substantially lower than the anode voltage, should derive the screen supply from a potential divider network. Valves with grids not in alignment, other than frequency changers, may derive the screen supply by means of a series resistor.

Suppressor grids should be maintained at the same potential as the cathode, except where valves have been specially designed for suppressor-grid modulation.

MAINS VOLTAGE REGULATION IN AMERICAN MIDGET SETS

The difference between the voltage required to operate an American AC-DC set and the British mains supply voltage is dropped by a resistor. This can be either a vitreous-enamelled resistor, a ballast or barretter tube, or a line cord resistor in which the flex connecting the set to the mains plug has the required resistance value.

Dropper resistors of the vitreous-enamelled type have the advantage that they are usually tapped for various supply voltages, and thus provide for operation for different supply voltages. Where space permits they can sometimes be incorporated in a set where the line cord is objected to.

Ballast or barretter tubes provide automatic adjustment of resistance over a certain voltage range. For example, if the input voltage is low, the current is low, and the element automatically becomes lower in resistance, until the current is restored to a substantially correct value.

Line cords were used for voltage adjustment on most imported American AC-DC receivers. Most of them are in two sections, that connected to the set being the original cord designed to operate on American supply mains which, on average, have a voltage of 117·5. These cords usually have three leads in them, but some have an additional tapping for a pilot lamp. They must not be shortened.

The second portion, usually joined by an American cord-type plug and socket, drops the difference between 117·5 volts and the British standard of 230 volts. Sometimes the joints are made internally and braided over.

Valves in sets using line cords must have their heaters wired in series. To determine the total amount of line cord resistance required, add together the heater voltages of the valves used; subtract the total from the mains voltage to find the volts to be dropped; then divide this by the heater current in amps. The result is the line cord resistance in ohms. (See also 'Filament, etc., Supplies'.)

Where two section cords are fitted, the resistance of the first section can be found in the same way, by taking the supply voltage as being 117·5, and, for the second section, the difference between this and 230 volts.

When sets using 0·3-amp valves and fitted with a suitable resistance for 117·5-volt mains are to be used on higher voltages, the following two-core line cords are needed: 200 volts, 280 ohms; 230 volts, 380 ohms; 250 volts, 450 ohms.

Check Heater Current

Some midget sets use 0·15-amp valves, so that it is essential to verify the heater current rating before starting on line cord calculations.

Another practice in American set design is to choose valves so that their total voltage equals that of the mains supply, and dropper resistances are thus not needed. To adapt these sets for British use, a two-core line cord must be used.

It is not sufficient to replace a cord with a new one of the same length, since, although the standard is about 50 ohms a foot, different values are marketed. Many service engineers prefer to start with an overlength cord and to shorten this a little at a time, checking the heater current at each step. Care must be taken when replacing multi-core cords to see that the correct leads and tappings are incorporated.

VALVES AND VALVE CIRCUITS

The Valve. The *electronic valve* is appositely so described inasmuch as its action is that of controlling a flow of electricity, just as a steam valve controls the flow of steam, a carburettor valve the flow of a mixture of air and petrol, and a water valve the flow of water.

TABLE XXIV: VALVE LETTER SYMBOLS

A	=	Amplification
E_A	=	Anode voltage
E_G	=	Grid voltage (as an alternating RMS voltage)
g_m	=	Mutual conductance
g_c	=	Conversion conductance
I_A	=	Anode current
μ	=	Amplification factor
m	=	Amplification under practical conditions of working
R_A	=	Anode slope resistance
R_L	=	Anode load resistor (external)

The root distinction between an electronic and any form of mechanical valve is that in the electronic valve a flow of electricity may be increased and decreased with enormous rapidity, whereas the inertia of moving parts in a mechanical valve limits the frequency at which the turning on and off process may be performed.

The term *thermionic valve* is somewhat unfortunate and will not be used here. There is no root reason why the necessary emission of electrons should not take place at a cold cathode, and the action of the most commonly used electronic valve is not concerned with ionic conduction, such conduction being, in fact, inimical to reliable performance, except in soft valves, which are only used in a relatively few applications.

A valve consists of an envelope containing gas at a low (possibly negligible) pressure, provided with a number of electrodes between two or more of which conduction of electricity through the virtual vacuum or the contained gas may take place as a result of the emission of electrons or ions from one of the electrodes.

The term *vacuum tube*, or *tube*, is used in the U.S.A. instead of valve, but with the wider significance that there is no restriction as to the primary source of emission.

A *hard valve* is a valve with a single source of emission in which the evacuation of gas is so complete as to make the performance of the hard valve independent of any ionization of the residual gas. Most valves used in radio practice are hard valves.

A *soft valve* is a valve with a single source of emission in which the amount of residual gas is enough to make an appreciable effect on the electrical characteristics of the valve.

A *gas-filled valve* is a valve in which the effect of gaseous ionization determines the electrical characteristics of the valve.

The *cathode* of a valve is the primary source of electrons, while a *filament* is a cathode heated by a current which passes through the whole or part of it.

A force is required to make electrons leave a cathode and the *work function* is the potential difference φ through which an electron moves to do an amount of work W. $\varphi = \frac{W}{E}$, where E is the electron charge. The lower the work function, the greater the number of electrons released (greater emission) for a given amount of work. The following gives the work function of various substances:

Tungsten, 4·52; thorium, 3·35; platinum, 4·4; molybdenum, 4·3; carbon, 4·1; lithium, 2·36; sodium, 1·82.

Table XXV relates emission of substances with temperature to which these substances are raised.

TABLE XXV

Substance	Temperature deg. Kelvin	mA/sq.cm.
Carbon	2,000	20
Oxygen on tungsten layer	1,000	350
Tungsten	2,000	1
Oxides on platinum:		
AC_2O_3	2,200	60
B_aO	1,200	500
C_aO	1,400	250
M_gO	1,000	100
S_rO	1,200	85
T_hO_2	2,000	25

Cathode efficiency is the emission obtainable for unit power expended in heating the cathode. Typical figures for this efficiency are tungsten, 1 mA/per watt; thoriated tungsten, 25 mA/watt; and for special oxide coatings, 250 mA/watt.

Diode Valve. The diode is the simplest form of valve and consists of a cathode (shown in Fig. 98 as a filament drawn in a hairpin form) and an anode (shown at the top of the envelope in Fig. 98 as a straight bar).

Electrons are emitted from the filament heated by the current from the battery and, being negatively charged, are attracted to the anode when this, as shown in Fig. 98, is connected to the positive terminal of the HT battery. Thus a current flows between cathode (consisting of a filament) and anode, the electrons emitted from the filament being replaced by the action of the high-tension battery.

Free electrons form in a cloud between cathode and anode and represent a negative charge. This charge, called the *space charge*, tends to repel new electrons emitted from the cathode and so to limit the anode current. This limitation is the greater as the anode voltage is less, and, the effects being non-linear, the result of plotting anode voltage against anode current is a non-linear function at low values of anode voltage, as shown in Fig. 99.

When the anode voltage becomes so great that the supply of electrons from the cathode is insufficient to carry a current of so great a value as would occur were the diode a linear metallic conductor, *saturation* sets in, due to the limitation of emission at the cathode. The higher the temperature of the filament, the higher the anode voltage at which saturation begins, but, of course, a limit is set inasmuch as the filament is destroyed or 'burnt out' if it is made too hot.

Thus the diode is a conductor which does not obey Ohm's law, since at different values of voltage applied, and consequent anode current flowing, the ratio $\frac{E}{I}$ is different. We cannot, therefore, speak of the anode resistance of a valve, because this would have no meaning, the resistance being a function of E. On the other hand, if a change of anode voltage ΔE is made, ΔE being

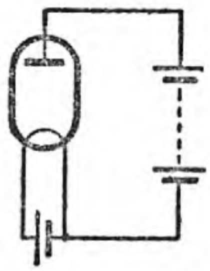


Fig. 98. Diode valve with filament and anode batteries.

so small that the consequent change of current ΔI makes ΔI proportional to ΔE, then we may write, $R_A = \frac{\Delta E_A}{\Delta I_A} = \frac{dE_A}{dI_A}$, showing that R_A is the slope of the curve at any given point on it, and is, therefore, called the *anode slope resistance* of the valve. Anode slope resistance must not be confused with the resistance of the valve considered as a conductor of electricity. The latter resistance, given certain electrode voltages, is the anode voltage divided by the anode current; the slope resistance is the inverse of the slope of the curve plotting anode current (x axis) and anode volts (y axis).

Anode slope conductance is the reciprocal of anode slope resistance.

Other definitions of terms, relevant to the diode as well as more complex forms of valves, are:

Schottky effect, a variation in the electrode current (anode current in the case of a diode) due to the lowering of the work function of the cathode with rise in anode voltage.

Shot effect is random variation in the emission of electrons from the cathode or for other causes. (The result is noise in high-magnification amplifiers.)

Flicker effect is fluctuation of the anode current, being a function of the nature of the cathode material causing variations in total emission.

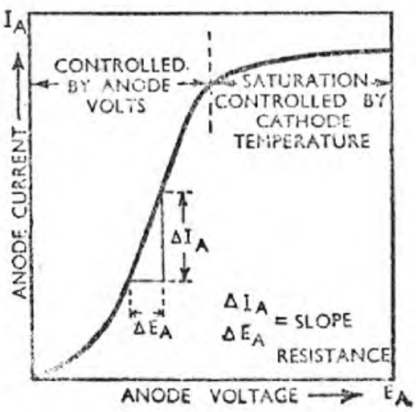


Fig. 99. How anode current of a diode varies with anode voltage.

The effect is different from shot effect.

Secondary emission is the liberation of electrons from an electrode caused by its bombardment by free electrons. Such electrons, released by bombardment, are called *secondary electrons*.

Triode Valve. (Figs. 100 and 101.) The triode valve contains an anode, a cathode, and a third electrode called a grid. The grid (Fig. 101) is placed between cathode and anode. Changes of voltage on the grid cause changes of anode current, the anode voltage remaining constant.

As the grid voltage is made more

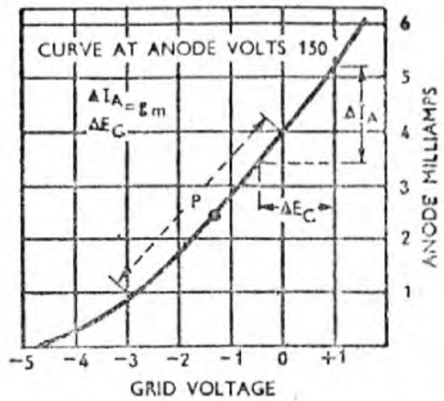


Fig. 100. Anode current/grid voltage curve of a triode valve.

and more negative, more and more of the electrons emitted from the cathode are repelled and cannot escape to the anode. Therefore, the more negative the grid with respect to the cathode, the less the anode current. Fig. 100 plots the grid-cathode volts against resulting anode current.

Suppose the grid voltage is changed by an amount ΔE_G (Fig. 100) so small that there is a proportionate increase of anode current ΔI_A (no impedance or resistance in the anode circuit tending to prevent this current rising). Now let the anode voltage be changed by an amount ΔE_A to restore the same anode current as existed before the grid voltage was changed.

The *voltage factor* of a valve is defined as the ratio of the change in

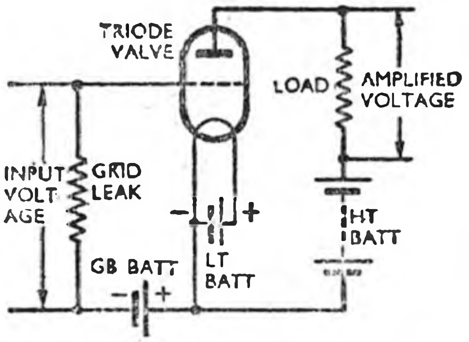


Fig. 101. Basic circuit for the use of a triode as an amplifier.

one electrode voltage to the change in another electrode voltage, to maintain a specified current unchanged, all other electrode voltages remaining constant, so that the *amplification factor* of a triode is the voltage factor of the anode and grid, the anode current remaining unchanged.

Thus one may write μ, the amplification factor, as, $\mu = \dfrac{\Delta E_A}{\Delta E_G} = \dfrac{dE_A}{dE_G}$.

The term *transconductance* from one electrode to another is strictly the quotient of the in-phase component of the short-circuit alternating current of the second electrode, divided by the alternating voltage on the first electrode, all other electrode voltages remaining constant.

Mutual conductance, usually symbolized as g_m, is the control-grid to anode transconductance, and we may write that, $g_m = \dfrac{\Delta I_A}{\Delta E_G}$, namely, the ratio of the small change of anode current given by a small change of grid voltage, the changes being so small that current is proportional to voltage. Thus g_m is expressed in current per potential, or, in practice, milliamps per volt. But $R_A = \dfrac{\Delta E_A}{\Delta I_A}$, while $g_m = \dfrac{\Delta I_A}{\Delta E_G}$, so that $g_m R_A = \dfrac{\Delta E_A}{\Delta E_G} = \mu$, or $g_m = \dfrac{\mu}{R_A}$.

If an impedance, say, a resistance, is connected in the anode circuit, then a change of grid volts produces a change of anode current, hence a voltage drop in the resistance, hence a change in anode voltage, and the valve acts as a voltage magnifier, but this magnification m is the value that, while related to μ, is not, in fact, μ, depending as it does upon the value of the anode resistance, or, with alternating voltages, upon the anode impedance. This is sometimes called a magnification factor, or 'm value', or *stage gain* of a valve and its associated circuit.

Triode as amplifier. (Figs. 101, 102, 103 and 104.) The basic circuit of a triode used as an amplifier is shown in Fig. 101. The so-called grid-leak resistor has the function of allowing the electrons (which would, if it were insulated, accumulate on the grid, causing it to be more and more negatively charged) to leak back to cathode.

If an alternating voltage be applied between grid and cathode, an alternating anode current flows, producing a magnified alternating voltage across the anode resistor.

The steady grid potential is made more negative than the cathode and the peak signal voltage is usually less than this grid-bias voltage, so that the grid never becomes more positive than the cathode. If the grid is positive with respect to cathode, a

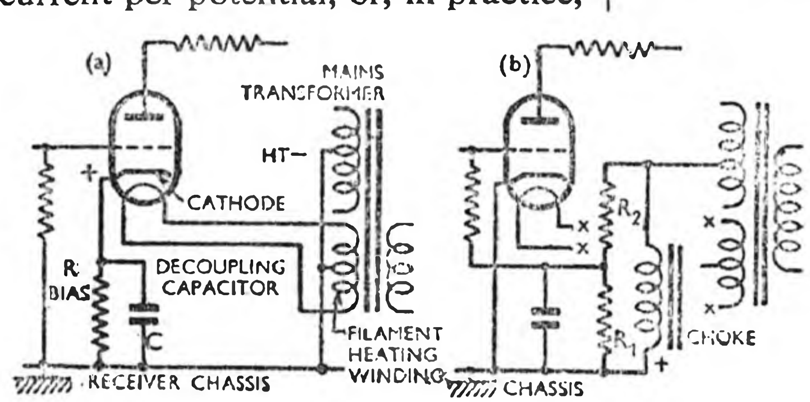


Fig. 102. Indirectly-heated mains-type valves usually have 'automatic' bias, either by (a) cathode resistor or (b) voltage dropper in HT negative of set.

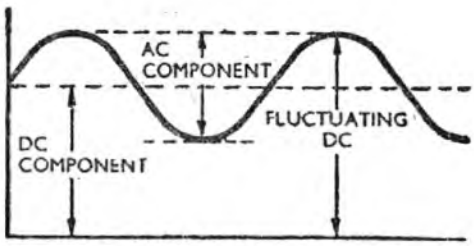


Fig. 103. Fluctuating DC in an anode circuit is equivalent to steady DC plus an AC component.

grid current flows and in so doing represents a resistance which is only finite when the grid is more positive than the cathode. This may cause a distortion of the input voltage and consequent distortion of the amplified voltage.

Grid bias may be supplied by a battery, as in Fig. 101, or by connecting a resistance in the cathode return circuit so that the steady anode current flowing in this resistance raises the cathode to a greater positive potential than the grid. This is equivalent to making the grid more negative than the cathode.

If it be desired to maintain the cathode at a steady positive potential, then the capacitor *C* is used to prevent the alternations of intensity of the anode current producing an alternating potential on the cathode. The reactance of *C* must be $\ll$ than the resistance of *R* at all frequencies amplified by the triode to maintain this condition. If *C* is removed, current feed-back takes place.

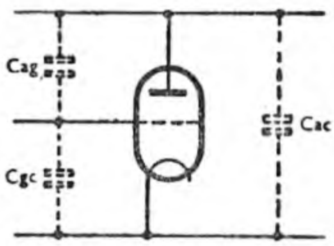
In Fig. 103 is shown the superimposition of the variations of anode current due to alternating potentials on the grid of the valve on the steady current flowing when the grid voltage is fixed. Thus the anode current contains an alternating plus a direct component.

The phase of the anode voltage and anode current in an amplifying valve having pure resistance in its anode circuit is shown in Fig. 104. The anode voltage is seen to be 180° out of phase with the grid voltage.

If the capacitor *C* in Fig. 102 is omitted, the cathode potential varies in phase with the grid potential, lowering the magnification factor of the system and producing current feed-back. This reduces distortion. The diagram is not to scale.

The phase relationships shown do not exist when the anode load is sensibly reactive.

Fig. 105. Capacitances between electrodes in a triode are equivalent to capacitors connected as shown.



Miller effect. (Fig. 105.) The electrodes in a valve have capacitance, which may be expressed as the capacitance between any two electrodes and is called *inter-electrode* capacitance. The effective value of this inter-electrode capacitance is increased because the voltages are amplified on certain electrodes.

In a triode, if C_{gc} is the capacitance between grid and cathode, and C_{ag} the capacitance between grid and anode, then the effective capacitance at the grid cathode electrodes (the input, in fact) is $C_{gc} + (M + 1)\ C_{ag}$, where M is the stage gain.

The impedance of the anode load makes an effect upon the input circuit because of the enhanced inter-electrode capacitance in the valve. This is called *Miller effect,* and can be expressed

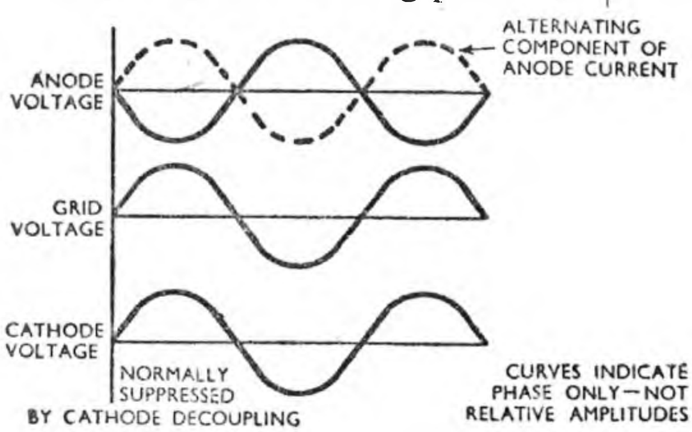


Fig. 104. Voltage and current phase relationships in a triode amplifier.

as an alteration in admittance of the control-grid circuit of a valve, due to capacitance between it and another electrode on which an alternating potential is developed, in consequence of the variation of the grid potential.

The effect depends upon the nature of the anode impedance. When this is resistive, the effect corresponds to negative feed-back, reducing gain; when the load is capacitive, the feed-back remains negative; when the load is inductive, the feed-back is positive.

Therefore, a triode, which exhibits Miller effect very strongly, cannot be used as an amplifier of high frequencies when grid and anode circuits contain parallel tuned circuits, because the anode load 'looks like' an inductive reactance at frequencies less than the resonance frequency and causes positive feed-back to set up oscillations. This can be prevented by methods of 'neutralization', producing feed-back of a negative kind, opposing the positive feed-back, but the circuits are inclined to be unstable.

Screen-grid Valve. (Fig. 106.) In a screen-grid valve a second grid is interposed between the control grid and the anode; the valve having four electrodes: cathode, control grid, screen grid, and anode. The function of the screen grid is to minimize grid to anode capacitance, seen to produce Miller effect in a triode. The screen-grid valve has a peculiar anode volts-anode (and screen) current characteristic, as illustrated in Fig. 106.

This is due to secondary electrons,

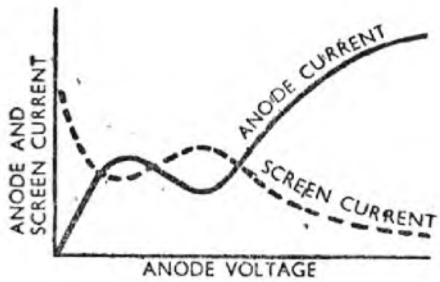
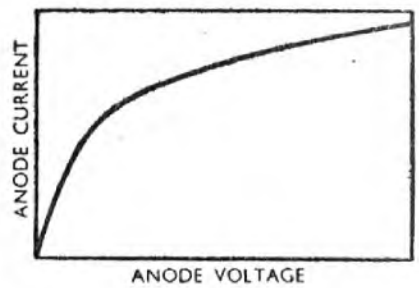


Fig. 106. Anode and screen current curves of a screen-grid valve have a characteristic kink.

released from the anode by bombardment, accumulating on the screen, the current of which increases at the expense of the anode current. The valve, used as a linear amplifier, has, therefore, severe limitations. Its chief use is as a means to get tuned circuits into oscillation, because it can be adjusted to have negative resistance (i.e. an increase of anode voltage can produce a decrease of anode current). Used in this way, it is called a *dynatron* oscillator.

Tetrode. A tetrode is also a screen-grid valve, the distinction between the screen-grid valve and the tetrode being that in the former a lot of care is taken to reduce grid-anode capacitance with less regard to the distortions in the resulting characteristic, while in a tetrode the screening is not so acute but the characteristic is less alinear.

Fig. 107. Typical anode current-anode voltage curve of a pentode.



Pentode. (For characteristic, see Fig. 107.) This is a five-electrode valve containing an anode, a cathode, a control electrode, and two additional electrodes, both having the nature of a screen grid. The *suppression-grid*, nearer the anode than the screen grid, is designed to shield the secondary electrons from the screen grid, and, being usually connected to cathode, passes the secondary electrons back to cathode. The pentode, among its other uses, is commonly used for high-frequency amplification, since it greatly minimizes Miller effect and yet has a good anode volts-anode current characteristic.

Pentodes are also used for audio-frequency amplification; indeed, they are used in most circuits. They are prone to produce more distortion than triodes, but the application of negative feed-back removes this disadvantage. Pentodes have a higher amplification factor than triodes for the same distortion factor.

Beam Valves. In beam valves, the effect of secondary emission is reduced by the relative spacing of the electrodes and not by the use of a suppressor grid.

Heptode and Octode. (See Frequency Changers.)

Cross Modulation is the modulation of the carrier of the desired signal by an undesired signal, and may occur when an unwanted transmission reaches the grid of the first HF valve of a high-frequency amplifier and, being added to the wanted signal, takes the grid swing on to the curved portion of the valve characteristic. On this part of the characteristic, the amplification alters with the grid voltage, and consequently the required signal becomes amplitude modulated by the unwanted transmission. The two signals cannot be filtered out by subsequent tuning. The remedy is to use more selective circuits before the first valve or, if the unwanted signal is of sufficient frequency difference from the wanted, to see that the valve is one not liable to give this type of distortion when correctly used.

Variable-μ (mu) Valve is a screen-grid, or pentode, type in which the characteristics of both low- and steep-slope valves are combined (Fig. 108). The characteristic is free

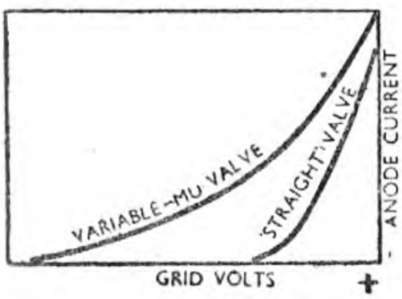


Fig. 108. Anode current / grid volts curves of a straight HF pentode and of a variable-mu type.

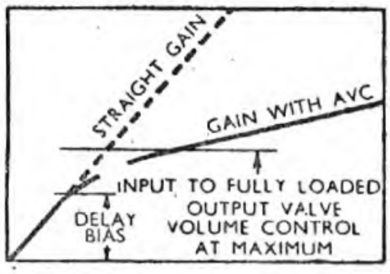


Fig. 109. How delayed AVC levels off receiver amplification after a minimum signal strength is exceeded.

from sharp bends and the possibility of rectification and cross modulation is, therefore, reduced. The main advantage, however, is that the gain of the valve can be controlled by alteration to the grid bias. With a large signal input and a large bias, the mutual conductance is low. With small input and small bias, the gain is high. The valve is an essential part of automatic volume-control circuits.

Automatic Volume Control, more exactly, automatic gain control, seeks to produce a constant value of signal at the demodulator stage, regardless of the signal input. The purpose is to prevent fading of the signal from affecting the sound output, and to prevent 'blasting' when dialling a receiver through powerful transmissions. Part of the amplified HF signal is rectified and smoothed to provide a negative bias. This is applied to the grids of the HF valves, which are variable-mu types, so that their gain is regulated. An increase of signal causes an increase of bias and a reduction of gain.

As the production of a control bias depends on change of signal at the end of the HF amplifier chain, it follows that no AVC system gives a perfectly constant output (Fig. 109).

The standard AVC circuit (Fig. 110) incorporates a 'delay' which prevents reduction of gain on signals which fail to produce a minimum signal at the demodulator stage. The delay is obtained by giving the cathode of the AVC rectifier diode a positive bias. Until the signal exceeds this, the valve does not rectify, and no AVC bias is generated. C_1

taps HF energy from the signal diode, or from the anode of the preceding HF valve. R_1 is the diode load, R_2, the delay-bias resistor, and R_3 with C_2 are decoupling components, which smooth out both HF and LF ripple.

Gas-filled Valves. A valve containing gas possesses characteristics which make it unsuitable for normal amplification purposes, but very useful in certain other applications. When a valve contains gas, electrons from the cathode collide with molecules with sufficient force to dislodge electrons from them. The molecules then become positive particles or 'ions'. These ions have two effects. They lower the internal resistance of the valve so that electrons find it much easier to leave the cathode; the anode current increases. Second, the ions are attracted to the negative grid, where they combine with electrons; to maintain the bias, current must flow through the grid circuit.

Both these effects are undesirable in a receiver, and when a valve goes 'soft' (loses vacuum), as indicated by increased anode current, or develops a blue glow and, perhaps, red-hot grid and anode, it must be replaced.

In the 'gas-filled relay', or 'thyratron', an inert gas is introduced into the valve. The grid is normally biased to such an extent that no anode current flows. When an impulse signal reduces the bias the valve begins to conduct. Ionization takes place, and a heavy current rises almost instantaneously to a large value. The grid ceases to effect any control, and the current can be stopped only by interruption of the anode voltage.

The valve behaves, therefore, as a relay in which a current flow is 'triggered' by a voltage. It finds use in saw-tooth oscillators for cathode-ray oscillographs and in 'counting' and other electronic devices requiring relay action. Fig. 111 shows a circuit for control of a counter. The ratio, $\frac{\text{anode potential}}{\text{grid potential}}$, at the critical striking point is known as 'grid control ratio'. The critical grid voltage varies with the anode voltage (Fig. 112).

The 'mercury-vapour' valve contains a small amount of mercury

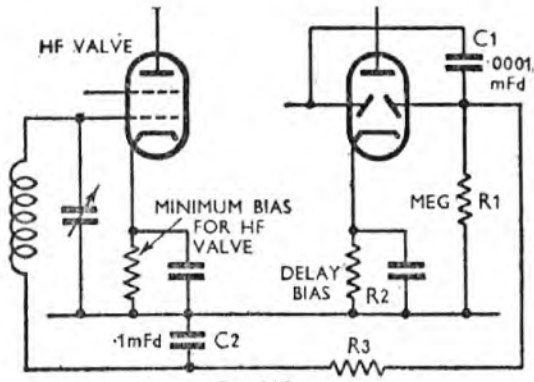


Fig. 110

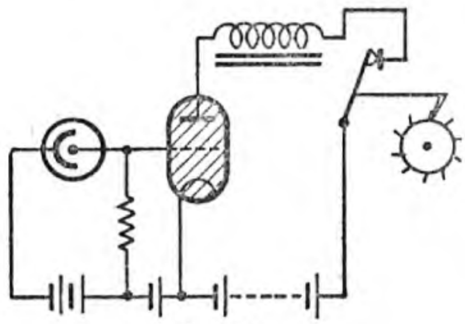
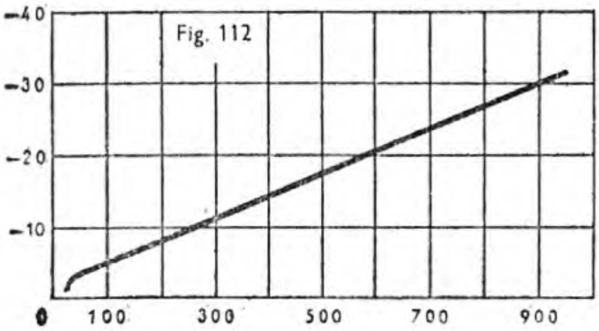


Fig. 111



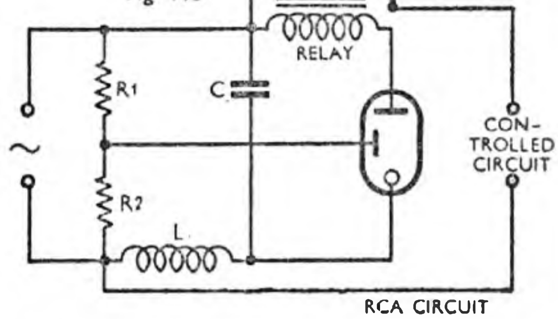
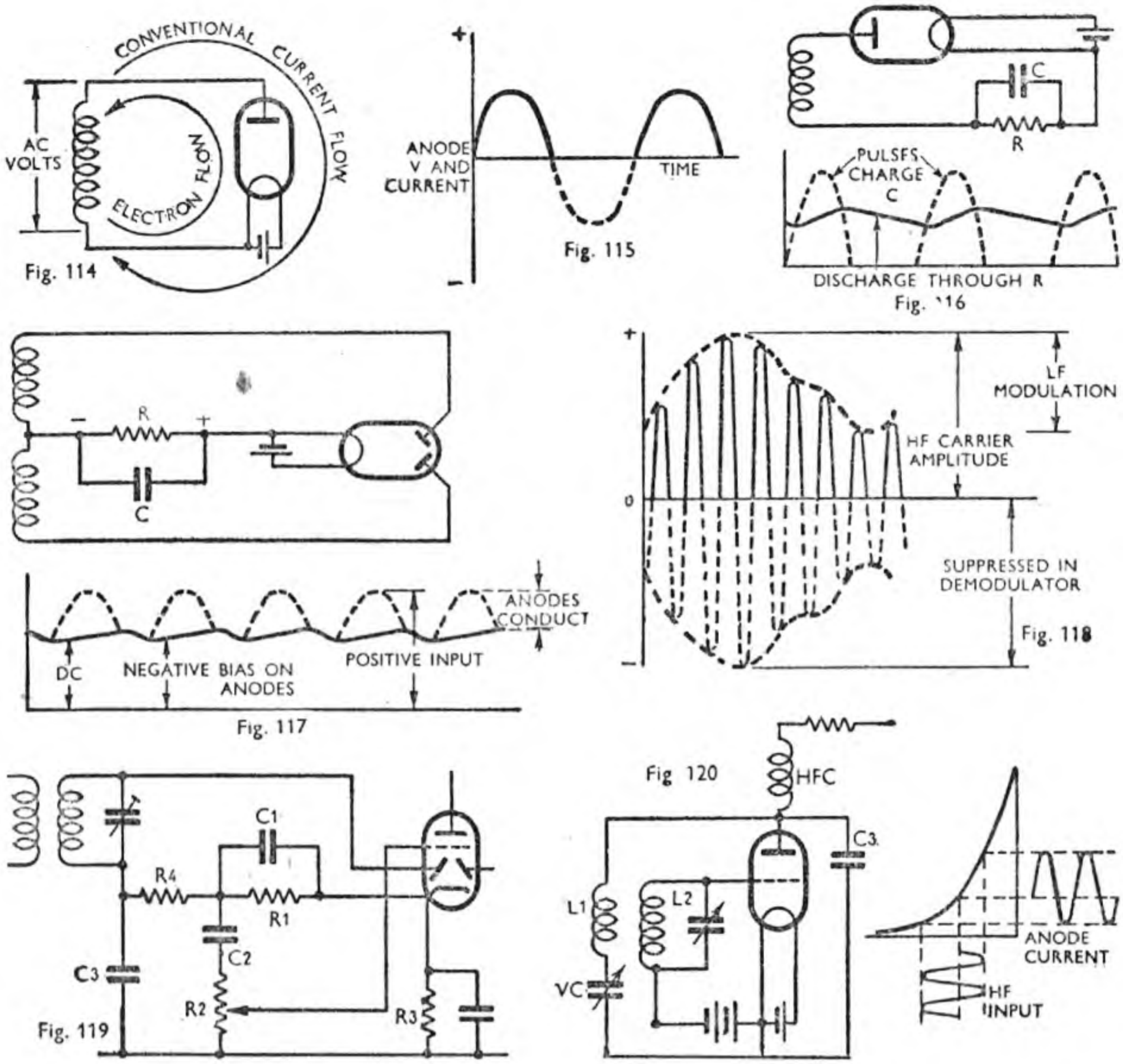


Fig 113

SPECIAL VALVES AND THEIR USES

Fig. 110. Standard AVC circuit. **Figs. 111-113.** Practical use of relay valves.



CIRCUITS FOR RECTIFICATION AND DEMODULATION

Figs. 114, 115. Illustrating the principle of rectification. **Fig. 116.** Use of filter. **Fig. 117.** Full-wave rectifier. **Fig. 118.** Principle of demodulation. **Fig. 119.** Using diode for demodulation. **Fig. 120.** Anode-bend 'detection'.

which is vaporized when the valve is operated. Ionization occurs (shown by a bluish-green glow) and a heavy current passes. The valve is used as a rectifier where outputs larger than those given by hard valves are needed. The drop between anode and cathode is only about 15 volts, and varies very little with the current demand.

Ionic Bombardment

In the 'cold cathode' or 'ionic-heated cathode' rectifier or relay valve, the bulb contains a reduced pressure of inert gas. The ions bombard the cathode and heat it; no other heat is applied. The ionic flow may be initiated by use of a starter anode causing a glow discharge.

Fig. 113 shows this valve as a relay operated by a radio transmission. In the quiescent condition, R_1 and R_2 provide the starting anode with a voltage just below the striking value. When a transmission energizes the tuned circuit L_c, the resonant voltage adds to the applied voltage, and the starting anode begins a glow discharge to the cathode. This discharge produces ions which lower the resistance of the valve so that current flows through the main anode and operates the relay. As the supply is AC, operation stops when the transmission ceases.

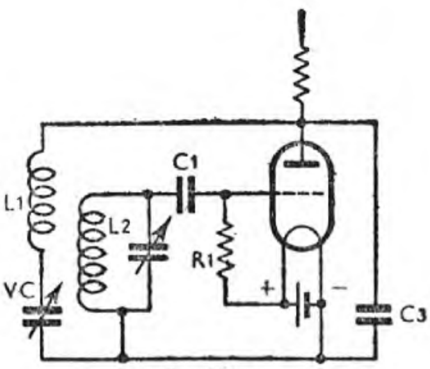


Fig. 121

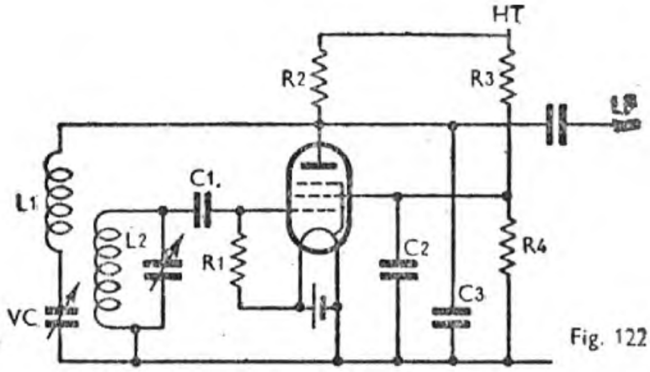


Fig. 122

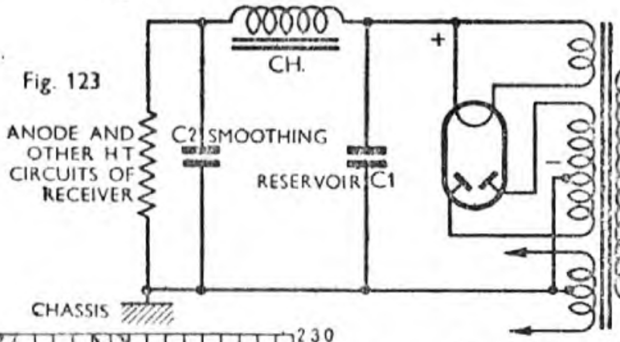


Fig. 123

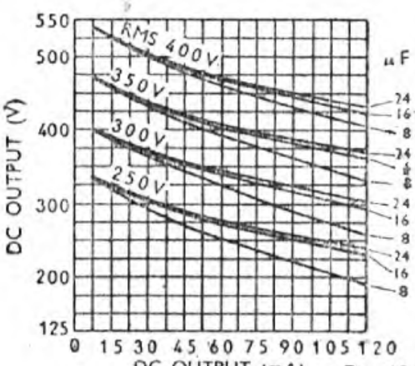


Fig. 124

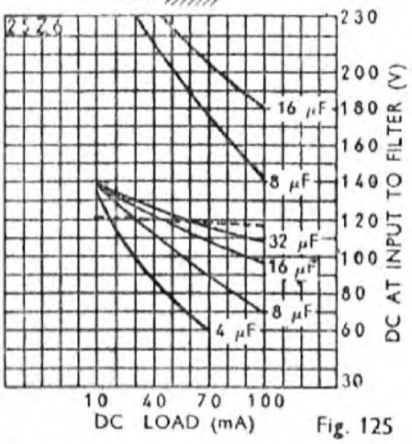


Fig. 125

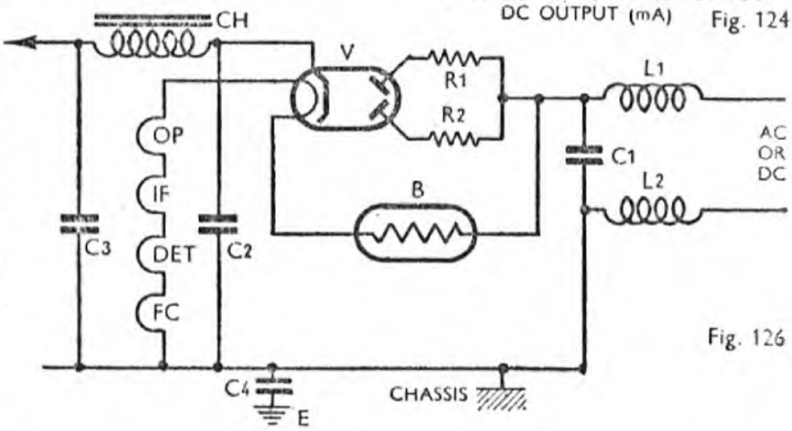


Fig. 126

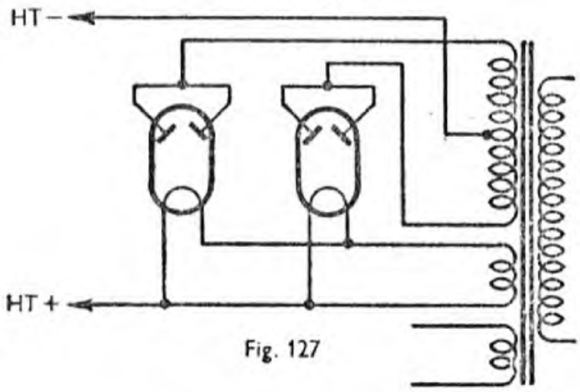


Fig. 127

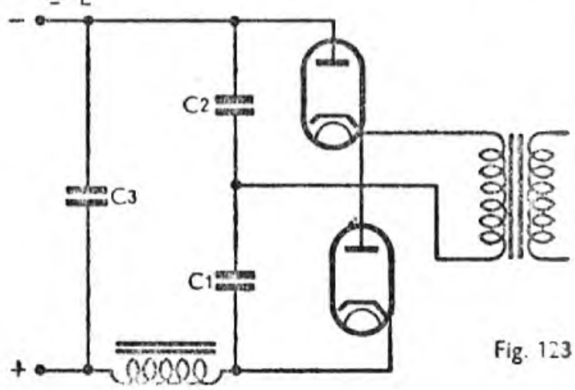
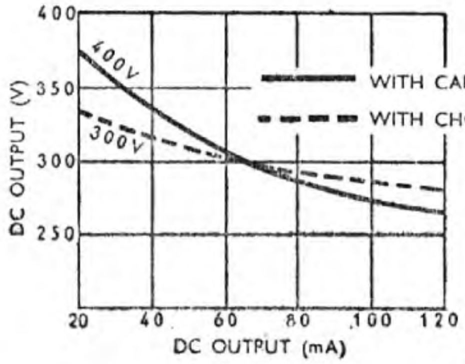


Fig. 123



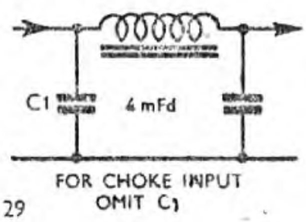


Fig. 129

Fig. 121. Leaky grid detection. **Fig. 122.** Pentode detection. **Figs. 123-129** illustrate various methods of mains rectification using diode and double-diode valves.

Rectification. Current flows through a diode only when the anode is positive to the cathode. The valve, therefore, passes unidirectional current pulses when an alternating voltage is applied (Figs. 114, 115).

A DC supply can be obtained from a rectified AC supply by the use of a low-pass filter structure to let the DC (zero frequency) pass and to attenuate the AC (Fig. 116).

By use of a centre-tapped secondary winding on the power transformer, and a valve containing two anodes (double-diode), full-wave rectification is obtained (Fig. 117).

In a circuit such as Fig. 117, where there is a cathode load, the loss of electrons by the cathode makes it positive. The polarity across R is, therefore, as indicated, and the anode receives a DC negative bias. The circuit adjusts itself, so that this bias is slightly less than the peak positive AC input, which makes the anode momentarily positive and so maintains current through the diode and the charging of C.

Detection. A carrier frequency, amplitude modulated by speech or music (LF) ,can be represented as in Fig. 118. The LF, or components of audio frequency, can be separated from the carrier (HF), or components of carrier frequency, by a diode circuit, as in Fig. 119.

The charge in C_1 over a short period varies according to the amplitude of the rectified unidirectional currents. The discharge through R_1 varies with the intensity of the carrier modulation, provided C_1 and R_1 are correctly related. The voltage across R_1 corresponds to steady DC with superimposed LF.

C_2 stops the DC but passes the LF through the volume control R_2 to the grid of the triode amplifier, which is biased by R_3; R_4 and C_3 form an HF filter to reduce the HF voltage across C_2, R_2.

Suitable values are: R_1, ·5 meg; R_2, 1 meg; R_3, 50,000-100,000 ohms; C_1, ·0001 mFd; C_2, ·01-·05 mFd; C_3, ·0003 mFd. R_1 may be as low as ·25 meg, and R_2 may be ·5 meg. Value of R_3 is determined by the triode bias and anode current.

Triode Detector. The triode can be used to separate LF from an HF carrier and, at the same time, provide a degree of LF magnification. In the 'anode bend' method (Fig. 120), the grid is biased to the bottom bend in the anode current-grid volts characteristic. Negative halves of the HF cycles are virtually suppressed, but the positive halves produce pulses of anode current.

The 'grid' or 'leaky grid' system (Fig. 121) produces demodulation in a similar way to the diode, and the grid also regulates the electron stream to the anode, thereby affording amplification.

The value of the grid leak R_1 is chosen so that the valve biases itself back to the bend in the characteristic. R_1 is usually 2 meg and C_1 is ·0003 mFd.

Power Grid Detection employs the same circuit but values are: R_1, ·25 meg; C_1, ·0001 mFd. The valve is worked in a less-sensitive condition, but the quicker charging and discharging of C permits the rectified voltage to follow faithfully the high audio frequencies, even when the carrier wave is deeply modulated.

Pentode Detection is sometimes employed in simple sets, where high sensitivity and gain are needed, even though harmonic distortion is probable. Typical values (Fig. 122) are: R_1, 2 meg; C_1, ·00025 mFd; R_2, ·25 meg. The high anode load is necessary because of the high AC resistance of the valve. R_3 and R_4 form a potential divider to apply the required voltage to the screen, and may be 40,000 and 25,000 ohms;

C_2, ·1 mFd. C_3 is an HF by-pass of ·0001 mFd.

Reaction, which is a name for *positive feed-back*, is employed with these two types of detector. Some HF reaches the anode with the LF. The HF choke (Fig. 120), or anode load resistance, opposes the passage of the HF, which thereupon flows through the reaction coil L_1 and capacitor VC.

L_1 is wound near to L_2, the tuning coil, so that the magnetic field set up by the HF current induces current in L_2. The direction of winding L_1 is such that the induced current in L_2 is in same direction as signal current.

The induced current compensates for the losses in the resistance of the tuned circuit, and results in increased gain and selectivity.

The amount of HF current and, therefore, of energy feed-back is controlled by the variable reaction capacitor VC. If VC is advanced too far, the positive feed-back is increased so that a continuous oscillation is set up in the tuned circuit. As the circuit is tuned, this oscillation will 'beat' with the incoming signal, and produce the well-known reaction howl.

C_3 provides an alternative HF by-pass route, necessary when VC has minimum capacitance.

MAINS RECTIFICATION

In most receivers operating from AC mains a diode or double-diode valve is used to obtain DC for the anode supplies to the receiving valves. The principle is illustrated in Figs. 116 and 117.

Since hum would be caused in the loudspeaker if any appreciable trace of the mains fluctuations appeared in the anode supplies, smoothing must be very complete. For this reason, in addition to the reservoir C_1 in Fig. 123, corresponding to C in Fig. 117, an additional smoothing impedance CH, and smoothing capacitor C_2, are included.

CH may be a resistance, but to secure high impedance with low DC resistance, and, therefore, low voltage drop, an inductance is generally employed. Frequently, the inductance is the field winding of an electromagnet type of loudspeaker.

The capacitance of the reservoir C_1 affects the rectified voltage. The 'smoothing' capacitor C_2 also provides a route by which signal currents in the anode circuits return to chassis. When C_2 becomes open circuit, instability as well as increased hum may result.

Electrolytic capacitors are generally employed for C_1 and C_2, and typical ratings are shown in Table XXVI. The current-voltage or regulation curves of two representative rectifiers are seen in Figs. 124 and 125.

In Fig. 127 two double-diode valves, each used as a half-wave rectifier, are combined in a full-wave circuit for heavy current duties. Fig. 128 shows a voltage doubling arrangement; the valves may be combined in a single double-anode, double-cathode type. Capacitors C_1 and C_2 are each charged by the input voltage and, as they are in series, the output across C_3 is double the input.

AC-DC Input. With sets for operation from AC or DC mains without alteration, an input transformer cannot be employed. Fig. 126 shows the usual arrangement, although the rectifier V may be a single-anode type. L_1, L_2 and C_1 form a filter to prevent HF 'noise' in the mains from entering the set.

R_1 and R_2 are resistors to prevent excessive current through the valve during voltage surges. The suitable value varies with reservoir capaci-

TABLE XXVI: CHARACTERISTICS OF TYPICAL RECTIFIERS

Showing regulation and effect of reservoir capacitance

Type of Valve and Heater Rating	Type of Cathode	Normal RMS Input to Anode	Reservoir Capacitance (mFds)	Smoothing Inductance (H)	DC Output			
					mA	Volts	mA	Volts
Full-wave, 4 volts 2 amps	IDH	350–0–350	8	25 upward	120	325	60	390
			16	"	120	365	60	405
			24 (max)	"	120	370	60	410
Full-wave, 4 volts 2·5 amps	DH	350–0–350	16 (max)	"	120	385	60	420
Two-path full-wave, 25 volts ·3 amp	IDH	225	8		120	160	60	220
			16	"	120	200	60	235
			24 (max)		120	205	60	240
Two-path full-wave, 25 volts ·3 amp	IDH	125	8	20 – 30	100	70	40	110
	IDH		32 (max)	20 – 30	100	110	40	125

tance approximately as follows: 8 μF, 50 ohms; 16 μF, 75 ohms; 32 μF, 1,250 ohms.

All the valve heaters are in series, and the detector is placed at the low potential end (chassis) to reduce noise. *B* is a barretter to control the heater current and may be replaced by a tapped adjustment resistor.

Regulation. A rectifier circuit with good regulation is one in which there is little change of output voltage with alteration of load current. Change of output voltage with output current is due to the internal resistance of the valve, transformer, etc., the whole circuit being in the nature of a voltage source with internal impedance (largely resistance if the transformer has little leakage inductance).

The value of this equivalent resistance is approximately $R = R_S + \left(\frac{R_2}{R_1}\right)^2 R_P$, where R_S is resistance of secondary, $\frac{R_2}{R_1}$ is step-up ratio of primary to secondary, and R_P is resistance of primary.

With a DC input as in an AC-DC set on DC, voltage drop across the rectifier is as low as, approximately, 5-25 volts with normal loads.

The apparent increase of voltage in AC circuits at certain reservoir capacitances and loads, is because the input is stated in RMS, and the peak voltage across the valve is greater by $\sqrt{2} = 1{\cdot}41$ times.

Increase of reservoir capacitance means that the valve works into a lower impedance; that is, the charging pulses become larger. This increases the output; but the charging pulses must not exceed the safe saturation emission of the rectifier valve. To limit the charging pulses, a choke input may be employed (Fig. 129).

Peak Inverse Voltage of a rectifier is the highest voltage it can safely stand, in the direction opposite to conduction. This inverse voltage is applied during that part of each cycle when the input voltage is opposite to the voltage across the reservoir capacitor during 'negative' half-cycles of input.

VALVE OSCILLATORS

A valve may be used to set up alternating currents in a parallel tuned circuit, the frequency of the currents being determined by the constants of the tuned circuit and being equal to or nearly equal to the resonance frequency of the tuned circuit.

The alternating currents caused to flow in the tuned circuit are called *oscillating currents*, or *oscillations*, and the valve and associated circuits are called *a valve oscillator circuit*, or *valve oscillator*, *or oscillator*. The distinction between oscillating currents and alternating currents lies only in the difference that the frequency of the oscillating current is determined by the constants of the circuit in which it flows, whereas an alternating current is independent of such constants.

If the voltage across the grid and cathode of a valve were varied, in some periodic manner, then the resulting anode voltage, if resistance were included in the anode circuit, would vary in a like manner.

Tuned Anode Circuit

If now a parallel tuned circuit were connected in the anode circuit and adjusted to have a resonance frequency equal to the frequency of the fundamental component of the alternating grid to cathode voltage, then the impedance of this tuned circuit would be in the nature of a resistance, and the currents in it and, therefore, the voltage across it, would be 180° out of phase with the grid cathode voltage.

Therefore, equal currents would flow in the (equal) reactances formed by the parallel connected capacitor and inductor of the tuned circuit and these would be oscillatory currents. The voltage across the tuned circuit would be the maximum possible voltage, because at resonance the tuned circuit has its maximum impedance.

Now, suppose that instead of some external source causing the grid cathode voltage to vary at the resonance frequency of the tuned circuit in the anode, means are provided to derive this voltage, at correct phase, from the anode circuit.

Begging the question as to how the process might start, consider that oscillatory currents do flow in the tuned circuit at the resonance frequency, then the grid cathode circuit will have voltages applied to it at the correct frequency and, by suitable adjustment, the correct amplitude to maintain the oscillations in the tuned circuit.

In both these cases, in one of which the grid cathode voltages are supplied from an external source at the correct frequency, and in the other where they are derived from a tuned circuit, presumed to have oscillatory currents flowing in it, at the correct frequency, phase and amplitude, the valve may be considered to act in the nature of an interrupter.

To say that energy is transferred from anode to grid circuit is allowable, but the basic conception of the valve causing pulses of current to 'tap' the tuned circuit into oscillation at its resonance frequency is, perhaps, the more rewarding.

It is also possible to say that there is positive feed-back, whereby the voltages applied from anode circuit to grid are such as to cause greater anode voltages to be developed until the oscillations build up to a value limited by saturations of one kind or another.

This conception helps to explain how oscillations start when power is applied from the high-tension source; any change of voltage in the anode circuit is fed back to the grid, in a sense tending to increase the anode voltage until oscillations build up.

Anode-Grid Coupling

There is no reason why the parallel tuned circuit should be connected in the anode circuit, it may be connected between grid and cathode, always provided the necessary means to ensure positive feed-back are provided.

Also, if desirable, both anode and grid circuits may contain tuned circuits. The essential feature of all oscillating circuits is to ensure positive feed-back so that the valve, acting as an interrupter, the interruptions being more or less sudden according to the conditions required, shall cause oscillating current to flow in a parallel tuned circuit or circuits connected to the valve electrodes.

In Fig. 131a the tuned circuit is connected between grid and cathode, positive feed-back being provided by coupling L_1 and L_2.

Self-Bias Action

The combination of the parallel resistor and capacitor in the grid circuit is called a *grid leak*. When currents build up in the tuned circuit, the grid becomes (once every cycle of alternation) more positive than the cathode and so collects electrons. These can return to cathode only via the resistor.

Depending upon the value of the resistance of the resistor, the rate of leak is greater or smaller, and so the mean negative change on the grid greater or smaller. Moreover, if relatively large currents flow in the tuned circuits, so there is a tendency for the positive pulses of grid cathode voltage to be larger and so a tendency to collect a greater mean negative change on the grid. The grid is thus biased by a steady negative voltage, on which the oscillation voltages are superposed, which negative voltage tends to become greater as the oscillation voltages tend to become greater.

A measure of automaticity is thus obtained, the circuit having a self-limiting action because the grid bias being more negative tends to reduce the amplitude of the oscillation. The grid leak assists the circuit to start to build up oscillation because, in the initial conditions, grid cathode voltage is zero and the mutual conductance of the valve is high.

In Fig. 131b the feed-back is caused by the inter-electrode capacitance of the triode, Miller effect enhancing the feed-back.

In Fig. 132a a common inductor is used to give positive feed-back, and Fig. 132b is a variant in which HFC is a 'high-frequency choke', i.e. an inductor of high impedance to currents having the resonance frequency of the tuned circuit.

The relative values of the reactances of the two capacitors of Fig. 132c determine the degree of positive feed-back.

Fig. 133 shows the circuit of the *dynatron oscillator*. A tetrode with the potentials on its electrodes appropriately proportioned has the characteristic of a negative resistance between anode and cathode; that is to say, an increase in anode voltage results in a decrease of anode current.

Imagine that oscillations are flowing in the tuned circuit. At one instant the back-e.m.f. from the oscillating circuit adds to that of the high-tension source, and in the time of half a cycle of oscillation later subtracts from it, and so on.

When added, the total voltage across the anode cathode circuit is high but the current small, when subtracted the total anode voltage is low but the anode current high.

Interrupter Principle

Thus the valve, acting as an interrupter to the currents from the source, causes pulses of current to flow through the tuned circuit and these maintain the oscillations. The rate of switching on and off of the valve, considered as an interrupter, is determined by the tuned circuit and takes place at a frequency equal to the resonance frequency of the tuned circuit, because it is at this frequency that its impedance is highest and so the effects described are the greatest.

The *magnetron* oscillator of Fig. 134 illustrates the interrupter principle, inasmuch as the voltages on the two anodes, when oscillating currents are set up in the tuned circuit, are 180° out of phase and so a stream of electrons is conductive first through one anode and then through the other at the appropriate frequency.

Fig. 135 shows a *crystal oscillator*.

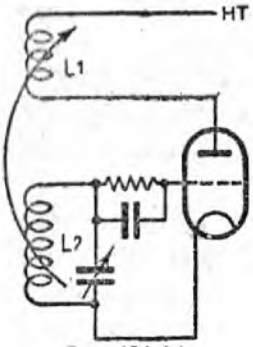


Fig. 131 (a)

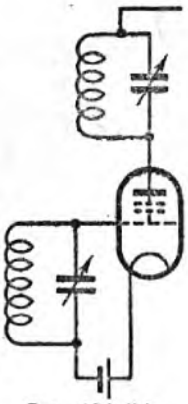


Fig. 131 (b)

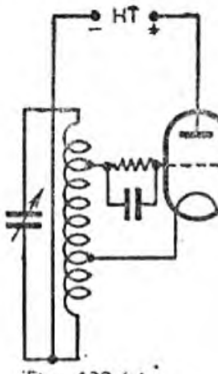


Fig. 132 (a)

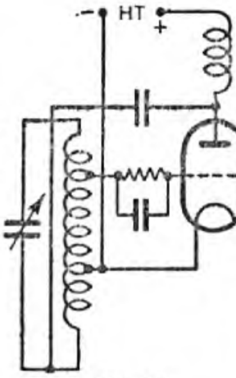


Fig. 132 (b)

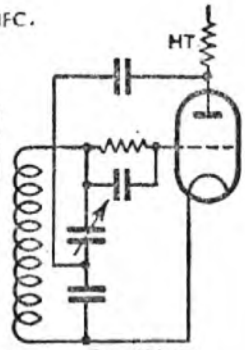


Fig. 132 (c)

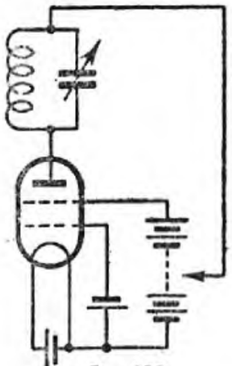


Fig. 133

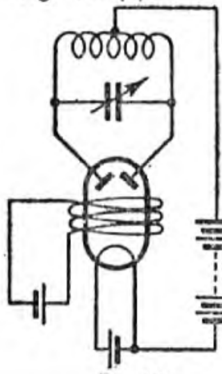


Fig. 134

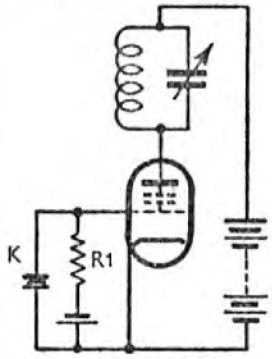


Fig. 135

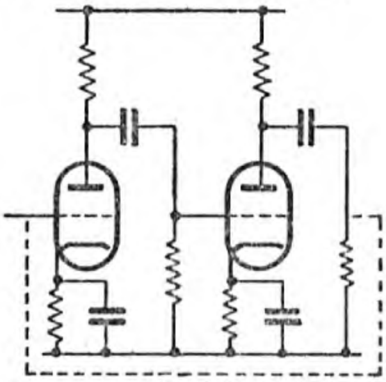


Fig. 136

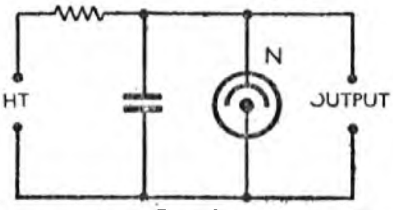


Fig. 137

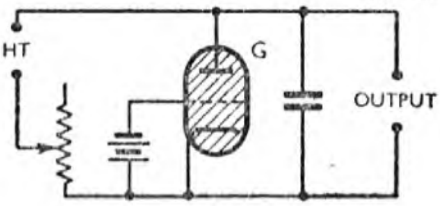


Fig. 138

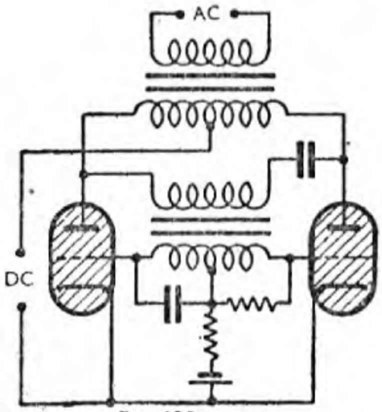


Fig. 139

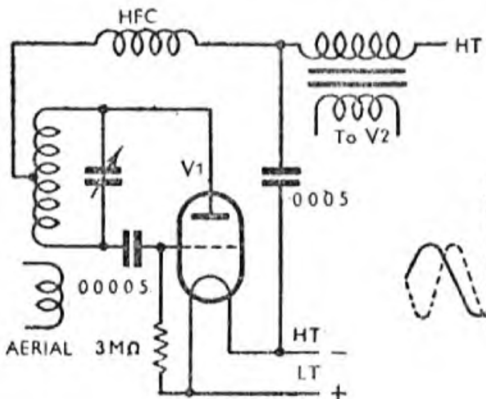


Fig. 140

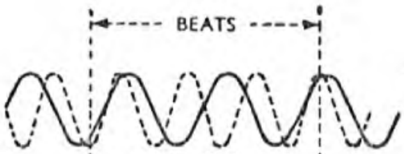


Fig. 141

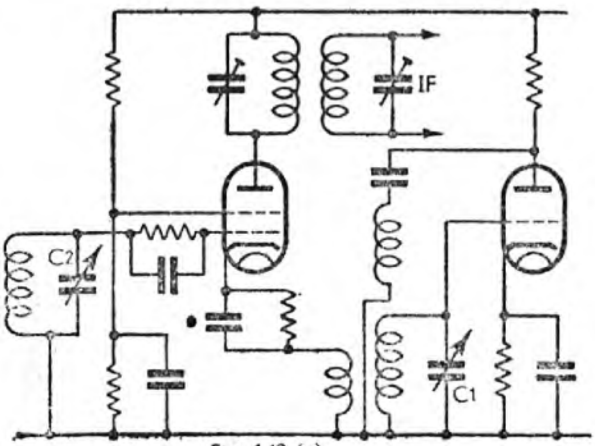


Fig. 142 (a)

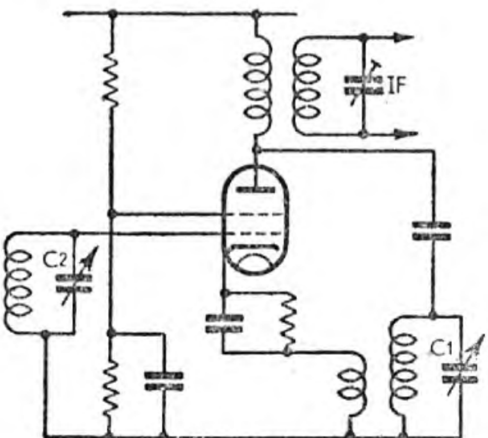


Fig. 142 (b)

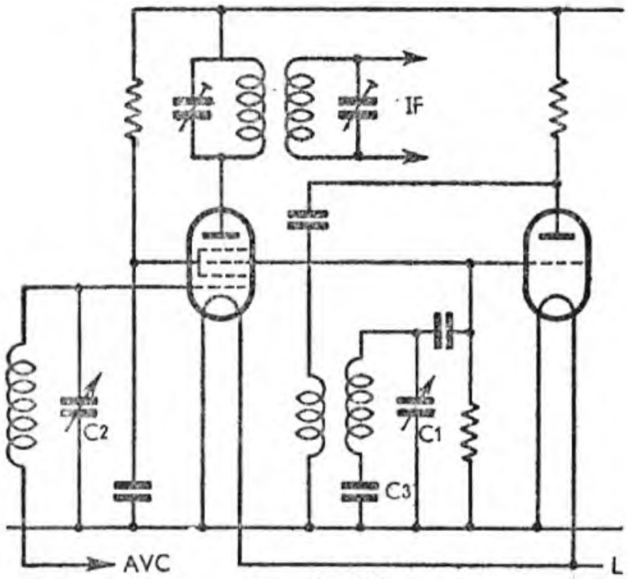


Fig. 143

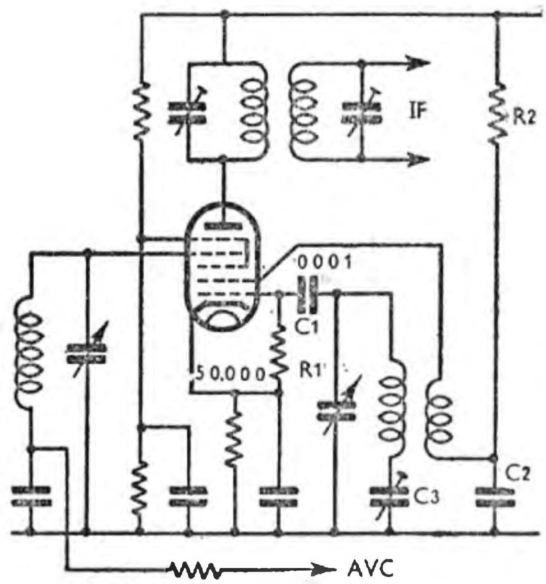


Fig. 144

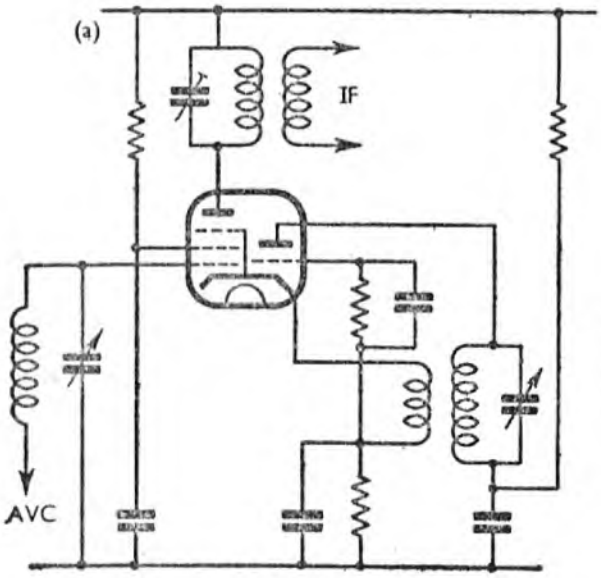


Fig. 145 (a)

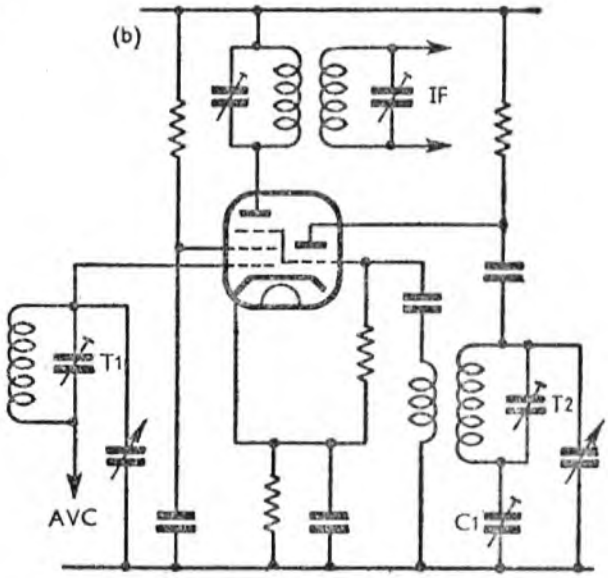


Fig. 145 (b)

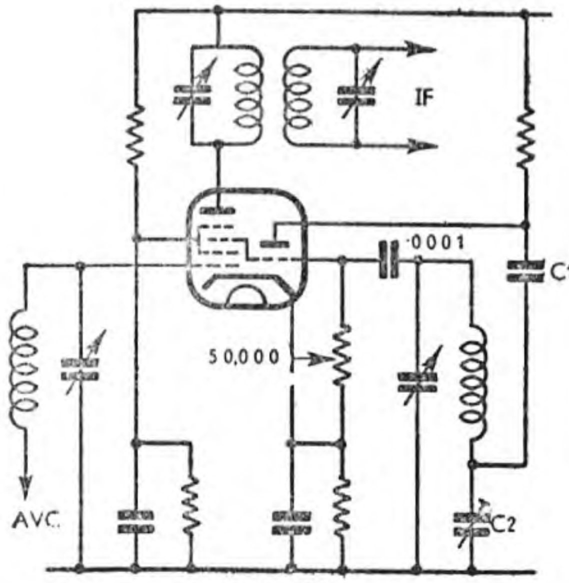


Fig. 146

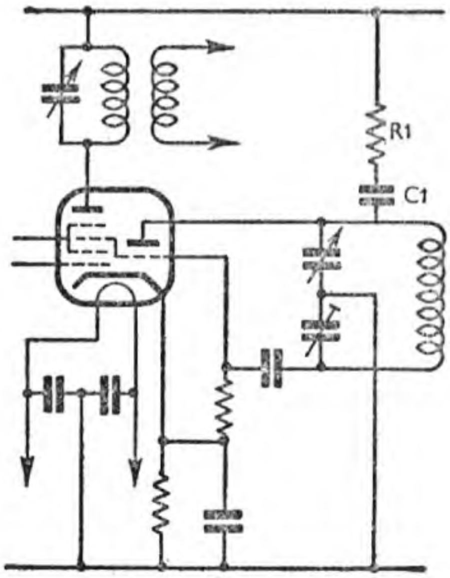


Fig. 147

Figs. 131-147. CIRCUITS WHICH INCORPORATE OSCILLATORS

Quartz crystals have notably the property that their conductivity to alternating currents shows a very marked increase at a certain frequency at which the crystal itself resonates mechanically. Figs. 131b and 135 are, electrically speaking, identical; the difference being that the crystal, labelled K in Fig. 135, behaves as a tuned circuit.

Frequency Stability

The crystal has the property of a tuned circuit, the resonance frequency of which diverges only very slightly from a mean, and so the frequency of oscillation of a crystal oscillator has a value which is constant, within very small limits. Divergences of as little as one part in a hundred million can be assured when great care is taken to ensure constancy of ambient temperature, stability of mounting, and constant electrical conditions.

Any circuit having positive feed-back will cause oscillations to be set up in it, and the circuit of a two-valve amplifier (Fig. 136) will set up oscillatory currents determined by the values of the contained resistors and capacitors.

No tuned circuit is used and, in consequence, no filtering action discriminating against the generation of harmonics (i.e. currents having frequencies which are whole number multiples of the lowest frequency), and the resulting wave form of the oscillation may not be sinusoidal.

If the valves are worked over non-linear portions of their characteristics, harmonic generation is the more prone to occur. When there is a large generation of harmonics, the circuit producing them is called a *multi-vibrator*.

The term *relaxation oscillator* refers to a generator of oscillations characterized by cycles, each consisting of a period during which energy is stored in a reactive element, followed by a period of transition, or relaxation, during which the reactance discharges; these processes usually occur at very different rates.

Fig. 137 shows a relaxation oscillator in which the capacitor is charged through a resistor (the time of charging depending upon the product $R \times C$) until the voltage across the capacitor rises to such a value that the neon tube N becomes highly conductive, its conductance being virtually zero at voltages less than a critical voltage, and so discharges the capacitor, the conductance of the tube being maintained at a low value until the voltage across it is but a few volts.

The tube then becomes non-conductive and the capacitor charges up to the critical voltage again, the process repeating *ad infinitum.*

In Fig. 138 the discharge takes place in a gas-filled valve G, the critical voltage being more accurately determined by the grid cathode voltage applied by the battery source (or any other DC source) shown. The time of charge is determined by the adjustable value of the resistor and by the grid voltage.

Gas-filled valves such as thyratrons may be used to set up oscillatory currents in tuned circuits, and an example of the type of circuit used is given in Fig. 139.

Super-regenerative reception of signals is a method of reception employing amplification in which feed-back is adjusted to a point at which oscillation occurs or is liable to occur; any oscillation produced is periodically suppressed or quenched. A circuit is shown (Fig. 140) which typifies the principle.

If the tuned circuit were oscillating at a frequency different from that of the signal frequency, audible beats could be produced in telephones energized from a chain of valves connected at its input to the transformer labelled 'To V_2' in Fig. 140. (The process of production of beats is indicated in Fig. 141, because if the two sinusoids shown are added, the resulting envelope will have, among others, a sinusoidal component of frequency equal to the difference between the two frequencies of the sinusoids added together.)

These beats, being audible, would interfere with the reception of telephony signals, and so means are provided, consisting of a grid leak (resistance, 3 MΩ, and capacitor, 50 micro-microfarads), to quench the oscillation so soon as it tends to build up. The arrangement is very sensitive but, unless carefully adjusted, may tend to be unstable.

FREQUENCY CHANGERS

The super-heterodyne receiver is based upon the principle whereby the frequency of the signals received at the aerial is changed, so that, whatever (within limits) the frequency of the received signals, they are detected (i.e. the envelope of modulation restored) at a fixed (supersonic) frequency.

The means to change the different frequencies of the different received signals to a constant frequency is based upon the principle that by combining two alternating voltages or currents which have sinusoidal functions, a complex wave form is produced which can be shown to be made up of a number of sinusoids of different amplitudes and frequencies, the chief components of which are two sinusoids having frequencies equal to the sum and difference respectively of the original frequencies before combination.

Thus, in a super-heterodyne receiver, a *local oscillator*, the frequency of which may be varied (usually by the adjustment of a variable capacitor), is supplied and the voltage from this is combined with the received signal voltages.

Let the frequency of the local oscillations be f_H and the frequency of the oscillations representing the received signals be f_S. Let f_{C1} and f_{C2} be the components existing after combination of f_H and f_S, then, $f_{C1} = f_H + f_S$; $f_{C2} = \pm(f_H - f_S)$; f_{C2} being expressed as shown to indicate that the result of subtraction must be positive.

Common practice in the design of super-heterodyne receivers is to make $f_H > f_S$. Thus a filter is connected at the output of the circuits in which signal and local oscillator voltages are combined, which filter passes frequencies equal to f_{C2} (and a small band of frequencies equally greater and smaller than f_{C2} to pass the sidebands of modulation) and rejects or stops all other currents having other frequencies (e.g. f_{C1}). The frequency $(f_H - f_S)$ is called the *intermediate frequency* (abbreviated IF), and it is commonly 450 Kc/s, so that the intermediate frequency filter passes a band of from $450 - f_m$ to $450 + f_m$, where f_m is the highest of the audio modulations substantially fully reproduced in the output after the modulation detector.

One of the many advantages of the super-heterodyne receiver is that the amplification and filtration of signals may be performed with currents of the same frequency; albeit, the signal currents have different frequencies. Only the adjustment of the local oscillator frequency is required to bring all signal frequencies to the same intermediate frequency.

The two methods of combination of the voltages due to signal and local oscillator which are used are (1) to add the instantaneous values of the two voltages; (2) to multiply the instantaneous values of the two voltages.

The former method is called the *heterodyne method*, and when the resulting difference frequency f is above audibility, it is called a supersonic frequency; therefore, the name *supersonic heterodyne* receiver was introduced and abbreviated to superheterodyne. This term, in the light of modern practice, is no longer strictly accurate because, according to this practice, the adding or heterodyne principle has been abandoned and the multiplying or modulation process substituted.

The heterodyne method demands that the complex resulting from the addition of the signal and local oscillator voltages shall be rectified, the output from the rectifier being taken to the IF filter.

First and Second Detectors

The term *first detector* is used to distinguish that which rectifies the component resulting from adding, from that which restores the modulation envelope and called the *second detector*.

To eliminate distortion of the IF wave form, the local oscillator voltage should be much greater than the signal voltage. A square-law first detector, however, removes all distortions, whatever the ratio of signal and local oscillator voltage.

In modern receivers, the local oscillator and signal voltages are multiplied by the use of a valve properly called a *frequency changer* and often called a *mixer*. The frequency changer valve is designed so that the signal voltages shall be multiplied by (i.e. modulated by) the local oscillator voltages.

In spite of the selective properties inherent in the super-heterodyne principle, the signal frequencies must be filtered, to some degree, in order to prevent *second channel interference*.

Suppose a signal frequency is 1,000 Kc/s and the oscillator frequency 1,450 Kc/s, then the IF is 1,450 – 1,000 = 450 Kc/s.

There may, however, exist a signal of frequency 1,900 Kc/s, which, if not stopped by a signal filter, produces also 450 Kc/s, as 1,900 – 1,450 = 450 Kc/s.

Since a constant difference between signal and oscillator frequencies is required, and assuming that both oscillator and signal frequency filter-pass frequency are determined by the setting of variable capacitors operated by the same adjustment, either such capacitors must have different laws connecting setting and resulting capacitance values, or the circuits must be devised so that the resonance frequencies of the two circuits have a constant difference whatever the common angular setting of the two variable capacitors.

The latter expedient is usually adopted and a so-called 'padder' capacitor, of fixed value, is connected in the oscillator circuit, in series with the variable capacitor, so that the total capacitance of the two capacitors in series is largely determined by the variable capacitor when this has its smaller values, but is to a greater extent independent of the value of the variable capacitor, as this is larger.

If the oscillator frequency is greater than the signal frequency, this method of 'tracking' ensures the required filtration of the signal frequencies and the constant frequency difference between signal and oscillator frequencies.

Fig. 142a shows, on the right, a triode oscillator which injects the local oscillator voltage (frequency determined by C_1) into the cathode circuit of a tetrode, the signal voltages being 'tuned in' with C_2. The tetrode valve takes the added voltages and rectifies them to produce the IF selected by the tuned circuit in the anode of the detector.

Fig. 142b economizes a valve, because the tetrode itself generates the local oscillation (frequency determined by C_1) as well as detecting the result of adding the voltages.

The Hexode, as used in the circuit of Fig. 143, is an early example of the modulation method. The triode on the right sets up voltages in the local oscillator circuit (frequency determined by C_1), which are applied to the (screened) electrode of the hexode, while the signals (tuned in by C_2) are applied to the grid of the hexode, the anode to cathode current being modulated by the amplitudes of oscillator and signal voltages, the IF being selected by the anode circuit filter. C_3 is the padding capacitor.

The Heptode (called Pentagrid in the U.S.A.) of Fig. 144 dispenses with the separate triode oscillator of Fig. 143, an oscillator circuit being formed between inner grid and the next grid, the latter being treated as an anode; C_1 and R_1 acting as a grid leak.

The signal is applied to a screened electrode as shown, and the resulting modulations produce the IF selected in the anode filter tuned to the IF frequency.

A so-called *virtual cathode* is formed in frequency changers of this type, which is a surface in the space-charge where the electric field is zero and the potential more negative than on either side of it, and which, by reason of high space-charge density, behaves as a source of electrons.

This virtual cathode acts as a cathode for the signal frequency amplifier, which is, in effect, formed by those electrodes not used for the oscillator portion of the valve, and forms the equivalent of a screen-grid valve.

C_1 and R_1 in Fig. 144 provide automatic bias for the oscillator section (i.e. a grid leak). R_2 and C_2 form a de-coupling means for the oscillator and C_3 is the tracking or padding capacitor.

Octode. This is similar to the heptode, but has an extra screen grid corresponding to the earth (or cathode connected) electrode in a pentode.

Triode-Pentode (Fig. 145). In this form of frequency changer the oscillator portion is separated. The principle is much the same and the difference is largely constructional.

External cathode or internal injection of the oscillator voltage may be employed, as shown in Figs. 145a and 145b respectively.

Triode-Hexode (Fig. 146) is another variant on the schemes hitherto described, the portion of the valve where multiplication of voltages is obtained being a hexode. In Fig. 147 the circuit shown is suitable when the signals have very high frequencies (short-wave band).

Obviously, some amplification is given in all the methods described; in other words, the voltage across the IF filter may be greater than the voltage applied by the signal to any given electrode. Thus, *conversion gain* is the ratio of the intermediate frequency voltage to the signal frequency voltage.

A term, *conversion conductance*, is also used to describe the ratio, in a frequency changing device, of a specified component, of single frequency, of the short-circuit output current to the applied sinusoidal input voltage (of a different frequency) to which the output current is due.

Conversion conductance in a frequency converter has much the same significance as mutual conductance in a valve used to amplify currents of one frequency.

AMPLIFICATION

Strictly speaking, all valve amplifiers amplify power because the anode circuit impedance, essential to secure amplification, must be partly resistive.

The term *voltage amplifier*, however, may be used when the function of the amplifier is to give as large a voltage output as is possible for a given harmonic content, and the term *power amplifier* for one which gives as large a power output as is possible for a given harmonic content. Intermediate conditions apply, so there is no hard-and-fast distinction between the two types of amplification.

Fig. 148 shows a single-valve amplifier. Considering the valve as a source having an internal impedance R_A and an EMF μE_g, μ being the amplification factor of the valve, a voltage E being developed across the load resistance, then,

$$\frac{E}{\mu E_g} = \frac{R_L}{R_A + R_L}, \text{ or}$$

$$\text{Voltage gain} = \frac{\mu R_L}{R_A + R_L}$$

$$= g_m \frac{R_A R_L}{R_A + R_L},$$

where $g_m = \dfrac{\mu}{R_A}$ is the mutual conductance of the valve.

The power output is, $\dfrac{\mu^2 E_g{}^2 R_L}{(R_A + R_L)^2}$, a limit being set to the value of E_g by the increasing harmonic distortion as E_g is increased beyond a given value.

With a certain HT voltage, R_L cannot be increased indefinitely without lowering the anode volts and so reducing g_m (i.e. increasing R_A). The HT voltage cannot be increased beyond certain limits for fear of too large voltages damaging the valve.

Fig. 149 differs only from Fig. 148 in that the anode impedance in Fig. 149 is a tuned circuit. If the grid-cathode voltages (which are the same as the grid-earth voltages if the cathode bias capacitor has negligible reactance at the relevant frequencies) are equal to the resonance frequency of the tuned circuit, the voltage amplification is, $\dfrac{\mu R_D}{R_A + R_D}$, where R_D is the resistive impedance of the tuned circuit at resonance, i.e. $R_D = \dfrac{L}{CR_0} = \omega_0 L Q_0 = \dfrac{\omega_0{}^2 L^2}{R_0}$, where L and C are the values of the inductor and capacitor respectively which form the parallel tuned circuit, R_0 is the high-frequency resistance of the inductor, while $\omega_0 = 2\pi f_0$, where f_0 is the resonance frequency and $Q_0 = \dfrac{\omega_0 L}{R_1}$.

If $R_D \gg R_A$ (the inductor having a large value and a large Q value), then the amplification of the circuit of Fig. 149 is approximately μ. If $R_D \ll R_A$, then the amplification is approximately $g_m R_D$, where g_m is the mutual conductance of the valve.

The input capacitance of the valve (a highly important factor in high-frequency amplification) is, $C_C = C_G + (A + 1)\, C_A$, where C_C is the input, C_G the grid to cathode and C_A the grid to anode capacitance, A being the stage gain. The larger is A, the greater is C_C, the percentage increase depending upon the ratio C_A to C_G.

The selectivity of the amplifier, measured as the variation of the grid input volts with the consequent variation of anode volts for small changes of frequency, $\Delta f = \dfrac{\Delta\omega}{2\pi}$, which small frequencies are added to or subtracted from the resonance frequency, namely, $f_0 = \dfrac{\omega_0}{2\pi}$, is given by,

$$\frac{1}{1 + \dfrac{R_A}{\omega_0 L}\left\{\dfrac{1}{Q_0} + j\dfrac{2\Delta\omega}{\omega_0}\right\}},$$

showing that for maximum selectivity R_A should be $\gg \omega_0 L$, and $Q_0 = \dfrac{\omega_0 L}{R_0}$ should be as great as possible.

Transformer coupling is used in the two-valve amplifier of Fig. 150a, and the effective anode impedance $\omega_0 L$ can be increased or decreased as desired by making the turns ratio L_C to L greater or smaller respectively, and so, with a constant R_A, reducing or increasing selectivity.

In Fig. 150b a band-pass filter circuit is used. The characteristics of this filter have already been discussed (see Tuned Circuits).

Multi-valve Amplifiers. Fig. 150a and Fig. 150b are representative of multi-valve high-frequency amplifiers (used, for instance, in the IF stages of a super-heterodyne receiver), while Figs. 151 to 154 inclusive are typically used for audio-frequency voltage amplification before the output or power stage.

Fig. 151 is a resistance-capacitance type of amplifier, the amplified voltage on the anode of the first valve being passed to the grid of the second, the HT voltage being blocked off from this grid by a capacitor C_1.

If the first valve is a triode, then R_1 should be as large as is permissible for the operation of the second valve. R_2 should be several times greater than the R_A of the first valve, but should not exceed a quarter of R_1.

R_3 should be selected to give the required bias voltage, a good guide to a suitable value being to make $R_3 = \frac{R_1}{\mu}$.

There are innumerable factors which alter the choice of values, and the above values are to be considered more as generalizations applying to typical conditions than rigid requirements.

If the valve is a pentode, then, owing to the very large value of R_A, shunting capacitance, caused mainly by the grid capacitance of the second valve, may appreciably affect stage gain at the higher frequencies, if R_2 is increased beyond a certain value.

For general use, R_2 is typically 250,000 ohms. If $R_2 = 100{,}000$ ohms, there will be of the order 2 dB loss at 25 Kc/s; if $R_2 = 250{,}000$ ohms, this loss will occur at 10 Kc/s, and if 500,000 ohms, at 5 Kc/s. R_1 should be not less than twice R_2.

Both for triodes and pentodes, low-note response is reduced if the cathode capacitor is of too high a reactance at low frequencies.

Electrolytic capacitors having values of the order 100 μF, and a reactance at 50 c/s of the order 30 ohms, may be used if low-frequency response down to very low values of frequency is required.

The intervalve transformer connection of Fig. 152 is valuable if, for any reason, the high-tension voltage is limited (e.g. in battery-operated receivers, where the bulk weight and renewal cost of batteries demand that the HT voltage shall be the least possible).

One disadvantage of the connection is that it is not altogether easy to design transformers to give substantially equal response over a wide band of frequencies, particularly when the steady anode current flowing in a winding magnetizes the core.

This is probably not a grave disadvantage in the cheaper types of receiver, where a compromise result is purchased for a low price.

Parallel Feed

Transformer core saturation is avoided in the connection shown in Fig. 153, but no economy of high-tension voltage is secured by it.

In all cases where a reactor forms part of the anode circuit, and when it is required to have substantially equal response from, say, 50 c/s to 10,000 c/s, then the primary inductance of the transformer must be very large.

The limitations of winding space and mechanical construction generally make it impossible to increase the secondary inductance beyond a certain value. Thus, while it is true that the voltage gain of a stage using an intervalve transformer is equal to the voltage gain of the valve times the step-up (primary to secondary) ratio of the transformer, the latter must approach unity, as the demands for equal response over a wide frequency range are greater.

Even though the transformer secondary 'looks' into the grid cathode impedance of the following stage, which may be a very high capacitive impedance, nevertheless this, added to the self-capacitance of the transformer secondary, and considered in relation to the enhanced R_A of the valve at the secondary, causes some considerable falling away of response at the higher frequencies.

An auto-transformer connection is shown in Fig. 154; it presents no particular advantages and the general observations made in the foregoing apply, if not exactly, at least in degree.

OUTPUT STAGE

Quite different considerations apply when considering the valve as a means to supply power, with reasonable efficiency, to a load such as a loudspeaker (Fig. 155a).

Provided the grid-cathode voltage does not exceed a value at which tolerable distortion exists in the output, the stages preceding the power (or output) stage exist to give the greatest possible voltage magnification consistent with a low distortion factor. The output stage must be designed for maximum power output and a given value of distortion.

Class A Operation. In so-called Class A valve-operation the anode current flows at all times during the entire electrical cycle; this condition is illustrated in Fig. 155b for a circuit such as that of Fig. 155a, the former figure (of the dynamic characteristic curve of anode current against grid volts) showing that the steady grid bias is symmetrical with respect to the total grid swing.

The dynamic characteristic is one

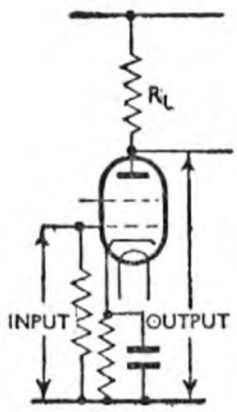


Fig. 148

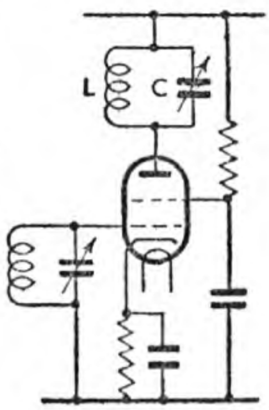


Fig. 149

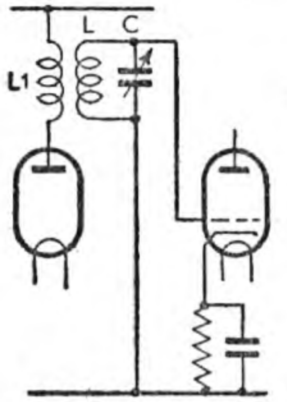


Fig. 150 (a)

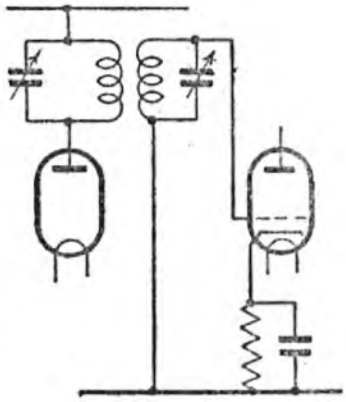


Fig. 150 (b)

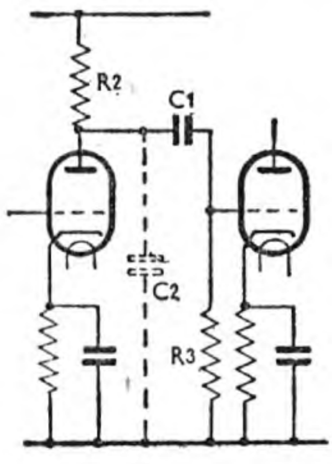


Fig. 151

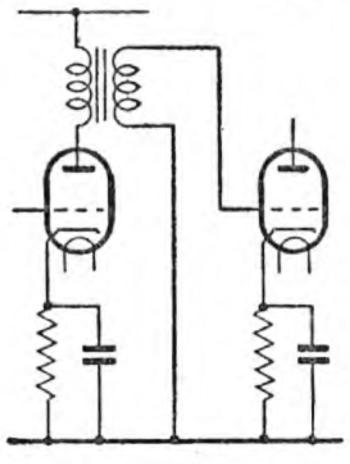


Fig. 152

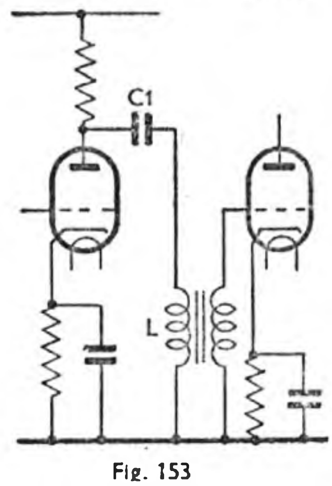


Fig. 153

BASIC VALVE COUPLING CIRCUITS FOR HF AND LF

Fig. 148. Essentials of a valve amplifier stage with automatic bias. **Fig. 149.** Development of Fig. 148 with tuned circuits as anode and grid loads. **Fig. 150.** Two forms of HF intervalve coupling. (a) Single tuned transformer and (b) transformer with both primary and secondary tuned. **Fig. 151.** Resistance-capacitance intervalve coupling; stray capacitance C_2 prevents HF use. **Fig. 152.** Audio-frequency transformer intervalve coupling. **Fig. 153.** Parallel-fed transformer coupling.

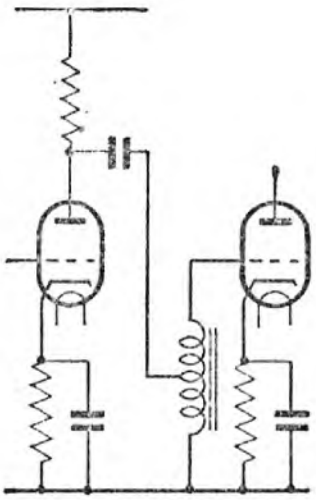


Fig. 154

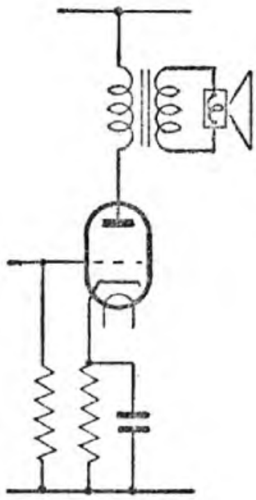


Fig. 155 (a)

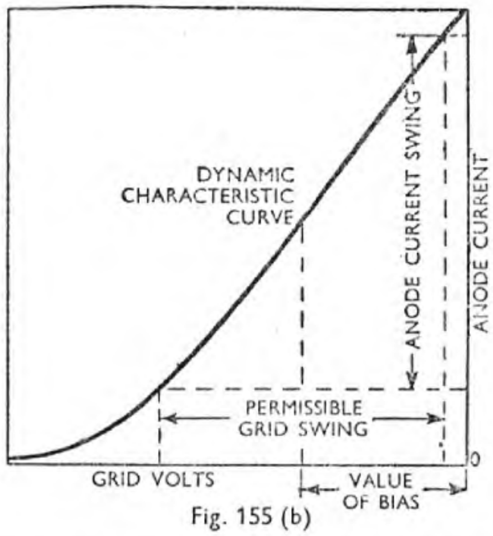


Fig. 155 (b)

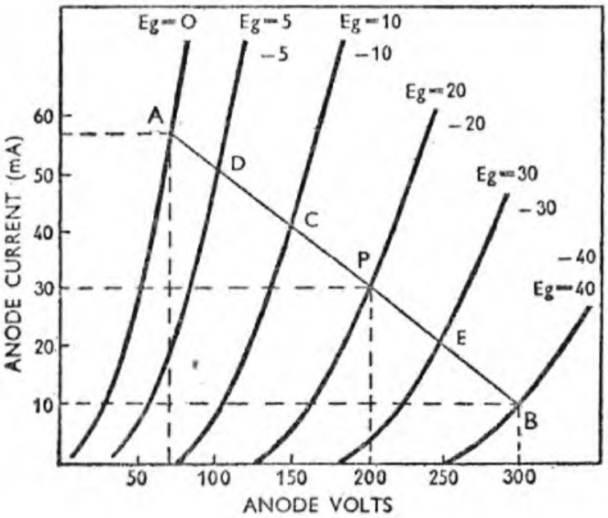


Fig. 156 (a)

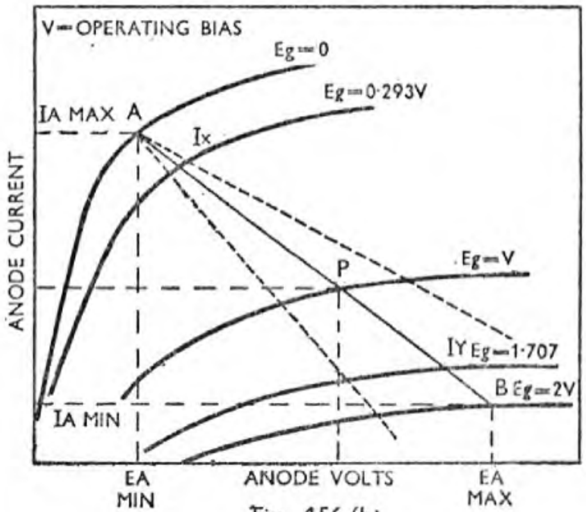


Fig. 156 (b)

COUPLING CIRCUITS AND OUTPUT VALVE LOADING

Fig. 154. Parallel-fed auto-transformer coupling. **Fig. 155.** (a) Output stage delivers power to loudspeaker through a matching transformer. (b) In Class A operation, a valve is biased to the centre of the straight part of its characteristic. **Fig. 156.** To get maximum power with minimum distortion, an optimum value of load is necessary. These are load curves for (a) a triode and (b) a pentode.

representing the relationship between grid volts and anode current where an impedance of a resistive nature but not necessarily a resistor is connected in the anode circuit.

The permissible grid swing is that over which the relationship between grid volts and anode current is linear, or substantially so, so that harmonic distortion is minimized.

A valve, as has been previously shown, may be considered for many practical cases as a source of power containing an EMF μE_g and an internal resistance R_A and, therefore (see Matching), the maximum power is delivered to a load of resistance R_L when $R_L = R_A$.

Since the maximum power output is $\frac{\mu^2 E_g{}^2 R_L}{(R_L + R_A)}$, therefore, when $R_L = R_A$, it is $\frac{\mu^2 E_g{}^2}{4R_A} = \frac{g_m{}^2 R_A E_g}{4}$.

As μ is increased, so the maximum value of E_g, to avoid distortion, is decreased, so that it cannot be said that a valve with a larger value of μ gives a greater power output; each case must be studied in detail and particularly with reference to the amount of distortion which appears under any given set of conditions.

In the foregoing, the case was considered in which R_L was made equal to R_A. It is possible to achieve this condition in a triode but not with a pentode, because R_A, in this latter case, is so large. But even with a triode the distortion when $R_L = R_A$ may be considerably greater than when $R_L > R_A$. Thus, efficiency must be sacrificed for the sake of reducing distortion. In some cases in which feed-back is used, the load may be matched to effective R_A of valve.

A graphical method for determining a maximum undistorted power output can be explained in terms of Fig. 156a and Fig. 156b, the former for a triode and the latter for a pentode-type valve.

The several graphs shown plot anode current against anode volts for different values of grid bias. The point *P* in Fig. 156a gives the steady anode current (30 mA) for a steady anode voltage (200 volts) with a fixed grid bias (– 20 volts).

If the grid volts be periodically varied from – 20 to zero, then from zero to – 20, then from – 20 to – 40, and back to zero again, the relationship between anode volts and anode current is given by the points on the line *AB*.

The (negative) slope of this line is in the nature of a resistance (voltage divided by current), and this resistance is the anode impedance assumed resistive.

Thus in Fig. 156a the resistance represented by the slope of the curve is of the order 300–75 volts divided by 58–10 mA, or 225 divided by 48 mA; approximately 4,800 ohms. Therefore, with 4,800 ohms resistive impedance in the anode circuit, the relationship between grid volts (assumed to vary sinusoidally) and anode current (which should also vary in a like manner if no distortion is to exist) is given in Fig. 156a.

Unless *PC* = *PE*, or, for larger grid excursions, *PD* = *PB*, some distortion must exist. A common specification for minimum tolerable distortion is that such intercepts as *PC* and *PE*, or *PD* and *PB*, shall not differ in length by more than 5 per cent.

The line *APB* is found, centred upon a point such as *P* until the required near equality of intercept is obtained, the resulting slope giving the optimum resistive impedance R_L. If R_L is reactive, the 'load line' becomes ellipsoidal in shape.

The power is given by,

$$\frac{(I_{A\max} - I_{A\min}) \times (E_{A\max} - E_{A\min})}{8}.$$

$I_{A\ \max}$, $E_{A\ \max}$, $E_{A\ \min}$, and $I_{A\ \min}$ being the maxima and minima of currents and voltages for the required distortion.

The divisor 8 comes from dividing the total excursion of current by 2 and of voltage by 2, giving a divisor 4, and then introducing $\sqrt{2} \times \sqrt{2}$; to bring peak values of current and voltage to R.M.S. values.

Anode Power and Efficiency. If the power output per given distortion be divided by the power dissipated at the anode of the valve, a figure for efficiency is arrived at. The power dissipated at the anode is $E_{HT} \times I_A$ in the steady condition (point *P* in Fig. 156a). A method for obtaining the output power has already been given.

In pentode valves this efficiency may be as high as 40 per cent; in triodes, with Class A operation, 25 per cent is a typical figure. Higher efficiencies are possible with different classes of valve operation, as will shortly be discussed.

In Fig. 156b the anode volt-anode current characteristics are typically applicable to pentode and beam power valves. The same considerations apply as for Fig. 156a. The dotted load lines show different values for R_L and different distortions.

A further point is brought out in Fig. 156b, namely, that if the maximum anode current be I_X and the minimum I_Y (corresponding to min. and max. values of grid swing), then the harmonic distortion may be calculated.

Per cent 2nd harmonic distortion =

$$\frac{I_{A\max} + I_{A\min} - 2I_A}{I_{A\max} - I_{A\min} + 1{\cdot}41\ (I_X - I_Y)} \times 100.$$

Per cent 3rd harmonic distortion =

$$\frac{I_{A\max} - I_{A\min} - 1{\cdot}41\ (I_X - I_Y)}{I_{A\max} - I_{A\min} + 1{\cdot}41\ (I_X - I_Y)} \times 100.$$

Per cent total 2nd + 3rd =

$$\sqrt{(\text{per cent 2nd})^2 + (\text{per cent 3rd})^2}.$$

In the above, I_X and I_Y are working minimum and maximum values of anode current and I_A is no-signal anode current.

Class A Parallel. Conditions with two similar valves in parallel (Fig. 157) are :

Anode current $= 2I_A$.
Anode dissipation $= 2I_A \times E_A$ watts.
Anode load $= \frac{1}{2}R_L$ for one valve.
Power output $= 2W_o$.

Balanced Valve Operation, commonly known as *push-pull*, is shown in Fig. 158. One advantage of balanced valve operation is that, the grid voltages being 180° out of phase, so are the anode voltages, so that the second, fourth, sixth, etc., harmonics, which may be produced in the valves individually, are greatly reduced when the valves are used together in the balanced connection, because the even number harmonics are in phase and so tend to cancel.

There is no need to connect a capacitor across the common cathode bias resistance, since no component of the fundamental component of the AC flows in it.

A further advantage of the push-pull circuit is that the net ampere turns of the primary winding of a transformer, such as T in Fig. 158, due to the anode currents in the two valves, is zero and so the core is not magnetized as when the unbalanced connection is used.

Class B Operation is achieved when the grid-bias voltage is approximately equal to the cut-off value, so that the anode current is approximately zero when no alternating grid voltage is applied, and so that anode current flows for approximately half of each cycle when an alternating grid voltage is applied.

Serious distortion in audio-frequency amplification would arise if only one valve were used, but this is largely eliminated by Class B operation with a balanced valve operation.

Fig. 159 shows how each valve contributes a half-cycle to the total wave form of resulting current, the sum of the effects being a sinusoid, or approximately so.

The advantage of the connection lies chiefly in the high efficiency obtainable, that is to say, the ratio of AC power output to DC power input is high.

$$\text{Efficiency} = \frac{\cdot 5\ I_{AX} \times E_{AO}}{\left(\frac{2}{\pi}\right) I_{AX} \times E_{AO}} \times 100,$$

where I_{AX} is peak anode current and E_{AO} the operating anode voltage. In practice, efficiency may approach 75 per cent.

Class AB Operation is a variant on Class B operation, distinguished by the condition that the anode current flows for less than the entire electrical cycle but for appreciably more than half the cycle.

Balanced valve operation is as essential in Class AB as in Class B operation for audio-frequency amplification. The efficiency is not so great as in Class B operation, but the maximum power output per given distortion, suitable valves being used, is greater than with Class B.

Positive Drive Operation. This type of operation, where again balanced operation must be employed, is characterized by working the valves in conditions in which the grid becomes, over part or the whole of the cycle of operation of each valve, more positive than the cathode, so that grid current flows between grid and cathode.

This current constitutes a load upon the valve supplying the grid voltage and so the internal impedance of this valve (or these valves) must

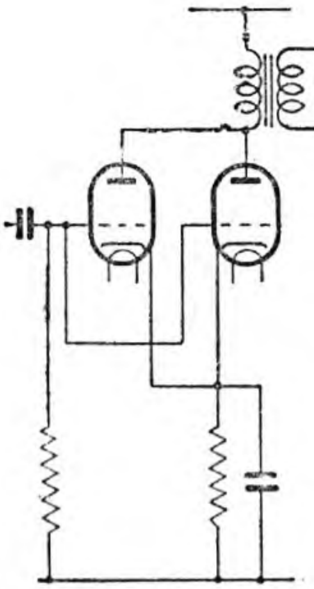


Fig. 157

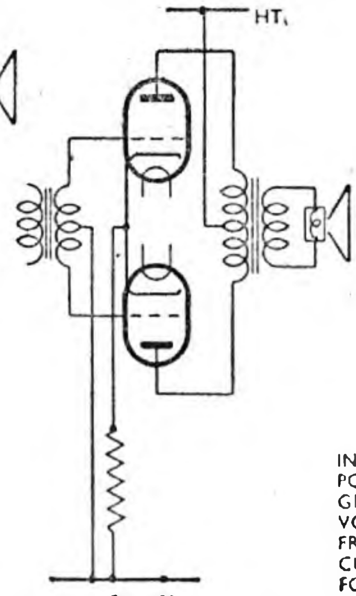


Fig. 158

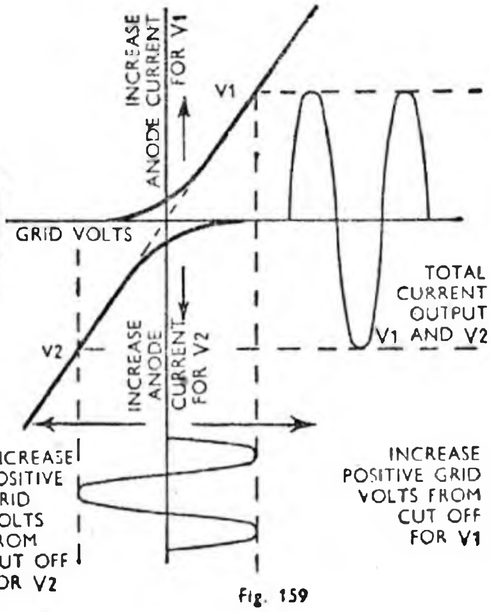


Fig. 159

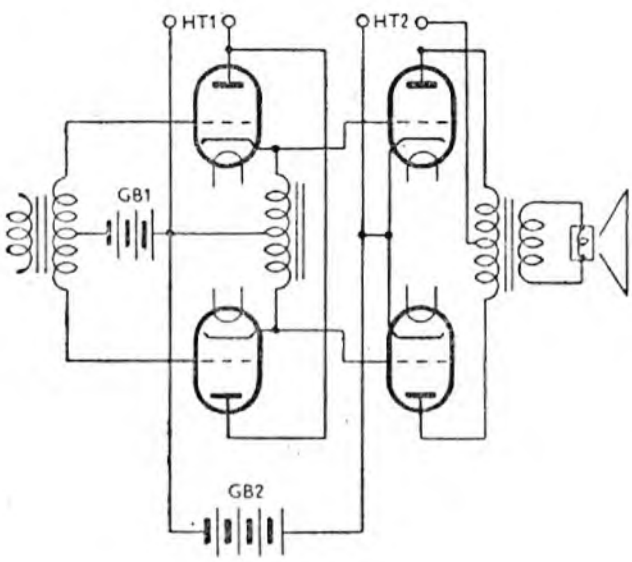


Fig. 160

Fig. 157. Output valves connected in parallel. **Fig. 158.** Transformer-fed push-pull output stage. **Fig. 159.** Graphical representation of push-pull operation. **Fig. 160.** Push-pull stage cathode-coupled to a push-pull output stage. **Fig. 161.** RC coupling to push-pull output using paraphase stages. **Fig. 162.** Two methods of connecting a 'phase splitter' valve when using resistance-capacitance coupling to push-pull valves.

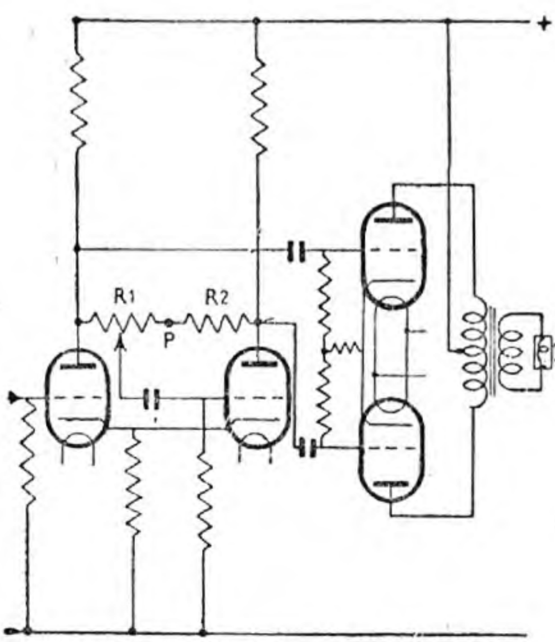


Fig. 161

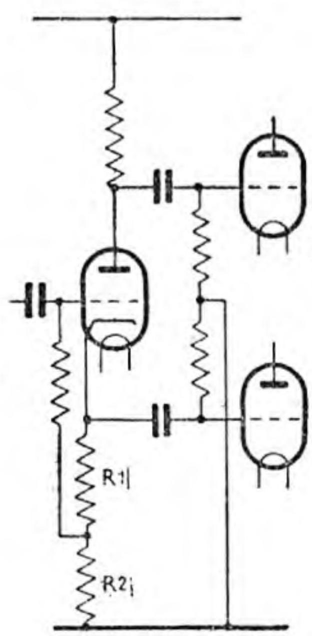


Fig. 162 (a)

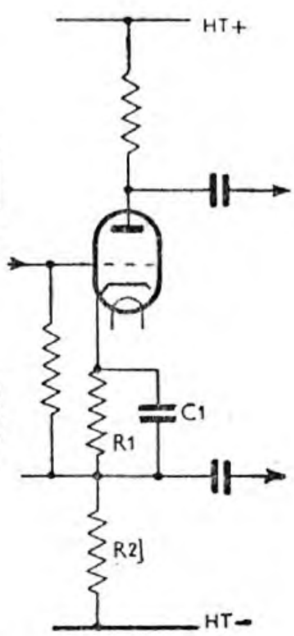


Fig. 162 (b)

be so low that the voltage output from it (or them) is not affected by the load. This implies considerable power output from the so-called 'driver' stage.

In order to distinguish the various classes of valve operation, the suffix 1 is added to the letter or letters of the class identification when grid current does not flow, while the suffix 2 may be used to denote that grid current flows during some part of the cycle.

Thus, Class AB_1 is Class AB operation when no grid current flows and Class AB_2 indicates that positive drive is used.

Fig. 160 shows a circuit for Class AB_2 operation in which a cathode-follower circuit (magnification < 1) is used to secure a low impedance drive stage capable of giving the required power to produce grid current in the driven stage without affecting the input voltage wave form from the driver stage.

Paraphase Connection. This connection secures balanced valve operation without the use of an input transformer to supply the grids of the output stage with voltages 180° out of phase, and has the advantage of resistance capacitance coupling.

Imagine the system working and the valves V_1 and V_2 of Fig. 161 to have anode voltage 180° out of phase and of equal magnitude. If the two resistors R_1 and R_2 are equal, P is a point of zero alternating potential.

A tapping on R_1 will have a positive potential if the grid of the valve V_1 is negative, so the grid of the valve V_2 will be positive when the grid of the valve V_1 is negative, and vice versa. Thus the voltages passed to the output stage are 180° out of phase.

The value of the arrangement is its tendency to maintain balance. If the amplification of V_2 falls relative to V_1, the tapping point on R_1 has a higher potential than in the balanced condition and so increases the voltage on the anode of V_2, thus restoring, or tending to restore, balance; on the other hand, the rising amplification of V_2 relatively to V_1 reduces the potential of the tapping point and so the self-balancing action is symmetrical for any relative change of amplification of V_1 and V_2.

Phase Inverter, Phase Splitter (Figs. 162a and 162b). If the anode load is divided between anode and cathode circuits, two output voltages, 180° out of phase, can be tapped off to feed a push-pull output stage.

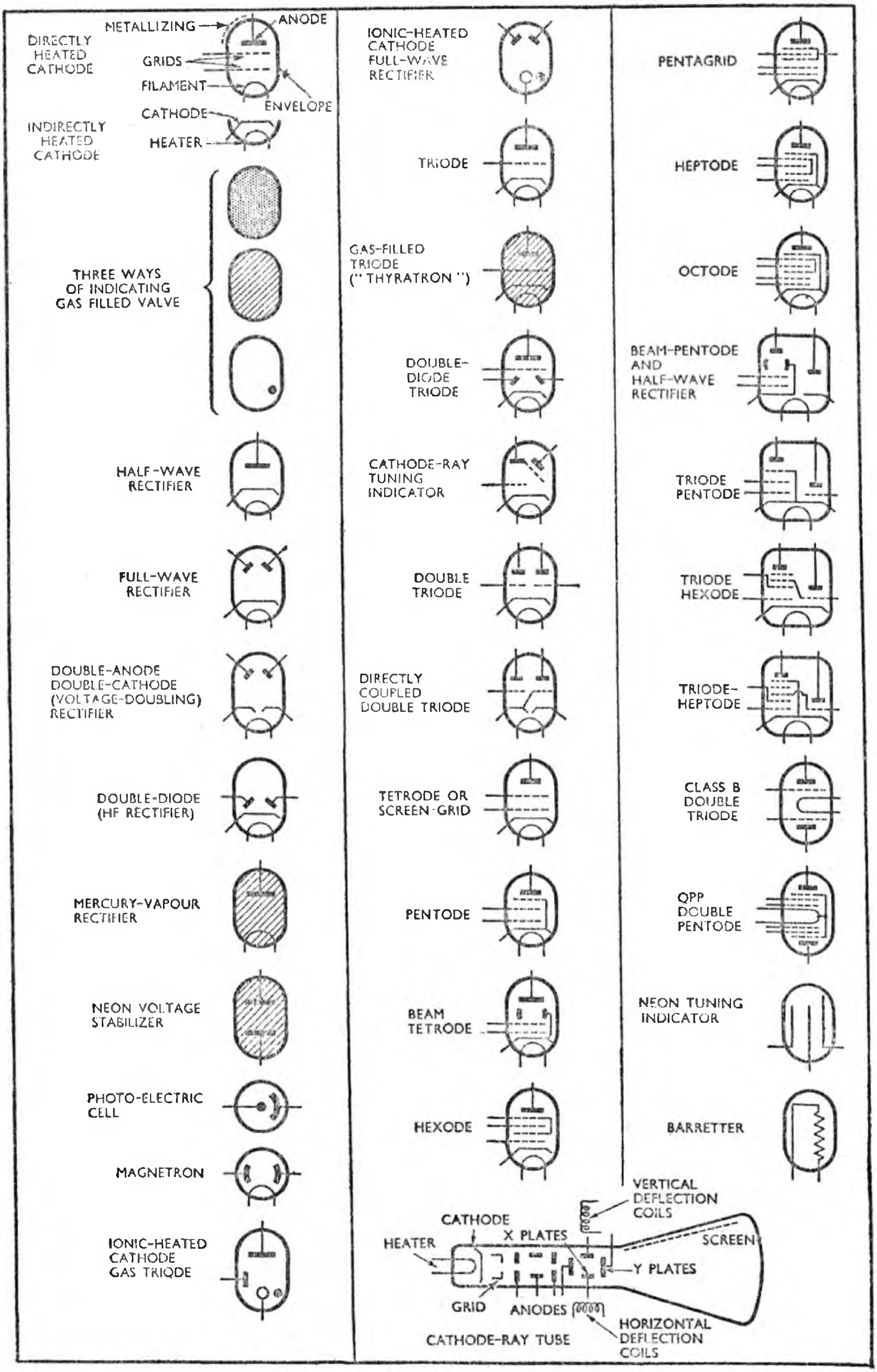
In Fig. 162a, R_1 and R_2 together equal half the anode load. The valve is biased by the drop across R_1. As the signal from the previous stage is developed between grid and chassis, the amplified signal across $R_1 - R_2$ exists in the grid circuit as negative feed-back and the effective stage gain is less than unity.

In Fig. 162b means are found to introduce the signal from two points, neither of which is connected to chassis. Negative feed-back is introduced only by R_1. If R_2 is equal to half the anode load, R_1 can be decoupled by C_1, thus preventing feed-back and loss of stage gain.

Cathode Follower. Included in Fig. 160 is a feature that is becoming more common in amplifier circuits and in certain stages of television receivers. It will be seen that the output of a valve is taken, not from a load in the anode circuit, but from a load in the cathode circuit. Since the cathode load is also in the grid circuit, there is negative feed-back and the output voltage is actually less than the input voltage to the grid.

The advantages of the cathode follower circuit are low 'internal generator' impedance presented to the output load, high input impedance, great stability, and low distortion.

As explained regarding Fig. 160, it is also adaptable to driver stages.


DIRECTLY HEATED CATHODE
METALLIZING
ANODE
GRIDS
FILAMENT
ENVELOPE
CATHODE
INDIRECTLY HEATED CATHODE
HEATER
THREE WAYS OF INDICATING GAS FILLED VALVE
HALF-WAVE RECTIFIER
FULL-WAVE RECTIFIER
DOUBLE-ANODE DOUBLE-CATHODE (VOLTAGE-DOUBLING) RECTIFIER
DOUBLE-DIODE (HF RECTIFIER)
MERCURY-VAPOUR RECTIFIER
NEON VOLTAGE STABILIZER
PHOTO-ELECTRIC CELL
MAGNETRON
IONIC-HEATED CATHODE GAS TRIODE
IONIC-HEATED CATHODE FULL-WAVE RECTIFIER
TRIODE
GAS-FILLED TRIODE ("THYRATRON")
DOUBLE-DIODE TRIODE
CATHODE-RAY TUNING INDICATOR
DOUBLE TRIODE
DIRECTLY COUPLED DOUBLE TRIODE
TETRODE OR SCREEN-GRID
PENTODE
BEAM TETRODE
HEXODE
PENTAGRID
HEPTODE
OCTODE
BEAM-PENTODE AND HALF-WAVE RECTIFIER
TRIODE PENTODE
TRIODE HEXODE
TRIODE-HEPTODE
CLASS B DOUBLE TRIODE
QPP DOUBLE PENTODE
NEON TUNING INDICATOR
BARRETTER
VERTICAL DEFLECTION COILS
CATHODE
X PLATES
HEATER
SCREEN
Y PLATES
GRID
ANODES
HORIZONTAL DEFLECTION COILS
CATHODE-RAY TUBE

VALVE CHARACTERISTICS AND BASE CONNECTIONS

VALVE Characteristic Tables on the following pages are for technical reference, and have been made as complete as possible. **They must not be taken as a guide to what types are available from the manufacturers.** Many types, although still in use in thousands of sets, are no longer being made. Alternatives can be chosen from a study of the characteristics, and of the bases.

The tables are subdivided into frequency changers, triodes, etc., and these appear approximately in the order in which they are used in receivers.

Order of Presentation

Battery valves are listed first. Then follow AC types, AC-DC types, and, finally, any special types. The appropriate base connection diagrams (pages 191-197) also serve to describe a valve.

Abbreviations in descriptions where these are not self-evident are: D, diode; DD, double-diode; S, screen-grid; VS, variable-mu screen-grid; P, HF pentode; VP variable-mu HF pentode; DDT, double-diode triode; DDP, double-diode LF pentode; Pen, LF pentode; DPen, diode pentode; DTetrode, diode LF tetrode; DT, diode triode.

Valve base diagrams are drawn to show the connections when looking at the base with the valve inverted.

In the tables the base used is indicated by a code reference contained in Base column. The first number and letter indicate the group of diagrams to which reference should be made, and the final number, the base diagram in that group. For example, 4B3 indicates that the valve has a 4-pin British base, and that the third diagram in the section shows the pin connections.

Basing diagram groups in addition to 4B are: 5B, meaning 5-pin British; 7B, 7-pin British; 9B, 9-pin British; 8S, British side contact; OM, Mazda Octal; O, International Octal; 7C, 7-pin Continental; OF, footless.

American Types

American valve manufacturers use a standard type-number code which makes separate lists of makes unnecessary.

The first figure in the code numbers indicates the heater voltage with the slight differences that 1 stands for 1·5 or 2 volts, 2 for 2·5 volts, and 6 or 7 for 6·3 volts.

The second number denotes the number of electrodes connected to the base, including the metallizing or metal shell, and counting the heater as one electrode.

The intervening letters differentiate between different types of valves with the same heater rating and the same number of electrodes connected to the base. As all the letters in the alphabet have been used, some valves now have two intervening letters, the first one of which is A. Another two-letter combination begins with the letter S, which denotes a single-ended octal type. Final letters are used to indicate other types of envelope, and special features. The 6J7G is a valve with similar characteristics to the 6J7, but with standard glass envelope; the 6J7GT is again the same, but with a small glass envelope. Some valves have a final E, indicating an English replacement type, while ML means a metal Loctal, and GL a glass Loctal.

Valve bases are indicated in the table by a code in which O means Octal, OL, Loctal, and UX, the earlier American pin-type connections; figure in front of letters UX indicates number of pins in the base.

TABLE XXVII: FREQUENCY CHANGERS

Make	Type	Description	Base	Fil. Volts	Fil. Amps	Anode Volts	Screen Volts	Oscillator Volts	Conv. Condct. Mhos	Bias Volts
BRIMAR ..	20A1	Triode Hexode	7B38	4·0	1·2	250	80	150	650	–1·5–30
	15A2	Heptode ..	7B35	4·0	0·65	250	100	200	550	–3–40
	15D1	Heptode ..	7B35	13·0	0·2	250	100	200	550	–3–40
	15D2	Heptode ..	7B35	13·0	0·15	250	100	200	550	–3–40
	20D2	Triode Hexode	7B39	13·0	0·15	250	100	100	350	–3–30
	6A8G	Heptode ..	—	6·3	0·3	250	100	200	550	–3–40
	6K8G	Triode Hexode	—	6·3	0·3	250	100	100	350	–3–30
COSSOR ..	210DG	Bigrid ..	5B1	2·0	0·1	150	—	—	190	0
	210PG	Pentagrid ..	7B7	2·0	0·1	150	80	150	450	0
	210SPG	Pentagrid ..	7B7	2·0	0·1	150	80	150	450	0
	210PGA	Pentagr d ..	7B7	2·0	0·1	150	80	150	450	0
	220TH	TriodeHeptode	7B11	2·0	0·2	150	150	100	200	0
	41MDG	Bigrid ..	5B16	4·0	1·0	200	—	—	150	0
	41MPG	Pentagrid ..	7B35	4·0	1·0	250	100	100	1,300	–1·5
	41STH	Triode Hexode	7B37	4·0	1·0	250	100	100	600	–1·5
	4THA	Triode Hexode	7B37	4·0	1·5	250	100	100	850	–2·0
	OM8	Octode ..	054	6·3	0·2	250	50	200	550	–2·0
	OM10	Triode Hexode	058	6·3	0·2	250	100	250	700	–2·0
	13PGA	Pentagrid ..	7B35	13·0	0·2	250	100	200	520	–3·0
	202MPG	Pentagrid ..	7B35	20·0	0·2	250	100	100	1,300	–1·5
	202STH	Triode Hexode	7B37	20·0	0·2	250	100	100	600	–1·5
	302THA	Triode Hexode	7B37	30·0	0·2	250	100	100	850	–2·0
	4TP	Triode Pentode	7B45	4·0	1·4	200	200	—	4,500	–5·0
DARIO ..	BK22	Octode ..	7B7	2·0	0·14	135	45	—	250	0–12
	BH12	Hexode ..	7B5	2·0	0·135	135	60	—	1,400	–1·5
	TK24	Octode ..	7B35	4·0	0·65	250	70	—	600	–1·5
	TCH24	Triode Hexode	7B37	4·0	1·45	250	100	—	—	–2·5–25
	TB5013	Octode ..	8S28	13·0	0·2	200	70	—	600	–1·5–25
	TCH229	Triode Hexode	7B37	21·0	0·2	200	70	—	1,200	–1·5
EVER READY	K80A	Octode ..	7B7	2·0	0·1	135	70	150	200	0
	K80B	Octode ..	7B8	2·0	0·13	135	45	135	270	–0·5
	A36A	Triode Hexode	7B37	4·0	1·0	250	70	—	1,000	–1·5
	A36C	TriodeHeptode	7B37	4·0	1·45	250	100	—	750	–2·5
	A80A	Octode ..	7B35	4·0	0·65	250	90	90	600	–1·5
	ECH3	Triode Hexode	8S29	6·3	0·2	250	100	—	650	–2·0
	ECH35	Triode Hexode	058	6·3	0·3	250	100	—	650	–2·0
	CCH35	Triode Hexode	058	6·3	0·2	250	100	—	650	–2·0
	C36A	Triode Hexode	7B37	21·0	0·2	250	70	—	1,000	–1·5
	C36C	TriodeHeptode	7B47	29·0	0·2	250	100	—	750	–2·5
	C80B	Octode ..	7B35	13·0	0·2	200	90	—	600	–1·5
	C36B	Triode Hexode	7B37	29·0	0·2	200	150	100	1,000	–1·5
FERRANTI	VHT2A	Heptode ..	7B7	2·0	0·1	150	70	70	—	–1·5
	VHT4	Heptode ..	7B35	4·0	1·0	250	100	100	650	–3·0
	VHTA	Heptode ..	7B35	13·0	0·2	250	100	100	—	—
	VHTS	Heptode ..	7B35	13·0	0·3	250	100	100	650	–3·0
HIVAC ..	TP230	Triode Hexode	9B2	2·0	0·3	150	70	150	325	0–12
MARCONI	X14	Heptode ..	010	1·4	0·05	90	45	90	250	0
	X21	Heptode ..	7B9	2·0	0·1	150	70	70	240	—
	X22	Heptode	7B9	2·0	0·15	150	70	110	350	0
	X23	Triode Hexode	7B9	2·0	0·3	150	60	100	250	–1·5
	X24	Triode Hexode	7B9	2·0	0·2	150	60	100	250	–1·5
	MX40	Heptode ..	7B35	4·0	1·0	250	100	150	500	–3
	X42	Heptode ..	7B35	4·0	0·6	250	100	150	490	–3
	X41	Triode Hexode	7B35	4·0	1·2	250	80	120	640	–1·5
	X41C	Triode Hexode	7B35	4·0	1·2	250	80	120	640	–1·5
	X61M	Triode Hexode	058	6·3	0·3	250	100	200	620	–3·0
	X63	Heptode ..	058	6·3	0·3	250	100	200	490	–3·0
	X64	Hexode ..	058	6·3	0·3	250	150	—	310	–6·0
	X65	Triode Hexode	058	6·3	0·3	250	100	150	225	–3·0
	X30/32	Heptode ..	7B35	13·0	0·3	250	80	150	800	–3·0
	X31	Triode Hexode	7B35	13·0	0·3	250	80	150	640	–3·0
MAZDA ..	FC141	Pentagrid ..	0M8	1·4	0·05	90	90	—	250	0
	TP22	Triode Pentode	9B2	2·0	0·25	150	150	150	500	–19·5
	TP23	Triode Pentode	7B10	2·0	0·25	150	150	150	400	–1·5
	TP25	Triode Pentode	0M5	2·0	0·2	150	150	150	225	–1·5
	TP26	Triode Pentode	0M5	2·0	0·2	150	150	150	550	—
	ACTP	Triode Pentode	9B5	4·0	1·25	250	250	200	700	–5
	ACTH1	Triode Hexode	7B38	4·0	1·3	250	250	250	750	–3
	ACTH1A	Triode Hexode	0M26	4·0	1·3	250	250	150	870	–3
	TH41	Triode Hexode	0M26	4·0	1·3	250	250	150	870	–3
	TP1340	Triode Pentode	9B5	13·0	0·4	250	250	200	700	–5
	TH2320	Triode Hexode	7B38	23·0	0·2	250	250	150	750	–3·0
	TH2321	Triode Hexode	7B38	23·0	0·2	250	250	150	640	–3

TABLE XXVII: FREQUENCY CHANGERS—*continued*

Make	Type	Description	Base	Fil. Volts	Fil. Amps	Anode Volts	Screen Volts	Oscil-lator Volts	Conv. Condct. Mhos	Bias Volts
MAZDA—*continued*	TH233	Triode Hexode	0M26	23·0	0·2	250	250	150	640	–3
	TP2620	Triode Pentode	9B5	26·0	0·2	250	250	200	650	–5
MULLARD	DK1	Heptode ..	8S10	1·4	0·05	90	90	45	250	0
	TH2	Triode Hexode	7B10	2·0	0·23	135	60	—	430	–5·0
	FC2	Octode ..	7B8	2·0	0·1	135	70	70	200	0
	FC2A	Octode ..	7B8	2·0	0·13	135	45	45	270	–0·5
	TH4	Triode Hexode	7B37	4·0	1·0	250	70	—	1,000	–1·5
	TH4A	Triode Hexode	7B37	4·0	1·45	250	100	100	750	–2·0
	TH4B	TriodeHeptode	7B37	4·0	1·45	250	100	—	750	–2·5
	FC4	Octode ..	7B36	4·0	0·65	250	90	70	600	–1·5
	ECH3/33	Triode Hexode	8S29/058	6·3	0·2	250	100	—	650	–2·0
	ECH35	Triode Hexode	058	6·3	0·3	250	100	—	650	–2·0
	EK2	Octode ..	8S28	6·3	0·2	250	200	50	550	–2·0
	EK3	Octode ..	8S28	6·3	0·72	250	100	—	650	–2·5
	CCH35	Triode Hexode	058	7·0	0·2	250	100	—	650	–2·0
	FC13	Octode ..	8S28	13·0	0·2	200	90	70	600	–1·5
	FC13C	Octode ..	7B36	13·0	0·2	200	90	70	600	–1·5
	TH13C	Triode Hexode	7B37	13·0	0·31	250	70	130	1,000	–1·5
	TH21C	Triode Hexode	7B37	21·0	0·2	250	70	—	1,000	–1·5
	TH22C	Triode Hexode	7B37	29·0	0·2	250	150	100	—	—
	TH30C	Triode Heptode	7B38	29·0	0·2	250	100	—	750	–2·5
OSRAM ..	X14	Heptode ..	010	1·4	0·05	110	60	—	250	—
	X21	Heptode ..	7B9	2·0	0·1	150	70	—	240	—
	X22	Heptode ..	7B9	2·0	0·15	150	70	150	350	0
	X23	Triode Hexode	7B10	2·0	0·3	150	60	150	250	–1·5
	X24	Triode Hexode	7B10	2·0	0·2	150	60	150	350	–1·5
	MX40	Heptode ..	7B35	4·0	1·0	250	100	250	500	–3·0
	X41	Triode Hexode	7B37	4·0	1·2	250	70	250	640	–1·5
	X42	Heptode ..	7B35	4·0	0·6	250	100	—	490	—
	X73M	Heptode ..	058	6·0	0·16	250	80	250	500	–3·0
	X61M	Triode Hexode	058	6·3	0·3	250	100	—	620	—
	X62	Triode Hexode	058	6·3	1·27	250	120	250	1,750	–1·5
	X63	Heptode ..	054	6·3	0·3	250	100	250	490	–3·0
	X64	Hexode ..	035	6·3	0·3	250	150	—	310	–6·0
	X65	Triode Hexode	058	6·3	0·3	250	100	250	225	–3·0
	X30/32	Heptode ..	7B35	13·0	0·3	250	100	—	800	—
	X31	Triode Hexode	7B37	13·0	0·3	250	80	150	640	–1·5
	X71M	Triode Hexode	058	13·0	0·16	250	100	—	520	—
	X75	Triode Hexode	058	15·0	0·16	250	100	250	225	–3·0
RECORD ..	OC2	Octode ..	7B8	2·0	0·13	135	45	135	270	–1–12
	AC/OC4	Octode ..	7B37	4·0	0·65	250	70	90	700	–1·5–25
	AC/TH4	Triode Hexode	7B37	4·0	1·0	300	80	150	1,000	–1·5–25
	OC/13	Octode ..	7B36	13·0	0·2	200	70	90	600	–1·5–25
	OC/13L	Octode ..	8S28	13·0	0·2	200	70	90	600	–1·5–25
	TH/21DA	Triode Hexode	7B37	21·0	0·2	200	80	150	1,000	–1·5–25
TRIOTRON	O202	Octode ..	7B8	2·0	0·13	135	45	—	250	0–12
	O406	Octode ..	7B36	4·0	0·65	250	70	—	600	–1·5
	TH401	Triode Hexode	7B37	4·0	1·0	300	150	—	750	–2·0
	O1307	Octode	7B36	13·0	0·2	200	70	—	600	–1·5–25
TUNGSRAM	VX2	Hexode ..	7B5	2·0	0·135	135	60	—	300	–1
	V02/S	Octode ..	7B9/8S11	2·0	0·13	135	45	135	270	—
	TH4A/B	TriodeHeptode	7B38	4·0	1·5	275	100	100	750	–2·5
	TX4	Triode Hexode	7B37	4·0	1·0	250	80	150	1,000	–1·5
	V04/S	Octode ..	7B36/8S28	4·0	0·65	250	70	90	600	1·5–25
	V06S	Octode ..	8S28	6·3	0·2	250	50	200	450	–2–25
	VX6S	Hexode ..	8S29	6·3	0·2	250	150	—	350	–3–25
	6E89	Triode Hexode	058	6·3	0·3	250	100	150	650	–2
	6TH8G	Triode Hexode	058	6·3	0·6	250	100	150	1,000	–1·5–25
	ECH11	Triode Hexode	0F5	6·3	0·2	250	100	150	650	–2
	ECH2	TriodeHeptode	8S29	6·3	0·95	250	100	100	750	–2·5
	ECH3/33	Triode Hexode	8S29/058	6·3	0·2	250	100	150	650	–2
	ECH35	Triode Hexode	058	6·3	0·3	250	100	150	650	–2
	EK2	Octode ..	8S28	6·3	0·2	250	50	200	550	–2
	EK3	Octode ..	8S28	6·3	0·65	250	100	100	650	–2·5
	V013/S	Octode ..	7B36/8S28	13·0	0·2	250	70	90	600	1·5–25
	TX21	Triode Hexode	7B37	21·0	0·2	250	80	150	1,000	–1·5
	TH29/30	TriodeHeptode	7B38	29·0	0·2	275	100	100	750	–2·5
	MH1118	Heptode ..	7C4	10·0	0·18	250	100	200	520	–2·5

TABLE XXVIII: SCREEN-GRIDS

Make	Type	Description	Base	Fil. Volts	Fil. Amps	
BRIMAR ..	8A1	P	5B19/7B23	4·0	1·0	(1)
	9A1	VP	5B19/7B23	4·0	1·0	(2)
	8D2	P	7B30	13·0	0·2	(3)
	9D2	VP	7B30	13·0	0·2	(4)
	6J7G	P	—	6·3	0·3	(5)
	6K7G	VP	—	6·3	0·3	(6)
COSSOR ..	215SG	S	4B5	2·0	0·15	(7)
	220SG	S	4B5	2·0	0·2	(8)
	220VSG	VS	4B5	2·0	0·2	(9)
	220VS	VS	4B5	2·0	0·2	(10)
	210VPT	VP	4B8/7B4	2·0	0·1	(11)
	210VPA	VP	4B8/7B4	2·0	0·1	(12)
	210SPT	P	4B8/7B4	2·0	0·1	(13)
	220IPT	P	7B28	2·0	0·2	(14)
	MSG/HA	S	5B17	4·0	1·0	(15)
	41MSG	S	5B17	4·0	1·0	(16)
	MSG/LA	S	5B17	4·0	1·0	(17)
	MVSG	VS	5B17	4·0	1·0	(18)
	4TSP	P	7B23	4·0	1·0	(19)
	MS/PEN	P	5B19/7B23	4·0	1·0	(20)
	MS/PEN A	P	7B23	4·0	1·0	(21)
	MVS/PEN	VP	5B19/7B23	4·0	1·0	(22)
	MS/PEN B	P	7B26	4·0	1·0	(23)
	MVS/PEN B	VP	7B26	4·0	1·0	(24)
	OM5	P	047	6·3	0·2	(25)
	OM6	VP	047	6·3	0·2	(26)
	13VPA	VP	7B26	13·0	0·2	(27)
	13SPA	P	7B26	13·0	0·2	(28)
	DVSG	VS	5B17	16·0	0·25	(29)
	DS/PEN	P	5B19	16·0	0·25	(30)
	DVS/PEN	VP	5B19	16·0	0·25	(31)
	202VP	VP	7B23	20·0	0·2	(32)
	202VPB	VP	7B26	20·0	0·2	(33)
	202SPB	P	7B26	20·0	0·2	(34)
	4TPB	P	7B26	4·0	1·0	(35)
	41MPT	P	7B23	4·0	1·0	(36)
	42MPT	P	7B23	4·0	2·0	(37)
	42PTB	P	7B26	4·0	2·0	(38)
	41MTS	Split anode P	7B43	4·0	1·0	(39)
	4TSA	,,	7B44	4·0	1·0	(40)
	42SPT	P	7B23	4·0	2·0	(41)
DARIO ..	PF462	P	7B4	2·0	0·18	(42)
	PF472	VP	7B4	2·0	0·18	(43)
	TB622	S	4B5	2·0	0·18	(44)
	TB552	VS	4B5	2·0	0·15	(45)
	TE424	S	5B17	4·0	1·0	(46)
	TE524	S	5B17	4·0	1·0	(47)
	TE554	VS	5B17	4·0	1·0	(48)
	TE464	P	5B19/7B23	4·0	1·1	(49)
	TF44	P	7B26	4·0	0·65	(50)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Anode Volts	Screen Volts	Bias Volts	Anode Current (mA)	Screen Current (mA)	Bias Res. Ohms	Slope mA/V
(1)	200	80	−1·5	3·5	0·7	200	4·0
(2)	200	80	−1·5 −30	5·0	1·0	200	4·25
(3)	250	100	−3	2·0	0·5	1,000	1·25
(4)	250	125	−3 −40	10·5	2·6	200	1·65
(5)	250	100	−3	2·0	0·5	1,000	1·25
(6)	250	125	−3 −40	10·5	2·6	200	1·65
(7)	150	80	−1·0	1·25	—	—	1·1
(8)	150	80	−1·0	1·4	—	—	1·6
(9)	150	80	−2·5	2·25	—	—	1·6
(10)	150	80	−2·5	1·0	—	—	1·6
(11)	150	80	−1·5	2·9	7·5	—	1·1
(12)	150	150	−3·0	2·2	—	—	1·1
(13)	150	80	−1·5	1·2	—	—	1·3
(14)	150	80	−1·5	2·5	—	—	1·0
(15)	200	100	−1·5	2·1	—	600	2·0
(16)	200	80	−1·5	0·8	—	1,500	2·5
(17)	200	100	−1·5	5·2	—	250	3·75
(18)	200	100	−1·5	7·8	7·5	V	2·5
(19)	250	250	−3·0	12·0	—	—	8·0
(20)	200	100	−1·5	5·0	—	—	2·8
(21)	200	150	—	9·0	5·0	200	4·0
(22)	200	100	−1·5	4·3	—	V	2·2
(23)	200	100	−1·5	5·0	—	—	2·8
(24)	200	100	−1·5	4·3	—	V	2·2
(25)	250	100	−2·0	3–0	—	—	1·8
(26)	250	100	−2·5	6·0	—	V	2·2
(27)	200	100	−3·0	7·0	—	V	1·8
(28)	200	100	−3·0	2·3	—	—	1·25
(29)	200	100	−1·5	7·5	—	V	2·5
(30)	200	100	−1·5	4·7	—	—	2·3
(31)	200	100	−1·5	5·5	—	V	2·0
(32)	250	100	−1·5	4·3	—	V	2·2
(33)	250	100	−1·5	4·3	—	V	2·2
(34)	250	100	−1·5	4·8	—	—	2·8
(35)	250	250	−3·0	12·0	—	—	8·0
(36)	250	200	−1·5	12·0	—	—	4·8
(37)	250	250	−3·0	34·0	—	—	8·5
(38)	250	250	−3·0	34·0	—	—	8·5
(39)	250	100	—	—	—	—	—
(40)	250	100	—	—	—	—	—
(41)	500	250	−15	27·0	—	—	11·0
(42)	150	150	−0·5	3·0	—	—	1·85
(43)	150	150	−0·5 −16	2·5	—	—	1·7
(44)	150	90	−0·5	2·0	—	—	1·4
(45)	150	75	0–9	1·8	—	—	1·5
(46)	200	100	−1·3	1·5	—	—	0·9
(47)	200	100	−2·0	3·0	—	—	2·0
(48)	200	100	−1·5 −40	3·0	—	V	2·0
(49)	200	100	−2·0	3·0	—	—	2·3
(50)	250	250	−2·4	4·0	—	—	3·4

[*Continued on next page*

TABLE XXVIII: SCREEN-GRIDS

Make	Type	Description	Base	Fil. Volts	Fil. Amps	
DARIO—*cont.*	TE474	VP	5B19/7B23	4·0	1·1	(51)
	TE564	VP	5B19/7B23	4·0	1·2	(52)
	TF64	VP	7B26	4·0	0·65	(53)
	TF713	P	7B23	13·0	0·2	(54)
	TF313	VP	7B26	13·0	0·2	(55)
	TB5613	VP	7B26	13·0	0·2	(56)
	TB4620	P	5B19	20·0	0·18	(57)
	TB4720	VP	5B19	20·0	0·18	(58)
EKCO ..	VP41	VP	7B26	4·0	0·65	(59)
	VPU1	VP	7B26	13·0	0·2	(60)
EVER READY	K50M	VP	4B8/7B4	2·0	0·18	(61)
	K50N	VP	7B5	2·0	0·14	(62)
	K40B	S	4B5	2·0	0·18	(63)
	K40N	VS	4B5/7B4	2·0	0·18	(64)
	A40M	VS	5B17/7B23	4·0	1·0	(65)
	A50M	VP	5B19/7B23	4·0	1·0	(66)
	A50N	VP	5B19/7B23	4·0	1·2	(67)
	A50P	VP	7B26	4·0	0·65	(68)
	A50A	P	5B19/7B23	4·0	1·0	(69)
	A50B	P	7B26	4·0	1·65	(70)
	EF9/39	VP	8S24/04	6·3	0·2	(71)
	C50N	VP	7B26	13·0	0·2	(72)
	C50B	P	7B26	13·0	0·2	(73)
FERRANTI ..	VS2	VS	4B5	2·0	0·1	(74)
	VPT2	VP	7B4	2·0	0·15	(75)
	SPT4A	P	7B23	4·0	1·0	(76)
	VPT4	VP	5B19	4·0	1·0	(77)
	VPT4B	VP	7B23	4·0	1·0	(78)
	SPTS	P	7B23	13·0	0·3	(79)
	VPTS	VP	7B23	13·0	0·3	(80)
	VPTA	VP	7B23	13·0	0·2	(81)
	VPTSB	VP	7B23	13·0	0·3	(82)
HIVAC.. ..	XSG 1·5V	S	4D2	1·5	0·08	(83)
	XW 1·5V	P	5D1	1·5	0·08	(84)
	XSG 2·0V	S	4D2	2·0	0·08	(85)
	XVS 2·0V	VS	4D2	2·0	0·08	(86)
	XW 2·0V	P	5D1	2·0	0·08	(87)
	SG215	S	4B5	2·0	0·15	(88)
	SG220	S	4B5	2·0	0·2	(89)
	SG220SW	S	4B10	2·0	0·2	(90)
	VS215	VS	4B5	2·0	0·15	(91)
	HP215	P	4B5/7B4	2·0	0·15	(92)
	VP215	VP	4B5/7B4	2·0	0·15	(93)
	AC/SL	S	5B17	4·0	1·0	(94)
	AC/SH	S	5B17	4·0	1·0	(95)
	AC/VS	VS	5B17	4·0	1·0	(96)
	AC/VH	VS	5B17	4·0	1·0	(97)
	AC/HP	P	5B17/7B23	4·0	1·0	(98)
	AC/VP	VP	5B17/7B23	4·0	1·0	(99)
	VP13	VP	7B23	13·0	0·3	(100)
LISSEN ..	SG215	S	4B5	2·0	0·15	(101)
	SG2V	VS	4B5	2·0	0·15	(102)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Anode Volts	Screen Volts	Bias Volts	Anode Current (mA)	Screen Current (mA)	Bias Res. Ohms	Slope mA/V
(51)	250	100	−1·5 −30	4·5	—	V	2·3
(52)	200	100	−2·0 −22	4·25	—	V	2·5
(53)	250	250	−3·0 −45	11·5	—	V	—
(54)	200	100	−2·0	3·0	—	—	2·1
(55)	200	100	−3·0 −50	8·0	—	V	1·8
(56)	200	100	−2·0 −22	4·5	—	V	2·2
(57)	200	—	−2·0	3·0	—	—	2·2
(58)	200	—	−2·0 −50	4·0	—	V	2·0
(59)	250	250	−3·0 −40	12·0	4·5	180	3·5
(60)	250	250	−3·0 −40	12·0	4·5	180	3·5
(61)	135	135	0–7	3·0	—	V	1·5
(62)	135	60	−1·5	2·0	—	V	1·4
(63)	150	90	0	2·9	—	—	1·5
(64)	150	90	0–7	2·5	—	V	1·4
(65)	200	110	−1·5 −40	6·0	—	V	2·5
(66)	200	100	−2 −50	4·5	—	V	2·3
(67)	200	100	−2·0	4·25	—	V	2·5
(68)	250	250	−3·0	11·5	—	V	2·0
(69)	200	100	−2·0	3·0	—	—	2·3
(70)	250	250	−2·4	4·0	—	—	3·4
(71)	250	100	−2·5	6·0	—	—	2·2
(72)	200	200	−2·0	9·0	—	V	2·2
(73)	200	200	−2·2	2·5	—	—	2·8
(74)	150	70	—	—	—	—	1·0
(75)	150	75	—	—	—	—	1·6
(76)	250	100	−1·5	2·0	1·0	—	3·0
(77)	250	100	−3·28	5·5	3·0	V	—
(78)	250	100	−2·0	6·0	3·0	V	3·6
(79)	250	100	−1·5	2·0	1·0	—	3·0
(80)	250	100	−3·28	5·5	2·0	V	—
(81)	250	100	—	4·2	2·0	V	—
(82)	250	100	−2·0	6·0	3·0	V	3·6
(83)	50	30	0	0·55	0·25	—	0·30
(84)	50	45	0	0·75	0·2	—	0·52
(85)	50	30	0	0·6	0·3	—	0·4
(86)	50	30	0	0·4	0·15	—	0·33
(87)	50	45	0	0·95	0·3	—	0·60
(88)	150	75	−1·5	2·7	0·8	—	1·0
(89)	150	70	−1·5	2·4	0·9	—	1·5
(90)	150	70	−1·5	2·4	0·9	—	1·5
(91)	150	75	0–14	6·0	1·7	V	1·0
(92)	150	70	−1·5	1·5	0·3	—	1·2
(93)	150	70	0·9	3·75	0·75	V	1·25
(94)	200	80	−1	3·8	0·4	250	2·2
(95)	200	80	−1·5	7·4	0·5	200	3·5
(96)	200	80	−1·5 −40	4·4	0·6	V	3·0
(97)	200	80	−1·5 −40	9·3	1·6	V	3·3
(98)	200	100	−2	4·2	1·4	350	3·2
(99)	200	100	−1·5 −30	5·7	2·3	V	3·0
(100)	200	100	−1·5 −30	6·3	2·0	V	3·0
(101)	150	80	—	—	—	—	1·1
(102)	150	80	—	—	—	—	1·2

[*Continued on next page*

TABLE XXVIII: SCREEN-GRIDS

Make	Type	Description	Base	Fil. Volts	Fil. Amps	
LISSEN—*cont.*	SG410	S	4B5	4·0	0·1	(103)
	AC/SG	S	5B17	4·0	1·0	(104)
	AC/SGV	VS	5B17	4·0	1·0	(105)
MARCONI ..	Z14	P	07	1·4	0·05	(106)
	S23	S	4B5	2·0	0·1	(107)
	S24	S	4B5	2·0	0·1	(108)
	VS2	VS	4B5	2·0	0·1	(109)
	VS24	VS	4B5	2·0	0·15	(110)
	VS24/K	VS	4B5	2·0	0·15	(111)
	Z21	P	4B8/7B4	2·0	0·1	(112)
	VP21	VP	7B4	2·0	0·1	(113)
	W21	VP	4B8/7B4	2·0	0·1	(114)
	MS4	S	5B17	4·0	1·0	(115)
	MS4B	S	5B17	4·0	1·0	(116)
	MS4B/K	S	5B17	4·0	1·0	(117)
	VMS4	VS	5B17	4·0	1·0	(118)
	VMS4/K	VS	5B17	4·0	1·0	(119)
	VMS4B	VS	5B17	4·0	1·0	(120)
	MSP4	P	5B17/7B23	4·0	1·0	(121)
	MSP41	P	5B17/7B23	4·0	1·0	(122)
	VMP4	VP	5B17/7B23	4·0	1·0	(123)
	VMP4/K	VP	5B17	4·0	1·0	(124)
	VMP4G	VP	7B23	4·0	1·0	(125)
	W42	VP	7B30	4·0	0·6	(126)
	KTZ41	T	7B41	4·0	1·5	(127)
	Z63	P	047	6·3	0·3	(128)
	W63	VP	047	6·3	0·3	(129)
	KTW61	VP	047	6·3	0·3	(130)
	KTW63	VT	047	6·3	0·3	(131)
	KTZ63	T	047	6·3	0·3	(132)
	W30	VP	7B23	13·0	0·3	(133)
	W31	VP	7B23	13·0	0·3	(134)
	DS	S	5B17	16·0	0·25	(135)
	DSB	S	5B17	16·0	0·25	(136)
	VDS	VS	5B17	16·0	0·25	(137)
	VDSB	VS	5B17	16·0	0·25	(138)
	S12	S	4D2	2·0	0·06	(139)
	ZA1	—	Acorn	4·0	0·25	(140)
	Z62	P	047	6·3	0·45	(141)
	ZA2	P	Special	6·3	0·15	(142)
MAZDA ..	SP141	P	0M7	1·4	0·05	(143)
	SG215	S	4B8/7B4	2·0	0·15	(144)
	S215A	S	4B8/7B4	2·0	0·15	(145)
	S215B	S	4B8/7B4	2·0	0·15	(146)
	S215VM	VS	4B8/7B4	2·0	0·15	(147)
	SP210	P	7B4	2·0	0·1	(148)
	SP215	P	7B4	2·0	0·15	(149)
	VP210	VP	7B4	2·0	0·1	(150)
	VP215	VP	7B4	2·0	0·15	(151)
	SP22	P	0M3	2·0	0·1	(152)
	VP22	VP	0M3	2·0	0·1	(153)
	VP23	VP	0M3	2·0	0·05	(154)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Anode Volts	Screen Volts	Bias Volts	Anode Current (mA)	Screen Current (mA)	Bias Res. Ohms	Slope mA/V
(103)	150	80	—	—	—	—	1·25
(104)	200	80	—	—	—	—	3·25
(105)	250	80	—	—	—	—	3·5
(106)	90	90	0	1·2	0·25	—	0·75
(107)	150	70	–1·5	1·3	0·6	—	1·1
(108)	150	70	0	4·5	0·5	—	1·4
(109)	150	70	—	—	—	—	1·25
(110)	150	75	0–9	4·5	0·5	—	1·5
(111)	150	75	0–9	4·4	0·3	—	1·5
(112)	150	150	0	1·7	0·6	—	1·7
(113)	150	60	0	2·8	0·7	—	1·1
(114)	150	150	–1·5	3·0	0·9	—	1·4
(115)	250	70	–1·5	2·4	0·3	550	1·1
(116)	250	80	–2·0	2·5	1·2	440	3·2
(117)	250	80	—	—	—	—	3·2
(118)	250	80	–2	9	2	V	2·4
(119)	250	80	–2	9	2	V	2·6
(120)	250	80	–1	5	1·2	V	2·9
(121)	250	100	–1·75	3·3	1·0	400	4·0
(122)	250	240	–4	8·5	3·2	—	3·2
(123)	250	100	–2	3·0	1·0	V	3·5
(124)	250	100	–2	7·0	3·5	V	2·5
(125)	250	100	–2·0	8·0	5·0	V	2·7
(126)	250	125	–3·0	7·6	1·9	V	1·5
(127)	250	250	–2·5	8·0	2·25	—	7·5
(128)	250	125	–3·0	2·0	0·5	—	1·225
(129)	250	100	–3·0	7·6	1·9	V	1·5
(130)	250	100	–3·0	8·0	2·3	V	2·9
(131)	250	100	–3·0	7·6	1·9	V	1·5
(132)	250	125	–3·0	2·0	0·5	—	1·225
(133)	250	250	—	—	—	V	4·5
(134)	250	100	–1·0	—	—	V	4·0
(135)	200	70	—	—	—	—	1·1
(136)	200	80	—	—	—	—	3·2
(137)	200	80	—	—	—	V	2·4
(138)	200	—	—	—	—	V	2·2
(139)	100	30	0	2·5	0·4	—	0·7
(140)	250	100	–3·0	2·0	0·7	1,500	1·4
(141)	300	150	–2·0	10·0	2·0	—	7·5
(142)	250	100	–3·0	2·0	0·7	—	1·4
(143)	90	90	—	1·8	—	—	0·8
(144)	150	80	–1·5	1·5	0·25	—	1·1
(145)	150	80	—	1·9	0·3	—	1·1
(146)	150	80	–1·5	1·5	0·3	—	1·7
(147)	150	80	0–8	1·0	0·15	—	1·4
(148)	150	150	–1	1·1	0·33	—	1·2
(149)	150	150	–1·5	1·35	0·47	—	1·3
(150)	120	70	–1·5	1·8	0·63	—	1·03
(151)	150	150	–1·5	1·1	0·385	—	0·82
(152)	150	150	–1·0	1·1	0·38	—	1·2
(153)	150	150	–1·5	1·2	0·32	—	0·02
(154)	150	150	–2·0	1·0	0·35	—	0·8

[*Continued on next page*

TABLE XXVIII: SCREEN-GRIDS

Make	Type	Description	Base	Fil. Volts	Fil. Amps	
MAZDA—*cont.*	AC/SG	S	7B23	4·0	1·0	(155)
	AC/S2	S	5B17	4·0	1·0	(156)
	AC/S1VM	VS	5B17	4·0	1·0	(157)
	AC/SGVM	VS	5B19/7B23	4·0	1·0	(158)
	AC/S2Pen	P	7B23	4·0	1·0	(159)
	AC/SP1	P	7B23	4·0	1·0	(160)
	AC/VP1	VP	7B23	4·0	0·65	(161)
	AC/VP2	VP	7B26	4·0	0·65	(162)
	VP41	VP	0M24	4·0	0·65	(163)
	SP41	P	0M24	4·0	0·95	(164)
	SP42	P	0M24	4·0	0·95	(165)
	SP1320	P	7B23	13·0	0·2	(166)
	VP1320	VP	7B23	13·0	0·2	(167)
	VP1321	VP	7B23	13·0	0·2	(168)
	VP1322	VP	7B26	13·0	0·2	(169)
	VP133	VP	0M24	13·0	0·2	(170)
	SP2220	P	7B23	22·0	0·2	(171)
	DC2/SG	S	7B23	20·0	0·1	(172)
	DC2/SGVM	VS	7B23	20·0	0·1	(173)
MULLARD ..	DF1	P	8S6	1·4	0·05	(174)
	DF51	P	4D3	1·5	0·067	(175)
	DAS1	T	4D2	2·0	0·06	(176)
	SP2	P	7B4	2·0	0·18	(177)
	PM12	T	4B5	2·0	0·15	(178)
	PM12A	T	4B5	2·0	0·18	(179)
	PM12M	VT	4B5	2·0	0·18	(180)
	VP2	VP	7B4	2·0	0·18	(181)
	VP2B	VP	7B5	2·0	0·14	(182)
	AP4	P	ACORN	4·0	0·2	(183)
	S4V	S	5B17	4·0	1·0	(184)
	S4VA	T	5B17	4·0	1·0	(185)
	S4VB	T	5B17	4·0	1·0	(186)
	MM4V	VT	5B17	4·0	1·0	(187)
	VM4V	VS	5B17	4·0	1·0	(188)
	TSP4	P	7B26	4·0	1·3	(189)
	SP4	P	5B19/7B23	4·0	1·0	(190)
	SP4B	P	7B26	4·0	0·65	(191)
	VP4	VP	5B19/7B23	4·0	1·0	(192)
	VP4A	VP	5B19/7B23	4·0	1·2	(193)
	VP4B	VP	7B26	4·0	0·65	(194)
	4672	P	ACORN	6·3	0·15	(195)
	EF5	VP	8S24	6·3	0·2	(196)
	EF6/36	P	8S24/047	6·3	0·2	(197)
	EF8/38	P	8S25/051	6·3	0·2	(198)
	EF9/39	P	8S24/047	6·3	0·2	(199)
	SP13	P	8S24	13·0	0·2	(200)
	SP13C	P	7B26	13·0	0·2	(201)
	VP13A	VP	8S24	13·0	0·2	(202)
	VP13C	VP	7B26	13·0	0·2	(203)
OSRAM ..	Z14	P	07	1·4	0·05	(204)
	S23	S	4B5	2·0	0·1	(205)
	S24	S	4B5	2·0	0·15	(206)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Anode Volts	Screen Volts	Bias Volts	Anode Current (mA)	Screen Current (mA)	Bias Res. Ohms	Slope mA/V
(155)	200	80	−1·5	8·5	—	—	2·4
(156)	200	80	−1·5	7·0	—	—	4·4
(157)	200	100	−1·5	5·7	—	—	1·1
(158)	200	80	−2	5·8	—	—	2·0
(159)	250	150	−4·25	5·25	1·75	—	5·5
(160)	250	250	−3·0	4·9	4·1	300	2·65
(161)	250	250	−4	8·8	2·2	—	2·0
(162)	250	250	−4	8·8	2·2	—	2·0
(163)	250	250	−4	8·6	2·3	—	2·0
(164)	250	250	−2·1	11·1	2·8	150	8·4
(165)	200	200	−1·25	27·0	6·75	37	9·0
(166)	250	250	−2·0	3·5	0·3	—	1·9
(167)	250	250	−1·5	4·7	1·25	—	2·0
(168)	250	250	−4	8·8	2·2	—	2·0
(169)	250	250	−4	8·8	2·2	—	2·0
(170)	200	200	−0·7	7·2	2·0	—	2·35
(171)	250	250	−3·0	4·9	4·1	—	2·65
(172)	200	100	−1·5	11·0	—	—	2·4
(173)	200	100	−4	8·0	—	—	1·6
(174)	90	90	0	1·2	—	—	0·75
(175)	45	13·5	0	0·125	—	—	0·17
(176)	120	60·0	−2·7	1·5	—	—	0·58
(177)	135	135·0	0	3·0	1·0	—	1·8
(178)	150	75	—	4·25	—	—	1·1
(179)	135	75	0	2·0	—	—	1·5
(180)	150	90	0–7	2·5	—	—	1·4
(181)	135	135	0–7	3·0	1·25	—	1·5
(182)	135	60	−1·5	2·0	—	—	1·4
(183)	250	100	−3·0	2·0	0·7	—	1·4
(184)	200	75	−1·0	1·5	—	600	1·1
(185)	200	110	−1·5	2·75	—	460	2·0
(186)	200	110	−1·5	4·6	—	—	2·5
(187)	200	110	−1·5 −40	6·0	—	V	2·5
(188)	200	100	−1·5 −40	8·5	—	200	1·2
(189)	250	250	−3·0	10·5	2·0	250	4·7
(190)	200	100	−2·0	3·0	—	—	2·3
(191)	250	250	−2·4	4·0	1·5	500	3·4
(192)	200	100	−2 −50	4·5	—	V	2·3
(193)	200	100	−2·0	4·25	1·8	V	2·5
(194)	250	250	−3·0	11·5	4·25	V	2·0
(195)	250	100	−3·0	2·0	—	—	1·4
(196)	250	100	−3 −50	8·0	—	V	1·7
(197)	250	100	−2·0	3·0	—	—	1·8
(198)	250	250	−2·5	8·0	—	—	1·8
(199)	250	100	−2·5	6·0	—	—	2·2
(200)	200	100	−2·0	3·3	—	400	2·2
(201)	200	200	−2·2	2·5	0·9	600	2·8
(202)	200	100	−2·0	4·0	1·4	V	2·2
(203)	200	200	−2·0	9·0	3·6	V	2·2
(204)	90	90	—	—	—	—	0·75
(205)	150	70	−1·5	1·3	0·6	—	1·1
(206)	150	70	0	4·5	0·5	—	1·4

[*Continued on next page*

TABLE XXVIII: SCREEN-GRIDS

Make	Type	Description	Base	Fil. Volts	Fil. Amps	
OSRAM—*cont.*	VS2	VS	4B5	2·0	0·15	(207)
	VS24	VS	4B5	2·0	0·15	(208)
	VS24K	VS	4B5	2·0	0·15	(209)
	Z21	P	4B8/7B4	2·0	0·1	(210)
	Z22	P	7B4	2·0	0·1	(211)
	VP21	VP	7B4	2·0	0·1	(212)
	W21	VP	4B8/7B4	2·0	0·1	(213)
	MS4	S	5B17	4·0	1·0	(214)
	MS4B	S	7B23	4·0	1·0	(215)
	VMS4	VS	5B17	4·0	1·0	(216)
	VMS4B	VS	5B19/7B23	4·0	1·0	(217)
	VMS4/B	VS	5B19/7B23	4·0	1·0	(218)
	MSP4	P	5B17/7B23	4·0	1·0	(219)
	MSP41	P	5B17/7B23	4·0	1·0	(220)
	VMP4	VP	5B19/7B23	4·0	1·0	(221)
	VMP4G	VP	7B23	4·0	1·0	(222)
	W42	VP	7B30	4·0	0·6	(223)
	KTZ41	T	7B41	4·0	1·5	(224)
	KTZ73	P	030	6·0	0·16	(225)
	KTW73M	T	030	6·0	0·17	(226)
	KTW74M	T	030	13·0	0·16	(227)
	Z62	P	047	6·3	0·45	(228)
	Z63	P	050	6·3	0·3	(229)
	W63	VP	050	6·3	0·3	(230)
	KTW61	VP	047/050	6·3	0·3	(231)
	KTW63	VP	050	6·3	0·3	(232)
	KTZ63	T	050	6·3	0·3	(233)
	W30	VP	7B23	13·0	0·3	(234)
	W31	VP	7B23	13·0	0·3	(235)
	DS	S	5B17	16·0	0·25	(236)
	DSB	S	7B23	16·0	0·25	(237)
	VDS	VS	5B17	16·0	0·25	(238)
	VDSB	VS	5B17	16·0	0·25	(239)
	S12	T	4D2	2·0	0·06	(240)
	ZA2	P	Acorn	6·3	0·15	(241)
RECORD ..	S2	S	4B5	2·0	0·12	(242)
	VS2	VS	4B5	2·0	0·12	(243)
	HFP2	P	4B5	2·0	0·12	(244)
	VHP2	VP	4B5	2·0	0·12	(245)
	AC/S	S	7B23	4·0	1·0	(246)
	AC/VS	VS	5B17	4·0	1·2	(247)
	AC/HFP	P	5B19/7B23	4·0	1·0	(248)
	AC/HPB	P	7B26	4·0	0·65	(249)
	AC/VHFP	VP	5B19/7B23	4·0	1·0	(250)
	AC/VHPB	VP	7B26	4·0	0·65	(251)
	HFP/13	P	7B26	13·0	0·2	(252)
	HFP/13L	P	8S24	13·0	0·2	(253)
	HPB/13	P	7B26	13·0	0·2	(254)
	VHFP/13	VP	7B26	13·0	0·2	(255)
	VHFP/13L	VP	8S24	13·0	0·2	(256)
	VHP/13	VP	7B26	13·0	0·2	(257)
	VHP/13L	VP	8S24	13·0	0·2	(258)
	VHPB/13	VP	7B26	13·0	0·2	(259)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Anode Volts	Screen Volts	Bias Volts	Anode Current (mA)	Screen Current (mA)	Bias Res. Ohms	Slope mA/V
(207)	150	75	0–15	5·0	2·0	—	1·25
(208)	150	75	0–9	4·5	0·5	—	1·5
(209)	150	75	0–9	4·4	0·3	—	1·5
(210)	150	150	–0·5	1·7	0·6	—	1·7
(211)	150	150	—	—	—	—	1·4
(212)	150	60	0	2·8	0·7	—	1·1
(213)	150	150	0	3·6	1·2	—	1·4
(214)	250	70	–1·5	2·4	0·3	550	1·1
(215)	250	80	–2·0	3·4	1·2	250	3·2
(216)	250	80	–2 –30	7·5	2·0	V	2·4
(217)	250	80	–1 –15	5·0	1·2	V	2·9
(218)	250	80	—	—	—	V	2·0
(219)	250	100	–1·75	3·3	1·0	400	4·0
(220)	240	240	–4·0	9·0	3·2	—	3·2
(221)	250	100	—	—	—	V	3·5
(222)	250	100	–2·0	8·0	5·0	V	2·8
(223)	250	125	–3·0	7·6	1·9	V	1·5
(224)	250	250	–1·5	18·0	5·25	65	12·0
(225)	250	100	–3·0	2·0	0·25	1,000	1·5
(226)	250	100	–3·0	6·5	1·3	V	1·7
(227)	250	100	—	—	—	V	1·5
(228)	300	150	–2·0	10·0	2·3	160	7·5
(229)	250	125	–3·0	2·0	0·5	1,200	1·225
(230)	250	100	–3 –40	7·6	1·9	V	1·5
(231)	250	100	–3·0	8·0	2·3	V	2·9
(232)	250	125	–3·0	7·6	1·5	V	1·5
(233)	250	125	–3·0	2·0	0·5	1,200	1·23
(234)	250	250	—	—	—	V	4·5
(235)	250	100	–2·5	8·1	5·0	V	2·78
(236)	200	70	—	—	—	—	1·1
(237)	200	80	—	—	—	—	3·2
(238)	200	80	—	—	—	—	2·4
(239)	200	—	—	—	—	—	2·2
(240)	100	30	0	2·5	0·4	—	0·7
(241)	250	100	—	—	—	—	1·4
(242)	150	75	–0·9	1·5	0·3	—	1·4
(243)	150	75	–0·5	1·0	0·1	—	1·5
(244)	150	150	–1·5	1·9	0·7	—	1·9
(245)	150	150	–0·9 –17	2·5	0·6	—	1·7
(246)	200	100	–2·0	3·0	0·8	500	3·0
(247)	200	100	–1·5 –40	3·0	0·8	V	3·0
(248)	200	100	–2·0	3·5	0·6	600	3·5
(249)	250	250	–2·0	2·9	0·8	500	4·0
(250)	200	100	–2·0 –35	5·0	1·3	V	3·5
(251)	250	250	–1·0 –50	10·0	2·5	V	4·0
(252)	200	100	–2·0	3·0	1·5	450	2·4
(253)	200	100	–2·0	3·0	1·5	450	2·4
(254)	200	200	–1·5	3·5	1·5	300	3·5
(255)	200	100	–1·0 –10	8·0	2·9	V	3·5
(256)	200	100	–1·0 –10	8·0	2·9	V	3·5
(257)	200	100	–3·0 –55	8·0	2·6	V	2·8
(258)	200	100	–3·0 –55	8·0	2·6	V	2·8
(259)	200	200	–1·0 –50	10·0	3·5	V	3·5

[*Continued on next page*

TABLE XXVIII: SCREEN-GRIDS

Make	Type	Descrip-tion	Base	Fil. Volts	Fil. Amps.	
TRIOTRON ..	S217	VP	7B4	2·0	0·2	(260)
	S218	P	7B4	2·0	0·2	(261)
	S215	S	4B5	2·0	0·18	(262)
	S213	VS	4B5	2·0	0·15	(263)
	S434N	VP	5B19/7B23	4·0	1·1	(264)
	S420	VP	7B26	4·0	0·65	(265)
	S440	P	7B26	4·0	0·65	(266)
	S435N	P	5B19/7B23	4·0	1·1	(267)
	S415N	VS	5B17	4·0	1·0	(268)
	S410N	S	5B17	4·0	1·0	(269)
	S430N	S	5B17	4·0	1·0	(270)
	S1324	P	7B26	13·0	0·2	(271)
	S1328	P	8S24	13·0	0·2	(272)
	S1323	VP	7B26	13·0	0·2	(273)
	S2034N	VP	5B19	20·0	0·18	(274)
	S2035N	P	5B19	20·0	0·18	(275)
TUNGSRAM ..	SE211	VS	4B5	2·0	0·12	(276)
	SE211C	VS	4B5	2·0	0·12	(277)
	HP210	P	4B8/7B4	2·0	0·12	(278)
	HP210C	P	7B4	2·0	0·12	(279)
	HP210NC	P	4B8/7B4	2·0	0·12	(280)
	SP2B	HF PEN	7B3	2·0	0·05	(281)
	SP2D	P	7B3	2·0	0·1	(282)
	SS210	T	4B5	2·0	0·12	(283)
	VP2B	VP	7B3	2·0	0·05	(284)
	VP2D	VP	7B3	2·0	0·1	(285)
	HP211C	VP	7B4	2·0	0·12	(286)
	AS4125	VS	5B17	4·0	1·2	(287)
	AS4120	T	5B17	4·0	1·0	(288)
	HP4101	P	5B19/7B23	4·0	1·0	(289)
	HP4115	P	7B23	4·0	1·0	(290)
	SP4B	P	7B26	4·0	0·65	(291)
	HP4106	VP	5B19/7B23	4·0	1·0	(292)
	VP4B	VP	7B26	4·0	0·65	(293)
	EF12	P	0F3	6·3	0·2	(294)
	SP6S	P	8S24	6·3	0·2	(295)
	VP6S	VP	8S24	6·3	0·2	(296)
	EF11	VP	0F3	6·3	0·2	(297)
	EF6	P	8S24	6·3	0·2	(298)
	EF5	VP	8S24	6·3	0·2	(299)
	EF9/39	VP	8S24/047	6·3	0·2	(300)
	SP13	P	7B26	13·0	0·2	(301)
	SP13B	P	7B26	13·0	0·2	(302)
	HP13	VP	7B26	13·0	0·2	(303)
	VP13	VP	7B26	13·0	0·2	(304)
	VP13B	VP	7B26	13·0	0·2	(305)
	EF8	HF HEX	8S25	6·3	0·2	(306)
	HP2118	VP	5B19	20	0·18	(307)
	HP2018	P	5B19	20	0·18	(308)
	HP1118	VP	7C3	10	0·18	(309)
	HP1018	P	7C3	10	0·18	(310)
	SS2018	S	5B17	20	0·18	(311)
	S2018	S	5B17	20	0·18	(312)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Anode Volts	Screen Volts	Bias Volts	Anode Current (mA)	Screen Current (mA)	Bias Res. Ohms	Slope mA/V
(260)	150	150	−0·5 −16	2·5	—	—	1·7
(261)	150	150	−0·5	3·0	—	—	1·85
(262)	150	90	−0·5	2·0	—	—	1·4
(263)	150	75	0–9	4·0	—	—	1·5
(264)	200	100	−1·5 −30	4·5	—	V	3·5
(265)	250	250	−3·0	11·5	—	V	—
(266)	250	250	−2·4	4·0	—	—	3·4
(267)	200	100	−2·0	3·0	—	—	3·5
(268)	200	100	−1·5 −40	3·0	—	V	—
(269)	200	60	−1·3	1·5	—	—	1·0
(270)	200	100	−2·0	3·0	—	—	2·0
(271)	200	100	−2·0	3·0	—	—	2·4
(272)	200	100	−2·0	3·0	—	—	2·4
(273)	200	100	−3 −55	8·0	—	V	1·8
(274)	200	100	−2 −35	5·0	—	V	3·5
(275)	200	100	−2·0	3·0	—	—	3·5
(276)	150	75	−9 −5	1·0	0·1	—	1·3
(277)	150	75	−5	1·0	0·1	—	1·5
(278)	150	150	−1·5	1·9	0·7	—	1·9
(279)	150	150	−1·5	1·9	0·7	—	1·9
(280)	150	150	−1·5	1·9	0·7	—	1·9
(281)	135	135	−0·5	2·6	1·0	—	1·0
(282)	150	150	−1·0	1·45	0·35	—	1·7
(283)	150	75	−0·9	1·5	0·3	—	1·4
(284)	135	135	0–15	2·5	0·8	—	0·65
(285)	150	150	−1·5 −12	1·3	0·6	—	2·0
(286)	150	150	−0 −17	2·6	0·6	—	1·7
(287)	200	100	−1·5 −40	3·0	0·8	V	3·0
(288)	200	100	−2·0	3·0	0·8	500	3·0
(289)	250	100	−3·0	3·5	1·8	600	3·5
(290)	200	100	−2·0	4·5	1·5	150	3·2
(291)	250	250	−3·0	3·2	1·5	500	4·0
(292)	250	100	−1·5 −35	5·0	1·3	V	3·5
(293)	250	250	−1 −50	10·0	2·5	V	4·0
(294)	300	100	−2·0	6·0	1·0	500	3·0
(295)	250	100	−2·0	3·0	1·0	500	2·0
(296)	250	100	−3 −50	8·0	2·5	V	1·7
(297)	300	125	−2·0	6·0	2·0	250	2·2
(298)	300	125	−2·0	3·0	1·1	—	2·0
(299)	250	125	−3·0 −50	8·0	2·6	V	1·7
(300)	300	300	−2·5 −55	6·0	1·7	V	2·2
(301)	200	100	−2	3·0	1·5	450	2.4
(302)	200	200	−1·5	3·5	1·5	—	3·5
(303)	200	100	0–10	8·0	2·9	V	3·5
(304)	200	100	−3 −55	8·0	2·6	V	2·8
(305)	250	200	−1 −50	10·0	2·0	V	3·5
(306)	250	250	−2·5	8·0	0·25	—	1·8
(307)	200	100	−2·0	5·0	1·1	—	3·5
(308)	200	100	−2·0	4·0	1·2	—	3·5
(309)	250	100	−3·0	8·2	2·0	—	1·6
(310)	250	100	−3·0	2·0	0·5	—	1·22
(311)	200	100	−3·0	3·0	1·0	—	3·0
(312)	200	60	−3·0	4·0	1·2	—	1·2

TABLE XXIX: DIODES

Make	Type	Descrip-tion	Base	Filament		Max. Diode Volts	Max. Diode Current
				Volts	Amps		
BRIMAR ..	10D1	DD	5B12	13·0	0·2	—	—
	6H6G	DD	—	6·3	0·3	—	—
COSSOR ..	220DD	DD	5B12	2·0	0·2	—	—
	DDL4	DD	5B12	4·0	0·75	—	—
	DD4	DD	5B12	4·0	0·75	—	—
	OM3	DD	O38	6·3	0·2	—	—
DARIO ..	TB24	DD	5B12	4·0	0·65	—	—
	TB213	DD	5B12	13·0	0·2	—	—
EVER READY	A20B	DD	5B12	4·0	0·65	200	0·8
	EB34	DD	O38	6·3	0·2	200	0·8
	C20C	DD	5B12	13·0	0·2	200	0·8
FERRANTI	ZD	DD	5B12	7·0	0·2	—	—
HIVAC ..	*Ac/DD	DD	5B12	4·0	1·0	—	—
MARCONI	D41	DD	5B12	4·0	0·3	—	—
	D42	D	4B18	4·0	0·6	75	15·0
	D63	DD	O38	6·3	0·3	100	2·0
MAZDA ..	DD207	DD	4B3	2·0	0·075	—	—
	DD41	DD	OM18	4·0	0·5	—	—
	V914	DD	5B12	4·0	0·3	—	1·0
	*DD620	DD	5B12	6·0	0·2	—	1·0
	DD101	DD	OM18	10·0	0·2	—	—

[*Continued on opposite page*

TABLE XXX: DIODE

Make	Type	Descrip-tion	Base	Fil. Volts	Fil. Amps	Anode Volts	
BRIMAR ..	11A2	DDT	7B19	4·0	1·0	200	(1)
	11D3	DDT	7B19	13·0	0·2	250	(2)
	11D5	DDT	7B19	13·0	0·15	250	(3)
	6Q7G	DDT	—	6·3	0·3	250	(4)
	6R7G	DDT	—	6·3	0·3	250	(5)
COSSOR ..	210DDT	DDT	5B2	2·0	0·1	150	(6)
	2102	DDT	6UX2	2·0	0·12	150	(7)
	DDT	DDT	7B19	4·0	1·0	200	(8)
	DD/Pen	DDP	7B34	4·0	1·0	250	(9)
	420TDD	DDP	7B22	4·0	2·0	250	(10)
	13DHA	DDT	7B19	13·0	0·2	250	(11)
	DDT16	DDT	7B19	16·0	0·25	200	(12)
	202DDT	DDT	7B19	20·0	0·2	200	(13)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

TABLE XXIX: DIODES—*continued*

Make	Type	Descrip-tion	Base	Filament		Max. Diode Volts	Max. Diode Current
				Volts	Amps		
MULLARD	2D2	DD	5B12	2·0	0·9	125	0·5
	2D4A	DD	5S2	4·0	0·65	200	0·8
	2D4B	DD	7B16	4·0	0·35	200	0·8
	EB4/34	DD	8S18/038	6·3	0·2	200	0·8
	EAB1	DDD	8S19	6·3	0·2	200	0·8
	2D13	DD	5B12	13·0	0·2	200	0·8
	2D13A	DD	5S1	13·0	0·2	200	0·8
	2D13C	DD	5B12	13·0	0·2	200	0·8
OSRAM	D41	DD	5B12	4·0	0·3	—	—
	*D42/43	D	4B18/4B19	4·0	0·6	75	15·0
	D63	DD	O38	6·3	0·3	100	2·0 each
RECORD	Ac/DD4A	DD	5B12	4·0	0·65	200	0·8
	DDA/13	DD	5B12	13·0	0·2	200	0·8
	DDA/13L	DD	8S16	13·0	0·2	200	0·8
TRIOTRON	D400	DD	4B12	4·0	0·65	200	0·8
	D1300	DD	8S16	13·0	0·2	200	0·8
TUNGS-RAM	DD4	DD	5B12	4·0	0·65	200	0·8
	DD4D	DD	7B16	4·5	0·4	100	4·0
	*D418	D	4B15	4·0	0·18	200	1·5
	*DD6DS	DD	8S16	6·3	0·2	200	0·8
	EB4	DD	8S18	6·3	0·2	200	0·8
	EAB1	DDD	8S19	6·3	0·2	200	0·8
	DD13/13S	DD	5B12/8S16	13·0	0·2	200	0·8
	DD18	DD	5B11	8·0	0·18	100	1·5

COMBINATIONS

	Screen Volts	Amp. Factor	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Output (mW)
(1)	—	50	2·8	−2·0	—	3·0	—
(2)	—	100	1·1	−2·0	5,000	0·4	—
(3)	—	40	1·5	−3·0	750	3·8	—
(4)	—	70	1·2	−3	4,000	1·1	—
(5)	—	16	1·9	−9	1,000	9·5	—
(6)	—	27·5	1·1	0	—	2·3	—
(7)	—	30	1·3	0	—	2·5	—
(8)	—	41	2·4	−3·0	—	3·4	—
(9)	200	—	2·7	−2·5	—	5·0	—
(10)	250	—	7·0	−5·5	—	34·0	—
(11)	—	125	1·5	−1·5	—	1·0	—
(12)	—	40	2·5	−3·0	—	5·0	—
(13)	—	41	2·4	−3·0	—	3·5	—

[*Continued on next page*

TABLE XXX: DIODE

Make	Type	Descrip-tion	Base	Fil. Volts	Fil. Amps	Anode Volts	
DARIO ..	BBC12	DDT	5B2	2·0	0·1	130	(14)
	TBC14	DDT	7B19	4·0	0·65	250	(15)
	TE444	D Tetrode	7B50	4·0	1·1	200	(16)
	TBL14	DDP	7B32	4·0	2·25	250	(17)
	TBL44	DDP	7B33	4·0	2·25	250	(18)
	TBC113	DDT	7B19	13·0	0·2	200	(19)
EKCO ..	DT41	DDT	7B19	4·0	0·65	200	(20)
EVER READY	K23A	DDT	5B2	2·0	0·1	150	(21)
	K23B	DDT	5B2	2·0	0·12	135	(22)
	A23A	DDT	7B19	4·0	0·65	250	(23)
	A27D	DDP	7B33	4·0	2·25	250	(24)
	EBC3/EBC33	DDT	8S21/041	6·3	0·2	275	(25)
	EBL1/31	DDP	8S27/053	6·3	1·5	250	(26)
	C23B	DDT	7B19	13·0	0·2	200	(27)
FERRANTI	H2D	DDT	SB2	2·0	0·1	150	(28)
	H4D	DDT	7B19	4·0	1·0	250	(29)
	PT4D	DDP	7B32	4·0	2·0	250	(30)
	HSD	DDT	7B19	13·0	0·3	200	(31)
	HAD	DDT	7B19	13·0	0·2	200	(32)
	PTSD	DDP	7B32	13·0	0·3	250	(33)
HIVAC ..	DDT215	DDT	5B2	2·0	0·15	150	(34)
	AC/DDT	DDT	7B19	4·0	1·0	200	(35)
	AC/2DD	DDTetrode	7B32	4·0	2·0	250	(36)
	DDT213	DDT	7B19	13·0	0·3	200	(37)
MARCONI	HD14	DD	04	1·4	0·05	90	(38)
	HD21	DDT	5B2	2·0	0·2	150	(39)
	HD22	DDT	5B2	2·0	0·2	150	(40)
	HD23	DDT	5B2	2·0	0·15	150	(41)
	HD24	DDT	5B2	2·0	0·1	150	(42)
	WD40	VPDD	9B6	4·0	1·0	250	(43)
	MHD4	DDT	7B19	4·0	1·0	200	(44)
	DH42	DDT	7B19	4·0	0·6	250	(45)
	DL63	DDT	041	6·3	0·3	250	(46)
	DN41	DDP	7B32	4·0	2·3	250	(47)
	DH63	DDT	041	6·3	0·3	250	(48)
	WD30	VPDD	9B6	13·0	0·3	250	(49)
	DH30	DDT	7B19	13·0	0·3	200	(50)
	DHD	DDT	7B24	16·0	0·25	200	(51)
MAZDA ..	H141D	DT	OM6	1·4	0·05	90	(52)
	HL21/DD	DDT	5B2	2·0	0·15	150	(53)
	L21/DD	DDT	5B2	2·0	0·1	150	(54)
	L22/DD	DDT	OM2	2·0	0·1	150	(55)
	HL23/DD	DDT	OM2	2·0	0·05	150	(56)
	AC/HLDD	DDT	7B19	4·0	1·0	250	(57)
	AC/HLDDD	Triple DT	9B3	4·0	1·0	250	(58)
	AC2/PENDD	DDP	7B32	4·0	2·0	250	(59)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Screen Volts	Amp. Factor	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Output (mW)
(14)	—	16	1·5	−4·5	—	2·5	—
(15)	—	27	2·0	−7·0	—	4·0	—
(16)	33	1,000	3·0	−2·3	—	0·35	—
(17)	250	—	9·5	—	—	36·0	—
(18)	250	—	9·5	—	—	36·0	—
(19)	—	27	2·0	−5·0	—	4·0	—
(20)	—	29	3·0	−3·5	470	7·5	—
(21)	—	16·5	1·4	−1·5	—	2·5	—
(22)	—	30	1·2	−1·5	—	1·95	—
(23)	—	27	2·0	−7·0	—	4·0	—
(24)	250	—	10·0	−6·0	—	36·0	4,300
(25)	—	30	2·0	−6·25	—	5·0	—
(26)	250	—	9·5	−6·0	—	36·0	4,300
(27)	—	27	2·0	−5·0	—	4·0	—
(28)	—	—	—	—	—	—	—
(29)	—	39	2·7	−3·0	—	4·5	—
(30)	250	—	7·5	−6·0	140	7·5	3,600
(31)	—	39	2·7	−3·0	—	4·5	—
(32)	—	39	2·7	−3·0	—	3·3	—
(33)	250	—	7·5	−6·0	140	7·5	3,600
(34)	—	20	1·6	−3·0	—	3·0	—
(35)	—	35	2·3	−4·0	800	5·0	—
(36)	250	—	8·0	−9·5	160	32·0	3,000
(37)	—	35	2·3	−4·0	800	5·0	—
(38)	—	65	0·275	0	—	0·14	—
(39)	—	27	1·5	−1·5	—	—	—
(40)	—	27	1·5	−1·5	—	—	—
(41)	—	40	1·4	−1·5	—	2·0	—
(42)	—	40	1·4	−1·7	—	1·7	—
(43)	100	—	3·5	—	—	—	—
(44)	—	40	2·2	—	750	3·2	—
(45)	—	70	1·2	−3·0	2,000	1·5	—
(46)	—	37	1·65	−3	—	5·0	—
(47)	250	—	10·0	−4·4	90	32·0	4,400
(48)	—	70	1·2	−3·0	2,000	1·1	—
(49)	100	—	2·6	—	—	—	—
(50)	—	80	4·5	−2·0	1,000	2·7	—
(51)	—	40	2·2	—	—	—	—
(52)	—	65	0·48	—	—	0·065	—
(53)	—	32	1·5	−2·0	—	2·0	—
(54)	—	18·5	1·85	−5·0	—	2·8	—
(55)	—	18·5	1·85	−5·0	—	2·3	—
(56)	—	25	1·2	−1·5	—	0·6	—
(57)	—	36	2·6	−3·0	700	4·3	—
(58)	—	35	2·7	−3·0	700	4·3	—
(59)	250	—	8·0	−5·3	140	32·0	3,500

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TABLE XXX: DIODE

Make	Type	Description	Base	Fil. Volts	Fil. Amps	Anode Volts	
MAZDA—*continued*	AC5/PENDD	DDP Tet	7B22	4·0	2·0	250	(60)
	PEN 45/DD	DDP Tet	OM25	4·0	2·0	250	(61)
	HL41/DD	DDT	OM21	4·0	0·65	250	(62)
	HL42/DD	DDT	OM21	4·0	0·65	250	(63)
	HLDD1320	DDT	7B19	13·0	0·2	250	(64)
	HL133/DD	DDT	OM21	13·0	0·2	250	(65)
	PENDD1360	DDP	7B32	13·0	0·6	250	(66)
	DC2HLDD	DDT	7B19	25·0	0·1	200	(67)
	PENDD4020	DDP	7B32	40·0	0·2	250	(68)
	PEN453/DD	DD Tet	OM25	45·0	0·2	200	(69)
MULLARD	DAC1	DT	8S3	1·4	0·05	90	(70)
	TDD2	DDT	5B2	2·0	0·1	150	(71)
	TDD2A	DDT	5B2	2·0	0·12	135	(72)
	SD4	D Tetrode	7B50	4·0	1·0	250	(73)
	TDD4	DDT	7B19	4·0	0·65	250	(74)
	PEN4DD	DDP	7B33	4·0	2·25	250	(75)
	EBC3/33	DDT	8S21/041	6·3	0·2	275	(76)
	EBF2	DDP	8S27	6·3	0·2	250	(77)
	EBL1/31	DDP	8S27/053	6·3	1·5	250	(78)
	TDD13C	DDT	7B19	13·0	0·2	200	(79)
	PEN40DD	DDP	7B33	44·0	0·2	200	(80)
	CBL1/31	DDP	8S27/053	44·0	0·2	200	(81)
OSRAM ..	HD14	DT	04	1·4	0·05	90	(82)
	HD21	DDT	5B2	2·0	0·2	150	(83)
	HD22	DDT	5B2	2·0	0·2	150	(84)
	HD23	DDT	5B2	2·0	0·15	150	(85)
	HD24	DDT	5B2	2·0	0·1	150	(86)
	WD40	VPDD	9B6	4·0	1·0	100	(87)
	MHD4	DDT	7B19	4·0	1·0	250	(88)
	DH42	DDT	7B19	4·0	0·6	250	(89)
	DH41	DDP	7B32	4·0	2·3	250	(90)
	DN41	DDP	7B32	4·0	2·3	250	(91)
	DH73M	DDT	O41	6·0	0·17	250	(92)
	DL74M	DDT	O41	13·0	0·16	250	(93)
	DH63	DDT	O41	6·3	0·3	250	(94)
	DL63	DDT	O41	6·3	0·3	250	(95)
	WD30	VPDD	9B6	13·0	0·3	250	(96)
	DH30	DDT	7B19	13·0	0·3	200	(97)
	DHD	DDT	7B19	16·0	0·25	200	(98)
RECORD	DDTR2	DDT	5B2	2·0	0·1	135	(99)
	AC/DDTR	DDT	7B19	4·0	0·65	250	(100)
	DDTR/13	DDT	7B19	13·0	0·2	200	(101)
	DDTR/13L	DDT	8S21	13·0	0·2	200	(102)
TRIOTRON	DT215	DDT	5B2	2·0	0·1	135	(103)
	DT436	DDT	7B19	4·0	0·65	250	(104)
	DP495/6	DDP	7B33/7B32	4·0	2·25	250	(105)
	DT1336	DDT	7B19	13·0	0·2	200	(106)
	DP4480	DDP	7B33	44·0	0·2	200	(107)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Screen Volts	Amp. Factor	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Output (mW)
(60)	250	—	9·0	–8·5	175	40·0	5,800
(61)	250	—	9·0	–8·5	175	40·0	5,800
(62)	—	30	2·5	–7·4	1,400	2·2	—
(63)	—	23	2·9	–1·25	450	2·8	—
(64)	—	30	2·0	–3·0	700	4·3	—
(65)	—	32	2·5	–2·2	1,750	1·25	—
(66)	250	—	8·0	–5·3	140	32·0	—
(67)	—	30	2·0	–3·0	700	3·75	—
(68)	250	—	7·0	–7·75	150	43	3,900
(69)	200	—	12·0	–10·0	130	64·0	3,750
(70)	—	65·0	0·275	0	—	0·14	—
(71)	—	16·5	1·4	–5·5	—	2·5	—
(72)	—	30·0	1·2	–1·5	—	1·95	—
(73)	100	—	3·0	—	—	—	—
(74)	—	27·0	2·0	–7·0	1,500	4·0	—
(75)	250	—	9·5	–6·0	150	36·0	4,300
(76)	—	30·0	2·0	–6·25	—	5·0	—
(77)	100	—	1·8	–2·0	—	5·0	—
(78)	250	—	9·5	–6·0	—	36·0	4,300
(79)	—	27·0	2·0	–5·0	1,250	4·0	—
(80)	200	—	8·0	–8·5	—	45·0	4,000
(81)	200	—	8·0	–8·5	—	45·0	4,000
(82)	—	65	0·275	—	—	—	—
(83)	—	27	1·5	–1·5	—	—	—
(84)	—	27	1·5	–1·5	—	—	—
(85)	—	40	1·4	–1·5	—	1·7	—
(86)	—	40	1·4	–1·7	—	1·7	—
(87)	—	—	2·6	—	—	—	—
(88)	—	40	2·2	–4·0	1,000	4·0 each	—
(89)	—	70	1·2	–3·0	1,500	—	—
(90)	250	—	10·0	–3·5	90	32·0	3,500
(91)	250	—	10·0	–5·0	120	32·0	—
(92)	—	44	2·0	—	—	—	—
(93)	—	36	1·6	—	—	—	—
(94)	—	70	1·2	–3·0	2,000	1·1 each	—
(95)	—	36	1·6	–3·0	1,500	4·2 each	—
(96)	100	—	2·6	—	—	—	—
(97)	—	80	4·5	–2·0	1,000	2·7	—
(98)	—	40	2·2	—	—	—	—
(99)	—	30	1·4	–3·0	—	1·0	—
(100)	—	40	3·6	–5·0	1,000	4·0	—
(101)	—	40	3·6	–5·0	1,000	4·0	—
(102)	—	40	3·6	–5·0	1,000	4·0	—
(103)	—	16	1·0	–4·5	—	2·5	—
(104)	—	27	2·0	–7·0	—	4·0	—
(105)	250	—	—	–6·0	—	36·0	—
(106)	—	27	2·0	–5·0	—	4·0	—
(107)	200	280	8·0	–8·5	—	45·0	—

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TABLE XXX: DIODE

Make	Type	Description	Base	Fil. Volts	Fil. Amps	Anode Volts	
TUNGSRAM	DDT2	DDT	5B16	2·0	0·1	135	(108)
	DDT2B	DDT	5B16	2·0	0·1	135	(109)
	DDT4/S	DDT	7B19/8S21	4·0	0·65	250	(110)
	DDPP4B/M	DDP	7B32/7B33	4·0	2·0	250	(111)
	EBF11	DDP (HF)	0F4	6·3	0·2	300	(112)
	DDT6S	DDT	8S21	6·3	0·2	250	(113)
	EBC3/33	DDT	8S21/041	6·3	0·2	300	(114)
	EBF2	DDP (HF)	8S27	6·3	0·2	300	(115)
	EBL1/31	DDP	8S27/053	6 3	1·4	250	(116)
	DDT13/S	DDT	7B19/8S21	13·0	0·2	250	(117)
	DDPP39/M/S	DDP	7B32/7B33 /8S27	39·0	0·2	200	(118)
	DDPP6B	DDP	7B32	6·3	1·4	250	(119)

TABLE XXXI: GENERAL-

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
BRIMAR ..	4215A	—	1·0	0·25	45	(1)
	HLA2	5B15	4·0	1·0	200	(2)
	4D1	7B18	13·0	0·2	200	(3)
	6C5G	—	6·3	0·3	250	(4)
	6J5G	—	6·3	0·3	250	(5)
COSSOR ..	210RC	4B4	2·0	0·1	150	(6)
	210HL	4B4	2·0	0·1	150	(7)
	210HF	4B4	2·0	0·1	150	(8)
	210DET	4B4	2·0	0·1	150	(9)
	210LF	4B4	2·0	0·1	150	(10)
	41MRC	5B15	4·0	1·0	200	(11)
	41MH	5B15	4·0	1·0	200	(12)
	41MHF	5B15	4·0	1·0	200	(13)
	41MHL	5B15	4·0	1·0	200	(14)
	41MLF	5B15	4·0	1·0	180	(15)
	DHL	5B15	16·0	0·25	200	(16)
	41MTL	5B15	4·0	1·0	250	(17)
	41MTB	5B15	4·0	1·0	250	(18)
	41MTA	5B15	4·0	1·0	200	(19)
DARIO ..	TB282	4B4	2·0	0·1	150	(20)
	TB172	4B4	2·0	0·1	150	(21)
	TB102	4B4	2·0	0·1	150	(22)
	TB122	4B4	2·0	0·2	135	(23)
	TE994	5B15	4·0	1·0	200	(24)
	TE384	5B15	4·0	1·0	200	(25)
	TE244	5B15	4·0	1·0	200	(26)
	TE094	5B15	4·0	1·0	200	(27)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

COMBINATIONS—*continued*

	Screen Volts	Amp. Factor	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Output (mW)
(108)	—	30	1·4	–1·5	—	1·0	—
(109)	—	16	1·0	–4·5	—	2·5	—
(110)	—	40	3·6	–5·0	—	4·0	—
(111)	250	—	10·0	—	150	36·0	3,600
(112)	125	—	1·8	—	—	—	—
(113)	—	30	2·5	–5·5	1,000	5·0	—
(114)	—	—	2·0	–6·25	—	5·0	—
(115)	300	—	1·8	–2·0	—	2·0	—
(116)	250	—	10·0	–6·0	150	36·0	3,600
(117)	—	40·0	3·6	–5·0	1,000	4·0	—
(118)	200	—	8·5	—	170	45·0	3,200
(119)	250	—	10·0	–6·0	—	2·0	—

PURPOSE TRIODES

	Amp. Factor	Impedance (Ohms)	Slope (mA/V)	Bias Volts	Anode Current (mA)	Bias Res. (Ohms)
(1)	6	25,000	0·4	–3·0	0·8	—
(2)	50	9,000	5·5	–2·0	8·0	400
(3)	40	10,000	4·0	–3·0	5·0	800
(4)	20	10,000	2·0	–8	8·0	1,000
(5)	20	7,700	2·6	–8	9·0	900
(6)	40	50,000	0·8	–1·5	0·45	—
(7)	24	22,000	1·1	–1·5	2·0	—
(8)	24	15,000	1·5	–1·5	2·25	—
(9)	15	13,000	1·15	–1·5	4·5	—
(10)	14	10,000	1·4	–3·0	4·5	—
(11)	50	19,500	2·6	–1·0	2·5	—
(12)	72	18,000	4·0	–1·5	1·5	—
(13)	41	14,500	2·8	–2·0	2·5	—
(14)	52	11,500	4·5	–3·0	4·0	—
(15)	15	7,900	1·9	–4·5	7·5	—
(16)	58	13,000	4·5	–1·5	3·8	—
(17)	44	15,000	3·0	–3·0	4·0	—
(18)	104	40,000	2·6	–1·0	3·4	—
(19)	—	—	—	—	—	—
(20)	28	22,000	1·3	–2·0	2·0	—
(21)	17	12,000	1·4	–3·0	4·5	—
(22)	10	8,000	1·25	–6·0	5·0	—
(23)	12	6,000	2·0	–6·0	5·0	—
(24)	100	25,000	4·0	–1·6	1·0	—
(25)	38	25,000	1·5	–2·5	1·5	—
(26)	24	10,000	2·4	–3·5	6·0	—
(27)	9	7,000	1·3	–16·0	12·0	—

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Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
DARIO—*cont.*	TC113	7B18	13·0	0·2	200	(28)
	TB9920	5B15	20·0	0·18	200	(29)
EVER READY	K30K	4B4	2·0	0·1	135	(30)
	K30D	4B4	2·0	0·1	150	(31)
	K30E	4B4	2·0	0·1	135	(32)
	A30B	5B15	4·0	0·65	200	(33)
	A30D	5B15	4·0	0·65	250	(34)
	C30B	7B18	13·0	0·2	200	(35)
FERRANTI ..	D4	5B15	4·0	1·0	200	(36)
	DA	7B18	13·0	0·2	200	(37)
	DS	5B15	13·0	0·3	200	(38)
HIVAC.. ..	XH1·5V	4D1	1·5	0·08	50	(39)
	XD1·5V	4D1	1·5	0·08	50	(40)
	XH2·0V	4D1	2·0	0·08	50	(41)
	XD2·0V	4D1	2·0	0·08	50	(42)
	H210	4B4	2·0	0·1	150	(43)
	D210	4B4	2·0	0·1	150	(44)
	D210SW	4B11	2·0	0·1	150	(45)
	L210	4B4	2·0	0·1	150	(46)
	AC/HL	5B15	4·0	1·0	200	(47)
	HL13	7B18	13·0	0·3	200	(48)
LISSEN ..	H2	4B4	2·0	0·1	150	(49)
	HL2	4B4	2·0	0·1	150	(50)
	L2	4B4	2·0	0·1	150	(51)
	AC/HL	5B15	4·0	1·0	200	(52)
MARCONI ..	H2	4B4	2·0	0·1	150	(53)
	HL21	4B4	2·0	0·1	150	(54)
	HL2	4B4	2·0	0·1	150	(55)
	HL2/K	4B4	2·0	0·1	150	(56)
	HL210	4B4	2·0	0·1	150	(57)
	L21	4B4	2·0	0·1	150	(58)
	L210	4B4	2·0	0·1	150	(59)
	H42	7B18	4·0	0·6	250	(60)
	MH41	5B15	4·0	1·0	200	(61)
	MH4	5B15	4·0	1·0	200	(62)
	MHL4	5B15	4·0	1·0	250	(63)
	H63	039	6·3	0·3	250	(64)
	L63	034	6·3	0·3	250	(65)
	H30	7B18	13·0	0·3	250	(66)
	L30	7B17	13·0	0·3	200	(67)
	DH	5B15	16·0	0·25	200	(68)
	ET1	4B1	1·0	0·1	4–10	(69)
	H11	4DS1	1·0	0·1	100	(70)
	L11	4D51	1·0	0·1	100	(71)
	H12	4D1	2·0	0·06	100	(72)
	L12	4D1	2·0	0·06	100	(73)
	A537	4DS	4·0	0·4	150	(74)
	A577	5B14	4·0	1·0	250	(75)
	MH40	5B15	4·0	1·0	200	(76)
	HA1	Acorn	4·0	0·25	180	(77)
	HA2	Acorn	6·3	0·15	180	(78)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Amp. Factor	Impedance (Ohms)	Slope (mA/V)	Bias Volts	Anode Current (mA)	Bias Res. (Ohms)
(28)	—	—	3·3	−3·7	5·0	—
(29)	100	—	3·0	—	—	—
(30)	30	21,500	1·4	−1·5	2·2	—
(31)	18	12,000	1·5	−4·5	4·0	—
(32)	18	12,000	1·5	−4·5	2·0	—
(33)	72	20,600	3·5	−2·0	2·2	—
(34)	40	11,500	3·5	−4·5	6·5	—
(35)	40	12,000	3·3	−3·7	5·0	—
(36)	40	12,500	3·3	−3·0	4·0	650
(37)	40	12,500	3·3	−3·0	3·7	650
(38)	40	12,500	3·3	−3·0	4·0	650
(39)	25	50,000	0·5	0	0·45	—
(40)	20	50,000	0·4	0	0·45	—
(41)	28	50,000	0·56	0	0·45	—
(42)	21	38,000	0·56	0	0·65	—
(43)	25	22,000	1·15	−3	1·1	—
(44)	16	12,000	1·35	−4·5	2·4	—
(45)	16	12,000	1·35	−4·5	2·4	—
(46)	12	7,500	1·6	−6·0	4·2	—
(47)	35	10,000	3·5	−2·75	6·0	460
(48)	35	10,000	3·5	−2·75	6·0	460
(49)	50	45,000	1·1	—	—	—
(50)	35	22,000	1·6	—	—	—
(51)	20	10,000	2·0	—	—	—
(52)	40	10,000	4·0	—	—	—
(53)	35	35,000	1·1	−1·5	1·5	—
(54)	27	18,000	1·5	−1·5	2·0	—
(55)	27	18,000	1·5	−1·5	2·0	—
(56)	27	18,000	1·5	−1·5	2·0	—
(57)	24	20,000	1·2	−3	1·2	—
(58)	16	8,900	1·8	−6·0	2·2	—
(59)	11	12,000	0·9	−7·5	2·5	—
(60)	100	66,000	1·5	−2	1·0	—
(61)	80	13,000	6·0	−2·0	—	400
(62)	40	11,100	3·6	−3·0	—	700
(63)	20	8,000	2·5	−9	5·5	850
(64)	100	66,000	1·5	−2·0	1·0	2,000
(65)	20	7,700	2·6	−9	7·5	—
(66)	80	13,300	6·0	−2·5	3·0	—
(67)	12	2,860	4·2	−10	20	—
(68)	40	10,800	3·7	—	—	—
(69)	—	—	0·08	—	—	—
(70)	15	30,000	0·5	0	—	—
(71)	4·4	7,700	0·57	0	—	—
(72)	26	108,000	0·24	0	—	—
(73)	4·8	6,000	0·8	—	2·5	—
(74)	15·5	10,000	1·55	—	—	—
(75)	6	3,000	2·0	—	—	—
(76)	45	18,000	2·5	—	—	—
(77)	25	12,500	2·0	−5·0	4·5	—
(78)	25	12,500	2·0	−5·0	4·5	—

[*Continued on next page*

TABLE XXXI: GENERAL-

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
MAZDA ..	H2	4B4	2·0	0·1	150	(79)
	HL2	4B4	2·0	0·1	150	(80)
	L2	4B4	2·0	0·1	150	(81)
	AC/HL	5B15	4·0	1·0	200	(82)
	AC2/HL	5B15	4·0	1·0	200	(83)
	HL41	0M19	4·0	0·65	250	(84)
	P41	0M19	4·0	0·95	250	(85)
	AC/P4	5B13	4·0	1·0	700	(86)
	HL1320	7B18	13·0	0·2	250	(87)
	HL133	0M20	13·0	0·2	250	(88)
	DC3HL	5B15	25·0	0·1	200	(89)
MULLARD ..	DC51	4D1	1·5	0·067	45	(90)
	DA1	4D1	2·0	0·05	40	(91)
	PM1A	4B4	2·0	0·1	150	(92)
	PM1HF	4B4	2·0	0·1	150	(93)
	PM1HL	4B4	2·0	0·1	135	(94)
	PM2HL	4B4	2·0	0·1	135	(95)
	PM1LF	4B4	2·0	0·1	150	(96)
	PM2DX	4B4	2·0	0·1	135	(97)
	PM2DL	4B4	2·0	0·1	135	(98)
	AT4	Acorn	4·0	0·25	200	(99)
	994V	5B15	4·0	0·65	200	(100)
	904V	5B15	4·0	0·65	200	(101)
	484V	5B15	4·0	1·0	200	(102)
	354V	5B15	4·0	0·65	250	(103)
	244V	5B15	4·0	0·65	200	(104)
	154V	5B15	4·0	0·65	200	(105)
	4761	Acorn	6·3	0·15	180	(106)
	HL13	8S20	13·0	0·2	200	(107)
	HL13C	7B18	13·0	0·2	200	(108)
OSRAM ..	H2	4B4	2·0	0·1	150	(109)
	HL2	4B4	2·0	0·1	150	(110)
	HL2/K	4B4	2·0	0·1	150	(111)
	HL210	4B4	2·0	0·1	150	(112)
	H210	4B4	2·0	0·1	150	(113)
	L21	4B4	2·0	0·1	150	(114)
	H42	5B15	4·0	0·6	250	(115)
	MH41	5B15	4·0	1·0	250	(116)
	MH4	5B15	4·0	0·1	250	(117)
	MHL4	5B15	4·0	1·0	250	(118)
	H63	039	6·3	0·3	250	(119)
	L63	039	6·3	0·3	250	(120)
	H30	5B15	13·0	0·3	250	(121)
	DH	5B15	16·0	0·25	200	(122)
	H12	4D1	2·0	0·06	100	(123)
	A577	5B14	4·0	1·0	250	(124)
	MH40	5B15	4·0	1·0	200	(125)
	HA1	Acorn	4·0	0·25	180	(126)
	HA2	Acorn	6·3	0·15	180	(127)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Amp. Factor	Impedance (Ohms)	Slope (mA/V)	Bias Volts	Anode Current (mA)	Bias Res. (Ohms)
(79)	50	45,000	1·1	0	2·5	—
(80)	32	21,000	1·5	–1·5	2·7	—
(81)	19	10,000	1·9	–3·0	5·3	—
(82)	35	11,700	3·0	–3·5	5·0	700
(83)	75	11,500	6·5	–1·75	4·5	390
(84)	36	10,300	3·5	–3·1	2·2	1,400
(85)	17	—	8·0	–10	30·0	—
(86)	20	2,800	7·0	–35	5·0	—
(87)	30	10,000	3·0	–4·5	7·5	600
(88)	36	10,600	3·4	–1·95	1·3	1,500
(89)	35	11,700	3·0	–3·5	5·0	700
(90)	25	66,000	0·38	0	0·34	—
(91)	32	80,000	0·4	0·25	0·25	—
(92)	50	41,600	1·2	–1·0	1·0	—
(93)	18	22,500	0·8	–3 –4·5	1·5	—
(94)	28	23,400	1·2	–1·5	2·3	—
(95)	30	21,500	1·4	–1·5	2·2	—
(96)	11	12,000	0·9	–7·5	4·0	—
(97)	18	18,000	1·0	–4·5	2·0	—
(98)	18	12,000	1·5	–4·5	2·0	—
(99)	25	12,500	2·0	–6·0	4·5	—
(100)	135	35,000	3·6	–1·5	1·35	1,000
(101)	72	20,600	3·5	–2·0	2·2	900
(102)	48	21,800	2·2	–3·0	2·8	1,000
(103)	40	11,500	3·5	–4·5	6·5	700
(104)	25	9,000	2·8	–5·5	5·5	1,000
(105)	15	7,500	2·0	–7·5	9·0	800
(106)	25	12,500	2·0	–5·0	4·5	—
(107)	40	12,000	3·3	–3·7	5·0	740
(108)	40	12,000	3·3	–3·7	5·0	740
(109)	35	35,000	1·0	–1·5	1·5	—
(110)	27	18,000	1·5	–1·5	2·0	—
(111)	27	18,000	1·5	–1·5	2·0	—
(112)	24	20,000	1·2	—	—	—
(113)	35	50,000	0·7	—	—	—
(114)	16	8,900	1·8	–6·0	2·2	—
(115)	100	66,000	1·7	–2·0	1·0	2,000
(116)	80	13,300	6·0	–2·5	3·6	700
(117)	40	11,000	3·6	–4·0	5·0	750
(118)	20	8,000	2·5	–8·0	8·0	1,000
(119)	100	66,000	1·5	–2·0	1·0	2,000
(120)	20	7,700	2·6	—	—	—
(121)	80	13,300	6·0	—	—	—
(122)	40	10,800	3·7	—	—	—
(123)	26	21,600	1·2	—	—	—
(124)	6·0	3,000	2·0	—	—	—
(125)	45	18,750	2·4	—	—	—
(126)	20	11,700	1·7	–6·5	4·5	—
(127)	25	12,500	2·0	—	—	—

[*Continued on next page*

TABLE XXXI: GENERAL-

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
RECORD ..	H2	4B4	2·0	0·1	200	(128)
	L2	4B4	2·0	0·12	150	(129)
	DL2	4B4	2·0	0·1	150	(130)
	AC/NHL	5B15	4·0	0·65	250	(131)
	NHL/13	7B18	13·0	0·2	200	(132)
	NHL/13L	8S20	13·0	0·2	200	(133)
TRIOTRON ..	HD2	4B4	2·0	0·08	200	(134)
	TD2	4B4	2·0	0·1	150	(135)
	A214	4B4	2·0	0·1	150	(136)
	W213	4B4	2·0	0·1	150	(137)
	A440N	5B15	4·0	1·0	200	(138)
	A2040N	5B15	20·0	0·18	200	(139)
TUNGSRAM ..	HR2	4B4	2·0	0·06	135	(140)
	HR210	4B4	2·0	0·1	200	(141)
	HL2	4B4	2·0	0·13	135	(142)
	LD210	4B4	2·0	0·1	150	(143)
	LL2	4B4	2·0	0·2	135	(144)
	HL4+	5B15	4·0	0·65	250	(145)
	HL4g	7B18	4·0	0·65	250	(146)
	LL4C	5B13	4·0	1·2	350	(147)
	HL13	7B18	13·0	0·2	200	(148)

TABLE XXXII: POWER

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
BRIMAR ..	PA1	5B15	4·0	1·1	200	(1)
COSSOR ..	215P	4B4	2·0	0·15	150	(2)
	220P	4B4	2·0	0·2	150	(3)
	220PA	4B4	2·0	0·2	150	(4)
	230XP	4B4	2·0	0·3	150	(5)
	2P	4B4	2·0	2·0	250	(6)
	2XP	4B4	2·0	2·0	300	(7)
	41MP	5B15	4·0	1·0	200	(8)
	41MXP	SB15	4·0	1·0	200	(9)
	4XP	4B4	4·0	1·0	250	(10)
	DP	7B18	16·0	0·25	200	(11)
	402P	7B18	40·0	0·2	200	(12)
DARIO ..	TB052	4B4	2·0	0·15	150	(13)
	TB062	4B4	2·0	0·33	150	(14)
	TB032	4B4	2·0	0·2	150	(15)
	TF104	4B4	4·0	2·0	550	(16)
	TF364	4B4	4·0	2·0	400	(17)
	TD044	4B4	4·0	0·65	250	(18)
	TD4	4B4	4·0	1·0	300	(19)
EVER READY ..	K30G	4B4	2·0	0·2	135	(20)
	S30C	4B4	4·0	1·0	300	(21)
	S30D	4B4	2·0	2·0	300	(22)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Amp. Factor	Impedance (Ohms)	Slope (mA/V)	Bias Volts	Anode Current (mA)	Bias Res. (Ohms)
(128)	30	23,000	1·3	–3·0	1·0	—
(129)	17	15,000	1·2	–5·0	3·2	—
(130)	18	14,000	1·3	–4·5	3·0	—
(131)	33	11,000	3·5	–4·5	5·0	1,000
(132)	30	12,000	3·5	–4·0	6·0	1,000
(133)	30	12,000	3·5	–4·0	6·0	1,000
(134)	15	15,000	1·0	–5·0	5·0	—
(135)	10	8,000	1·25	–6·0	5·0	—
(136)	17	12,000	1·4	–4·5	4·0	—
(137)	28	22,000	1·3	–2·5	1·0	—
(138)	100	25,000	4·0	–1·6	1·0	—
(139)	100	25,000	4·0	–1·5	0·2	—
(140)	25	40,000	0·6	–1·5	1·2	—
(141)	30	23,000	1·3	–3·0	1·0	—
(142)	30	21,000	1·5	–1·5	2·2	—
(143)	18	14,000	1·3	–4·5	3·0	—
(144)	30	11,500	2·6	–2·5	3·0	—
(145)	33	11,000	3·5	–4·5	5·0	1,000
(146)	33	11,000	3·5	–4·5	5·0	1,000
(147)	10	—	3·5	—	—	—
(148)	30	12,000	3·5	–5·5	6·0	1,000

OUTPUT TRIODES

	Impedance	Slope (mA/V)	Bias Volts	Anode Current (mA)	Bias Res. (Ohms)	Output (mW)	Optimum Load (Ohms)
(1)	1,050	12·0	–9·0	50·0	260	1,250	4,000
(2)	4,000	2·25	–7·5	10·0	—	150	9,000
(3)	4,000	2·25	–7·5	11·0	—	190	9,000
(4)	4,000	4·0	–4·5	10·0	—	180	9,000
(5)	1,500	3·0	–18·0	22·0	—	450	3,500
(6)	1,150	7·0	–22·0	40·0	—	—	3,000
(7)	900	7·0	–36·0	50·0	—	—	4,000
(8)	2,500	7·5	–7·5	24·0	320	1,250	3,000
(9)	1,500	7·5	–12·5	40·0	300	2,000	2,000
(10)	900	7·0	–28·5	48·0	600	3,000	3,000
(11)	2,800	6·0	–7·5	25·0	300	—	3,500
(12)	1,330	7·5	–9·5	30·0	320	—	2,500
(13)	4,200	1·2	–18·0	7·0	—	150	11,000
(14)	3,000	2·0	–10·5	13·0	—	1,550	6,000
(15)	2,000	1·5	–30·0	12·0	—	500	6,000
(16)	2,500	4·0	–36·0	45·0	—	—	—
(17)	3,000	3·8	–92·0	63·0	—	—	—
(18)	1,300	2·7	–40·0	40·0	—	—	—
(19)	1,200	5·0	–38·0	48·0	—	—	—
(20)	6,000	2·0	–6·0	5·0	—	150	7,000
(21)	1,200	5·0	–38·0	50·0	600	3,500	2,300
(22)	1,200	5·0	–38·0	50·0	600	3,500	2,300

[*Continued on next page*

TABLE XXXII: POWER

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
FERRANTI	L2	4B4	2·0	0·1	150	(23)
	LP4	4B4	4·0	1·0	250	(24)
HIVAC ..	XL1·5V	4D1	1·5	0·08	50	(25)
	XLO1·5V	4D1	1·5	0·08	50	(26)
	XP1·5V	4D1	1·5	0·08	50	(27)
	XL2·0V	4D1	2·0	0·08	50	(28)
	XLO2·0V	4D1	2·0	0·08	50	(29)
	XP2·0V	4D1	2·0	0·08	50	(30)
	P215	4B4	2·0	0·15	150	(31)
	P220	4B4	2·0	0·2	150	(32)
	PP220	4B4	2·0	0·2	150	(33)
	PX230	4B4	2·0	0·3	150	(34)
	PX230SW	4B11	2·0	0·3	150	(35)
	AC/L	5B15	4·0	1·0	200	(36)
	PX41	4B4	4·0	1·0	250	(37)
	PX5	4B4	4·0	2·0	400	(38)
LISSEN ..	LP2	4B4	2·0	0·2	150	(39)
	P220	4B4	2·0	0·2	150	(40)
	PX240	4B4	2·0	0·4	200	(41)
MARCONI ..	LP2	4B4	2·0	0·2	150	(42)
	P215	4B4	2·0	0·15	150	(43)
	P2	4B4	2·0	0·2	150	(44)
	ML4	5B15	4·0	1·0	200	(45)
	PX4	4B4	4·0	1·0	300	(46)
	PX25	4B4	4·0	2·0	400	(47)
	PX25A	4B4	4·0	2·0	400	(48)
	DA30	4B4	4·0	2·0	500	(49)
	DA60	4L1	6·0	4·0	500	(50)
	DA100	4L1	6·0	2·7	1,000	(51)
	DA250	4M1	10·0	2·0	2,500	(52)
	DA41	4UX1	7·5	2·5	1,000	(53)
	DL	5B15	16·0	0·25	200	(54)
MAZDA ..	P220	4B4	2·0	0·2	150	(55)
	P220A	4B4	2·0	0·2	150	(56)
	PA20	4B4	2·0	2·0	300	(57)
	AC/P	5B15	4·0	1·0	200	(58)
	AC/P1	5B15	4·0	1·0	200	(59)
	PP5/400	4B4	4·0	2·0	400	(60)
	PP3/250	4B4	4·0	1·0	300	(61)
Per pair in push-pull	PA40	4B4	4·0	2·0	400	(62)
	PP3521	7B17	35·0	0·2	250	(63)
	DC2/P	5B15	35·0	0·1	200	(64)
MULLARD	DD51	4D1	1·5	0·67	45	(65)
	DA2	4D1	2·0	0·05	40	(66)
	DA3	4D1	2·0	0·05	40	(67)
	PM2A	4B4	2·0	0·2	135	(68)
	PM2	4B4	2·0	0·2	150	(69)
	PM252	4B4	2·0	0·2	150	(70)
	PM202	4B4	2·0	0·2	150	(71)
	164V	5B15	4·0	0·65	200	(72)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Impedance	Slope (mA/V)	Bias Volts	Anode Current (mA)	Bias Res. (Ohms)	Output (mW)	Optimum Load (Ohms)
(23)	6,800	1·6	—	5·6	—	—	—
(24)	980	5·5	−35·0	48·0	730	2,800	2,500
(25)	20,000	0·6	−1·0	0·7	—	—	—
(26)	20,000	0·65	−1·0	0·9	—	—	—
(27)	7,250	0·72	−4·5	1·75	—	—	—
(28)	12,500	0·84	−1·0	1·0	—	—	—
(29)	12,500	0·92	−1·1	1·1	—	—	—
(30)	6,000	1·0	−3·0	2·0	—	—	—
(31)	3,600	2·2	−12	8·0	—	150	10,000
(32)	4,700	3·0	−7·5	6·0	—	175	9,000
(33)	2,300	3·0	−12·0	12·5	—	250	5,000
(34)	1,850	3·5	−15·0	17·5	—	450	4,000
(35)	1,850	3·5	−15·0	17·5	—	450	4,000
(36)	2,350	4·25	−13·5	17·0	760	675	6,300
(37)	830	6·0	−40·0	48·0	830	2,500	3,500
(38)	1,480	6·5	−34·0	62·5	530	5,750	3,000
(39)	3,500	3·5	—	—	—	200	—
(40)	4,000	1·75	—	—	—	100	—
(41)	1,500	3·0	—	—	—	800	—
(42)	3,900	3·85	−6·0	7·0	—	—	9,700
(43)	5,000	1·4	−12·0	8·5	—	—	12,000
(44)	2,150	3·5	−12·0	14·0	—	200	6,000
(45)	2,860	4·2	−8·0	25	400	—	6,000
(46)	830	6·0	−50·0	50·0	1,000	4,500	3,500
(47)	1,265	7·5	−30·0	6·25	530	5,500	4,000
(48)	580	6·9	−103·0	62·5	1,630	8,400	4,500
(49)	910	3·85	−134·0	60·0	—	—	—
(50)	835	3·0	−135·0	120·0	1,100	—	2,800
(51)	1,410	3·9	−150·0	100·0	—	—	—
(52)	2,300	7·0	−130·0	80·0	—	—	—
(53)	17,500	3·6	0	—	—	—	—
(54)	2,660	4·5	—	—	—	—	—
(55)	3,700	3·4	−7·0	5·5	—	180	10,000
(56)	1,850	3·5	−14·0	15·0	—	350	4,100
(57)	1,000	6·5	−29·0	42·0	690	2,650	2,750
(58)	2,650	3·75	−13·5	17·0	750	650	6.000
(59)	1,450	3·7	−28·0	24·0	1,200	1,000	5,000
(60)	1,500	6·0	−32·0	62·5	510	5,900	2,700
(61)	1,000	6·5	−30·0	42·0	715	2,650	2,750
(62)	425	4·5	−85·0	210·0	400	33,500	3,700
(63)	600	10·0	−25·0	70·0	360	2,300	2,000
(64)	2,650	3·75	−13·5	17·0	800	650	6,000
(65)	10,000	0·5	−3·0	1·7	—	—	—
(66)	13,600	0·5	−2·15	1·25	—	—	—
(67)	7,600	0·62	−2·8	1·8	—	—	—
(68)	6,000	2·0	−6·0	5·0	—	150	7,000
(69)	4,400	1·7	−12·0	6·6	—	—	9,000
(70)	2,000	3·5	−12·0	14·0	—	—	3,700
(71)	2,000	3·5	−12·0	14·0	—	—	3,700
(72)	3,640	4·5	−8·5	13·0	—	—	—

[*Continued on next page*

TABLE XXXII: POWER

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
MULLARD—*continued*	104V	5B15	4·0	1·0	250	(73)
	TT4	5B15	4·0	1·0	250	(74)
	TT4A	5B15	4·0	1·0	250	(75)
	AC104	4B4	4·0	1·0	200	(76)
	AC064	4B4	4·0	1·0	200	(77)
	AC044	4B4	4·0	1·0	300	(78)
	AC042	4B4	2·0	2·0	300	(79)
	D024	4B4	4·0	1·85	400	(80)
	D026	4B4	4·0	2·0	400	(81)
	D030	4B4	4·0	1·85	500	(82)
	D010	4B4	6·0	0·85	400	(83)
	D025	4B4	6·0	1·1	400	(84)
	D020	4B4	7·5	1·1	425	(85)
	EC31	034	6·3	0·65	250	(86)
OSRAM ..	L12	4D1	2·0	0·06	100	(87)
	LP2	4B4	2·0	0·2	150	(88)
	P215	4B4	2·0	0·15	150	(89)
	P2	4B4	2·0	0·2	150	(90)
	ML4	5B15	4·0	1·0	250	(91)
	PX4	4B4	4·0	1·0	300	(92)
	PX25	4B4	4·0	2·0	400	(93)
	PX25A	4B4	4·0	2·0	400	(94)
	DA30	4B4	4·0	2·0	500	(95)
	DET 5	4B4	4·0	2·0	600	(96)
	DA60	4L1	6·0	4·0	500	(97)
	DA100	4L1	6·0	2·7	1,000	(98)
Double	DET19	7UX10	6·3	0·8	300	(99)
	DA41	4UX3	7·5	2·5	1,000	(100)
	DET12	4B4	7·5	3·2	1,250	(101)
	DET14	4UX3	7·5	3·0	1,500	(102)
	DA250	4M1	10·0	2·0	2,500	(103)
	DL	5B15	16·0	0·25	200	(104)
TRIOTRON	ZD2	4B4	2·0	0·15	150	(105)
	UD2	4B4	2·0	0·33	150	(106)
	E235	4B4	2·0	0·2	150	(107)
	E430N	5B15	4·0	1·0	200	(108)
	K480	4B4	4·0	2·0	550	(109)
	K435/10	4B4	4·0	0·65	250	(110)
	T1325	7B49	13·0	0·2	200	(111)
TUNGSRAM	LP220	4B4	2·0	0·2	150	(112)
	P215	4B4	2·0	0·15	150	(113)
	SP220	4B4	2·0	0·2	150	(114)
	LL4	5B15	4·0	1·2	350	(115)
	P12/250	4B4	4·0	1·0	250	(116)
	P15/250	4B4	4·0	1·0	250	(117)
	015/400	4B4	4·0	1·0	400	(118)
	P26/500	4B4	4·0	2·0	500	(119)
	P27/500	4B4	4·0	2·0	500	(120)
	P25/500	4B4	6·0	1·1	500	(121)
	P60/500	4L1	6·0	4·0	600	(122)
	P25/450	4B4/4UX3	7·5	1·25	450	(123)
	PX2100	4B4	7·5	1·25	425	(124)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

OUTPUT TRIODES—*continued*

	Impedance	Slope (mA/V)	Bias Volts	Anode Current (mA)	Bias Res. (Ohms)	Output (mW)	Optimum Load (Ohms)
(73)	3,300	3·2	−16·0	20·0	—	500	10,000
(74)	3,300	3·2	−16·0	20·0	—	500	10,000
(75)	4,400	4·1	−9·0	20·0	—	400	5,000
(76)	2,850	3·5	−14·0	11·0	1,500	400	6,000
(77)	2,000	3·0	−21·0	20·0	1,000	620	5,000
(78)	1,200	5·0	−38·0	50·0	—	3,500	2,300
(79)	1,200	5·0	−38·0	50·0	—	3,500	2,300
(80)	1,070	7·5	−40·0	63·0	—	7,100	3,200
(81)	950	3·8	−92·0	63·0	1,500	7,500	3,000
(82)	890	3·5	−140·0	60·0	—	—	—
(83)	2,850	0·85	−130·0	25·0	5,500	2,500	6,000
(84)	800	3·75	−112·0	63·0	1,780	7,000	4,000
(85)	2,000	2·5	−66·0	40·0	1,650	5,000	5,000
(86)	3,300	3·2	−16·0	20·0	—	500	10,000
(87)	6,000	0·8	−4·5	1·9	—	1·2	—
(88)	4,170	3·6	−6·0	5·6	—	100	—
(89)	5,000	1·4	—	—	—	—	—
(90)	2,150	3·5	−12·0	14·0	—	200	—
(91)	2,860	4·2	−16·0	14·0	1,000	—	7,000
(92)	830	6·0	−42·0	50·0	900	3,500	4,000
(93)	1,265	7·5	−31·0	62·5	530	5,500	3,200
(94)	580	6·9	−103·0	62·5	1,630	8,400	4,500
(95)	580	6·9	−134·0	60·0	—	11,000	6,000
(96)	1,265	7·0	—	—	—	35,000	—
(97)	835	3·0	−135·0	120·0	1,100	—	2,800
(98)	1,410	3·9	−150·0	100·0	—	30,000	6,800
(99)	3,340	2·1	—	—	—	16,000	—
(100)	17,500	3·6	—	—	—	—	—
(101)	—	—	—	—	—	70,000	—
(102)	—	—	—	—	—	80,000	—
(103)	2,290	7·0	−130·0	80·0	—	800,000	12,000
(104)	2,660	4·5	—	—	—	—	—
(105)	4,200	1·2	−18·0	7·0	—	—	—
(106)	2,000	2·0	−15·0	12·0	—	—	—
(107)	3,000	3·0	−7·5	13·0	—	—	—
(108)	7,000	1·3	−16·0	12·0	—	—	—
(109)	2,500	4·0	−36·0	45·0	—	—	—
(110)	1,300	2·7	−40·0	40·0	—	—	—
(111)	—	3·3	−3·7	5·0	—	—	—
(112)	3,500	3·5	−6·0	5·0	—	200	7,500
(113)	3,300	1·5	−12·0	8·0	—	260	7,000
(114)	2,200	3·0	−18·0	14·0	—	360	6,700
(115)	—	3·5	—	24·0	—	—	—
(116)	850	6·0	−33·0	48·0	700	2,800	2,400
(117)	660	6·0	−44·0	60·0	750	3,500	2,500
(118)	1,800	5·0	−38·0	30·0	1,000	3,700	7,000
(119)	670	4·7	−100·0	62·5	1,600	6,500	5,000
(120)	1,100	8·0	−32·0	62·5	500	5,000	4,000
(121)	1,000	3·0	−112·0	62·5	1,950	4,000	7,000
(122)	1,000	3·5	−125·0	116·0	1,080	15,000	3,000
(123)	2,000	2·0	−82·0	55·0	1,500	5,100	5,000
(124)	5,000	1·6	−39·0	18·0	2,000	1,600	10,200

TABLE XXXIII: OUTPUT PENTODES

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
BRIMAR ..	6F6G	—	6·3	0·7	250	(1)
	6V6G	—	6·3	0·45	250	(2)
	25A6G	—	25·0	0·3	180	(3)
	PENB1	5B4	2·0	0·2	150	(4)
	7A2	5B18/7B31	4·0	1·2	250	(5)
	7A3	7B31	4·0	2·0	250	(6)
	PENA1	5B4	4·0	1·0	250	(7)
	7D5	7B31	13·0	0·315	250	(8)
	7D8	7B31	13·0	0·65	250	(9)
	7D3	7B31	40·0	0·2	180	(10)
	7D6	7B31	40·0	0·2	250	(11)
COSSOR ..	210PT	4B6/5B4	2·0	0·2	150	(12)
	220HPT	4B6/5B4	2·0	0·2	150	(13)
(Tetrode)	220 0T	5B3	2·0	0·2	150	(14)
	230PT	4B6/5B4	2·0	0·3	150	(15)
	PT41	5B4	4·0	1·0	250	(16)
	PT41B	5B4	4·0	1·0	400	(17)
	MP Pen	5B18/7B27	4·0	1·0	250	(18)
	42MP Pen	7B27	4·0	2·0	250	(19)
	41MPT	7B23	4·0	1·0	250	(20)
	42MPT	7B23	4·0	2·0	250	(21)
	41MTS	7B43	4·0	1·0	250	(22)
	PT10	7B27	4·0	2·0	250	(23)
(Tetrode)	42 0T	7B20	4·0	2·0	250	(24)
	DP/Pen	7B27	16·0	0·25	250	(25)
(Tetrode)	402 0T	7B21	40·0	0·2	250	(26)
	40PPA	7B27	40·0	0·2	150	(27)
	402 Pen	7B29	40·0	0·2	250	(28)
	402 Pen/A	7B29	40·0	0·2	150	(29)
DARIO ..	TC432	4B6/5B4	2·0	0·2	150	(30)
	TC434	5B4	4·0	0·25	300	(31)
	TE534	7B27	4·0	1·1	250	(32)
	TE434	5B4	4·0	1·1	250	(33)
	TE634	5B18/7B27	4·0	1·35	250	(34)
	TL44	7B27	4·0	1·75	250	(35)
	TL54	7B27	4·0	2·0	250	(36)
	TL413	7B27	33·0	0·2	200	(37)
	TB4320	8S22	24·0	0·2	200	(38)
	TBL226	5B4	24·0	0·18	200	(39)
EKCO ..	OP41	7B27	4·0	1·8	300	(40)
	0P42	7B27	4·0	1·8	250	(41)
EVER READY	K70B	5B4	2·0	0·15	135	(42)
	K70D	5B4	2·0	0·3	135	(43)
	A70B	7B27	4·0	1·35	250	(44)
	A70D	7B27	4·0	1·95	250	(45)
	A70E	7B27	4·0	2·1	250	(46)
	EL32	030	6·3	0·2	250	(47)
	EL3/33	8S23/048	6·3	0·9	250	(48)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Screen Volts	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode and Screen Current (mA)	Output (mW)	Optimum Load (Ohms)
(1)	250	2·35	−16·5	410	40·5	3,000	7,000
(2)	250	4·10	−12·5	240	49·5	4,250	5,000
(3)	135	2·5	−20	440	45	2,750	5,000
(4)	150	2·5	−4·5	—	9·6	—	18,000
(5)	250	3·2	−17·5	330	38·5	3,500	8,000
(6)	250	10·0	−6	150	38·0	3,750	8,500
(7)	250	3·6	−16·5	450	38·5	2,700	8,000
(8)	250	2·35	−16·5	410	40·5	3,000	7,000
(9)	250	10·0	−6	150	38·0	3,750	8,500
(10)	135	2·5	−20	440	45·0	2,750	5,000
(11)	250	10·0	−6	150	38·0	3,750	8,500
(12)	150	2·5	−7·5	—	—	—	8,000
(13)	150	2·5	−3·0	—	—	—	20,000
(14)	150	2·5	−4·5	—	—	—	20,000
(15)	150	2·0	−15·0	—	23·0	—	10,000
(16)	200	3·0	−12·5	350	36·0	—	8,000
(17)	300	2·25	−33·0	—	—	—	8,000
(18)	250	3·5	−16·0	450	36·0	—	10,000
(19)	250	7·0	−5·5	140	38·0	—	8,000
(20)	200	4·8	—	—	—	—	—
(21)	250	7·0	—	—	—	—	—
(22)	100	1·6	—	—	—	—	—
(23)	250	9·0	−7·5	—	—	—	5,000
(24)	250	7·0	−5·5	130	—	—	6,500
(25)	250	3·5	−10·0	300	—	—	10,000
(26)	250	7·0	−6·6	—	—	—	5,500
(27)	150	4·0	−25·0	600	42·0	—	4,000
(28)	250	7·0	−6·7	140	—	—	5,500
(29)	150	8·0	−9·0	—	—	—	2,500
(30)	150	2·4	−4·5	—	—	—	—
(31)	200	1·7	−25·0	—	—	—	—
(32)	250	2·5	−15·0	—	—	—	—
(33)	250	2·8	−14·0	—	—	—	—
(34)	250	2·7	−22·0	—	—	—	—
(35)	250	9·5	—	—	—	—	—
(36)	275	8·5	—	—	—	—	—
(37)	200	8·0	−8·5	—	—	—	—
(38)	100	3·1	−19·0	—	—	—	—
(39)	—	8·0	−19·0	—	—	—	—
(40)	250	9·0	−13·0	200	66·0	8,000	4,000
(41)	250	11·0	−6·0	145	36·5	3,800	8,000
(42)	135	2·2	−4·5	—	—	340	19,000
(43)	135	3·0	−2·4	—	—	300	24,000
(44)	250	2·8	−22·0	—	—	3,800	6,000
(45)	250	9·5	−5·8	—	—	3,800	8,000
(46)	275	8·5	−14·0	—	—	8,800	3,500
(47)	250	2·8	−18·0	—	—	3,600	8,000
(48)	250	9·0	−6·0	—	—	4,500	7,000

[*Continued on next page*

TABLE XXXIII: OUTPUT PENTODES

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
FERRANTI	PT4	7B27	4·0	2·0	250	(49)
	PTA	7B27	13·0	0·3	250	(50)
	PTSA	—	26·0	0·3	250	(51)
	PTZ	—	40·0	0·2	250	(52)
HIVAC ..	XY1·5V	5D2	1·5	0·16	45	(53)
	XY2·0V	5D2	2·0	0·16	50	(54)
(Tetrode)	Y220	4B12	2·0	0·2	150	(55)
,,	Z220	4B12	2·0	0·2	150	(56)
,,	AC/Y	5B18/7B27	4·0	1·0	250	(57)
,,	AC/YY	7B27	4·0	2·0	250	(58)
,,	AC/Z	7B27	4·0	2·0	250	(59)
,,	AC/Q	7B27	4·0	1·35	375	(60)
,,	FY	4B12	4·0	1·0	250	(61)
,,	AC/QA	7B27	6·3	0·9	375	(62)
,,	Y13	7B27	13·0	0·3	250	(63)
,,	Z26	7B27	26·0	0·3	250	(64)
LISSEN ..	PT225	4B6/5B4	2·0	0·2	150	(65)
	PT240	4B6/5B4	2·0	0·4	200	(66)
	PT2A	4B6/5B4	2·0	0·2	250	(67)
	PT425	4B6/5B4	4·0	0·25	200	(68)
	PT611	4B6	6·0	0·1	150	(69)
	AC/PT	5B4/7B27	4·0	1·0	250	(70)
MARCONI ..	N14	08	1·4	0·1	90	(71)
(Tetrode)	KT2	5B4	2·0	0·2	150	(72)
,,	PT2	5B4	2·0	0·2	150	(73)
,,	KT21	4B4	2·0	0·3	150	(74)
,,	KT24	4B4	2·0	0·2	150	(75)
,,	MKT4	7B27	4·0	1·0	250	(76)
,,	MPT4	7B27	4·0	1·0	250	(77)
,,	MPT4K	7B27	4·0	1·0	250	(78)
,,	KT41	7B27	4·0	2·0	250	(79)
,,	N40	7B27	4·0	1·0	250	(80)
,,	N41	7B27	4·0	2·0	250	(81)
,,	KT42	7B27	4·0	1·0	250	(82)
,,	N42	7B27	4·0	1·0	250	(83)
	N43	7B29	4·0	2·0	250	(84)
	PT4	5B4	4·0	1·0	250	(85)
	PT25	5B4	4·0	2·0	400	(86)
	PT25H	5B4	4·0	2·0	400	(87)
	PT16	5B4	4·0	1·0	300	(88)
,,	KT61	048	6·3	0·95	250	(89)
,,	KT63	048	6·3	0·7	250	(90)
,,	KT66	048	6·3	1·27	400	(91)
	N30	7B27	13·0	0·3	250	(92)
	KT30	7B27	13·0	0·3	250	(93)
	DPT	7B27/5B4	16·0	0·25	200	(94)
,,	KT31	7B46	13·0 26·0	0·6 0·3	200	(95)
	N31	7B46	13·0 26·0	0·6 0·3	200	(96)
,,	KT32	048	26·0	0·3	135	(97)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Screen Volts	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode and Screen Current (mA)	Output (mW)	Optimum Load (Ohms)
(49)	250	7·0	—	—	—	—	—
(50)	250	—	—	—	37·5	—	—
(51)	250	—	–8·9	—	37·5	—	—
(52)	250	—	—	—	47·0	—	—
(53)	45	1·0	–1·5	—	2·1	—	—
(54)	50	1·4	–2·0	—	2·15	—	—
(55)	150	2·5	–4·5	—	11·8	500	11,500
(56)	150	2·5	–6·0	—	20·1	1,000	7,500
(57)	250	3·5	–10·0	300	36·3	3,000	6,500
(58)	250	7·5	–10·0	140	78·0	5,000	3,000
(59)	250	8·0	–5·5	160	36·3	3,000	6,500
(60)	250	6·0	–22	370	59·5	11,500	4,000
(61)	250	5·0	–10	250	38·0	3,000	6,000
(62)	250	6·0	–22	370	59·5	11,500	4,000
(63)	250	4·0	–22	550	39·5	3,000	4,000
(64)	250	8·0	–11	250	44·0	3,000	4,000
(65)	150	1·6	—	—	—	300	—
(66)	150	2·3	—	—	—	1,000	—
(67)	150	2·5	—	—	—	1,100	—
(68)	150	2·3	—	—	—	1,000	—
(69)	150	1·4	—	—	—	300	—
(70)	250	4·0	—	—	—	2,500	—
(71)	90	1·55	–7·5	—	9·0	250	8,000
(72)	150	2·5	–4·5	—	9·2	500	17,000
(73)	150	2·5	–4·5	—	9·2	500	17,000
(74)	150	5·3	–2·5	—	12·3	750	10,000
(75)	150	3·2	–2·8	—	12·1	640	10,000
(76)	225	3·0	–13·5	360	37·0	3,200	7,000
(77)	200	3·0	–10·5	250	37·5	—	8,000
(78)	200	3·0	–10·5	250	37·0	—	8,000
(79)	250	10·5	–4·4	90	48·5	4,300	6,000
(80)	225	2·9	—	—	—	—	—
(81)	250	10·5	–4·4	90	48·5	4,300	6,000
(82)	250	2·5	–16·5	420	39·5	3,000	7,000
(83)	250	2·5	–16·5	420	39·5	3,000	7,000
(84)	250	10·0	–4·5	—	50·0	—	5,400
(85)	250	2·85	–10·0	400	38·0	2,500	7,500
(86)	200	4·0	—	—	—	—	—
(87)	400	6·5	–16·0	250	75·0	10,000	5,000
(88)	300	4·8	–15	270	63·0	—	5,000
(89)	250	10·5	–4·4	90	47·5	4,300	6,000
(90)	250	2·5	–16·5	420	39·5	3,000	7,000
(91)	300	6·3	–15	170	92·0	7,250	2,200
(92)	250	3·9	–14·0	375	37·0	2,600	7,500
(93)	250	3·9	–14·0	375	37·0	2,600	7,500
(94)	200	3·0	—	—	—	—	—
(95)	200	10·0	–4·5	95	54·0	3,000	6,500
(96)	180	10·0	–4·5	95	—	3,000	6,500
(97)	135	9·0	–7·6	95	80·0	3,500	1,300

[*Continued on next page*

TABLE XXXIII: OUTPUT PENTODES

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
MARCONI—*continued*	KT33C	048	26·0 / 13·0	0·3 / 0·6	200	(98)
	KT35	048	26·0 / 13·0	0·3 / 0·6	200	(99)
	KT44	7B23	4·0	2·0	400	(100)
MAZDA ..	PEN141	0M4	1·4	0·1	90	(101)
	PEN231	5B4	2·0	0·3	150	(102)
	PEN220	5B4	2·0	0·2	150	(103)
	PEN220A	5B4	2·0	0·2	150	(104)
	PEN24	0M4	2·0	0·3	150	(105)
	PEN25	0M4	2·0	0·15	150	(106)
	AC/PEN	7B27	4·0	1·0	250	(107)
	AC2/PEN	7B27	4·0	1·75	250	(108)
	AC4/PEN	7B20	4·0	1·75	250	(109)
	AC5/PEN	7B20	4·0	1·75	250	(110)
	AC6/PEN	7B47	4·0	1·75	330	(111)
	PEN44	0M22	4·0	2·1	275	(112)
	PEN45	0M22	4·0	1·75	250	(113)
	PEN46	0M23	4·0	1·75	330	(114)
	PEN1340	7B27	13·0	0·4	250	(115)
	PEN3520	7B27	35·0	0·2	250	(116)
	DC2/PEN	7B27	35·0	0·1	250	(117)
	PEN3820	7B20	38·0	0·2	200	(118)
	PEN383	0M22	38·0	0·2	200	(119)
MULLARD	DL1	8S8	1·4	0·05	90	(120)
	DL2	8S8	1·4	0·1	90	(121)
	DL51	4D3	1·5	0·134	45	(122)
	PM22	4B6/5B4	2·0	0·2	150	(123)
	PM22A	4B6/5B4	2·0	0·15	135	(124)
	PM22C	5B4	2·0	0·3	150	(125)
	PM22D	5B4	2·0	0·3	135	(126)
	PEN4VA	5B18/7B27	4·0	1·35	250	(127)
	PEN4VB	7B27	4·0	1·95	250	(128)
	PENA4	7B27	4·0	1·95	250	(129)
	PENB4	7B27	4·0	2·1	250	(130)
	PEN428	7B27	4·0	2·1	375	(131)
	PM24	4B6/5B4	4·0	0·15	150	(132)
	PM24A	5B4	4·0	0·275	300	(133)
	PM24M	5B4	4·0	1·1	250	(134)
	PM24B	5B4	4·0	1·0	400	(135)
	PM24C	5B4	4·0	1·0	400	(136)
	PM24E	5B4	4·0	2·0	500	(137)
	EL2/32	8S22/050	6·3	0·2	250	(138)
	EL3/33	8S23/048	6·3	0·9	250	(139)
	EL35	048	6·3	1·35	250	(140)
	EL6/36	8S23/048	6·3	1·3	250	(141)
	PEN13C	7B27	13·0	0·5	250	(142)
	PEN26	8S22	24·0	0·2	200	(143)
	PEN36C/ CL33	7B27/048	33·0	0·2	200	(144)
	CL4	8S22	33·0	0·2	200	(145)
	CL6	8S22	35·0	0·2	200	(146)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Screen Volts	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode and Screen Current (mA)	Output (mW)	Optimum Load (Ohms)
(98)	200	10·0	−13·2	188	70·0	5,000	3,000
(99)	200	10·0	−11·5	200	58·5	4,300	4,000
(100)	300	6·3	—	—	—	—	—
(101)	90	1·75	−8·1	—	5·0	210	10,000
(102)	150	5·3	−2·2	—	5·5	290	19,000
(103)	150	2·5	−4·5	—	6·0	350	17,000
(104)	150	2·5	−9·0	—	22·2	1,000	7,500
(105)	150	5·7	−3·3	—	6·0	440	16,000
(106)	150	4·5	−3·6	—	6·0	400	14,000
(107)	250	2·5	−15·5	250	32·0	3,300	7,500
(108)	250	8·0	−5·3	140	38·0	3,500	6,700
(109)	250	11·0	−8·75	114	77·0	6,900	3,300
(110)	250	9·0	−8·5	175	47·5	5,800	4,500
(111)	220	8·5	−6·9	90	77·0	—	—
(112)	275	11·0	−11·1	135	82·0	9,250	2,650
(113)	250	9·0	−8·5	175	47·5	4,850	5,200
(114)	220	8·5	−6·9	90	77·0	—	—
(115)	250	6·5	−8·6	175	49·0	4,000	5,500
(116)	250	7·0	−8·0	165	48·0	3,000	4,400
(117)	200	2·5	−10·0	300	30·0	2,300	10,000
(118)	200	12·0	−8·7	145	60·0	2,650	2,800
(119)	200	12·0	−8·7	145	60·0	2,650	2,800
(120)	90	1·25	−3·0	—	—	170	22,500
(121)	90	1·55	−7·5	—	—	240	8,000
(122)	45	1·5	−1·5	—	—	—	—
(123)	150	1·3	−10·0	—	19·0	600	8,000
(124)	135	2·2	−4·5	—	7·0	340	19,000
(125)	150	3·0	−20·0	—	27·0	1,450	8,000
(126)	135	3·0	−2·4	—	5·8	300	24,000
(127)	250	2·8	−22·0	500	39·0	3,800	6,000
(128)	250	9·5	−5·8	145	41·0	3,800	6,000
(129)	250	9·5	−5·8	145	41·0	3,800	8,000
(130)	275	8·5	−14·0	175	79·0	8,800	3,500
(131)	275	8·0	−20·5	165	71·0	8,000	6,500
(132)	150	1·75	−11·0	650	25·0	—	8,000
(133)	200	2·0	−22·5	1,000	23·5	—	10,000
(134)	250	3·0	−17·0	500	35·6	2,800	7,000
(135)	300	2·1	−40·0	1,100	37·0	—	8,000
(136)	200	3·0	−28·0	850	34·5	—	12,000
(137)	200	4·0	−35·0	750	59·0	—	7,000
(138)	250	2·8	−18·0	—	—	3,600	8,000
(139)	250	9·0	−6·0	—	—	4,500	7,000
(140)	250	5·0	−15·5	—	—	—	—
(141)	250	15·0	−7·0	—	—	8,000	3,500
(142)	250	6·0	−11·9	250	39·0	3,200	6,400
(143)	100	3·1	−19·0	420	45·0	3,000	5,000
(144)	200	8·0	−8·5	—	—	4,000	4,500
(145)	200	8·0	−8·5	—	—	4,000	4,500
(146)	100	8·0	−9·5	—	—	4,000	4,500

[*Continued on next page*

TABLE XXXIII: OUTPUT PENTODES

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
OSRAM ..	N14	08	1·4	0·1	90	(147)
	N15	012	1·4/2·8	0·05/0·1	90	(148)
(Tetrode)	KT2	5B4	2·0	0·2	150	(149)
,,	KT21	5B4	2·0	0·3	150	(150)
,,	KT24	5B4	2·0	0·2	150	(151)
	PT7	7B27	2·0	0·3	240	(152)
	ZA1	Acorn	4·0	0·25	250	(153)
,,	MKT4	5B18/7B27	4·0	1·0	250	(154)
	MPT4	7B27	4·0	1·0	250	(155)
,,	KT41	7B27	4·0	2·0	250	(156)
	N41	7B27	4·0	2·0	250	(157)
,,	KT42	7B27	4·0	1·0	250	(158)
	N42	7B27	4·0	1·0	250	(159)
	N43	7B29	4·0	2·0	250	(160)
	PT4	5B4	4·0	1·0	250	(161)
	PT5	5B4	4·0	1·0	1,250	(162)
	DET8	7B27	4·0	2·0	400	(163)
	PT10/14	7B23	4·0	1·25	500	(164)
	PT25	5B4	4·0	2·0	400	(165)
	PT25H	5B4	4·0	2·0	400	(166)
	KT73	048	6·0	0·4	175	(167)
	KT8	5B17	6·3	1·27	600	(168)
,,	KT61	048	6·3	0·95	250	(169)
,,	KT63	048	6·3	0·7	250	(170)
,,	KT66	048	6·3	1·27	400	(171)
	N30	7B27	13·0	0·3	250	(172)
	N30G	7B27	13·0	0·3	250	(173)
	KT30	7B27	13·0	0·3	250	(174)
,,	KT72	048	16·0	0·17	175	(175)
,,	KT74	048	15·0	0·16	175	(176)
	DPT	7B27/5B4	16·0	0·25	200	(177)
,,	KT31	7B46	26·0	0·3	200	(178)
	N31	7B46	26·0	0·3	200	(179)
,,	KT32	048	26·0	0·3	135	(180)
,,	KT35	046	26·0	0·3	200	(181)
	KT33C	046	26·0	0·6	200	(182)
RECORD ..	PT2	4B6/5B4	2·0	0·22	150	(183)
	PT2C	5B4	2·0	0·26	150	(184)
	AC/PT	5B18/7B27	4·0	1·2	350	(185)
	AC/PTA	5B18/7B27	4·0	1·2	250	(186)
	AC/PT4VB	7B27	4·0	2·0	250	(187)
	PT/24M	5B4	4·0	1·1	250	(188)
	PT/24DA	7B27	24·0	0·2	200	(189)
	PT/24DAL	8S23	24·0	0·2	200	(190)
	PT/35DA	7B27	35·0	0·2	200	(191)
TRIOTRON	P225	4B6/5B4	2·0	0·2	150	(192)
	P469	7B27	4·0	2·0	250	(193)
	P441N	7B27	4·0	1·35	250	(194)
	P440N	5B18/7B27	4·0	1·1	250	(195)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Screen Volts	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode and Screen Current (mA)	Output (mW)	Optimum Load (Ohms)
(147)	90	1·55	—	—	—	—	—
(148)	90	2·0	—	—	—	—	—
(149)	150	2·5	−4·5	—	9·5	—	17,000
(150)	150	5·3	−2·5	—	6·5	—	19,000
(151)	150	3·2	−3·2	—	12·0	800	10,000
(152)	150	—	—	—	—	1,500	—
(153)	100	1·4	—	—	—	—	—
(154)	225	3·0	−11·0	300	37·0	—	8,000
(155)	225	3·0	—	—	—	—	—
(156)	250	10·5	−4·4	90	50·0	—	5,400
(157)	250	10·0	—	—	—	—	—
(158)	250	2·5	−16·5	420	39·5	—	7,000
(159)	250	2·5	—	—	—	—	—
(160)	250	10·0	−4·5	—	40·0	—	5,400
(161)	250	2·85	−16·0	400	40·0	2,500	7,500
(162)	300	4·0	—	—	—	80,000	—
(163)	200	4·0	—	—	—	—	—
(164)	250	—	—	—	—	20,000	—
(165)	200	4·0	—	—	—	—	—
(166)	400	6·5	−16·0	240	75·0	10,000	4,000
(167)	175	2·5	−12·5	300	39·0	2,000	6,000
(168)	300	—	—	—	—	38,000	—
(169)	250	10·5	−4·1	90	47·5	4,300	6,000
(170)	250	2·5	−16·5	420	39·5	3,000	7,000
(171)	300	6·3	−30·0	—	—	50,000	2,800
(172)	250	3·9	—	—	—	—	—
(173)	250	3·9	—	—	—	—	—
(174)	250	3·9	−14·0	375	37·0	3,000	7,500
(175)	175	2·5	−12·5	300	36·0	2,000	6,000
(176)	175	2·5	—	—	—	—	—
(177)	200	3·0	—	—	—	—	—
(178)	200	10·0	−4·4	90	50·0	2,500	5,500
(179)	200	10·0	—	—	—	—	—
(180)	135	9·0	−7·6	95	80·0	3,500	1,300
(181)	200	10·0	—	—	—	—	—
(182)	200	10·0	−13·2	188	70·0	5,000	3,000
(183)	150	3·0	−6·0	—	8·0	600	14,000
(184)	150	2·0	−12·0	—	20·0	1,000	6,000
(185)	250	3·5	−18·0	400	40·0	3,000	7,000
(186)	250	3·5	−16·5	400	41·0	3,000	7,000
(187)	250	10·0	−6·0	150	40·0	3,600	7,000
(188)	250	4·0	−15·0	400	42·0	3,100	7,500
(189)	100	8·0	−19·0	400	45·0	3,000	5,000
(190)	100	8·0	−19·0	400	45·0	3,000	5,000
(191)	200	8·5	−8·0	170	50·0	3,200	4,400
(192)	150	2·0	−4·5	—	10·0	500	15,000
(193)	275	8·5	−14·0	—	—	—	—
(194)	250	4·0	−22·0	500	37·0	3,800	7,000
(195)	250	3·5	−15·0	650	28·0	2,000	7,500

[*Continued on next page*

TABLE XXXIII: OUTPUT PENTODES

Make	Type	Base	Fil. Volts	Fil. Amps	Anode Volts	
TRIOTRON —*continued*	P496	7B27	4·0	1·5	250	(196)
	P425	5B4	4·0	0·25	300	(197)
	P435	5B4	4·0	1·1	250	(198)
	P3580	7B27	33·0	0·2	200	(199)
	P2060	8S23	24·0	0·2	200	(200)
	P2460	5B4	24·0	0·18	200	(201)
	P2020N	5B4	20·0	0·18	200	(202)
TUNGSRAM	PP2/S	5B5/8S8	2·0	0·14	135	(203)
	PP222	4B6/5B4	2·0	0·22	150	(204)
	PP225	5B4	2·0	0·26	135	(205)
	PP4/S	5B4/8S8	4·0	1·1	250	(206)
	APP4A/S	7B31/8S22	4·0	1·2	250	(207)
	APP4B/S	7B27/8S23	4·0	1·95	250	(208)
	APP4C	7B24	4·0	2·0	250	(209)
	APP4E	7B27	4·0	2·1	375	(210)
	APP4G	7B30	4·0	2·0	250	(211)
	PP6AS	8S23	6·3	0·2	250	(212)
	PP6BS	8S23	6·3	1·2	250	(213)
	PP6B	6UX9	6·3	1·2	250	(214)
	PP6C	7B27	6·3	1·2	250	(215)
	PP6E	7B27	6·3	1·2	375	(216)
	EL2	8S22	6·3	0·2	250	(217)
	EL3/33	8S23/048	6·3	1·0	250	(218)
	EL5	8S23	6·3	1·35	250	(219)
	EL6/36	8S23/048	6·3	1·4	250	(220)
	6M6G	048	6·3	1·0	250	(221)
Double P	ELL1	8S26	6·3	0·45	250	(222)
	PP13A	7B27	13·0	0·3	250	(223)
	PP24	7B29	24·0	0·2	200	(224)
	CL6/PP37	8S22/7B29	35·0	0·2	200	(225)
	PP34	7B29	35·0	0·2	200	(226)
	PP35	7B27	35·0	0·2	200	(227)
	PP36	7B24	35·0	0·2	200	(228)
	CL33	048	35·0	0·2	200	(229)

TABLE XXXIV: DOUBLE

Make	Type	Circuit	Base	Fil. Volts	Fil. Amps	
COSSOR ..	220B	Class B	7B2	2·0	0·2	(1)
	240B	Class B	7B2	2·0	0·4	(2)
	2103	QPP	7UX5	2·0	0·26	(3)
	240QP	QPP	7B6	2·0	0·4	(4)
DARIO ..	TB402	Class B	7B2	2·0	0·2	(5)
	BLL32	QPP	9B1	2·0	0·45	(6)
EVER READY	K33A	Class B	7B2	2·0	0·2	(7)
	K33B	Class B	7B2	2·0	0·2	(8)
	K77A	QPP	9B1	2·0	0·45	(9)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Screen Volts	Slope (mA/V)	Bias Volts	Bias Res. (Ohms)	Anode and Screen Current (mA)	Output (mW)	Optimum Load (Ohms)
(196)	250	9·5	-6·0	—	—	—	—
(197)	200	1·7	-25·0	—	—	—	—
(198)	250	3·5	-14·0	—	—	—	—
(199)	200	8·0	-23·0	—	—	—	—
(200)	100	3·1	-19·0	—	—	—	—
(201)	200	8·0	-19·0	—	—	—	—
(202)	200	2·5	-18·0	1,000	19·0	1,350	9,000
(203)	135	2·1	-5·0	—	8·0	440	19,000
(204)	150	3·0	-6·0	—	9·0	600	14,000
(205)	135	2·0	-12·0	—	18·0	1,000	6,000
(206)	250	4·0	-15·0	400	42·0	2,800	7,500
(207)	250	3·5	-16·5	400	40·5	3,000	7,000
(208)	250	10·0	-6·0	140	40·0	3,600	7,000
(209)	250	10·0	-6·0	140	40·0	4,000	7,000
(210)	275	8·5	-13·5	175	80·0	8,000	3,500
(211)	250	10·0	-6·0	150	40·0	4,000	7,000
(212)	250	2·8	-18·0	500	37·0	2,250	8,000
(213)	250	10·0	-5·5	140	40·0	3,600	7,000
(214)	250	10·0	-5·5	140	40·0	3,600	7,000
(215)	250	10·0	-5·5	140	40·0	3,600	7,000
(216)	275	8·5	-17·0	200	80·0	8,800	3,500
(217)	250	2·8	-18·0	480	37·0	3,600	8,000
(218)	275	10·0	-7·0	175	40·5	3,600	7,000
(219)	275	8·5	-14·0	175	79·0	8,800	3,500
(220)	250	15·0	-7·0	85	80·5	8,200	3,500
(221)	250	10·0	-7·0	175	40·5	3,600	7,000
(222)	275	1·3	-21·5	600	44·6	5,400	16,000
(223)	250	2·5	-16·5	410	40·5	3,000	7,000
(224)	100	8·0	-19·0	400	45·0	3,000	5,000
(225)	100	8·5	-9·5	140	50·0	4,000	22,000
(226)	200	8·5	-8·0	170	50·0	3,200	4,400
(227)	200	8·5	-8·0	170	50·0	3,200	4,400
(228)	200	8·5	-8·0	170	50·0	3,200	5,000
(229)	200	8·5	-8·0	170	50·0	3,200	4,400

OUTPUT VALVES

	Anode Volts	Screen Volts	Quiescent Current (mA)	Peak Current (mA)	Bias Volts	Output (mW)	Optimum Load (Ohms)
(1)	120	—	2·5	—	0	—	12,000
(2)	120	—	4·0	—	0	—	8,000
(3)	150	150	4·0	—	-10·5	—	35,000
(4)	120	120	3·5	—	-9·0	—	24,000
(5)	150	—	—	—	0	—	—
(6)	135	135	—	—	-10·5	—	—
(7)	120	—	3·0	—	0	1,250	14,000
(8)	120	—	3·0	—	-4·5	1,450	14,000
(9)	150	150	4·0	—	-13·5	2,000	16,000

[*Continued on next page*

TABLE XXXIV: DOUBLE

Make	Type	Circuit	Base	Fil. Volts	Fil. Amps	
FERRANTI	HP2	Class B	7B2	2·0	0·4	(10)
HIVAC ..	B230	Class B	7B2	2·0	0·3	(11)
	DB240	Driver / Class B	7B12	2·0	0·4	(12)
	QP240	QPP	7B6	2·0	0·4	(13)
LISSEN ..	BB240	Class B	7B2	2·0	0·4	(14)
MARCONI ..	QP21	QPP	7B6	2·0	0·4	(15)
	B21	Class B	7B2	2·0	0·2	(16)
	B30	Class B	7B2	13·0	0·3	(17)
MAZDA ..	QP230	QPP	7B6	2·0	0·3	(18)
	QP240	QPP	9B1	2·0	0·4	(19)
	QP25	QPP	0M9	2·0	0·2	(20)
	PD220	Class B	7B2	2·0	0·2	(21)
	PD220A	Class B	7B2	2·0	0·2	(22)
MULLARD	PM2B	Class B	7B2	2·0	0·2	(23)
	PM2BA	Class B	7B2	2·0	0·2	(24)
	QP22A	QPP	9B1	2·0	0·45	(25)
	QP22B	QPP	7B6	2·0	0·3	(26)
	ECC31	Double Triode	042	6·3	0·95	(27)
OSRAM ..	QP21	QPP	7B6	2·0	0·4	(28)
	B21	Class B	7B2	2·0	0·2	(29)
	B30	Class B	7B2	13·0	0·3	(30)
RECORD ..	BB2A	Class B	7B6	2·0	0·25	(31)
	BB2B	Class B	7B6	2·0	0·25	(32)
TRIOTRON	E220B	Class B	7B2	2·0	0·2	(33)
TUNGSRAM	CB215/S	Class B	7B2/8S5	2·0	0·22	(34)
	CB220	Class B	7B2	2·0	0·25	(35)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

TABLE XXXV: METAL RECTIFIERS—WESTECTORS

Make	Type	Class	Max. safe input voltage	Max. current output (mA)
WESTING-HOUSE	W.4 ..	Half-wave ..	24 volts peak carrier	0·25
	W.6 ..	Half-wave ..	36 ,, peak carrier	0·28
	WX.6 ..	Half-wave ..	36 ,, peak carrier	0·12
	WM.142	Full-wave centre-tapped	24 ,, each side of C.T.	0·5
	WM.162	Full-wave centre-tapped	36 volts each side of C.T.	0·5

(WM.142 and WM.162 are the new code numbers of the earlier WM.24 and WM.26 respectively.)

OUTPUT VALVES—*continued*

	Anode Volts	Screen Volts	Quiescent Current (mA)	Peak Current (mA)	Bias Volts	Output (mW)	Optimum Load (Ohms)
(10)	150	—	3·0	—	—	—	—
(11)	150	—	2·5	32·0	0	1,250	14,500
(12)	120	—	3·0	3·0	–4·5	—	—
	150	—	2·5	32·0	0	1,250	14,500
(13)	150	150	8·0	32·0	–18	1,400	14,500
(14)	150	—	—	—	—	2,400	—
(15)	150	150	3·5	—	–9	1,200	30,000
(16)	150	—	2·2	—	–6	1,500	12,000
(17)	180	—	—	—	0	5,000	7,000
(18)	110	110	5·3	—	–8·6	700	17,000
(19)	150	150	4·0	—	–11·5	—	15,000
(20)	120	120	5·5	—	–9·75	1·2	15,500
(21)	150	—	0·8	45·0	–1·15	—	—
(22)	150	—	2·5	50·0	–6·0	—	—
(23)	120	—	3·0	20·0	0	1,250	14,000
(24)	120	—	3·0	20·0	–4·5	1,450	14,000
(25)	135	135	—	—	–12·0	1,400	16,000
(26)	135	135	—	—	–11·7	1,330	14,700
(27)	250	—	—	—	–4·6	—	—
(28)	150	150	3·5	—	–9·0	1,200	24,000
(29)	150	—	2·2	—	–6·0	1,500	12,000
(30)	180	—	—	—	0	5,000	7,000
(31)	150	—	2·5	—	–3·0	2,000	10,000
(32)	135	—	—	—	0	1,700	10,000
(33)	150	—	—	—	—	—	—
(34)	135	—	3·0	21·0	0	1,700	10,000
(35)	150	—	3·0	26·7	–3·35	2,000	10,000

TABLE XXXV: METAL RECTIFIERS—LT TYPES

Make	Type	Output		Nominal AC input (Volts)	Replaces
		Volts	Amps		
WESTINGHOUSE	LT.41	12	1	22	LT.5, LT.9, A.3
	LT.42	6	1	11	LT.1, LT.2, LT.4, LT.7, LT.8
	LT.44	12	2	22	LT.10, A.4
	LT.45	6	4	11	LT.11, A.6

TABLE XXXV: METAL RECTIFIERS

Make	Type	Maximum smoothed DC output		Max. current output (mA)	Maximum AC input Half-wave		
		Volts	mA		Volts	mA	
WESTINGHOUSE	HT.14	130	20	30	135	30	(1)
	HT.15	200	30	40	250	80	(2)
	HT.16	300	60	60	400	90	(3)
	HT.17	200	100	150	250	150	(4)
(For Class B)	HT.17	150	25	—	150	40	(5)
(2 in series)	HT.17	500	120	150	—	—	(6)
Used voltage doubler only	HT.41	250	60	100	300	90	(7)
Used voltage doubler only	HT.42	450	100	100	540	150	(8)
	H.1	3·6	10	10	3·5	20	(9)
	H.10	36	10	10	35	20	(10)
	H.50	180	10	10	175	20	(11)
	H.75	270	10	10	260	20	(12)
	H.100	360	10	10	350	20	(13)
	H.120	432	10	10	420	20	(14)
	H.176	650	10	10	620	20	(15)
	J.10	80	2	2	74—80	4	(16)
	J.50	400	2	2	370—400	4	(17)
	J.100	800	2	2	740—800	4	(18)
	J.125	1,000	2	2	920—1,000	4	(19)
	J.176	1,400	2	2	1,300—1,400	4	(20)
2 units in series	H.120	870	10	10	—	—	(21)
2 ,, ,, ,,	H.176	1,300	10	10	—	—	(22)
10 ,, ,, ,,	H.176	6,500	10	10	—	—	(23)
2 ,, ,, ,,	J.10	170	2	2	—	—	(24)
2 ,, ,, ,,	J.50	850	2	2	—	—	(25)
2 ,, ,, ,,	J.100	1,700	2	2	—	—	(26)
4 ,, ,, ,,	J.125	4,000	2	2	—	—	(27)
2 ,, ,, ,,	J.176	3,000	2	2	—	—	(28)
10 ,, ,, ,,	J.176	15,000	2	2	—	—	(29)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

TABLE XXXVI: HT RECTIFYING VALVES

Make	Type	Base	Filament		Anode Volts Max. (RMS)	Output (mA)
			Volts	Amps		
BRIMAR ..	25Z4G	—	25	0·3	250	75
	5Z4G	—	5·0	2·0	350 + 350	125
	R1	4B17	4·0	1·0	250 + 250	60
	R2	4B17	4·0	2·5	350 + 350	120
	R3	4B17	4·0	2·5	500 + 500	120
	1D5	5B10	40·0	0·2	250	75
	(Mercury)	4B2	2·0	1·2	6,000	3
COSSOR ..	44SU	4B1	4·0	0·4	200	20
	412SU	4B1	4·0	1·0	250	70

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—HIGH-TENSION TYPES

	Maximum AC input		Capacitors		Remarks
	Full-wave		Capacity of each (V.D.) mFd	Working voltage (V.D.)	
	Volts	mA			
(1)	80	60	6	200	Replaced by HT.41
(2)	140	120	4	200	Replaced by HT.41
(3)	240	200	4	400	Replaced by HT.42
(4)	150	300	8	250	Replaced by HT.41
(5)	—	—	8	350	Replaced by HT.41
(6)	300	550	6	500	Replaced by HT.41
(7)	150	180	8	250	—
(8)	270	300	8	400	—
(9)	—	—	100	12	—
(10)	—	—	10	50	—
(11)	—	—	2	250	—
(12)	—	—	2	400	—
(13)	—	—	1	500	—
(14)	—	—	0·85	600	—
(15)	—	—	·5	1,100	—
(16)	—	—	10	250	—
(17)	—	—	2	650	—
(18)	—	—	1	1,250	—
(19)	—	—	1	1,500	—
(20)	—	—	·5	2,000	—
(21)	430	30	0·5	700	—
(22)	720	30	0·25	1,000	—
(23)	3,600	30	0·35	5,000	—
(24)	74—80	6	10	250	—
(25)	370—400	6	2	650	—
(26)	740—800	6	1	1,250	—
(27)	1,600—1,700	6	0·5	3,000	—
(28)	1,300—1,400	6	0·5	2,000	—
(29)	6,500—7,000	6	0·1	12,000	—

TABLE XXXVI: HT RECTIFYING VALVES—*continued*

Make	Type	Base	Filament		Anode Volts Max. (RMS)	Output (mA)
			Volts	Amps		
COSSOR—*continued*	506BU	4B3	4·0	1·0	250 + 250	60
	408BU	4B3	4·0	1·0	250 + 250	30
	412BU	4B3	4·0	1·0	250 + 250	70
	442BU	4B3	4·0	2·5	350 + 350	120
	460BU	4B3	4·0	2·5	500 + 500	120
	431U	4B17	4·0	2·5	350 + 350	120
	441U	4B17	4·0	2·5	500 + 500	120
	4/100BU	4B3	4·0	2·5	500 + 500	200
	451U	4B17	4·0	3·5	500 + 500	250

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TABLE XXXVI: HT RECTIFYING VALVES—*continued*

Make	Type	Base	Filament Volts	Filament Amps	Anode Volts Max. (RMS)	Output (mA)
COSSOR—*continued*	405BU	4B3	4·0	0·5	1,500 + 1,500	20
	SU2150A	4B16	2·0	1·5	5,000	10
	SU2150	4B16	2·0	1·15	8,000	2
	612BU	4B3	6·0	0·4	250 + 250	50
	825BU	4B3	7·5	2·0	500 + 500	120
	40SUA	5B10	40·0	0·2	250	75
	225DU	7B1	2+2	·5+·5	750 + 750	20
DARIO ..	TW1	SB10	20·0	0·2	250	80
	TW2	7B15	30·0	0·2	250	120
	TBY233	7B15	33·0	0·18	250	120
	SW1	4B3	4·0	1·0	400	60
	FW1	4B3	4·0	1·0	300 + 300	75
	FW2	4B3	4·0	2·0	350 + 350	120
	TZ34	4B17	4·0	2·0	350 + 350	120
	FW3	4B3	4·0	2·0	500 + 500	120
	IFW1	4B17	4·0	2·5	500 + 500	120
EKCO ..	R41	4B3	4·0	2·0	350 + 350	120
EVER READY	S11A	4B3	4·0	1·0	250 + 250	60
	A11B	4B17	4·0	2·4	350 + 350	120
	S11D	4B3	4·0	2·0	350 + 350	120
	A11D	4B17	4·0	2·0	350 + 350	120
	A11C	4B17	4·0	2·4	500 + 500	120
	AZ1/31	8S1	4·0	1·1	300 + 300	100
	CY31	O35	20·0	0·2	250	75
	C10B	5B10	20·0	0·2	250	75
FERRANTI	R4	4B3	4·0	2·5	350 + 350	120
	R4A	4B3	4·0	2·5	500 + 500	120
(Mercury)	IR4	—	4·0	1·0	5,000	3
(Mercury)	GR4	4B3	4·0	3·0	350 + 350	350
	RS	5B10	13·0	0·3	250	75
	RA	5B12	13·0	0·3	250 + 250	50
	RZ	5B10	20·0	0·2	250	75
HIVAC ..	UU60/250	4B3	4·0	1·25	300 + 300	75
	UU120/350	4B3	4·0	2·5	350 + 350	120
	UU120/500	4B3	4·0	2·5	500 + 500	120
	U26	7B42	13or26	·6 or ·3	250	120
	MR1	4B1	4·0	3·0	1,000	250
LISSEN ..	UU41	4B3	4·0	1·0	300 + 300	80
	U650	4B1	5·6	0·5	300	40
MARCONI	MU12	4B17	4·0	2·5	350 + 350	120
	MU14	4B17	4·0	2·5	500 + 500	120
	U5	4B3	5·0	1·6	400 + 400	45
	U8	4B3	7·5	2·4	500 + 500	120
	U9	4B3	4·0	1·0	250 + 250	75
	U10	4B3	4·0	1·0	250 + 250	75
	U12	4B3	4·0	2·5	350 + 350	120
	U14	4B3	4·0	2·5	500 + 500	120
	U16	4B2	2·0	1·0	5,000	5
	U17	4B2	4·0	1·0	2,500	30
	U18	4B3	4·0	3·75	500 + 500	250
	U20	4B3	4·0	3·75	850 + 850	125
	U30	7B42	{26·0 / 13·0}	{0·3 / 0·6}	250	120
	U31	O35	26·0	0·3	250	120

TABLE XXXVI: HT RECTIFYING VALVES—*continued*

Make	Type	Base	Filament		Anode Volts Max. (RMS)	Output (mA)
			Volts	Amps		
MARCONI	U50	O2	5·0	2·0	350 + 350	125
—*continued*	U52	O2	5·0	3·0	500 + 500	250
(Mercury)	GU1	4B1	4·0	3·0	1,000	250
(Mercury)	GU5	4B2	4·0	3·0	1,500	250
(Mercury)	GU50	4B2	4·0	3·0	1,500	250
	A831	4B3	1·8	2·8	30 + 30	1·3 amp
MAZDA ..	UU4	4B17	4·0	2·2	350 + 350	120
	UU5	4B17	4·0	2·3	500 + 500	120
	UU120/500	4B17	4·0	2·5	500 + 500	120
	UU6	OM17	4·0	1·4	350 + 350	120
	UU7	OM17	4·0	2·3	350 + 350	180
	UU8	OM17	4·0	2·8	350 + 350	250
	U4020	5B10	40·0	0·2	250	120
	U403	OM15	40·0	0·2	250	120
	UD41	7B48	4·0	1·15	550	35
	U21	4B16	2·0	1·85	4,500	5
	U22	OM16	2·0	2·0	4,500	5
(Mercury)	MU2	4B2	2·0	3·1	12,500	5
MULLARD	DW2	4B3	4·0	1·0	250 + 250	60
	DW3	4B3	4·0	2·0	350 + 350	120
	DW4/350	4B3	4·0	2·0	350 + 350	120
	DW4	4B3	4·0	2·0	500 + 500	120
	DW4/500	4B3	4·0	2·0	500 + 500	120
	IW2	4B17	4·0	1·2	250 + 250	60
	IW3	4B17	4·0	2·4	350 + 350	120
	IW4/350	4B17	4·0	2·0	350 + 350	120
	IW4	4B17	4·0	2·4	500 + 500	120
	IW4/500	4B17	4·0	2·4	500 + 500	120
	FW4/500	4B3	4·0	3·0	500 + 500	250
	CY1/31	8S15/035	20·0	0·2	250	75
	UR1	8S15	20·0	0·2	250	75
	UR1C	5B10	20·0	0·2	250	75
	CY/2/32	8S17/038	30·0	0·2	250 + 250	120
	UR3	8S17	30·0	0·2	250 + 250	120
	UR3C	7B15	30·0	0·2	250 + 250	120
	UY31	O35	50·0	0·1	250	125
	HVR1	4B2	2·0	0·3	6,000	5
	HVR2	4B2	4·0	0·65	6,000	3
OSRAM ..	MU12/14	4B17	4·0	2·5	500 + 500	120
	MU14	4B13	4·0	2·5	500 + 500	120
	U5	4B3	5·0	1·6	400 + 400	45
	U8	4B3	7·5	2·5	500 + 500	120
	U10	4B13	4·0	1·0	250 + 250	60
	U12/14	4B13	4·0	2·5	500 + 500	120
	U14	4B13	4·0	2·5	500 + 500	120
	U16	4B2	2·0	1·0	5,000	5
	U17	4B2	4·0	1·0	2,500	30
	U18/20	4B3	4·0	3·75	{ 500 + 500 850 + 850	250 125
	U23	4B2	4·0	3·3	1,750	250
	U30	7B42	{ 25·0 26·0 13·0	0·3 0·3 0·6	180 220 250	120 75 120
	U31	O35	26·0	0·3	250	120

TABLE XXXVI: HT RECTIFYING VALVES—*continued*

Make	Type	Base	Filament Volts	Filament Amps	Anode Volts Max. (RMS)	Output (mA)
OSRAM—*continued*	U50	O2	5·0	2·0	400 + 400	110
	U52	O2	5·0	3·0	500 + 500	250
	U71	O35	30·0	0·17	250	100
	U74	O35	30·0	0·16	250	75
(Mercury)	GU1	4B1	4·0	3·0	1,000	250
(Mercury)	GU5	4B2	4·0	3·0	1,500	250
	GU50	4B2	4·0	3·0	1,500	250
PHILIPS ..	373	4B1	4·0	1·0	220	40
(Miniwatt)	505	4B1	4·0	1·0	400	60
	506	4B3	4·0	1·0	300 + 300	75
	506K	4B17	4·0	1·2	250 + 250	60
	1560	4B3	5·0	2·0	300 + 300	125
	1561	4B3	4·0	2·0	500 + 500	120
	1801	4B3	4·0	0·6	250 + 250	30
	1802	4B3	4·0	0·5	250	30
	1803	4B1	4·0	—	500	30
	1805	4B3	4·0	1·0	250 + 250	60
	1807	4B3	4·0	2·0	350 + 350	120
	1815	4B3	4·0	2·3	500 + 500	180
	1817	4B3	4·0	4·0	350 + 350	300
	1821	4B3	4·0	1·0	250 + 250	60
	1831	4B3	4·0	1·0	700 + 700	60
	1832	4B1	4·0	1·2	700	120
	1861	4B17	4·0	2·4	500 + 500	120
	1867	4B17	4·0	2·4	350 + 350	120
	1876	8S12	4·0	0·3	850	5
	1877	4B16	4·0	0·65	6,000	5
	1881	4B17	4·0	1·0	250 + 250	60
	1881A	4B17	4·0	2·4	250 + 250	60
	AZ1/31	8S1/02	4·0	1·1	300 + 300	100
	EZ2	8S16	6·3	0·4	350 + 350	60
	CY1/31/C	8S15/035/5B10	20·0	0·2	250	75
	CY2	5B10	30·0	0·2	250 + 250	120
RECORD ..	1FW4A	4B17	4·0	2·0	400 + 400	120
	FW350	4B13	4·0	1·0	300 + 300	80
	FW3	4B17	4·0	2·0	350 + 350	120
	FW5	4B13	4·0	2·0	500 + 500	120
	FW6	4B13	4·0	2·0	600 + 600	180
	UFW/30	5B10	30·0	0·2	275	120
	UFW/30L	8S17	30·0	0·2	275	120
	HW/20	5B10	20·0	0·2	250	80
	HW/20L	8S15	20·0	0·2	250	80
	HW/30	5B10	30·0	0·2	275	120
TRIOTRON	G429	4B1	4·0	0·3	250	30
	G470	4B13	4·0	1·0	300 × 300	70
	G4120	4B13	4·0	2·0	500 × 500	120
	G4120N	4B17	4·0	2·0	500 × 500	120
	G2080	5B10	20·0	0·2	250	80
	G3060	8S17	30·0	0·2	125 × 125	120
	G3120	7B15	30·0	0·2	250	120
TUNGSRAM	PV4	4B3	4·0	2·0	350 + 350	120
	PV4200	4B3	4·0	2·0	500 + 500	120
	PV4201	4B3	4·0	2·0	600 + 600	180

TABLE XXXVI: HT RECTIFYING VALVES—*continued*

Make	Type	Base	Filament		Anode Volts Max. (RMS)	Output (mA)
			Volts	Amps		
TUNGSRAM —*continued*	AP4V	4B17	4·0	2·0	350 + 350	120
	RV120/350/S	4B3/8S1	4·0	2·4	350 + 350	120
	RV120/500/S	4B3/8S1	4·0	2·4	500 + 500	120
	RV200/600	4B3	4·0	2·8	600 + 600	200
	PV75/1000	4B3	2·2	4·0	1,000 + 1,000	75
	PV100/2000	4B3	4·0	2·2	2,000 + 2,000	100
	PVA6S	8S16	6·3	0·25	350 + 350	60
	PVB6S	8S16	6·3	0·65	350 + 350	100
	PVC6S	8S16	6·3	0·9	350 + 350	175
	EZ2	8S16	6·3	0·4	350 + 350	60
	EZ3	8S16	6·3	0·65	400 + 400	100
	EZ4	8S16	6·3	0·9	400 + 400	175
	V20/S	5B10/8S15	20·0	0·2	250	80
	PV25	7B15	25·0	0·3	275 and 275	120
	V 30	5B10	30·0	0·2	275	120
	PV29/S	7815/8S17	30·0	0·2	125 and 125	60
	PV30	7B15	30·0	0·2	275	120
	PV30S	8S17	30·0	0·2	275	120
	V2118	5B10	20·0	0·18	250	80
	PV3018	7C1	30·0	0·18	250	100

TABLE XXXVII: BARRETTERS

Make	Type	Base	Current (amps)	Voltage range
ATLAS ..	150A/4	4B20	0·2	100—200
	150A/C	8S27	0·2	100—200
	150B/UX4	4-pin US	0·3	100—200
	130B	6-pin US	0·3	85—170
	110B	6-pin US	0·3	75—145
	150C	4B20	0·18	100—200
DARIO ..	T1	ES cap	0·2	100—200
MARCONI ..	171	ES cap	0·16	100—200
	202	ES cap	0·2	120—200
	251	ES cap	0·25	100—180
	301	ES cap	0·3	138—221
	302	ES cap	0·3	112—195
	303	ES cap	0·3	86—129
	304	ES cap	0·3	95—165
OSRAM ..	301	ES cap	0·3	138—221
	302	ES cap	0·3	112—195
	303	ES cap	0·3	86—129
	304	ES cap	0·3	95—165
	251	4B20	0·25	100—180
	202	4B20	0·2	120—200
PHILIPS .. (Miniwatt)	C1/C	8S33/4B20	0·2	90—230
	C2	8S33	0·2	60—120
	C3	8S33	0·2	100—200
	C9	8S33	0·2	35—100
	C13	8S33	Special low resistance	-voltage lamp.

TABLE XXXVII: BARRETTERS—*continued*

Make	Type	Base	Current (amps)	Voltage range
PHILIPS—*continued*	1941	4B20/ES	0·3	100—240
	1933	4B20	0·1	50—160
	1934	4B20	0·25	85—195
	1927	4B20	0·18	60—120
	1928	4B20	0·18	100—210
	1920	4B20	0·25	40—70
	1904	4B20/and bayonet cap	0·1	40—70
TUNGSRAM	BR201	4B20	0·2	100—200
	BR201/S	8S33	0·2	100—200

TABLE XXXVIII: GAS-FILLED RELAYS

Make	Type	Base	Filament		Anode Volts	Anode Current
			Volts	Amps		
BRIMAR ..	4039A	5B13	4·0	1·0	500	100 mA
COSSOR ..	GDT4B	5B13	4·0	1·75	350	100 ,,
	GDT4	5B13	4·0	1·5	500	20 ,,
MARCONI	GT1	5B15	4·0	1·3	1,000	1·0 amp
	GT1A	5B15	4·0	1·3	300	0·6 ,,
	GT1B	5B15	4·0	1·35	120	2·0 mA
	GT1C	5B15	4·0	1·3	500	1·0 amp
MAZDA ..	T11	5B13	4·0	1·2	700	300 m/A
	T21	5B13	4·0	1·2	200	300 ,,
	T31	5B13	4·0	1·5	400	500 ,,
	T41	OM19	4·0	1·5	400	500 ,,
OSRAM ..	GT1	5B15	4·0	1·3	1,000	0·3 amp
	GT1A	5B15	4·0	1·3	300	0·2 amp
	GT1B	5B15	4·0	1·35	120	2·0 mA
	GT1C	5B15	4·0	1·3	500	0·3 amp

PILOT AND DIAL LAMPS

British Dial Lamps. Radio panel or dial lamps are made by E.L.M.A. firms in the following standard shapes and sizes. All have clear finish, miniature screw cap and an objective life of 1,000 hours, except those marked * in Table XXXIX, which have an objective life of 10 hours.

TABLE XXXIX

Rating		Bulb	Dimensions	
Volts	Amps		Diameter (mm)	Overall length (mm)
6	0·04	Round	11	—
6	0·06	Round	11	—
6	0·5	Round	15	—
*6·2	0·3	Round	15	—
6·3	0·64	Round	15	—
6·5	0·3	Round	11	—
10	0·2	Round	18	—
4	0·3	Tubular	10	30
*6·2	0·3	Tubular	10	30
*6·3	0·15	Tubular	10	30
6·5	0·3	Tubular	10	30

Standard Flashlamps given in Table XL with round bulbs, clear finish and miniature Edison Screw (MES) caps are:

TABLE XL

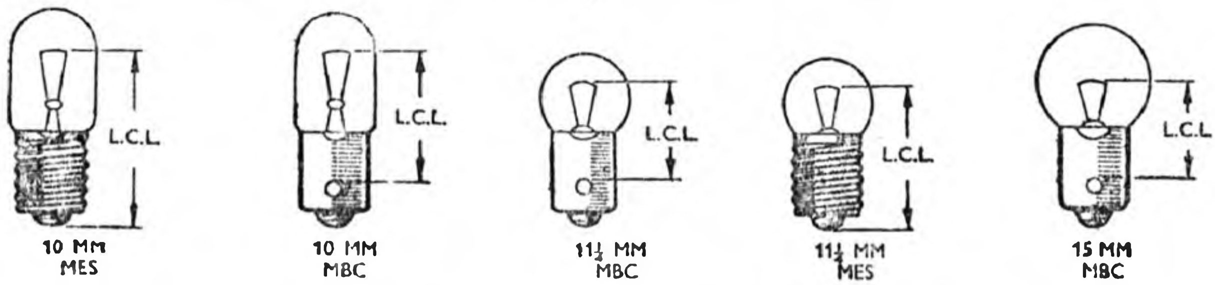
Rating		Diameter mm	Rating		Diameter (mm)
Volts	Amps		Volts	Amps	
2	0·3	11	3·5	0·3	11
2	0·6	15	4	0·3	11
2·5	0·2	11	4·5	0·3	15
2·5	0·3	11	6·2	0·3	15
3·5	0·15	11	6·5	0·3	11

Recommended lamps and uses are shown in Table XLI.

TABLE XLI

Description	Type of receiver for which suitable
2 volts 0·6 amp, 15 mm flat ..	2-volt battery
3·5 volts 0·15 amp, 15 mm flat ..	Fuse
2·5 volts 0·3 amp, 12 mm round ..	2-volt battery
3·5 volts 0·15 amp, 12 mm round ..	2-volt battery
3·5 volts 0·3 amp, 12 mm round ..	AC, 2 in series across 4-volt transformer
6·2 volts 0·3 amp, 15 mm round ..	AC, 4-volt transformer. AC-DC with 0·2-amp valves
6·5 volts 0·16 amp, 12 mm round ..	AC-DC with 0·16-amp valves
6·5 volts 0·3 amp, 12 mm round ..	AC-DC with 0·3-amp valves. AC with 6·3-volt transformer
8 volts 1·6 watt, MES Indicator ..	AC

American Pilot Lamps. Current ratings of American Pilot Lamps are indicated on their bases by code numbers which are given in the first column of Table XLII. Caps are standard Miniature Edison Screw (MES) and Miniature Bayonet Cap (MBC). Types 40, 44, and 46 are sometimes marked 6·3 volts; when marked 6-8 volts they are usually of 7·5-volt rating and are produced for use in certain AC-DC sets where they are temporarily overrun while the valves are warming up. MOL means maximum overall length; other features are shown in Fig. 163.



AMERICAN PILOT LAMPS

Fig. 163. Types and dimensions of the common pilot lamps in use in the U.S.A.

TABLE XLII

Code No.	Volts	Amps	CP	Bulb (mm)	Base	Bead Colour	LCL (in.)	MOL (in.)
40	6-8	0·15	0·5	10	MES	Brown	$\frac{29}{32}$	$1\frac{1}{8}$
41	2·5	0·5	0·5	10	MES	White	$\frac{29}{32}$	$1\frac{1}{8}$
42	3·2	0·5	0·75	10	MES	Green	$\frac{29}{32}$	$1\frac{1}{8}$
43	2·5	0·5	0·5	10	MBC	White	$\frac{23}{32}$	$1\frac{1}{8}$
44	6-8	0·25	0·8	10	MBC	Blue	$\frac{23}{32}$	$1\frac{1}{8}$
45	3·2	0·5	0·75	10	MBC	Green	$\frac{23}{32}$	$1\frac{1}{8}$
46	6-8	0·25	0·8	10	MES	Blue	$\frac{29}{32}$	$1\frac{1}{8}$
47	6-8	0·15	0·5	10	MBC	Brown	$\frac{23}{32}$	$1\frac{1}{8}$
48	2·0	0·06	0·03	10	MES	Pink	$\frac{29}{32}$	$1\frac{1}{8}$
49	2·0	0·06	0·03	10	MBC	Pink	$\frac{23}{32}$	$1\frac{1}{8}$
49-A	2·1	0·12	0·07	10	MBC	White	$\frac{23}{32}$	$1\frac{1}{8}$
50	6-8	0·2	1·0	11½	MES	White	$\frac{23}{32}$	$\frac{15}{16}$
51	6-8	0·2	1·0	11½	MBC	White	$\frac{1}{2}$	$\frac{15}{16}$
55	6-8	0·4	1·5	15	MBC	White	$\frac{1}{8}$	$1\frac{1}{16}$
292	2·9	0·17	0·3	10	MES	White	$\frac{29}{32}$	$1\frac{1}{8}$
292-A	2·9	0·17	0·3	10	MBC	White	$\frac{23}{32}$	$1\frac{1}{8}$
631	6-8	0·1	—	10	MES	Black	$\frac{29}{32}$	$1\frac{1}{8}$
713	3·8	0·3	—	11½	MES	Green	$\frac{23}{32}$	$\frac{15}{16}$
714	2·5	0·3	—	11½	MES	Blue	$\frac{23}{32}$	$\frac{15}{16}$

American Equivalents. Certain valves in the Marconi and Osram International ranges are equivalent to standard American types. These are given below, the American type being shown first in each case: 1A7 = X14; 1N5 = Z14; 1H5 = HD14; 1C5 = N14; 5X4 = U52; 573 and 5Z4 = U50; 6AG6 = KT61; 6A8 = X63; 6F5 = H63; 6F6 = KT63; 6H6 = D63; 6J5 = L63; 6J7 = 263 and KTZ63; 6U7 and 6K7 = KTW63 and W63; 6K8 = X65; 6L6 = KT66; 6L7 = X64; 6N7 = B63; 6Q7 = DH63; 6R7 = DL63; and 25L6 = KT32.

TABLE XLIII: TUNING INDICATORS

Make	Name	Base	Type	Operation Characteristics
BRIMAR ..	6G5/6U5	—	Cathode Ray	Fil. 6·3 volts, 0·3 amps; max. anode 250 volts
COSSOR ..	3180	NE1	Neon	145—160 volts
	3184	NE2	Neon	145—160 volts
	41ME	8S31	Cathode Ray	Fil. 4·0 volts, 0·3 amps; max. anode 250 volts
DARIO ..	TM14	8S31	Cathode Ray	Fil. 4·0 volts, 0·3 amps; max. anode 250 volts
EVER READY ..	A39A	8S31	—	Fil. 4 volts, 0·3 amps; max. anode 250 volts
MARCONI ..	Y61/62 Y63/64	O59	Cathode Ray	Fil. 6·3 volts, 0·3 amps; max. anode 250 volts
MAZDA ..	AC/ME	7B40	Cathode Ray	Fil. 4·0 volts, 0·5 amps; max. anode 250 volts
	ME41	OM27	,,	Fil. 4·0 volts, 0·5 amps; max. anode 250 volts
	ME91	OM27	,,	Fil. 9·0 volts, 0·2 amps; max. anode 200 volts
	ME920	7B40	,,	Fil. 9·0 volts, 0·2 amps; max. anode 250 volts
MULLARD	TV4	8S31	Cathode Ray	Fil. 4·0 volts, 0·3 amps; max. anode 250 volts
	TV4A	8S31	,,	Fil. 4·0 volts, 0·3 amps; max. anode 250 volts
	*TV6	8S31	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
	EM1	8S31	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
	EM3	8S31	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
	EM4	8S32	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
	EFM1	8S30	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
OSRAM ..	Y61/62/ 63/64	O59 O59	Cathode Ray	Fil. 6·3 volts, 0·3 amps; max. anode 250 volts
	Y73	O59	,,	Fil. 6·0 volts, 0·16 amps; max. anode 180 volts
TUNGSRAM	ME4S	8S31	Cathode Ray	Fil. 4·0 volts, 0·3 amps; max. anode 250 volts
	VME4	7B40	,,	Fil. 4·0 volts, 0·5 amps; max. anode 250 volts
	ME6S	8S31	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
	EM1	8S31	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
	EM4	8S32	,,	Fil. 6·3 volts, 0·2 amps; max. anode 250 volts
	EFM1	8S30	,,	Fil. 6·3 volts, 0·2 amps; max. anode 300 volts

TABLE XLIV: VALVE EQUIVA-

Brimar	Cossor	Ever-Ready	Ferranti	Hivac	
—	210DG	—	—	—	(1)
—	—	K50N	—	—	(2)
—	—	—	—	—	(3)
—	210PG 210SPG	K80A K80B	VHT2 VHT2A	—	(4)
—	—	—	—	—	(5)
—	210VPT	K50M	—	VP215	(6)
—	210SPT	—	—	HP215	(7)
—	—	—	—	—	(8)
—	—	—	—	—	(9)
—	—	—	—	—	(10)
—	—	—	—	—	(11)
5B1	215SG 220SG	K40B	—	SG215 SG220 SG210	(12)
—	220VS 220VSG	K40N	VS2	VS215 VS210	(13)
HLB1	210HL	K30C	—	—	(14)
—	—	—	—	—	(15)
—	210HF 210RC	K30A	—	H210	(16)
—	—	—	—	—	(17)
—	—	K23B	—	DDT220	(18)
—	—	—	—	—	(19)
—	—	K23A	H2D	DDT215	(20)
—	—	—	—	—	(21)
—	210LF 210DET	K30B K30D	—	D210	(22)
—	—	K30E	L2	L210	(23)
—	—	—	—	—	(24)
PB1	220P 220PA	K30G	—	P220	(25)
—	215P	—	—	P215	(26)
—	230XP	—	—	PP220 PX230	(27)
PenB1	220HPT 220OT	K70B	PT2	Y220	(28)
—	—	—	—	—	(29)
—	220PT 230PT	—	—	Z220	(30)
—	—	—	—	—	(31)
—	240B 220B	K33A	HP2	B230	(32)
—		—	—	—	(33)
—	—	—	—	—	(34)
—	—	K33B	—	—	(35)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Marconi Osram	Mazda	Mullard	Philips	Tungsram
(1)	DG2	—	PM1DG	—	DG210/0
(2)	—	—	VP2B	—	VX2
(3)	—	—	—	KH1	VX2s
(4)	X21 X22	—	FC2 FC2A	—	VO2
(5)	—	—	—	KK2	VO2s
(6)	VP21 W21 KTW21	VP215 VP210	VP2	—	HP211c
(7)	Z21 KTZ21	SP215 SP210	SP2 —	—	HP210nc
(8)	—	—	—	KF3	VP2Bs
(9)	W22	—	—	—	VP2D
(10)	—	—	—	KF4	SP2Bs
(11)	Z22	—	—	—	SP2D
(12)	S21 S22 S23 S24	SG215 S215 S215A S215B	PM12 PM12A	—	SS210
(13)	VS24 VS24K	S215VM	PM12M PM12V	—	SE211c
(14)	HL2 HL2K	HL2	PM1HL PM2HL PM2DX	B228	HL2
(15)	—	—	—	KC4	HL2s
(16)	H2 H210 HL210 DEH210	H2 HL210	PM1A PM1HF	—	HR210
(17)	—	—	—	KC1	HR2s
(18)	HD22 HD23	HL21DD	TDD2A	—	DDT2
(19)	HD21	—	—	—	DDT2A
(20)	—	L21DD	TDD2	—	DDT2B
(21)	—	—	—	KBC1	DDT2Bs
(22)	L210 DEL210	—	PM1LF	B217	LD210
(23)	L21	L2	PM2DL	—	LL2
(24)	—	—	—	KC3	LL2s
(25)	LP2	P220	PM2A	—	LP220
(26)	P215 DEP215	P215	PM2	—	P215
(27)	P2 P2B	P220A	PM202 PM252	—	SP220
(28)	PT2 KT2	Pen220	PM22 PM22A	C243N	PP2
(29)	—	—	—	KL1	PP215s
(30)	—	Pen220A	PM22C	—	PP225
(31)	—	—	—	KL2	PP225s
(32)	—	PD220	PM2B	B240	CB215
(33)					
(34)	—	—	—	KDD1	CB215s
(35)	B21	PD220A	PM2BA	—	CB220

TABLE XLIV: VALVE EQUIVA-

Brimar	Cossor	Ekco	Ever-Ready	Ferranti	Hivac	
20A1	—	—	A36B A36C	—	—	(1)
—	41STH	—	A36A	—	—	(2)
—	—	—	A80A	—	—	(3)
—	—	—	—	—	—	(4)
15A2	41MPG	—	—	VHT4	—	(5)
—	—	—	—	—	—	(6)
9A1	—	—	A50M	VPT4A	AC/VP	(7)
—	—	—	—	—	—	(8)
—	MVS/Pen	—	A50N	VPT4B	—	(9)
8A1	MS/PenA 41MPT MS/Pen	—	A50A	SPT4A	AC/HP	(10)
—	MVS/PenB	—	—	—	—	(11)
—	—	—	—	—	—	(12)
—	—	—	—	—	—	(13)
—	—	VP41	A50P	—	—	(14)
—	MS/PenB	—	—	—	—	(15)
—	—	—	—	—	—	(16)
—	—	—	A50B	—	—	(17)
—	MVSG	—	A40M	—	AC/VS	(18)
—	MSGHA MSGLA 41MSG	—	—	—	AC/SH AC/SL	(19)
HLA1 HLA2	41MH 41MHF 41MHL 41MLF 41MRC	T41	A30B A30D	D4	AC/HL	(20)
—	—	—	—	—	—	(21)
—	—	—	—	—	—	(22)
—	—	—	—	—	—	(23)
—	DD4	—	A20B	—	AC/DD	(24)
—	—	2D41	—	—	—	(25)
—	—	—	—	—	—	(26)
11A2	DDT	DT41	A23A	H4D	AC/DDT	(27)
—	—	—	—	—	—	(28)
PA1	41MP 41MXP	—	—	—	AC/L	(29)
—	—	—	—	—	—	(30)
—	—	—	—	—	—	(31)
7A2	MP/Pen	—	A70B	—	AC/Y	(32)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

LENTS—4-VOLT (AC) RANGE

	Marconi Osram	Mazda	Mullard	Philips	Tungsram
(1)	—	AC/TH1	TH4A TH4B	—	TH4A TH4B
(2)	X41	—	TH4	—	TX4
(3)	—	—	FC4	—	VO4
(4)	—	—	—	AK2	VO4s
(5)	MX40 X42	—	—	—	MH4105/71
(6)	—	—	—	AK1	MH4105/73
(7)	—	—	—	E447	HP4106c
(8)	VMP4 VMP4G	—	—	—	HP4105
(9)	—	—	VP4A	AF2	HP4115c
(10)	MSP4	AC/SP1 AC/S2Pen	SP4	E446	HP4101c
(11)	W42	—	—	—	VP4
(12)	—	—	—	AF3	VP4s
(13)	—	—	—	AH1	VX4s
(14)	—	AC/VP2	VP4B	—	VP4B
(15)	—	—	—	—	SP4
(16)	—	—	—	AF7	SP4s
(17)	—	—	SP4B	—	SP4B
(18)	VMS4 VMS4B	ACS1VM ACSGVM	VM4V MM4V	E445 E455	AS4125
(19)	MS4 MS4B	ACSG ACS2	S4V S4VA S4VB	E452T E442 E442S	AS4120
(20)	MH4 MH41 MHL4	AC/HL AC2/HL	154V 164V 244V 354V 484V 904V 994V	E424N E438 E499	HL4+
(21)	H42	—	—	—	HL4g
(22)	—	—	—	AC2	HL4gs
(23)	—	—	2D4	AB1	DD465
(24)	D41	V914 AC/DD	2D4A	—	DD4
(25)	—	—	2D4B	—	DD4D
(26)	—	—	—	AB2	DD4s
(27)	MHD4 DH42	ACHLDD	TDD4	—	DDT4
(28)	—	—	—	ABC1	DDT4s
(29)	ML4	AC/P AC/P1	104V TT4 054V	E409	LL4
(30)	—	AC/P4	—	—	LL4C
(31)	—	—	—	AL2	APP4As
(32)	MKT4 N42 MPT4 KT42	AC/Pen	Pen4V Pen4VA	—	APP4A

[*Continued on next page*

TABLE XLIV: VALVE EQUIVA-

Brimar	Cossor	Ekco	Ever-Ready	Ferranti	Hivac	
7A3	42OT 42MP/Pen	OP42	A70C A70D	PT4	AC/Z	(33)
—	—	—	—	—	—	(34)
—	42OTDD	—	—	PT4D	AC/ZDD	(35)
—	—	DO42	A27D	—	—	(36)
—	—	OP41	A70E	—	AC/YY	(37)
—	—	—	—	—	—	(38)
PenA1	425PT PT41 415PT 410PT	—	—	—	FY	(39)
—	—	—	—	—	—	(40)
—	4XP	—	S30C	LP4 P4	PX41	(41)
—	—	—	—	—	—	(42)
1A7 R1 R2	431U	—	A11B A11D	—	UU60/250 UU120/350	(43)
—	—	—	—	—	—	(44)
—	442BU 506BU	—	S11A S11D	R4	—	(45)
—	—	—	—	—	—	(46)
R3	—	R41	—	R4A	—	(47)
—	—	—	—	—	—	(48)
—	4/100BU	—	—	—	—	(49)
—	—	—	—	—	—	(50)
—	—	—	—	—	—	(51)

TABLE XLIV: VALVE EQUIVA-

Cossor	Ekco	Ever-Ready	Ferranti	Marconi Osram	
202STH	—	C36A	—	—	(1)
—	—	C36B C36C	—	—	(2)
—	—	—	—	—	(3)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

LENTS—4-VOLT (AC) RANGE—*continued*

	Marconi Osram	Mazda	Mullard	Philips	Tungsram
(33)	KT41 N41	AC2/Pen AC5/Pen	Pen4VB PenA4	—	APP4B
(34)	—	—	—	AL3 AL4	APPB4s
(35)	DN41	AC2/PenDD AC5/PenDD	—	—	DDPP4B
(36)	—	—	Pen4DD	—	DDPP4M
(37)	—	—	PenB4 Pen428	—	APP4E*
(38)	N43	—	—	—	APP4G*
(39)	PT4	Pen425	PM24M PM24 PM24A	E443H E443N	PP4
(40)	—	—	—	AL1	PP4s
(41)	PX4	PP3/250	AC044 AC064	E406N	P12/250
(42)	—	—	—	AD1	P15/250s
(43)	MU12	UU4 UU60/250 UU120/350	1W2 1W3 1W4/350	1881 1867 1881A	APV4
(44)	—	—	AZ3	—	IRV120/350s
(45)	U10 U12	UU120/350	DW2 DW3 DW4/350	506 1805 1807 1821	RV120/350
(46)	—	—	AZ1	AZ1	RV120/350s
(47)	U14	UU120/500	DW4 DW4/500	1561	RV120/500
(48)	—	—	AZ2	AZ2	RV120/500s
(49)	U18	—	FW4/500	1560 1815 1831	RV200/600
(50)	—	AC/ME	—	—	VME4
(51)	—	—	TV4 TV4A	—	ME4s

LENTS—UNIVERSAL (AC-DC) RANGE

	Mazda	Mullard	Philips	Tungsram
(1)	—	TH21C	—	TX21
(2)	TH2320 TH2620	TH22C TH30C	—	TH29 TH30
(3)	—	—	CH1	VX13s

[*Continued on next page*

TABLE XLIV: VALVE EQUIVALENTS—

Cossor	Ekco	Ever-Ready	Ferranti	Marconi Osram	
13PGA	—	C80B	VHTA	—	(4)
—	—	—	—	—	(5)
—	—	—	VPTA	—	(6)
13VPA	—	—	—	—	(7)
—	—	—	—	—	(8)
—	VPU1	C50N	—	—	(9)
—	—	—	—	—	(10)
13SPA	—	—	—	—	(11)
—	—	—	—	—	(12)
—	—	C50B	—	—	(13)
—	—	C30B	DA	—	(14)
—	—	—	—	—	(15)
—	—	C20C	—	—	(16)
—	—	—	—	—	(17)
—	—	—	ZD	—	(18)
13DHA 202DDT	DTU1	C23B	HAD	—	(19)
—	—	—	—	—	(20)
—	—	—	—	—	(21)
—	—	—	PTA	N30 N30G KT30	(22)
—	—	—	—	—	(23)
402Pen 402OT	—	—	—	—	(24)
—	—	—	—	—	(25)
—	—	C70D	PTZ	—	(26)
—	—	—	—	—	(27)
—	—	—	—	—	(28)
—	—	—	—	—	(29)
—	—	C10B	RZ	—	(30)
—	—	—	—	—	(31)
—	—	—	—	U30	(32)
—	—	—	—	—	(33)
40SUA	—	—	—	—	(34)
—	—	—	—	—	(35)
—	—	—	—	—	(36)
—	—	C39A	—	—	(37)
—	—	—	—	—	(38)
—	—	—	—	—	(39)
—	—	—	—	—	(40)
—	—	—	—	—	(41)
—	—	—	—	—	(42)
—	—	—	—	—	(43)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Mazda	Mullard	Philips	Tungsram
(4)	—	FC13C	—	VO13
(5)	—	FC13	CK1	VO13s
(6)	—	—	—	VP13
(7)	—	—	—	VP13K
(8)	—	—	CF3	VP13s
(9)	VP1322	VP13C	—	VP13B
(10)	—	VP13A	CF2	HP13s
(11)	—	SP13A	—	SP13
(12)	—	SP13	CF1 CF7	SP13s
(13)	—	SP13C	—	SP13B
(14)	HL1320	HL13C	—	HL13
(15)	—	HL13	CC2	HL13s
(16)	—	2D13C	—	DD13
(17)	—	2D13A	CB2	DD13s
(18)	DD620	—	—	DD6
(19)	HLDD1320	TDD13C	—	DDT13
(20)	—	TDD13	CBC1	DDT13s
(21)	—	—	CL1	PP13s
(22)	—	—	—	PP13A
(23)	—	Pen26	CL2	PP24s
(24)	—	—	—	PP34
(25)	—	—	CL4	PP34s
(26)	Pen3520	Pen36C	—	PP35
(27)	—	CL6	CL6	CL6
(28)	PenDD4020	—	—	DDPP39
(29)	—	Pen40DD	—	DDPP39M
(30)	—	URIC	CY1C	V20
(31)	—	UR1	CY1	V20s
(32)	—	—	—	PV25
(33)	—	UR2	CY2	PV29s
(34)	U4020	—	—	V30
(35)	—	UR3C	—	PV30
(36)	—	UR3	CY3	PV30s
(37)	—	TV6	—	ME6s
(38)	—	VP20 MM20 VM20	B2047 B2045	HP2118
(39)	—	SP20	B2046	HP2018
(40)	—	SG20A	B2052T	SS2018
(41)	—	SG20	—	S2018
(42)	—	H20 HL20	B2038	R2018
(43)	—	Pen20	B2043	PP2018

TABLE XLV: CATHODE-

Type No.	Description	Base	Screen		Heater		
			Diam.	Colour	V	A	
BAIRD							
12MW1	Elec.-Magnetic ..	—	12 in.	W	2·2	2·5	(1)
15MW2	,,	—	15 in.	W	2·2	2·5	(2)
MARCONI (EMISCOPE)							
3/1	Magnetic ..	—	5 in.	—	4·0	1·3	(3)
3/2	,, ..	—	7 in.	—	4·0	1·3	(4)
3/3	,, ..	—	9 in.	—	4·0	1·3	(5)
6/5	Electrostatically Focused Hexode	—	9 in.	—	4·0	1·3	(6)
6/6	,, ..	—	12 in.	—	4·0	1·3	(7)
4/1	,, ..	—	3½ in.	G	—	—	(8)
MAZDA							
CRM71	Double Magnetic ..	—	180 mm	W	2·0	1·4	(9)
CRM91	,, ..	—	228 mm	W	2·0	1·4	(10)
CRM121	,, ..	—	316 mm	W	2·0	1·4	(11)
MULLARD							
MS11/1	Projection-Magnetic	—	—	—	4·0	1·0	(12)
MW18/2	Magnetic ..	R	7 in.	W	2·0	1·2	(13)
MW22/1	,, ..	Q	9 in.	W	4·0	1·0	(14)
MW22/3	,, ..	R	9 in.	W	2·0	1·2	(15)
MW22/5	,, ..	Q	9 in.	W	6·3	0·65	(16)
MW31/3	,, ..	Q	12 in.	W	6·3	0·65	(17)
MW31/6	,, ..	Q	12 in.	W	6·3	0·6	(18)
MW39/3	,, ..	Q	15 in.	W	6·3	0·65	(19)

TABLE XLVI: CATHODE-RAY

Type No.	Description	Base	Screen		Heater		Anode Volts				No. of Anodes	
			Diam. (in.)	Colour	V	A	1st	2nd	Final Max.	Final Normal		
COSSOR							(V = Final anode volts)					
32	Standard Gas Focused	B	5¼	B	0·65	1·25	—	—	1,500	1,000	1	(1)
37	Non-Origin Distortion, Gas Focused	A	4½	B & GD	0·6	1·25	—	—	1,500	1,000	1	(2)
36	,,	B	5¼	B & GD	0·6	1·2	—	—	1,500	500	1	(3)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

RAY TUBES—MAGNETIC

	Anode Volts				No. of Anodes	Cathode Current (μA)	Overall Dimensions	
	1st	2nd	Final Max.	Final Normal			Diameter	Length
(1)	—	—	5,300	—	—	—	—	—
(2)	—	—	7,000	—	—	—	—	—
(3)	—	—	2,500	—	—	—	—	13 in.
(4)	—	—	2,500	—	—	—	—	16·5 in.
(5)	—	—	3,500	—	—	—	—	$20\frac{1}{8}$ in.
(6)	850	5,000	—	—	—	—	—	24 in.
(7)	850	5,000	—	—	—	—	—	28·5 in.
(8)	—	—	—	800	—	—	—	—
(9)	—	—	4,000	—	—	—	—	—
(10)	—	—	6,000	—	—	—	—	—
(11)	—	—	6,000	—	—	—	—	—
(12)	500	25,000	—	—	—	—	114 mm	341–354 mm
(13)	4,000	—	—	—	1	–43	185 mm	364–372 mm
(14)	250	5,000	—	—	2	0–100	226 mm	360 mm
(15)	4,000	—	—	—	1	0–55	217–223 mm	352–360 mm
(16)	125–250	5,000	—	—	2	0–100	225–231 mm	368–376 mm
(17)	125–250	5,000	—	—	2	0–100	310 mm	460 mm
(18)	125–250	5,000	—	—	2	0–100	302–308 mm	455–465 mm
(19)	125–250	6,000	—	—	2	0–1,000	395 mm	580 mm

TUBES—ELECTROSTATIC

	Cathode Current (μA)	Negative Grid Volts			Sensitivity		Capacitances (μμF)				Overall Dimensions	
		Normal	Cut-off	Min.	Y Axis (mm/V)	X Axis (mm/V)	Grid (To o	X Plate ther elec	Y Plate trodes)	Y or X to Opposites	Diameter (mm)	Length (mm)
(1)	70–150	$\frac{1}{10}$V	—	—	430/V	430/V	8	6	6	3·0	135	409
(2)	50–150	$\frac{1}{10}$V	—	—	300/V	275/V	9	5	5	1·5	114	345
(3)	50–150	$\frac{1}{10}$V	—	—	375/V	340/V	9	5	5	3·0	135	409

[*Continued on next page*

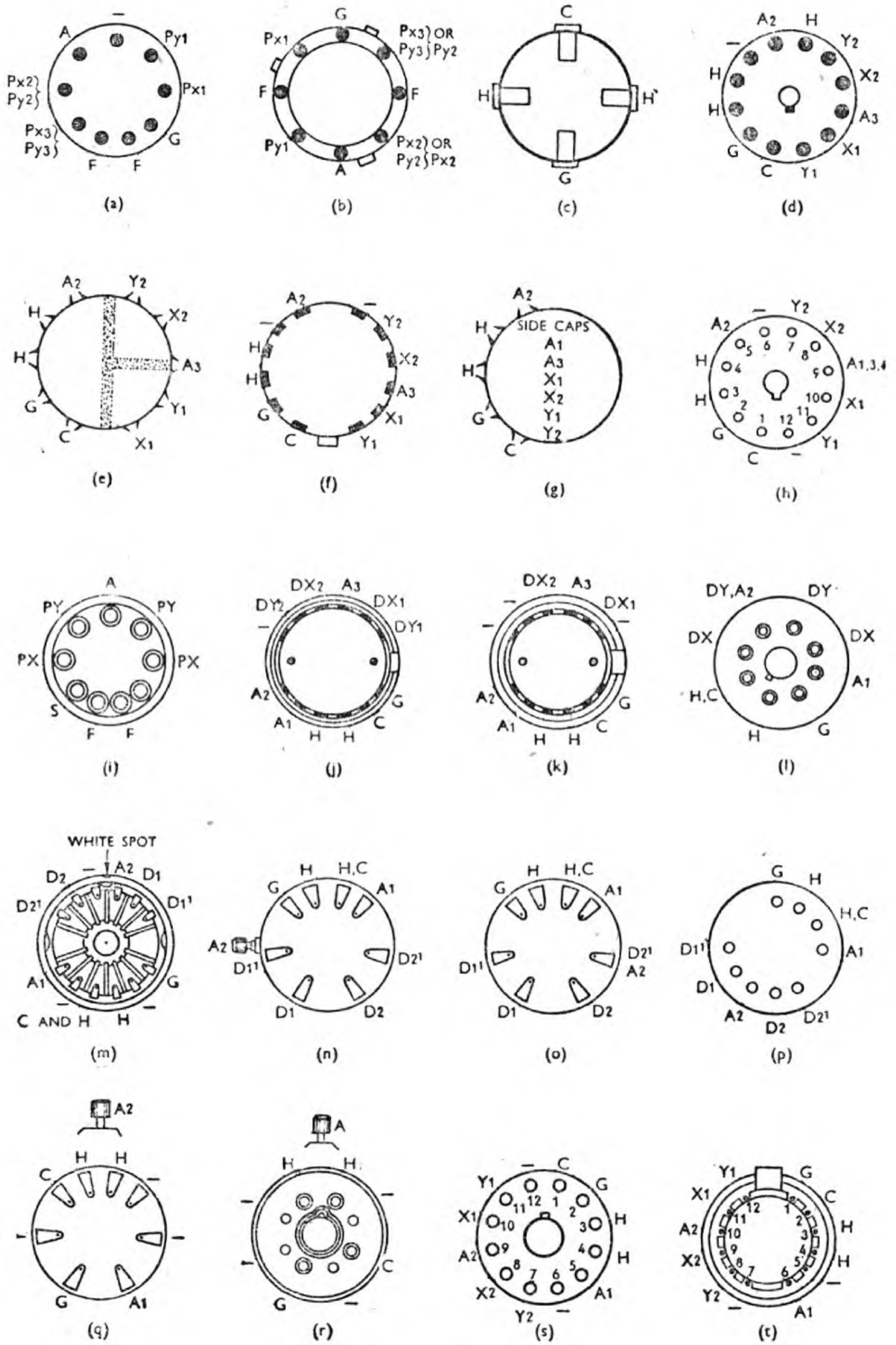
Type No.	Description	Base	Screen		Heater		Anode Volts				No. of Anodes	
			Diam. (in.)	Colour	V	A	1st	2nd	Final Max.	Final Normal		
COSSOR—*continued*												
09	Double Beam, Non-Trapezium, High Vacuum	D	4½	G	4·0	1·0	—	¼V	2,000	1,200	3	(4)
39	„	E	6¼	B	4·0	1·1	—	V/5–V/6	5,000	3,000	3	(5)
59	„	F	9	BG	4·0	1·0	—	V/5–V/6	5,000	3,000	3	(6)
26	Single Beam „	D	4½	G	4·0	1·0	—	¼V	2,000	1,200	3	(7)
21	„	E	8	W	4·0	1·1	—	V/6	6,000	5,000	3	(8)
79	„	F	9	B & GD	4·0	1·0	—	V/5–V/6	5,000	3,500	3	(9)
41	„	F	11	W	4·0	1·0	—	V/6 V/5	5,000	3,000	3	(10)
22	„ (High volt)	G	6¼	B	4·0	1·0	1,000 V	V/5–V/6	10,000	5,000	3	(11)
23	„ (Monitor)	H	2¾	G	4·0	1·1	—	V/6	2,000	800	3	(12)
18	Magnetic ..	C	13½	W	4·0	1·1	—	—	6,000	5,000	1	(13)
66	„	C	15	W	4·0	1·1	—	—	6,000	5,000	1	(14)
MULLARD												
E40/G3	Double Electrostatic Oscillograph	N	3	G	4·0	1·0	140–220	500–800	—	—	2	(15)
A40/G3	„	O	3	G	4·0	1·0	140–220	500 800	—	—	2	(16)
A40/N3	„	O	3	GD	4·0	1·0	140–220	500–800	—	—	2	(17)
A41/G4	„	P	4	G	4·0	1·0	400	1,000	—	—	2	(18)
A41/B4	„	P	4	B	4·0	1·0	400	1,000	—	—	2	(19)
A41/N4	„	P	4	GD	4·0	1·0	400	1,000	—	—	2	(20)
E42/G6	„	M	6	G	4·0	1·0	200–400	1,000–2,000	—	—	2	(21)
E42/B6	„	M	6	B	4·0	1·0	200–400	1,000–2,000	—	—	2	(22)
E46/G10	„	—	—	G	4·0	1·0	250	1,400	5,000	—	—	(23)
E46/B10	„			B	4·0	1·0	250	1,400	5,000	—	—	(24)
E41/G4	Double Electrostatic Oscillograph	P	4	G	4·0	1·0	400	1,000	—	—	2	(25)
E41/B4	„	P	4	B	4·0	1·0	400	1,000	—	—	2	(26)
ECR30	Electrostatic Oscillograph	S	3	G	4·0	1·0	120–150	1,000	—	—	2	(27)
ECR35	„	T	3·5	G	4·0	1·0	130–270	1,200	—	—	2	(28)
ECR60	„	T	6	G	4·0	1·0	250–450	2,000	—	—	2	(29)
E46/10	Electrostatic	—	—	—	4·0	1·0	250	1,400	—	—	—	(30)
E46/12	„	—	—	—	4·0	1·0	250	1,400	—	—	—	(31)
STANDARD												
4050AB	Gas filled	I	—	B	0·75	0·7–1·1	—	—	1,500	500	—	(32)
4050AD	„	I	—	BD	0·75	0·7–1·1	—	—	1,500	500	—	(33)
4050AG	„	I	—	G	0·75	0·7–1·1	—	—	1,500	500	—	(34)
4050BB	„	I	—	B	0·75	0·7–1·1	—	—	1,500	500	—	(35)
4050BD	„	I	—	BD	0·75	0·7–1·1	—	—	1,500	500	—	(36)
4050BG	„	I	—	G	0·75	0·7–1·1	—	—	1,500	500	—	(37)
4063AB	Vacuum	J	5½	B	2·0	1·8–2	150	·27V	5,000	—	—	(38)
4063YB	„	K	5¼	B	2·0	1·8–2	150	·27V	5,000	—	—	(39)
VLS492 AG	„	L	1½	G	2·0	1·8	60–300	—	250–1,000	—	—	(40)

(Screen Colour: B, Blue; G, Green; W. White; D, Long Delay).

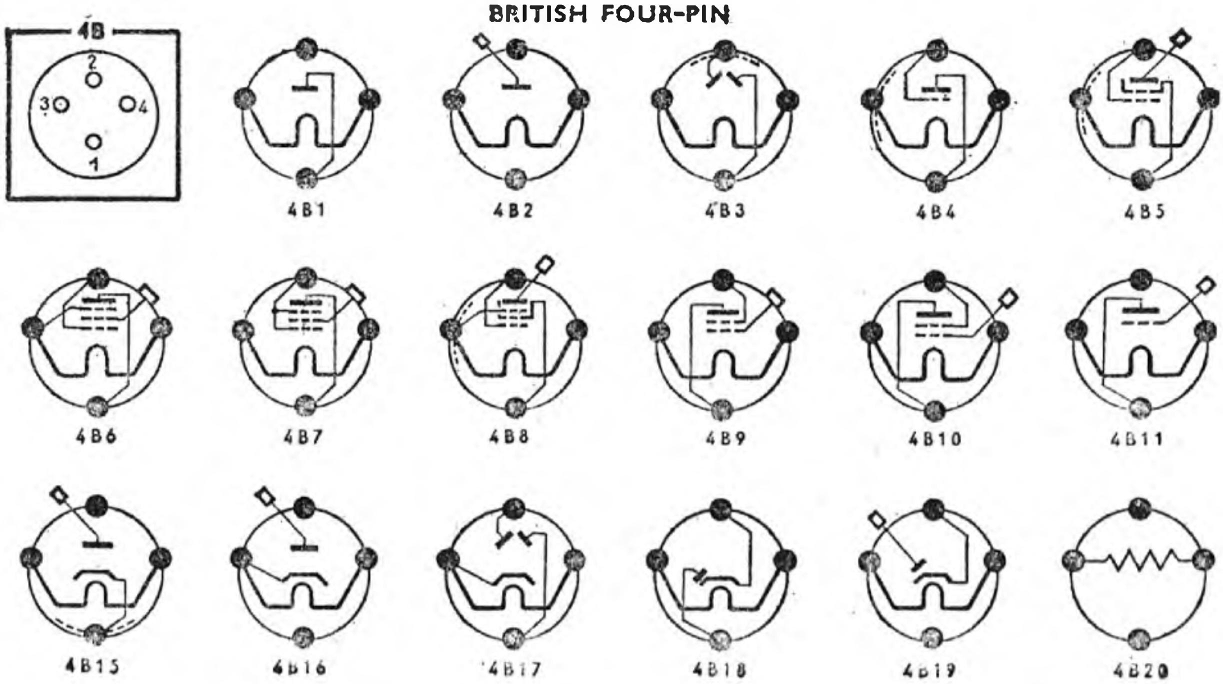
NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

TUBES—ELECTROSTATIC—*continued*

	Cathode Current (µA)	Negative Grid Volts			Sensitivity		Capacitances (µµF)				Overall Dimensions	
		Normal	Cut-off	Min.	Y Axis (mm/V)	X Axis (mm/V)	Grid (To o	X Plate ther elec	Y Plate trodes)	Y or X to Opposites	Diameter (mm)	Length (mm)
(4)	0–500	V/80	V/40	0	400/V	400/V	8·5	14	14	1·0	114	375
(5)	0–400	V/360	V/180	0	650/V	700/V	7	11	12	1·0	160	455
(6)	0–350	V/360	V/180	0	650/V	750/V	7	11	12	1·0	228	525
(7)	0–50	V/80	V/40	0	390/V	350/V	9	14	11	1·0	114	375
(8)	0–350	V/360	V/180	0	966/V	735/V	8	16	13	5·0	205	507
(9)	0–350	V/360	V/180	0	600/V	600/V	7	11	12	1·0	228	525
(10)	0–350	V/360	V/180	0	600/V	600/V	11	17	15	1·0	295	580
(11)	0–250	V/360	V/180	0	980/V	780/V	6	14	10	3·0	135	490
(12)	0–150	6·5	V/70	0	170/V	170/V	20	15	15	1·0	70	200
(13)	—	—	—	—	—	—	—	—	—	—	350	605
(14)	—	—	—	—	—	—	—	—	—	—	382	675
(15)	—	0–30	—	—	—	—	—	—	—	—	75	150–165
(16)	—	0–30	—	—	—	—	—	—	—	—	75	150–165
(17)	—	0–30	—	—	—	—	—	—	—	—	75	150–165
(18)	—	0–40	—	—	—	—	—	—	—	—	103	326–349
(19)	—	0–40	—	—	—	—	—	—	—	—	103	326–349
(20)	—	0–40	—	—	—	—	—	—	—	—	103	326–349
(21)	—	0–35	—	—	—	—	—	—	—	—	167	425–450
(22)	—	0–35	—	—	—	—	—	—	—	—	167	425–450
(23)	—	0–60	—	—	—	—	—	—	—	—	258	570–595
(24)	—	0–60	—	—	—	—	—	—	—	—	258	570–595
(25)	—	0–40	—	—	—	—	—	—	—	—	103	326–349
(26)	—	0–40	—	—	—	—	—	—	—	—	103	326–349
(27)	—	–1–15	—	—	—	—	—	—	—	—	70	200
(28)	—	–1–50	—	—	—	—	—	—	—	—	90	340
(29)	—	–1–100	—	—	—	—	—	—	—	—	160	431
(30)	—	—	—	—	—	—	—	—	—	—	258	570–595
(31)	—	—	—	—	—	—	—	—	—	—	310	630–660
											(in.)	(in.)
(32)	—	—	—	—	370/V	370/V	—	—	—	7·0	4½	13¼
(33)	—	—	—	—	370/V	370/V	—	—	—	7·0	4½	13¼
(34)	—	—	—	—	370/V	370/V	—	—	—	7·0	4½	13¾
(35)	—	—	—	—	580/V	580/V	—	—	—	7·0	7	18¼
(36)	—	—	—	—	580/V	580/V	—	—	—	7·0	7	18½
(37)	—	—	—	—	580/V	580/V	—	—	—	7·0	7	18½
(38)	—	0–5	–30	—	600/V	700/V	18	16	10	—	6½	21
(39)	—	0–5	–30	—	600/V	700/V	18	16	3·5	—	6½	21
(40)	—	0–5	—	—	110/V	120/V	8·5	6·6	6·0	—	1½	6½


(a) A Py1 Px1 G F F Px3 Py3 Px2 Py2
(b) G Px3 OR Py3 Py2 Px1 F F Py1 A Px2 OR Py2 Px2
(c) C H H G
(d) A2 H Y2 X2 A3 X1 Y1 C G H H
(e) A2 Y2 X2 A3 Y1 X1 C G H H
(f) A2 Y2 X2 A3 X1 Y1 C G H H
(g) A2 SIDE CAPS A1 A3 X1 X2 Y1 Y2 H H G C
(h) Y2 X2 A1,3,4 X1 Y1 C G H H A2 1 2 3 4 5 6 7 8 9 10 11 12
(i) A PY PY PX PX S F F
(j) DX2 A3 DX1 DY1 DY2 A2 A1 H H C G
(k) DX2 A3 DX1 A2 A1 H H C G
(l) DY,A2 DY DX DX A1 G H H,C
(m) WHITE SPOT A2 D1 D1' D2 D2' A1 G C AND H H
(n) H H,C A1 G A2 D1' D2' D1 D2
(o) H H,C A1 G D1' D2' A2 D1 D2
(p) G H H,C A1 D1' D1 A2 D2 D2'
(q) A2 H H C G A1
(r) A H H C G
(s) C G H H A1 Y2 X2 A2 X1 Y1 1 2 3 4 5 6 7 8 9 10 11 12
(t) Y1 G C H H A1 Y2 X2 A2 X1 1 2 3 4 5 6 7 8 9 10 11 12

BRITISH FOUR-PIN



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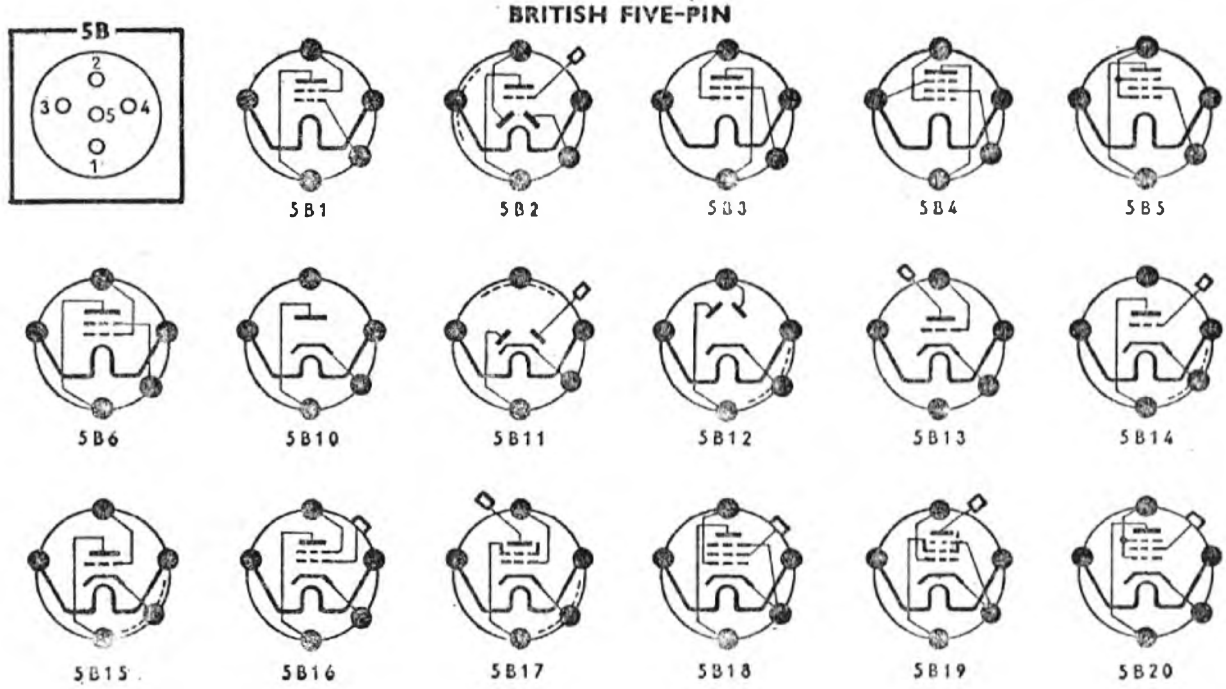

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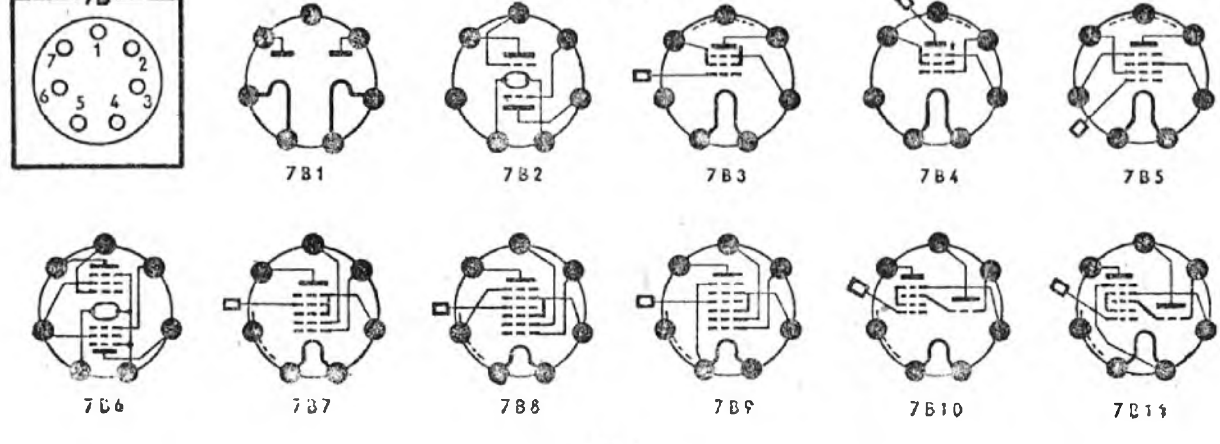

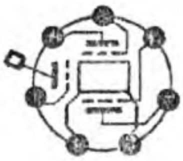
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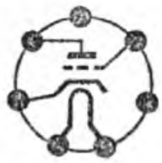
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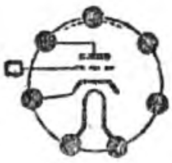
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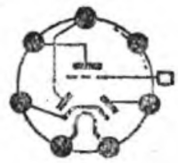
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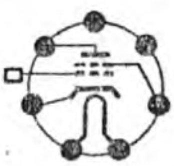
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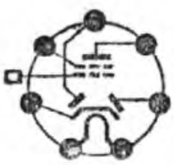
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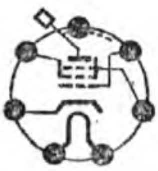
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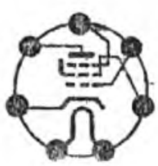
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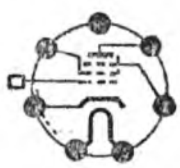
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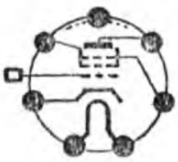
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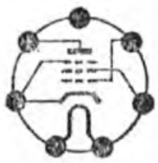
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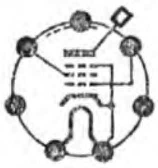
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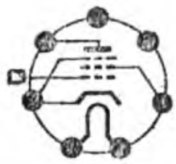
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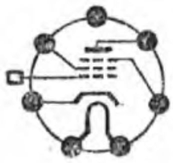
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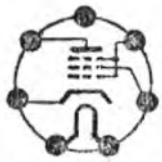
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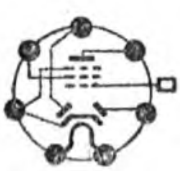
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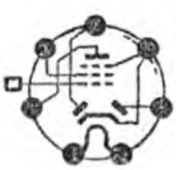
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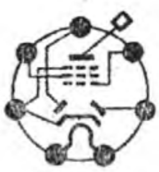
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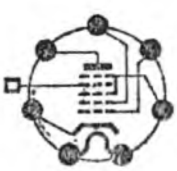
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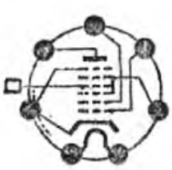
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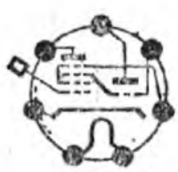
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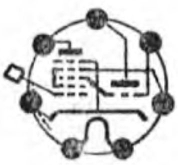
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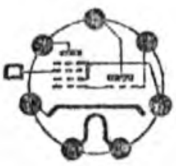
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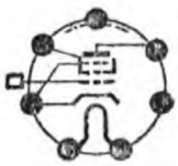
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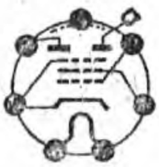
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7B47


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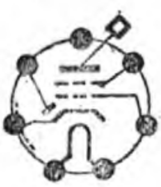
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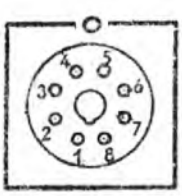
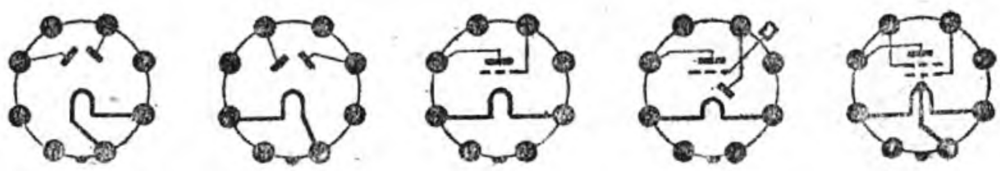
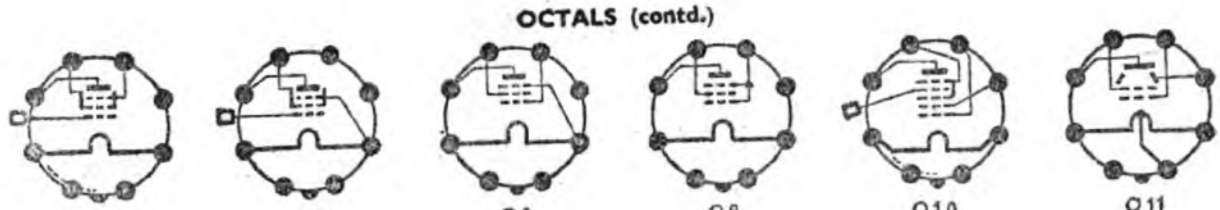
BLANKS HAVE BEEN LEFT AT THE END OF SOME GROUPS SO THAT THE READER MAY INSERT DETAILS OF FUTURE TYPES

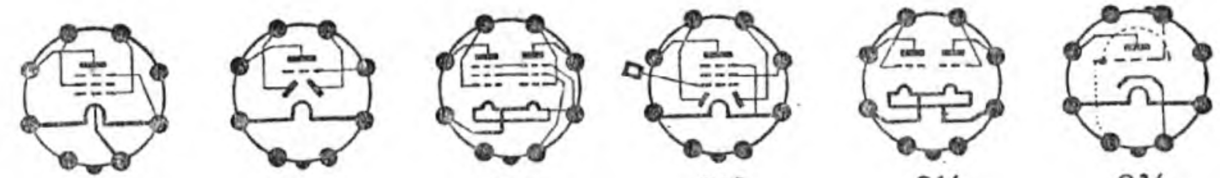
OCTALS



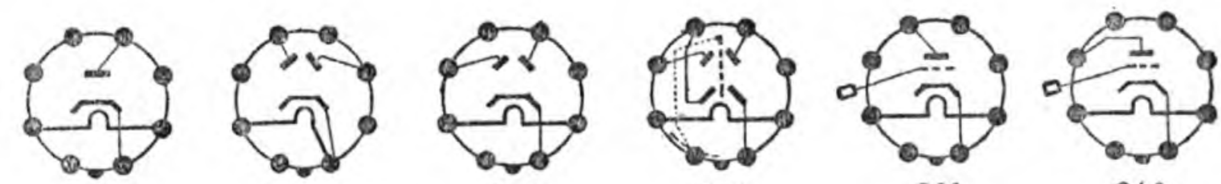

O1 O2 O3 O4 O5



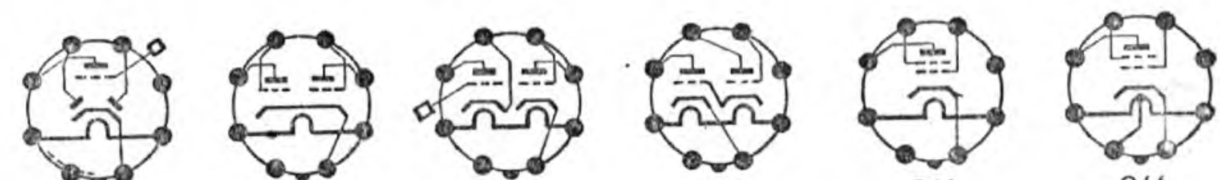
O6 O7 O8 O9 O10 O11



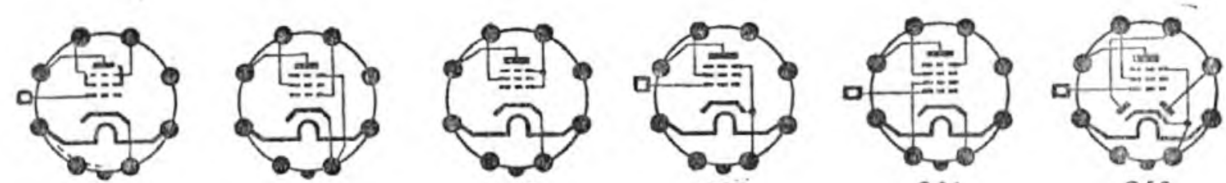
O12 O13 O14 O15 O16 O34



O35 O36 O37 O38 O39 O40



O41 O42 O43 O44 O45 O46



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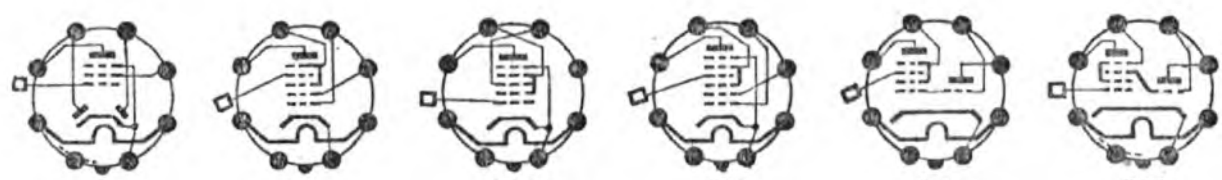

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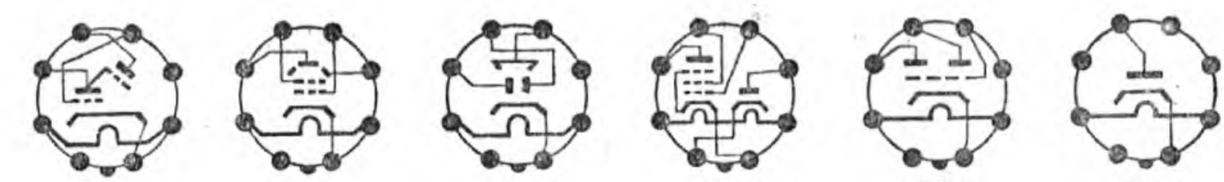

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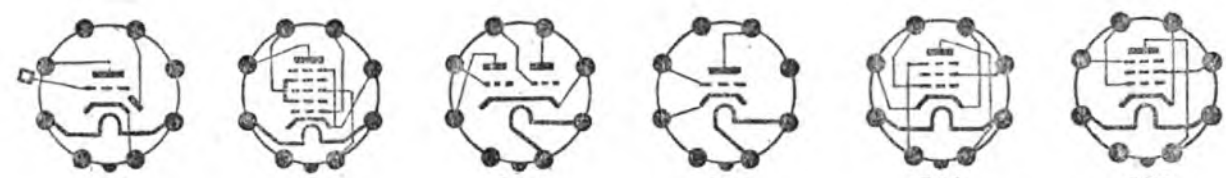

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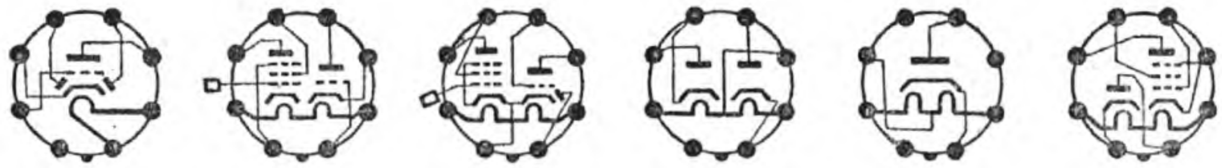
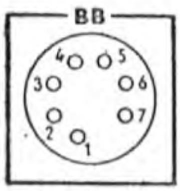


O71 O72 O73 O74 O75 O76

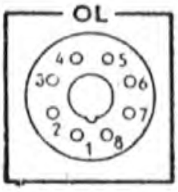
O77 O78

AMERICAN MINIATURE BUTTON BASES

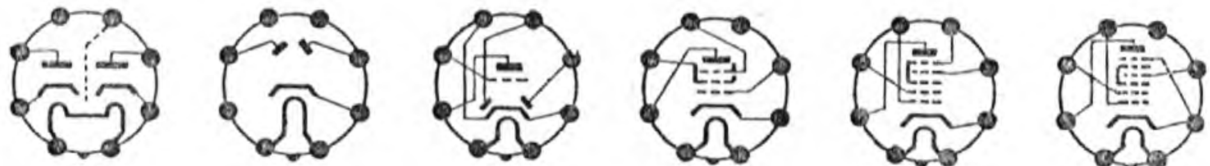


BB1 BB2 BB3 BB4

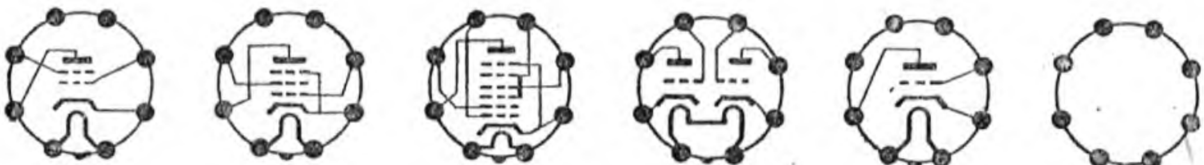
LOCTALS



OL1 OL2 OL3 OL4 OL8

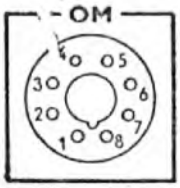


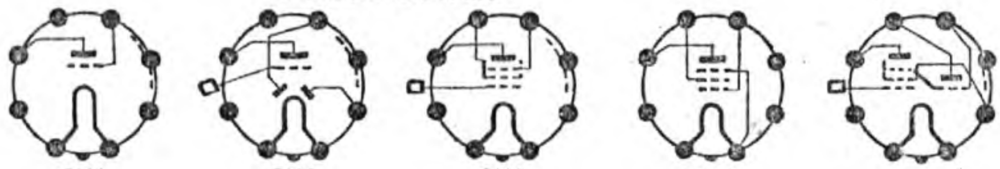
OL9 OL10 OL11 OL12 OL13 OL14



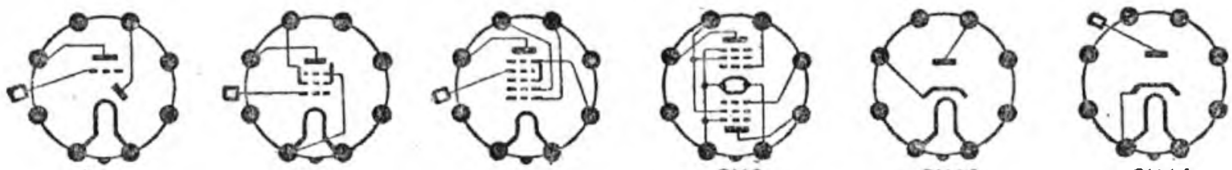
OL15 OL16 OL17 OL18 OL19

MAZDA OCTALS



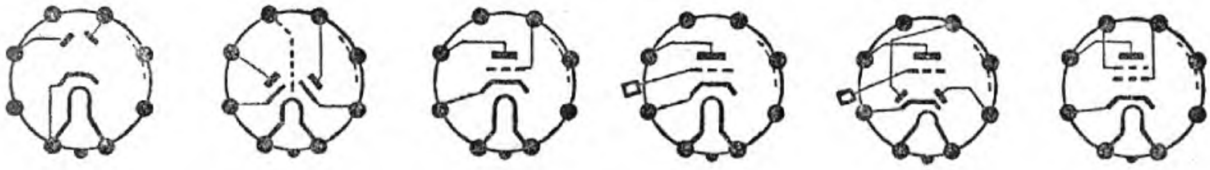


OM1 OM2 OM3 OM4 OM5

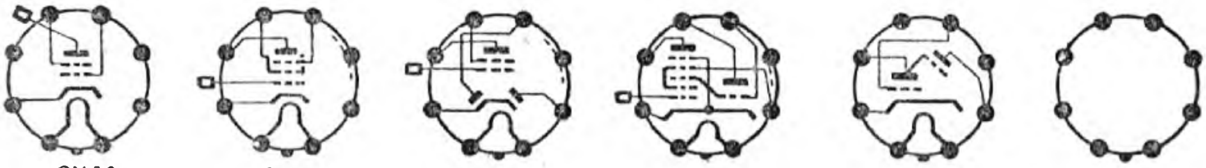


OM6 OM7 OM8 OM9 OM15 OM16

MAZDA OCTALS (contd.)

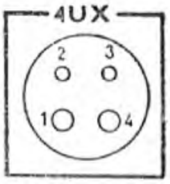


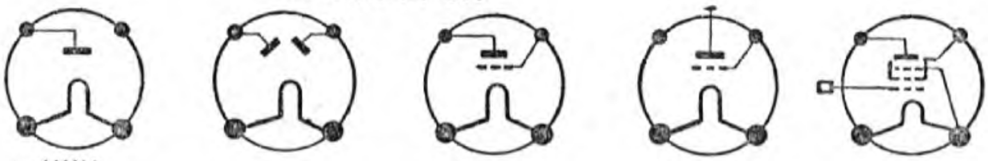
OM 17 OM 18 OM 19 OM 20 OM 21 OM 22



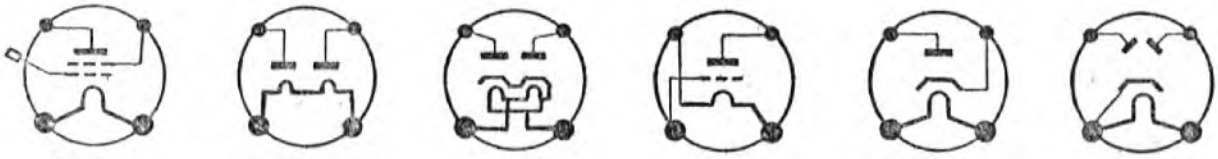
OM 23 OM 24 OM 25 OM 26 OM27

AMERICAN UX

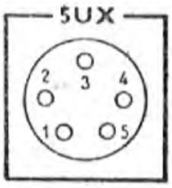




4UX1 4UX2 4UX3 4UX4 4UX5



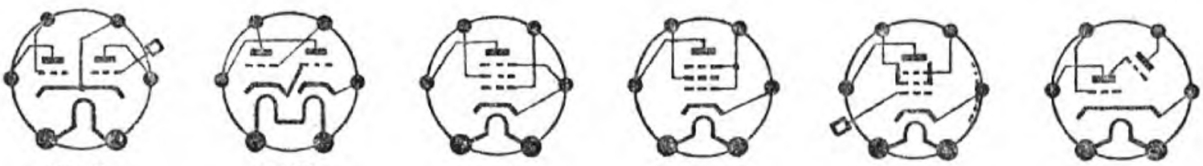
4UX6 4UX7 4UX8 4UX9 4UX10 4UX11



5UX1 5UX2 5UX4 5UX5 5UX6

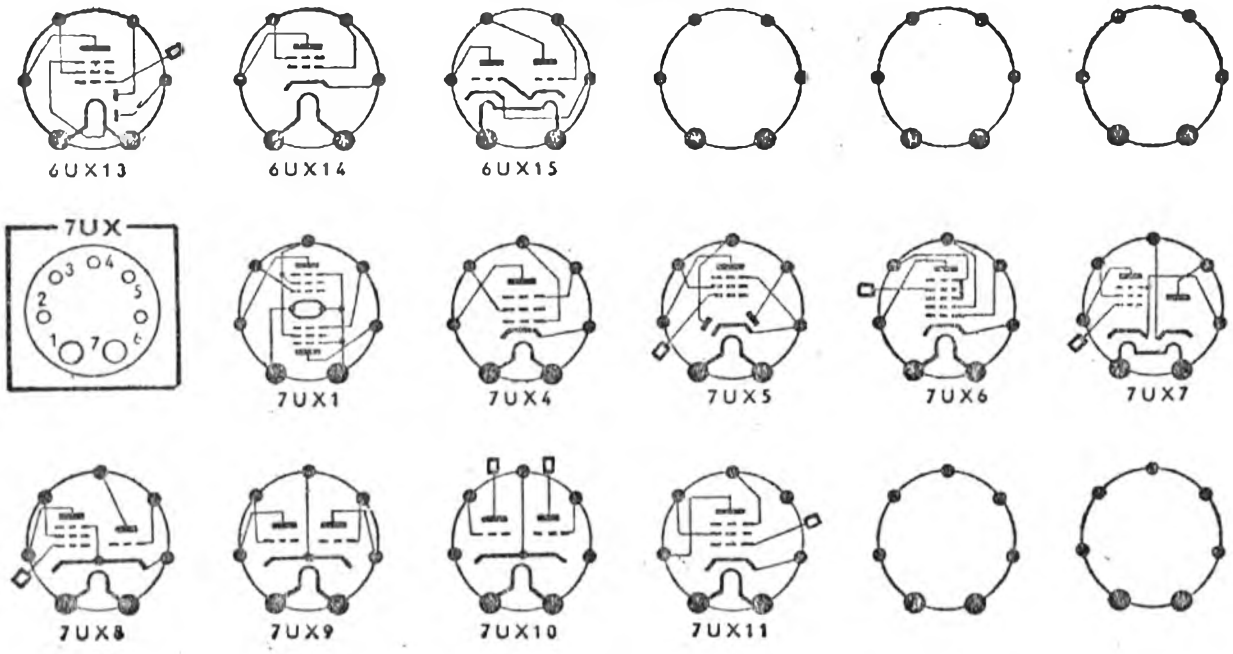
5UX7 5UX8

6UX1 6UX2 6UX3 6UX5 6UX6

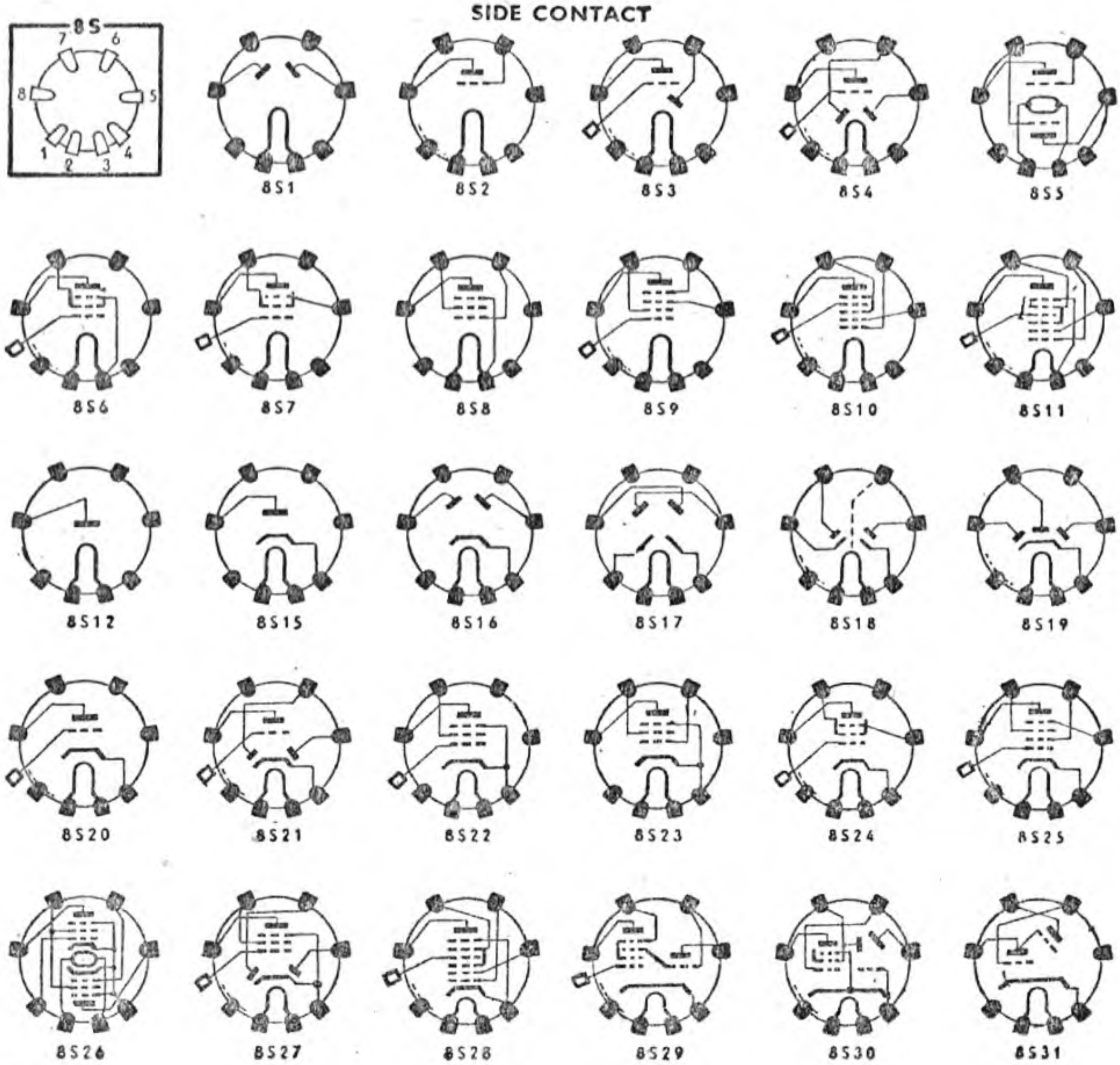


6UX7 6UX8 6UX9 6UX10 6UX11 6UX12

AMERICAN UX (contd.)

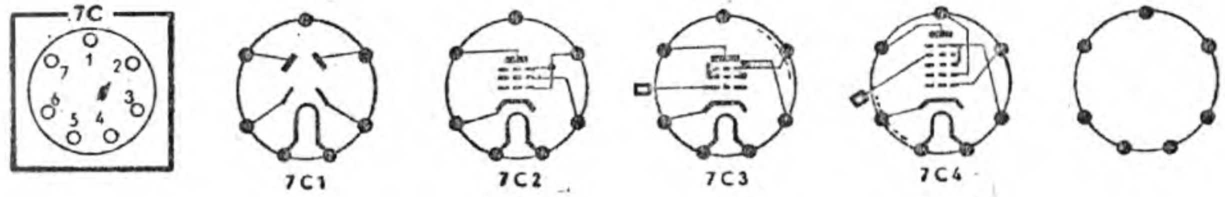


SIDE CONTACT

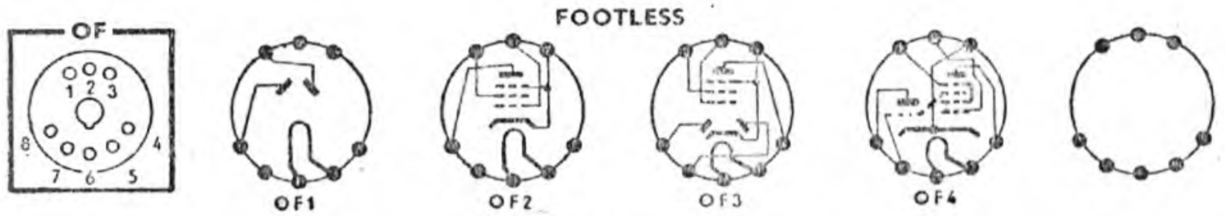


SIDE CONTACT (contd.)

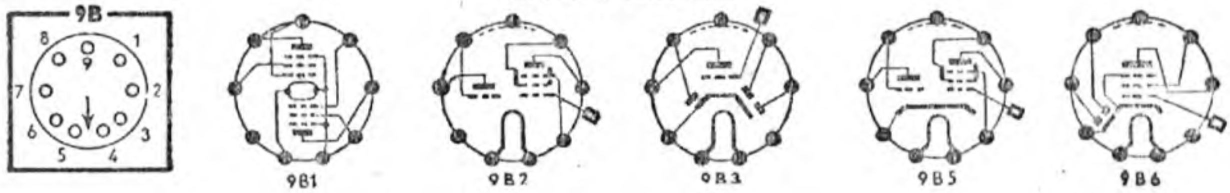
CONTINENTAL



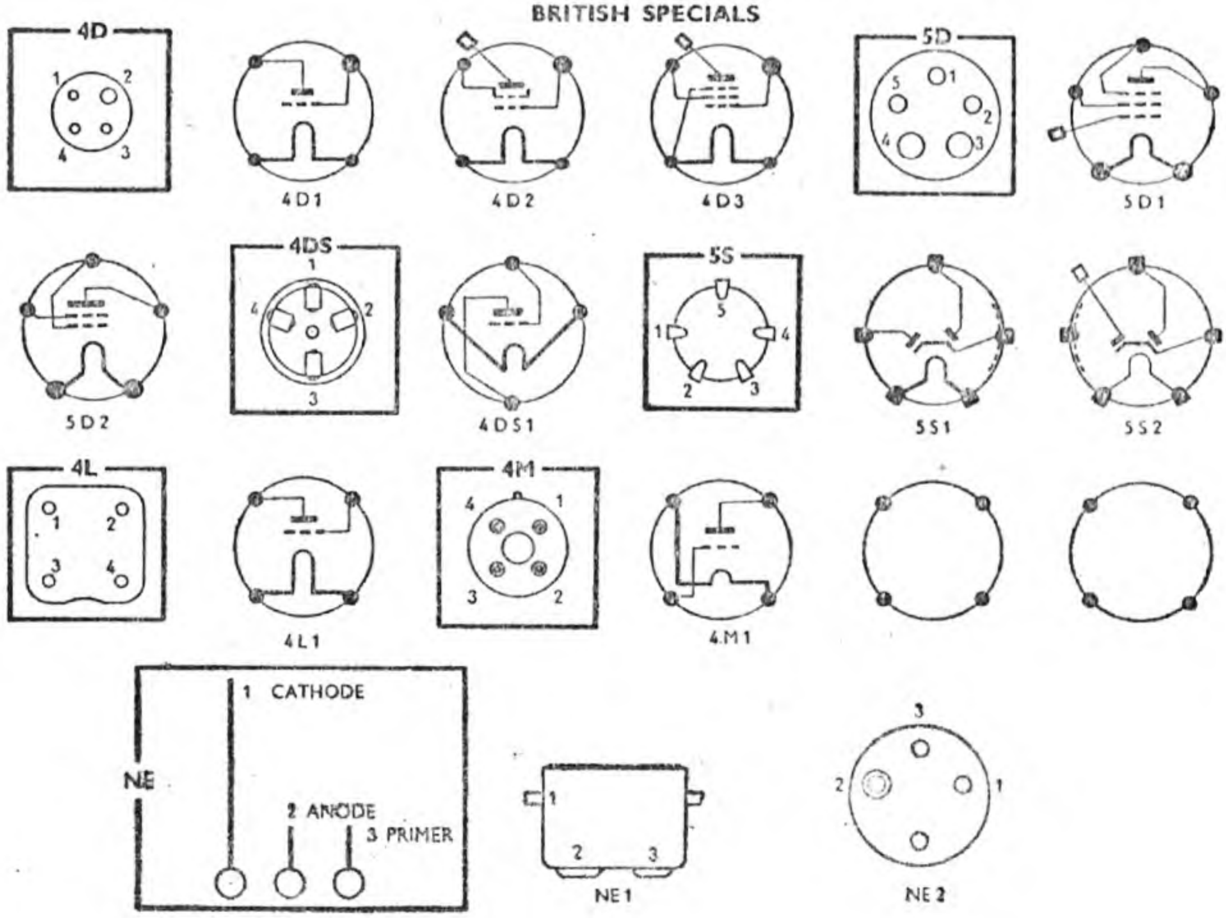
FOOTLESS



BRITISH NINE-PIN



BRITISH SPECIALS



Type	Description	Base	Fil. or Heater (Volts)	Fil. or Heater Current (Amps)	Anode Volts	Screen Volts	
00A	Triode (Gas) ..	4UX3	5·0	0·25	45	—	(1)
0Z4	Rectifier (Gas) ..	078	—	—	RMS 300	—	(2)
01-A	Triode	4UX3	5·0	0·25	45	—	(3)
1A4	HF Pentode ..	4UX5	2·0	0·06	180	67·5	(4)
1A5	LF Pentode.. ..	09	1·4	0·05	90	90	(5)
1A6	Heptode	6UX3	2·0	0·06	180	67·5	(6)
1A7	Pentagrid	010	1·4	0·05	90	45	(7)
1A7V	VMu. Pentagrid ..	010	1·4	0·05	90	90	(8)
1B4	HF Pentode ..	4UX5	2·0	0·06	180	67	(9)
1B5/25S	DD Triode	6UX2	2·0	0·06	135	—	(10)
1C5	LF Pentode.. ..	09	1·4	0·1	90	90	(11)
1C6	Heptode	6UX3	2·0	0·12	180	67·5	(12)
1C7	Pentagrid	010	2·0	0·12	180	67·5	(13)
1D5	HF Pentode ..	07	2·0	0·06	180	67·5	(14)
1D7	Pentagrid	010	2·0	0·06	180	67·5	(15)
1E5	HF Pentode ..	07	2·0	0·06	180	67	(16)
1E7	Twin LF Pentode ..	014	2·0	0·24	135	135	(17)
1F4	LF Pentode.. ..	5UX1	2·0	0·12	180	180	(18)
1F5	LF Pentode.. ..	08	2·0	0·12	180	180	(19)
1F6	DD LF Pentode ..	6UX13	2·0	0·06	180	67·5	(20)
1F7	DD LF Pentode ..	015	2·0	0·06	180	67·5	(21)
1H4	Triode	03	2·0	0·06	180	—	(22)
1H5	Diode Triode ..	04	1·4	0·05	90	—	(23)
1H6	DD Triode	013	2·0	0·06	135	—	(24)
1J6	Class B	016	2·0	0·24	135	—	(25)
1LA4	LF Pentode.. ..	0L2	1·4	0·05	90	90	(26)
1LA6	Frequency Changer	0L4	1·4	0·05	90	45	(27)
1LH4	Diode Triode ..	0L1	1·4	0·05	90	—	(28)
1LN5	HF Pentode ..	0L3	1·4	0·05	90	90	(29)
1N5	HF Pentode ..	06	1·4	0·05	90	90	(30)
1N5V	HF Pentode ..	06	1·4	0·05	90	90	(31)
1Q5	LF Pentode.. ..	060	1·4	0·1	90	90	(32)
1R5	Pentagrid	BB1	1·4	0·05	90	67·5	(33)
1S4	LF Pentode.. ..	BB2	1·4	0·1	67·5	67·5	(34)
1S5	LF Pentode.. ..	BB3	1·4	0·05	90	90	(35)
1T4	HF Pentode ..	BB4	1·4	0·05	90	67·5	(36)
1-V	Rectifier	4UX10	6·3	0·3	RMS 325	—	(37)
2A3	Power Triode ..	4UX3	2·5	2·5	250	—	(38)
2A5	LF Pentode.. ..	6UX10	2·5	1·75	250	250	(39)
2A6	DD Triode	6UX6	2·5	0·8	250	—	(40)
2A7	Pentagrid	7UX6	2·5	0·8	250	100	(41)
2B7	DD HF Pentode ..	7UX5	2·5	0·8	250	100	(42)
2E5	Tuning Indicator ..	6UX12	2·5	0·8	250	—	(43)
2G5	Tuning Indicator ..	—	2·5	0·8	250	—	(44)
3Q5	LF Pentode.. ..	011	2·8	0·05	90	90	(45)
5T4	Rectifier	02	5·0	2·0	RMS 450	—	(46)
5U4	Rectifier	02	5·0	3·0	RMS 500	—	(47)
5V4	Rectifier	036	5·0	2·0	RMS 400	—	(48)
5X4	Rectifier	01	5·0	3·0	RMS 500	—	(49)
5Y3	Rectifier	02	5·0	2·0	RMS 350	—	(50)

Note.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Screen Current (mA)	Slope mA/V (*=Conv. Condt. μA/V)	Impedance (Ohms)	Amp. Factor	Output (Watts)	Optimum Load (Ohms)
(1)	—	—	1·5	—	0·666	30,000	20	—	—
(2)	—	—	—	—	—	—	—	75mA	—
(3)	—	—	1·5	—	0·666	30,000	20	—	—
(4)	–3–15	—	2·3	0·8	0·75	1 meg.	750	—	—
(5)	–4·5	—	4·0	0·8	0·85	300,000	255	0·115	25,000
(6)	–3–22·5	—	1·3	2·4	*300	500,000	—	—	—
(7)	0–3	—	1·2	0·6	*250	600,000	—	—	—
(8)	0	—	2·3	—	*250	—	—	—	—
(9)	–3·0	—	1·7	0·6	0·65	1·5 meg.	—	—	—
(10)	–3·0	—	0·8	—	0·575	35,000	20	—	—
(11)	–7·5	—	7·5	1·6	1·55	115,000	180	0·24	8,000
(12)	–3–14	—	1·5	2·0	*325	750,000	—	—	—
(13)	–3·0	—	1·5	2·0	*325	750,000	—	—	—
(14)	–3·0	—	2·3	0·8	0·75	1 meg.	—	—	—
(15)	–3·0	—	1·3	2·4	0·3	500,000	—	—	—
(16)	–3·0	—	1·7	0·6	0·65	1·5 meg.	—	—	—
(17)	–7·5	—	7·5	2·2	1·425	260,000	—	0·575	24,000
(18)	–4·5	432	8·0	2·4	1·7	200,000	—	0·31	16,000
(19)	–4·5	432	8·0	2·4	1·7	200,000	—	0·31	16,000
(20)	–1·5	—	2·2	0·7	0·65	1 meg.	—	—	—
(21)	–1·5	—	2·2	0·7	0·65	1 meg.	—	—	—
(22)	–13·5	—	3·1	—	0·9	10,300	9·3	—	—
(23)	0	—	0·14	—	0·275	240,000	65	—	—
(24)	–3·0	—	0·8	—	0·575	35,000	20	—	—
(25)	0	—	5·0	—	—	—	—	2·1	10,000
(26)	–4·5	—	4·0	0·8	0·85	300,000	255	0·115	25,000
(27)	0–3·0	—	1·2	0·6	*250	600,000	—	—	—
(28)	0	—	0·14	—	0·275	240,000	65	—	—
(29)	0	—	1·6	0·35	0·8	1·1 meg.	880	—	—
(30)	0–4·0	—	1·2	0·3	0·75	1·5 meg.	1160	—	—
(31)	0	—	1·6	—	0·65	1 meg.	—	—	—
(32)	–4·5	—	9·5	1·6	2·1	—	—	0·27	8,000
(33)	—	—	1·7	3·0	—	—	—	—	—
(34)	–7·0	—	7·2	1·5	—	—	—	—	—
(35)	—	—	3·0	7·0	—	—	—	—	—
(36)	—	—	3·7	1·25	—	—	—	—	—
(37)	—	—	—	—	—	—	—	45mA	—
(38)	–45·0	750	60·0	—	5·25	800	4·2	3·5	2,000
(39)	–16·5	410	34·0	6·5	2·65	30,000	190	3·0	7,000
(40)	–2·0	5,000	0·8	—	1·1	90,000	100	—	—
(41)	–3–40	300	3·5	2·2	*520	360,000	—	—	—
(42)	–3·0	—	10·0	2·3	1·2	600,000	—	—	—
(43)		—	—	—	—	—	—	—	—
(44)	—	—	—	—	—	—	—	—	—
(45)	–4·5	—	9·5	1·6	2·1	—	—	0·27	8,000
(46)	—	—	—	—	—	—	—	250mA	—
(47)	—	—	—	—	—	—	—	250mA	—
(48)	—	—	—	—	—	—	—	200mA	—
(49)	—	—	—	—	—	—	—	200mA	—
(50)	—	—	—	—	—	—	—	125mA	—

[*Continued on next page*

TABLE XLVII: AMERICAN

Type	Description	Base	Fil. or Heater (Volts)	Fil. or Heater Current (Amps)	Anode Volts	Screen Volts	
5Y4	Rectifier	01	5·0	2·0	RMS 350	—	(51)
5Z3	Rectifier	4UX2	5·0	3·0	RMS 500	—	(52)
5Z4	Rectifier	036	5·0	2·0	RMS 350	—	(53)
6A3	Power Triode ..	4UX3	6·3	1·0	250	—	(54)
6A4	LF Pentode.. ..	5UX1	6·3	0·3	180	180	(55)
6A6	Double Triode ..	042	6·3	0·8	300	—	(56)
6AG6	LF Pentode.. ..	049	6·3	1·2	250	250	(57)
6A7	Frequency Changer	7UX6	6·3	0·3	250	100	(58)
6A8	Frequency Changer	054	6·3	0·3	250	100	(59)
6AB5	Tuning Indicator ..	6UX12	6·3	0·15	180	Target 180	(60)
6AD6	Tuning Indicator ..	061	6·3	0·15	—	Target 150	(61)
6AE6	Twin Anode Control	063	6·3	0·15	250	—	(62)
6AF6	Tuning Indicator ..	061	6·3	0·15	—	Target 135	(63)
6B4	Power Triode ..	03	6·3	1·0	250	—	(64)
6B5	Double Triode ..	6UX8	6·3	0·8	300	—	(65)
6B6	DD Triode	041	6·3	0·3	250	—	(66)
6B7	DD HF Pentode ..	7UX5	6·3	0·3	250	125	(67)
6B8	DD HF Pentode ..	053	6·3	0·3	250	125	(68)
6B8S	DD HF Pentode ..	053	6·3	0·3	250	100	(69)
6C5	Triode	034	6·3	0·3	250	—	(70)
6C6	HF Pentode ..	6UX11	6·3	0·3	250	100	(71)
6C7	DD Triode	—	6·3	0·3	250	—	(72)
6D6	HF Pentode ..	6UX11	6·3	0·3	250	100	(73)
6D8	Pentagrid	054	6·3	0·15	250	100	(74)
6E5	Tuning Indicator ..	6UX12	6·3	0·3	250	—	(75)
6E6	Double Triode ..	7UX9	6·3	0·6	250	—	(76)
6E7	HF Pentode ..	7UX11	6·3	0·3	250	100	(77)
6E8	Triode Hexode ..	058	6·3	0·3	250	100	(78)
6F5	Triode	039	6·3	0·3	250	—	(79)
6F6	LF Pentode.. ..	049	6·3	0·7	250	250	(80)
6F7	Triode Pentode ..	7UX8	6·3	0·3	250	100	(81)
6G5	Tuning Indicator ..	6UX12	6·3	0·3	250	—	(82)
6G6	LF Pentode.. ..	048	6·3	0·15	180	180	(83)
6H4	Diode	064	6·3	0·15	100	—	(84)
6H6	Double Diode ..	037	6·3	0·3	—	—	(85)
6J5	Triode	034	6·3	0·3	250	—	(86)
6J7	HF Pentode ..	050	6·3	0·3	250	125	(87)
6K5	Triode	040	6·3	0·3	250	—	(88)
6K6	LF Pentode.. ..	048	6·3	0·4	250	250	(89)
6K7	HF Pentode ..	047	6·3	0·3	250	125	(90)
6K8	Triode Hexode ..	057	6·3	0·3	250	100	(91)
6L5	Triode	034	6·3	0·15	250	—	(92)
6L6	LF Pentode.. ..	060	6·3	0·9	250	250	(93)
6L7	Frequency Changer	055	6·3	0·3	250	150	(94)
6M6	LF Pentode.. ..	048	6·3	1·2	250	250	(95)
6N5	Tuning Indicator ..	6UX12	6·3	0·15	180	—	(96)
6N6	Double Triode ..	044	6·3	0·8	300	—	(97)

Note.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Screen Current (mA)	Slope mA/V (*=Conv. Condt. μA/V)	Impedance (Ohms)	Amp. Factor	Output (Watts)	Optimum Load (Ohms)
(51)	—	—	—	—	—	—	—	125mA	—
(52)	—	—	—	—	—	—	—	250mA	—
(53)	—	—	—	—	—	—	—	125mA	—
(54)	−4·5	—	60·0	—	5·25	800	4·2	3·2	2,500
(55)	−12·0	465	22·0	3·9	2·2	45,500	—	1·4	8,000
(56)	0	0	—	—	—	—	35	10·0	—
(57)	−6·0	150	32·0	6·0	10·0	60,000	600	3·75	8,500
(58)	−3–40	300	3·5	2·2	*550	360,000	—	—	—
(59)	−3–40	300	3·5	2·2	*550	360,000	—	—	—
(60)	—	—	—	—	—	—	—	—	—
(61)	—	—	—	—	—	—	—	—	—
(62)	—	—	6·5	—	—	—	—	—	—
(63)	—	—	—	—	—	—	—	—	—
(64)	−45·0	—	60·0	—	5·25	800	4·2	3·2	2,500
(65)	—	—	43·0	—	2·25	24,000	54	5·0	7,000
(66)	−2·0	5,000	0·4	—	1·1	90,000	100	—	—
(67)	−3·0	250	7·5	2·1	1·1	650,000	700	—	—
(68)	−3·0	—	9·0	2·3	1·1	600,000	800	—	—
(69)	−3–30	—	6·5	1·4	1·0	800,000	800	—	—
(70)	−8·0	1,000	8·0	—	2·0	10,000	20	—	—
(71)	−3·0	600	2·0	0·5	1·25	1·5 meg.	1,900	—	—
(72)	−9·0	—	5·5	—	1·25	16,000	20	—	—
(73)	−3–40	300	8·2	2·0	1·6	800,000	1,280	—	—
(74)	−3·0	—	3·5	2·6	*550	400,000	—	—	—
(75)	—	—	—	—	—	—	—	—	—
(76)	−27·5	—	36·0	—	3·4	7,000	6·0	1·6	14,000
(77)	−3·0	—	7·5	1·75	1·5	770,000	20	—	—
(78)	—	—	3·3	—	*650	—	—	—	—
(79)	−2·0	2,000	0·9	—	1·5	66,000	100	—	—
(80)	−16·5	410	34·0	6·5	3·25	80,000	190	3·5	7,000
(81)	−3–35	500	6·5	1·5	1·1	850,000	900	—	—
(82)	0–22	—	—	—	—	—	—	—	—
(83)	−9·0	—	15·0	2·5	2·3	—	—	—	—
(84)	—	—	4·0	—	—	—	—	—	—
(85)	—	—	—	—	—	—	—	—	—
(86)	−8·0	—	9·0	—	2·6	7,700	20	—	—
(87)	−3·0	600	2·0	0·5	1·25	1·5 meg.	1,900	—	—
(88)	−3·0	3,000	1·1	—	1·4	50,000	70	—	—
(89)	−18·0	—	32·0	—	2·2	68,000	—	3·4	7,600
(90)	−3·0	200	10·5	2·6	1·65	600,000	1,000	—	—
(91)	−3–30	300	2·5	4·5	*350	1 meg.	—	—	—
(92)	−9·0	—	8·0	—	1·9	9,000	17	—	—
(93)	−14·0	170	72·0	5·0	6·0	22,500	135	6·5	2,500
(94)	−3·0	260	3·3	8·3	*350	1 meg.	—	—	—
(95)	—	140	36·0	4·0	10·0	—	—	4·4	7,000
(96)	—	—	—	—	—	—	—	—	—
(97)	0	—	43·0	8·0	8·0	24,000	54	5·0	7,000

[*Continued on next page*

Type	Description	Base	Fil. or Heater (Volts)	Fil. or Heater Current (Amps)	Anode Volts	Screen Volts	
6N7	Double Triode ..	042	6·3	0·8	300	—	(98)
6P8	Triode Hexode ..	058	6·3	0·8	250	80	(99)
6Q6	Diode Triode ..	065	6·3	0·15	250	—	(100)
6Q7	DD Triode	041	6·3	0·3	250	—	(101)
6R7	DD Triode	041	6·3	0·3	250	—	(102)
6S7	HF Pentode ..	047	6·3	0·15	300	100	(103)
6T7	DD Triode	041	6·3	0·15	250	—	(104)
6U5	Tuning Indicator ..	6UX12	6·3	0·3	250	—	(105)
6U7	HF Pentode ..	047	6·3	0·3	250	100	(106)
6V6	LF Pentode.. ..	060	6·3	0·45	250	250	(107)
6W7	HF Pentode ..	047	6·3	0·15	300	100	(108)
6X5	Rectifier	037	6·3	0·6	RMS 350	—	(109)
6Y5	Rectifier	—	6·3	0·8	RMS 350	—	(110)
6Z4	Rectifier	—	6·3	0·5	RMS 350	—	(111)
6ZY5	Rectifier	037	6·3	0·3	RMS 350	—	(112)
7A6	Double Diode ..	0L9	6·3	0·15	150	—	(113)
7A7	HF Pentode ..	—	6·3	0·3	250	100	(114)
7A8	Frequency Changer	0L17	6·3	0·15	250	100	(115)
7B5	LF Pentode.. ..	0L12	6·3	0·4	250	250	(116)
7B6	DD Triode ..	0L11	6·3	0·3	250	—	(117)
7B7	HF Pentode ..	0L12	6·3	0·15	250	100	(118)
7B8	Frequency Changer	0L13	6·3	0·3	250	100	(119)
7C5	LF Pentode.. ..	0L16	6·3	0·45	250	250	(120)
7C6	DD Triode	0L11	6·3	0·15	250	—	(121)
7C7	HF Pentode ..	0L12	6·3	0·3	250	100	(122)
7Y4	Rectifier	0L10	6·3	0·5	RMS 350	—	(123)
10	Power Triode ..	4UX3	7·5	1·25	450	—	(124)
12	Triode	4UX3	1·1	0·25	135	—	(125)
12A6	Beam Power Output	048	12·6	0·15	250	250	(126)
12A7	Diode Pentode ..	7UX7	12·6	0·3	135	135	(127)
12A8	Pentagrid	054	12·6	0·15	300	100	(128)
12B6	Diode Triode ..	065	12·6	0·15	250	—	(129)
12B7	HF Pentode ..	0L12	12·6	0·15	250	—	(130)
12C8	DD HF Pentode ..	053	12·6	0·15	300	125	(131)
12E5	Triode	034	12·6	0·15	250	—	(132)
12F5	Triode	039	12·6	0·15	250	—	(133)
12G7	DD Triode	041	12·6	0·15	250	—	(134)
12J5	Triode	034	12·6	0·15	250	—	(135)
12J7	HF Pentode ..	047	12·6	0·15	250	100	(136)
12K7	HF Pentode ..	047	12·6	0·15	300	125	(137)
12K8	Triode Hexode ..	057	12·6	0·15	250	100	(138)
12Q7	DD Triode	041	12·6	0·15	250	—	(139)
12SA7	Pentagrid	066	12·6	0·15	300	100	(140)
12SC7	Double Triode ..	067	12·6	0·15	250	—	(141)
12SF5	Triode	068	12·6	0·15	250	—	(142)
12SG7	HF Pentode ..	069	12·6	0·15	250	150	(143)
12SJ7	HF Pentode ..	070	12·6	0·15	250	100	(144)
12SK7	HF Pentode ..	070	12·6	0·15	250	100	(145)
12SQ7	DD Triode	071	12·6	0·15	250	—	(146)
12SR7	DD Triode	071	12·6	0·15	250	—	(147)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Screen Current (mA)	Slope mA/V (*=Conv. Condt. μA/V)	Impedance (Ohms)	Amp. Factor	Output (Watts)	Optimum Load (Ohms)
(98)	0	—	—	—	—	—	35	10·0	—
(99)	−1·5–30	300	2·2	3·0	*650	750,000	—	—	—
(100)	−3·0	—	1·2	—	1·05	—	—	—	—
(101)	−2·0	4,000	1·1	—	1·2	58,000	70	—	—
(102)	−9·0	1,000	9·5	—	1·9	8,500	16	—	—
(103)	−3·0	—	8·5	2·0	1·75	1 meg.	—	—	—
(104)	−3·0	—	1·2	—	1·05	62,000	65	—	—
(105)	0–22	—	—	—	—	—	—	—	—
(106)	−3–40	300	8·2	2·0	1·6	800,000	1,280	—	—
(107)	−12·5	240	45·0	4·5	4·1	52,000	218	4·25	5,000
(108)	−3·0	—	2·0	0·5	1·225	1·5 meg.	—	—	—
(109)	—	—	—	—	—	—	—	75mA	—
(110)	—	—	—	—	—	—	—	50mA	—
(111)	—	—	—	—	—	—	—	60mA	—
(112)	—	—	—	—	—	—	—	35mA	—
(113)	—	—	8·0 (each anode)		—	—	—	—	—
(114)	−3–35	300	8·6	2·0	2·0	800,000	1,600	—	—
(115)	−3–35	300	3·0	2·8	*600	700,000	—	—	—
(116)	−18·0	500	32·0	5·5	2·2	68,000	150	3·4	7,600
(117)	−2·0	2,000	1·0	—	1·1	91,000	100	—	—
(118)	−3·0	300	8·5	2·0	1·7	700,000	1,200	—	—
(119)	−3·0	300	3·5	2·7	*550	360,000	—	—	—
(120)	−12·5	240	45·0	4·5	4·1	52,000	218	4·25	5,000
(121)	−1·0	—	1·3	—	1·0	100,000	100	—	—
(122)	−3·0	1,200	2·0	0·5	1·2	1·5 meg.	1,850	—	—
(123)	—	—	—	—	—	—	—	60mA	—
(124)	−32·0	—	18·0	—	1·6	5,000	—	1·6	10,000
(125)	−10·5	—	3·0	—	0·44	15,000	6·6	—	—
(126)	−12·5	—	30·0	3·5	3·0	50,000	—	—	—
(127)	−13·5	1,250	9·0	2·5	0·975	102,000	100	0·55	13,500
(128)	−3·0	—	3·5	2·7	*550	360,000	—	—	—
(129)	−2·0	—	0·9	—	1·1	91,000	—	—	—
(130)	−3·0	—	9·2	—	2·0	800,000	—	—	—
(131)	−3·0	—	10·0	2·3	1·325	600,000	—	—	—
(132)	−13·5	—	5·0	—	1·45	9,500	—	—	—
(133)	−2·0	—	0·9	—	1·5	66,000	—	—	—
(134)	−3·0	—	—	—	1·2	58,000	—	—	—
(135)	−8·0	—	9·0	—	2·6	7,700	—	—	—
(136)	−3·0	2·0	0·5	—	1·225	2 meg.	—	—	—
(137)	−3·0	—	10·5	2·6	1·65	600,000	—	—	—
(138)	−3·0	—	2·5	6·0	0·35	600,000	—	—	—
(139)	−3·0	—	1·1	—	1·2	58,000	—	—	—
(140)	—	—	3·5	8·5	*450	1 meg.	—	—	—
(141)	−2·0	—	2·0	—	1·325 each	53,000	—	—	—
(142)	−2·0	—	0·9	—	1·5	66,000	—	—	—
(143)	−2·5	—	9·2	3·4	4·0	1 meg.	—	—	—
(144)	−3·0	—	3·0	0·8	1·65	1·5 meg.	—	—	—
(145)	−3·0	—	9·2	3·4	1·65	1·5 meg.	—	—	—
(146)	−2·0	—	0·8	—	1·1	91,000	—	—	—
(147)	−9·0	—	9·5	—	1·9	8,500	—	—	—

[*Continued on next page*

Type	Description	Base	Fil. or Heater (Volts)	Fil. or Heater Current (Amps)	Anode Volts	Screen Volts	
12Z3	Rectifier	4UX10	12·6	0·3	RMS 250	—	(148)
14A4	Triode	OL19	12·6	0·15	250	—	(149)
14A5	Beam Power Output	OL16	12·6	0·15	250	250	(150)
14A7/12B7	HF Pentode ..	OL12	12·6	0·15	250	100	(151)
14B8	Pentagrid	OL13	12·6	0·15	250	100	(152)
14C7	HF Pentode ..	OL12	12·6	0·15	250	100	(153)
14F7	Double Triode ..	OL18	12·6	0·15	250	—	(154)
15	HF Pentode ..	5UX8	2·0	0·22	135	67·5	(155)
18	LF Pentode.. ..	6UX10	14·0	0·3	250	250	(156)
19	Class B	6UX1	2·0	0·26	135	—	(157)
20	Power Triode ..	4UX3	3·3	0·132	135	—	(158)
22	Screen Grid ..	4UX6	3·3	0·132	135	67·5	(159)
24	Screen Grid ..	5UX8	2·5	1·75	250	90	(160)
24A	Screened Tetrode ..	5UX8	2·5	1·75	250	90	(161)
25A6	LF Pentode.. ..	049	25·0	0·3	180	135	(162)
25A7	Diode Pentode ..	062	25·0	0·3	100	100	(163)
25B5	Double Triode ..	6UX15	25·0	0·3	180	100	(164)
25B8	Triode Pentode ..	072	25·0	0·15	100	100	(165)
25D8	Diode-Triode-Pentode	073	25·0	0·15	—	—	(166)
25L6	LF Pentode.. ..	060	25·0	0·3	110	110	(167)
25N6	Double Triode ..	—	25·0	0·3	180	110	(168)
25R	Rectifier	6UX5	25·0	0·3	RMS 250	—	(169)
25X6	Rectifier	—	25·0	0·15	RMS 125	—	(170)
25Y4	Rectifier	035	25·0	0·15	RMS 125	—	(171)
25Y5/25Z5	Rectifier	6UX5	25·0	0·3	RMS 250	—	(172)
25Z6	Rectifier	037	25·0	0·3	RMS 250	—	(173)
26	Triode	4UX3	1·5	1·05	180	—	(174)
27	Triode	5UX6	2·5	1·75	250	—	(175)
30	Triode	4UX3	2·0	0·06	180	—	(176)
31	Triode	4UX3	2·0	0·13	180	—	(177)
32	HF Tetrode ..	4UX5	2·0	0·06	180	67·5	(178)
33	LF Pentode.. ..	5UX1	2·0	0·26	135	135	(179)
34	HF Pentode ..	4UX5	2·0	0·06	180	67·5	(180)
35	HF Tetrode ..	5UX9	2·5	1·75	250	90	(181)
35A5	Beam Power Output	OL16	32·0	0·15	110	110	(182)
35L6	Beam Power Output	048	35·0	0·15	110	110	(183)
35R	Rectifier	6UX5	35·0	0·3	RMS 250	—	(184)
35Z3	Rectifier	OL8	35·0	0·15	RMS 170	—	(185)
35Z4	Rectifier	015	35·0	0·15	RMS 125	—	(186)
35Z5	Rectifier	075	35·0	0·15	RMS 125	—	(187)
36	Screened Tetrode ..	5UX8	6·3	0·3	250	90	(188)
37	Triode	5UX6	6·3	0·3	250	—	(189)
38	LF Pentode.. ..	5UX7	6·3	0·3	250	250	(190)
39/44	HF Pentode ..	5UX8	6·3	0·3	250	90	(191)
40	Triode	4UX3	5·0	0·25	180	—	(192)
40Z5	Rectifier	075	45·0	0·15	RMS 125	—	(193)
41	LF Pentode.. ..	6UX10	6·3	0·4	250	250	(194)
42	LF Pentode.. ..	6UX10	6·3	0·7	250	250	(195)
43	LF Pentode.. ..	6UX10	25·0	0·3	180	135	(196)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Screen Current (mA)	Slope mA/V (*=Conv. Condt. μA/V)	Impedance (Ohms)	Amp. Factor	Output (Watts)	Optimum Load (Ohms)
(148)	—	—	—	—	—	—	—	60mA	—
(149)	−8·0	—	—	—	2·6	7,700	—	—	—
(150)	−12·5	—	30·0	3·5	3·0	50,000	—	—	—
(151)	−3·0	—	9·2	2·6	2·0	800,000	—	—	—
(152)	−3·0	—	3·5	2·7	*550	360,000	—	—	—
(153)	−3·0	—	2·2	0·7	1·575	1 meg.	—	—	—
(154)	−2·0	—	2·3	—	1·6	44,000	—	—	—
(155)	−1·5	—	1·85	0·3	0·75	800,000	600	—	—
(156)	−16·5	410	34·0	6·5	2·35	80,000	190	3·5	7,000
(157)	0	—	—	—	—	—	—	2·1	—
(158)	−22·5	—	6·5	—	0·525	6,300	3·3	0·11	6,500
(159)	−1·5	—	3·7	1·3	0·5	325,000	—	—	—
(160)	−3·0	500	4·0	1·7	1·0	400,000	400	—	—
(161)	−3·0	500	4·0	1·7	1·05	600,000	630	—	—
(162)	−20·0	440	38·0	7·5	2·5	40,000	100	2·75	5,500
(163)	−15·0	—	20·5	4·0	1·8	50,000	—	0·77	4,500
(164)	0	—	46·0	5·8	2·3	15,200	35	3·8	3,800
(165)	−3·0	—	7·6	2·0	*2,000	75,000	—	—	—
(166)	—	—	—	—	1·9 1·1	200,000 91,000	Pentode Triode	—	—
(167)	−7·5	140	49·0	4·0	8·2	10,000	82	2·2	2,000
(168)	0	—	45·0	7·0	11·4	11,400	25	2·0	2,000
(169)	—	—	—	—	—	—	—	80mA	—
(170)	—	—	—	—	—	—	—	60mA	—
(171)	—	—	—	—	—	—	—	75mA	—
(172)	—	—	—	—	—	—	—	85mA	—
(173)	—	—	—	—	—	—	—	85mA	—
(174)	−14·5	—	6·2	—	1·15	7,300	8·3	—	—
(175)	−21·0	—	5·2	—	0·97	9,250	9·0	—	—
(176)	−13·5	—	3·1	—	0·9	10,300	9·3	—	—
(177)	−30·0	—	12·3	—	1·05	3,600	3·8	0·375	5,700
(178)	−3·0	—	1·7	0·4	0·65	1·2 meg.	780	—	—
(179)	−12·0	—	—	—	2·0	—	—	1·0	6,000
(180)	−3–22·5	—	2·8	1·0	0·62	1·2 meg.	620	—	—
(181)	−3·0	—	6·5	2·5	1·05	400,000	—	—	—
(182)	−7·5	—	41·0	7·0	5·8	14,000	—	—	—
(183)	−7·5	—	41·0	7·0	5·8	13,800	—	—	—
(184)	—	—	—	—	—	—	—	120mA	—
(185)	—	—	—	—	—	—	—	100mA	—
(186)	—	—	—	—	—	—	—	100mA	—
(187)	—	—	—	—	—	—	—	100mA	—
(188)	−3·0	850	3·2	1·0	1·08	550,000	595	—	—
(189)	−18·0	—	7·5	—	1·1	8,400	9·2	—	—
(190)	−25·0	970	22·0	3·8	1·2	100,000	1·2	2·5	10,000
(191)	−3·0	400	5·8	1·4	1·05	1 meg.	1,050	—	—
(192)	−3·0	—	0·2	—	0·2	150,000	30	—	—
(193)	—	—	—	—	—	—	—	100mA	—
(194)	−18·0	480	32·0	5·5	2·2	68,000	150	3·4	7,600
(195)	−16·5	410	34·0	6·5	2·35	80,000	190	3·5	7,000
(196)	−20·0	440	38·0	7·5	2·5	40,000	100	2·75	5,000

[*Continued on next page*

TABLE XLVII: AMERICAN

Type	Description	Base	Fil. or Heater (Volts)	Fil. or Heater Current (Amps)	Anode Volts	Screen Volts	
45	LF Triode	4UX3	2·5	1·5	250	—	(197)
45Z5	Rectifier	075	45·0	0·15	RMS 125	—	(198)
46	Dual Grid LF ..	5UX4	2·5	1·75	250	—	(199)
47	LF Pentode.. ..	5UX1	2·5	1·75	250	250	(200)
48	LF Tetrode ..	6UX14	30·0	0·4	125	100	(201)
49	Dual Grid LF ..	5UX4	2·0	0·12	135	—	(202)
50	Power Triode ..	4UX3	7·5	1·25	450	—	(203)
50C6	Beam Power Output	048	50·0	0·15	200	135	(204)
50L6	Beam Power Output	048	50·0	0·15	110	110	(205)
50Y6	Rectifier	038	50·0	0·15	RMS 117	—	(206)
50Z7	Rectifier	074	50·0	0·15	RMS 117	—	(207)
51	HF Tetrode ..	5UX9	2·5	1·75	250	90	(208)
53	Class B	7UX9	2·5	2·0	300	—	(209)
55	DD Triode	6UX6	2·5	1·0	250	—	(210)
56	Triode	5UX6	2·5	1·0	250	—	(211)
57	HF Pentode ..	6UX11	2·5	1·0	250	100	(212)
58	HF Pentode ..	6UX11	2·5	1·0	250	100	(213)
59	Triple Grid Output	7UX4	2·5	2·0	250	250	(214)
70A7	Rectifier and Beam Power Output	062	70·0	0·15	RMS 117 110	— —	(215) (216)
70L7	Rectifier and Beam Power Output	076	70·0	0·15	RMS 117 110	— 110	(217) (218)
71A	Power Triode ..	4UX3	5·0	0·25	180	—	(219)
75	DD Triode	6UX6	6·3	0·3	250	—	(220)
76	Triode	5UX6	6·3	0·3	250	—	(221)
77	HF Pentode ..	6UX11	6·3	0·3	250	100	(222)
78	HF Pentode ..	6UX11	6·3	0·3	250	125	(223)
79	Class B	6UX7	6·3	0·6	250	—	(224)
80	Rectifier	4UX11	5·0	2·0	RMS 350	—	(225)
80A	Rectifier	4UX10	7·5	1·25	RMS 700	—	(226)
81	Rectifier	4UX10	7·5	1·25	RMS 700	—	(227)
82	Rectifier (mercury)..	4UX7	2·5	3·0	RMS 450	—	(228)
83	Rectifier (mercury)	4UX7	5·0	3·0	RMS 450	—	(229)
83V	Rectifier	4UX8	5·0	2·0	RMS 400	—	(230)
84	Rectifier	5UX5	6·3	0·5	RMS 350	—	(231)
85	DD Triode	6UX6	6·3	0·3	250	—	(232)
89	Triple Grid Output	6UX11	6·3	0·4	250	—	(233)
V99	Triode	4UX9	3·0–3·3	0·06–0·063	90	—	(234)
X99	Triode	4UX3	3·0–3·3	0·06–0·063	90	—	(235)
112A	Triode	4UX3	5·0	0·25	180	—	(236)
117Z6	Rectifier	077	117·0	0·15	RMS 117	—	(237)
183	Triode	4UX3	5·0	1·25	250	—	(238)
484	Triode	—	3·0	1·3	180	—	(239)
950	LF Pentode.. ..	5UX2	2·0	0·12	135	135	(240)
2101	LF Pentode.. ..	5UX1	2·0	0·12	135	135	(241)
2102	DD Triode	6UX2	2·0	0·12	135	—	(242)
2103	Double LF Pentode	7UX1	2·0	0·26	135	135	(243)
2151	LF Pentode.. ..	6UX10	14·0	0·3	250	250	(244)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

	Bias Volts	Bias Res. (Ohms)	Anode Current (mA)	Screen Current (mA)	Slope mA/V (*=Conv. Condt. μA/V)	Impedance (Ohms)	Amp. Factor	Output (Watts)	Optimum Load (Ohms)
(197)	–50·0	—	34·0	—	2·17	1,600	3·5	1·6	3,900
(198)	—	—	—	—	—	—	—	100mA	—
(199)	–33·0	—	22·0	—	2·35	2,380	5·6	1·25	6,400
(200)	–16·5	450	31·0	6·0	2·5	60,000	150	2·7	7,000
(201)	–20·0	310	56·0	9·5	3·9	—	—	2·5	1,500
(202)	–20·0	—	6·0	—	1·125	4,175	4·7	0·17	11,000
(203)	–84·0	1,530	55·0	—	2·1	1,800	3·8	4·6	4,350
(204)	–14·0	—	16·0	2·2	7·1	18,300	—	—	—
(205)	–7·5	—	49·0	4·0	8·2	10,000	—	—	—
(206)	—	—	—	—	—	—	—	75mA	—
(207)	—	—	—	—	—	—	—	65mA	—
(208)	–3·0	—	6·5	2·5	1·05	400,000	—	—	—
(209)	0	0	—	—	—	—	35	10·0	—
(210)	–20·0	2,500	8·0	—	1·1	7,500	8·3	0·35	20,000
(211)	–13·5	2,500	5·0	—	1·45	9,500	13·8	—	—
(212)	–3·0	600	2·0	0·5	1·22	1 meg.	—	—	—
(213)	–3–40	300	8·2	2·0	1·6	800,000	1,280	—	—
(214)	–18·0	410	35·0	9·0	2·5	40,000	—	3·0	6,000
(215)	—	—	—	—	—	—	—	60mA	—
(216)	–7·5	—	40·0	—	5·8	—	—	—	—
(217)	—	—	—	—	—	—	—	70mA	—
(218)	–7·5	—	43·0	6·0	7·5	15,000	—	—	—
(219)	–40·5	—	20·0	—	1·7	1,750	3	0·79	4,800
(220)	–2·0	5,000	0·4	—	1·1	90,000	100	—	—
(221)	–13·5	2,500	5·0	—	1·45	9,500	13·8	—	—
(222)	–3·0	1,000	2·3	0·5	1·25	1·5 meg.	1,500	—	—
(223)	–3–40	200	10·5	2·6	1·65	600,000	1,000	—	—
(224)	0	—	—	—	—	—	—	8·0	14,000
(225)	—	—	—	—	—	—	—	125mA	—
(226)	—	—	—	—	—	—	—	85mA	—
(227)	—	—	—	—	—	—	—	85mA	—
(228)	—	—	—	—	—	—	—	115mA	—
(229)	—	—	—	—	—	—	—	225mA	—
(230)	—	—	—	—	—	—	—	200mA	—
(231)	—	—	—	—	—	—	—	50mA	—
(232)	–20·0	2,500	8·0	—	1·1	7,500	8·3	0·35	20,000
(233)	–31·0	970	32·0	—	1·8	2,600	4·7	0·9	5,500
(234)	–4·5	—	—	—	—	—	—	—	—
(235)	–4·5	—	—	—	—	—	—	—	—
(236)	–13·5	—	—	—	—	—	—	0·285	10,650
(237)	—	—	—	—	—	—	—	60mA	—
(238)	–60·0	—	25·0	—	1·8	1,800	3·2	2·0	4,500
(239)	–9·0	—	6·0	—	1·35	9,300	12·5	—	—
(240)	–16·5	—	7·0	2·0	0·95	105,300	100	0·45	13,500
(241)	–4·5	—	8·0	2·6	1·7	200,000	340	0·45	16,000
(242)	–1·5	—	2·1	—	1·3	23,000	30	—	—
(243)	–7·5	—	4·0	1·2	1·6	—	350	0·6	—
(244)	–31·0	—	47·0	11·6	2·4	50,000	120	6·0	—

AMERICAN BARRETTERS OR BALLAST TUBES

American sets fitted with barretters or ballast tubes for voltage regulation do not need a line cord resistor unless used on mains of a higher voltage than those for which they were designed.

Octal-based barretters are listed under a standard code consisting of prefix letters, a number, and suffix letters such as K55B. The central number denotes the volts dropped by the tube when it is correctly run. The letter prefixes denote the current rating and the type of pilot lamp to be used with the barretter: K, 6·3 volts, 0·15 amp and type 40 pilot lamps. L, 6·3 volts, 0·25 amp and type 46 pilot lamps. M, 6-8 volts, 0·2 amp and type 50 or 51 pilot lamps. B, when in front of either of the above, denotes a ballast tube, and can be ignored.

The suffixes indicate the base wiring diagrams: A, Plain resistance. B, 1 tap for 1 pilot lamp. C, 1 tap for 2 pilot lamps. D, 2 taps for 1 pilot lamp. F, 1 tap for 1 pilot lamp (tap isolated from body). G, 1 tap for 2 pilot lamps (tap isolated from body). H, 2 taps for 1 pilot lamp (tap isolated from body). Final letters G or MG, in addition to the above, indicate glass or metal-glass envelopes. G also denoted at one time that an octal base was fitted.

UX-based barretters, introduced before the above types, are also coded, but this was not adhered to strictly. It consists of a number indicating the resistance of the tube, followed by a letter, or combination of letters, denoting the basing arrangement. The suffixes usually used are: R, Plain resistor. R4, 1 tap for 1 0·15-amp lamp. R8, 1 tap for 2 0·15-amp lamps. R44, 2 taps for 1 0·15-amp lamp. L4, 1 tap for 1 0·25-amp lamp. L8, 1 tap for 2 0·25-amp lamps. L44, 2 taps for 1 0·25-amp lamp.

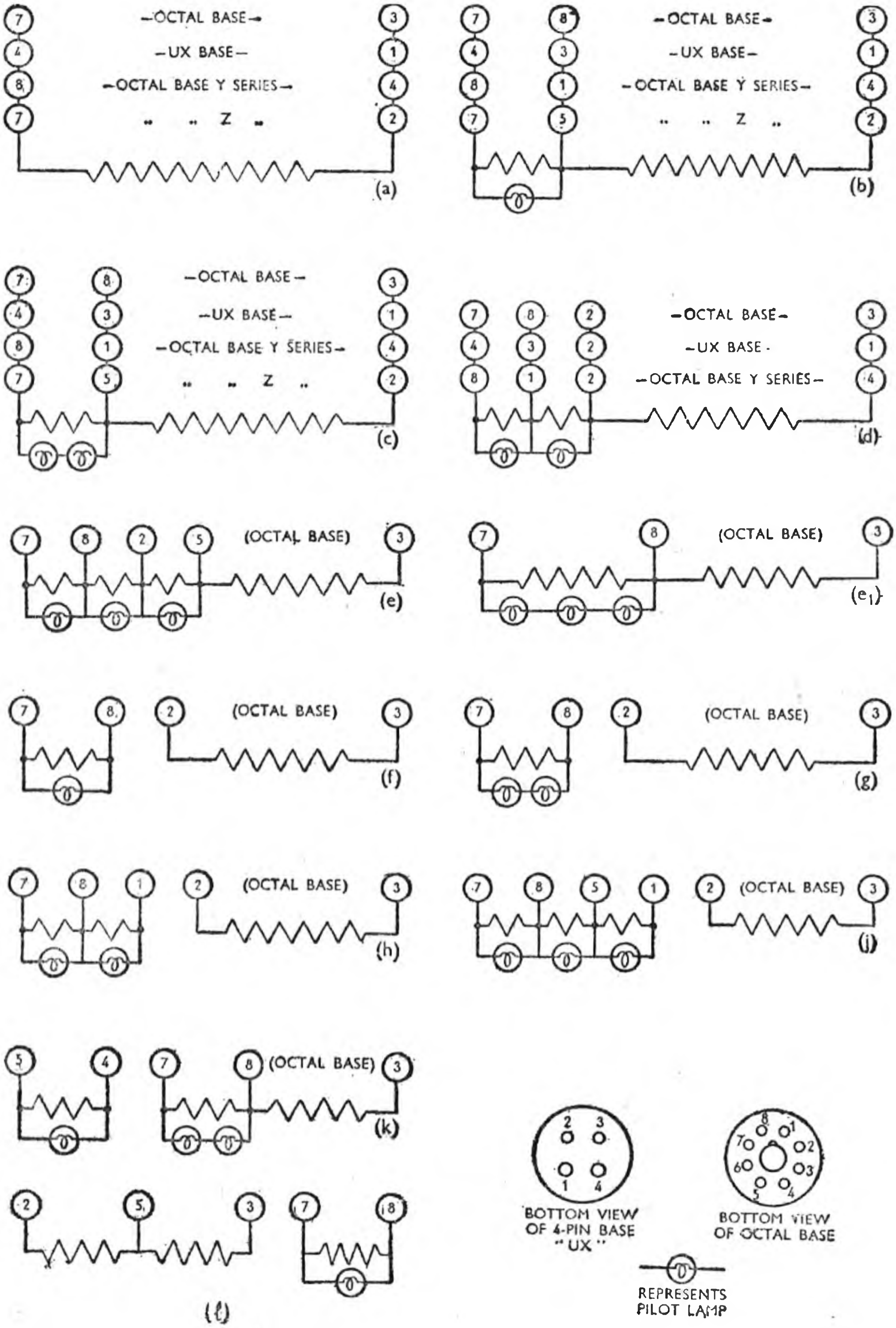
Tubes generally in use are listed in Table XLVIII, together with recommended alternatives. The code letters in the base column refer to the Standard American RMA ballast tube connection diagram, which is also reproduced. (See Fig. 164.)

TABLE XLVIII: AMERICAN BALLAST TUBES

Type	Volts Dropped at 117·5 V	No. of Pilot Lamps	Rating of Lamps (Amps)	Base Code	Base Type	Equivalents	Equivalent with Base Changed
42A	42·3	0	—	A	Octal	K42A, 42AG, K42AG, K43A	140R
42A1	42·3	0	—	AY	Octal	KY42A	140R
42A2	42·3	1	0·15	BY	Octal	KY42B	140R4
42B2	42·3	2	0·15	CY	Octal	KY42C	140R8
K42A	42·3	0	—	A	Octal	42A	140R
K42B	42·3	1	0·15	B	Octal	K42BG, K43B, 135K1	140R4
K42C	42·3	2	0·15	C	Octal	K42CG, BK42C, 95K2, K40C, 5516, 5530	140R8
K42D	42·3	2	0·15	D	Octal	K42DG, BK42D, K40D, 3326	140R44
KX42B	42·3	1	0·15	BX	4-pin	140R4	K42B
KX42C	42·3	2	0·15	CX	4-pin	140R8	K42C
KY42D	42·3	2	0·15	DY	Octal	2LR213	—
L42B	42·3	1	0·25	B	Octal	BL42B, L42BG, 5547	104L4
L42BX	42·3	1	0·25	BX	4-pin	140L4, LX42B	L42B
L42C	42·3	2	0·25	C	Octal	BL42C, L42CG, L40C, 69-2037, 5548, 16035	140L8
L42D	42·3	2	0·25	D	Octal	BL42D, L42DG, 5549	104L44
L42DX	42·3	2	0·25	DX	4-pin	140L44	L42D

TABLE XLVIII: AMERICAN BALLAST TUBES—*continued*

Type	Volts Dropped at 117·5 V	No. of Pilot Lamps	Rating of Lamps (Amps)	Base Code	Base Type	Equivalents	Equivalent with Base Changed
L42F	42·3	1	0·25	F	Octal	—	—
L42S1	42·3	1	0·25	S1	Octal	L40S1	—
L42S2	42·3	2	0·24	S2	Octal	L40S2	—
M42C	42·3	2	0·2	C	Octal	K42C or L42C and alter pilot lamps	—
49A	48·6	0	—	A	Octal	K49A, 49KA, K50A	165R
49A1	48·6	0	—	AY	Octal	KY49A	165R
49A2	48·6	1	0·15	BY	Octal	KY49B	165R4
49B2	48·6	2	0·15	CY	Octal	KY49C	165R8
K49A	48·6	0	—	A	Octal	49A	165R
K49B	48·6	1	0·15	B	Octal	BK49B, 49KB, K43B2, W43357, 115·41, 5533, 8593, 5623	165R4
K49C	48·6	2	0·15	C	Octal	49KC, BK49C, K50C, K49CB, A16040, 81966-2, 5534	165R8
K49D	48·6	2	0·15	D	Octal	49KD, BK49D, BK49D-10, 5633, 5518, 69116, 115·28, 3334, 3334A	165R44
KX49A	48·6	0	—	AX	4-pin	165R, 340	49A
KX49C	48·6	2	0·15	CX	4-pin	165R8, 50A2	K49C
KZ49B	48·6	1	0·15	B2	Octal	50B2MG	165R4
KZ49C	48·6	2	0·15	CZ	Octal	50A2MG	165R8
L49B	48·6	1	0.25	B	Octal	49LB, BL49B, 2UR224, 69·2033, 5511, 5550	165L4
L49C	48·6	2	0·25	C	Octal	49LC, L49-5·5C, BL49C, 2995, 5552, 16036	165L8
L49D	48·6	2	0·25	D	Octal	49LD, BL49D, 3CR-241, 5567	165L44
L49F	48·6	1	0·25	F	Octal	—	—
M49B	48·6	1	0·2	B	Octal	BM49B, 38710	—
M49C	48·6	2	0·2	C	Octal	BM49C	—
M49H	48·6	2	0·2	H	Octal	M49HG	—
55A	54·9	0	—	A	Octal	K55A	185R
55A1	54·9	0	—	AY	Octal	KY55A	185R
55A2	54·9	1	0·15	BY	Octal	KY55B	185R4
55B2	54·9	2	0·15	CY	Octal	KY55C	185R8
K55A	54·9	0	—	A	Octal	55A	185R
K55B	54·9	1	0·15	B	Octal	55KB, K55BG, K54B, BK55B, 3613, 5519, 7-TU-9, 5535, 16039	185R4
K55C	54·9	2	0·15	C	Octal	BK55C, 5536	185R8
K55D	54·9	2	0·15	D	Octal	BK55D, 115·22	185R44
K55H	54·9	2	0·15	H	Octal	K52H	—
L55B	54·9	1	0·25	B	Octal	2V4215, 2903, 5555, 8598, 2VR215	185L4
L55C	54·9	2	0·25	C	Octal	85LC, L55-5·5C, 2904	185L8
L55D	54·9	2	0·25	D	Octal	85LD	185L44
L55F	54·9	1	0·25	F	Octal	BL55F	—
M55F	54·9	1	0·2	F	Octal	—	—
M55H	54·9	2	0·2	H	Octal	M55HG, M52H	—
C9266	54·9	—	—	L	Octal	—	—
100R8	29·7	2	0·15	CX	4-pin	KX30C	K30C
120R8	36·0	2	0·15	CX	4-pin	KX36C	K36C
140L4	42·3	1	0·25	BX	4-pin	L42BX, LX42B	L42B
140L8	42·3	2	0·25	CX	4-pin	L42CX, LX42C	L42C
140L44	42·3	2	0·25	DX	4-pin	L42DX, LX42D	L42D
140R	42·3	0	—	AX	4-pin	—	42A
140R4	42·3	1	0·15	BX	4-pin	40B2, KX42B	K42B
140R8	42·3	2	0·15	CX	4-pin	40A2, KX42C	K42C
165L4	48·6	1	0·25	BX	4-pin	L49BX, LX49B	L49B
165L8	48·6	2	0·25	CX	4-pin	LX49C	L49C
165R	48·6	0	—	AX	4-pin	—	49A
165R4	48·6	1	0·15	BX	4-pin	50B2, KX49B	K49B
165R8	48·6	2	0·15	CX	4-pin	50A2, KX49C	K49C
185L4	54·9	1	0·25	BX	4-pin	LX55B	L55B
185L8	54·9	2	0·25	CX	4-pin	—	L55C
185R	54·9	0	—	AX	4-pin	50X3, KX55A	K55A
185R4	54·9	1	0·15	BX	4-pin	KX55B	K55B
185R8	54·9	2	0·15	CX	4-pin	50X3T, KX55C	K55C
200R	60·0	0	—	AX	4-pin	—	—
290L4	—	1	0·25	BX	4-pin	Special Type	—
300R4	79·5	1	0·15	BX	4-pin	KX80B	K80B



BASES OF U.S.A. BALLAST 'TUBES'

Fig. 164. These are the diagrams issued by the American R.M.A. and in which are shown the base connections of the common plug-in resistor or ballast 'tubes'.

SECTION 12

INTERMEDIATE FREQUENCIES

This list covers models going back to the first commercial superhets and has been submitted, where possible, to the makers for checking. Frequencies thus: 465, 473, are alternatives, but 123-127 indicates the circuits should be staggered over the band indicated. Sometimes the frequencies for each circuit in a 'staggered' set are shown thus : 127-123-123-127.

ACE	Kc/s
RG3	470
RG5	427
RG6	427
S6	125
SH6	125
RG7	427
RG8	470
RG9	427
AW35	470
AW53	427
AW53B	427
AW73	427
AC85	470
AW94	427
AW115	470
AW563	427
AC939	450
A50	465

AERODYNE	
Aerogram	125
Aeromagic	125
Cardinal	125
Falcon	125
Silver Wing	125
Swallow	125
42	125
47	125
50	125
53	125
54	465
56	125
58	125
63	465
73	125
100	117·5
105	465
110	117·5
115	465
135	465
290	465
291	465
295	465
300	117·5
301 AC	460
302 AC/DC	460
305	117·5

ALBA	Kc/s
AC superhet	473
5V Bat. SH, 1934	473
Clipper	470
35	470
40 Universal	370
57 AC and Universal	117·5
67	473
68 AC and Universal	117·5
78	473
79 AC and Universal	117·6
90	465
98	365
230	117·5
315	117·5
320	460
330	117·5
335	460
340	470
450	117·5
455	460
461 AC	460
462 AC/DC	460
510	470
540	117·5
550 AC and Universal	117·5
605	465
610	470
615	117·5
620	117·5
625	117·5
635	460
640	117·5
650	117·5
660 AC and Universal	117·5
670	117·5
698	365
710	470
725	117·5
730	470
740	117·5
745	470
755	470
770 AC and Universal	117·5
790	465
798	365
805	465
810	470
815	117·5
820	117·5
825	117·5
830	470
835	460
845	470
850	117·5
855	470
870 AC and Universal	117·5
880 AC and Universal	117·5
890 AC and Universal	117·5
905	465
910	117·5
920	117·5
930	460
970	117·5
990 and Universal	117·5

ALLWAVE	
Standard Superhet, 1935	465
Standard Superhet RG	465
Tallboy RG, 1935	465
Ambassador 6778	465

AMPLION	
Radiolux Superhet	110
Radiolux Superhet RG	110

ARMSTRONG	
5V 7 stage	110
5V 8 stage	110
RF/PP	465
RF/PR	465
2B/PR	118
2B/T	118
3NBP/8	457
3NBP/8 Late model	470
3NBP/10	427
3WT/PB	427

ARMSTRONG—*cont.*

AW3/PB 427
AW/33 465
4B/PR 118
4B/T 118
AW/36 465
AW/59 470
AW93PP 427
RF94PP 427
AW125PP .. 470
SS10 465
3NWT 450
3NBP/T 427
U3NBP/T .. 427

ATLAS

758 .. 117·5
A13 126
A17 126
A24 126

BEETHOVEN

Baby Grand 450·5
Little Prodigy AC 450·5
Little Prodigy, Bat. 450·5
Twin Speaker, All-electric Superhet 118
AC40 .. 450·5
AC42 .. 450·5
B43 .. 450·5
AC77 118
B88 118
PBA201 .. 450·5
AD303 .. 450·5
AD404 .. 450·5
RG717 118
AC720 .. 450·5
B730 .. 450·5
AC740 .. 450·5
PBB750 .. 450·5
AD770 .. 450·5
PBA780 .. 450·5
RG827 118
PBA820 .. 450·5
B848 .. 450·5
AC852 .. 450·5
909 .. 450·5
909AC .. 450·5
RG938 .. 450·5

BELMONT

520 465
525 465
530AC-DC Midget 456
541 456
544 465
545 465
555 465
566 465
570P 465
600 465
625 465
650 465
700 465
720 465
721 465
746 465
755 465
760P 465
770 465
780 465
781 465
800 465
820 465
821 465
845 465
856 465
860P 465
900 465
1100 465
1150 465

BENSON

AWP Midget Portable 470

BLUE SPOT

Aristocrat .. 465
A67 465
A68 465
A69 465
AC5 110

BRUNSWICK

BCA/01 456
BCA/1 456
BCW/01 456
BGA/01 456
BGA/1 456
BGA/1E 456
BGA/2 456
BGA/3 465
BGCA/01 456
BGCA/1 456
BGCA/3 465
BGU/01 456
BPU/1 465
BTA/01 456
BTA/1 456
BTA/1E 456
BTA/2 456
BTA/3 465
BTB/1 456
BTU/01 456
39CGM 465
39EH 120
39TGM 465
40 465
40U 465
42 380
42D 380
43D 380
45 380
47 380
47U 380
50 465
51 465
54 465
56 465

BTS

Trophy 5 465

BURGOYNE

AW47 473
AWS 473
AWS/G 473
BSH .. 117·5
DTG 473
Dragon 437
Dragon AC Recordagraph .. 473
Dragonette .. 473
Superhet 5, B5 117·5

BURNDEPT

Ethodyne 209 .. 473
Universal Trans. .. 130
Universal Superhet 473
201 130
203 473
209 473
210 473
211 473
218 130
225 130
226 130
229 130
231 130
233 450
257 130
259 473
266 473
267 473
276 473
281 473
285 473
290 473
292 450
298 473
299 473
303 473
309 450
312 473

COSSOR—*cont.*

394		465
395		465
396		465
397		465
398		465
438	(SW 1363)	465
438U	(SW 1363)	465
439		465
456AC		465
456B		465
464AC		465
483	(SW 1363)	465
484	(SW 1363)	465
484U	(SW 1363)	465
485		465
535		128
538		465
583		465
584		465
584U		465
598		465
634		128 or 134
635		128 or 134
736		128
737		128
836		128
837		465
3733 SW only		1563
3764		465
3774		465
3783 SW only		1563
3864		465
3884		465
3952		465
3974		465
3974A		465
6864		465
6874		465

CROSLEY

Roamio		455
A358		455
5C2		181·5
538BT		450
638T		450
848C		450
848CU		450
848R		450
848RU		450
848T		450
848TU		450
1058AR		450
1058T		450

DECCA

Twin S/het R/GAC6		183
AW3		380
AW3P		380
AW4 341		465
AW6		465
AW6V		465
Decca-Brunswick 6V RG (Med W only)		183
AW7		465
AW8		465
AW9		465
AW10		465
AWD47		380
AWG16		465
ML		465
MLB		465
ML4		380
ML5 and 42		380
ML6		465
ML6U		465
MLD/3		380
MLD/5		380
PC/AW		465
PC/ML		465
PG/AC		465
PG/AW		465
PG/ML		465
PG/U	450	465
PT/AC5		456
PT/AW		465
PT/BS		465
PT/M	125	465
PT/ML		465
PT/ML/B		465
PT/ML/U	450	465
PT/U		465
PAW5		465
UAW78		465
Double Decca MB5		380
Portrola		130
Portrola AC/DC 1939		465
44		465
55		465
56		465
Prestomatic		465
66		465
77		465
88		465
88U		465
99		456
110		456
120		456
180		130
190		130
350		130
400		130
405		130
500		130
510		130
520		456
530		456
540		456
550		130
919		130
1010		130
1111		130
1616		130
4040		130
4141		130
4242		130
4343		130

DRUMMER

M45		117·5

EKCO

C25		110
RG25		110
SH25		110
AC64		110
DC64		110
AD65		110
B67		126·5
BV67		126·5
AW69		126·5
BAW69		126·5
C69		126·5
CU69		126·5
UAW69		126·5
AW70		126·5
UAW70		126·5
BAW71		126·5
AC74		110
B74		110
DC74		110
AD75		480
AC76		130
AD76		130
AC77		126·5
AD77		126·5
CT77		126·5
CTU77		126·5
BAW78		460
BV78		460
C78		460
UAW78		460
RG84		110
AC85		110
B86		130
AC86		130
AD86		130
B86		110
RG86		130
AW87		460
CTA87		460
AW88		126·5
C88		126·5
UAW88		126·5
ADT95		110
BT95		110

FERRANTI—*cont.*

1933/4 Lancastria	125
1933/4 Arcadia ..	125
1933/4 Battery S/het	125
1934/5 Arcadia AC S/het	125
1934/5 Gloria ..	125
1934/5 Gloria Arcadia ..	125
1934/5 Lancastria	125
„ Lancastria Portable ..	125
„ Lancastria Reflex ..	125
„ Universal ..	125
1936/7 Magna AC	125
1935/6 Gloria Autogram	125
1935/6 Nova AC ..	125
1935/6 Nova AC-DC	125
1935/6 Lancastria AC	125
1935/6 Lancastria AC-DC ..	125
1935/6 Arcadia Cons and R/G	125
1935/6 Arcadia AC	125
1935/6 Nova Batt.	125
1936 All Wave S/het	125
1936/7 Nova 2-wave AC	125
1936/7 Nova All-wave	125
1936/7 Nova All-wave Batt. ..	125
1936/7 Nova All-wave AC-DC ..	125
1936/7 Magna All-wave AC ..	125
1936/7 Magna AC-DC	125
1936/7 Arcadia All-wave AC ..	125
1936/7 Arcadia Console	125
1936/7 Arcadia R/G	125
A1	135
48B	125
49B	125
139	450
141	450
239	450
241 and 341 ..	450
512AM	450
513	450
513AM	450
514	450
514PB	450
515PB	450
539	450
617PB	450
837	450
1037	450
1037U	125
1137	450
1137B	125
1137U	125
1237B	125
1737	125
1737 Gram ..	125
2037	125
2337	450
145	450

GAROD

930	456
931 Consoles ..	456
930D	456
931D	456
930KC	456
931KC Gram ..	456
1240	456
1240E Gram ..	456
1240LC	456
1650	456
1650H Console ..	456
1650LC Gram ..	456

GEC

3358	110
3440	107
3441	107
3442	107
3443	107
3444	107
3445	107
3446	125
3448	107
3449	107
3460	125
3466	125
3480	125
3484	125
3488	125
3540	125
3541	125
3542	125
3544	125
3545	107
3548	125
3550	125
3551	125
3558	125
3558R	125
3566	125
3640	125
3645	125
3646	125
3650	125
3651	125
3658	125
3659	125
3740	125
3745	125
3746	125
3748	125
3750	445
3754	125
3758	445
3760	445
3762	445
3766	445
3780	445
3781	445
3782	445
3788	445
3789	445
3846	456
3850	456
3855	456
3856	456
3857	456
3860	456
3862	456
3865	456
3866	445
3867	456
3868	456
3880	445
3882	445
3888	445
3889	445
3890	456
3892	456
3910	456
3918	456
3940	456
3942	445
3946	456
3950	456
3955	456
3956	456
3957	445
3960	456
3964	456
3965	456
3966	445
3967	456
3968	456
3969	456
3970	456
3972	445
3978	445
3977	445
3979	445
4010	445
4018	445
4040	456
4045	456
4046	456

GEC—*cont.*

4050	456
4051	456
4054	456
4055	456
4056	456
4058	456
4059	456
4060	456
4065	456
4066	456
4070	456
4135	456
4141	456
4157	445
4166	445
4172	445
4173	445
4177	445
4177U	445
4178	445
4178R	445
4179R	445
4227	430
4237	445
4247	445
4242	445
4262	445
4267	445
4337	445
4342	445
4347	445
4362	445
4367	445
4641	456
4650	456
4652	456
4655	456

GILBERT

Kumfe 2	122·5
A50	110
A63	122·5
C64	122·5
Gordon Elf	430
Cameo AC, DC5	430

HMV

146	456
147	456
166	465
340	456
341	456
381	123-127-125-125
404	128-123-128-125·5
425	123-127-125-125
438	128-123-128-125·5
440	128-123-128-125·5
441	125
442	123-127-123-127
443	123-127-123-127
444	125
445	123-127-125-125
446	123-127-125-125
456	465
457	465
458	465
459	125
462	125
463	127-123-123-127
464	126·5-121·5-121·5-126·5
467	120-114-117-117
469	465
470	128-125-125-125
479	465
480	460
481	460
482	465
485	460
485A	460
486	465
487	465
488RG	460
489	465
490	465
491	465
492	465
493	465
494	465
495	465
496	460
497	460
498	460
499	465
505	128-123-128-125·5
512	128 123-128-125·5
523	128-125 125-125
524 and 524A	120-114-117-117
531	125·2
532	125·2
532C	125·2
540	128·123·128·125·5
540A	125
541	125
542	128-123-128-125·5
545RG	123-127-125-125
546	123-127-125-125
570	123-127-123-127
580	122-112-117-117-117-117
581RG	460
582	460
622RG	123-127-125-125
632	123-127-125-125
642	465
645	123-127-125-125
650	465
651	465
653	465
654	465
655	465
656	465
657	465
658	465
659	465
660	465
661	465
663	465
664	465
665	465
666	465
668	465
670	465
671	465
682	465
800 Auto RG	125
801 Auto RG	460
1100	465
1101	465
1102	465
1103	465
1104	465
1105	465
1106	465
1107	465
1111	485
1112	485
1113	465
1200	465
1300	465
1301	465
1350	465
1351	465
1351A	465
1354	485
1355	485
1400	465
1403	465
1404	465
1406	465
1500	465
1501	465
1504	465
1600	465
1601	465
1750	465
5211	485
5212	485
5311	485
5312	485

HALCYON

Briton	130·5
Briton Radiogram	130·5
Nine-Stage AC	110
Royal County	130·5
Seven-Stage Universal	110

HALCYON—*cont.*

Royal Gram and Auto .. 130·5
A57 .. 130·5
A581 .. 130·5
A5820 .. 130·5
AC5 110
AC6 110
AC7 110
AC7G 110
B691 .. 130·5
GA33 .. 130·5
GR37 .. 130·5
MS6 465
RGA581 .. 130·5
RGCA581 .. 130·5
RGCU6801 130·5
RGU6801 130·5
U57 .. 130·5
U537 .. 130·5
U571 .. 130·5
U573 .. 130·5
U5820 .. 130·5
U6801 .. 130·5
701 110
4501 110
4501G 110
4501GA 110
4701 110
4701G 110
4701GA 110
6701 110

HARTLEY-TURNER

MA 130
MA7 130
MA12 130
MA25 130
RF41 465
RGMA12 .. 130
RGNA25 130

HAYNES

All Superhet Models 110

HIGGS

A48R (and G) .. 465
A49R 450
AW49C 450
AW49R 450
AW57R (and G) .. 465
AW58R (and G) .. 465
AW59C 450
AW59R 450
AW69B 450
AW69G 450
AW69PB 450
AW69PG 450
AW99C 450
AW99G 450
BW49PR 450
BW49R 450
UW57R (and G) 465
UW58R (and G) 465
UW59C 450
UW59R 450
UW69B 450
UW69G 450
UW69PB 450
UW69PG 450

INVICTA

Multi Mains .. 110
SF 119
SHB 127
UP2 467
A29 465
B29P 465
A40RG 465
A40 465
A40C 465
B39 465
B40 465
U40 465
AC/45 127
AC/45D 127
AC/45RG .. 127
45U 127
45U/RG 127
A46PB 465
AC47 127
47B 127
47U 127
47U/RG 127
AC48/RG .. 127
A49 465
A49C 465
A49PB 465
A49RG 465
AR49 465
B29P 465
B39 465
B49 465
U49 465
AW56 465
AW57 465
AW57/RG .. 465
300 465
310 465
310/RG 465
330 465
360 465
390 465
400 465
430 465
431 465
440 465
450 465
460 465
461 465
500 465
502 465
503 465
510 465
520 465
570 465
580 465
635 110
635 (D) 110
635/RG 110
650/NJ 465
800 469
820 465

KOLSTER-BRANDES

285 114
286 114
339 130
345 130
346 130
365 130
365A 130
378KB 130
381 130
383 130
398 130
405 130
405A 130
422 130
425 130
426 130
427 130
427A 130
428 130
428A 130
444 130
444A 130
540 130
550 130
560 464
580 130
590 464
592 464
610 130
630 464
632 464
640 464
642 464
650 464
652 464
660 464
666 130
666A 130
666B 130
666C 130
670 464
720 130
730 464

KOLSTER-BRANDES —*cont.*

735	464
740	464
740P	464
750	464
760	464
770	464
800	464
808	464
817	464
820	464
830 and OA1	464
831	464
835 and OA1	464
840	464
850	472
860	464
865	464
870	464
875	464
880	464
885 and OA1	464
888 A, B, C	130
890	472
935	130

LISSEN

All Purpose	452
Arundel	452
Balmoral	452
Caernarvon	473
Carisbrooke	452
Conway	452
Dover	455
Edinburgh	473
Glamis	452
Kenilworth	452
Lancaster	452
Marquis	455
Richmond	452
Salisbury	452
Skyscraper 7 (Fixed)	126
Winchester	452
York	452
8060	126
8108	127
8109	127
8110	127
8111	127
8114	465
8116	127
8117	127
8121	127
8125	127
8128	127
8129	127
8169	127
8214	465
8301	455
8302	455
8304	455
8317	455
8318	455
8319	455
8321	455
8322	455
8329	455
8401	452
8402	473
8414, 8415	452
8417	452
8418	452
8421	473
8422	473
8424	455
8432	473
8458	452
8468	452
8480	452
8481	452
8482	452
8485	452
8503	452
8514	452
8515	452
8518	452
8521	455
8529	452
8533	452
8539	452
8547	452
8563	452
8647	452

MAJESTIC

4V Midget Superhet	465
15/15B	175
20	175
21	175
22	175
23	175
25	175
44	465
49	465
52	175
60	175
61A	175
120	175
150	175
151	175
153	175
154	175
155	175
156	175
163	175
194	465
261A	125
261B	125
264	125
265	125

MARCONIPHONE

209	123-127-125-125
219	123-127-125-125
222	465
223	456
224	456
234	456
236	456
239	123-127-125-125
249	123-127-125-125
255	125
256	128-125-125-125
257	456
258	128-125-125-125
262	128-123-128-125·5
264	125
269	125
272	128-123-128-125·5
273	125
274	128-123-128-125·5
276	120-114-117-117
278DC	128-123-128-125·5
279	127-123-123-127
280DC	128-123-128-125·5
286	128-123-128-125·5
Q286	125
287	125
288	128-123-128-125·5
289	123-127
290	120-114-117-117
291	120-114-117-117
292	122-112-117-117-117-117
296	123-127
297	125
298	123-127
336	125-125-122-128
345	460
346	460
347	460
363	460
365	460
366	460
367	460
382	465
392	465
395	465
534	465
535	128·8-122·8-126·5-122·5
536	128·8-122·8-126·5-122·5
537	465
538	465
539	465
549	465
556	465
557	465
559	465

MARCONIPHONE —*cont.*

561	465
562	126·5-121·5-121·5-126·5
563	465
564	465
566	465
567	465
571	465
572	465
573	465
575	465
576	465
851	465
852	465
853	465
855	465
857	465
857T	465
858	465
859	465
861	465
864	465
865	465
866	465
868	465
869	465
870	465
871	465
872	465
873	465
874	465
878	465
879	465
880	465
881	465
882	465
883	465
884	465
885	465
888	465
890	465
891	465
892	465
893, 893A	465
895	465
911	465
918	485
919	485
920	485
921	485
922	465
950	465

McCARTHY

BPS6	127
BS4	127
BS4/AW	465
BS6/AW	465
PP6/AW	125
PP8/AW	465
PP9/AW	473
PP9/AW De Luxe	473
RF6/AW	465
RF6/AW/AC-DC	465
RF7/AW	465
RF7/AW/AC-DC	465
RGS6	465
S5/AW/AC-DC	465
S5/AW/AC	465
S6/AW	465
S6/AW/AC-DC	465
S8/AW	465
S6/AW/AC-DC De Luxe	110

McMICHAEL

AC Mains Superhet	428·5
Superhet Trans	110
Twin Spker S/H (Early Models 406/410)	428
135	128·5
135U	128·5
137	465
137U	465
138	465
235	128·5
235	128·5
361	128·5
362	465
363	128·5
364	128·5
365	128·5
366	128·5
368	128·5
369	128·5
371	128·5
371U	128·5
372	128·5
373	128·5
374	128·5
375	465
378	128·5
380	460
380U	460
381	465
382	465
385	460-465
386	460
386RC	460
386RG	460
386U	460
388	465
389	465
390	465
391	465
393	465
394	465
396	465
396RC	465
396RG	465
398	465
399	465
401	128·5
401U	128·5
435	128·5
535	128·5
802	465
803	465
808	465
903	465

McMURDO-SILVER

Masterpiece VI	465
Masterpiece Chippendale	465
Masterpiece Olympic	465
Masterpiece Sheraton	465
15-17 Chassis	465
15-17 Georgic	465
15-17 Homeric	465
15-17 Olympic	465

MILNES

Diamond (SW 3·1 Mcs.)	465
Emerald (SW 3·1 Mcs.)	465
Mercury	450
Onyx	450
Pearl (SW 3·1 Mc/s)	465
Ruby (SW 3·1 Mc/s)	465
Saturn	450
Venus	450
466 (SW 3·1 Mc/s)	465
466 B (SW 3·1 Mc/s)	465
589 (SW 3·1 Mc/s)	465

MULLARD

MAS2	128
MAS3	128
MBS3	128
MUS3	128
MAS4	128
MBS4	128
MUS4	128
MAS5	128
MUS5	128
MAS6	128
MBS6	128
MUS6	128
MAS7	128
MBS7	470
MAS8	128
MAS12	128
MUS12	128
MAS15	470
MUS15	470

REGENTONE—*cont.*
Transportable 6 .. 465
World Wide 5 .. 456
5V S/Het with round cans 110
—Otherwise .. 123
AC/47 .. 110-123
AC/56 .. 110-123
AC/56U .. 110-123
AC/57 .. 110-123
AC/57U .. 110-123
AW/S 465
RG66 .. 110-123
RG66U .. 110-123
USP59 465
R55 465
R55A 465
AW44 465
AW66 465
U33 465
U33X 465

REMCO
All Models .. 465

RGD
166 465
166U 465
196 465
196U 465
296 465
296U 465
356 465
356U 465
516AC 460
522 460
535 460
623AC 460
623DC 460
625AC 460
625DC 460
628AC 460
628DC 460
630AC 460
630DC 460
643DC 460
645AC 460
645DC 460
658 460
660 460
700AC 110
700DC 110
701AC 110
701DC 110
702AC 110
702DC 110
703AC 110
704AC 110
704C 110
704DC 110
704RG 110
705 460
718AC 460
718AC-DC .. 465
722 465
723AC 465
723AC-DC .. 465
727 465
739AC 465
739AC-DC .. 465
A739AC 465
A739AC-DC .. 465
743 465
748 465
878 460
880 460
901AC 110
901DC 110
925 465
930 465
948 465
955 465
1015 465
1129 465
1135 465
1153 465
1155 465
1175 465
1201 110
1202 110
1203 460
1204 110
1220 460
1221 465
1295 465
3611 465
5311 465
5511 465
7511 465
1046G 465
1046 465

RI
4V Batt. Superhet 118
Superhet RG .. 118
Airflo 118
Duotone 118
Moderne 118
Ritz 118
Ritz AC S/Het .. 118
Ritz Micrion Batt 5 118
Ritz Twin Speaker 118

ROBERTS
Up to 1939 :
M5A 430
P6 126
M4D 430
From 1939 onwards :
M5A 465
P6 126
M4D 465
1946
P5A 465
P4D 465

ROGERS MAJESTIC
11/6 456
11/8 456
11/8X 456
11/9 456
11/9DX 456
11/11 456
11/11X 456
12/6 456
12/7 456
12/9 456
13/8 456
13/8C 456
13/10 456
13/15 456
14/8C 456
14/8R 456
14/8T 456

SELMER
Truvoice 5 .. 450
139 450
140 450
1239 450

SPARTAN
401 465
501 465
510 465
511 465
519 465
520 465
521 465
530 465
531 465
540 465
541 465
548RG 345
548T 345
559 465
610 465
611 465
619 465
620 465
621 465
629 465
630 465
631 465
639 465
640 465
641 465
648AG 345
648C 345

SPARTAN—*cont.*

648RG	345
649	465
650	465
651	465
719	345
748AG	345
748C	345
748T	345
1268AG	456

SPENCER

All Models	430

STANDARD

S40	130
S60	130

SUNBEAM

22	456

SUNRAY

55	110
99	465

TELSEN

6V Superhet	117·5
3435/BH	117·5
3435/BV	117·5
3435/MH	117·5
3435/MV	117·5

TEMPOREX

R3	465
R3G	465
R3U	465
R3UG	465

TRUPHONIC

AT5	127
AW5	127
AW5A	127
AW5B	127
AW5C	127
AW5T	127
AW6	456
B4	127
BB4	127
BW5	127
BW5B	127
CA6	127
CU6	127
MA5	465
MA5RG	465
MA5T	465
MU5	465
MU5RG	465
MU5T	465
MA6	465
MA7	465
MA8	465
MA8RG	465
MU5	465
MU5RG	465
MU5T	465
NA5	127
NAC5	127
NAW5	127
NU5	127
NUWS	127
PA5	465
PAT5	127
PU5	465
PUT5	127
RGAW5C	127
RGA6	127
RGUW5	127
RGU5C	127
RGU6	127
UT5	127
UW5	127
UW5B	127
UW5C	127
NW5T	127
U6	127
UW6	127

ULTRA

1934 Panther AC	456
Tiger M AC-DC	456
M22	470
22AC	456
22 Batt	456
22DC	456
M23	470
25AC	456
25DC	456
26AC and AC-DC	456
44	456
47	456
48	456
49	456
50	456
P60	510
P61	510
P62	510
P63	460
P70	510
88	456
95	456
96	456
97	456
99	456
101	456
102	456
103	456
105	470
106	470
115	456
116	456
121	456
122	456
123	456
125	456
133	456
134	456
140	456
150	456
201	470
202	470
203	470
204	470
205	470
206	470
207	470
208	470
209	470
210	470
301	470
302	470
303	470
304	470
305	470
306	470
307	470
308	470
309	470
310	470
315	470
316	470
320	470
330	470
400	456
500	470
401	470
402	470
405	470

VARLEY

AC Superhet 4	110
AP46	110
AP48	110
Square Peak Mains Superhet	110

VIDOR

220	473
221	473
227	130
237	130
258	130
275	473

VIDOR—*cont.*

277	473
280	473
284	473
288	450
291	473
300	473
301	473
302	473
308	450
322	465
323	465
351	456

WAR-TIME CIVILIAN RECEIVER

(See Civilian War-time Receivers, page 213).

WB

4VA/wave Superhet	128
5VA/wave Superhet	128
394B	128
395	128

ZENITH

5S29	252·5

ZETAVOX

ST/AC	125

USA Receivers Imported by Board of Trade

ADMIRAL

67M5	455
76P5	455
77P5	455
78P6	455
79P6	455
P6XP6	455
4202B6	455
4203B6	455
4204B6	455
4220 D5	455

ANDREA

35H5	455

EMERSON

301	455
310	455
311	455
318	455
320	455
330	455
331	455
332	455
336	455
343	455
349	455
350	455
351	455
353	455
363	455
376	455
389	455
400	455
402	455
413	455
414	455
415	455
418	455
419	455
421	455
422	455
424	262
425	455
426	455
427	262
428	262
433	455
439	455
440	455
441	455
461	455
463	455
465	455
465A	455
467	455

FADA

115	455
148	455
200	455
203	455
205	455
209	455
215	456
220	455
252	455
PD41	456
PL23	456
PL41	456
169W	456
215T	456

GE

HJ612	455
J54W	455
L513	455
L541	455
L543	455
L570	455
L571	455
L572	455
L574	455
L600	455
L604	455
L613	455
L621	455
L643	455
L651	455
LB673	455
LB700	455
LB702	455

MOTOROLA

51X16	455
51X19	455
61X17	455
61L11	455

PHILCO

PT3	455
PY87	455
PT88	455
PT95	455
321T	455
42-327T	455
42-842T	455

RCA

1X	455
6X2	455
14X	455
34X	455
35X	455
36X	455
45X12	455
15X	455
55X	455
16X2	455
16X3	455
16X11	455
16X13	455
26X1	455
26X3	455
26X4	455
26BP	455
26X21	455

STROMBERG-CARLSON

500H	455

WESTINGHOUSE

12X4	455
13X8	455
WR13X8	455
WR62K1	455
WR62K2	455

ZENITH

5G603M	455
6G601	455

SECTION 13

COLOUR CODES

BRITISH

Resistors. Small moulded and wire-wound resistors usually have their ohmic values indicated by the same three-colour code as the American (Table L).

In past years, tolerance was seldom indicated. Where it was, gold denoted 5 per cent tolerance, and silver 20 per cent. Most unmarked resistors had a tolerance of 10 per cent.

Recently, preference has been given to a four-band coding, identical with the American code, including tolerance indication. With these band-marked resistors, therefore, a fourth band of gold indicates 5 per cent tolerance, and silver indicates 10 per cent, while the standard no-colour, or unmarked, resistor has a tolerance of 20 per cent.

Moulded Mica Capacitors. The latest proposal is that the American code (Table L) should be adopted, giving the capacitance in micro-microfarads.

Colour coding for small capacitors has not been widely employed in Britain. A five-dot system was at one time recommended, the first three dots indicating the value in micro-microfarads, in the same way as for resistors. Fourth and fifth dots indicated tolerance and voltage as shown in Table XLIX.

Where there were only three dots, or bands, the capacitance was indicated; two dots showed tolerance and voltage; one dot showed tolerance.

In another system, tolerances are indicated as follows: White, 1 per cent ; orange, 2 per cent; green, 3 per cent; red, 10 per cent; brown, 15 per cent; blue, 20 per cent; yellow, 25 per cent. (No colour shows standard tolerance of $-0+100$.) Test voltages are shown by: 1,000 V, no colour; 2,200 V, green; 5,000 V, brown.

TABLE XLIX

Colour	Tolerance per cent	Voltage Rating
Brown	1	100
Red ..	2	200
Orange	3	300
Yellow	4	400
Green	5	500
Blue ..	6	600
Violet ..	7	700
Grey ..	8	800
White ..	10	1,000

In a third system, tolerances are indicated as follows: Green, 1 per cent; violet, 2 per cent; yellow, 3 per cent; white, 5 per cent; red, 10 per cent. Up to and including 1,000 V DC test, there is no voltage marking; a light blue star indicates 1,500 V DC test.

Electrolytic Capacitors. These are not coded for voltage or capacitance.

An agreement was made some years ago, regarding the following wiring code, but was never universally adopted, while, during the war, the wire supply position made any coding impracticable. Single capacitor with two leads: positive, red; negative, black. Multiple capacitor, case insulated; lead connected to capacitor of highest voltage and/or capacitance, red; lower voltage and/or capacitances in descending order, yellow, green, blue; negative, black; other negative leads, brown; any special connections, white.

AMERICAN

Capacitors. When the ratings of a moulded mica capacitor are not stamped on the case, a colour code may be employed to indicate the values (Table L).

The colours are applied as dots on the trade-mark side of the case. The dots are read from left to right. An arrow or the trade name is provided to indicate which way up the component must be held, to read the dots in the right sequence.

The first three dots indicate the capacitance in micro-microfarads:

(1) The colour of the first dot (*A* in the diagrams) gives the first figure.

(2) The colour of the second dot (*B*) indicates the second figure.

(3) The colour of the third dot (*C*) indicates the number of noughts following the first two figures.

Example: If the sequence of colours is red, green, black, the capacitance is 25 mmFd, or ·000,000,000,025 F. Usually, capacitances are stated in microfarads, hence the value is ·000025 mFd.

If the colours were green, black, red, the value would be 5,000 mmFd, or ·005 mFd.

Note: To convert mmFd to mFd, move decimal point six places to left.

Where only three dots are given, the capacitor is rated at a working voltage of 500 DC, and the capacitance tolerance is plus or minus 20 per cent.

(4) A fourth dot (*D*) indicates the *DC* working voltage rating, and this is shown in Table LI.

(5) A fifth dot (*E*) indicates the percentage tolerance in the accuracy of the capacitance rating.

Six-dot Code. When there are

TABLE L

Colour	First or second figure	Noughts after second figure
Black	0	None
Brown	1	0
Red ..	2	00
Orange	3	000
Yellow	4	0,000
Green	5	00,000
Blue ..	6	000,000
Violet ..	7	0,000,000
Grey ..	8	00,000,000
White ..	9	000,000,000

TABLE LI

Colour	DC voltage rating	Tolerance per cent
Brown ..	100	± 1
Red ..	200	± 2
Orange	300	± 3
Yellow	400	± 4
Green ..	500	± 5
Blue ..	600	± 6
Violet ..	700	± 7
Grey ..	800	± 8
White ..	900	± 9
Gold ..	1,000	—
Silver ..	—	±10

three significant figures in the capacitance value, six dots are necessary if voltage and tolerance are also indicated. In this case, the first three dots give the three significant figures, and the lower right-hand dot the number of noughts. Remaining two dots show working voltage and tolerance.

Resistors. Carbon-type moulded resistors and small wire-wound types are given a protective paint covering which is coloured in dots, or bands, to provide indication of the resistance value (Table L) and, in some cases, the tolerance in accuracy of rating.

(1) The first figure of the value is indicated by the colour of the body of the resistor (*A* in Fig. 165).

(2) The second figure is indicated by the colour of one end (*B*).

(3) The number of noughts following these two figures is indicated by a dot or band (*C*).

(4) When given, the tolerance is indicated by the colouring of the other end of the resistor (*D*).

The colour code for the value is the same as for capacitors.

The code for tolerance is: Gold, ± 5 per cent; silver, ± 10 per cent; no colour, ± 20 per cent.

As gold and silver are not used for values, there is no question as to the sequence in which colours are read.

Examples: A resistor has a red body, green end and black dot. The value is 25 ohms with a tolerance of ± 20 per cent.

A resistor is coloured yellow with violet and gold ends, and a green dot. Value is 4,700,000 ohms accurate, within ± 5 per cent.

Note: If a dot or end colour is missing, it is same as the body.

Coding by Bands. An alternative coding employs three- or four-coloured bands and dispenses with the body colour and dot. The sequence from left to right is :

(1) First figure.
(2) Second figure.
(3) Number of noughts.
(4) Tolerance.

Flexible Resistors. Flexible wire-wound fabric-covered resistors are also coded. The body colour gives the first figure, the thicker thread the second figure, and the thinner thread the number of noughts. If either of the threads is missing, it is taken as being the body colour.

Line Cord Resistors. American line cords have three wires, two directly from the line plug and one from the resistor. The two line wires are red and blue or red and black. The colour of the third wire indicates the resistance value as shown in Table LII.

Power Transformer. The standard code to identify leads is:

Primary: If the primary winding is not tapped, both primary leads are black. If the primary winding is tapped, the leads are as follows: Common, black; tap, black/yellow; finish, black/red.

Rectifier HT winding: Outside leads, red; centre tap, red/yellow.

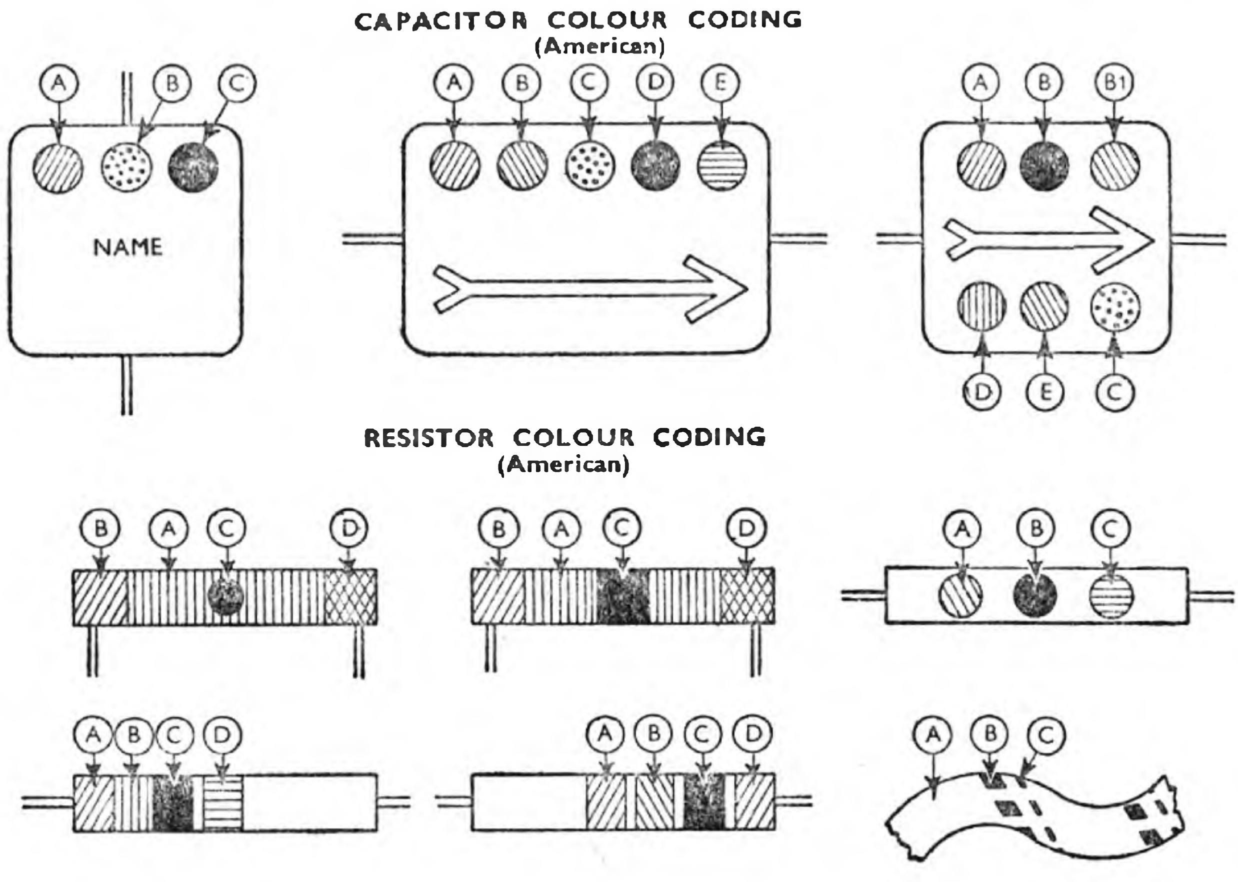
Rectifier LT winding: Outside leads, yellow; centre tap, yellow/blue.

Heater winding 1: Outside leads, green; centre tap, green/yellow.

Heater winding 2: Outside leads, brown; centre tap, brown/yellow.

Heater winding 3: Outside leads, slate; centre tap, slate/yellow.

It should be appreciated that as



AMERICAN COLOUR CODINGS
Fig. 165. Showing the different ways that capacitors and resistors may be marked with the standard American value codes.

TABLE LII

Colour	Resistance (ohms)
Yellow	135
Blue	160
White	180
Green	200
Light brown ..	220
Orange	260
Maroon	315-320
Dark brown ..	350-360

TABLE LIV

Filament positive	Red
Filament negative	Black
HT positive maximum	Blue
HT positive intermediate	White
HT negative	Yellow
GB positive	Brown
GB negative maximum	Green
GB negative intermediate	Orange

TABLE LIII

Input and Interstage Transformers		Output Transformers	
Anode lead	Blue	Anode lead	Blue
HT lead	Red	HT lead	Red
Control-grid lead ..	Green	Diode or control grid	Green
AVC lead	Black	Grid or diode return	Black
		Full-wave diode ..	Green and black

late as 1940 many makers were using their own codes and not the above RMA standard.

Audio Transformers. The standard American RMA colour code employed on the leads of AF transformers is shown in Fig. 166.

For push-pull interstage and output transformers, the colour coding is also indicated. In the case of single primary and/or single secondary transformers, only the upper portion of the diagram (above the dotted line) is used.

When the polarity of the primary (and/or secondary) is not a factor, both outside leads may be the same colour as indicated. Where polarity must be indicated, the brown and yellow leads indicate the start of primary and secondary winding respectively. In the case of an output transformer, the black lead shall be the start of the secondary.

IF Transformers. The American RMA colour code employed on the leads of intermediate-frequency transformers is indicated in Table LIII.

Battery Leads. Code employed by members of the American National Electrical Manufacturers' Association appears in Table LIV.

Gramophone Motors. A code used on many American gramophone motors is: No mark, 60 cycles; green spot, 50 cycles ; white spot, 25 cycles.

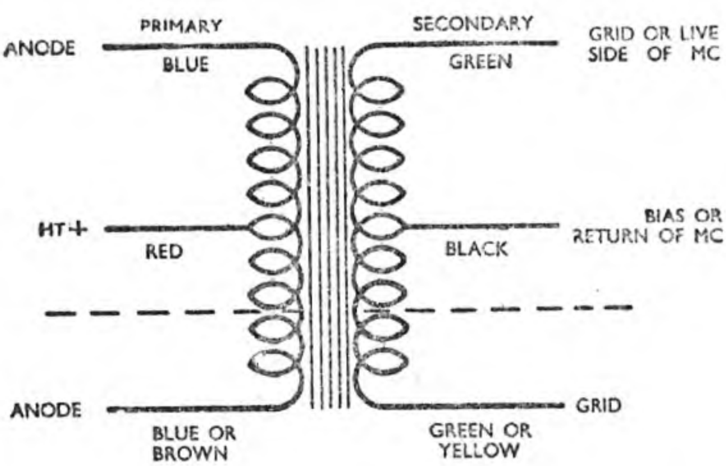


Fig. 166. Colour coding for output and intervalve transformers.

STANDARD RESISTANCE VALUES

To simplify production and stocking, the manufacturers of composition re-

TABLE LV

Ohms ± 20%	Ohms ± 10%	Ohms ± 5%	Ohms ± 20%	Ohms ± 10%	Ohms ± 5%	Ohms ± 20%	Ohms ± 10%	Ohms ± 5%
10	10	10	1,000	1,000	1,000	100,000	100,000	100,000
		11			1,100			11,000
	12	12		1,200	1,200		120,000	120,000
		13			1,300			130,000
15	15	15	1,500	1,500	1,500	150,000	150,000	150,000
		16			1,600			160,000
	18	18		1,800	1,800		180,000	180,000
		20			2,000			200,000
22	22	22	2,200	2,200	2,200	220,000	220,000	220,000
		24			2,400			240,000
	27	27		2,700	2,700		270,000	270,000
		30			3,000			300,000
33	33	33	3,300	3,300	3,300	330,000	330,000	330,000
		36			3,600			360,000
	39	39		3,900	3,900		390,000	390,000
		43			4,300			430,000
47	47	47	4,700	4,700	4,700	470,000	470,000	470,000
		51			5,100			510,000
	56	56		5,600	5,600		560,000	560,000
		62			6,200			620,000
68	68	68	6,800	6,800	6,800	680,000	680,000	680,000
		75			7,500			750,000
	82	82		8,200	8,200		820,000	820,000
		91			9,100			910,000
100	100	100	10,000	10,000	10,000	1·0 meg	1·0 meg	1·0 meg
		110			11,000			1·1 meg
	120	120		12,000	12,000		1·2 meg	1·2 meg
		130			13,000			1·3 meg
150	150	150	15,000	15,000	15,000	1·5 meg	1·5 meg	1·5 meg
		160			16,000			1·6 meg
	180	180		18,000	18,000		1·8 meg	1·8 meg
		200			20,000			2·0 meg
220	220	220	22,000	22,000	22,000	2·2 meg	2·2 meg	2·2 meg
		240			24,000			2·4 meg
	270	270		27,000	27,000		2·7 meg	2·7 meg
		300			30,000			3·0 meg
330	330	330	33,000	33,000	33,000	3·3 meg	3·3 meg	3·3 meg
		360			36,000			3·6 meg
	390	390		39,000	39,000		3·9 meg	3·9 meg
		430			43,000			4·3 meg
470	470	470	47,000	47,000	47,000	4·7 meg	4·7 meg	4·7 meg
		510			51,000			5·1 meg
	560	560		56,000	36,000		5·6 meg	5·6 meg
		620			62,000			6·2 meg
680	680	680	68,000	68,000	68,000	6·8 meg	6·8 meg	6·8 meg
		750			75,000			7·5 meg
	820	820		82,000	82,000		8·2 meg	8·2 meg
		910			91,000			9·1 meg
						10·0 meg	10·0 meg	10·0 meg

sistors have standardized three-tolerance ranges of ± 20 per cent, ± 10 per cent and ± 5 per cent.

Examples: A '100-ohm' resistor in the ± 20 per cent range may have a value between 80 and 120 ohms. In the ± 5 per cent range, the value will be accurate between 95 and 105 ohms.

The standardization given in Table LV reduces the total of resistors necessary to cover 10 ohms-10 meg from well over 800 to 255.

SECTION 14

INTERFERENCE SUPPRESSION

THE principle of the suppression of interference at the source is illustrated in Fig. 167. *S* is the source, usually an interrupted contact such as a switch or a commutator. An high-frequency potential appears across the impedance of the gap; unless suppressed, it drives HF currents back through the machine into the mains. The interference may thus be conducted to radio sets, or electromagnetic waves may be radiated and picked up by receiver aerials.

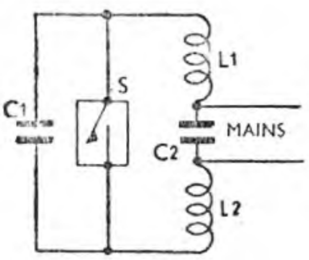


Fig. 167. Principle of mains filter.

Suppression is applied by connecting a capacitor C_1 across the source. C_1 must be of sufficient size to present a low impedance in comparison to the impedance of the gap and of the machine and mains. Average impedance of mains is about 150 ohms. Various examples of the application of suppression at source are given in Figs. 168-174.

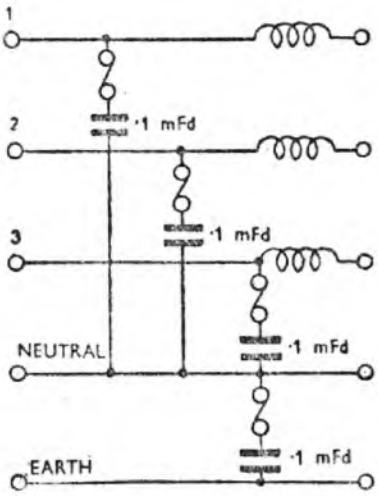


Fig. 169. Filter components for a four-wire mains system.

Where C_1 alone is not adequate, reduction of the HF voltage applied to the mains can be obtained by the filter structure L_1, C_2, L_2. The HF potential is across the capacitor C_1, but little appears across C_2 since it is of low impedance, while the chokes L_1, L_2, are of high impedance.

Exact values of capacitance and inductance are best determined by trial, but will be within the ranges set out in Tables LVI and LVII.

SUPPRESSION CAPACITORS

Suppression Capacitors are classified in three types:

Type X, employed across AC or DC mains up to 250 volts working.

Type Y, employed from any main to earth or frame where voltage to earth does not exceed 500 volts working, or employed across 500 volts DC mains.

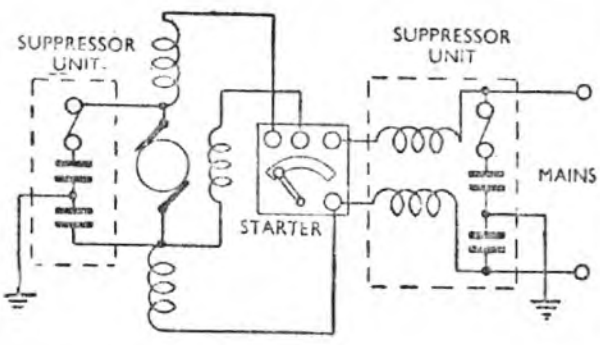


Fig. 168. Suppression applied to motor and starter.

Type XX, employed across mains up to 500 volts AC.

Other requirements of capacitors are set out in BSS613.

Post Office Recommendation

With unearthed appliances, the G.P.O. recommends that the capacitor connected between main and frame should not exceed ·005 mFd, or any person touching the frame may receive a shock from the charging current.

Suitable standard inductance values as given by Belling & Lee, Ltd., are shown in Table LVII.

TABLE LVI

Designation of Capacitor	Voltage Tests		Insulation—Resistance Tests	
	Between Terminals of Capacitor (Volts)	Between Terminals and Metal Casing (Volts)	Between Terminals of Capacitor (Megohms)	Between Terminals and Metal Casing (Megohms)
X0·005 to X0·1 X0·5 X1 X2	1,500 (DC)	1,500 (AC)	1,000 600 300 150	100
Y0·005 to Y0·1 Y0·5 Y1 Y2	2,250 (DC) or 1,500 (AC)	1,500 (AC)	1,000 600 300 150	100
XX0·005 to XX0·1 XX0·5 XX1 XX2	3,000 (DC) or 2,000 (AC)	2,000 (AC)	1,000 600 300 150	100

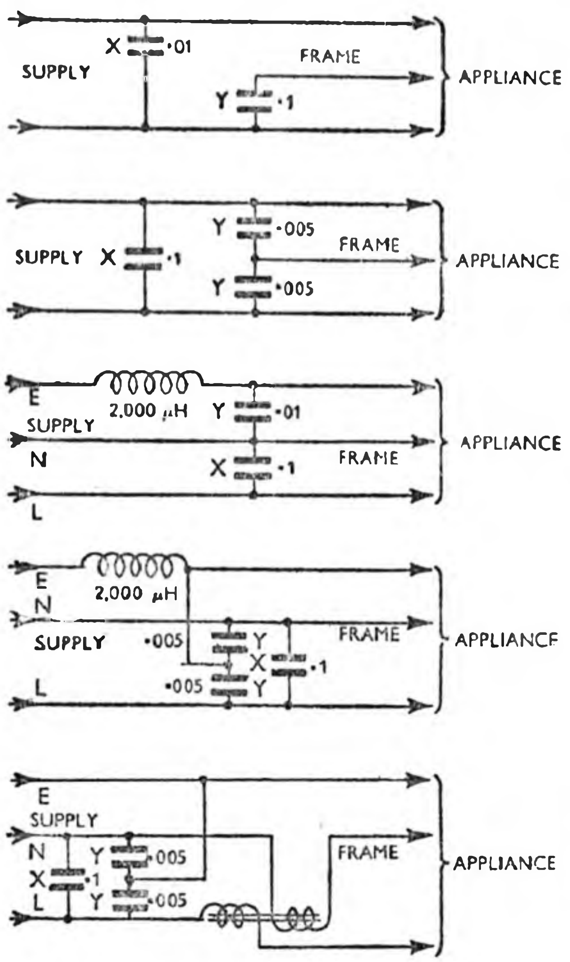


Fig. 170. Suppression filter circuits for mains leads to portable appliances.

TABLE LVII

Circuit Current (amps)	Inductance (microhenries)
·5	10,000
1	5,000
5	2,000
15	1,000
30	500
60	250
100-300	100

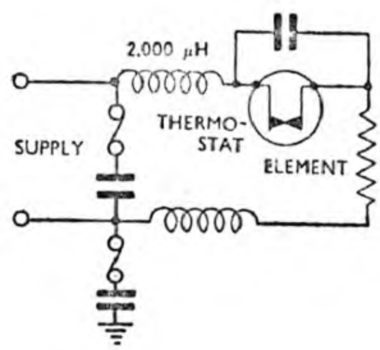


Fig. 171. Suppressor for a thermostat as fitted to a refrigerator or cooker. It consists of two 2,000-microhenry chokes in series with the appliance and a parallel capacitor of ·005 mFd or more.

Limits of Interference. According to BSS800, 1939, a signal-to-noise ratio of 100-1 is desirable.

Between 200-1,500 Kc/s, interference level at the machine terminals, or from terminals to frame, should not exceed 500 microvolts, whether the frame is earthed or not.

Over the same frequency range, the field intensity at 10 yards or less should not exceed 100 mV per M.

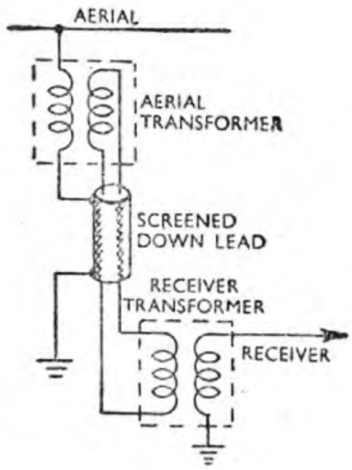


Fig. 177. Screened anti-static lead-in system for aerial connection to receiver.

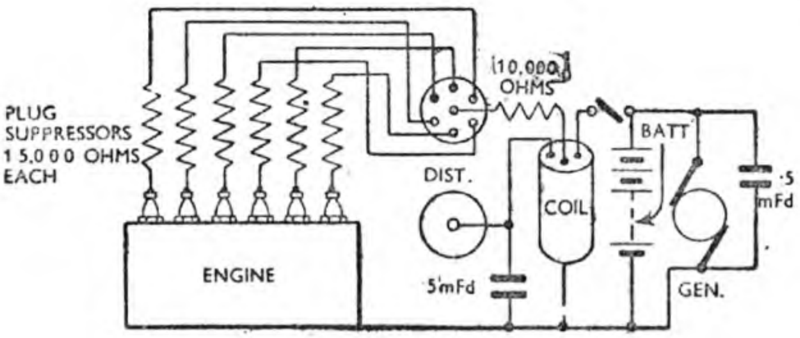


Fig. 172. Comprehensive suppression applied to an automobile.

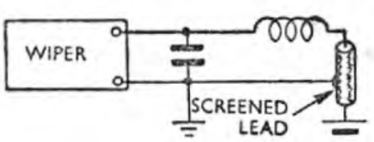


Fig. 173. Windscreen-wiper suppression.

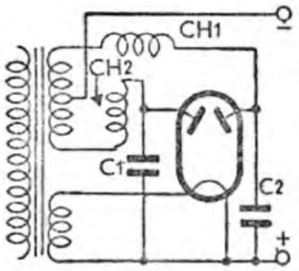


Fig. 174. HF filter capacitors and inductors added to a full-wave rectifier circuit.

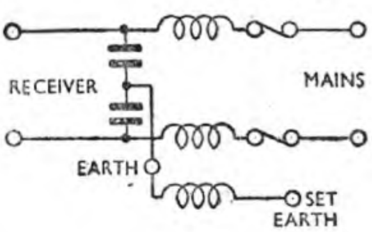


Fig. 175. HF filter in mains lead to a receiver.

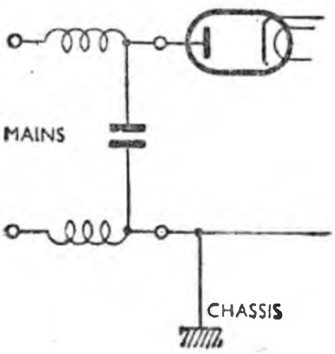


Fig. 176. Mains filter for AC-DC receiver.

Suppression at Receiver. Where adequate suppression at source is not possible, the following steps may be taken at the receiver to prevent the entry of interference: (*a*) By conduction over the mains; (*b*) by direct

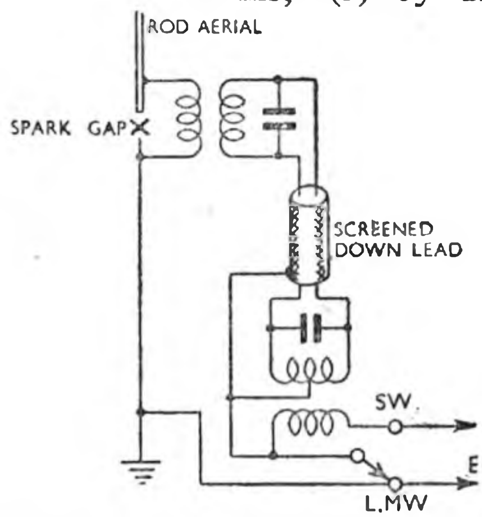


Fig. 178. Anti-static lead-in system used with Belling Lee 'Skyrod' aerial.

pick-up in the receiver; (*c*) by pick-up on the aerial.

For (*a*) there are set-lead filters (Fig. 175). Screening of the receiver cabinet is necessitated by (*b*), and (*c*) is secured by the use of a screened aerial system. In the latter, the open signal collector is erected outside the interference field, and the lead-in is fully screened.

To prevent undue signal loss in the screened cable, the impedance is reduced by transformer.

Reference to Figs. 176-178 will make clear the methods adopted.

SECTION 15

SOUND RELATED TO ITS AMPLIFICATION BY ELECTRICAL APPARATUS

Absorption Co-efficient. This is the fraction of sound energy absorbed by a surface. Theoretically, the absorption of an open window is taken as unity. (*See* Table LVIII.)

Audio Frequency is a frequency occurring at a rate between approximately 20 and 20,000 cycles per second. Air waves of these frequencies are heard as sound. Frequencies of the musical scale, and of instruments, are shown in Figs. 179 and 180 and Tables LIX and LX.

Intelligence can be communicated within a limited frequency range. It has been internationally agreed that minimum bands desirable are: for commercial telephony, 300-3,400 cycles; for music over wires, 50-6,400 cycles; for radio, 30-8,000 cycles.

Bar. Unit of sound pressure, equal to one dyne per sq. cm, and one-millionth of the bar in meteorology.

Bel. Logarithmic unit for comparison of powers. Where P_1 and P_2 are two powers, and N is the number of bels expressing their ratio : $N = \log_{10} \frac{P_1}{P_2}$.

Decibel is a tenth of a bel, and is the unit commonly used to express ratios of power, voltage or current. If N is the number of decibels, $N = 10 \log_{10} \frac{P_1}{P_2}$.

Where two powers are dissipated in equal resistances, the ratio of voltage to voltage, or current to current, may be expressed in decibels (or bels). For a given resistance, the power is proportional to the square of the voltage or current, and since, in logarithms, to square a quantity the logarithm is multiplied by two, then,

N bels $= 2 \log_{10} \frac{V_1}{V_2}$, or $2 \log_{10} \frac{I_1}{I_2}$;

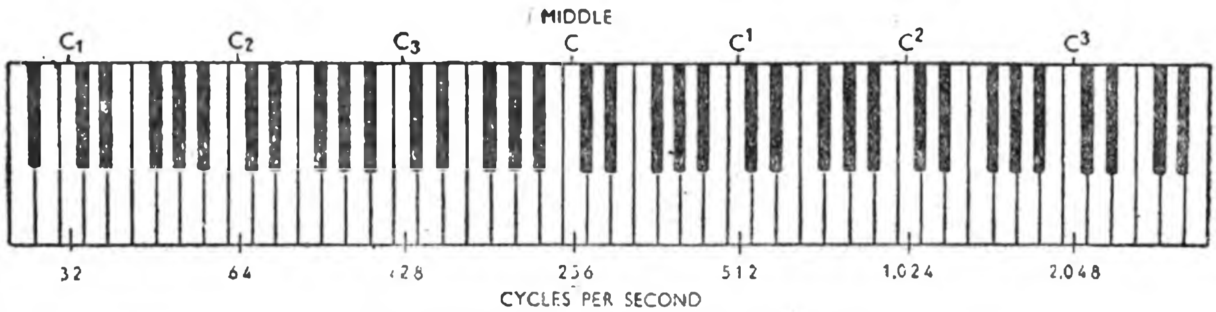
N decibels $= 20 \log_{10} \frac{V_1}{V_2}$, or $20 \log_{10} \frac{I_1}{I_2}$;

where V is voltage and I is current.

Advantage of the decibel is that it provides a unit of ratio which corresponds in some degree to the average person's perception of change in loudness.

To produce an apparent doubling of loudness, the actual intensity must be increased about ten times. A difference in loudness of one decibel is about the smallest change that can be discerned by the ear.

A second advantage is, that when the decibel gain or loss of the

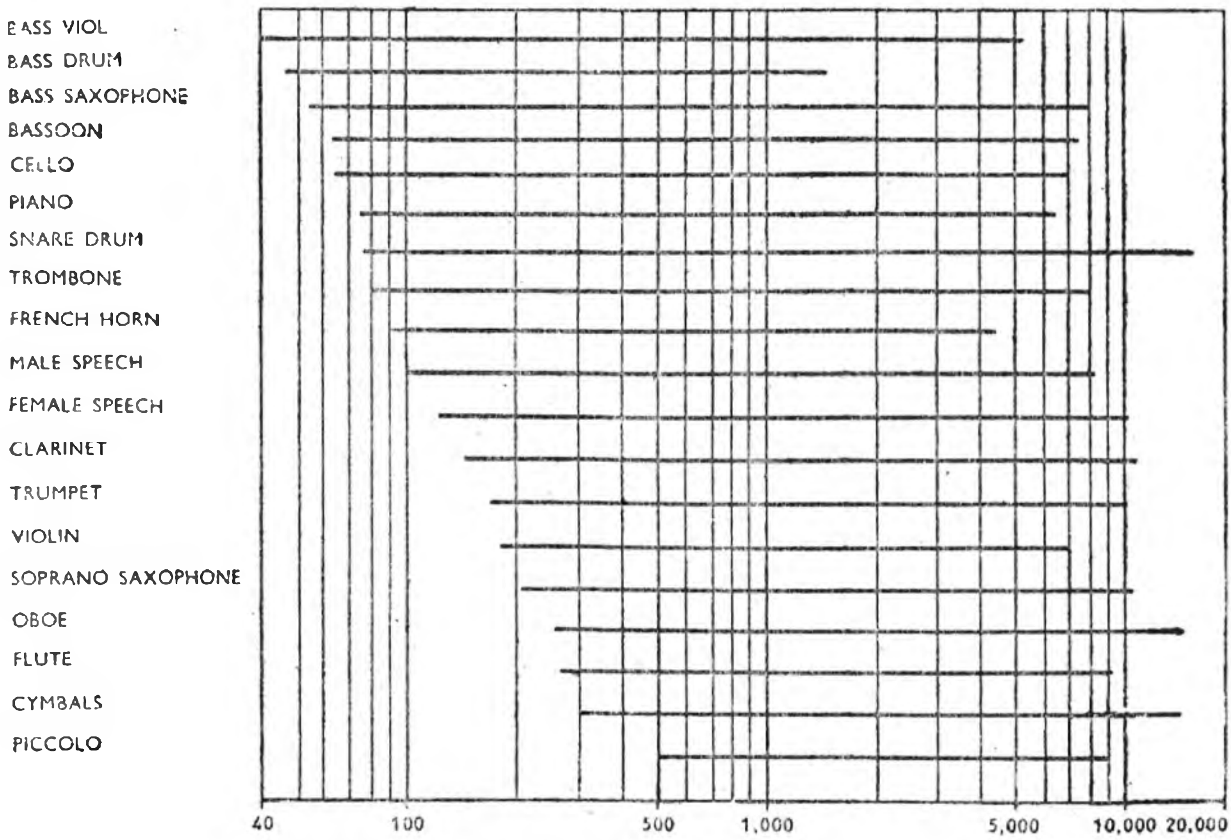


FREQUENCIES OF PIANO NOTES

Fig. 179. Showing a piano keyboard and frequency limits of octaves of C.

TABLE LVIII:
ABSORPTION COEFFICIENTS OF COMMON MATERIALS

Material	Absorption Coefficient for Frequency						
	64	128	256	512	1,024	2,048	4,096
Brick wall	·021	·024	·025	·03	·042	·049	·07
Plaster on brick	—	·013	—	·025	—	—	·045
Lime on wood lath with finishing coat	·036	·012	·013	·018	·045	·028	·055
Cork (coarse, 1 in.) ..	—	·14	·25	·4	·25	·34	·21
Hair felt (1 in.)	·09	·1	·2	·52	·7	·66	·44
Rock wool (1 in.) ..	—	·35	·49	·63	·80	·83	—
Carpet	—	·09	·08	·21	·26	·27	·37
Wood flooring	—	·05	·03	·06	·09	·1	·22
Cushions, canvas and plush	·86	·99	1·1	1·8	1·7	1·4	·91
Curtains, heavy	—	·1	—	·5	—	—	·9
Fibreboard (·5 in.) ..	—	·05	—	·54	—	—	·6

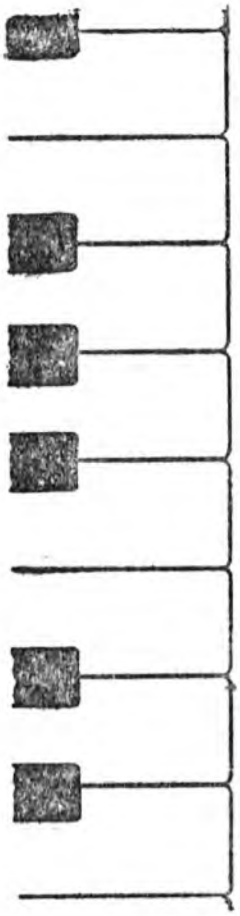


FREQUENCY RANGES COVERED BY INSTRUMENTS AND VOICES

Fig. 180. These ranges include harmonics; the range of fundamental frequencies is much less and can be discovered from the musical notation.

component parts of a system is known, the overall gain or loss can be found by simple addition and subtraction of the individual decibel ratings. To say an amplifier has a gain of so many decibels is correct, but the information is more complete if the input power is stated. An

TABLE LIX:
MUSICAL INTERVALS



	Equal Temperament Frequency Ratios	True Diatonic Frequency Ratios
C^2	2 ($\times f_{C^1}$)	2
B	1·888	1·875
A♯	1·782	—
A	1·682	1·667
G♯	1·587	—
G	1·489	1·500
F♯	1·414	—
F	1·335	1·333
E	1·260	1·250
D♯	1·189	—
D	1·122	1·125
C♯	1·059	—
C^1	1	1

arbitrary zero level may be used and, in sound engineering, this is frequently accepted as 6 mW, or ·006 watt. Zero level in telecommunications technology is defined as 1 mW.

Examples: If an amplifier gives an output of 50 watts with an input of ·1 watt, the decibel gain is calculated as follows:

The power ratio is $\frac{50}{\cdot 1} = 500$.

The log of 500 is 2·699, or about 2·7; therefore, the gain is 2·7 bels, or 27 decibels. (See Fig. 181.)

The output power from, for instance, a transformer will be less than the input power. This loss of power is called the *insertion loss* of the transformer.

If there is an input of 20 watts and an output of 17, then

$$\frac{17}{20} = \cdot 85, \log_{10} \cdot 85 = \bar{1}\cdot 9294.$$

As one part of the log is negative and the other positive, the actual log is $-1 + \cdot 9294 = \cdot 0706$. The loss is ·706 dB.

Suppose an amplifier is stated to have a gain of 40 dB, the reference level being 6 mW, the output will be 10^4 the power of the input, i.e. 60 watts.

If the gain of an amplifier is given as 64 dB, we know that 60 dB is 10^6 and 4 dB is 2·512. The power gain, therefore, is $2\cdot 512 \times 10^6 = 2{,}512{,}000$.

Gains and losses are readily ascertainable from the accompanying conversion chart (Fig. 181).

Distortion is the change of wave form which occurs between two points in a transmission system.

TABLE LX:
PEAK POWER OF INSTRUMENTS

(As stated by C. W. Horn)

Instrument	Peak Power (watts)
Heavy orchestra ..	70
Large bass drum ..	25
Pipe organ ..	13
Cymbals	10
Trombone	6
Piano	·4
Trumpet	·3
Bass viol	·16
Clarinet	·05
Triangle	·05

Attenuation distortion, sometimes called frequency distortion, is due to gain or loss with frequency of a transmission system. Variation of group velocity with frequency causes phase distortion. Harmonic distortion consists in the production of harmonic frequencies at an output by the non-linear response of a network or system when a sinusoidal voltage is applied at the input. Variation of the time of propagation (measured in milliseconds with reference to a wave of specified frequency, usually 800 cycles) and variation of gain or loss with amplitude of input are further causes of distortion.

Echo. A reflected wave received with such magnitude and delay that it is perceived as distinct from the direct wave.

Doppler Effect. Change of pitch due to motion between sound source and hearer. This velocity being vectorially added to, or subtracted from, that of sound, alters the wavelength and frequency.

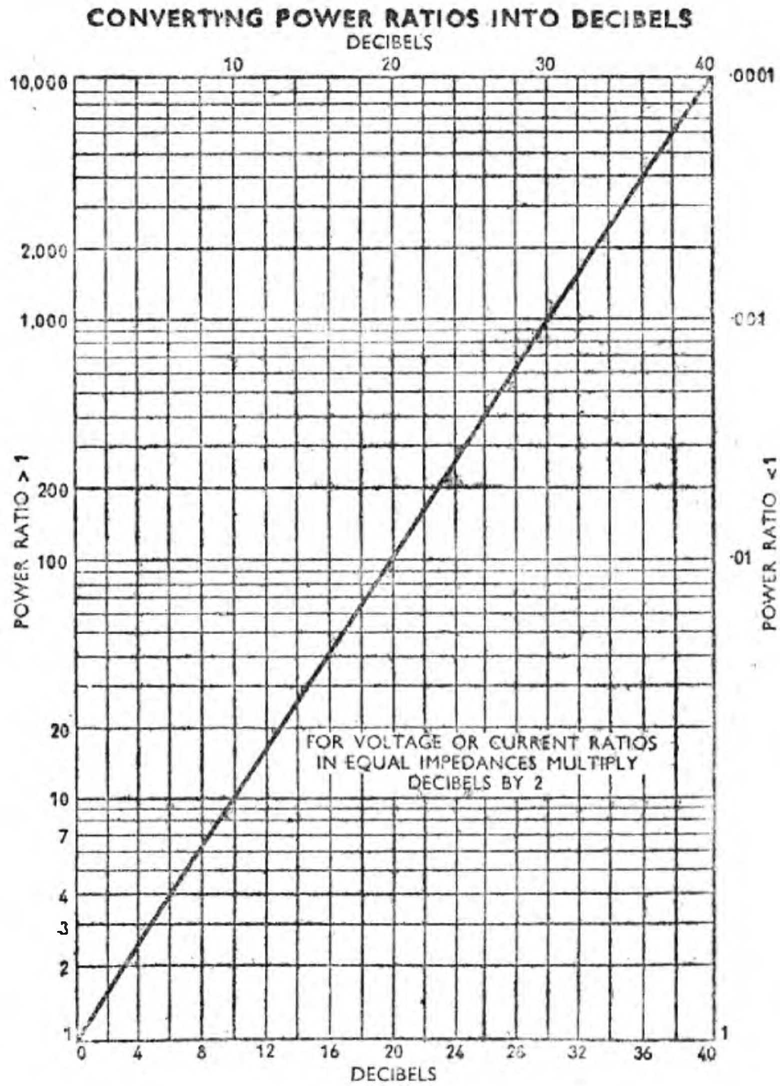


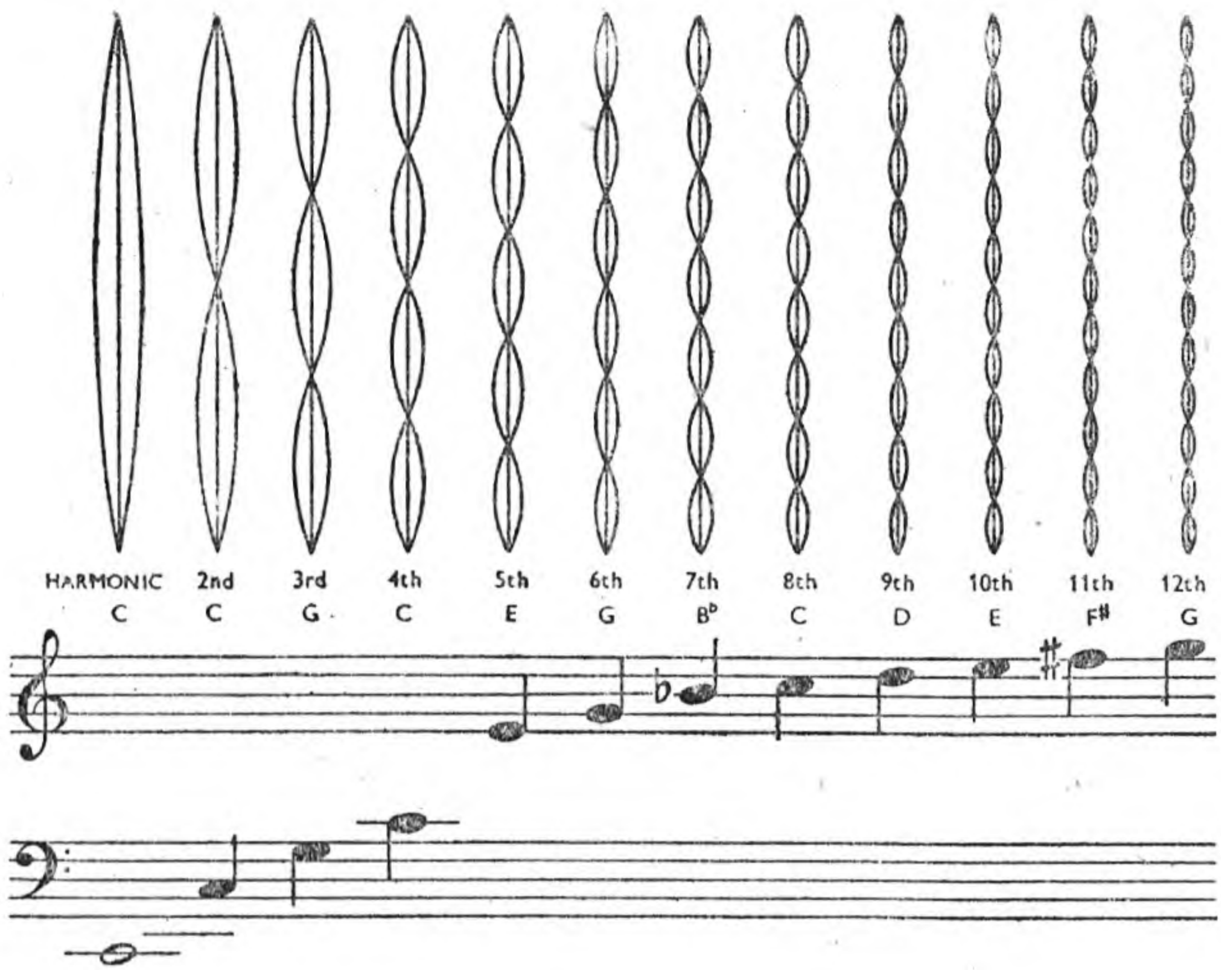
Fig. 181. Power ratio to decibel conversion chart. Ratios of current or voltage can be converted to decibels if the ratio of currents flowing in or voltages acting across the same value of resistance be substituted for the power ratio, when the decibel scale must be multiplied by two.

Harmonic or Overtone is a sinusoidal oscillation, acoustic, electric or otherwise, at a frequency which is a whole multiple of the fundamental frequency. The second harmonic is twice the fundamental, the third is three times the fundamental, and so on (Fig. 182). In some countries, but not in Britain or America, the fundamental is called the first harmonic.

Any wave, however complex, may be analysed into a fundamental and harmonics.

In sound, the fundamental sets the pitch of the note, and the numbers and relative strengths of the harmonics determine the characteristic quality of the sound.

Hearing. The human ear can appreciate sounds represented by changes of air pressure having frequencies lying between approximately 20 to 20,000 cycles in frequency and ·004 to 3,000 bars. Very few ears can detect frequencies much higher than 15,000 cycles, unless the intensity is very great. The lowest sound pressure which gives a sensation of tone is the *threshold of*



HARMONICS WITH CORRESPONDING VIBRATIONS

Fig. 182. Fundamental vibration of a cord and its harmonics. If the length of the cord is such that the fundamental is C, the harmonics have the notation shown.

audibility, and the lowest pressure which gives a sensation of feeling is the *threshold of feeling*. Both vary with the frequency (Fig. 183).

Loudness is the psychological effect of a sound, and *intensity* is measured in physical units.

Appreciation of pitch varies slightly with loudness.

Interference between sound waves may result in 'beats' and in zones of silence.

Logatom. An isolated syllable.

Neper. A unit of comparison giving the natural logarithm of the ratio of two currents independently of the resistance of the circuit. $N = \log_e \frac{I_1}{I_2}$, where N is the number of nepers and I is current.

This unit is used in some continental countries, but the decibel is commonly employed in Great Britain and America.

The decineper is $\frac{1}{10}$th of a neper.

Phon. British standard unit for the measurement of sound intensity. The sound under measurement and a standard tone are heard alternately, and the standard tone adjusted until judged by a normal hearer to be of equal loudness. The intensity level of the standard tone with reference to an R.M.S. sound pressure of ·0002 dyne per sq. cm (10^{-16} watts per sq. cm) stated in decibels, is the equivalent loudness of the original sound in phons.

The standard tone is a plane sinusoidal 1,000-cycle wave from a position directly in front of the hearer. The reference level, with exactness, is an R.M.S. pressure of

·000204 dyne per sq. cm at 20° C. and 76 cm of mercury, and corresponds to the threshold of hearing for the average person.

Power for Sound Distribution. An approximate indication of the acoustic watts necessary in a hall is:

$$\frac{\text{Volume in cubic feet}}{100{,}000}$$

The necessary electrical output of the amplifier will be: Acoustic watts × Loudspeaker efficiency.

For speech, only a third or quarter of this power may be necessary.

Example: For a hall 150 ft. long, 50 ft. wide and 30 ft. high, acoustic watts needed are : $150 \times 50 \times 30 = \frac{225{,}000}{100{,}000} = 2{\cdot}25$.

An average figure for loudspeaker efficiency is 10 per cent. Amplifier output necessary, therefore, is 20-25 watts for music and 8 watts for speech. (See also page 247.)

Outdoor power requirements vary considerably. For open-air concerts with an audience of 5,000 people, 40 watts may be needed for music and 10 watts for speech (Fig. 184).

Refraction. Sound, like light, changes direction on passing from one medium to another, the media having different characteristics.

Reverberation is a succession of reflected sounds, following each other too rapidly to be heard as echoes.

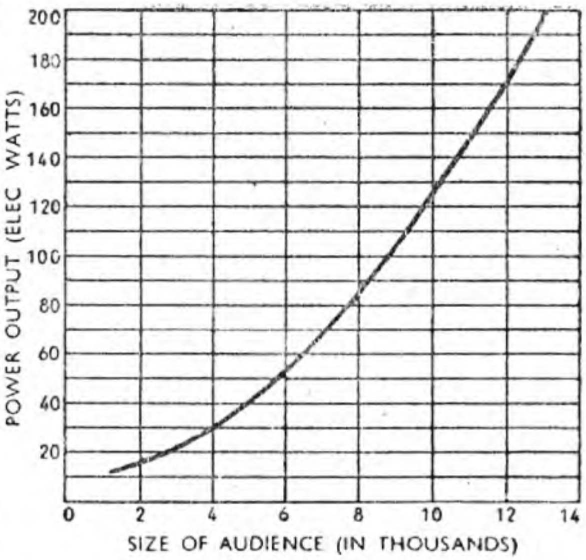


Fig. 184. Approximate power required for public-address installations which cater for an open-air audience.

For practical purposes, reverberation time is given by the Sabine formula, $T = \frac{{\cdot}05\,V}{A}$, where T is time in seconds, V volume of hall in cubic feet and A is the product of the area of absorbent and the co-efficient of absorption in sq. ft. units.

Sensation Level is the logarithm of the ratio of the physical intensity of a sound to the intensity at the threshold of audibility :

$$S\,\text{dB} = 20 \log_{10} \frac{P}{P_0},$$

where P_0 is the threshold pressure.

Singing. Self-sustained oscillation in a sound-amplifying system.

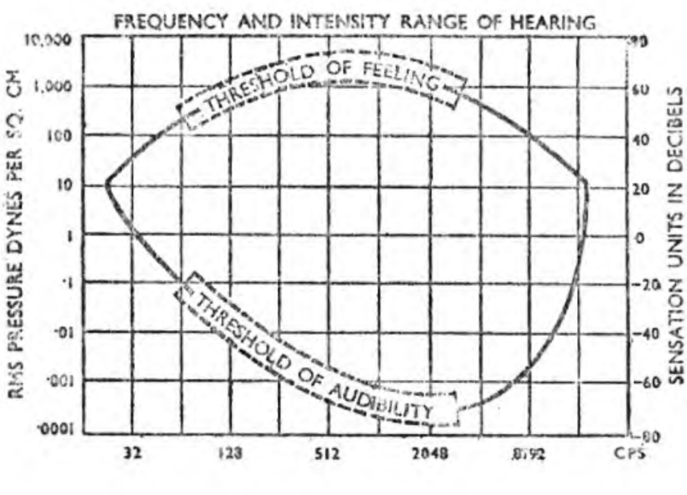


Fig. 183. How the average normal human ear responds to sound waves of different intensities and frequencies.

Sound is sensation caused by pressure waves travelling through a gas, or a liquid or a solid. It cannot travel through a vacuum. In air, sound is a series of 'waves', comprising regions of compressed and rarefied air (Fig. 185). The passage of these pressure waves causes to-and-fro motion of particles of the medium, but no displacement of the particles from a mean position.

Relations between amplitude of motion of air particles, velocity of motion of the

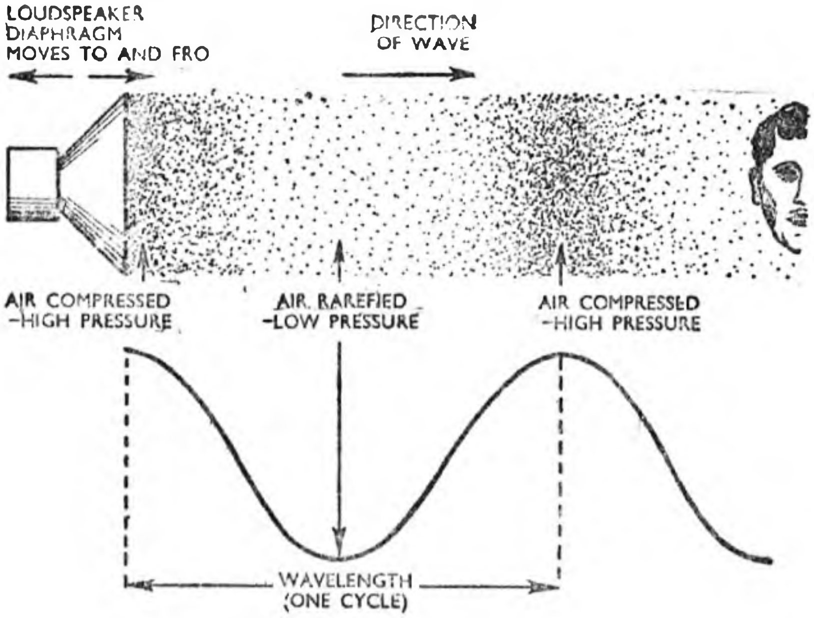


Fig. 185. Sound is caused by a pressure wave and can be represented, as shown in this diagram, by a sine wave.

particles and pressure in a plane wave are:

$$u = U\cos\frac{2\pi}{\lambda}(ct - x),$$

$$a = \frac{\lambda U}{2\pi c}\sin\frac{2\pi}{\lambda}(ct - x),$$

$$p = Cp_0 U\cos\frac{2\pi}{\lambda}(ct - x),$$

where u is the instantaneous velocity of a particle; U the maximum velocity; ct, velocity of the sound wave; x, a co-ordinate taken in the direction of propagation; λ, the wavelength; a, the displacement of the particles; p, the pressure; and p_0 the density of air.

For a spherical wave, where A is the strength of a source at the centre of the sphere and r the radius:

$$u = \frac{A}{2\lambda r}\cos\frac{2\pi}{\lambda}(ct - r) + \frac{A}{4\lambda r^2}\sin\frac{2\pi}{\lambda}(ct - r),$$

$$a = \frac{A}{4\pi r^2}\sin\frac{2\pi}{\lambda}(ct - r) - \frac{\lambda A}{8\pi^2 r^2 c}\cos\frac{2\pi}{\lambda}(ct - r),$$

$$p = \frac{Cp_0 A}{2\lambda r}\cos\frac{2\pi}{\lambda}(ct - r).$$

A sound wave is a form of energy. The transfer of energy through a sq. cm of surface is called the energy flux density (J). The kinetic or potential energy in any small region of the path of the wave is called the energy density (E):

$$J = \frac{p^2}{p_0 c}; \; E = \frac{p^2}{p_0 c^2}.$$

Wavelength of a sound wave λ is: $\lambda = \frac{V}{f}$, where V is the velocity and f the frequency.

Sound Intensity. Rate of flow of sound energy per unit area in the normal direction of propagation. The unit is an erg per second per sq. cm.

Sound Pressure. The alternating component of the total pressure in a sound field. It is stated in dynes per sq. cm.

Speed of Sound varies with the medium and the temperature. For most purposes, the velocity in air can be taken as 1,140 ft. per second, or approximately one mile in 5 seconds. Where θ is the air temperature in degrees centigrade, the velocity in metres per second is given by: $330{\cdot}6\sqrt{1 + {\cdot}003707\theta - 1{\cdot}256\theta^2 10^{-7}}$.

Velocity in air is independent of pressure, but is proportional to the

TABLE LXI

Material	Metres per second	Material	Metres per second
Brick ..	3,600	Woods:	1,250
Cork ..	500	Ash (across grain)	4,700
Ebonite	1,500		
Glass ..	5,000		
Marble	3,800	Ash (parallel to grain)	5,250
Nitrogen	340		
Oxygen	315		
Slate ..	4,500	Fir ..	4,150
Steel ..	5,000	Mahogany	3,380
Water ..	1,433	Oak ..	3,320
		Pine ..	4,780

square root of the absolute temperature:

$\frac{V_0}{V_t} = \sqrt{\frac{T}{273}}$, where V_0 is velocity at 0° C.

Approximate velocities in other media are given in Table LXI.

Stationary waves occur when waves of equal frequency and amplitude are originated at different sources. A wave reflected from a surface may be considered to originate in a different source from that creating the direct wave. The medium at the nodes is stationary but at maximum pressure; at the antinodes, the particle velocity is at maximum but the mean pressure is normal.

Transient. Sudden change or irregularity of wave form, as when an oscillation is started by bowing or striking a string or when an electrical circuit is switched on.

A transient contains a number of sinusoids, some of extremely high frequency if the wave front is steep.

MICROPHONES

A microphone converts variations of pressure in the medium by which it is surrounded into corresponding variations of electrical potential.

Variations of air pressure representing sound may be converted into corresponding potentials, and these, amplified if necessary, may be used to energize loudspeakers in Public Address systems or to modulate some characteristic of a carrier in a carrier telephony system, or to make gramophone and cinema recordings, or, of course, the microphone output may be applied, as in domestic and business telephone systems, to line wires.

In order to convert variations of mechanical pressure into variations of electrical potential, a microphone embodies some part which is free to move and which, in its movement, generates potentials proportional either to the displacement or the velocity of the moving part.

Obviously, this 'armature' or moving part may exhibit mechanical resonance, thus making the electrical output from the microphone greater for pressure variations having certain frequencies than for pressure variations of other frequencies.

When mechanical resonance of the armature takes place, the microphone characteristic, that is, a graph plotting electrical output against frequency of the periodic pressure stimulus, exhibits peaks corresponding to one or more frequency bands.

A *high-fidelity* microphone is one having, among a number of other qualities, a 'flat' response characteristic, that is to say, one in which little or no mechanical resonance of the armature exists.

When an armature resonates, the apparent sensitivity of the microphone is much higher at the resonance frequencies than at frequencies where no resonance takes place. The high-fidelity microphone, therefore, tends to have a sensitivity equal to the lowest sensitivity of the type which relies upon resonance.

This leads to the conclusion that high-fidelity microphones are relatively insensitive and that the apparent high sensitivity of a microphone exhibiting armature resonance is offset by a poorer frequency characteristic.

Fig. 186 deals with microphone sensitivity.

The interpretative powers of the human ear are so great that for ordinary communication purposes the sensitivity of the resonant type of microphone (provided the resonance frequencies lie in and around a mid-speech band) justifies its use; for broadcasting, cinema and P.A. work the demands for fidelity make the use of microphones with flatter response characteristics essential.

There is a large number of methods by which armature movement is used to create electrical potential. A *moving-coil microphone* is one in which the armature carries a coil of wire which moves in a constant magnetic field and so has EMF's induced in it. A *moving-iron microphone* is one in which the ferromagnetic armature moves in a magnetic field to vary the intensity of the field and so induce EMF's in a coil embraced by the lines of force due to the field.

A *capacitive microphone* embodies an armature which forms one movable electrode of a capacitor, the other being fixed so that, a steady

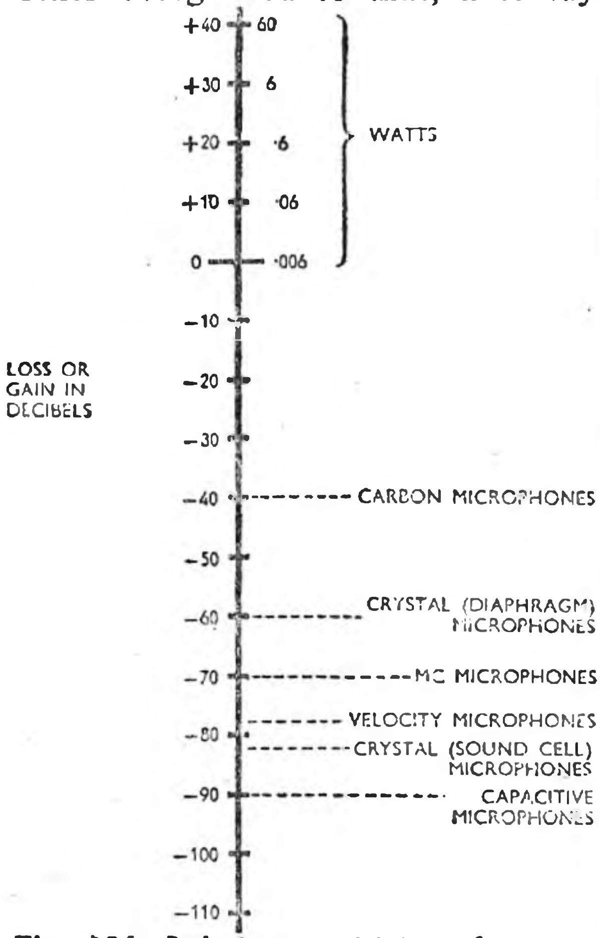


Fig. 186. Relative sensitivity of microphones. This diagram facilitates the estimation of the gain of an amplifier required to produce a certain output. For example, if an output of 6 watts (+30 dB) is desired when using a moving-coil microphone (–70 dB), the amplifier must have a gain of 100 dB (30 dB+70dB).

potential being applied to the capacitor so formed, varying currents flow into the capacitor as its capacitance varies by the mechanical displacement of one of its electrodes.

A *carbon microphone* contains powdered carbon and the moving armature exerts varying pressures on the carbon, so sympathetically varying its conductance. Or the movement of a capsule attached to the moving armature may also produce a varying conductivity.

The variation of conductance of the carbon causes a variation of current in a circuit containing a DC source and the carbon, and so varying potentials may be derived from the circuit, commonly by the use of a transformer, the primary of which carries both the steady current and its variations, the secondary producing only varying potentials.

Certain types of crystal generate EMF's proportional to a mechanical pressure correctly applied, and in the *crystal microphone* the armature exerts varying pressures upon the crystal to produce corresponding EMF's at the electrodes.

A *ribbon microphone* is a type of moving-coil microphone inasmuch as it embodies an armature which is essentially a conductive strip free to move in a magnetic field.

Avoiding Mechanical Resonance

Common to all devices which aim at producing high-fidelity results are means to avoid mechanical resonance. One basic method is to produce extreme rigidity so that resonance takes place at a supersonic frequency, or at an audio frequency above the range considered sufficiently wide for sufficiently good results; another to make the armature resonate at a sub-audio frequency; another to make the structure so flabby that all resonances are damped out.

The *sensitivity* of a microphone is stated in terms of the ratio of powers required to produce a measured open-circuit voltage to that required to give an open-circuit voltage of 1 volt when the pressure stimulus is 1 dyne per sq. cm (called 1 bar). This ratio is commonly stated in decibels. In a high-fidelity microphone, the sensitivity may be considered as being constant over a wide range of frequencies; in a resonant type, the frequency should be stated or the sensitivity expressed as a maximum or a mean, etc.

The *impedance* of a microphone is its internal impedance measured as that resistance which, connected across the microphone terminals of a microphone acted upon by a periodic stimulus, reduces the open-circuit voltage by half.

This impedance should be related to sensitivity, because if the impedance is lower than a certain amount the voltages may be stepped up and applied to the grid cathode circuit of a valve, thus making the effective sensitivity of the microphone the greater.

If the microphone impedance is very high, transformers cannot be used, since the inductance of the windings would have to have an impractically high value. As a very rough guide, and supposing that it is impractical to use transformers having a secondary impedance greater than 50,000 ohms, *transformer gain* in decibels is, $G_T = 20 \log_{10}\sqrt{\frac{5 \times 10^4}{Z_M}}$, where Z_M is the microphone impedance. It is doubtful if, Z_M being very small, the value of G_T could exceed 30 decibels.

Background noise in a microphone is due to some inherent quality of the device which causes it, when quiescent, to generate small EMF's; typically, the variations of conductivity of carbon granules in a carbon microphone generate hiss and this is a form of background noise.

It must also be realized that if a microphone is very insensitive, requiring, therefore, the use of high-gain amplifiers, these may generate *amplifier noise*, and it should be counted a criticism of the microphone that it is so insensitive as to demand the use of amplifiers of such high gain that they generate background noise.

On the other hand, if an amplifier, considered as part of the microphone system, can be designed to give very high gain with substantially no amplifier noise, then the microphone associated with it, and having great fidelity but low sensitivity, should be classed as a superior type for high-fidelity results.

Certain microphones exhibit directional qualities, that is to say, their response characteristics are different according to the direction of incidence of the wave front by which they are stimulated. A *non-directional microphone* is one which has the same response characteristic whatever the angle of incidence of the sound waves acting upon it.

The term *wind flutter* is used to describe the effects of wind or draughts upon a microphone in which the armature is not so rigid as to remain stationary when the air around exhibits pressure variations of very low frequency; a microphone prone to exhibit wind flutter is not suitable for out-of-doors work.

A comparison of microphones is almost impossible without stating requirements. As these vary enormously, a comprehensive analysis would be impossible. Any of the principles may be used, and while it may be said that the carbon type is prone to create hiss, certain types have been made in which this has been minimized and high-fidelity results obtained.

In some cases, the high-impedance types may seem to have the disadvantage that long leads from them cause falling off at the top frequencies, but this trouble may be minimized by embodying a single-valve amplifier in the microphone housing; types of microphone with resonant diaphragms may give a poor frequency characteristic, but as the diaphragms are more stretched, so sensitivity reduces but fidelity increases.

Table LXII compares the sensitivities, direct and with transformer gain, of different types of microphone and broadly specifies the typical performance of typical designs.

TABLE LXII: MICROPHONE CHARACTERISTICS

Type	Sensitivity (1,000-2,000 c/s)		Impedance
	Without Transformer Gain	With Transformer Gain	
General description and performance	Decibels below 1 volt/bar		Ohms
Carbon, Post Office type. Poor frequency characteristic. Suitable commercial uses. Background hiss.	– 30	– 10	200 - 400
Carbon. Better fidelity than Post Office type. Used in simple P.A. systems. Prone to background hiss.	– 50	– 30	200 - 400
Capacitive. High fidelity. Disadvantage of high impedance overcome by amplifier in housing. May require electrostatic shielding.	– 90	– 90	500,000 to 1,000,000
Crystal. High fidelity. May require electrostatic shielding.	– 60 – 100	– 60 – 100	50,000
Moving Iron. Sound power. Sometimes used in aeroplanes. Poor frequency characteristic, but good intelligibility, high sensitivity at maximum.	– 10	– 10	100 - 600
Moving Coil. A ubiquitous type for fidelity and high-fidelity work. Subject wind flutter. May require magnetic shielding.	– 60 – 80	– 30 – 50	25
Ribbon. Much used in broadcasting and cinema work. Liable wind flutter. May require magnetic shielding.	– 70 – 80	– 40 – 50	0·5 to 1

The loudspeaker acts, oppositely to the microphone, to convert variations of electrical intensity into corresponding variations of pressure in the surrounding medium. The basic principles concerning response as a function of frequency apply equally to microphones as to loudspeakers; the loudspeaker has a moving part and this is prone to resonate and give selective response according to the frequency of stimulus.

There is, however, this difference, that a loudspeaker movement or armature is attached to a diaphragm and it is the mode of vibration of this which determines, in large measure, the resulting characteristic.

At very low frequencies, the diaphragm may move as a whole, like a piston, and in so moving moves an air column with it; at higher frequencies, the diaphragm, not being rigid, breaks up and exhibits different motions at different positions on it.

These nodes and antinodes of motion are found in cone-shaped diaphragms to lie in circles centred upon the central point of attachment of the diaphragm and a vibrating armature, the position and numbers of the circles varying with the frequency of stimulus.

In horn loudspeakers, the diaphragm is small and is placed at the narrow end of the horn; the horn opens out (in logarithmic horns according to a logarithmic law) as the distance from the diaphragm increases.

In order to increase the apparent response at low frequencies of diaphragm loudspeakers not using horns, a *baffle*-board may be used.

This baffle-board constitutes a plane surface at right angles to the axis of movement of the diaphragm, which is mounted in a hole cut in the board; its effect is, like a horn, to increase the coupling between moving diaphragm and air column at low frequencies by preventing an equalization of pressure from the front to back of the diaphragm which would occur were no separating means provided. Table LXIII compares the performance of various types of loudspeakers.

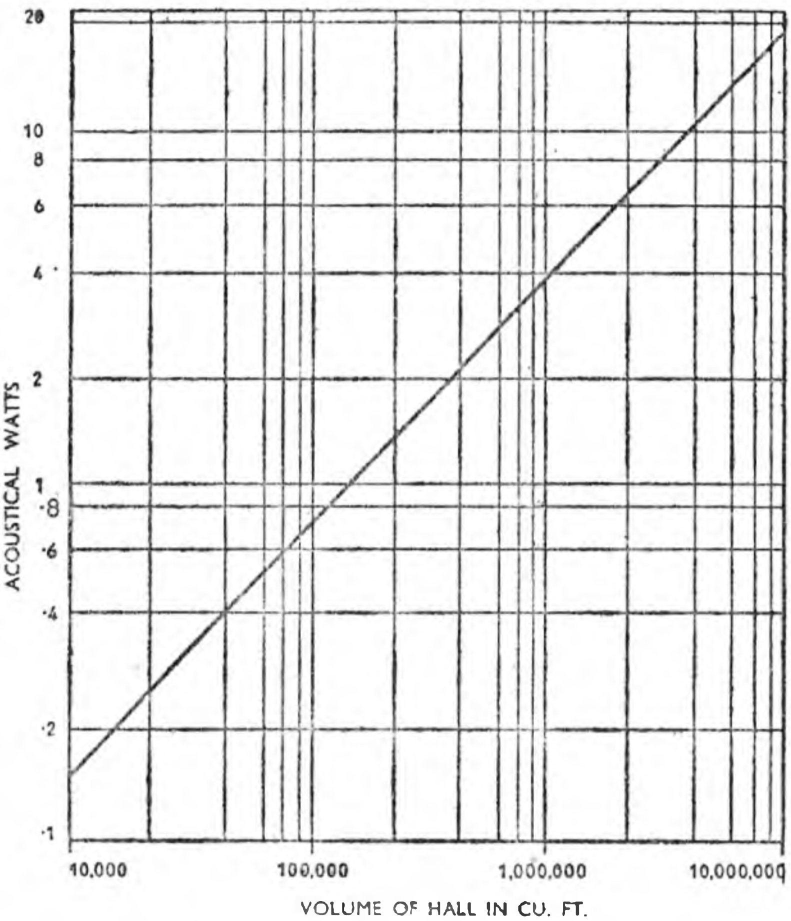


Fig. 187. Chart giving the approximate acoustical watts needed for halls of various sizes.

Loudspeaker Efficiency. Most loudspeakers have a poor efficiency with regard to the conversion of electrical energy into acoustical energy. Table LXIII gives relative figures for the different types, but it must be appreciated that the design and manufacture of individual speakers of any one type vary considerably. Most manufacturers will give the

TABLE LXIII:

TYPICAL MOVING-COIL LOUDSPEAKER CHARACTERISTICS

Type	Power-handling capacity (watts)	Efficiency (per cent)	Angle of distribution (deg.)	Average frequency range (c/s)
Baffle and Cabinet:				
Small permanent magnet ..	1½ to 2	5 - 10	90	120 - 8,000
Large permanent magnet ..	5	5 - 10	90	80 - 8,000
Very large energized (auditorium type)	15	5 - 10	90	80 - 8,000
Directional Baffle	5	10 - 20	60 - 100	150 - 8,000
Projector:				
45 in. air column	7	10 - 35	35 - 60	200 - 7,000
72 in. to 96 in. air column ..	8	10 - 35	35 - 60	200 - 8,000

TABLE LXIV:

ELECTRICAL POWER OUTPUT REQUIRED FOR CERTAIN COVERAGES

Power Output (watts)	Coverages			
	Indoors		Outdoors	
	Cu. ft.	No. of people	Sound dispersal (radius in ft.)	Distance along speaker axis (ft.)
1	2,000 (Small domestic rooms)	—	—	—
2	5,000 (Large domestic rooms)	—	—	—
5	50,000 (Halls)	500	—	—
10	130,000 (Halls)	1,000	300	450
15	300,000	2,000	400	650
30 to 40	1,000,000	5,000	600	1,000
90	—	—	1,500 (Audience between 75,000 and 100,000 people)	2,500

efficiency of their loudspeakers upon request.

Upon the efficiency of any particular loudspeaker will depend the watts output from an amplifier necessary to provide the required acoustical wattage to cover a certain area or cubic volume. Fig. 187 gives a curve of acoustic watts against cubic volume, but this is only approximate for average conditions. Furnishings, material of walls.

ceilings, etc., will effect the power required.

As an example of the use of this chart, if it is required to know how much amplifier output is required for a cubic volume of 100,000 cu. ft., the chart gives acoustic watts as ·7 watt approximately. If the speakers have an efficiency of 10 per cent, the electrical watts required will be 7. Or,

$$\text{Electrical watts} = \frac{100}{\text{Speaker efficiency}} \times \text{Acoustic watts} = \frac{100}{10} \times \cdot 7 = 7.$$

Table LXIV gives approximate coverage data for electrical watts output based on 10 per cent loudspeaker efficiency, but here again abnormal conditions call for a reserve of power to meet sudden demands. For example, three times the power output may be necessary for a hall filled with an audience having wet clothes, as compared with a half-empty hall of people wearing dry clothes. Therefore, if 5 watts will just about meet a certain estimation, a 15-watt amplifier and speaker network should be used.

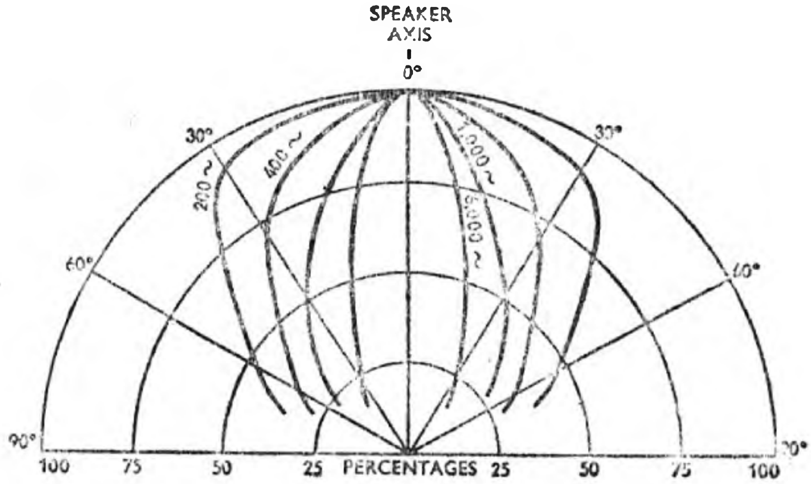


Fig. 189. Polar curves of typical projector loudspeaker.

Distribution Angle. Fig. 188 shows how the distribution angle of a loudspeaker (LS_1) may be employed to prevent reflections, in this case from a ceiling, which could cause 'echo' perhaps to the point of unintelligibility in the rear seats of the circle. This is due to the reception of two waves, one direct from the speaker, and the second, the reflected wave, which will arrive later.

The lower speakers (LS_2), situated at the sides of the stage, direct the sound to the pit and stalls.

It should be appreciated that all frequencies are not 'beamed' to the same extent. The lower frequencies have a wide spread, but highly directional effects are associated with the upper frequencies. The polar diagram, Fig. 189, illustrates this. For speech reinforcement, therefore, where high frequencies are necessary, it is wise to work on a maximum distribution angle of about 60°.

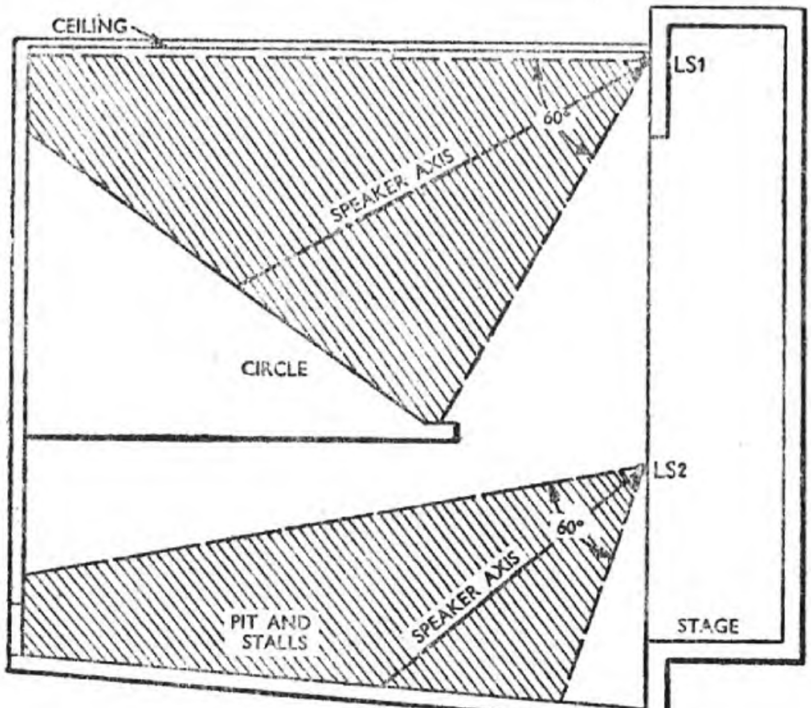


Fig. 188. Distribution angle of a speaker assists in preventing reflections. Note how the maximum sound from the upper speaker is kept parallel to the ceiling.

SECTION 16

INSTRUMENTS AND MEASUREMENTS

THERE is a large variety of instruments for measuring electrical quantities and the majority of them embody means to convert electrical into mechanical force, the mechanical force being used to deflect a pointer over a calibrated scale.

Moving-coil Instruments. In a moving-coil instrument, the current to be measured is passed through a coil of wire, thus producing a magnetic field external to the coil.

The coil is so placed in relation to a steady magnetic field that the field due to the coil, reacting with the steady field, causes the coil to turn upon its axis of rotation and move a pointer over a circular scale, the pointer being attached to the coil.

The torque experienced by the coil is determined as to its sense by the direction of the flow of current in the coil, and as to intensity by the amount of current flowing.

A moving-coil instrument measures direct currents. If alternating current passes in the coil it merely tends to turn first this way, then that, mechanical inertia preventing any considerable angular movement.

Moving-coil instruments can be made so sensitive as to be capable of measuring even microamperes and, with quite simple arrangements, milliamperes. This means that if a sensitive moving-coil instrument be connected in series with a resistance, the voltage between the two terminals of a source may be measured, provided the internal resistance of the source producing the voltage is negligibly small compared with the resistance of the voltmeter.

Ranges of Instruments. Given an instrument capable of measuring a given maximum current, it is possible, by connecting a shunt circuit across it (i.e., a conductor in parallel with the instrument), to use it to measure currents greater than this maximum, because a part of the total current flows in the shunt and a part in the instrument.

Table LXV gives useful meter ranges with their applications.

In order to calculate the required resistance of a shunt, the expression $R_1 = \frac{R_2}{n-1}$ may be used, where R_1 is the shunt resistance, R_2 the resistance of the instrument and n is the number by which the scale reading must be multiplied to give the total current flowing in the circuit (i.e., the sum of the currents in the meter and in the shunt).

If the resistance of an instrument reading 1 mA for full-scale deflection is 36 ohms and this instrument is required to measure 10 mA at full-scale deflection, then $R_2 = 36$, $n = 10$, so that the shunt resistance necessary is $\frac{36}{9}$ ohms $= 4$ ohms.

Measuring Resistance of Instruments. Provided a known variable resistor is available, the unknown resistance of a meter may be determined by connecting the variable resistance in shunt with the meter and reducing the meter reading by half. The resistance necessary to reduce the instrument reading by half is then the resistance of the meter.

Making Shunts by Trial and Error. When the resistance of a meter is not known, and no known variable resistor is available, a shunt may be made up by trial and error, the circuit shown in Fig. 190 being used. Here, a single dry cell is in series with a variable resistor of about 250 ohms, both being in series with the meter across which a shunt is connected. The variable resistor should at first be set so as to present

TABLE LXV:

USEFUL METER RANGES AND THEIR APPLICATIONS

Measurement	Range	Application
Current (DC)	0 – 100 μA	Grid current; diodes.
	0 – 2·5 mA	Resistance-capacitance-coupling anode circuits.
	0 – 10 mA	HF, osc., IF, LF, valves and battery output valve anode feeds.
	0 – 50 mA	Majority of power valves in domestic receivers; total HT feed through field windings of medium-sized receivers.
	0 – 500 mA	PA power valves; total HT feeds in large domestic receivers; heater current of valves on DC up to ·5 amp.
Current (AC)	0 – 500 mA	Heater current of AC valves up to ·5 amp.
	0 – 1 amp	Heater current of AC valves up to 1 amp; mains transformer primary current of equipment taking up to 250 watts on 250-volt mains.
Volts (DC)	0 – 2·5 volts	Grid bias of general-purpose valves; single dry cells; accummulator cells if not on charge.
	0 – 10 volts	Grid bias of small power valves; grid-bias batteries; valve heaters up to 10 volts on DC supplies.
	0 – 50 volts	Grid bias of large power valves; heaters of most AC/DC type valves on DC; sections of HT batteries; screen-grid and detector anode voltages in battery sets.
	0 – 250 volts	HT batteries; anode and screen circuit voltages of battery receivers and most 4-5-valve mains receivers; check up of DC mains voltages.
	0 – 1,000 volts	HT circuits of large domestic receivers and PA equipment.
Volts (AC)	0 – 10 volts	Heater circuit of AC receivers; LT secondaries of mains transformers; as an output meter across loudspeaker speech coils.
	0 – 50 volts	Heater voltages of AC/DC valves on AC; low-voltage turntable motors fed through a dropping resistance; voltage applied to tuning motors (generally about 20 volts).
	0 – 250 volts	AC mains voltage check; AC volts on anodes of rectifying valves up to 250 volts-0-250 volts; as an output meter with blocking capacitor between anode and chassis of output valves.
	0 – 1,000 volts	AC mains voltage on 'high' mains which may go up to 265 volts; AC volts on rectifier anodes up to 1,000 volts-0-1,000 volts.

[*Continued on page* 252

TABLE LXV: USEFUL METER RANGES AND THEIR APPLICATIONS—*continued*

Measurement	Range	Application
Resistance	0 – 100 ohms	Tuning coils; wavechange switch contact efficiency; speech coils; primary and LT secondaries of mains transformers; LF chokes; motor windings; low impedance pick-ups; valve heaters and filaments; resistances up to 100 ohms.
	0 – 1,000 ohms	Some of the above when over 100 ohms; field windings; intervalve transformer windings; mains transformer secondaries; line cords, voltage droppers and other forms of resistances up to 1,000 ohms.
	0 – 100,000 ohms	Resistances up to 100,000 ohms; high impedance pick-ups; continuity checks (lower ranges often take heavy current from internal dry cells, and should be used only sparingly for measurements).
	0 – 10 megohms	Resistances up to 10 meg; indication of low insulation if a fairly high battery voltage is used.

its maximum resistance, ensuring that the minimum current flows through the meter.

Assume that a meter has a 0–10-mA range and it is desired to increase this to 0–50 mA. First adjust the variable resistor until the meter reads exactly 10 mA without the shunt. Then connect the shunt and alter its resistance until the meter reads exactly 2 mA. This means that the 10 mA flowing through the circuit now registers only as 2 mA on the meter scale, and that the full-scale deflection of the meter will be five times its original value, i.e., 50 mA.

The maximum value of the variable resistor should be such that, with the applied voltage, the current flowing

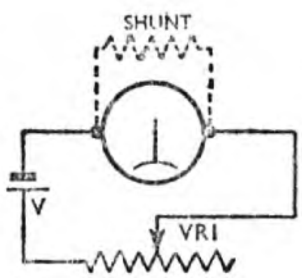


Fig. 190. Circuit for making a shunt by trial and error.

is less than that taken by the meter for full-scale deflection. For example, a 10-mA meter with a 3-volt dry cell would require a resistor of resistance at least 300 ohms, because, from Ohm's Law, $R = \frac{E}{I} = \frac{3}{\cdot 01} =$ 300 ohms.

A suitable practical value for the resistor would be 500 ohms, but too high a value should not be used, otherwise difficulty will be found in getting a fine control at low readings.

Shunting Shunts. If a meter already incorporates shunts but it is required to provide a lower range, it is quite in order to add an external shunt if it is not desired to open up the meter and interfere with its internal shunts and switching arrangements. The extra shunt may be made by the trial-and-error method described above, or the total resistance of meter and its shunts measured by well-known methods.

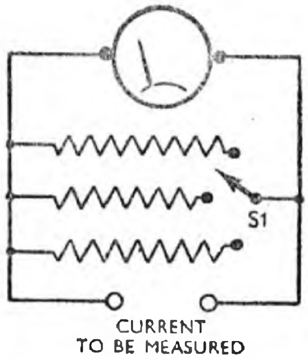


Fig. 191. Number of separate shunts made available by switch S_1.

Physical Characteristics of Shunts. Shunts should be designed so that the temperature rise in the wire shall be as small as possible, otherwise their resistance values may increase with rising temperature. Shunts should, therefore, be made from wires which have a very low temperature coefficient and which are affected very little by ambient temperature changes.

When a shunt of a very low value is required, it is advisable to start with a length of wire giving a slightly lower value than is needed and then gradually to increase the resistance of the piece of wire by carefully scraping it with a knife, at the same time watching the meter reading.

Figs. 191 and 192 show how shunts can be arranged to give several ranges by means of switches. It must be arranged that the switch can never give an open-circuit condition between stops, otherwise no shunt would be connected across the meter, which might, in consequence, be burnt out if the meter were in circuit when the switch was in a position to open-circuit the shunt.

Voltmeters. When using sensitive moving-coil instruments to measure

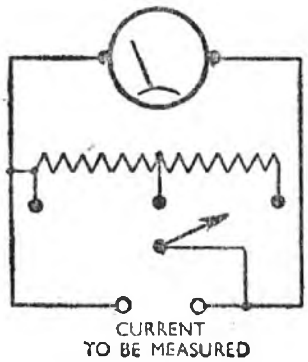


Fig. 192. Single shunt tapped at the required points to give two additional current ranges.

voltage, series resistors are necessary to limit the current flowing in the circuit to the maximum that can be handled by the instrument. These resistors are often termed multipliers. In Fig. 193 the multiplier is shown as R, and if the meter is a 0–1 mA, then the resistor R must have a value of 1,000 ohms when a voltage of

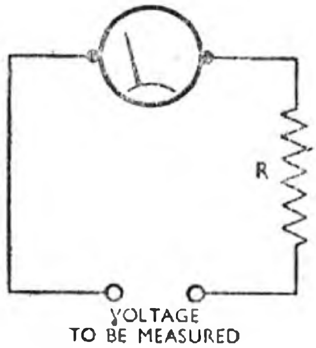


Fig. 193. Multiplier resistance R limits the current to the maximum that meter can carry.

1 volt is applied to the test terminals.

The sensitivity of the meter would then be 1,000 ohms per volt. To measure 100 volts, R would have to be 100,000 ohms, and so on.

Fig. 194 shows how several resistors may be connected with a rotary switch to give a multi-range instrument. For extreme accuracy on lower voltage ranges, the resistance

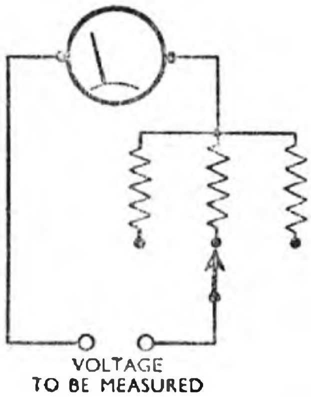


Fig. 194. Three multiplier resistances arranged with a switch to give a triple-range voltmeter.

of the meter must be taken into account. For example, if the resistance of the meter is 50 ohms, then the multiplier should have a resistance of 950 ohms on the 1-volt range, and 9,950 ohms on the 10-volt range.

Extending Range of Voltmeters. If a low-range voltmeter is available and it is required to extend its range so that higher voltages may be used, the following formula can be employed: $R_1 = R_2 \times \text{Range} \times (n-1)$,

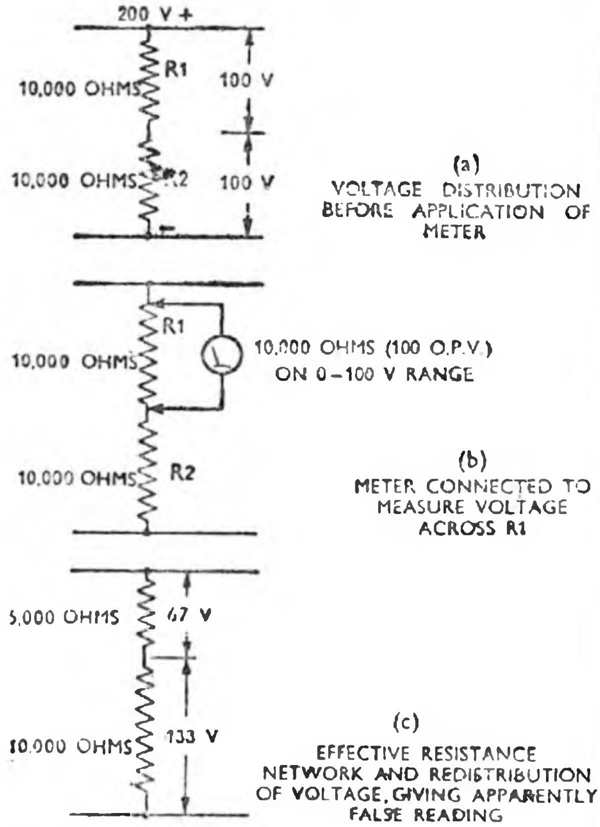


Fig. 195. Indicating in detail the effect of meter resistance on voltage readings.

where R_1 = multiplier resistance in ohms, R_2 = ohms-per-volt sensitivity figure of the meter, range = original range of meter in volts, n = multiplication ratio.

Example: A meter having a sensitivity of 200 ohms-per-volt and a range of 0-150 volts is required to measure 0-750 volts; what is the value of the multiplier resistance required?

The multiplication ratio is 150 : 750, or 1 : 5, and from the above formula we have, $R_1 = 200 \times 150 \times (5 - 1) = 30{,}000 \times (4) = 120{,}000$ ohms.

Effect of Voltmeter on Circuits being Tested. When a voltmeter is applied to a resistance network in order to measure the voltage across any part of that network, the resistance of the voltmeter and the current required to operate it (which is drawn from the circuit under test) give rise to a rearrangement of the potentials across the various portions of the resistance network. Fig. 195a shows a simple network of two resistances of equal value across a supply of 200 volts; this can represent an HT potential divider for the screening grids of the valves in a radio receiver.

Figs. 195b and 195c show how the voltage across the two resistances is altered by the application of a voltmeter to R_1. It will be appreciated from this simple example how important it is to have a meter with as high a sensitivity as possible, i.e., with a high value of ohms-per-volt; 1,000 ohms-per-volt is a general figure, but many good-class voltmeters have sensitivity figures exceeding 20,000 ohms-per-volt.

AC Measurements. To measure AC, moving-coil meters may be

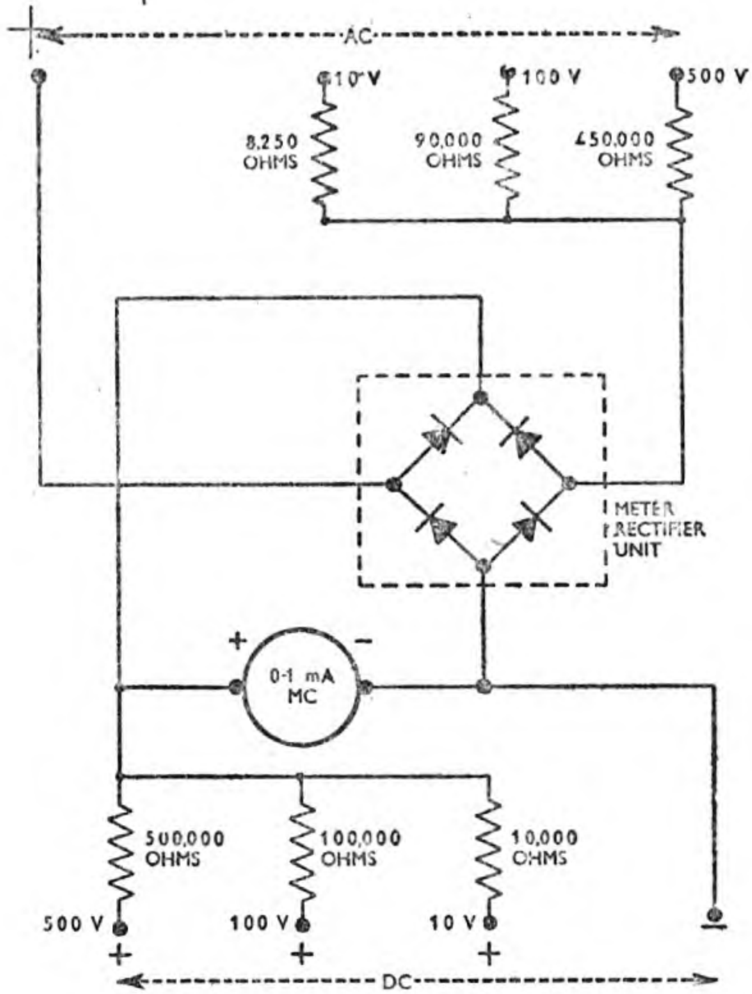


Fig. 196. Circuit for a triple-range AC-DC voltmeter. Note the lower values of AC multipliers to compensate for voltage drop across rectifier unit.

fitted with small rectifier units which are switched into circuit when it is desired to measure alternating current. Moving-iron meters which measure AC directly are very seldom used for the measurement of small alternating currents, owing to their low sensitivity. Fig. 196 shows a typical arrangement for an AC-DC voltmeter. For various current ranges, a small transformer with a tapped primary winding is used so as to keep the current flowing through the meter and rectifier to the maximum for which the rectifier is designed.

Ohmmeters. Fig. 197 shows the evolution of a typical ohmmeter circuit. At (a) of this figure, the resistor *R* is of a value which would draw the maximum current required by the meter for full-scale deflection. At (b) two test terminals have been provided and, when these are shorted, we have the (a) circuit again, so that full-scale deflection is the zero-ohms end of the resistance scale. If the test terminals are opened and a resistor of unknown value connected to them, as shown at (b), then less current will flow due to the additional resistance, and the meter needle will read some value less than full-scale deflection.

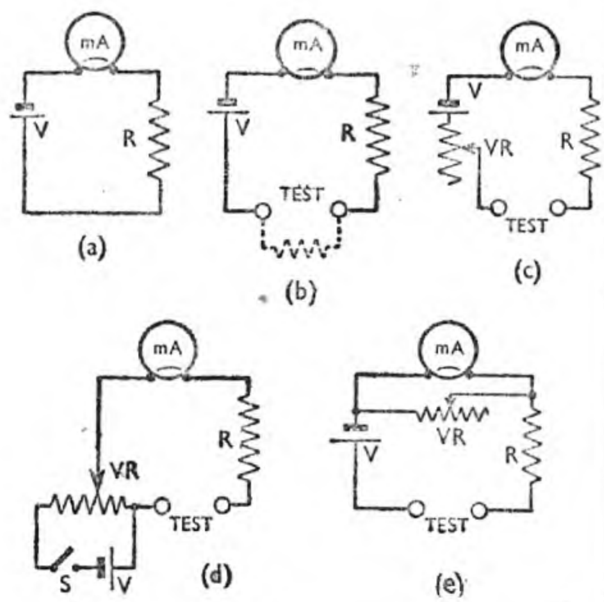


Fig. 197. (a) and (b) Fundamental circuit of an ohmmeter. (c), (d) and (e) Methods of battery voltage control.

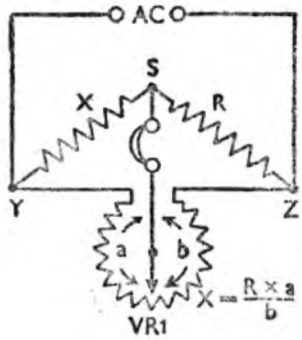


Fig. 198. Bridge circuit for finding value of X and using earphones to find balance.

For example, if *R* is 10,000 ohms and gives a full-scale deflection when the test terminals are shorted, a resistance of 10,000 ohms applied across the test terminals will halve the current flowing so that the meter will read ·5 mA, and this point on the scale represents 10,000 ohms. By a similar calculation, other points can be plotted for the scale.

Ohmmeters incorporate one or more batteries for driving the current through the unknown resistance and through the limiting resistance in the ohmmeter. To provide for the deterioration of the battery during its useful life, various methods of battery-voltage control are employed, as shown in Fig. 197c, d and e.

The Wheatstone or Resistance Bridge. Another method of measuring resistance, and one which is more accurate and causes very little current to flow through the component under test, is the bridge method shown in Fig. 198. The resistor having an unknown resistance is at *X* and the standard resistor of known value is at *R*. VR_1 is a variable resistor, the slider of which is connected through an indicating device to point *S* at the junction of *X* and *R*.

When a voltage is applied to *Y* and *Z*, the current will divide, some of it flowing through *X* and *R* and some of it through the variable resistor. By adjusting the slider on the variable resistor, a point will be reached where the voltage drop across the variable resistor at the slider contact equals the voltage at *S* (the junction of *X* and *R*). When this occurs, no current will flow through

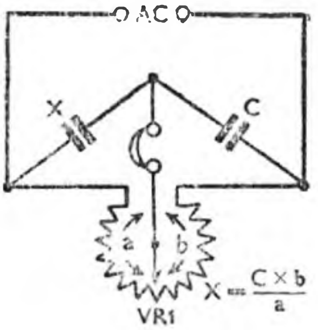


Fig. 199. Bridge circuit for finding reactance of X when C and ratio a/b are known.

the indicating device, and the bridge is said to be balanced.

The value of the unknown resistance is then: $X = \dfrac{R \times a}{b}$.

The variable resistor must have a linear law element so that a certain amount of slider travel will give the same change of resistance along any part of the element.

Dividing the length, in inches, of the element into the ohmic value of the element will give an approximation of the ohms per fraction of an inch, and a rough calibration chart can be made up using the above formula. This can then be corrected, as and when resistances of known value become available for more accurate calibration.

In most manufactured bridges, the arms of the bridge are altered in steps by plugs which when in position short-circuit and when disconnected open-circuit resistors. The steps are so fine that accuracies of measurement to four significant figures are possible.

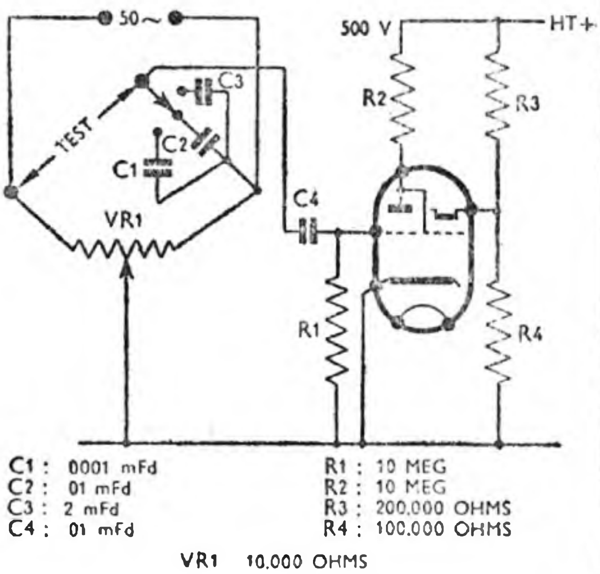


Fig. 200. Capacitance bridge shown using the 'Magic Eye' as a balance indicator.

Capacitance Bridges. The bridge principle can also be applied to the measurement of capacitance as shown in Fig. 199, when X (unknown capacitance) $= \dfrac{C \times b}{a}$.

Balance Indicator for Bridges. Where an audio-frequency note, from an *LF* oscillator or a mains transformer, is applied as a source of voltage to a bridge, a pair of headphones may be used for finding the position of the balance, which will be indicated by a cessation of signals in the phones.

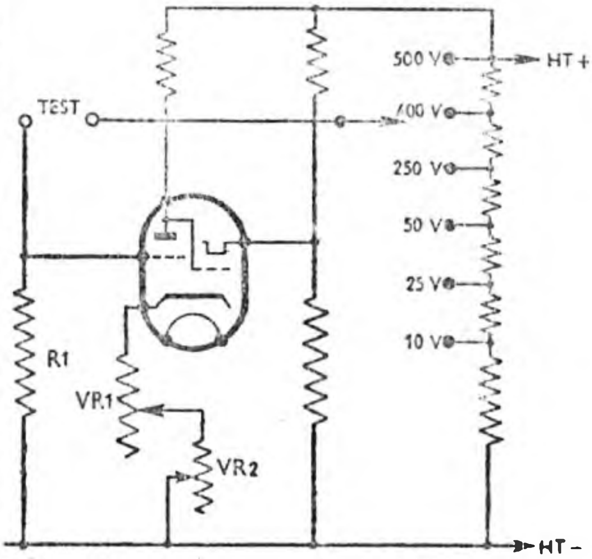


Fig. 201. This sketch shows how a 'Magic Eye' indicator can be used to measure electrolytic capacitor leakage current.

In commercial bridges, as often used for radio-service work, the cathode-ray type of indicator, or 'Magic Eye', is often used. Fig. 200 shows a typical circuit for a bridge for the measurement of capacitance.

The three 'standard' capacitors, C_1, C_2, C_3, will give three ranges of approximately ·00001 mFd, ·01 mFd, ·001 mFd; 1 mFd and ·1 mFd; 80 mFd.

'Magic Eye' Insulation Tester. Fig. 201 shows the fundamental circuit by which the 'Magic Eye' indicator can be made to indicate a flow of current. The amount of flow of current through an insulator indicates the insulation resistance of that insulator, and the 'Magic Eye' indicator, being very sensitive, measures the very high resistances exhibited by insulators.

To indicate current, it must be made to develop a voltage which can affect the grid of the 'Magic Eye' and, in Fig. 201, R_1 performs this function. If a capacitor with high insulation resistance be connected to the 'test' terminals, no current will flow through R_1, and the 'Magic Eye' segment will remain closed by virtue of a negative bias adjusted previously by VR_1, and VR_2.

If a capacitor be leaky, appreciable direct current will flow through it, causing a voltage drop across R_1 and a positive potential on the grid, so counteracting the negative bias. The shadow segment will then open, indicating a faulty capacitor.

Measuring the Leakage Current in an Electrolytic Capacitor. The circuit of Fig. 201 will measure the current flowing through a component connected to the terminals if the VR_1 control is calibrated.

VR_1 is first adjusted to minimum resistance and VR_2 is adjusted so that the shadow segment of the 'Magic Eye' is just closed.

If no current flows between the 'test' terminals (good paper capacitor), the segment will remain closed. VR_1 is thus at the 0-mA position.

If current flows, as it would through an electrolytic capacitor, the shadow segment will open, but by adjusting VR_1 it can be made to close again. The position of the VR_1 control at this point can then be calibrated in milliamps, if the current is measured by a meter in series with the capacitor. Several checking points can be obtained by using different capacitors.

The various tappings on the HT potential divider provide suitable potentials for testing capacitors of different working voltages.

OSCILLATORS AND SIGNAL GENERATORS

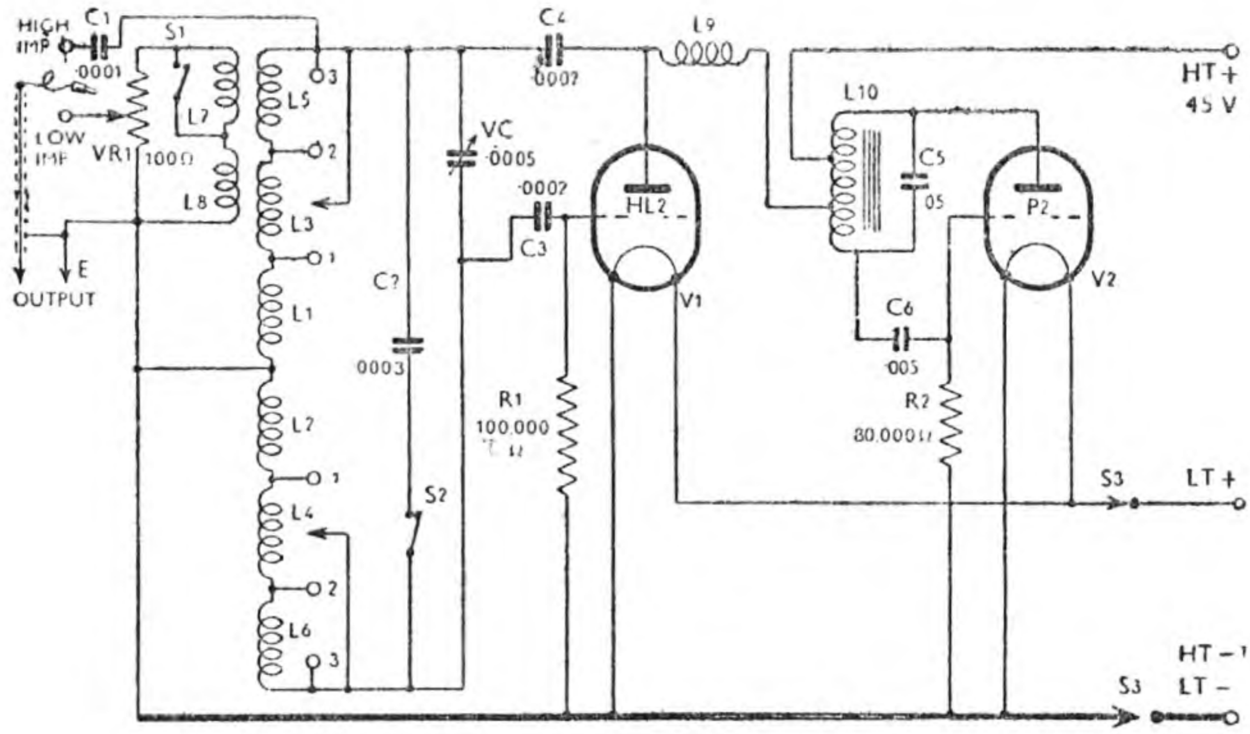
Testing and calibration of radio apparatus is greatly assisted by the use of oscillators producing a pure wave form and an accurately determined frequency.

Unless the circuit of the oscillator is designed to fulfil these requirements, changes of supply voltages to it, or a change of valve, albeit the type is the same as the one substituted, will cause substantial departures from an original calibration. The dynatron oscillator, in which there is only one inductor and capacitor, is often used, and the Hartley circuit, in which positive feed-back is obtained from the tank circuit inductor, therefore eliminating the effects of variable coupling when two inductors are coupled, is also used.

A battery-operated service oscillator employing this type of circuit is shown in Fig. 202. The tuning coil may be regarded as a single coil with a tap, so that for the medium range L_1 and L_2 are brought into circuit across the tuning capacitor VC. The other tappings on the coil bring in further windings for extending the frequency range.

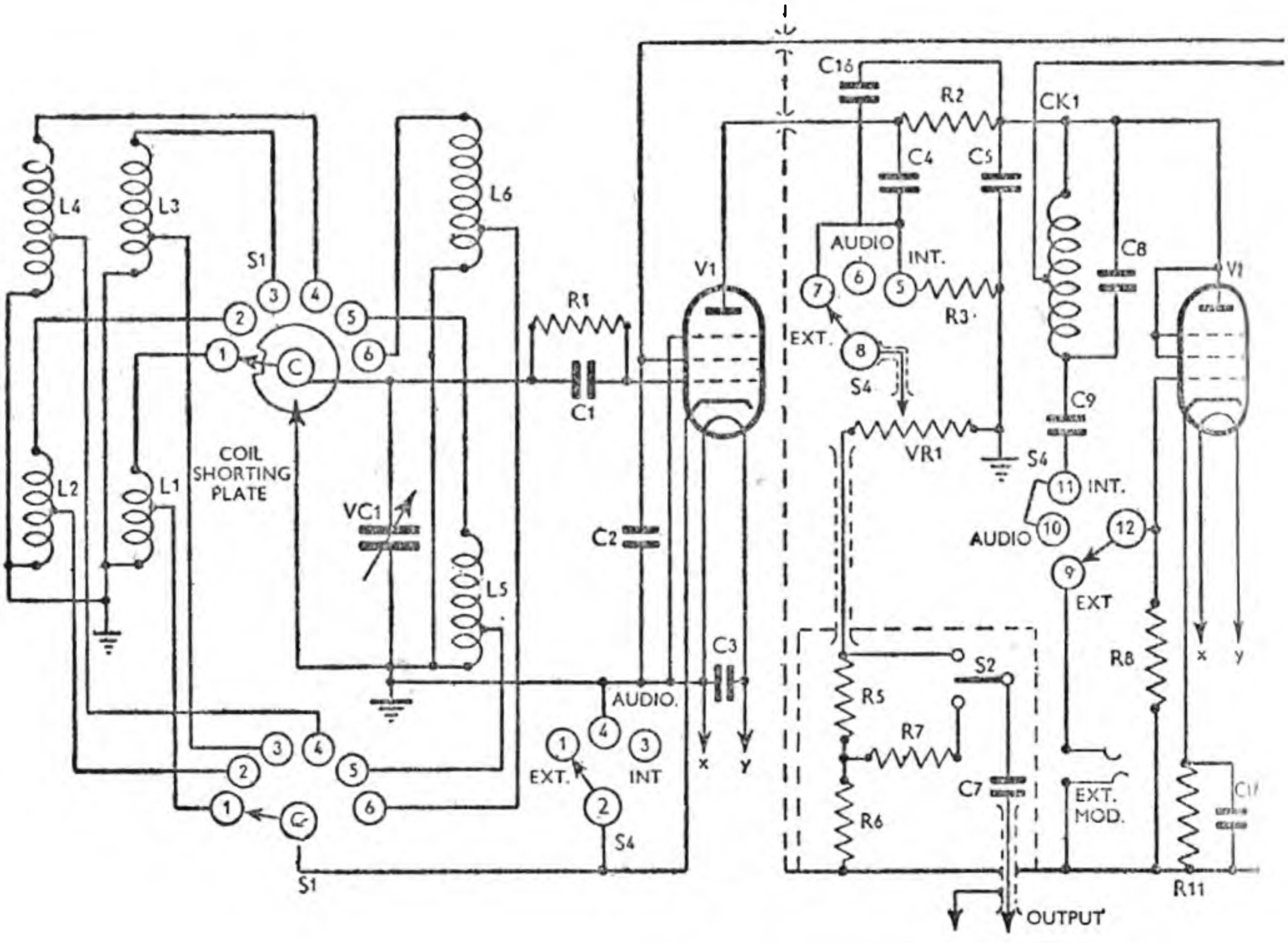
Concerning ourselves only with L_1 and L_2, it will be seen that L_1 is fed from the anode circuit of V_1, the HF oscillator valve, via the blocking capacitor C_4, the radio-frequency choke L_9 assisting in this feed-back. L_2 is the grid coil connected between the grid capacitor and HT negative.

The HF output is taken from the oscillator circuit via coupling coils L_7 and L_8 across a variable resistor VR_1, acting as a variable attenuator. For maximum output, a direct



CIRCUIT FOR A BATTERY-DRIVEN SERVICE OSCILLATOR

Fig. 202. V_1 with its associated tuning circuit generates high-frequency oscillations which are modulated at audio-frequency by oscillations generated by V_2 stage. Radio-frequency output can be calibrated against known frequencies.



MAINS-DRIVEN OSCILLATOR

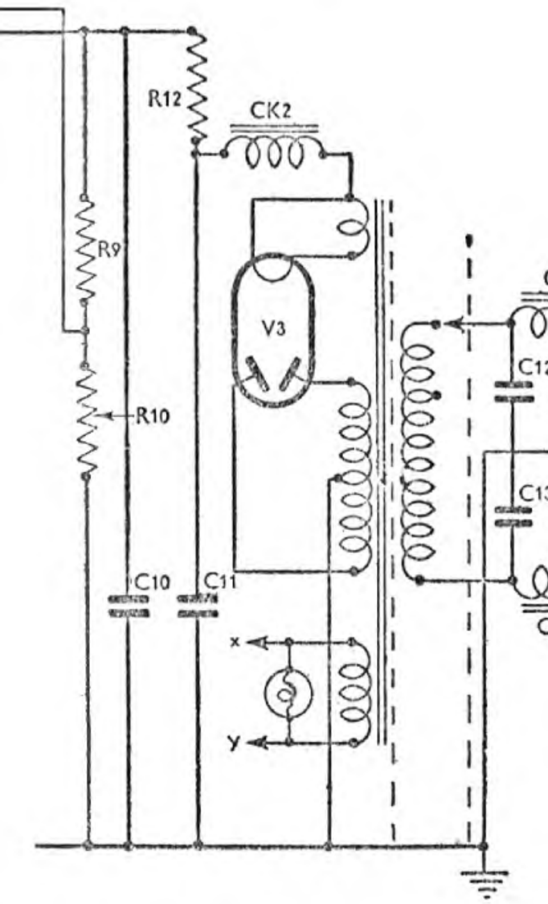
Fig. 203. Illustrated above is the circuit of an alternating-current mains operated all-wave oscillator for realignment of domestic radio sets. (It is published with acknowledgements to E.M.I. Service, Ltd.) It will be seen that again V_1 stage is the

connection is made to the oscillator coil via the blocking capacitor C_1.

For LF modulation of the HF output, a separate LF oscillator valve is employed, arranged so that the anode feed to V_1 has to pass through a portion of the winding of the LF choke L_{10}, so that the output of V_1 is LF modulated.

This simple circuit is quite effective for service work, but the load imposed on the output leads reflects on the tuned circuit, thus producing small departures from a given calibration.

The circuit of a mains-driven oscillator is shown in Fig. 203. In this it will be seen that the output leads are connected via C_7 to a resistance network R_5-R_6, which is fed from the anode circuit of the HF oscillator valve V_1; thus there is very little, if any, disturbance of the grid circuit by the output load. The LF modulation circuit is similar to that



CIRCUIT
RF oscillator, and V_2, with associated components, generates audio-frequency modulation. V_3 is the full-wave mains rectifier.

previously mentioned, and switches have been incorporated to enable the output from the instrument to be connected to the LF modulator valve, so as to obtain an audio-frequency output. This is arranged by feeding the switch S_4 (contact 6) from the anode circuit of V_2 via C_6.

The HF oscillator valve may be modulated from an external source when the switch is in the EXT position. The external source of modulation is fed into a jack which feeds the grid of V_2 across R_8, while other contacts on the switch break the LF oscillator circuit so that it does not function. V_2 then acts simply as an amplifier of the external modulation and modulates the anode circuit of V_1 in the usual way.

Signal generators in which extreme stability is required have additional features, such as voltage stabilizers across the HT feed, and the best possible quality components designed to remain constant in value over a wide range of temperatures.

Wavemeters. A wavemeter consists essentially of a tuned circuit which, when set into oscillation, gives an output of known frequency, or when coupled to an oscillating circuit and brought into resonance with the oscillations indicates the resonant condition.

Since wavelength and frequency are related to one another, an instrument measuring frequency also measures wavelength; usage is such that what might be more legitimately called a frequency meter is, in fact, called a wavemeter.

A wavemeter consists in most examples of a fixed inductor and a variable capacitor, the dial showing the capacitor settings being calibrated in either frequency or wavelength.

The more accurate the instrument, the more care is taken to make the construction rigid and to avoid errors due to ambient temperature changes, and to ensure that any valve circuit associated with the tuned circuit shall not cause variations in the calibration due to supply voltage variations, changes of valves, and so forth.

If an oscillating circuit, the frequency of oscillation of which is to be measured, has an anode-feed meter measuring the HT current to the oscillation valve, then when an external tuned circuit, coupled to the oscillating circuit, is brought into resonance, the feed meter will show a change of reading indicating the resonant condition.

If, therefore, a wavemeter be coupled to the oscillator, it absorbs power at resonance and this is indicated by the anode-feed meter. In this case, the wavemeter is called an *absorption wavemeter*.

The method is not very accurate; if accurate measurements are required, it is essential that the wavemeter be very loosely coupled to the source of oscillation (the frequency of which is to be measured) and that the wavemeter itself be equipped with some indicator showing the increase of voltage across the wavemeter circuit when resonance takes place. This indicator must not affect the calibration of the wavemeter; a valve voltmeter circuit having a very large input impedance is, therefore, suitable.

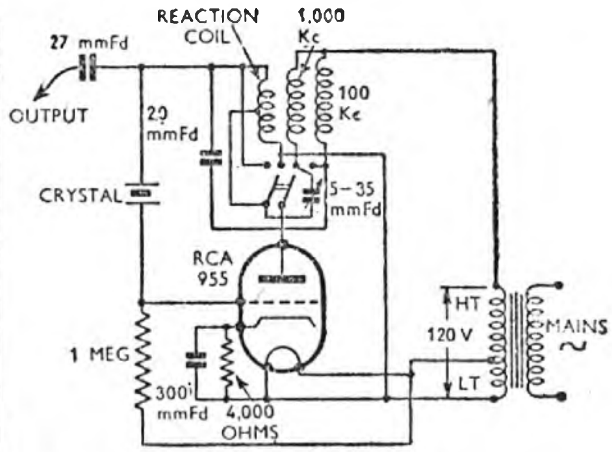


Fig. 204. Simple single-valve, mains-operated oscillator with crystal control and modulated at mains frequency.

Crystal Calibrators. Fig. 204 gives the circuit of a simple crystal calibrator which may be used for calibrating oscillators and receivers by means of harmonics from a crystal-controlled oscillator valve. The crystals employed in these calibrators have a dual frequency and will oscillate on 100 Kc/s along the length, and at 1,000 Kc/s through the thickness. The 100-Kc/s frequency range and harmonics is the more accurate, and the 1,000-Kc/s output is convenient for identifying the 100-Kc/s points.

Precautions should be taken to ensure that ambient temperature variations are the less as the demands for consistency of performance of the crystals are the greater.

AUDIO-FREQUENCY OSCILLATORS

An audio-frequency oscillator suitable for testing audio-amplifiers and so forth should be capable of giving any frequency between about 20 and 20,000 c/s at a constant output and good wave form.

The very large ratio of maximum to minimum frequency makes it difficult to design oscillators embodying tuned circuits, tuned to the audio-frequency required, and set into oscillation by valve circuits. Certain resistance-capacitance networks can be designed to fulfil the requirements, but here again the very wide range of frequencies introduces difficulties.

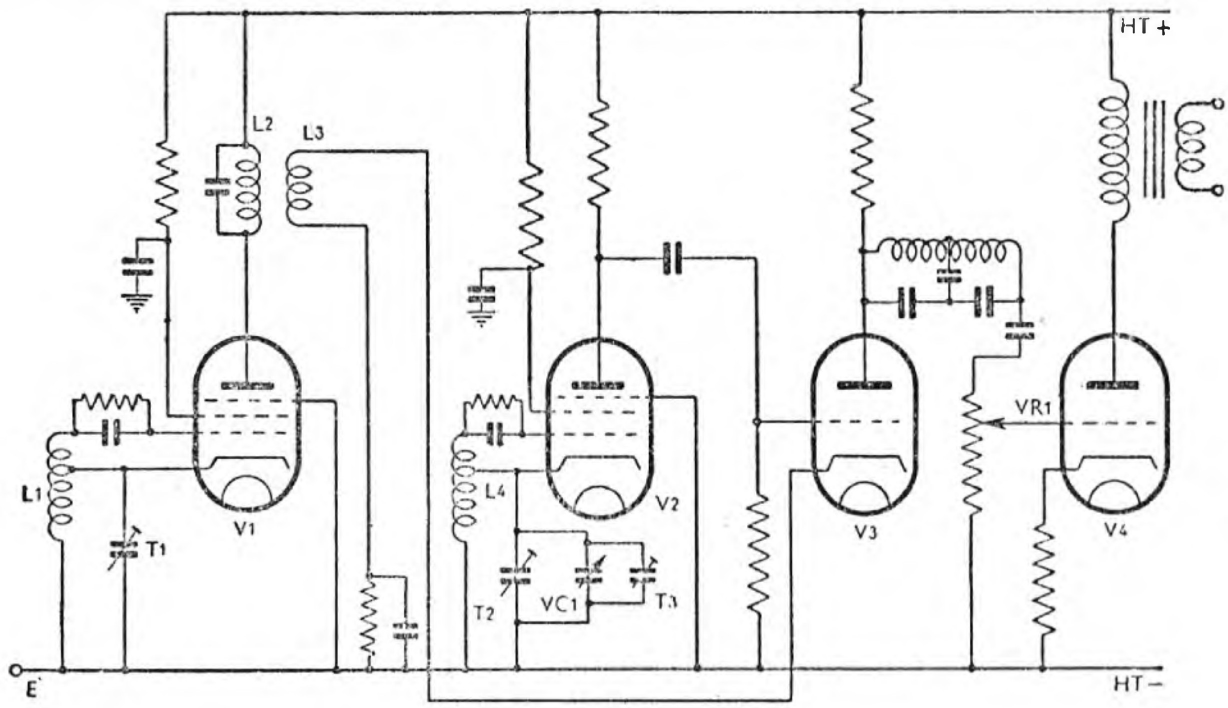
The most practical solution to the problems introduced by the wide range of frequencies required is to produce audio-frequencies the values of which are given as the difference between two much higher frequencies.

In the *beat-frequency oscillator*, two oscillating circuits are provided, one having a fixed, the other a variable frequency, so that the difference frequency varies over wide ranges by small alterations of the variable frequency.

If the fixed frequency be 300 Kc/s, then, to cover a range of difference (audio) frequencies from 0 to 30,000 c/s, the frequency of one oscillator need only be changed by 10 per cent.

Fig. 205 shows the circuit of a typical BFO.

V_1 is the fixed oscillator, with its tuning inductor L_1 and trimmer capacitor T_1. The output from the oscillator is coupled by a transformer L_2 and L_3 to V_3, the detector valve, the secondary, L_3, being in the cathode circuit of that valve.



ANOTHER AUDIO-FREQUENCY OSCILLATOR CIRCUIT

Fig. 205. V_1 and V_2 are two high-frequency oscillators. Their outputs are combined, forming in V_3 an audio-frequency beat signal which is amplified by V_4.

The variable oscillator is V_2, with its tuning inductor L_2 and primary trimmer T_2. T_1 and T_2 are used initially to set up the two oscillators to the same frequency (zero beat). Across T_2 is the main control of the instrument, VC_1, with a subsidiary trimmer T_3 for resetting calibration when required.

The output of V_2 is resistance-capacitance coupled to the grid of V_3, which acts to produce the required difference frequency, since it is also energized from both oscillators. The output from V_3 is passed through a filter network and blocking capacitor to the attenuator VR_1, which feeds the grid of the amplifier output valve V_4. The filter network is designed to suppress all radio frequencies greater than the difference frequency which is produced by the two oscillators. The output from the instrument is taken via a coupling transformer from the output valve V_4.

All circuits are very carefully screened from each other, especially the V_1 and V_2 circuits, and it will be seen that electron coupling to the anodes of V_1 and V_2 is employed, the screening grids being the actual oscillator anodes. This arrangement minimizes interaction between circuits, particularly when the difference frequency is small and the oscillators, therefore, tend to 'cog'.

Another much-used circuit is that of Fig. 206. V_1 is the fixed oscillator and V_2 the variable oscillator. VC_1 is the variable capacitor altering the frequency of one oscillator. The output of V_1 is resistance-capacitance coupled to the coupling coils L_5 and L_6, a portion of the anode signal being fed to the tuning coil L_1, whose reaction coil is L_2. From L_6 the signal is fed to the grid of the detector valve V_3.

The variable oscillator V_2 circuit is similar to that of V_1, L_3 being the tuning coil and L_4 the grid reaction coil. The output of V_2 is resistance-capacitance coupled to the grid circuit of V_3, via a centre-tapped resistance network. The output from V_3 is resistance-capacitance coupled to a filter circuit for suppressing radio frequencies, so that the intermediate frequency of AF is passed to the attenuator VR_1 and, in this particular circuit, passed straight out to the test leads without further amplification.

Other Sources of AF. Where good turntable equipment is available, with, preferably, a hysteresis motor operating from controlled mains, special gramophone records may be employed as a source of AF.

For fault-finding and simple tests, a constant-frequency audio output, produced from a simple audio-frequency oscillator such as the modulator circuit of a signal generator, suffices.

Calibration. If the equipment is available, a BFO may be calibrated by means of Lissajous figures on an oscillograph, using a known single frequency input to one set of plates, and feeding the output from the BFO across the second pair of plates. Quite a number of calibration points can be obtained using a 50-cycle or 100-cycle input.

Having got up to 1,000 cycles in this way, a simple LF oscillator-valve circuit may be connected up and tuned to 1,000 cycles by the aid of the BFO. The oscillator can then

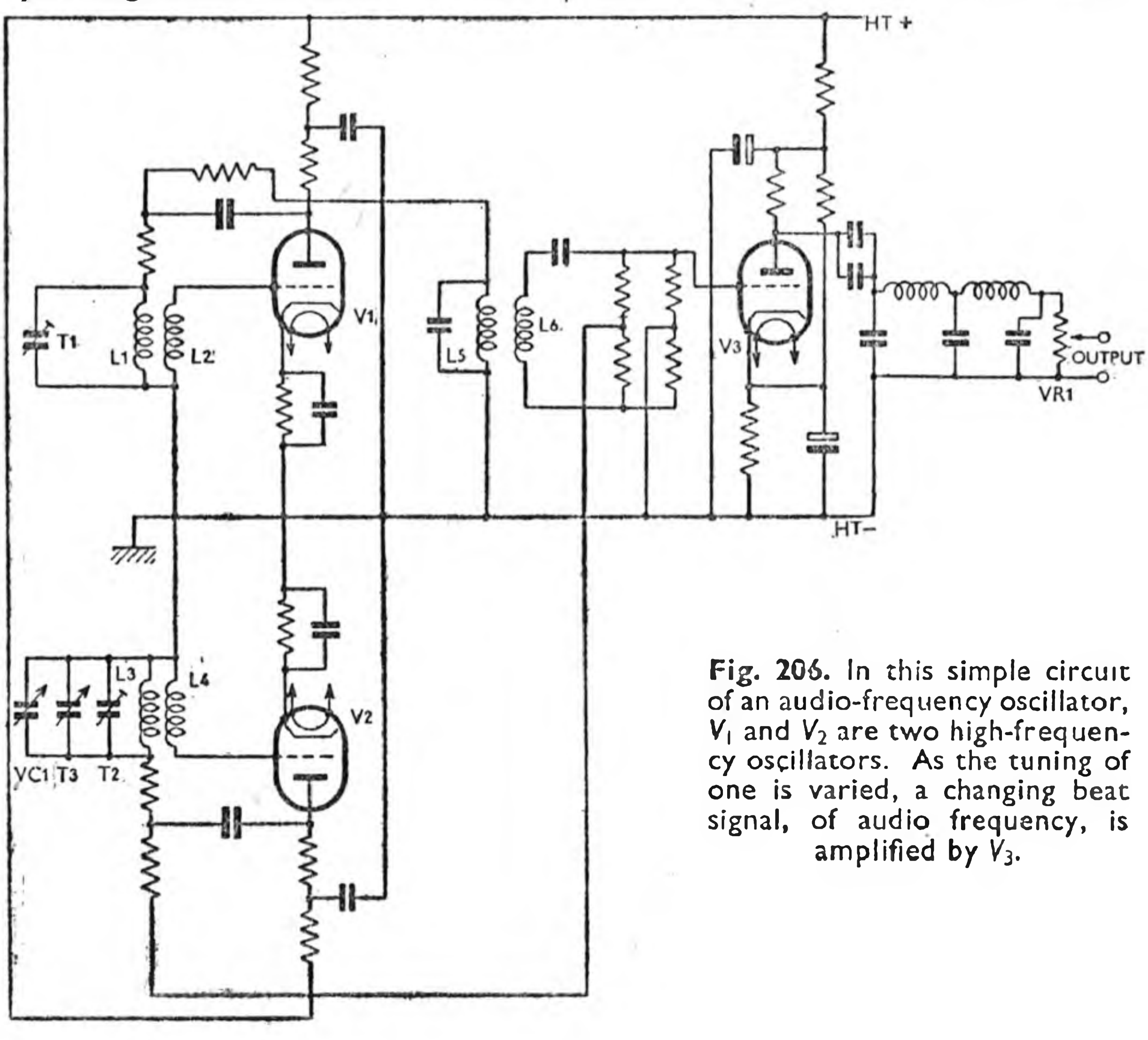


Fig. 206. In this simple circuit of an audio-frequency oscillator, V_1 and V_2 are two high-frequency oscillators. As the tuning of one is varied, a changing beat signal, of audio frequency, is amplified by V_3.

be used as the source of known frequency, and the remainder of the BFO scale calibrated.

Although not so accurate, an organ or piano can be used to calibrate a BFO used principally for service or comparative work, taking care not to be confused with octave differences. Also, the lower notes are very strong in harmonics, which can easily be confused with the weaker fundamental. Fig. 179 gives the piano keyboard with frequencies of the notes. The accuracy of this method of calibration will depend upon whether the piano is properly tuned and is 'pitched' correctly, but, even so, results will be satisfactory for most work where great accuracy is not a paramount consideration.

THE CATHODE-RAY OSCILLOGRAPH

The principles of the cathode-ray tube may be appreciated from Fig. 207 which shows the main features of a normal type tube, while Fig. 208 gives a circuit diagram of a typical commercial oscillograph. Average component values are given in Tables LXVI and LXVII.

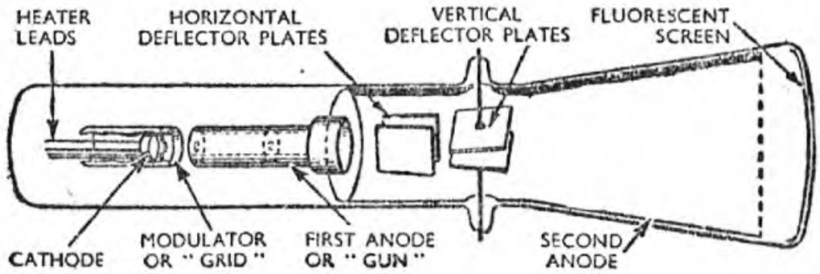


Fig. 207. Simplified sectional diagram of a cathode-ray tube employing electrostatic deflection.

Saw-tooth Time Base. For most kinds of investigations, the internal time base is used to swing the spot across the screen in a certain time and then to return it to its starting point, as rapidly as possible. This rapid return period is called the fly-back period. The wave form to be examined is applied to the vertical plates and, by adjusting the time base frequency, one or more cycles of the wave form can be made to appear on the screen of the tube.

The resultant trace on the screen is thus due to the application of a saw-tooth wave form across the horizontal plates, and a sine-wave (simple or complex) voltage across the vertical plates (Fig. 209).

Lissajous Figures. For frequency comparisons, phase-shift measurements, etc., a time base is not used; instead one voltage is applied to the vertical plates, either direct or through an amplifier, and the other voltage to the horizontal plates. One of the voltages will require investigation, while the other will be one the characteristics of which are known and will be derived from an oscillator (HF or LF, according to requirements) or from a standard controlled mains supply. Some examples of Lissajous figures are given on page 267.

Some Applications in Radio Work:

Tracing faults in receivers.

Checking cause of distortion in amplifiers.

Observation of ripple and filter efficiency in power circuits.

Valve characteristics.

Phase shift test.

Wave-form examination of oscillator output.

Frequency comparison (Lissajous figures).

Modulation tests.

[*Continued on page* 267

TABLE LXVI: CONTROLS AND FUNCTIONS

Control Designations	Operational Function
Brilliance, Intensity, Brightness	Adjusts brightness of spot and image.
Focus	Controls definition or clarity of the trace by altering the size of the spot and, therefore, the thickness of trace.
Range, Capacitor, Frequency Coarse	Governs approximate frequency range of internal time base.
Frequency, Frequency Fine, Velocity	Fine control of time base frequency.
Sync., Syn., Hold ..	Stops movement of trace across the screen so that one or more cycles may be examined stationary.
'Int-50∼-Ext' Switch ..	Selects sync. signal to time base circuits from either applied signal, mains supply, or external frequency source.
Ampl. A, Ampl. Y, Vert Ampl. Switch	Applies input either direct or through an amplifier to vertically deflecting (Y) plates.
Ampl.B., Ampl.X, Horiz.-Ampl. Switch	Applies input either direct or through an amplifier to horizontally deflecting (X) plates.
Gain, Height, Vert. Gain	Controls amplitude of trace in a vertical direction. (Top to bottom of screen.)
Gain, Width, Base, Horiz.-Gain	Controls amplitude of trace in a horizontal direction. (Across screen.)
Y Shift, Vert. Shift, Beam Centring	Generally a pre-set control for centring spot in screen area in a vertical direction to counteract stray magnetic fields, etc.
X Shift, Horizontal Shift, Beam Centring	As above but in a horizontal direction.

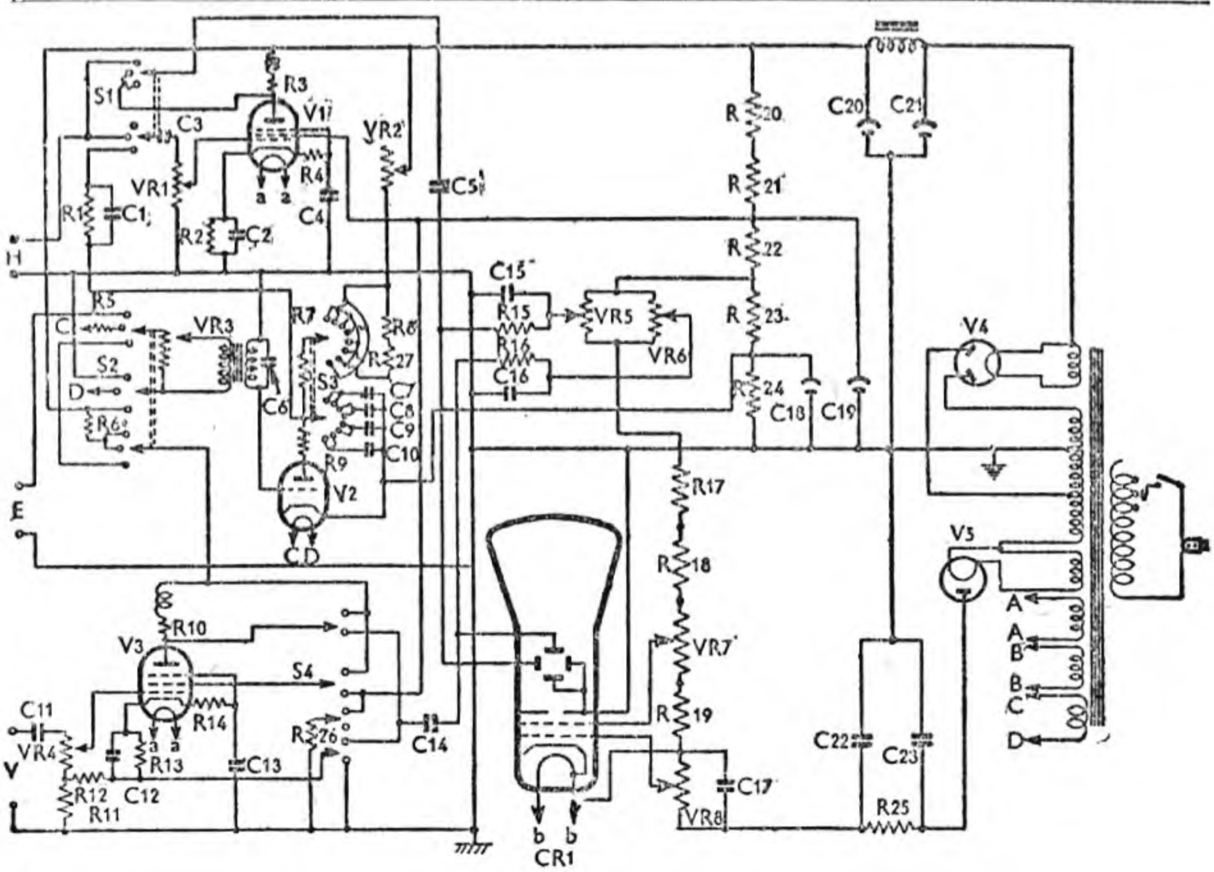


Fig. 208. Circuit diagram of a typical commercial oscillograph.

Fig. 208 Circuit Component	Technical Function
VR_8	Controls bias on grid of cathode-ray tube.
VR_7	Affects difference of potential between first and second anodes for electrostatic focusing of beam.
S_3 (Two-bank)	Selects applicable time base capacitor for approximate frequency. Gives two ranges for each capacitor by means of R_8, R_{27}.
VR_2	Alters frequency by V_2 anode voltage adjustment.
VR_3	Applies part of 'work' or input to time base to keep its frequency in step, or synchronized, with frequency of input.
S_2 (Three-bank)	Switches VR_3 to 'work' input. Ext. Sync. terminals (to which could be connected a standard source of frequency) or to secondary winding CD for 50~ synchronizing signal.
S_4 (Four-bank)	Cuts out amplification of V_3 in upper (OFF) position and connects signals across R_{11} to vertical plates via C_{14}.
S_1 (Two-bank)	Connects horizontal plates via C_5 either direct to input terminals or to output of V_1. In third position feeds VR_3 with time base signals.
VR_4	Controls input to grid of V_3.
VR_1	Controls input to grid of V_1.
VR_6	Applies a standing 'bias' voltage across vertical plates.
VR_5	Applies a standing 'bias' voltage across horizontal plates.

TABLE LXVII:
COMPONENT VALUES OF TYPICAL COMMERCIAL OSCILLOGRAPH

R	Purpose	Ohms
1	Decoupler between V_2 and V_1	1·5 meg
2	Cathode bias V_1	750
3	Anode load V_1	·1 meg
4	Cathode decoupler V_1	·23 meg
5	Current limiter for 50~ input	2,000
6	Voltage dropper for V_3 anode (compensates for VR_3) ..	1,000
7	Anode load V_2	·25 meg
8 } 27 }	Voltage dropper to change frequency of time base to give two ranges for C_7, C_8, etc.	·75 meg 1 meg
9	Anode suppressor V_2	100
10	Anode load V_3	·1 meg
11	Load resistance for direct input to vertical plates ..	1 meg
12	Residual grid-cathode resistance for V_3	15,000
13	Cathode bias V_3	750
14	Cathode decoupler V_3	·23 meg
15	Decoupler for beam centring (horizontal plates) circuit	·5 meg
16	Decoupler for beam centring (vertical plates) circuit ..	·5 meg
17 } 18 } 19 }	Potential divider network for cathode-ray tube, second anode and grid biasing	·5 meg ·5 meg ·23 meg

[*Continued on page* 266

TABLE LXVII: COMPONENT VALUES OF TYPICAL COMMERCIAL OSCILLOGRAPH—*continued*

R	Purpose	Ohms
20	Potential divider network for V_1, V_2, V_3, voltage supplies	40,000
21		40,000
22		35,000
23		15,000
24		1,000
25	Smoother for cathode-ray tube HT	·23 meg
26	Compensating load for V_3 screen	·1 meg
27	See R_8	—
VR_1	V_1 gain control	1 meg
VR_2	Fine control of time base frequency	2 meg
VR_3	Sync. control to time base	1,000
VR_4	V_3 gain control	2 meg
VR_5	Horizontal beam centring	·375 meg
VR_6	Vertical beam centring	·375 meg
VR_7	Focus control	·375 meg
VR_8	Brilliance control	·1 meg

VALVES

V	Purpose	Type
1	Amplifier for horizontal plates	6J7G, Z63
2	Time base oscillator	884, GT1B
3	Amplifier for vertical plates	6J7G, Z63
4	HT rectifier for V_1, V_2, V_3	5Y3G, U50
5	HT rectifier for cathode-ray tube	879, U17
CR_1	Cathode-ray tube. 1,500 volts max anode 1, 475 volts max anode 2	3 in. hard vacuum

C	Purpose	mFd
1	HF by-pass for R_1	23 mmFd
2	V_1 cathode decoupler	·0035
3	V_1 grid blocking capacitor	·1
4	V_1 suppressor decoupler	·1
5	Horizontal plates feed from V_1	·23
6	By-pass for oscillator transformer	·005
7	Time base capacitors	·15
8		·023
9		·005
10		·00075
11	Blocking capacitor for vertical input	·1
12	V_3 cathode decoupler	·0035
13	V_3 suppressor decoupler	01
14	Vertical plates feed from V_3	·23
15	Horizontal centring decoupler	·23
16	Vertical centring decoupler	·23
17	Cathode-ray tube cathode decoupler	·23
18	V_2 cathode decoupler	20
19	V_1, V_3, screens decoupler	8
20, 21	HT smoothing	4
22, 23	EHT smoothing	·25

Examination of speech and musical instrument's wave-forms.
Detection of parasitic oscillation.
Examination of effect of tone-control circuits.
Monitoring.
Observation of atmospherics.

With Frequency-Modulator:
Aligning band-pass circuits.
Adjusting AFC circuits.
Sensitivity and selectivity tests.
Band-width measurements.
Adjusting wave-trap circuits.

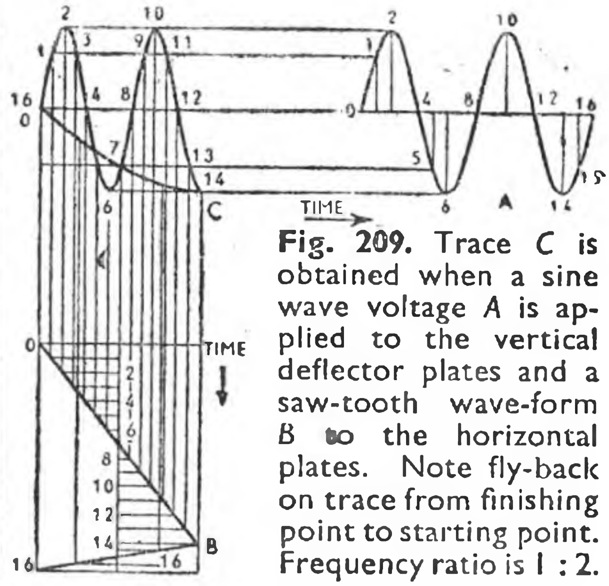


Fig. 209. Trace *C* is obtained when a sine wave voltage *A* is applied to the vertical deflector plates and a saw-tooth wave-form *B* to the horizontal plates. Note fly-back on trace from finishing point to starting point. Frequency ratio is 1 : 2.

LISSAJOUS FIGURES

Figs. 210-213 show the graphical construction of four fundamental Lissajous figures. From these it will be seen that, if the frequency of one of the voltages is known, the frequency of the other voltage can be determined by knowledge of the resultant of combination.

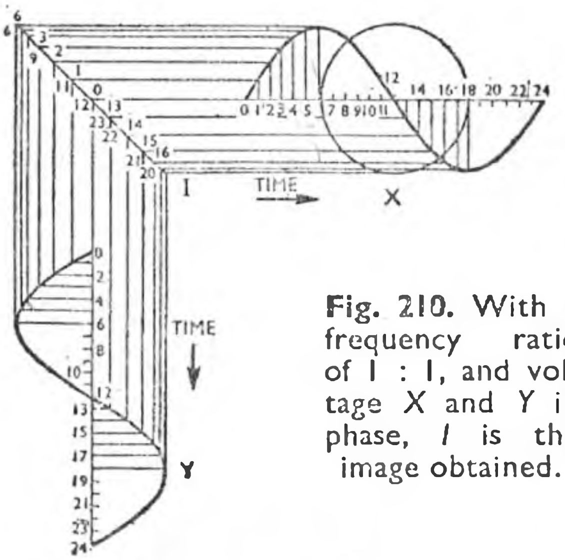


Fig. 210. With a frequency ratio of 1 : 1, and voltage *X* and *Y* in phase, *I* is the image obtained.

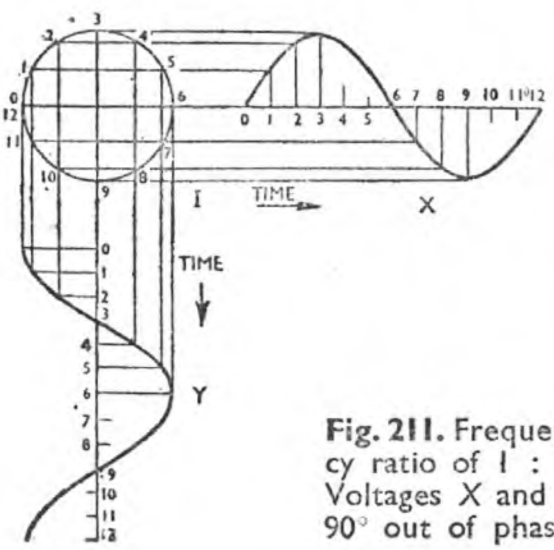


Fig. 211. Frequency ratio of 1 : 1. Voltages *X* and *Y* 90° out of phase.

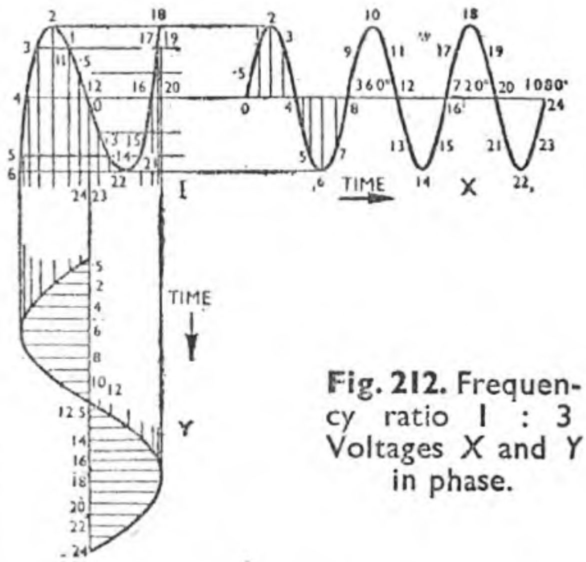


Fig. 212. Frequency ratio 1 : 3 Voltages *X* and *Y* in phase.

Fig. 214a-e are for 1 : 1 frequency ratio, while below (f-j) will be seen the effect of making the frequency ratio 2 : 1 for the different phase relationships.

As the frequency ratio increases above about 10 : 1, the figures become more complex. They are then difficult to diagnose, and it is of assistance to separate the left-to-right movement of the spot from the right-to-left movement. This can be accomplished by vertically displacing the latter movement so that the figure appears as a slowly rotating

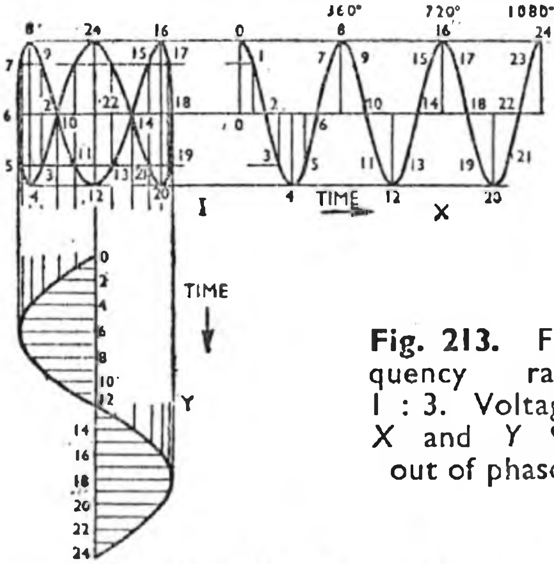


Fig. 213. Frequency ratio 1 : 3. Voltages X and Y 90° out of phase.

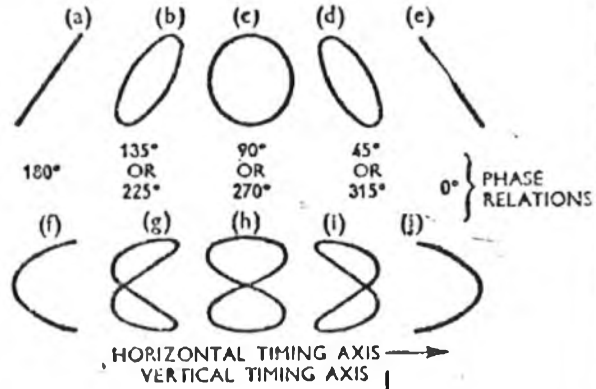


Fig. 214. Oscillograph traces indicate by shape and tilt the phase relations of waves having known frequency relationship.

illustrated in Fig. 217, where the peaks and loops have been numbered to demonstrate the method. This method is only satisfactory

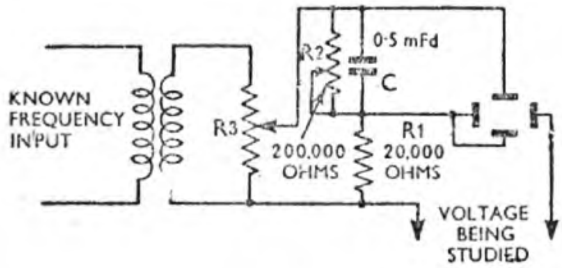


Fig. 215. Method of applying two wave forms with phase shift control.

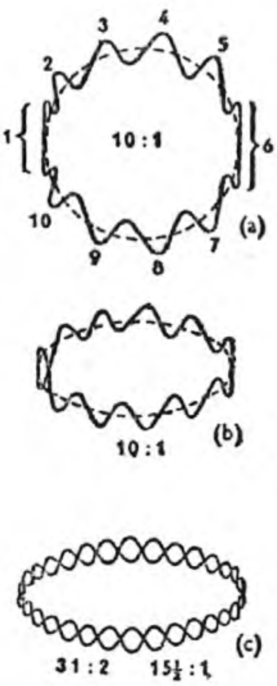
when fairly well-defined end loops are visible.

An alternative method is, therefore, often used. It consists of counting the number of complete peaks (two halves counting as one) for one frequency, and then noting the number of intersections; to this latter number, one is added, and the result gives the second frequency (Fig. 218). Stated another way, the frequency ratio (fractional) is equal to the number of peaks on the circumference divided by the term

ring. This can be achieved by using the phase-splitting circuit given in Fig. 215.

When R_2 is at maximum resistance, the phase shift is nearly 90° and is decreased as R_2 is decreased. Figs. 216a and 216b are of the same pattern but obtained with different settings of R_2 and R_3. By this means such difficult patterns as that in Fig. 216c may be analyzed with more certainty.

One method of determination of frequency ratio is to count the number of peaks on the top of the figure, and the number of loops at one end. This is well



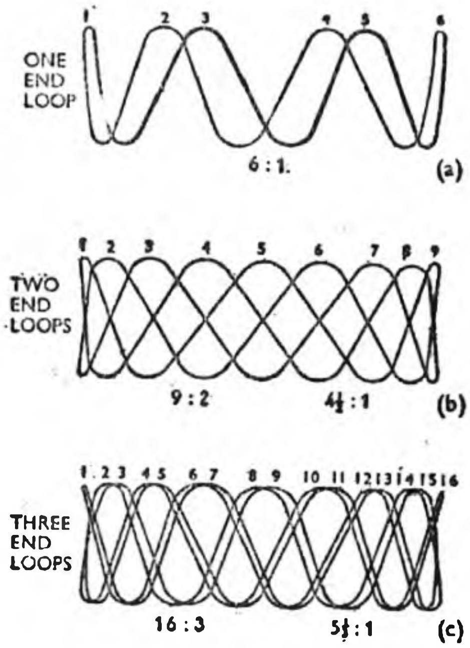
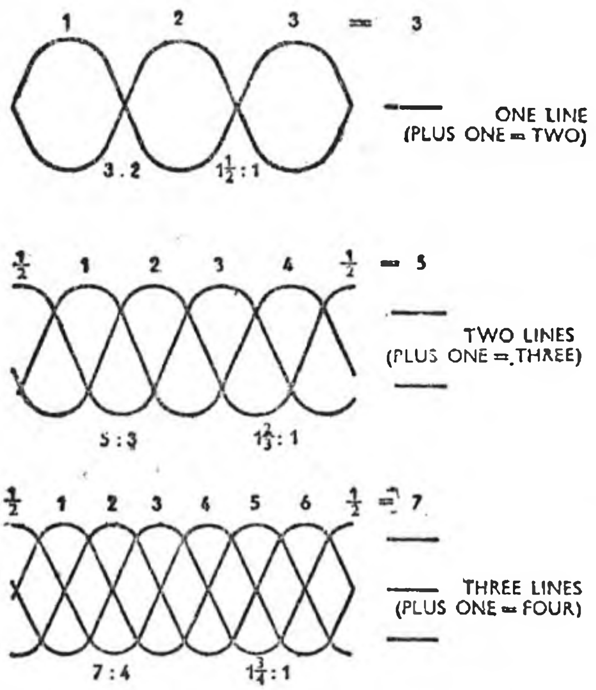


Fig. 216. (Left) Figure obtained with phase-splitting circuit. **Fig. 217.** (Right) Frequency ratio determination by examination of peaks and end loops. These are 'flat' patterns obtained when not using phase-splitting circuit.



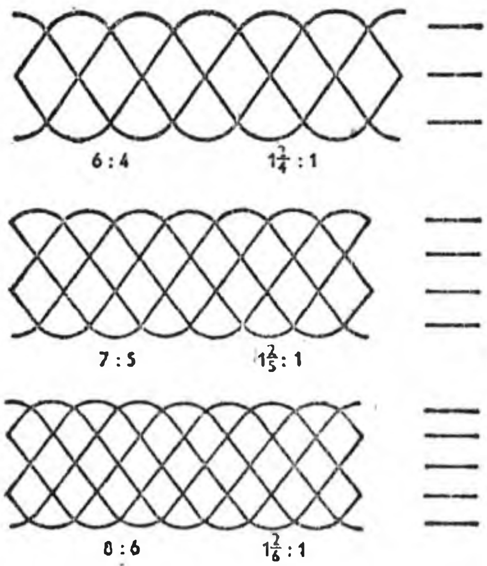


Fig. 218. Frequency ratio determination by peaks and lines of intersection.

'one + number of horizontal lines of intersection'.

Fig. 217 gives three examples of this method. Note that where two half peaks occur at each end (or there may be, say, a quarter peak one end and three-quarters of a peak the other end), these are added together and counted as one peak.

It is important when examining 'flat' patterns (i.e., those not obtained with a phase-splitting circuit), that the front trace does not coincide with the back trace and so cause confusion and the incorrect calculation of the frequency ratio. For example, in the Fig. 217a pattern, the front trace is shown in a thick line, and the back trace as a fine line to emphasize this point. If the traces do remain stationary and coincident, the unknown frequency should be altered very slightly to cause the figure to commence turning.

ATTENUATORS AND GAIN CONTROL SYSTEMS

The term attenuator is often used to describe a device producing the attenuation of power, or voltage, or current between its input and output terminals. (Note that an attenuator composed of reactances does not give a reduction of power.)

A more restricted use of the term describes an adjustable resistance network arranged so that the input and output resistance is constant at all settings of the attenuator and so that the ratio of output to input power is known from a calibration or labelling of the adjustment. The term attenuator will be used in this restricted sense here.

The term volume control is, in fact, a misnomer, unless it is taken to describe a device to maintain the mean volume of the reproduced sounds constant by increasing the loudness of the weaker and decreasing the loudness of the stronger. The term gain control is more descriptive when it means a device changing the gain of an amplifier between input and output terminals.

A potential divider (potentiometer means a device for measuring potential, not altering it), is shown in Fig. 219, and is arranged to alter the power supplied to the loudspeaker as the slider is moved along the resistor. The load presented to the input is not constant, if the slider

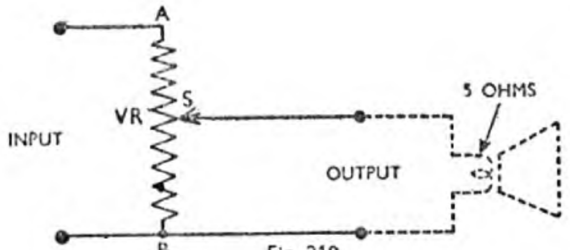


Fig. 219

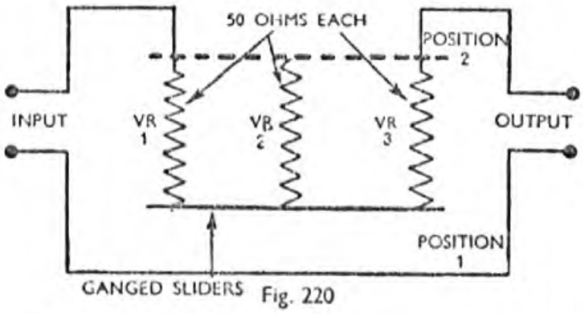


Fig. 220

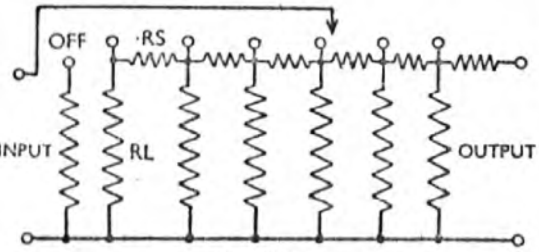


Fig. 221

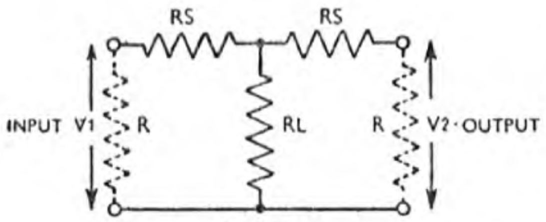


Fig. 222

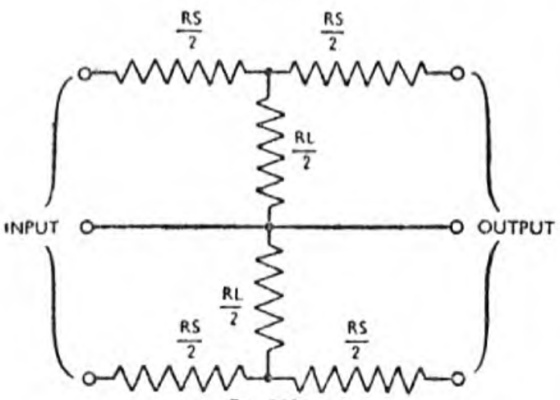


Fig. 223

Fig. 219. Attenuator or volume control applied to a loudspeaker. **Fig. 220.** Three ganged potential dividers for attenuation with little effect on impedance matching. **Fig. 221.** Resistance network for attenuation with constant impedance. **Fig. 222.** Simple Tee attenuator. **Fig. 223.** Attenuator of two Tee units back to back.

is at A, it is of the total resistance of the potential divider in parallel with the loudspeaker; if at B, of the potential divider only.

The variation of load if the input is from a valve may cause distortion; if the total resistance of the potential divider is much less than the loudspeaker impedance, the load tends to remain constant but the arrangement is inefficient, the greater part of the input power being dissipated in the potential divider.

Fig. 220 shows three ganged potential dividers for attenuation with little effect on impedance matching.

The attenuator of Fig. 221 consists of a network with series and shunt arms, so arranged that as the slider contacts the different studs a different attenuation is produced, the input resistance remaining constant. This is achieved by choosing different resistance values for the different resistors.

'T' Attenuator. By correctly apportioning the values of R_S and R_L, the input resistance of the T network of Fig. 222 can be made constant and equal to R, the terminating resistance, and the total attenuation of the network varied by varying the resistance values of the three arms, the two series arms R_S always having equal values.

If α be the ratio $<$ 1 of the input to the output voltage, then,

$$R_S = R\,\frac{1 - \alpha}{1 + \alpha};$$

$$R_L = R\,\frac{2\alpha}{1 - \alpha^2}.$$

'H' Attenuators. In circuits having systems balanced to earth, such as in push-pull circuits, two 'T' types inverted are used, as in Fig. 223. These are generally termed 'H' type attenuators. To obtain the same results with 'H' as in 'T' networks, the values of the resistances are half those in the 'T' type.

The table given in Fig. 181, p. 239,

will be of assistance in calculating losses or gains in terms of decibels, and was compiled primarily for use with VHF field-strength measuring equipment.

This chart gives gain or loss ratio in voltage, current or power when the dB gain or loss is known; or it will give the dB gain or loss for any gain or loss ratio.

Example: 10-volt input is reduced to 1-volt output. What is the loss in dB? Loss ratio is ·1. Find ·1 in 'Loss Ratio' column and trace horizontal line to where it intersects the diagonal. Then trace vertical line from this point to dB scale. *Answer:* 20 dB.

Example: A 2-volt input is amplified to a 10-volt output. What is the gain in dB? Gain ratio is 5. Find 5 in 'Gain Ratio' column and trace horizontal line to where it intersects the diagonal. Then trace vertical line from this point to dB scale. *Answer*: 14 dB.

Example: A loss of 12 dB is required. What does this represent in terms of volts in and out? Find 12 dB in the dB scale and trace vertical line down to diagonal and then along to 'Loss Ratio' column. *Answer*: ·25 = loss ratio, meaning that 4-volt input is reduced to 1-volt output or 40-volt input is reduced to 10-volt output.

VALVE VOLTMETERS

The advantage of the valve voltmeter compared with many other types of voltmeters is that its input impedance may be made extremely high, so that the connection of the valve voltmeter to a high-impedance source of high-frequency voltage will not greatly disturb the conditions in the circuit producing the voltage to be measured.

A valve voltmeter may also be constructed to measure steady voltages (as contrasted with alternating voltages) and has the advantage of having so high an input resistance that its connection to the circuit is not liable to alter the value of the voltage to be measured, even though the resistance of the source from which the voltage is derived is very high.

Valve voltmeters for DC measurement may be designed having an input resistance of even megohms per volt.

DC Valve Voltmeters. Fig. 224 shows a DC valve-voltmeter circuit which operates on the principle of the mutual conductance or 'slope' of a valve. For example, a valve having a 'slope' of 6·3 mA per volt would show a change of anode current of 6·3 mA for every one volt change of grid voltage.

This simple arrangement, however, gives a very limited range and

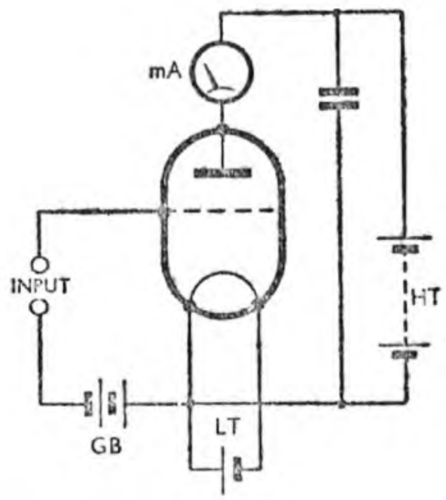


Fig. 224. Basic arrangement of a valve voltmeter using batteries.

by employing cathode biasing, as shown in Fig. 225, the range is extended, because every increase in anode current will cause a rise in bias which will counteract the rise and make it less than in the circuit shown in Fig. 224. Thus, a greater

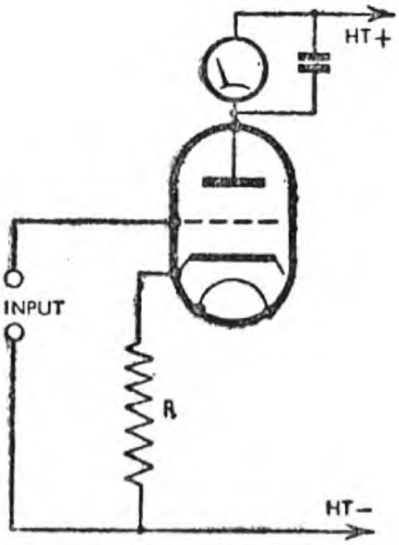


Fig. 225. Mains-driven version of Fig. 224. *R* not only biases the valve, but extends the input volts range.

voltage range can be applied to the grid before the upper limit of the milliammeter scale or valve curve is reached.

Increasing Range. To increase the range still further, a potential-divider network may be connected across the input, but this, of course, will create a greater load upon the circuit being tested, but it can still be made very high, as shown in Fig. 226.

This is an American circuit, and an interesting feature is that by biasing the valve up to the middle of its curve, a centre-zeroed milliammeter (calibrated in volts, of course) gives a positive or a negative reading, so that a correct reading is obtained no matter which way round the test leads are applied to the circuit under test.

The variable bias resistor (pre-set) is adjusted with the particular valve to give the necessary anode current to bring the meter needle to its centre position. A positive-grid potential will increase the reading, so the right half of the scale is calibrated as positive volts 0–5, 50, etc., according to the ranges provided.

A negative grid potential will decrease the meter reading, and the left half of the scale is calibrated with negative volts.

How to Zero the Meter

The meter is set to zero by shorting the input to the instrument and adjusting the variable resistance in the HT potential divider, thereby altering the anode current by adjusting the anode volts.

In other types, the valve is biased nearly back to the lower bend of its curve. This leaves a very small anode current flowing, and the meter needle may be set on zero by means of the usual mechanical adjustment so that the needle reads zero with the input shorted. The application of a positive voltage to the grid will then increase the anode current, and the whole meter scale is available for calibration in a forward direction. The test leads must be reversed to obtain the negative voltage readings.

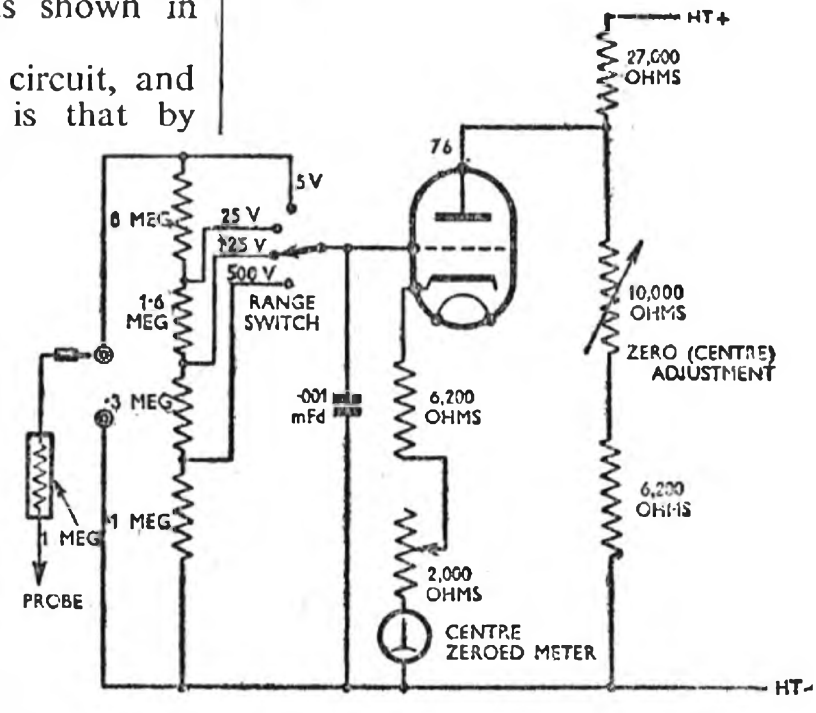


Fig. 226. Direct-current valve voltmeter. The meter is centre-zeroed and is not of the centre zero type. It does not register a change of current direction, only an increase or decrease in value.

Anode-bend AC Valve Voltmeters. The last-mentioned type of valve voltmeter could be biased to give an indication of AC volts because,

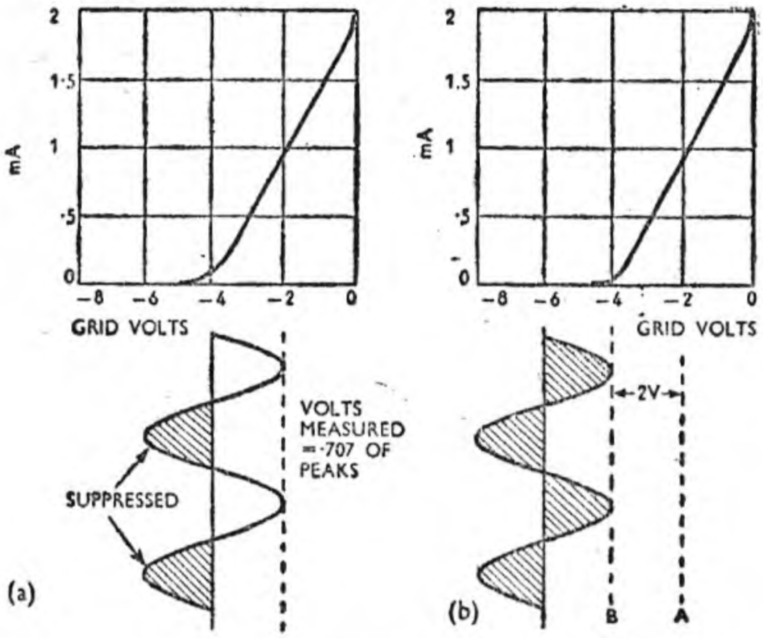


Fig. 227. Left (a) Anode-bend valve voltmeter indicates, by the change in anode current, the effective value of the applied AC volts. (b) Peak valve voltmeter indicates (by a voltmeter across the bias supply) the volts necessary to shift the peaks from position *A* to position *B*.

being biased back to the lower bend, rectification will occur, the negative half cycles having little effect upon the anode current. The anode current is then a measure of the effective value of the positive half-cycles.

If the valve is biased back still further so that only the peaks of each cycle just give rise to a change of anode current, the reading will indicate peak volts. Fig. 227a shows how the valve curve is used for effective volts measurement, while Fig. 227b shows peak measurement.

Peak Valve Voltmeter. Fig. 228 is the circuit of a peak-valve voltmeter and is of the type often termed 'slide back', because of its operation, which is as follows. The valve is first biased to its cut-off point (zero anode current) by VR_1 with VR_2 at zero and the input shorted. The application of an AC voltage to the input will then cause the anode current to rise to a certain figure. VR_2 is then adjusted (thereby providing more negative bias) until the anode milliammeter just reads zero again. The reading of the bias voltmeter is then that of the peak value of the AC input.

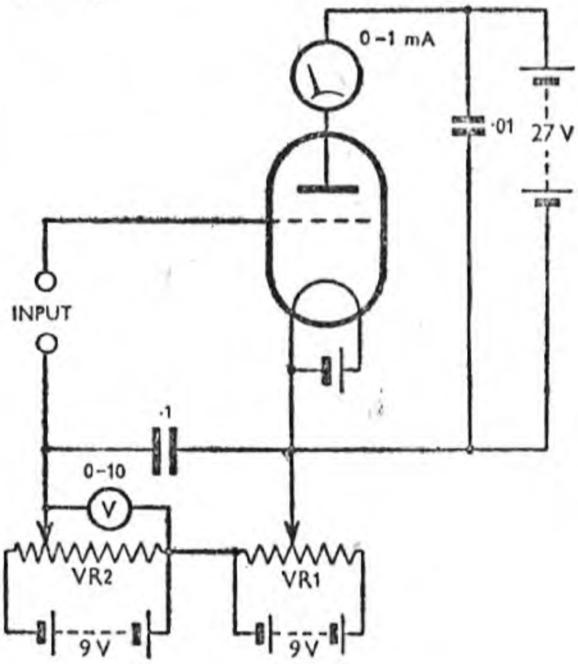


Fig. 228. Peak valve voltmeter of the slide-back type. The bias voltmeter *V* should be accurate but need not be exceptionally sensitive; 500 or 1,000 ohms-per-volt being suitable.

'Magic Eye' as an Indicator. As the milliammeter is used only to give an indication of zero anode current, it may be dispensed with and a 'Magic Eye' tuning indicator used so that at zero or minimum anode current the shadow segment closes. The applied AC voltage being measured will then cause the segment to open and the bias control is adjusted until the shadow closes again.

Diode Rectifier Valve Voltmeter. To obviate the need of the adjustment of controls every time a measurement is to be made, a separate diode rectifier may be used, as shown in Fig. 229. The diode load comprises a resistance network which forms a range-potential divider for the DC amplifier-triode valve, which is biased by an adjustable cathode resistance for setting to zero on DC. A second variable resistance is to give the diode a slight bias and it is used for setting to zero on AC.

The capacitor in the input circuit exists to block off any DC that may be present, such as in the anode circuit of a valve stage.

In some commercial instruments, the diode is incorporated in the triode valve, a double-diode-triode being used with the diodes strapped.

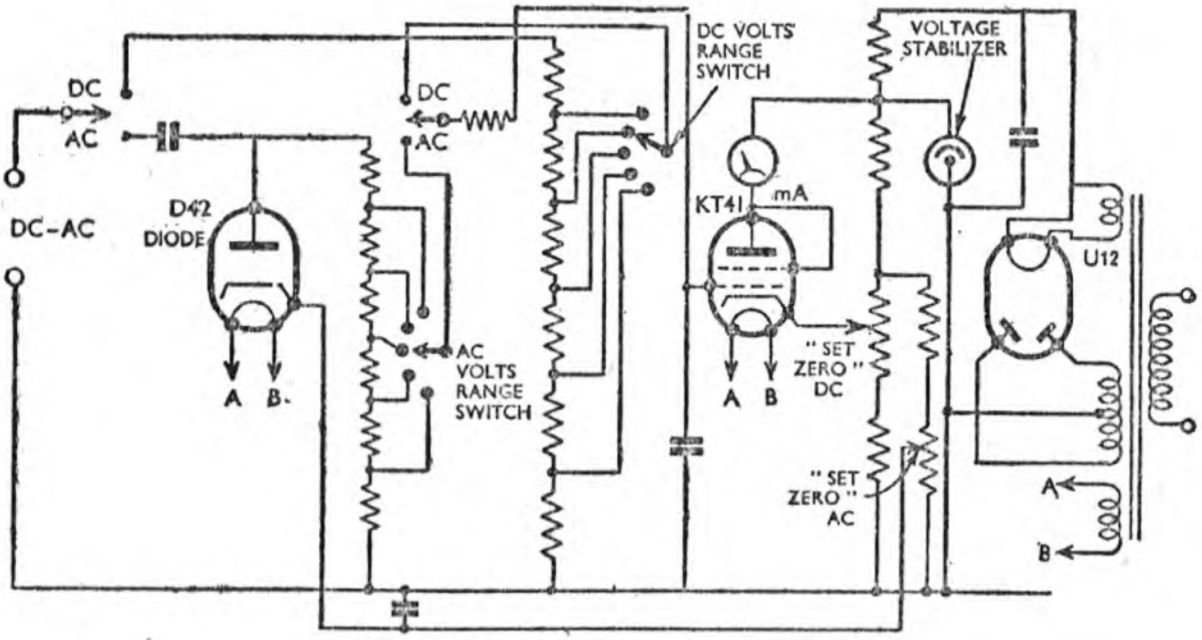
In Fig. 229 a tetrode is connected as a triode.

General Notes. As both test leads may be at a high DC potential (e.g., across an anode coil), the case of a valve voltmeter must not be connected to the 'earth' side of the voltmeter circuit and must be earthed on its own.

Meters and HT-supply circuits must be thoroughly decoupled by high-quality capacitors.

Voltage stabilizers are advisable across the HT supply, to keep the voltage constant over the mains-voltage range of each particular tapping on the mains transformer.

It should be appreciated that for many applications, with an input signal to a circuit under test that can be properly attenuated, a valve voltmeter need not be accurately calibrated, or may even not be calibrated at all. Taking a single stage gain measurement as an example, if when the valve voltmeter is connected to the input to the stage a certain measurement is obtained, say one division on the meter scale, and then when connection is made to the output of the stage a higher reading is obtained, the attenuator on the signal generator providing the signal source has only to be adjusted to give a lower output that will bring the meter needle back to the one division mark. The attenuator ratio between



MAINS-DRIVEN VALVE VOLTMETER FOR AC AND DC READINGS

Fig. 229. Showing a direct-voltage valve voltmeter with the addition of a diode and separate range resistance network for reading alternating voltages.

its first and second readings will then be a measure of the stage gain.

AC Voltage Values. Fig. 230 shows the relationship between peak, effective (RMS) and average values. The

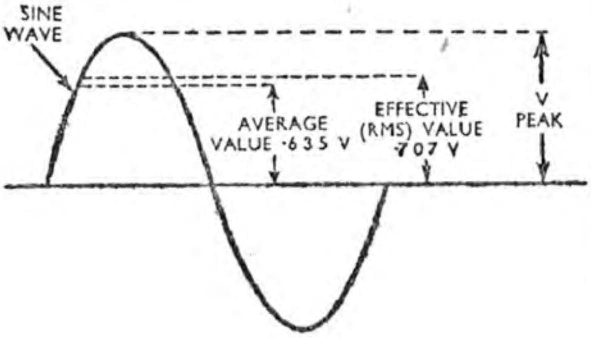


Fig. 230. Relationship between peak, RMS, and average values of alternating current.

relationship is only as shown for pure sine waves.

A peak valve voltmeter may be calibrated (or its calibrations converted) for RMS values by multiplying the peak values by ·707.

'Bucking' Meter Current. In some types of valve voltmeters where a standing or residual current flows through the anode meter, this current is 'bucked out' by applying a reverse voltage across the meter. By means of a variable resistor, the 'bucking' current is made exactly to cancel out the standing current, and so bring the meter needle to zero. Thus the whole length of the scale is available for voltage calibration. Fig. 231 shows two methods of applying this feature.

A way of obviating 'bucking' circuits is sometimes employed in valve voltmeters of the type shown in Fig. 229, and is accomplished by using a meter, the needle of which when at rest is at the right-hand end of the scale. When current is switched on, the needle moves to the left, which becomes a zero reading at a maximum anode-current reading. This point is calibrated as zero volts.

The input is arranged so that negative potentials are applied to the grid which reduce the anode current and bring the meter needle toward the right. The scale voltage calibrations increase, of course, from left to right.

This method not only does away with 'bucking' circuits, but also safeguards the meter against overloads, because the higher the voltage applied to the grid of the valve, the lower is the current flowing through the meter.

Tools and Leads. It is not inappropriate to conclude this section with a word on the importance, in workshop and laboratory, of having a proper set of tools and connecting leads. Too often people spend many pounds on oscillographs, oscillators and other instruments and baulk at the few extra pounds needed for the 'bits and pieces' that go with them.

For example, proper trimming tools permit trimmer adjustments to be done rapidly, without damage to the components, and ensure freedom from spurious magnetic or capacitive effects.

With the oscillograph in particular, it is necessary to employ correctly

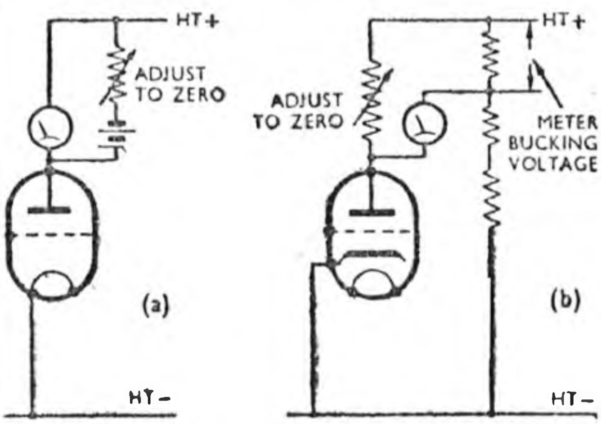


Fig. 231. (a) Battery and (b) mains versions of meter current bucking circuits.

screened and terminated leads if spurious effects are to be avoided. As long as there is possibility of these, the results of tests are difficult to interpret or misleading, and to obviate them, by makeshift methods, is a long and wearisome job.

Work is much quicker using leads properly fitted with clips, plugs and so forth, and chances of accident much reduced owing to the tidier terminations and neat insulation,

SECTION 17

PROPAGATION AND AERIALS

THE radiation from a transmitting aerial at ground level can be considered as made up of a 'ground wave', which is guided by the earth's surface, and a 'sky wave', which is propagated upward at an angle to the surface, and travels in the atmosphere.

Causes of Attenuation

The ground wave is attenuated at a rate which depends on the distance, the frequency, and on the electrical properties (dielectric constant and electrical conductivity) of that part of the earth's surface over which it is travelling.

The behaviour of the sky wave is governed by the presence of ionized layers of rarefied gas in the upper atmosphere, the *F* (or Heaviside) layer, at an average height of 60-70 miles, and the *E* (or Appleton) layer at a height of about 140 miles. Such ionized layers reflect electromagnetic waves in much the same way as does a conductor and, subject to certain conditions connected with the angle of incidence, the sky wave is reflected.

The heights, and the states of ionization in the layers, depend upon the radiations from the sun, and therefore they vary between day and night, with the seasons, and with solar phenomena, such as sunspots, causing corresponding variations in the propagation of electromagnetic waves. There are strong fluctuations with sunspot activity which have to be reckoned with.

The general features of the propagation depend upon the frequency range considered.

(*a*) Long wavelength (low-frequency, 20-600 Kc/s, waves). Over a range up to about 1,000 miles, most of the energy reaches the receiving station by way of the ground wave and, therefore, transmission is nearly independent of the time and the seasons.

At ranges of 2,000-4,000 miles, propagation is almost entirely due to the sky wave, and there are annual and seasonal variations in signal strength which follow changes in the *E* layer. In the intervening range, 1,000-2,000 miles, both the sky wave and the ground wave are received and, as their paths are different, they arrive in different phases. With changes in the height of the *E* layer, the phase of the reflected wave varies, and there may be strong fluctuations in signal strength between day and night.

Broadcasting Wavelengths

(*b*) Medium wavelength (medium frequency, 600-1,500 Kc/s, waves). The frequencies of the principal broadcasting stations lie within this band, and studies of the propagation have been chiefly concerned with the provision of good signal strength over a range of a few hundred miles by means of the ground waves, owing to the uncertainties of the sky wave.

Except over cities, the field strength can be predicted with reasonable accuracy from the known characteristics of the soil by means of standard formulæ.

(*c*) Short wavelength (high-frequency, 1,500-30,000 Kc/s, waves). The ground wave is highly attenuated, and long-distance propagation takes place almost entirely by way of the sky wave. It depends, therefore, on the frequency, the condition and height of the ionized layers, and the angle at which the waves meet the layers.

For any frequency, there is a critical angle of incidence, beyond which the wave passes through and fails to return. The angle becomes smaller, as frequency rises. When reflection does occur, there is a region between the ground wave area and the region where the reflected wave returns to earth, over which there is no reception (skip distance). Therefore, the greater the distance, the lower is the permissible frequency. The best frequency will depend upon the season and upon the time of day. (See Figs. 232 and 233.)

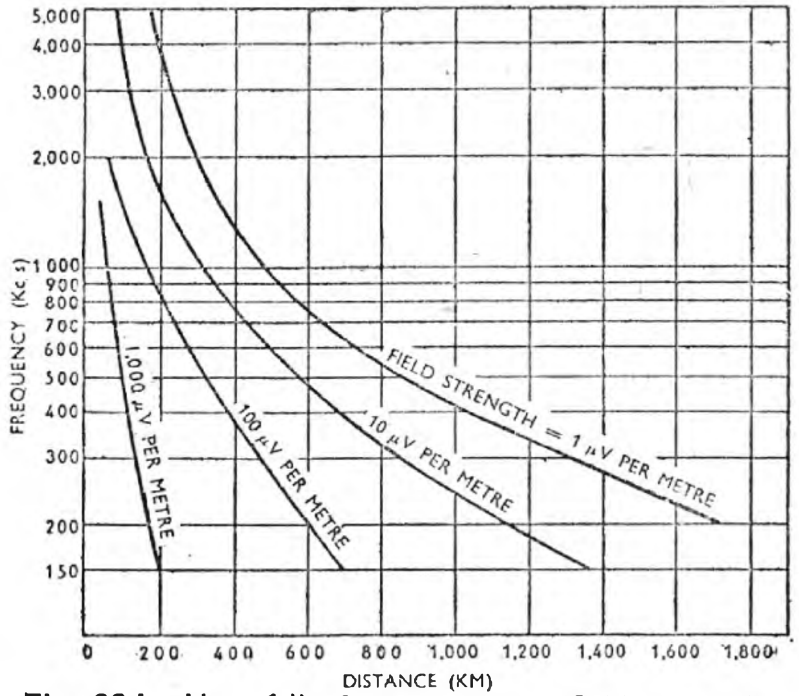


Fig. 234. How fall of ground wave field strength with distance varies with transmission frequency.

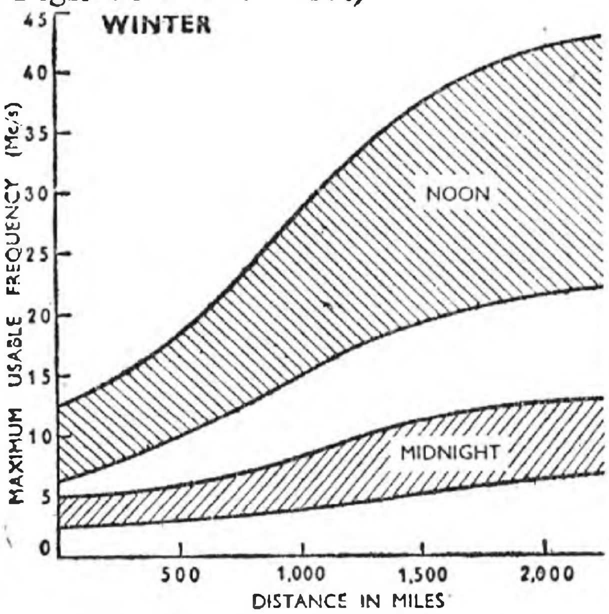


Fig. 232. Showing usable frequency band for short-wave distance communication at noon and midnight in winter.

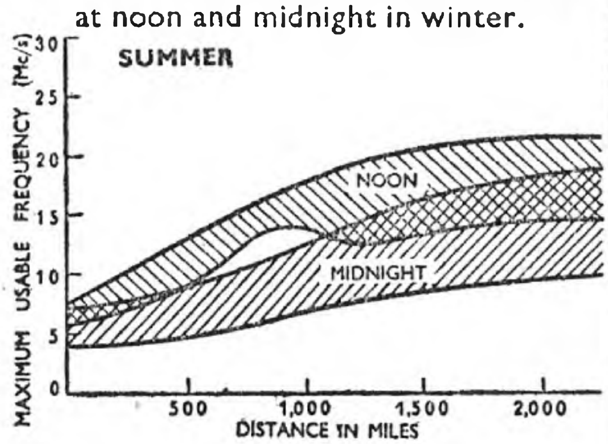


Fig. 233. In summer, the frequencies usable are more limited than in winter.

With very short waves, in the decimetre region, propagation is possible only over optical distances.

Propagation Data and Formulæ. The field strength in an electromagnetic wave is defined as the potential difference between two points in the wave front, one metre apart, and is usually measured in millivolts or microvolts per metre. This means that the EMF induced in a receiving aerial by the wave is obtained by multiplying the field strength by the effective height of the aerial in metres.

Ground-wave Propagation. The field strength F due to the ground wave from a vertical quarter-wave aerial is given by:

$$F = \frac{11{,}400 \quad \sqrt{WA}}{d} \text{ mV/metres,}$$

where W is power radiated (kilowatts), d is distance in kilometres, and A is an attenuation factor depending on the nature of the soil.

$$A = \frac{2 + 0{\cdot}3\,\rho}{2 + \rho + 0{\cdot}6\,\rho^2}, \text{ where}$$

$$\rho = \frac{9{\cdot}38 + 0{\cdot}621 \times 10^{-21} f^2 d}{\rho \times 10^{-9}},$$

ρ is the specific conductivity of the soil (mhos per cm cube), and f is the frequency in Kc/s per sec.

ρ varies from about 10^{-4} to 10^{-5} mhos per cm cube between soils of good and bad conductivity; its value for sea water is about 4×10^{-2}.

Fig. 234 shows the field strength in the ground wave, per kilowatt of power radiated, for soil of conductivity $\rho = 10^{-4}$ mhos per cm cube.

Long-distance Propagation. The curves (Figs. 232 and 233) show the maximum usable frequency for various distances, at different times and at different seasons of the year, where the propagation is by reflection from the ionized layers.

AERIALS

Half-wave Dipole. The fundamental type of aerial is the half-wave dipole. It is resonant to the transmitter frequency when its length is

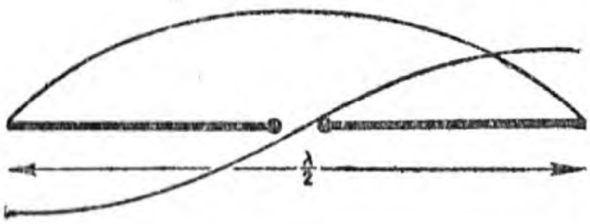


Fig. 235. Voltage and current distribution in a half-wave dipole.

about 95 per cent of the half wavelength (excluding the length of insulator at the middle), and the input impedance is then 70-80 ohms. The current is greatest at the centre, falling to zero at the ends, the distribution of current strength along the dipole following almost exactly a sine curve.

The voltage is lowest at the centre and has its greatest value at the ends (the curve in Fig. 235 represents the voltage at any point above the voltage where the feed is connected).

It is convenient for use at all wavelengths below a few metres, where its length becomes manageable, and it may be used vertically or horizontally. The intensity of radiation from it varies in the vertical plane in the first case and in both vertical and horizontal planes in the second case, in a manner which depends on its height above the ground and on the electrical characteristics of the soil.

In Fig. 236, the vertical (*a*) and horizontal (*b*) directivity curves for a vertical half-wave dipole in free space are shown.

Assuming a length equal to 95 per cent of the half wavelength, the length can be calculated from the formula, $L = \frac{468}{f}$ ft., where f is frequency in Mc/s.

Simple Reflectors. The directivity in the horizontal and vertical planes of a vertical half-wave dipole can be much improved by using a reflector, both for transmission and reception. The simplest type of reflector is a

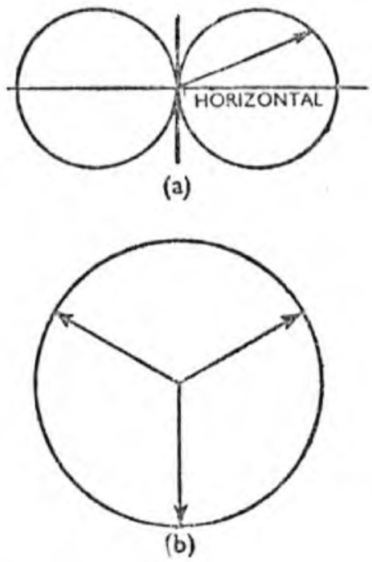


Fig. 236. Directivity curves of vertical dipole in free space. (a) Vertical directivity curve ; length of the arrow indicates the intensity of radiation in that direction. (b) Horizontal directivity curve; the dipole radiates equally well in all horizontal directions.

second dipole, in the form of a plain rod, mounted parallel to the 'active' dipole, and separated from it by one-quarter wavelength.

In the case of transmission, a current is induced in the reflector by the current in the excited dipole, and the reflector radiates. The effect of the spacing is that, on the line joining the dipoles, the two radiated waves are in phase on the side towards the excited dipole, and the total field strength is increased. On the side toward the reflector, the two radiated waves are in opposite phase, and annul each other. The polar diagrams for both vertical and horizontal directivity are shown in Figs. 237a and 237b respectively.

This system is used considerably in television reception. The line joining the two dipoles must point toward the transmitting station, the 'active' dipole being nearer to it. Then the wave passing the system sets up a current in the reflector,

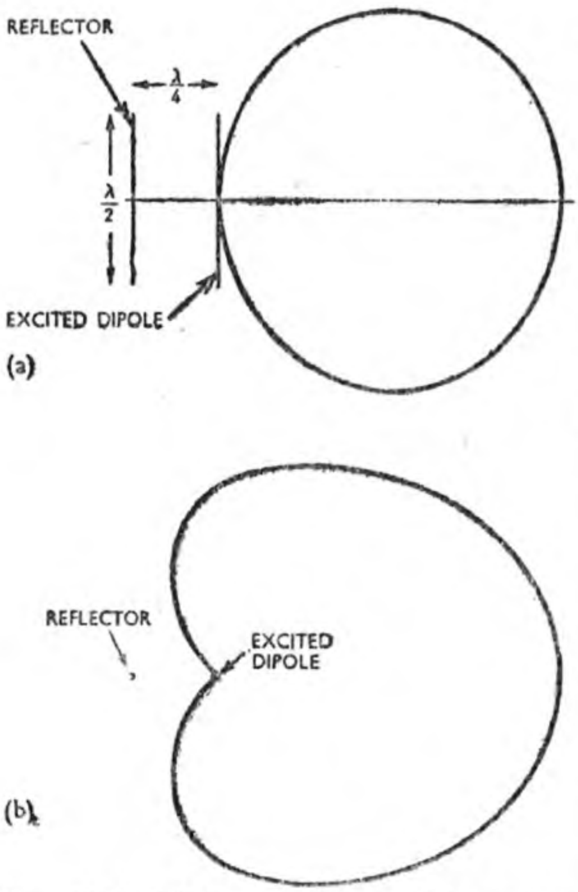


Fig. 237. (a) Vertical directivity curve of dipole with reflector. (b) Horizontal directivity curve of dipole with reflector.

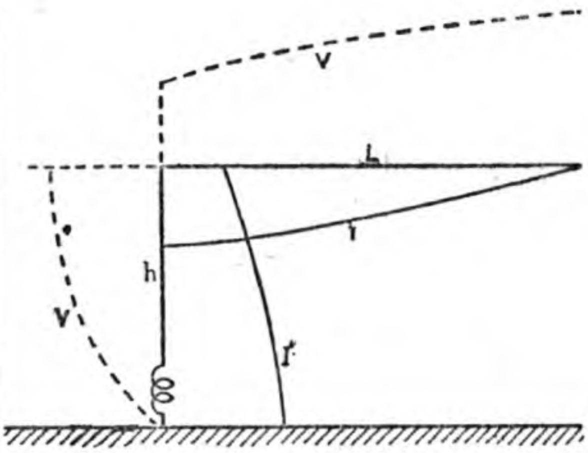


Fig. 238. Theoretic diagram showing *L* aerial with added curves representing current and voltage distribution.

which re-radiates, and produces a current in the active dipole in phase with that set up by the direct wave. The result is equivalent to an increase in signal strength.

Such dipoles are usually made with copper tube, of about ½ in. diameter, cadmium plated to prevent corrosion. They should be mounted as high above the earth's surface as possible.

The Marconi Aerial. At lower frequencies where the dipole is too cumbersome, the simplest type of aerial is the Marconi or $\lambda/4$ aerial. This consists of a vertical wire (or a tower or mast in the case of transmitting aerials) one-quarter wavelength long, whose lower end is earthed, the feed being between two points close to the earthed end.

The radiated field is that which would be obtained from the aerial and an 'image' in the surface of the earth. The radiated field is greatest over a perfectly conducting earth and, to increase the conductivity in the neighbourhood of the aerial, a network of copper wires is usually buried below the aerial, radiating out from it.

The distributions of current and voltage are similar to those in the upper half of a half-wave dipole, but in any actual case they will be influenced by the nature of the soil in the neighbourhood of the foot of the aerial. Marconi aerials of this or similar types, frequently in the form of self-supporting masts, are used for broadcasting at medium frequencies. The aerial, being vertical, radiates equally well in all horizontal directions.

At lower frequencies, the wavelength becomes too great for the length of the aerial to be made a quarter wavelength, and it must be tuned by adding inductance or capacitance at the base. In transmitting aerials, tuning is necessary in order to obtain maximum current in the aerial, and at medium and low frequencies it is desirable that the current in the vertical part should be as large and as uniform as possible to obtain maximum radiation.

To obtain an approximately uniform current, a horizontal top section or 'roof' is added to the aerial, giving it the well-known T or L form (Fig. 238). The radiation takes place principally from the vertical portion, the top part providing a large capacitance to earth.

Receiving Aerials. The aerial usually used for domestic reception of broadcasting is the L or the T aerial. The purpose of the vertical portion is to provide a conductor parallel to the electric lines of force in the electromagnetic wave, which induce an EMF in the vertical portion. The greater the height, up to a half-wave in length, the greater is the EMF, which may be calculated by multiplying the field strength, in volts per metre, by the 'effective height' of the aerial.

The effective height is less than the actual height by a factor which depends on the shape of the aerial and on its situation with respect to buildings, and other factors altering the electrical characteristics of the aerial. The presence of the horizontal portion increases the effective height, and the greater its length, the more nearly does the effective height approach the actual height.

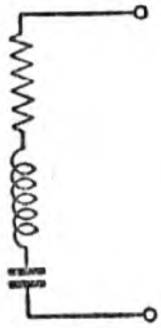


Fig. 239. Components of standard artificial aerial.

For an L aerial in a clear position, effective height = actual height × form factor.

Table LXVIII shows the form factor for various values of the ratio L/h.

TABLE LXVIII

L/h	Form Factor
0·5	0·830
1·0	0·904
2·0	0·958
5·0	0·993

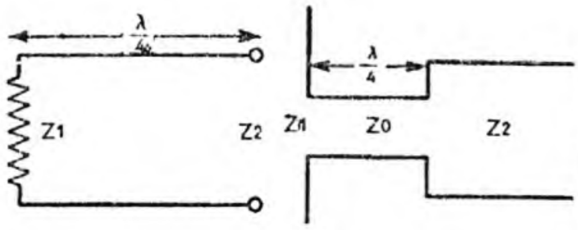
In the case of receiving aerials, it is permissible to use only a limited length of wire (100 ft.), and it is evident that the vertical height should be as great as possible. But where, as is usual, the vertical height is limited by the situation, it is advantageous to use the horizontal portion, although little is to be gained by making it more than about twice the vertical height.

Copper or phosphor-bronze wire should be used, and for preference it should be stranded.

The L aerial has slight directional properties, the best reception being obtained if the length of the aerial is directed toward the transmitting station, with the 'elbow' nearest to it.

The aerial-tuning circuits of receivers, for use with domestic aerials, which may differ widely in their properties, are usually designed for an assumed standard aerial, which is equivalent to an average L aerial.

The equivalent circuit of this artificial aerial for medium and long waves is shown in Fig. 239. For short waves, the artificial aerial is taken as equivalent to a resistance of 400 ohms. 'Dummy aerials', incorporating components of these values, are



Figs. 240-241. Maximum power is delivered to an aerial by using matching devices.

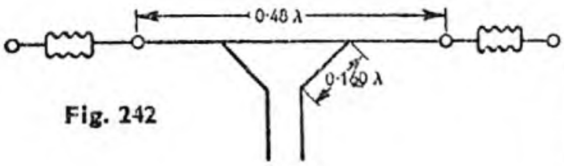


Fig. 242

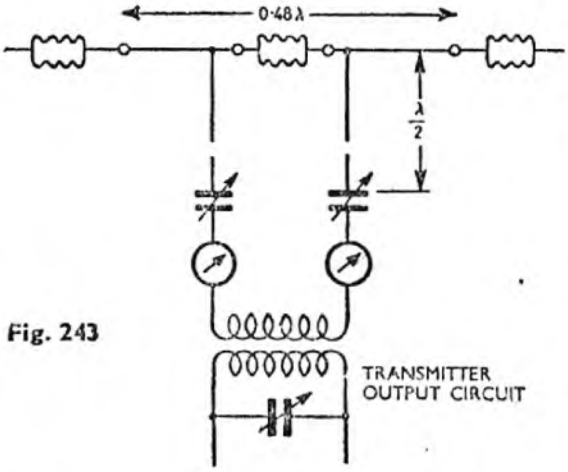


Fig. 243

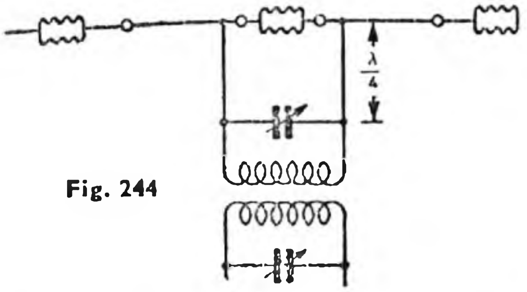


Fig. 244

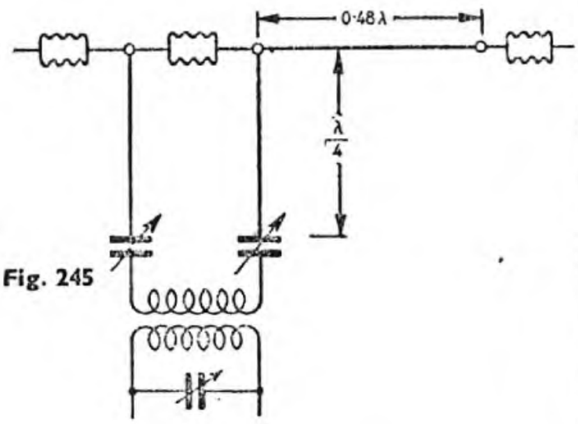


Fig. 245

Figs. 242-245. Feeder circuits for coupling transmitter, or receiver, to aerial.

used with signal generators for aligning receivers.

Matching Devices for Transmission Lines. In order that a transmission line may deliver maximum power to the aerial which it is feeding, the load on the line must be equal to its characteristic impedance. Thus if a half-wave dipole, whose input resistance is 75 ohms, is fed by a 600-ohm twin transmission line, some matching device is needed between the line and the dipole which will make the effective load on the former 600 ohms. Some matching devices which are used are:

(1) Quarter-wave transformer.

If a length of feeder one-quarter wavelength long is loaded by an impedance Z_1 (Fig. 240), then the transferred impedance across the other end is $Z_2 = \frac{Z_0^2}{Z_1}$, where Z_0 is the characteristic impedance. To match a dipole to a feeder line of characteristic impedance Z_2 (Fig. 241), a quarter wavelength of feeder of characteristic impedance Z_0, calculated from this formula, is interposed.

(2) Delta match.

The feeder may be fanned out. Dimensions are given for a 600-ohm feeder (Fig. 242).

(3) Current-fed (centre-fed) half-wave dipole with half-wavelength tuned feeder (Fig. 243).

The capacitors are adjusted for maximum current.

(4) Current-fed (centre-fed) half-wave dipole with quarter-wavelength tuned feeder (Fig. 244).

The arrangements in Figs. 242, 243 and 244 are used where it is possible to place the aerial close to the transmitter.

(5) End-fed (voltage-fed) half-wave dipole, with quarter-wavelength tuned feeder (Zeppelin aerial) (Fig. 245).

In this arrangement, only one wire of the feeder is actually transferring energy. The presence of the second keeps radiation from the feeder low.

PROPERTIES OF

Material	Dielectric Constant	Power Factor	Frequency (Mc/sec)	Dielectric Strength (kV/mm)	
Amber	2·8	0·002	1	—	(1)
Bakelite (mouldings)	5–11	0·02–0·06	3	—	(2)
Bakelite laminated (paper base)	5	0·04	—	10	(3)
Bakelite laminated (fabric base)	6	0·03	—	10	(4)
Beetle, Calan	6·5	0·004	10	40	(5)
Calit	6·5	0·0004	—	—	(6)
Cellulose acetate	4–4·8	0·06–0·08	3	—	(7)
Conda N	40–50	0·00055	—	—	(8)
Conda S	80–100	0·00041	—	—	(9)
Cotton, varnished	3	High	—	—	(10)
Diakon, Perspex	2·8	0·02	1	20	(11)
Ebonite, pure	3·0	0·009	1	150	(12)
Ebonite, mineral loaded ..	4·5	0·03	1	85	(13)
Ebonite, silica loaded	3·5	0·007	1	80	(14)
Empire cloth	4–6	—	—	—	(15)
Frequentite	6	0·0008	10	50	(16)
Frequelex	6	0·0006	3	—	(17)
Faradex	80	0·0003	3	—	(18)
Glass	3–4·5	High	—	—	(19)
Guttapercha	8	—	—	—	(20)
Isolantite	6	0·0018	3	—	(21)
Kerafar	80	0·001	1	—	(22)
Keramot	3·6	0·010	1	—	(23)
Marble	8	High	—	—	(24)
Mica	7	0·0002	10	50	(25)
Micanite	7	Poor	—	—	(26)
Mycalex	6·5	0·011	1	14	(27)
Paper, dry	1·5–2·5	—	—	—	(28)
Paper, impregnated	2·5–4·0	—	—	—	(29)
Paraffin wax	2·2	0·0001	1	20	(30)
Paxolin	2	0·05	—	—	(31)
Permalex	80	0·0013	—	—	(32)
Permitel	5	0·01	—	—	(33)
Phenol fibre	6	Poor	—	—	(34)
Porcelain	5·5	0·008	1	—	(35)
Polystyrene	2·5	0·0003	1	30	(36)
Polyethylene	2·2	0·0006	3	—	(37)
Polyisobutylene	2·5	0·0005	3	—	(38)
Pyrex	4·5	0·00017	3	—	(39)
Quartz, fused	3·8	0·0002	1	20	(40)
Rubber, pure	2·2–2·4	—	—	—	(41)
Rubber, vulcanized	3·0–3·5	—	—	—	(42)
Shellac	3·0–3·5	—	—	—	(43)
Silvonite	3	0·009	—	—	(44)
Slate	6	High	—	—	(45)
Steatite	6·1	0·002	—	—	(46)
Tempas	16	0·0005	3	—	(47)
Transformer oil	2·2	0·0001	3	—	(48)
Trolitul	2·2	0·0004	3	—	(49)
Tufnol	5	0·03	—	—	(50)
Ultra-calan	7·1	0·0001	—	—	(51)
Vinyl chloride	4·5–6·5	0·04–0·1	3	—	(52)

NOTE.—*The figures in parentheses are for quick reference and to facilitate reading across the pages.*

INSULATING MATERIALS

	Volume Resistivity (Ohm/cm)	Surface Resistivity (Ohm/cm sq.)	Water Absorption (per cent)	Nature and Chief Constituent
(1)	10^{17}	10^{14}	—	Natural resin
(2)	10^{5}	—	0·1–1·2	Phenol formaldehyde (synthetic resin)
(3)	10^{11}	10^{12}	—	—
(4)	10^{12}	10^{12}	—	—
(5)	—	—	—	Finely divided mica
(6)	—	—	—	—
(7)	$4{\cdot}5 \times 10^{10}$	—	—	—
(8)	—	—	—	—
(9)	—	—	—	—
(10)	4×10^{8}	—	—	—
(11)	10^{16}	10^{14}	0·4	Methyl methacrylate
(12)	10^{16}	10^{9}–10^{15}	—	Rubber and sulphur
(13)	10^{14}	—	—	—
(14)	—	—	—	—
(15)	—	4×10^{8}	—	—
(16)	10^{15}–10^{17}	—	—	Magnesium silicate
(17)	10^{20}	—	—	—
(18)	—	—	—	Ceramic (rutile)
(19)	10^{7}–10^{9}	10^{13}	—	—
(20)	4×10^{8}	—	—	—
(21)	10^{17}	—	—	—
(22)	—	—	—	Ceramic (rutile)
(23)	—	10^{13}	—	—
(24)	10^{6}–10^{8}	—	—	—
(25)	10^{17}	10^{11}	—	—
(26)	3×10^{9}	—	—	Mica
(27)	10^{13}	4×10^{0}	0–0·2	Mica
(28)	10^{5}	—	—	—
(29)	10^{8}	—	—	—
(30)	10^{17}	10^{16}	—	—
(31)	10^{12}	—	—	—
(32)	—	—	—	—
(33)	—	—	—	Chlorinated diphenyl
(34)	—	—	0·3–9·0	Phenol formaldehyde
(35)	10^{14}	—	—	—
(36)	10^{20}	10^{14}	Nil	Plastic
(37)	10^{17}	3×10^{16}	Nil	Plastic
(38)	10^{16}	2×10^{15}	Nil	Plastic
(39)	10^{14}	—	—	—
(40)	10^{17}	10^{13}	—	—
(41)	10^{16}	—	—	—
(42)	5×10^{9}	—	—	—
(43)	5×10^{9}	—	—	—
(44)	10^{16}	—	—	—
(45)	$2{\cdot}5 \times 10^{6}$	—	—	—
(46)	10^{14}–10^{15}	—	—	—
(47)	—	—	—	—
(48)	—	—	—	—
(49)	—	—	—	—
(50)	10^{12}	—	—	—
(51)	—	—	—	—
(52)	3×10^{12}	2×10^{11}	0·2	Plastic

SECTION 19

TRIGONOMETRIC RATIOS

THE circle is divided into 360 degrees and each degree is divided as follows:

1 degree = 60 minutes,
1 minute = 60 seconds.

If two diameters divide a circle into four equal parts, the four angles at the intersection are $\frac{360^\circ}{4} = 90^\circ$, and are known as right angles.

The circumference of a circle divided by its diameter is a fixed ratio known as π ('pi'). π is an indeterminable non-recurring decimal but, to five places of decimals, the value is 3·14159.

The area of a circle is $\frac{\pi d^2}{4}$, or πr^2, where r is the radius and d the diameter ($r = \frac{1}{2}d$).

Any angle, θ ('theta'), in a right-angle triangle may be measured in terms of the ratio of one side to another. (See Fig. 246a.)

Ratio $\frac{c}{a}$ is the *sine* of the angle;

" $\frac{b}{a}$ is the *cosine* of the angle;

" $\frac{c}{b}$ is the *tangent* of the angle.

Their reciprocals are:

$\frac{a}{c}$ is the *cosecant* of the angle;

$\frac{a}{b}$ is the *secant* of the angle;

$\frac{b}{c}$ is the *cotangent* of the angle.

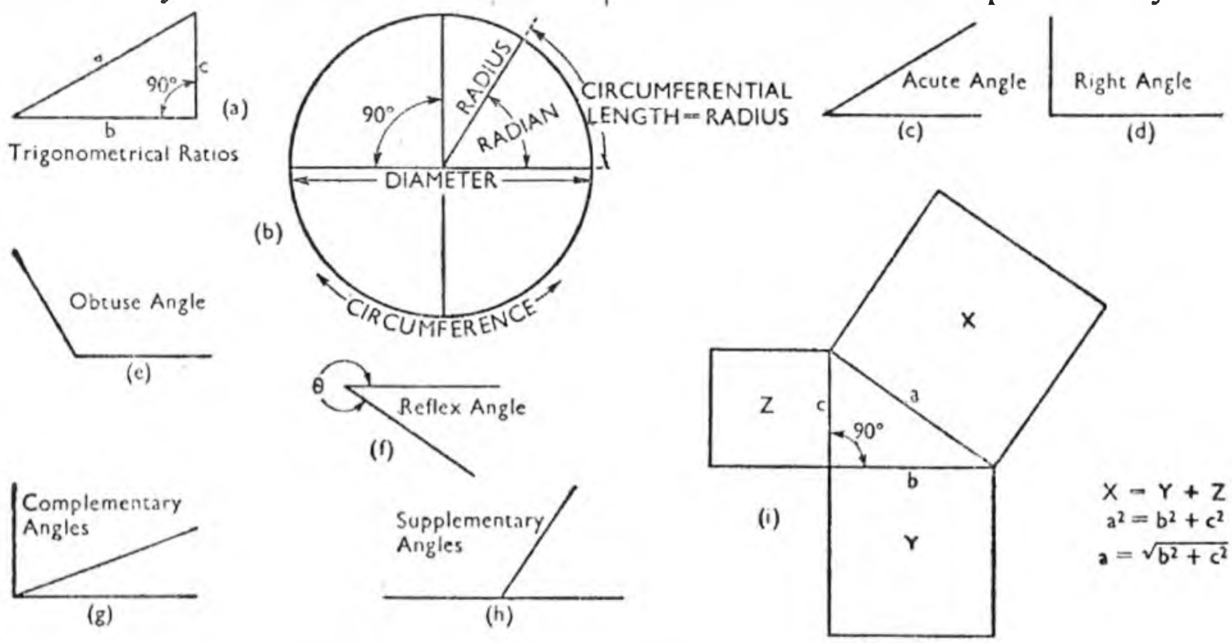
Angles may be measured in radians. A radian is an angle formed between lines drawn from the centre of a circle to points on its circumference which are separated by a circumferential length equal to the radius of the circle. (See Fig. 246b.)

Since circumference $= 2\pi \times$ radius, there are 2π radians in a circle, or

$$360^\circ = 2\pi \text{ radians;}$$
$$180^\circ = \pi \text{ radians;}$$
$$90^\circ = \frac{\pi}{2} \text{ radians;}$$

and one radian = 57·3° (approx.).

(c), (d), (e), (f), (g), and (h) in the diagram above give pictorial definitions of terms used in geometry as well as illustrating the fact that the sum of the squares of the lengths of the two shorter sides of a right-angle triangle is equal to the square of the length of the longest side.



PICTORIAL DEFINITIONS OF ANGLES

Fig. 246. Self-explanatory diagrams showing geometrical terms in frequent use.

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