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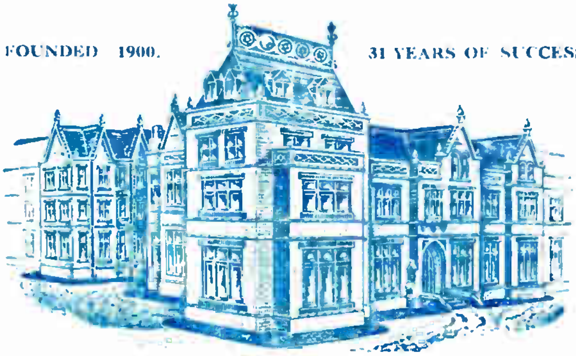


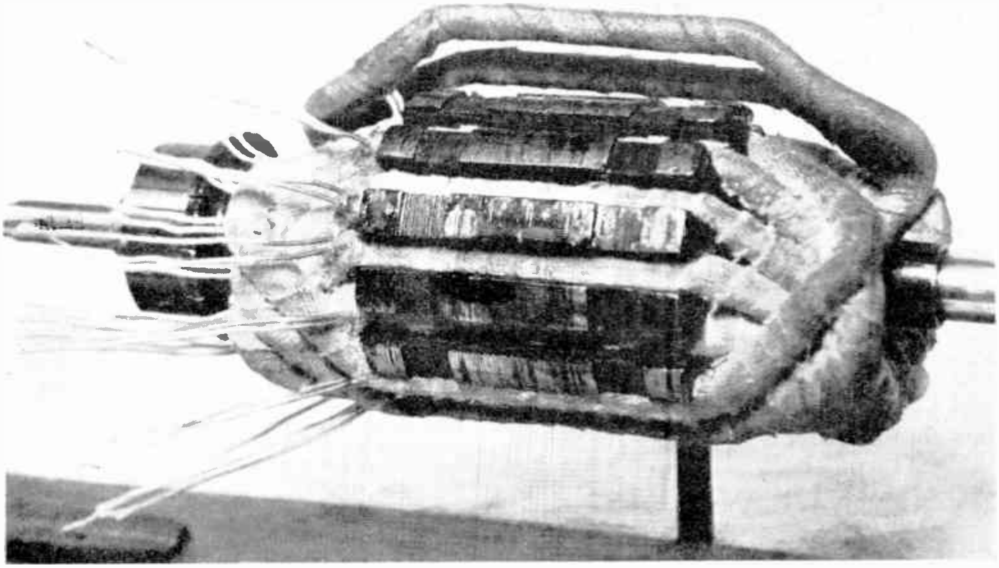


Fig. 10.—The Partially Assembled Armature.
Showing the stage when the last four coils have to be laid under the first four.

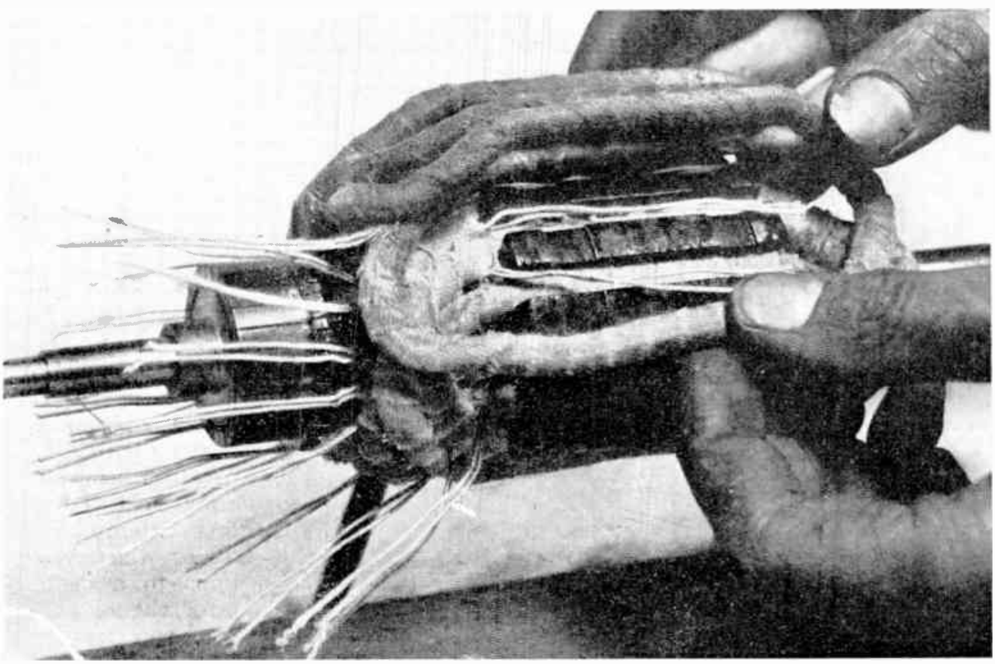


Fig. 11.—Inserting the Last Coil.
In order to do this it is necessary to raise up the first part of the winding. Note how the leads are bent back over the armature.

A

The slots in the commutator risers are already tinned from the previous winding. The ends are not twisted together but are put into the slots in the risers one on top of the other. The wire should fit tightly in the slots unless the gauge has been made smaller for a higher voltage. Where the armature is to be rewound with thicker wire for a lower voltage, it will be necessary to enlarge these slots before putting any wire on the armature.

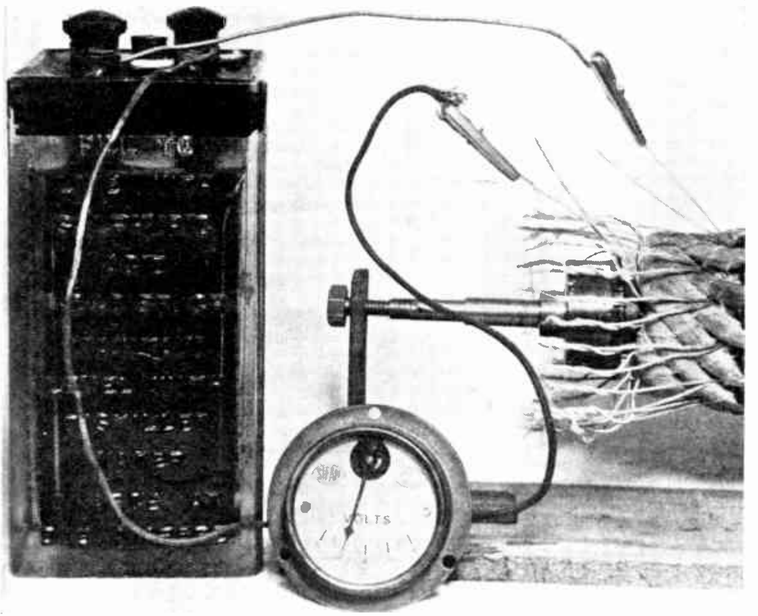


Fig. 12.—How to Identify the Pairs of Ends to Each Coil.
Showing a simple method when there is more than one section to each coil.

Fig. 15 shows the operation of soldering the connections to the commutator. The narrow side of the bit should be used so as to heat up only one segment at a time, or the previous connections may be loosened, besides taking an unnecessary amount of heat from the iron.

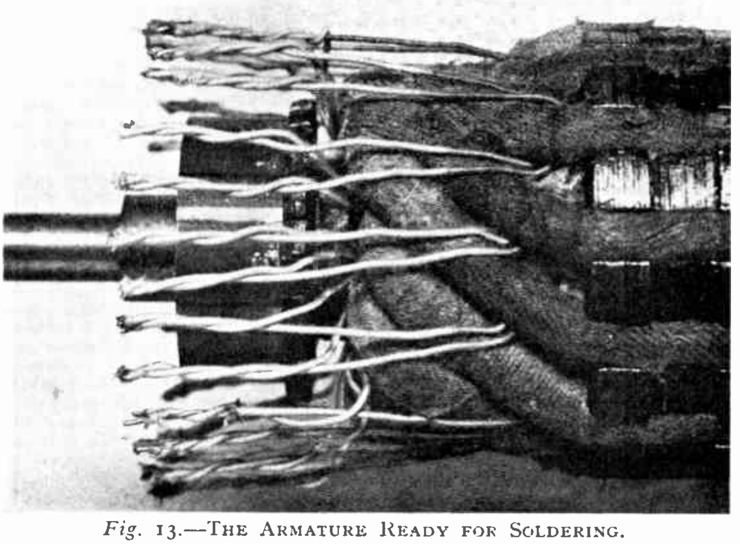


Fig. 13.—The Armature Ready for Soldering.
Showing the leads of the coils twisted in pairs and placed in order ready for soldering to the commutator.

Do not attempt to solder the wires to the commutator with a soldering iron having a copper bit of less than one pound. If the job is attempted with a small soldering iron the copper bars of the commutator will conduct all the heat from the bit and cool it rapidly to a temperature below soldering heat. If, on first attempting to solder the connections to a commutator, the solder does not run properly, then either the bit is not hot enough or else the commutator is dirty. Make sure that the soldering iron is kept clean and properly tinned. Do not allow the iron to become overheated and avoid placing the iron in an open fire, rather heat it on a gas ring.

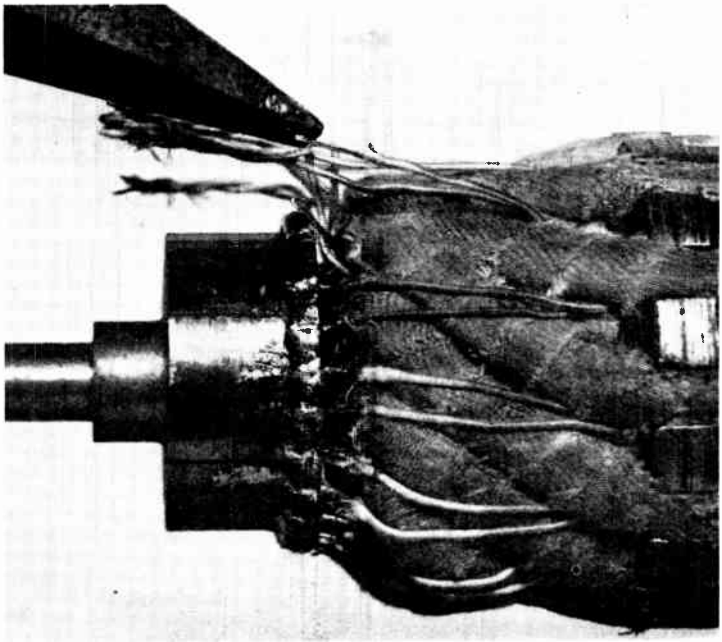


Fig. 14.—TINNING A LEAD BEFORE SOLDERING IN POSITION.
This ensures a sound joint. Do not use soldering spirits or paste for any of the soldering operations; use only resin or resin dissolved in methylated spirit.

Finishing Off.

When the armature has been connected up, the end windings and the portions of the coils in the slots are bound with tinned copper or steel wire. Before the binding wire is put on, a layer of thin presspahn is wound round to protect the winding from the binders.

The binders are prevented from becoming loose by running the turns together with solder. As the binders are tinned wire there is no difficulty in making them solid with solder. After this the armature is, if necessary, varnished and baked. The moisture in the windings is first expelled by baking the armature as a whole for one or two hours according to size. It is very necessary to expel the moisture before impregnating the armature with insulating varnish or the moisture will be permanently imprisoned in the winding and thus cause low insulation. To drive out the moisture the baking temperature should be kept between 200-220 degrees Fahrenheit. A higher temperature is liable to char the insulation. Finally, the superfluous solder is turned off in a lathe and the commutator also turned and polished if necessary.

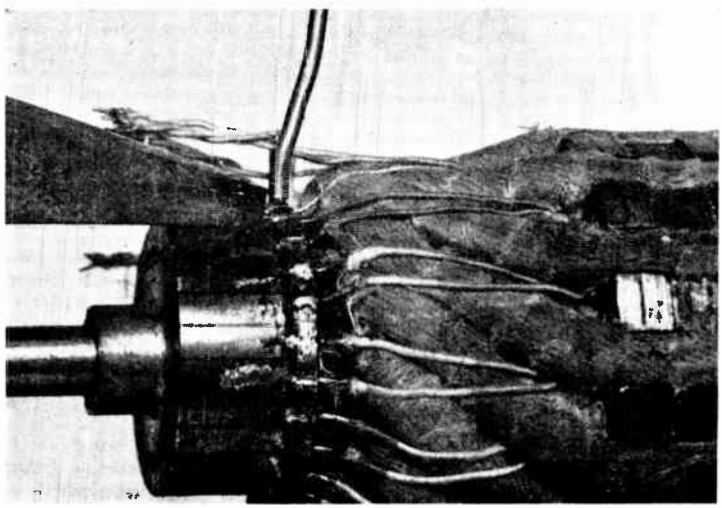


Fig. 15.—SOLDERING ONE OF THE CONNECTIONS TO THE COMMUTATOR.
Resin-cored solder gives a clean joint.

ELECTRIC TRAMWAYS AND TROLLEY-BUS SYSTEMS

OPERATING CONDITIONS

By A. T. Dover, M.I.E.E.

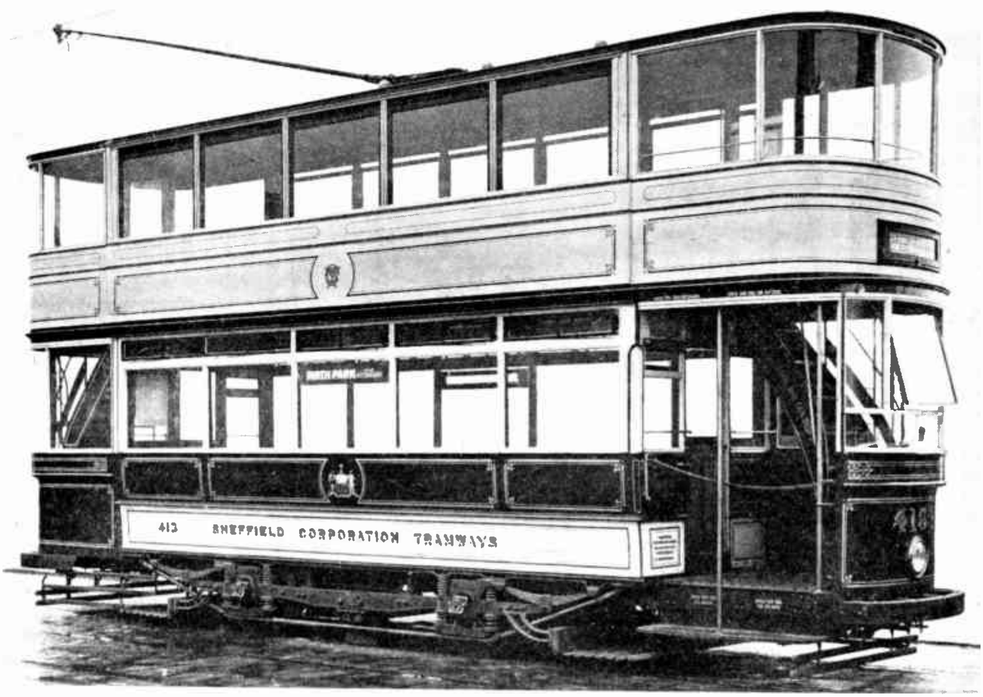


Fig. 1.—A Typical Electric Tramcar. (*Brush Electrical Engineering Co.*)
Tramcars are designed for double-end operation and the car body must be provided with loading platforms, staircases, controllers, brake gear, sanders, gongs and life-guards at both ends.

How the Two Systems Differ.

An *electric tramway system* operates cars on rails laid along ordinary roads, with the tread or surface of the rails flush with the road surface in order that the road may be used by other vehicles. The cars are equipped with motors, control gear, current collectors and brakes: they receive energy either from overhead contact wires (*overhead system*) or underground contact rails (*conduit system*). With the overhead system two contact wires (called *trolley wires*) of the same polarity are usually provided along each route on which a two-way service of cars is run, and the track rails are used as the return conductors.

A *trolley-bus* (trackless trolley) *system* operates cars along ordinary roads, i.e., no special track is necessary. The cars are equipped with motors, control gear, current collectors and brakes: they receive energy from overhead contact

Fig. 2.—One of the Latest Six-wheel Trolley-buses. (*English Electric Co.*)
The trolley-collectors are supported on a steel framework which is clear of the roof and is incorporated with the body framing

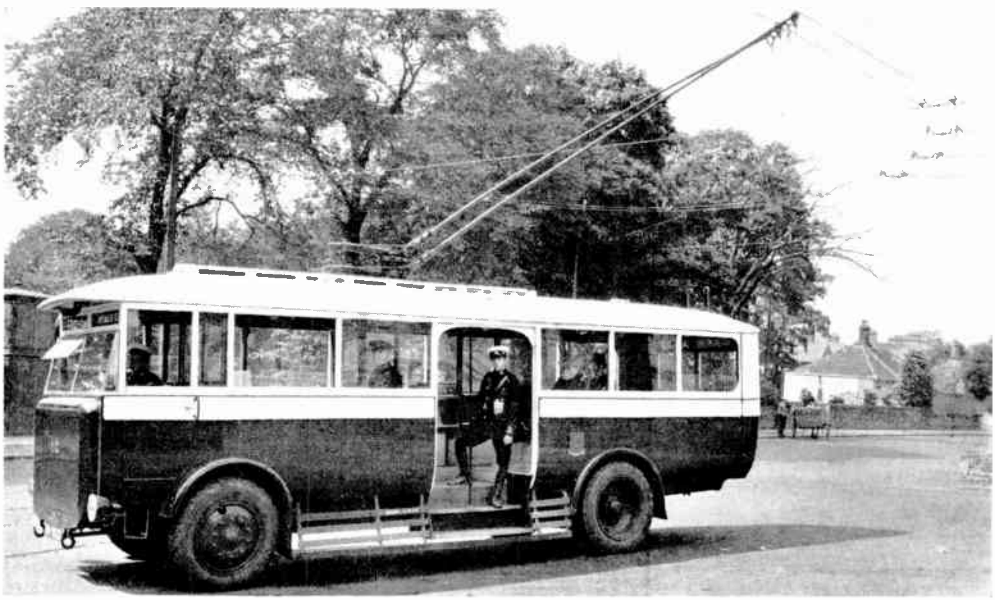


Fig. 3.—A Single-Deck Trolley-Bus. (*B.-T.-H. Co.*)
This view shows also the overhead wi-ing at a terminus

wires, of which two pairs of wires (two positive and two negative) are usually installed along each route on which a two-way service of cars is run.

Spheres of Operation.

A tramway system, in consequence of the large initial expenditure on the track, should be used for handling heavy traffic in large towns, as a remunerative return on the invested capital is thereby assured. Tramcars are better suited for this traffic than buses on account of the larger number of passengers which can be carried on the former vehicle. Hence fewer vehicles are required for a given volume of traffic.

A trolley-bus system is better suited for light traffic in towns and country districts; in fact, this system is the natural means of extending a tramway system to suburban and country districts. Trolley-buses are also desirable in busy towns with narrow streets where cars running on rails would be at a disadvantage and add to the traffic congestion.

Responsibility of Tramway Authority for Road Maintenance.

A tramway authority is responsible for the maintenance not only of the track rails, but also of the road surface between the rails and a width of 15 inches on each side of the track.

A trolley-bus authority is not responsible for the maintenance of the road surface on which its vehicles run, and is therefore relieved of the heavy track and road charges with which a tramway system is saddled. On the other hand, each trolley-bus has to pay an annual licence, from which grants are made to local authorities for general road maintenance and improvements.

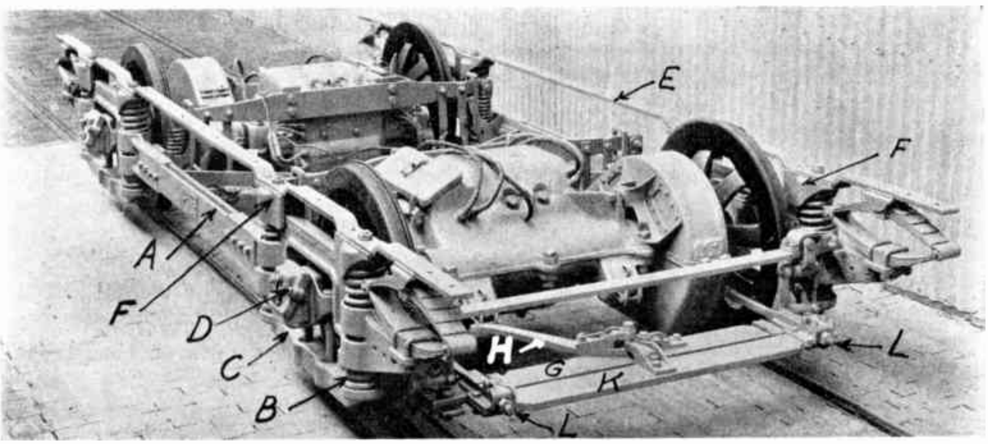


Fig. 4.—THE UNDER-CARRIAGE OF A TRAMCAR.

Showing a single truck. *A*, rigid steel frame; *B*, spiral springs; *C*, sub-frames; *D*, axle-box; *E*, longitudinal "top plate"; *F*, special thrust blocks, of which there are eight; *G*, brake beam; *H*, brake lever; *K*, equalising lever; *L*, rod connecting outer transverse bars.

SOME CONSTRUCTIONAL DETAILS OF TRAMCARS AND TROLLEY-BUSES.

Car Bodies.

Tramcars are designed for double-end operation, and the car body must be provided with loading platforms, staircases (on double-deck cars), controllers, brake gear, sanders, gongs and life-guards at both ends.

Trolley-buses are always designed for single-end operation, and the loading platforms, staircases, control and brake gear do not require duplication. But owing to the necessity of steering gear the controller has to be arranged for foot operation. Again, a trolley-bus requires two current collectors or trolleys, compared with a single trolley on a tramcar, and in consequence the roof of a trolley-bus must be stronger than that of a tramcar.

In both vehicles the skeleton or framing of the car body is built up of timber and steel, with aluminium for the outer panels. The roof of the lower saloon consists, in many cases, of a single piece of 7-ply wood; that of the upper saloon is also made of plywood and is covered on the outside with waterproofed canvas. The trolley collectors of the bus are supported on a steel framework, which is incorporated into the body framing, but the single trolley collector of the tramcar is usually supported on a plank bolted to the roof.

The differences in body construction are well shown in Figs. 1, 2, 3.

Differences in Chassis Construction.

Some striking differences in construction occur in the under-carriage or chassis which supports the body and carries the wheels and motors. These differences are due to: (1) the front or leading wheels of a trolley-bus must be provided with steering gear; (2) the back wheels of a bus are driven collectively by a cardan shaft and, accordingly, differential gearing is necessary in the back axle to enable the wheels to rotate at different speeds when rounding curves (thereby preventing skidding); (3) heavy and powerful vehicles must have duplicate back axles, i.e., four driving wheels, in order to obtain suitable loads and tractive conditions on these wheels.

UNDER-CARRIAGE OF TRAMCAR.

This may consist either of a single truck with two axles or a pair of bogie (or swivelling) trucks, each having two axles. The choice depends upon the length of car body and radius of sharpest curve on the track. Single trucks are suitable for small and medium car bodies and tracks with moderate curvature. Bogie trucks are suitable for large car bodies and tracks with sharp curves.

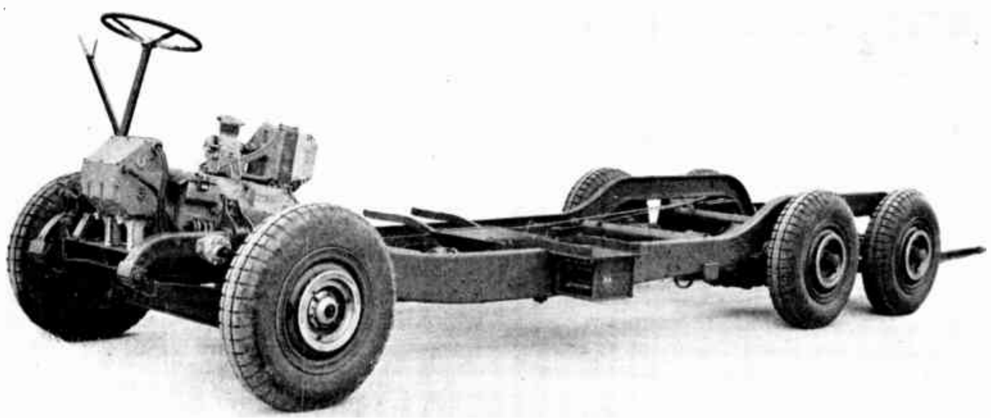


Fig. 5.—TYPICAL CHASSIS OF A TROLLEY-BUS.
Similar in design to that of the latest six-wheel petrol-driven bus.
(*English Electric and Associated Equipment Cos.*)

Single Truck.

A single truck is illustrated in Fig. 4. This illustration shows the truck complete with motors, and ready for the car body to be fixed in position. The truck consists of a rigid steel frame *A*, which is supported by spiral springs *B*, resting on sub-frames *C*. These sub-frames are suspended from the axle boxes *D* by links. With this arrangement the axle boxes (which contain the bearings for the axles) are allowed a certain amount of transverse movement relative to the truck frame, and in consequence the truck is able to negotiate curves with less wheel

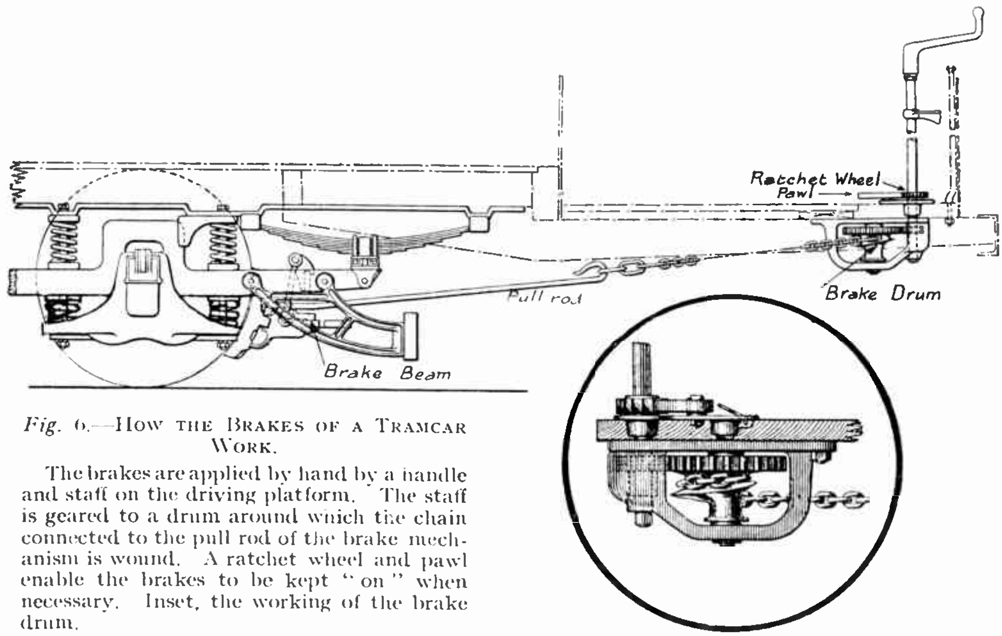


Fig. 6.—HOW THE BRAKES OF A TRAMCAR WORK.

The brakes are applied by hand by a handle and staff on the driving platform. The staff is geared to a drum around which the chain connected to the pull rod of the brake mechanism is wound. A ratchet wheel and pawl enable the brakes to be kept "on" when necessary. Inset, the working of the brake drum.

slippage than one in which the axle boxes work in machined guides and are not allowed to move transversely.

The car body is fixed to longitudinal "top plates" *E*, which are supported on the truck frame by a compound spring system, of spiral and laminated springs, designed to give easy riding and freedom from oscillations. In cars with considerable overhang and short wheel base the elliptic springs are replaced by semi-elliptic springs. The thrusts between car body and truck are taken by special thrust blocks *F*, of which there are eight.

Each axle is driven by a separate motor, and the power is transmitted through spur gearing. This method of driving necessitates supporting one side of the motor on the axle by suitable bearings. The other side of the motor is spring-supported from the truck frame by a transverse bar, which can be seen in Fig. 4.

Bogie Trucks.

The car body is not rigidly fixed to the truck framing, as above, but is supported on the bogies at two "points" only, viz., one "point" in the centre of each truck. The points of support (called "swivelling centres") allow the trucks to swivel independently and so adjust themselves to the curvature of the track. Each swivelling centre rests on a "bolster," which floats on springs fitted in the truck frame and is provided with guides through which the thrust is transmitted. Each truck is equipped with either one or two motors. In the latter case the pivotal centre is midway between the axles and all wheels are of the same diameter; but in the former case the pivotal centre is nearer the driving axle and the wheels of the non-driven axle are usually of smaller diameter than the driving wheels, as, due to the unsymmetrical pivotal centre, these wheels swing under the car body when the car rounds a curve.

CHASSIS OF A TROLLEY-BUS.

This is very similar to that of a petrol-propelled bus. It is built up of pressed steel with cast steel brackets for the spring shackles, brake gear, etc. The springs at both front and rear are of the semi-elliptic pattern. The motor, or motors, are fixed in the forward part of the chassis and transmit power to the back axle through a cardan shaft, flexible couplings and differential gear, similar to the drive on a petrol-propelled vehicle. When two motors are used (in order to obtain more efficient speed control) they are always arranged in tandem and are usually built with a common frame and a single shaft.

A Typical Chassis.

A typical chassis is illustrated in Fig. 5. This chassis is of similar design to that of the latest six-wheel petrol-driven bus. The single motor is mounted forward, in practically the same position as the petrol engine; the controller is mounted forward of the motor; the electrically driven air compressor (for the brakes) is mounted on the top of the motor; and the rheostats are mounted on the side frame of the chassis.

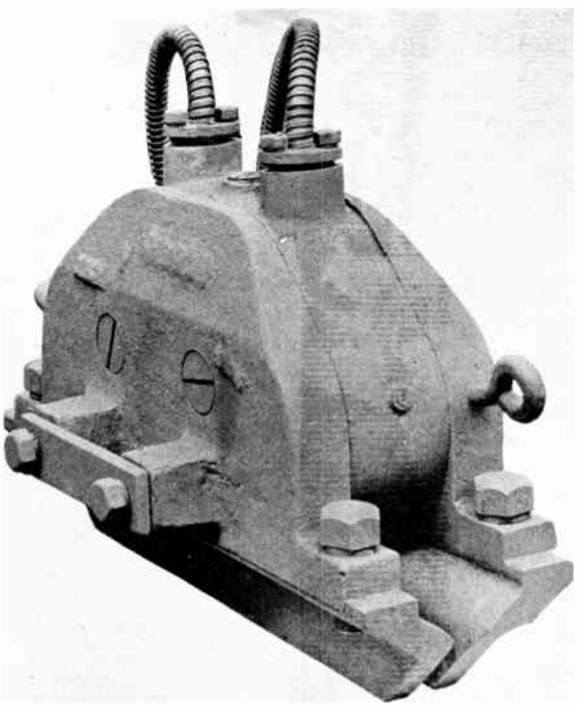


Fig. 7.—ELECTRO-MAGNET USED FOR BRAKING ON A TRAMCAR. (*B.T.-H. Co.*)
Showing the water-tight metal case in which is enclosed the single coil which supplies the excitation.

BRAKES ON TRAMCARS.

All tramcars in this country must be fitted with both wheel brakes and an electric brake which can be applied step by step. When gradients are steeper than 1 in 15 a track brake is also necessary.

Wheel Brakes on a Tramcar.

These are applied by hand by a handle and staff on the driving platform. The staff is geared to a drum around which the chain connected to the pull rod of the brake mechanism is wound. A ratchet wheel and pawl enable the brakes to be kept "on" when necessary. The general arrangement is shown in Fig. 6.

A separate brake block, or shoe, is provided for each wheel. Each block is independently suspended by links from the truck frame (see Fig. 4), but all blocks are mechanically interconnected and equalised so as to ensure uniform braking action. A portion of this mechanism for a single truck can be seen in Fig. 4. The inner transverse bar *G* (called a "brake beam") is fixed to the brake shoes and carries a fulcrum for the brake lever *H*, to which the pull rod is attached. The outer transverse bar *K* (called an "equalising lever") is connected to a similar bar at the other end of the truck by the rods *L*, and its centre is hinged to the brake lever *H*.

How the Brake Mechanism Works.

When a pull is applied to the pull rod (Fig. 6) the brake lever (*H*, Fig. 4) moves anti-clockwise about the hinge pin fixed to the equalising lever *K*, and the front brake beam *G* moves towards the front wheels until the brake blocks touch these wheels. When this occurs the front brake beam becomes stationary and the pivotal point of the brake lever is transferred from the equalising lever to the brake beam. Hence further movement of the brake lever causes a further forward movement of the front equalising lever, and a similar movement of both the rear equalising lever and brake beam (which move together as a single beam), since the equalising levers are rigidly connected together. This movement stops when the

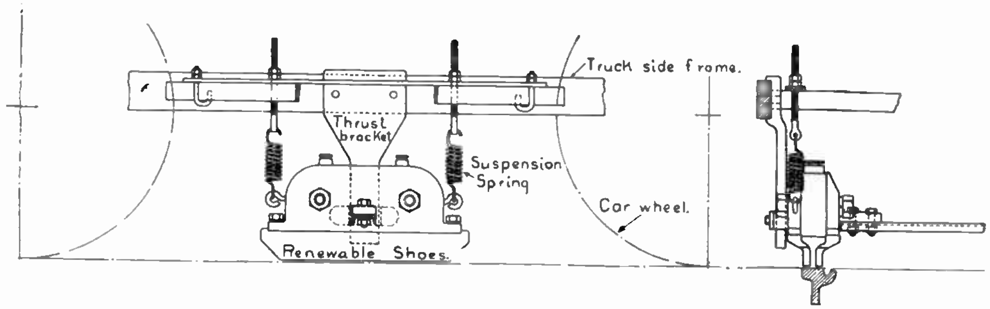


Fig. 8A.—How the Electro-Magnet is Mounted.
Each magnet is suspended from the sideframe of the truck by spiral springs, and opposite magnets are connected together by crossbars, as shown on the right.

rear brake blocks touch the wheels. Thus all the four brake blocks are applied by one handle and pull rod, and the equalising lever ensures uniform pressures between brake blocks and wheels.

The Electric, or Rheostatic, Brake.

Electric braking, on both tramcars and trolley buses, is obtained by using the car motors as self-excited generators and loading them with rheostats. Thus the energy due to the momentum of the rear is converted into electrical energy, which is dissipated as heat in the rheostats. It is important to realise that the *electric brake depends for its action on the motion of the car*, and that the *energy available is proportional to the square of the speed of the car.* Hence the electric brake is very effective at moderate speeds, and very high retardations are possible at these speeds. But precautions must be taken to prevent skidding of the wheels at high retardations, as such skidding puts the brake out of action.

The electrical characteristics of the self-excited machines (which are connected for *series* excitation) are such that the e.m.f. generated varies with both the speed and the resistance of the loading rheostats. Hence these rheostats must be arranged so that their resistance can be varied. In practice, seven values of resistance are provided for tramcar braking. The application and regulation of the brake is effected by a controller. On a tramcar the same controller is used for both the power and braking connections, the operating handle being moved in one direction for "power" and in the opposite direction for "brake." On trolley buses a separate controller must be used for electric braking as the main controller is foot-operated.

Magnetic Track Brake.

This brake forms a valuable adjunct to the electric brake on a tramcar. It consists of two or more electro-magnets flexibly suspended from the truck so as normally to clear the rails by about ¼ inch. The magnets are wound for series excitation and are connected in series with the loading rheostats of the electric brake. When the magnets are energised the pole faces are attracted to the rails, and the drag on the magnets is transmitted to the truck frame and car body. In some cases the drag is arranged to cause automatically an application of the wheel brakes, so that *three brakes become effective when the electric brake is applied*, viz.: (1) the braking due to the generator action of the motors; (2) the track brake; (3) the wheel brakes. In consequence, very high retardations up to 12 feet per second are possible. Such triple braking is used on the cars of the London County Council.

Tramcar Magnetic Track Brakes.

Fig. 8B shows a transverse section of a track brake magnet in position on the tram rail. The exciting coil is well insulated and is enclosed in a metal case sealed with compound so that the insulation of the coil shall not be affected by the mud and water thrown up by the wheels.

The body of the magnet is built up of cast steel, and the pole shoes which come into contact with the rail are of soft rolled steel of the special shape shown in the sketch. These shoes are easily renewable by removing two hexagon-headed screws at the ends of each shoe. Soft steel is used for the shoes in order that they may take the wear due to the friction between the brake magnet and the rail when the brake is in action, as it is cheaper to renew the shoes than the track rails. The shoes only become worn when the brake magnet is excited as for normal running the pole faces are held about $\frac{1}{4}$ inch above the rails by the suspension springs.

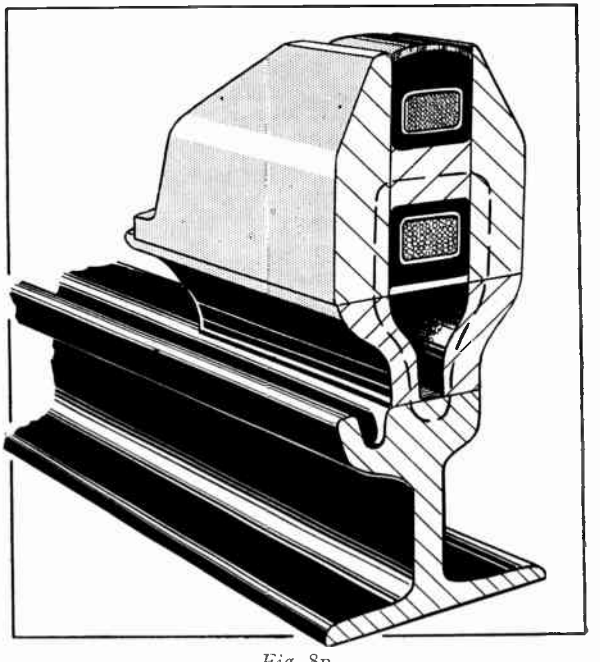


Fig. 8B.

Showing how the pole faces of a magnetic track brake are located with respect to the rail. Notice that the brake magnet is really a modified form of horse shoe electromagnet.

Why Cast Steel is Used.

Cast steel is used for the body of the magnet on account of its superior magnetic qualities, and because it can be worked at high magnetic flux densities, both of which are very important items in the design of the magnet. Thus the force of attraction or pull between the magnet and rail is proportional to : (Area of pole faces × *square* of magnetic flux density at pole faces). Now cast steel can be worked at three times the flux density which would be practicable with cast iron, and therefore for a given pole face area the pull obtained with a cast steel magnet will be nine times that obtained with a cast-iron magnet.

Extending the Pole Faces.

The path of the magnetic lines is shown by the dotted line in the sketch. This path is transverse to the rail head in order to utilise the rail to the best advantage for carrying the magnetic flux. Used in this manner the rail head offers little restriction to the flux whereas if the pole faces were arranged longitudinally with respect to the rail the flux would be seriously restricted by the cross section of the rail head. It is interesting to note that the original brake magnets were actually constructed with longitudinal poles, but this type of construction was soon abandoned for the present type, shown in the sketch, because with this type almost any desired pull can be obtained by extending the pole faces and magnet body longitudinally. Thus when small pulls of the order of a ton are required a short magnet with pole faces about 8 or 9 inches long is used, but when larger pulls of, say, 3 tons, are required, a long magnet with pole faces about 24 inches long would be used.

The Question of Wear.

In several large tramway systems the magnetic brake is used for service stops instead of the hand brake. This relieves the motorman of a considerable amount of fatigue during his day's work. Whenthis method is adopted there is, of course, considerable wear on the pole shoes of the magnetic brake. It is found in practice that the shoes must be replaced about every six weeks.

The Power of the Magnetic Brake.

Very high braking retardations up to 12 feet per second per second are *possible*, but with magnetic track brakes only moderate retardations, 2 to 3 feet per second per second, are used in service.

The magnetic circuit is *transverse* to the rail head, and therefore the flux is not restricted by the relatively small transverse section of the rail head. This arrangement enables any required force between magnet and rail to be obtained by making the pole faces of a suitable length. Thus in practice one may see brake magnets of different lengths, the short magnets being used on light single-truck cars or on bogie cars, and the long magnets on heavy single-truck cars. Fig. 7 illustrates a typical magnet.

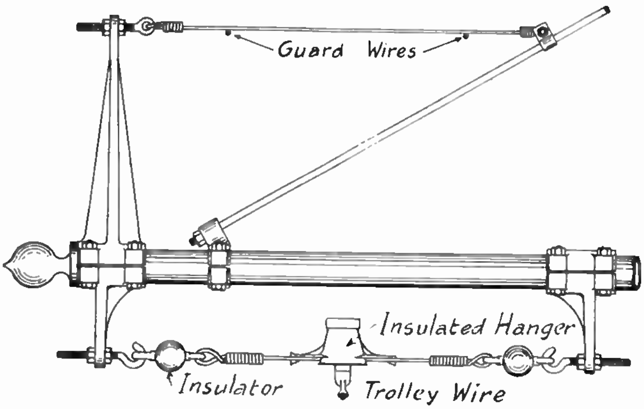


Fig. 9A.—TROLLEY-WIRE SUPPORT FOR A TRAMWAY SYSTEM.
The wires are supported and insulated from a transverse span wire which is also insulated from its supports.

Mounting Electro-magnets.

Two magnets are used on single-truck cars (one on each side) and four magnets on bogie-truck cars. Each magnet is suspended from the side frame of the truck by spiral springs in the manner shown in Fig. 8A, and opposite magnets are connected together by cross bars. The projecting lugs on the outer pole faces engage with the tails of thrust levers on the truck. When the magnetic track brakes operate independently of the wheel brakes, these thrust levers are fixed rigidly to the side frames of the truck, but when the wheel brakes are to be operated automatically by the track brake, the thrust levers are hinged and operate other levers connected with the brake beams.

BRAKES ON TROLLEY BUSES.

Modern trolley vehicles are equipped with three brakes: (1) hand-operated wheel brakes; (2) foot or power (compressed air) operated wheel brakes; (3) an electric rheostatic brake. The wheel brakes are of the internal expanding type with friction lined shoes acting upon steel drums fitted to the wheels. When brakes are fitted to all the wheels, the hand-operated brakes act only upon the rear wheels (i.e., the brake drums of these wheels have two sets of shoes, one being hand-operated and the other foot- or power-operated).

Air Brakes.

Compressed air is used for operating the brakes on large vehicles. The brake levers are connected to diaphragms in air cylinders, which are supplied with compressed air from an electrically driven compressor and storage reservoir. Control of the air pressure in the braking cylinders is effected by a foot-operated valve.

Combined Electric Air-braking.

Large double-deck buses weighing 12 tons fully laden usually have combined electric and compressed air braking. The brake pedal is so arranged that the initial depression operates a switch which applies rheostatic braking in two steps and further depression applies the compressed air brake while still retaining electric braking. From what has been said previously about the electric brake, it will be realised that with this arrangement the electric brake is used under the most effective conditions, and its use does not put any undue strain on the cardan shaft couplings and transmission gear. An advantage of this combined electric-air braking is that the life of the brake linings is much longer than that when no electric brake is used.

ELECTRICAL DISTRIBUTION SYSTEMS FOR TRAMWAYS AND TROLLEY-BUS ROUTES.

General.

The distribution must be on the direct-current system. The maximum voltage at the trolley wires (or contact rails in a conduit system) must not exceed 600 volts, and the maximum voltage at the generating station or sub-station must not exceed 650 volts.

Sectionalisation of Trolley Wires.

On overhead tramways and trolley-bus routes the positive trolley wires must be divided into sections not exceeding half a mile in length. The sections are normally interconnected by switches located in pillars or boxes adjacent to the track. Hence if a fault occurs on any half-mile section of trolley wire, that section may be isolated by opening the appropriate switches in the boxes at the ends of the section. Thus the fault affects only one half-mile section of the system, and the running of cars on this portion of the system need not be interrupted if two positive trolley wires, each sectionalised, are used over the route, as is usually the case.

Material of Trolley Wire.

Hard-drawn copper is generally used for trolley wire. The ultimate tensile strength is about 24 tons per square inch, the elastic limit is about 10 tons per square inch, and the specific resistance at 60° F. is 0.69 microhm per inch cube. A grooved circular cross section is used in order to eliminate soldering the wire to the suspension fittings. Moreover, these fittings for grooved wire give smoother running than soldered fittings for non-grooved wire and they can be erected in a shorter time.

Erection and Support of Trolley Wires.

The trolley wires must be erected at a minimum height of 17 feet above the road surface (except under bridges) and the interval between the supports must not exceed 120 feet. The wires are supported and insulated from a transverse span wire, which is also insulated from its supports. Hence on overhead tramways there is double insulation (i.e., two insulators in series) between the trolley wires and earth. On trolley-bus routes, both positive and negative wires are insulated from the supporting span wire, but the portion of the span wire carrying the positive trolley wires is insulated from the non-insulated portions carrying the negative trolley wires, so that in this case there is double insulation between the positive wires and earth, and triple insulation between positive and negative wires. Figs. 9A and 9B show typical arrangements for the two cases.

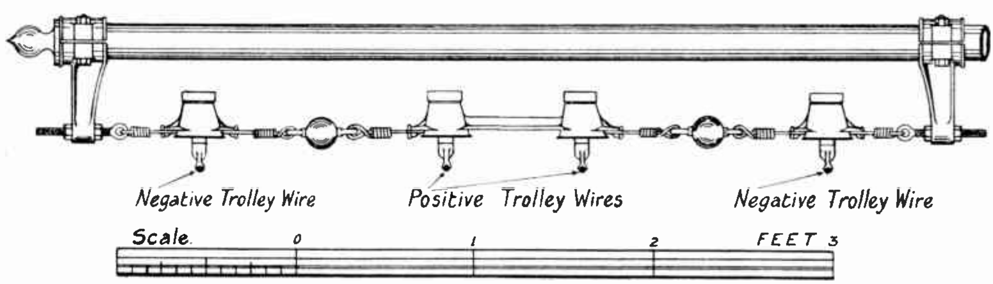


Fig. 9B.—TROLLEY-WIRE SUPPORT FOR A TROLLEY-BUS SYSTEM.
On trolley-bus routes, both positive and negative wires are insulated from the supporting span-wire, but the portion of the span-wire carrying the positive trolley wires is insulated from the non-insulated portion carrying the negative trolley wires. Thus there is double insulation between the positive wires and earth, and triple insulation between positive and negative wires.

Contact-rail System for Conduit Tramways.

In conduit tramways the cars obtain their energy from underground contact rails located in a slotted conduit. Connection between these rails and the motors is made by a special form of current collector (called a plough), which is carried on the car and extends through the slot of the conduit, terminating in a pair of contact shoes which press against the contact rails.

The running rails are not used as conductors, and accordingly positive and negative contact rails are required. These rails are supported by insulators, and *each* rail is divided into half-mile sections with sectionalising switches. In the event of a fault or leakage occurring on one of the contact rails, the polarity of that rail is made negative, special switchgear being provided at the power station for this purpose.

Use of Track Rails as Return Conductors.

On overhead tramways the track rails are usually used as the return conductors to avoid duplication of the trolley wires and current collectors. In these cases the rails must be connected to the negative side of the electrical system, which must be earthed through either an ammeter or a maximum demand indicator. Moreover, both the track construction and the distribution system between the track and the negative bus-bar at the power station must conform to stringent statutory regulations. These require the return system to be so designed that the maximum potential difference between any two points in the track rails shall not exceed 7 volts. A continuous record must be kept of the potential difference between selected points in the track.

Negative Boosters.

In a tramway system with routes extending considerable distances from the power station, boosters must be used in conjunction with the long negative feeders in order to neutralise the voltage drop, or a portion thereof, in these feeders and so enable the conductors to be worked at an economic current density. The booster used with negative feeders is a series-wound dynamo having the armature connected in series with the negative feeder and the field widening connected in series with the positive feeder which supplies the trolley wires appropriate to the portion of the track to which the negative feeder is connected. The field winding has to be connected in this manner to ensure the proper working of the booster, as if the machine were self excited it would circulate current continuously through the negative feeders and track rails, since both ends of all the negative feeders are permanently connected—the station ends being connected to the negative bus-bar and the distant ends to the track rails (which are continuous throughout the system).

How the Negative Boosters Help the Distribution System.

In normal working the e.m.f. of the booster acts in the same direction as that of the current returning by the negative feeder, and in consequence the overall voltage drop in the booster and feeder is less than that in the feeder itself. Hence the combination of booster and feeder is equivalent, as far as current and overall voltage are concerned, to a reduction in the resistance of the feeder. Thus long and short feeders of the same cross section, which are connected in parallel, may be worked at the same current density; whereas without the booster the current density in the long feeders would be much lower than that in the short feeders (i.e., the copper in the long feeders would be used very uneconomically for current-carrying purposes).

Another important feature in the use of negative boosters is that the several negative feeding points (i.e., the points where the feeders are connected to the track rails) may be maintained at the same potential even if the loading of the track may change from the normal condition for which the feeding system was designed, as the load characteristic of the booster (i.e., the relationship between armature voltage and positive feeder current) may be changed by connecting a tapped resistance (called a *diverter*) across the field winding. By maintaining the negative feeding points at the same potential, these points may be placed at the maximum distance apart while the potential difference in the rails is kept within the 7-volt limit. Hence, with this scheme, a minimum number of negative feeders is obtained.

FUSES FOR VERY SMALL CURRENTS

By A. C. BARKLIE.

Fig. 1.—ASSEMBLING A GOLD FILM FUSE (1).
In the cartridge type fuse the gold strips are fitted into glass tubes with metal end contacts.

Fig. 2.—ASSEMBLING A GOLD FILM FUSE (2).
Fitting the metal cap through which electrical connection is made. Note the fuse gap between contacts.

SINCE the growth of wireless popularity a definite demand has arisen for fuses of a low-rupturing capacity for the protection of the valves and other costly components of the set.

It was natural that early attempts to produce such fuses should have consisted in modification and adaptation of existing types of fuses. Alloys of low fusing point were drawn into wire as fine as possible. But unfortunately there is a definite limit to the ductility of any particular metal or alloy, and the production of a wire fuse which could be relied upon to operate at less than about 150 milliamperes has not so far proved successful. Other devices have been resorted to, such as the use of solder to give a weak point in the fuse, mechanical springs to bring about disconnection at a lower current than would normally be needed, and so on. But these have only been partially successful and in no case have resulted in a reliable fuse to operate at 50 milliamperes or less.

A New Principle.

An alternative to wire drawing is the use of narrow strips of extremely thin electrolytically deposited metallic films. This entirely new principle has made possible the production of reliable fuses to operate as low as 1 milliampere.

For such a low value there is, of course, no demand, but 5 milliampere fuses have been on the market for some years, manufactured by Messrs. Microfuses, Ltd., under a series of patents, covering the production and application of extremely thin gold films for delicate fuses.

How the Gold Film is Deposited.

Chemical details of the preparation

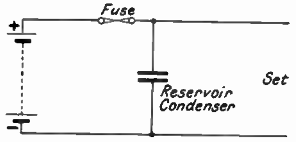


Fig. 3.—USE OF SMALL FUSES IN WIRELESS SETS.

In the anode circuit of a battery-operated set the fuse should be placed as near as is convenient to the H.F. battery. It should not be placed in a position where it would be subjected to the charging current of a reservoir condenser.

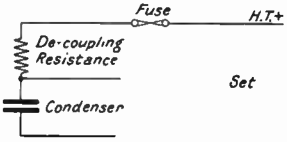


Fig. 4.—USE OF SMALL FUSES IN WIRELESS SETS.

In actual practice the reservoir condensers are generally charged through a de-coupling resistance, so that the fuse is not subjected to the charging current.

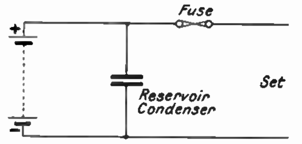


Fig. 5.—USE OF SMALL FUSES IN WIRELESS SETS.

An alternative position for the fuse is on the valve side of the condenser.

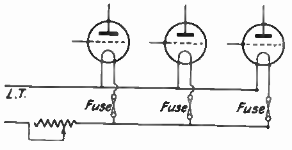


Fig. 6.—PROTECTING DULL EMITTER VALVES.

Each fuse should be rated to "blow" at about $1\frac{3}{4}$ of the normal filament current, so as to protect the valves against accidental use of a L.T. battery of too high a voltage. Dull emitter valves are very easily spoiled by overrunning.

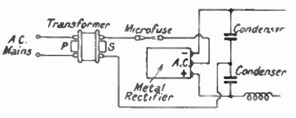


Fig. 7.—USE OF SMALL FUSES IN WIRELESS SETS.

Where a high tension eliminator replaces the H.T. battery a fuse in series with the rectified H.T. supply serves as a protection both for the rectifier and the set itself.

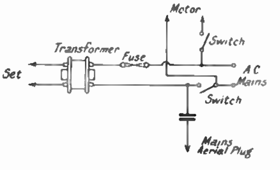


Fig. 8.—USE OF SMALL FUSES IN WIRELESS SETS.

Main fuses of $\frac{1}{2}$ to 1 amp. carrying capacity are usually used in the mains lead, but in addition a lighter fuse to blow at about 250 m.a. is recommended.

of such films would prove tedious. It is sufficient to say that the gold film is electrolytically deposited on a thin sheet of copper or silver cathode. This thin sheet is then floated gold side uppermost on a suitable bath of acid or other chemical which dissolves away the silver or copper, leaving the gold film floating alone on the surface. After a series of washes in other baths the film is finally drawn out on to a sheet of celluloid or other insulating material and firmly stuck to it by a suitable adhesive.

It must be understood that these films are so thin that they could not continue to exist as a continuous film without some support. The thinnest beaten gold with any degree of continuity is of the order of three millionths of an inch thick, but gold films can be and are regularly made by the process outlined above twenty times as thin as this.

Figs. 10 and 11 show sheets of gold through which print may be easily read. This sheet is about 3×10^{-7} or one three-millionth of an inch thick. In other words three million sheets would have to be superimposed to give a thickness of one inch! Such is the type of film used for making fuses to rupture at from 20 to 50 milliamperes according to the width of strip used.

Assembling the Fuses.

The actual assembly of the fuses presents little difficulty. The sheet of gold on its celluloid backing is cut into strips of the desired thickness by a guillotine having a micrometer adjustment.

The Cartridge Type.

In the cartridge type fuse the strips are fitted into glass tubes and gripped therein between two pairs of brass jaws, the protruding ends of which are covered by metal caps through which electrical connection is made. See Figs. 1 and 2.

Fig. 9.—TESTING A FUSE.
Each fuse is tested by measuring its resistance on a specially designed instrument.

A Simpler Form.

In another simpler form the strip of gold is gripped at each end by eyelets between a pair of brass washers. The eyelets pass through holes in a bakelite base and the gold faces this base to avoid accidental injury in handling.

How the Fuse is Tested.

Each fuse is then tested by measuring its resistance (which bears a close relation to the fusing point), and any fuse which does not come between the prescribed limits of resistance is ruthlessly rejected. These resistance limits are decided on by a comprehensive series of tests continually being carried on for each rating of fuse.

Fig. 9 shows the resistance being measured on a specially designed instrument. After the first test the fuses (of the cartridge type) are labelled and then retested in case any rough treatment has resulted in some irregularity. Finally, each individual fuse is retested again before despatch.

Gold Films and Their Properties.

The properties of these gold films are most interesting. It would be quite impossible to draw a wire having such a small cross sectional area as can be obtained by using a gold film, say 1/20th of an inch wide and half a millionth of an inch thick. Even a wire 1/1000 of an inch in diameter would expose a cooling surface per cubic inch of metal, 500 times smaller than would be exposed by one side only of such gold film. The cross sectional area of a 5 m.a. fuse is approximately 1.5×10^{-10} square inches.

Blowing Speed of the Fuses

Even more surprising is the speed with which such fuses blow; and this is surely the real test of the quality of a fuse; for though a fuse which takes a long time to blow may save the protected instrument from complete rupture, it may yet allow it to warm too much and be slightly damaged thereby.

A time overload curve (see Fig. 12) shows the speed of operation of a 150 m.a. Microfuse under various conditions of overload, as found from oscillograph tests. Here we see that with an 8-fold overload, i.e., an overload corresponding to short circuit conditions, the fuse blows in 1/1000 of a second. The relative speeds of fusing of the filament of a Mullard P.M.4 valve and a microfuse have been measured by the oscillograph. The results are shown graphically in Fig. 13.

Protecting Valve Filaments.

Further tests show that a valve filament (as an example of a delicate instrument) may be protected against

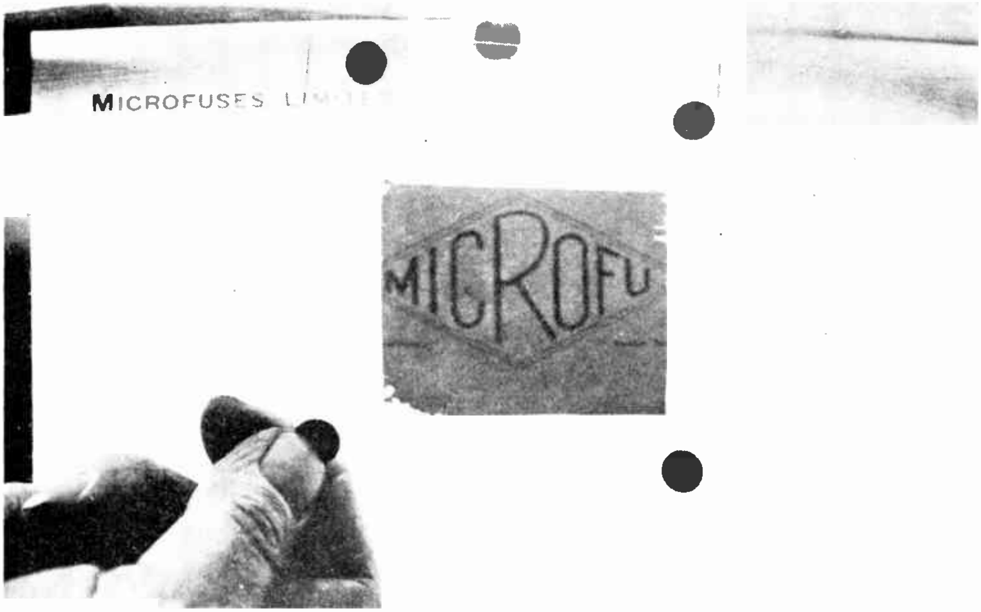


Fig. 10.—PHOTOGRAPHED THROUGH A SHEET OF GOLD.

This shows the gold sheet before cutting for insertion in the glass tube (see Fig. 1). This sheet of gold is two-millionths of an inch thick, and it will be seen that print can be easily read through it. It is so thin that it could not continue to exist as a continuous film without some support. It is, therefore, drawn out on to a sheet of celluloid, to which it is stuck.

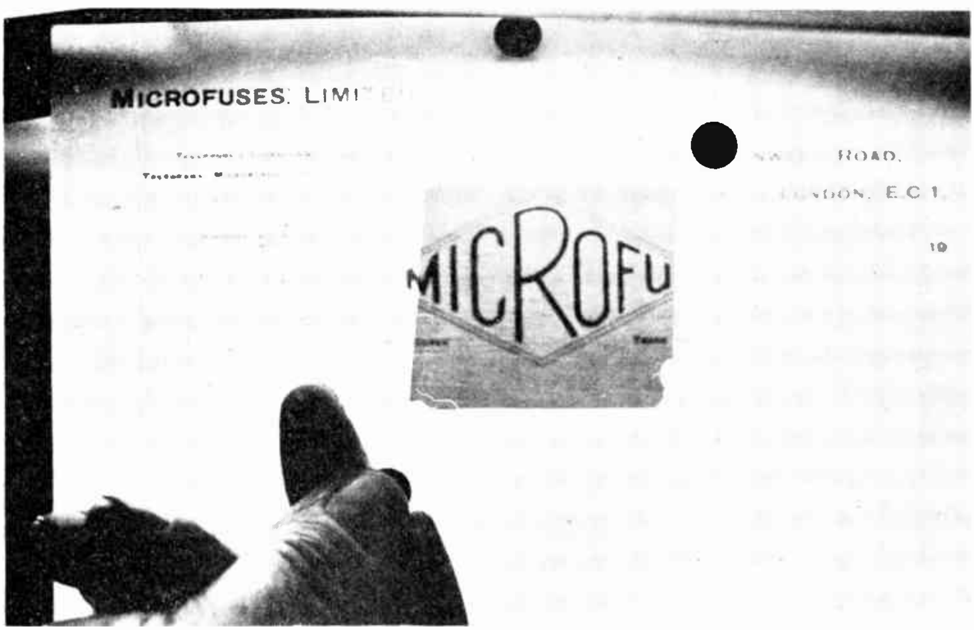


Fig. 11.—A SHEET OF GOLD ONE MILLIONTH OF AN INCH THICK.

This sheet is one-millionth of an inch thick. The thinnest beaten gold with any degree of continuity is in the order of three-millionths of an inch thick, but gold films can be and are regularly made twenty times as thin as this.

"overrunning" by a fuse (or by several fuses in parallel) rated to blow at about one and three-quarter times the normal current of the filament, and that the degree of the protection increases as the voltage increases. Thus owing to their great speed of blowing, fuses heavy enough to be immune from slight occasional overloads can be used, without lessening the degree of protection to the instrument from serious overload.

A Peculiar Property of Gold Film.

But it is not only at heavy overloads that such fuses are so fast in operation. Thin gold film in close contact with a smooth supporting surface such as glass or celluloid has the peculiar property first noticed by Faraday in 1857 that on heating the gold loses its colour and, more important still, its thermal and electrical conductivity, and this occurs at a temperature far below the melting point of gold.

Consequently on a slight excess current being applied to a gold film fuse disconnection occurs as soon as the centre of the fuse has reached a temperature of only 200° to 400° C. The fuse after disconnection appears to have a fine scratch across the gold.

Why Silver is Added.

In actual practice gold containing a small percentage of silver is found to be more suitable for fuses than pure gold.

Such an alloy is unlike pure gold and conductors in general, inasmuch as increase of temperature does not appreciably increase the resistance. From a fuse point of view this means that the resistance of the fuse is practically independent of the load. The percentage of silver is so small that the alloy retains all the useful properties of gold itself.

It is non-tarnishing, non-corroding and its electrical characteristics cannot depreciate with time.

Thus from their very nature these gold film fuses possess protective properties far in advance of any other type of fuse and are the most reliable safeguard not only for wireless sets but for any delicate electrical instruments.

They are extensively used in Research Laboratories and designing departments, where accuracy and reliability are essential for the protection of delicate electrical measuring instruments, experimental apparatus and so on.

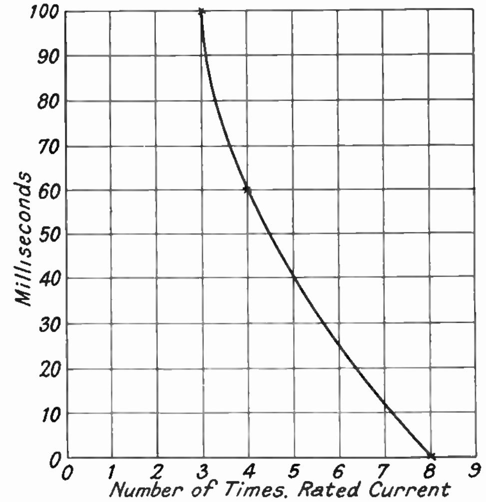


Fig. 12.—BLOWING SPEED OF A MICRO-FUSE.

It will be seen that with an overload current eight times above normal, which corresponds to short circuit conditions, the fuse blows in 1-1,000th of a second.

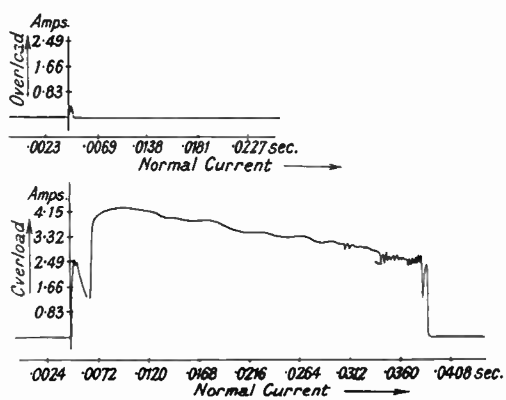


Fig. 13.—RELATIVE SPEEDS OF FUSING OF A VALVE FILAMENT AND A MICROFUSE.

These speeds are measured by an oscillograph and it will be seen that the Microfuse blows almost instantaneously with no appreciable increase in current, while the valve filament does not fuse until after an appreciable increase in current. Thus the use of a Microfuse protects the valve from possible damage.

A few hints on their use in ordinary wireless sets may be helpful.

Anode Circuit of Wireless Receivers.

In the case of a battery-operated set the fuse should be placed as near as is convenient to the positive terminal of the high tension battery. But one precaution is necessary. The fuse should not be placed in a position where it would be subjected to the charging current of a reservoir condenser. The condenser takes only a small fraction of a second to charge up, but that is quite long enough to blow a Microfuse. See Fig. 3.

In practice this difficulty seldom occurs because reservoir condensers are generally charged through a decoupling resistance as shown in Fig. 4, and the initial surge current is limited.

Alternatively, the fuse may be placed on the valve side of the condenser. Fig. 5.

The actual value of fuse to use for protection of the H.T. battery depends on the current consumption of the set and the capacity of the battery.

Use in Eliminators.

Where a high tension eliminator replaces the H.T. battery, a fuse in series with the rectified H.T. supply serves as a protection both for the rectifier and the set itself, as in Fig. 7.

Here again it should be noticed that the fuse is placed between the transformer secondary and the rectifier and not between the secondary and the reservoir condenser. The lowest rating of fuse which will carry the required current should be used here, as metal rectifiers are damaged by overload. The use of fuses in low tension eliminators is on similar lines, but the fuse is much heavier.

All Electric Wireless Receivers.

Mains fuses of ½ to 1 amp. carrying capacity are usually used in the mains leads, but in addition a lighter fuse to blow at about 250 m.a. is recommended by some manufacturers of radio-gramophones. See Fig. 8.

Transmitting Valves.

Amateur transmitters understand the tendency of a heavy anode current through a valve to increase suddenly in operation in spite of the fact that the grid bias may be correct. This sudden increase causes serious damage to the valve. Microfuses to operate at small overloads have been specially prepared to prevent such damage.

WHEN DISCONNECTING A CAR BATTERY

A car dynamo will generate many times its rated voltage when the battery is disconnected. The voltage may rise to 50 or even 100 volts. As a car dynamo is a shunt-wound machine, this may result in burning out the field windings or the lamps if they are switched on. The constant current dynamo, which is used on the majority of car lighting systems, depends, for its correct operation, on the presence of the battery connected across its main terminals. When the dynamo is run with the battery disconnected, there is no low resistance path for the current which maintains the correct amount of armature reaction. Thus the voltage rises.

To prevent damage to the dynamo when the battery is disconnected, there are two methods of procedure. The first is to short-circuit the positive and negative terminals of the machine. This prevents the dynamo generating, because, since the field is in parallel with the armature, no current can then flow in it to produce a field for generation of E.M.F. in the armature. The other way is to open the field circuit of the dynamo by removing the fuse in the field circuit, if there is one, or by disconnecting one of the field connections.

These remarks do not apply to systems such as Bosch, where the current and voltage are regulated by vibrators, or the Gaumont system, where the voltage is limited in the same way, and cannot rise above a safe value.

ELECTRICAL PROPERTIES OF RUBBER

By M. G. Say, Ph.D., M.Sc.

THE latex (or milk) of the rubber tree, when dried, is the raw rubber of commerce. The finest rubber is obtained from wild trees in the Amazon valley in South America; it is known as Para rubber. Many years ago rubber plants were smuggled out of Brazil, and plantations established in Africa. More recently, plantations have been made in Ceylon and Malay. Although inferior to the genuine native Para product, plantation rubber provides a considerable bulk of the world's market.

How Rubber is Obtained.

In order to obtain the rubber, V-shaped cuts are made in the bark of the rubber tree. Latex oozes out of these cuts and is collected in little cups. The latex is strained, smoked and dried, then washed and made into sheets. The latter have the now-familiar crinkly surface termed "crêpe."

How Rubber is Vulcanised.

Crêpe rubber becomes soft and tacky when hot, and hard when cold. It is thus unusable for electrical insulation purposes. A process known as "vulcanisation," discovered about a century ago, has revolutionised the use of rubber. It consists in adding sulphur to the rubber and subjecting the mixture to a temperature of about 145° C. The process greatly increases the mechanical strength and durability of rubber, enabling it to withstand greater limits of temperature without becoming hard or sticky. Unfortunately, the purely electrical qualities are impaired, although not seriously.

The amount of sulphur added in the process of vulcanisation may be anything between 5 per cent. and 45 per cent. Filling materials such as clays and bitumen may also be added to add to the bulk and cheapen the material. The proportion of these ingredients determines the electrical and mechanical properties. With the smallest proportion of sulphur the rubber is elastic, soft, and perishable. The higher percentages of sulphur give a tough, strong, durable material of quite considerable mechanical strength and good electrical properties. It is known as *ebonite* or *vulcanite*.

Uses of Rubber for Electrical Purposes.

The flexible nature of rubber makes it immediately suitable for the covering of low-voltage wires, and to some extent also for flexible high-voltage wires (e.g., the high-tension leads from the ignition device to the spark plugs of an internal-combustion engine; these wires are called upon to withstand voltages up to 10,000 volts to earth).

Small bell wires for very low voltages are often made with single strands of tinned copper, surrounded by one or two lappings of thin rubber tape containing but little sulphur, then covered with cotton lapped on, and finished off finally with a waxed braiding. The wax is intended to make the wire tolerably waterproof.

How Insulated Wire is Manufactured.

For electric light and power wiring the insulating treatment above is insufficient, and would be dangerous. Ordinary house wiring is carried out with conductors (usually of several strands) covered with an inner layer of fairly pure rubber; next, a layer of "separator rubber," sometimes omitted, which consists of a mixture of rubber and zinc oxide; a third coating of vulcanised rubber, finally a layer of cotton tape impregnated with vulcanised rubber and bitumen and known as "black tape" or "sticky tape." If the wires are to be used in screwed steel conduit, they are given a protective covering of waxed hemp braid, and such cables are ordinarily

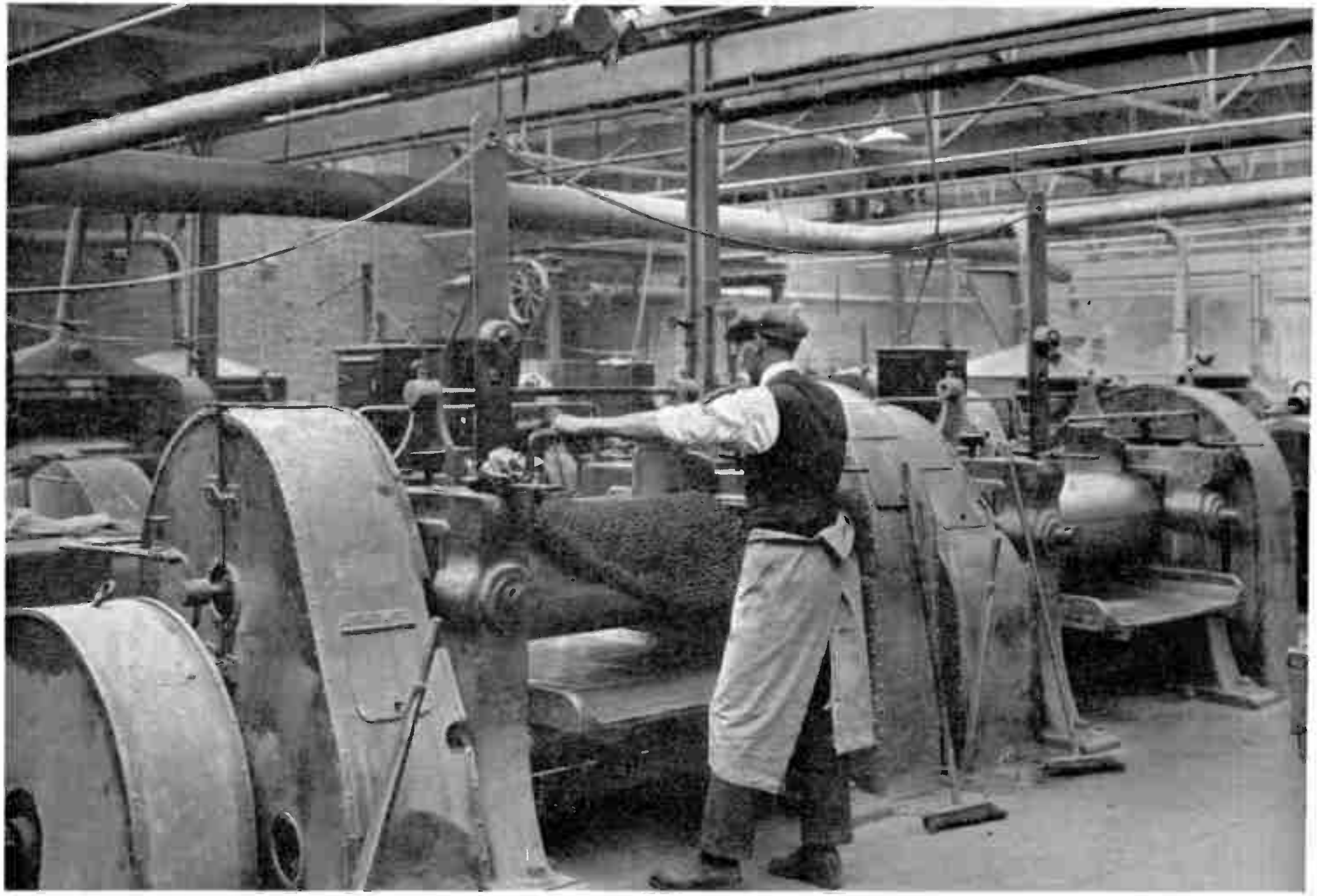


Fig. 1.—Masticating the Raw Rubber and Mixing Various Ingredients.—(*St. Helens Cable and Rubber Co., Ltd.*)

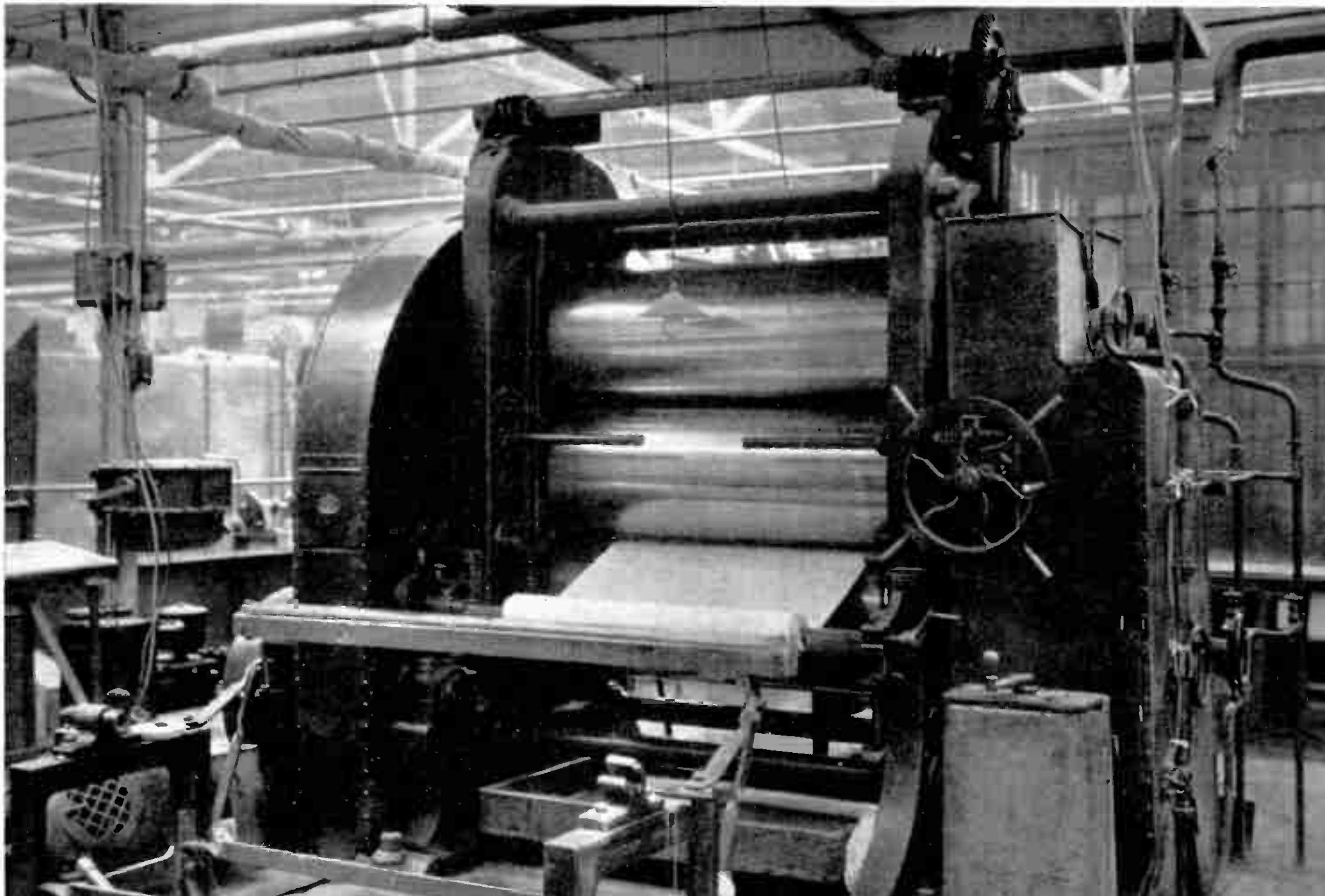


Fig. 2.—CALENDERING THE RUBBER COMPOUND.—(*St. Helens Cable and Rubber Co., Ltd.*)

referred to as "V.I.R.," or vulcanised india-rubber cables. A commonly used method of house wiring dispenses with the screwed conduit by armouring the individual insulated wires in ones, twos or threes by means of a sleeving of alloyed lead. In this case the sticky tape is replaced by a coloured cotton tape.

In the wiring system known as "C.T.S." (cab-tyre sheathing), the conductors with their pure and V.I.R. coverings are enclosed in a thick sleeving of heavy, tough, black vulcanised rubber. This material was formerly developed for use on the solid tyres of horse-cabs. It forms a tough, strong protection, and while it is easily cut by sharp edges, is otherwise mechanically strong and resistant to perishing.

How to Insulate a Joint in a Rubber Cable.

A joint can never be so satisfactory from the standpoint of insulating qualities as the original cable. Nevertheless, on occasion a joint cannot be avoided, and when made should be carefully insulated. With V.I.R. cables an approved method is as follows:—

(1) When baring the conductors preparatory to making the joint, remove the various layers of braiding and insulation in sections, each layer being taken off without damaging that underneath, as far as possible. It is sometimes found, however, that the two inner layers are firmly adherent. It is specially important not to "nick" the conductor, as this makes it very liable to break.

(2) After making and smoothing the joint, taper off the inner layers of rubber.

(3) Wind on over the metal of the joint a wrapping of rubber tape. This is a brown, translucent, "stretchy" material obtained in flat rolls with the rubber strip interleaved with thin paper to prevent sticking. The tape should be quite dry, and well stretched when applying. Care should be taken to avoid trapping air under the tape.

(4) Treat the outside of the first layer of rubber tape very thinly with rubber solution, wait until it is tacky, then wind on a second layer of rubber tape, and repeat the process until the rubber has been brought up to the level of the original insulation. By this time the levelled edges of original rubber on each side of the joint should be well covered.

(5) If the conductor is braided, a layer or two of black tape should be wound on over the joint, covering the braiding for 1-2 inches at each side. The ends may be stuck down with solution.

(6) The outside taping may be covered with a coat of shellac varnish.

If it is desired to vulcanise the joint, which is strongly to be recommended for damp situations, the procedure is rather different.

Vulcanising a Joint.

A joint is vulcanised as follows:—After proceeding as in (1) and (2) rub the tapered ends and the joint with benzole, and warm the joint and rubber slightly with a spirit lamp. One layer of pure rubber strip (or two for a large conductor) is then put over the joint and the tapered ends, and covered with a special vulcanising rubber solution, excluding air as much as possible. When tacky, a wrapping of rubber strip is wound on tightly and evenly in helical formation until the joint is built up to the same size as the original conductor. Care must be taken to exclude air.

The rubber is now covered with a layer of black tape. The joint is covered with a special sheeting bound on tightly with strong cotton tape to form a mould.

The joint is now vulcanised. It is put into a cast-iron box with bolted cover, the original insulation on each side of the joint being covered with layers of tape to protect it from damage and to make the box tight. A thermometer is inserted to enable the temperature to be read. The temperature is raised to and maintained at 145° C. (295° F.), by means of a spirit lamp or other suitable method of heating, for half an hour.

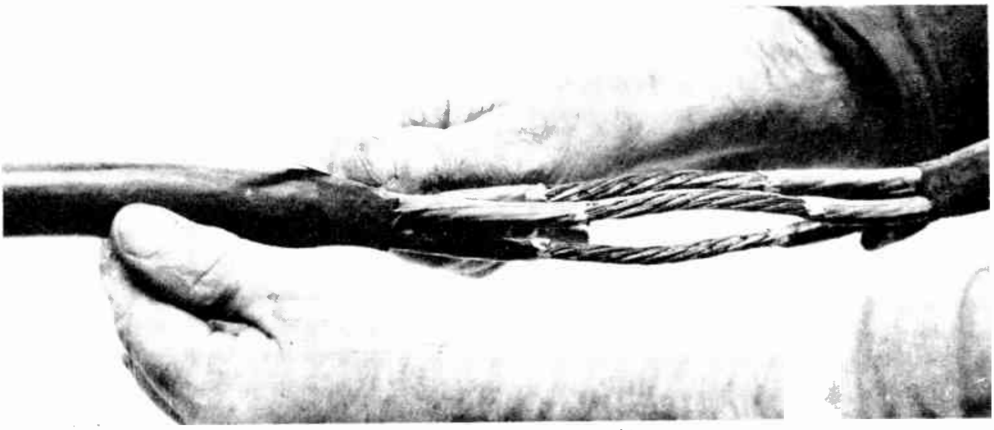


Fig. 3.—PREPARING C.T.S. CABLE FOR VULCANISING.
(*St. Helens Cable and Rubber Co., Ltd.*)

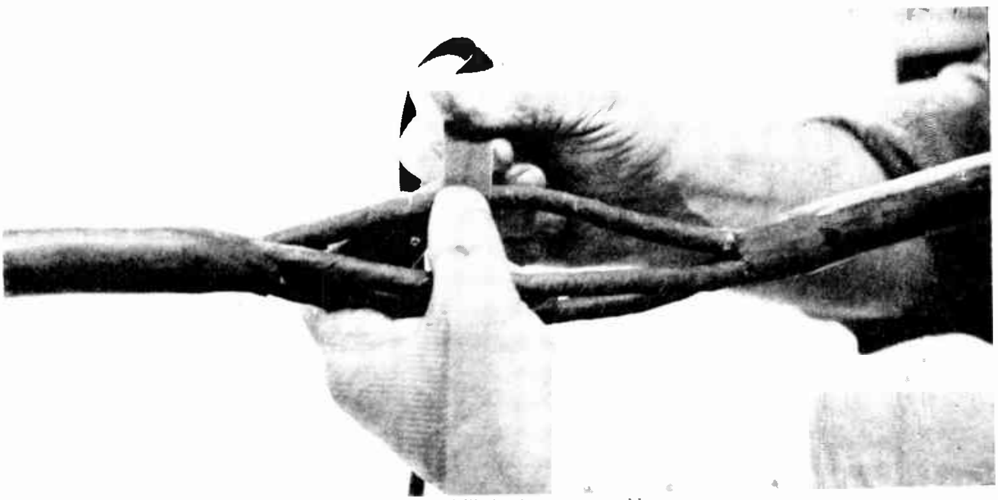


Fig. 4.—PREPARING C.T.S. CABLE FOR VULCANISING.
Adding the rubber strip.—(*St. Helens Cable and Rubber Co., Ltd.*)

Fig. 5.—PREPARING C.T.S. CABLE FOR VULCANISING.
Covering the joint with black tape.—(*St. Helens Cable and Rubber Co., Ltd.*)

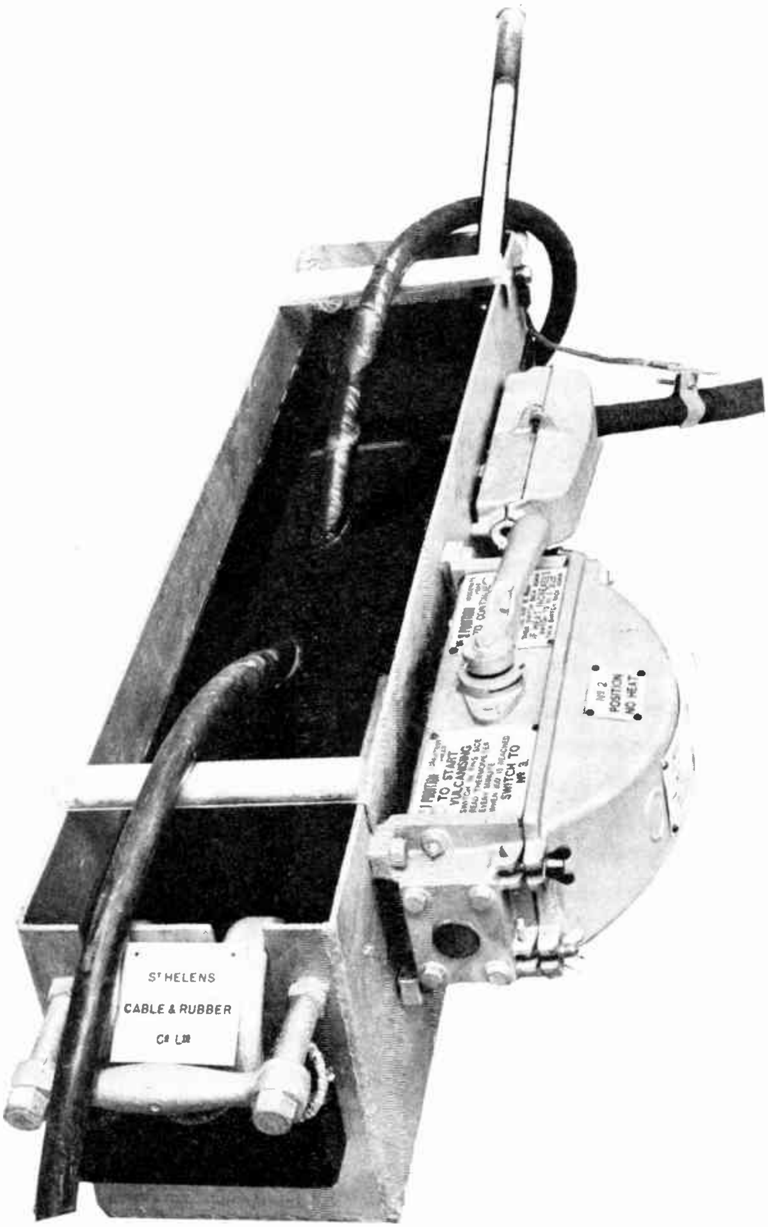


Fig. 6.—VULCANISING A C.T.S. CABLE.

The joint after being prepared as shown in Figs. 3, 4 and 5, is immersed in vulcanising compound, and the temperature is raised to 290 deg. F. After half an hour the vulcanisation is complete.—(*St. Helens Cable and Rubber Co., Ltd.*)

When the vulcanisation is completed the joint is removed. On stripping off the wrappings, the joint should be tested with the thumb-nail. If the rubber is indented, the joint is too soft. If the joint is stiff, the rubber is too hard. If satisfactory, the joint is completed by layers of tape extending over the braiding, followed by a coat of shellac varnish.

Moulded rubber articles and ebonite are vulcanised in a " curer " fed with live steam for 4-8 hours at 145-150° C.

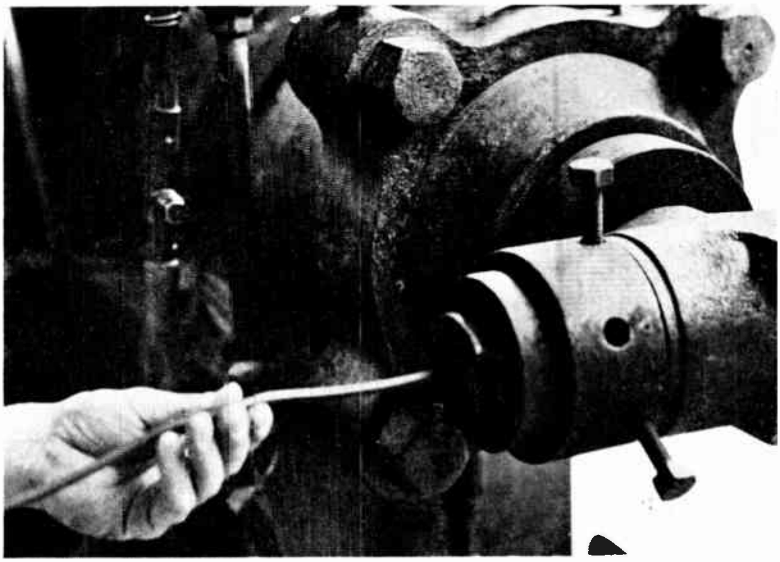


Fig. 7.—EXTRUDING THE TOUGH RUBBER SHEATHING ON TO THE INSULATED CORE OR CORES.—(*St. Helens Cable and Rubber Co., Ltd.*)

Why Copper Wires Should be Tinned.

It should be noted that copper wires used with rubber, especially vulcanised rubber, should be tinned. Otherwise the sulphur attacks and corrodes the surface of the metal, causing it to go black. In this state copper is very difficult to solder.

Working with Ebonite.

As already indicated, ebonite or vulcanite is composed of rubber vulcanised with, say, 45 per cent. of sulphur, and some adulterative filler such as zinc oxide. The material is hard, somewhat brittle, but otherwise reasonably strong. It is a good insulator, and has the very valuable property of easy machining. It can be drilled, tapped, filed, ground, etc., with ordinary metal-working tools, and can be quickly cut with a hack-saw. The high polish obtained by manufacturers (as seen in telephone and radio parts) is usually beyond the amateur. It is easy to obtain a satin-matt finish, however, by smoothing with very fine glass-paper and oil.

If exposed for long periods to light and damp, the sulphur in ebonite develops sulphuric acid, and leaves a greenish surface. This can be removed by repolishing.

The Value of Gutta-Percha.

Like rubber, this is another tropical tree product, being the latex of a tree found only in Malay. It is soft and mouldable at a temperature of 60-70° C., but hardens and becomes brittle on exposure to air. It has been found to be extremely durable when immersed in water away from light, and consequently has been used for the insulation of submarine telegraph cables, in spite of its somewhat inferior electrical insulating value.

Chatterton's Compound is a mixture of gutta-percha, Stockholm tar and resin in the proportion 3 : 1 : 1. It is a gummy substance, hard when cold, but soft and sticky when hot. It finds many uses in the workshop, such as sealing off the ends of small insulated cables to prevent the entrance of moisture, sticking down the ends of small coils of wire, etc.

Moulded Compositions.

A later article will deal with the manufacture and applications of moulded compositions in detail. Some of these have rubber as the base, others are entirely synthetic, but all are becoming of greater importance as the applications of electricity are extended.

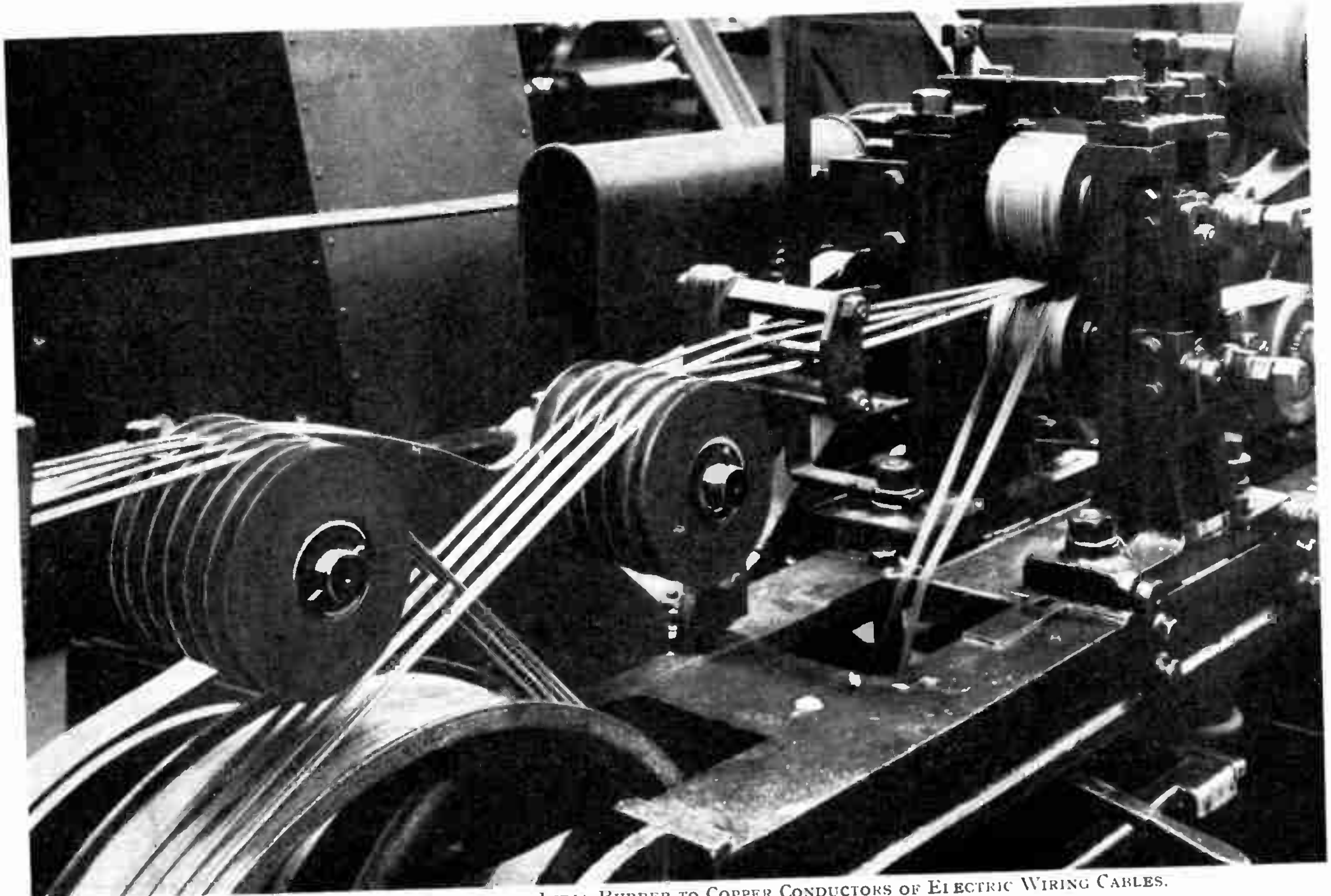


Fig. 8.—APPLICATION OF VULCANISED INDIA RUBBER TO COPPER CONDUCTORS OF ELECTRIC WIRING CABLES.
(*St. Helens Cable and Rubber Co., Ltd.*)

RADIO RECEIVING CIRCUITS

HOW TO READ AND UNDERSTAND THEM, WITH NOTES ON DESIGNING ORIGINAL CIRCUITS

By A. E. Watkins.

It is very easy to follow a wiring diagram, but it is first necessary that the symbols used for the various parts of the circuit are memorised, and, for that reason, the common symbols used in wiring diagrams are illustrated; for it is much easier to follow a circuit by means of symbol diagrams than if the actual illustration of the components are shown, because the symbols show the complete circuit.

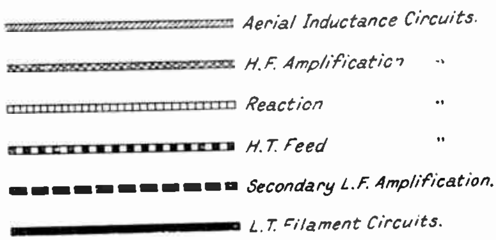


Fig. 1.
This shows the special symbols used to denote the different parts of a circuit in the first fifteen illustrations which accompany this article.

The Tuning System.

The first essential part in a radio circuit is the tuning system, which consists of one or more inductances shunted by variable condensers, the number of condensers and coils depending upon the circuit. In the simplest of tuning circuits, one inductance and one variable condenser are used. This is shown in Fig. 2. It will be noted that the aerial is tapped part-way down the coil. The reason for connecting the aerial in this position is to reduce the load on the inductance and thereby increase the selectivity and overall efficiency of the tuning system.

Obtaining Selectivity.

The smaller the number of turns between the aerial tapping and earth the higher the selectivity. Usually, for medium waves between 200 and 600 metres, the number of turns between the aerial and the earth is from 15 to 25, the number of turns depending on the area where the receiver is used: the smaller number of turns being necessary near the broadcasting stations.

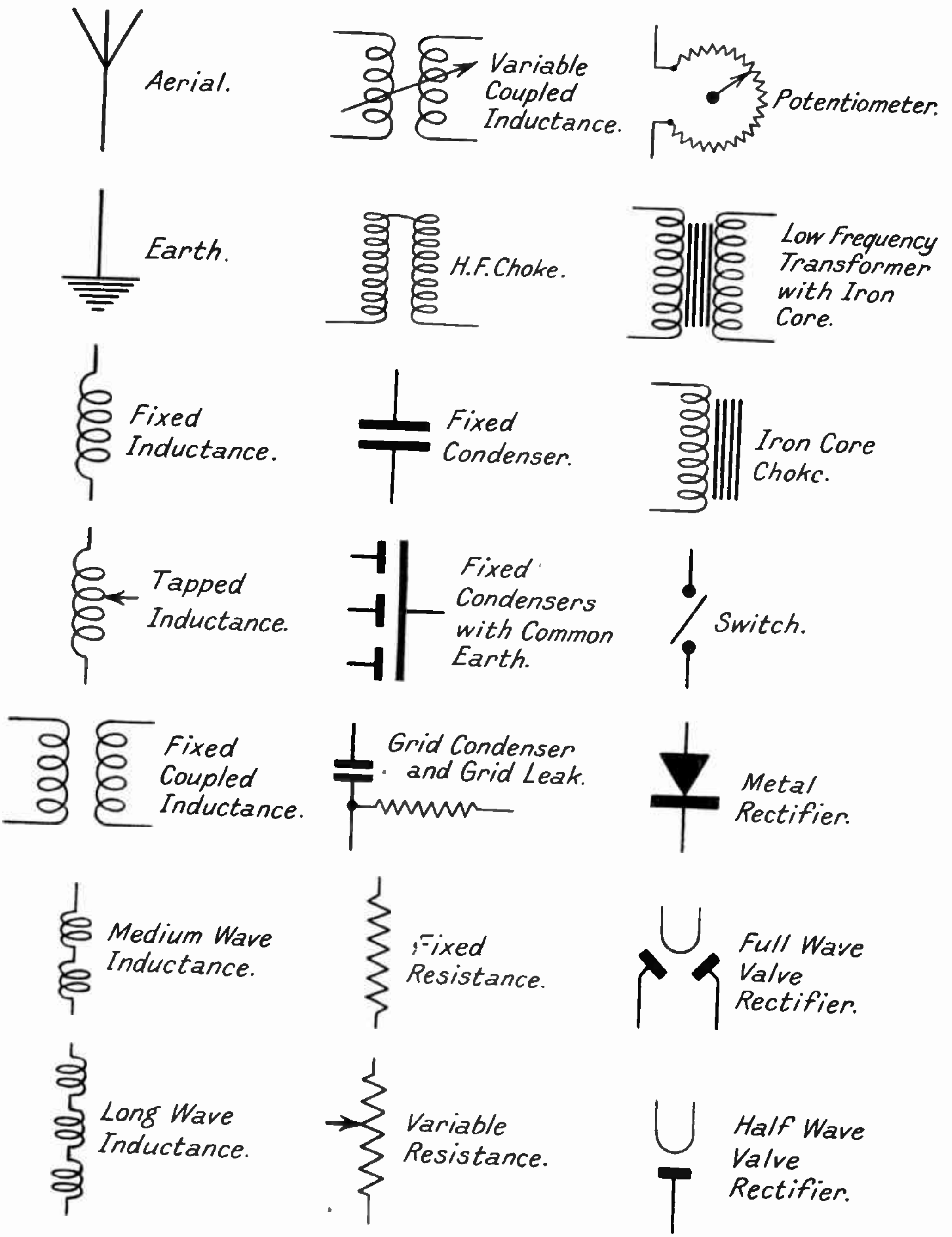
Using a Series Condenser.

It is also sometimes advisable to connect in series with the aerial a small condenser, as shown in Fig. 3. The value may be from .0001 to .0002 m.f. A small variable condenser is often preferred as this can be adjusted to suit the aerial conditions. This aerial condenser is very necessary on the higher wave-lengths because in order to obtain simple switch design, usually the long wave coil only is short-circuited, as in Fig. 4. It will be noted that when the switch is closed, the circuit is the same as in Fig. 3, but when open, the extra inductance is added. This leaves the aerial in a very bad condition for good selectivity, but the aerial condenser improves matters. There is no reason why a switch should not be added to the aerial to change the position of the tapping as in Fig. 5.

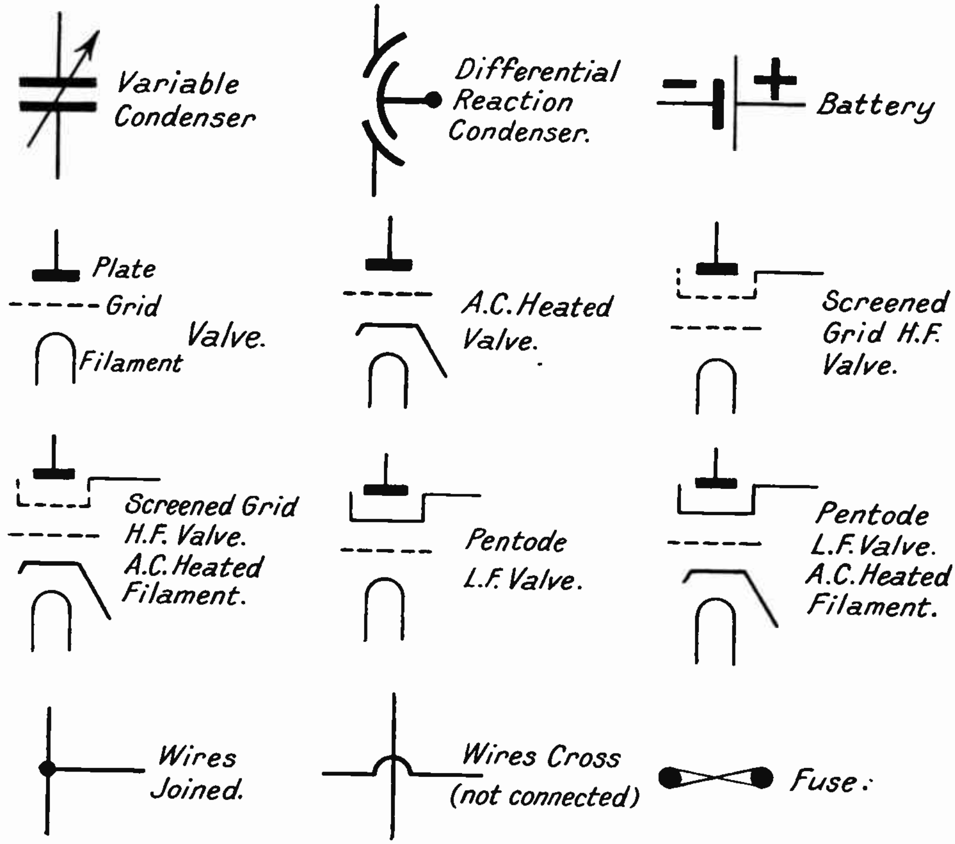
Tapping the Long Wave Coil.

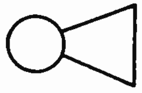
The tap on the long wave coil should be about one-third of the coil. The only disadvantage in switching the aerial is that the switch must be carefully designed so as not to introduce losses, as otherwise it will partly short-circuit the energy to earth, and again, the lever for operating the switch must be carefully insulated. Also, the lead wire from the tapping of the inductance, and also

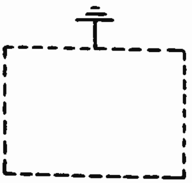
SIGNS USED IN



WIRELESS DIAGRAMS







SYMBOLS

D.C. = Direct Current.

A.C. = Alternating Current.

Periods or Cycles per Second called Frequency, usually written 50∼.

Milliampere = 1/1000 of an Ampere.

Volt = Unit of Pressure.

Ohm = Unit of Resistance.

Megohm = 1 000 000 Ohms.

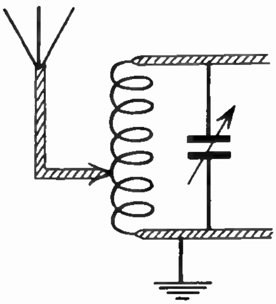


Fig. 2. THE SIMPLEST TUNING CIRCUIT. This consists of one inductance and one variable condenser.

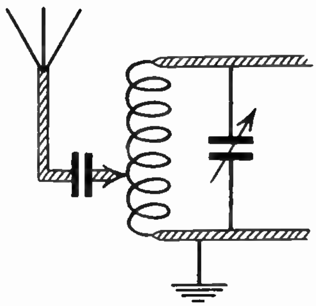


Fig. 3.—ADDING A SERIES CONDENSER. A small condenser of .0001 or .0002 m.f. is sometimes connected in series with the aerial to increase selectivity.

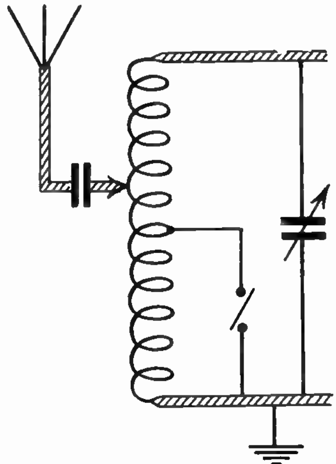


Fig. 4.—ADDING EXTRA INDUCTANCE FOR LONG WAVES. Showing the position of the switch.

for the switch, must be short. This system of tuning is used in most types of simple detector and L.F. amplification receivers.

More advanced methods of tuning will be described later, particularly in cases where H.F. amplification is used. In circuit Fig. 10 no H.F. amplification is introduced, excepting that obtained by reaction.

The Grid Condenser and Grid Leak.

The second part of the circuit is the grid condenser and grid leak.

THE GRID CONDENSER.

From Fig. 6 it will be seen that one side of the grid condenser is connected to the top end of the inductance and to the fixed vanes of the tuning condenser. This is important, for, if the moving vanes, which are usually connected to the spindle of the condenser, are connected to the top end of the inductance, hand capacity will be introduced. This will upset the tuning and the selectivity of the receiver.

The other side of the grid condenser is connected to the grid of the detector valve.

THE GRID LEAK.

This is connected from the grid to the positive side of the valve filament.

H.T. Feed to Plate of Valve.

In every receiver the valve must have H.T. voltage positive supplied to the plate or anode. This is worth remembering, for a fault can quickly be detected if a voltmeter is connected between the plate and filament. This will give a reading if the circuit is correct. (This voltmeter must be of suitable voltage and above the H.T. battery.)

Tranformer Coupling Between Detector and L.F. Amplifier.

The H.T. battery, being connected between the plate of the valve and the filament, every time the grid receives an impulse from the aerial the H.T. current is interrupted. It therefore follows that if the primary of the transformer is connected in series with the H.T. supply and the plate, the varying currents will induce current in the secondary winding, which is connected to the grid and filament of the next valve. (Fig. 7 shows this simplified circuit, which should be thoroughly memorised.)

The H.F. Choke.

Connected in series with the transformer and the anode of the valve is an H.F. choke. The reason for the H.F. choke is that it acts as a resistance to the H.F. current, thereby forcing the current

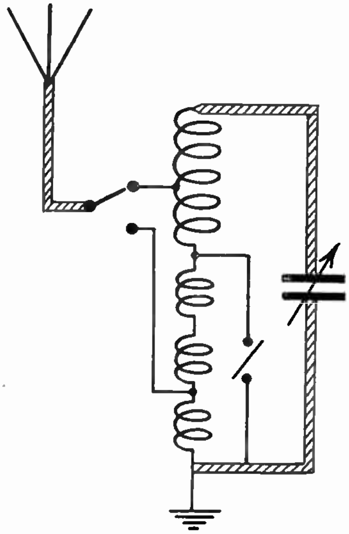


Fig. 5.—ANOTHER METHOD OF ADDING EXTRA INDUCTANCE.
A switch is added to the aerial to change the position of the tapping.

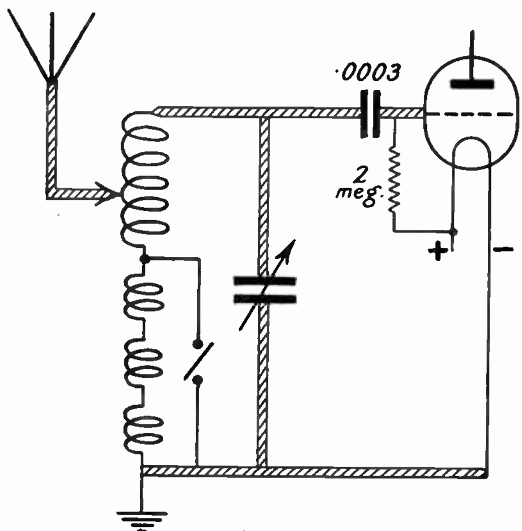


Fig. 6.—THE GRID CONDENSER.
One side of the grid condenser is connected to the top end of the inductance and to the fixed vanes of the tuning condenser. The other side of the grid condenser is connected to the grid of the detector valve.

through the reaction windings. The amount of reaction is easily controlled by a variable condenser or by varying the coupling of the coils.

The Reaction Winding.

It is advisable to have the reaction winding at the earth end of the tuning inductance as this gives smoother control, and the tuning is not varied by the reaction. The circuit is shown in Fig. 8, and for clearness the long-wave windings have been omitted. It will also be noted that the reaction currents, after passing through the coils, are passed to the earth.

A Warning and a Hint.

Remember that there is a direct connection from the plate of the valve to earth, and if the variable condenser be faulty, that is, the plates shorting, the H.T. current will be short-circuited to earth, and this may ruin the H.T. battery and burn out the reaction coil. It is, therefore, a wise plan to connect a fixed condenser at the position marked " X " on the diagram. The size of this condenser should be not less than three times the size of the variable condenser

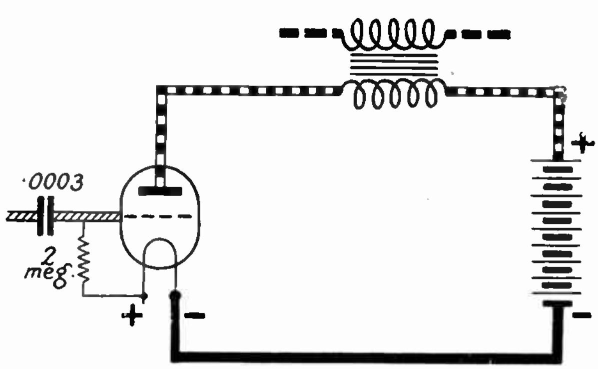


Fig. 7.—TRANSFORMER COUPLING BETWEEN DETECTOR AND L.F. AMPLIFIER.
If the primary of the transformer is connected in series with the H.T. supply and the plate, the varying currents will induce current in the secondary winding, which is connected to the grid and filament of the next valve.

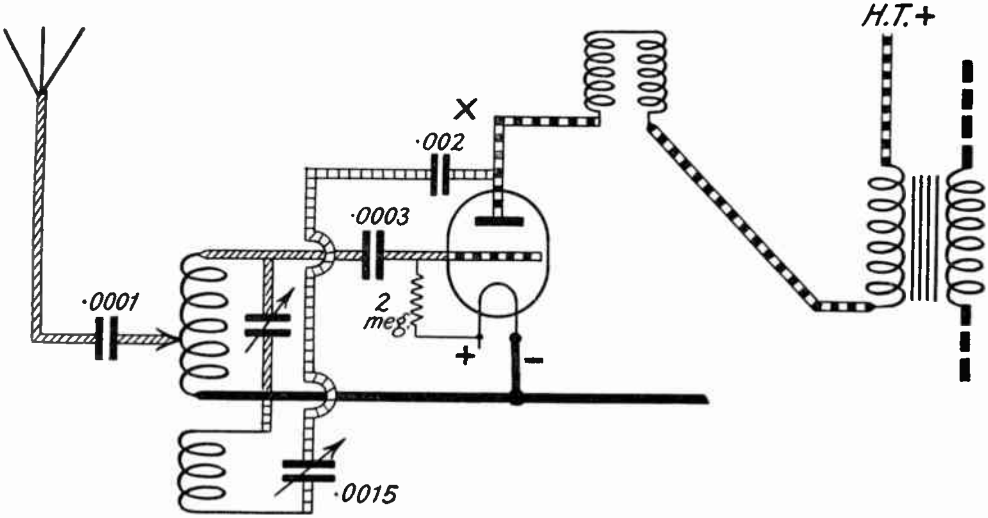


Fig. 8.—THE REACTION WINDING.
It is advisable to have the reaction winding at the earth end of the tuning inductance as this gives smoother control. Note that the reaction currents after passing through the coils are passed to the earth. It is advisable to connect a fixed condenser of not less than three times the size of the variable condenser between the plate of the valve and reaction condenser, as shown at X.

Coupling the Valves.

The next step in the circuit is to transfer the energy in the transformer to the next valve. All that is required here is to connect one end of the secondary to the grid of the next valve, and the other terminal to the grid bias battery, the positive of the grid bias battery being connected to the filament, as shown in Fig. 9, and for clearness only the secondary side of the transformer circuit is shown.

The Grid Bias Battery.

The voltage of the grid bias battery will, of course, depend upon the valves, and this can easily be obtained by reference to the valve maker's table.

A Simple Two-valve Circuit Completed.

Now if Figs. 8 and 9 are drawn together we have Fig. 10, which is that of a straight two-valve circuit and, of course, the loud-speaker would be connected between the plate and the H.T. battery.

Now a Three-valve Circuit.

If we wish to construct a three-valve receiver, we now only have to add a similar transformer circuit to that between the detector valve and the first L.F. valve, with the exception that we omit the H.F. choke and the reaction winding. This would therefore give us a circuit as shown in Fig. 11.

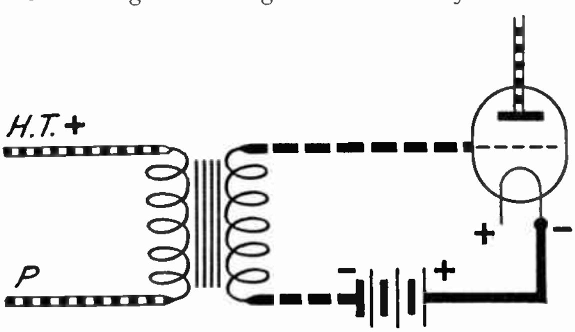


Fig. 9.—COUPLING THE VALVES.
For clearness only the secondary side of the transformer circuit is shown.

Why Two Stages of L.F. are Rarely Exceeded in Practice.

It will therefore be seen from this explanation that we could go on adding stages of L.F. amplification to obtain any desired amplification, but this in

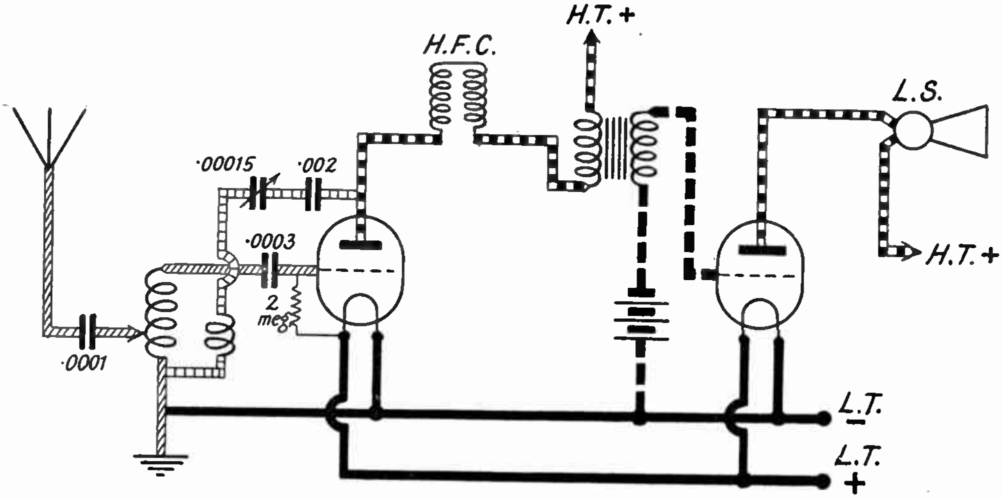


Fig. 10.—A SIMPLE TWO-VALVE CIRCUIT COMPLETED.
This is really a combination of Figs. 8 and 9, with the addition of the loud-speaker between the plate of the L.F. valve and the H.T. battery.

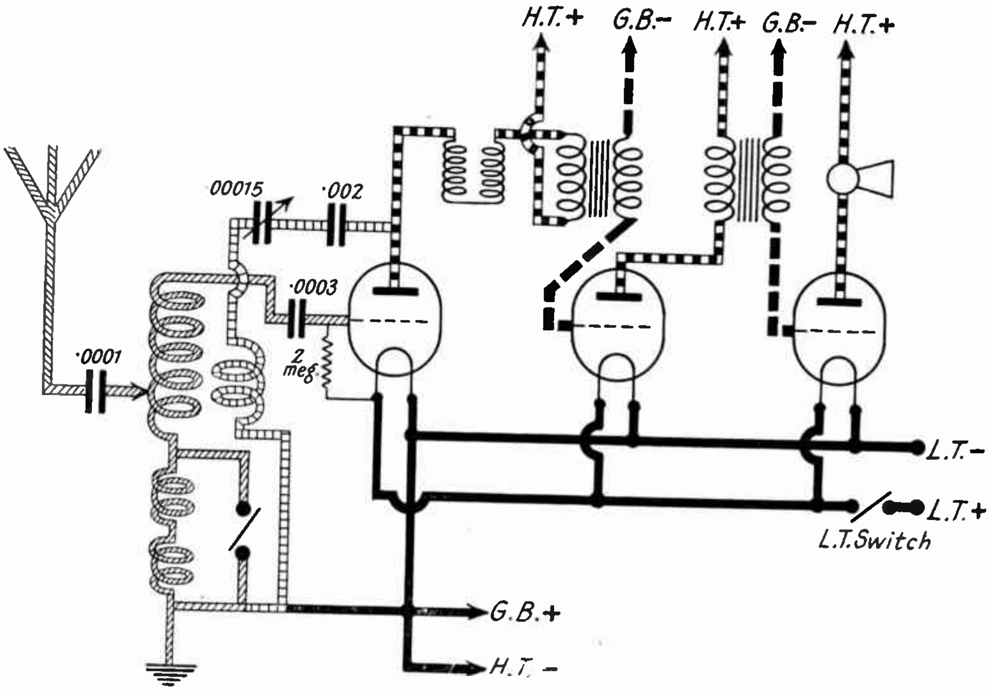


Fig. 11.—A THREE-VALVE CIRCUIT.
To construct a three-valve receiver, it is only necessary to add a similar transformer circuit to that between the detector valve and the first L.F. valve, with the exception that the H.F. choke and reaction winding are omitted. Usually if more than two stages of L.F. amplification are added great care has to be taken to prevent distortion, and that is why with ordinary standard commercial receivers only two stages of L.F. amplification are used at the most.

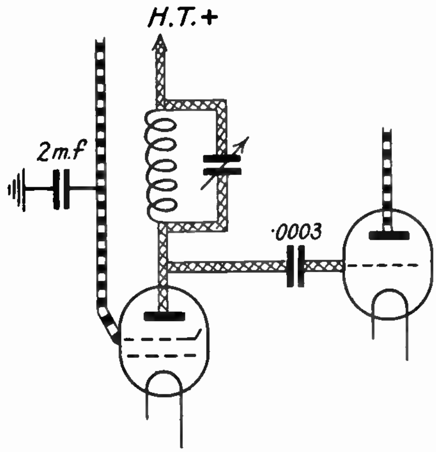


Fig. 12.—The Tuned Anode Circuit.
This consists of an inductance in the plate circuit tuned by a variable condenser, the amplified H.F. current being passed to the next valve by the fixed condenser.

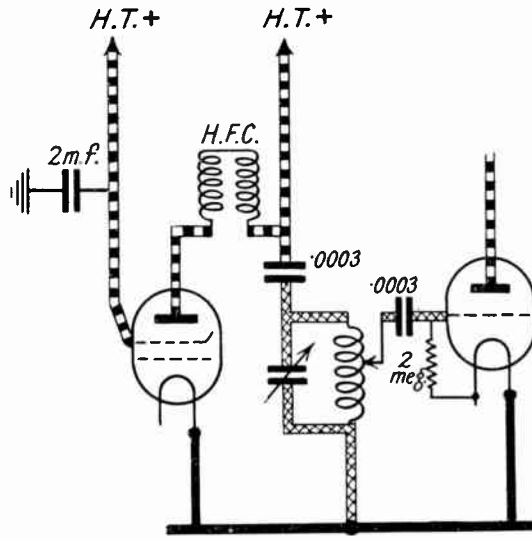


Fig. 13.—The Tuned Grid Circuit.
Nearly all modern receivers employ the tuned grid. It will be seen that the inductance in the plate circuit is replaced by a H.F. choke and the inductance is connected between the grid and the filament.

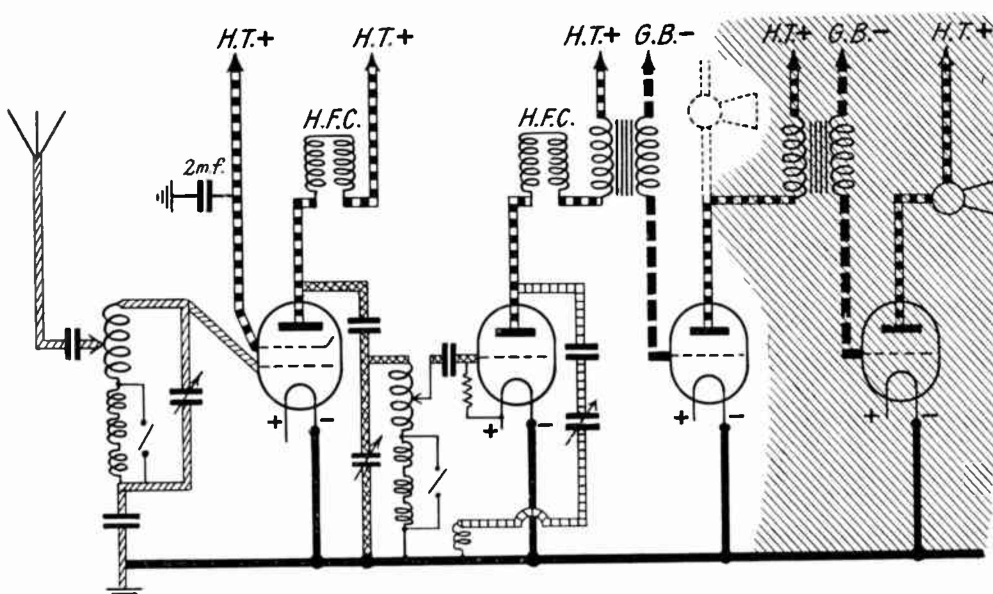


Fig. 14.—A Four-Valve Screened Grid Receiver.
This is the circuit shown in Fig. 11, with the addition of the tuned grid circuit shown in Fig. 13. In this circuit are shown the connections to the screened grid, to which is connected the H.T. positive, also a fixed condenser of 2 m.f. is connected to earth. If we take away the shaded portion we have left a three-valve receiver consisting of screened grid, detector, and L.F.

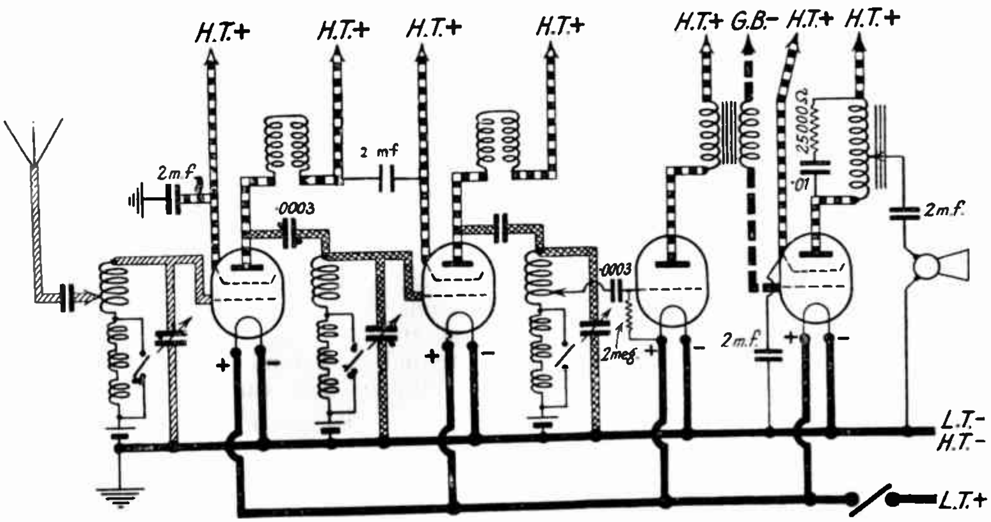


Fig. 15.—Two Stages of H.F. Amplification.
It is not practical to add more than two stages of H.F. amplification to any receiver.

practice is not possible, and usually, if more than two stages are added, great care has to be taken to prevent distortion; that is why with ordinary standard commercial receivers usually only two stages at the most of L.F. amplification are used.

L.T. Filament Supply.

The only other part of this circuit which has not been mentioned is that of the filament current. The filaments are all joined together in a parallel, that is to say, one side of each filament of the valves is connected to the earth, which is in turn connected to the negative side of the L.T. battery, and all the other sides of the filaments are connected to the positive side of the L.T. battery, as shown in circuit Fig. 11. It should be remembered that in all battery receivers it is usual to connect all the filaments of the valves in parallel.

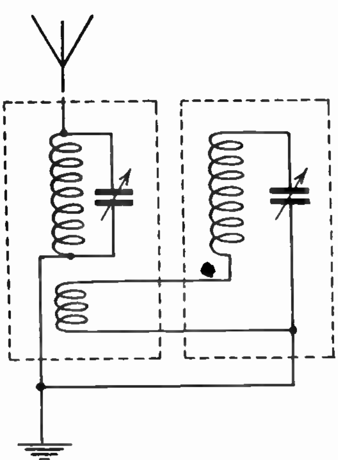


Fig. 16.—Band-Pass Tuning.
(1) The inductive coupled circuit.

How to Use the Standard Diagrams When Tracing Faults.

The diagrams show each individual circuit drawn in different shadings, and if on testing a receiver for faults each of these circuits is taken in turn one cannot help but find the faulty part.

For instance, should a transformer be broken down, there would obviously be no circuit, and the same would apply to any other component, excepting, of course, condensers, which offer a resistance to direct current. When testing a condenser with direct current, it should be remembered that no indication of current should be observed. A flow of current would indicate a faulty condenser.

H.F. Amplification.

H.F. amplification means amplifying the high frequency aerial current before it is rectified by the detector valve. All modern receivers employ the

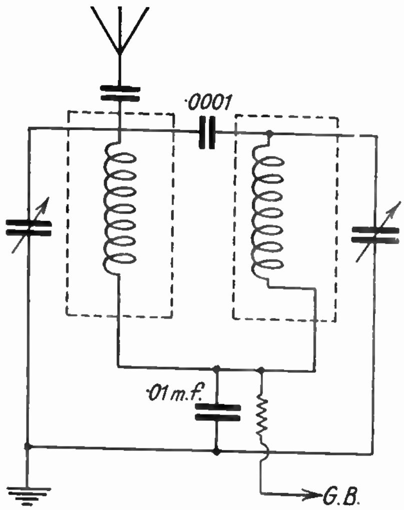


Fig. 17.—BAND-PASS TUNING.
(2) The capacity coupled circuit.

screened grid valve, as its efficiency is very much greater than the ordinary three-electrode valve, also the circuits used with the screened grid valve are of the simplest, for the screen controls the self-oscillation.

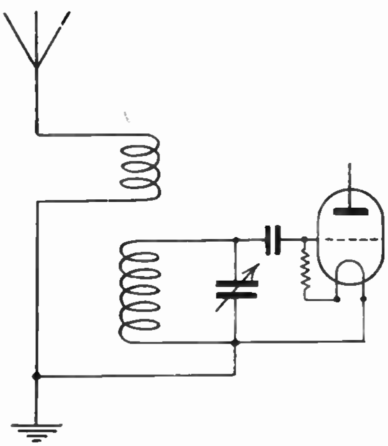


Fig. 18.—LOOSE COUPLING FOR SELECTIVITY.

When the aerial is fed through a small inductance loosely coupled to the grid coil, as shown, the looser the coupling the greater will be the selectivity.

The Simplest H.F. Amplification Circuit—The Tuned Anode.

The simplest circuit is that shown in Fig. 12, called the "tuned anode," as the inductance is in the plate circuit and tuned by the variable condenser, the amplified H.F. current being passed to the next valve by the fixed condenser.

A Disadvantage of the Tuned Anode.

Now, while this system is efficient, it has one very great drawback, and that is that the variable condenser is at high potential, and it must be insulated from the frame, also tuning is affected by hand capacity.

The Tuned Grid.

For this reason practically all modern receivers employ the tuned grid, as shown in Fig. 13. It will be seen that the inductance in the plate circuit is replaced by an H.F. choke, and inductance is connected between the grid and filament. Now, in this system, the moving vanes of the tuning condensers are connected to the earth and therefore, being at earth potential, the tuning is not affected by hand capacity and it is therefore easy to gang all the tuning condensers together, thus simplifying tuning.

Connections for the Tuned Grid System.

It is a great advantage in the tuned grid system to connect the grid of the next valve to a tapping about one-third down the coil, and should this next valve be the detector valve, the grid condenser and grid leak should be connected as shown in Fig. 13.

Adding a Stage of H.F. Amplification to a Three-valve Receiver.

All that it is necessary to do is to remove the aerial inductance and replace this with a circuit similar to that in Fig. 13. We shall now have a circuit similar to that in Fig. 14. In this circuit, also, are shown the connections to the screened grid, to which is connected the H.T. positive, also a fixed condenser of 2 m.f. is connected to earth. The voltage usually supplied to the screen of these valves is, approximately, half that of the H.T. current supplied for the plate, but this, of course, depends upon the type of valve, and instructions for this must be taken from the valve maker's instructions.

We will now add the aerial inductance and the circuit is complete.

The only difference between this and the grid circuit already dealt with is that it is often necessary to apply a grid bias to the grid of the H.F. valve. To accomplish this it is only necessary to break the circuit where it is connected to earth and add a grid bias battery, 1½ volts. Otherwise, the aerial tuning system is exactly the same as a straight detector and L.F. receiver.

The Importance of Screening.

With this type of receiver it is very essential that the tuning inductances are completely screened, as otherwise interaction will occur between the two inductances, and then the whole efficiency of the receiver would be spoiled. It is also a great advantage to screen the tuning condenser and also the H.F. valve.

Running the Wires on the H.F. Side.

Secondly, it is most important that the wiring should be as short as possible, and the wires between the aerial tuning inductance and the H.F. inductance kept well apart.

A Typical Three-valver.

Fig. 14 (without the screened portion) shows a three-valve, screened grid, detector and L.F. receiver in which the circuits are clearly shown. The screened portion shows the circuit with an extra stage of L.F. amplification.

Two Stages of H.F. Amplification.

It is very rarely that more than one stage of H.F. amplification is necessary with the screened grid valve, but should there be circumstances in which it is necessary to use two stages in a case where frame aerials are employed, or is in a position in which greater H.F. amplification is necessary, the circuit in Fig. 15 shows a receiver with two stages of screened grid H.F. amplification. It is not practical to add more than two stages of H.F. amplification to any receiver.

Band Pass Tuning.

The next most important matter in the receiver is that of band pass tuning. Owing to the great increase of broadcasting stations and the necessity for higher selectivity, this system of tuning has had to be developed to increase the selectivity of the receiver. It is really two inductances each tuned by separate condensers. These two circuits are coupled together, either inductively or by means of a fixed condenser. This is called the mixed filter unit. In each case it is only the method of transferring the energy developed in the first tuning inductance to that of the second tuning inductance.

An Explanation of the Circuits.

The circuits are really simple, as shown in Figs. 16 and 17. That shown in Fig. 16 is the inductive coupled and that shown in Fig. 17 is the capacity coupled. In the inductive coupled tuning, the first inductance equals the value of the second inductance plus the small coupling coil on the first tuner.

How and Why Ganged Condensers are Used.

The reason for the first inductance being the same value as the second inductance plus the coupling coil, is at once apparent as, by carefully balancing these coils, the tuning condensers can be ganged.

Of course, it is not absolutely essential that the tuning condensers should be ganged together, and it is quite usual to use two separate condensers, but if the inductances are matched it simplifies the tuning as the two condensers will always be in step, providing, of course, that the condensers are properly made: that is to say, that they are of the same capacity in every position throughout their scale.

The Aerial Condenser for Band Pass Tuning.

In the mixed filter system, both inductances are equal, and the energy developed in the first coil is transferred to the second coil by the fixed condensers. In most systems of tuning, it is advisable to connect the aerial to the first inductance by a small condenser. It is advisable

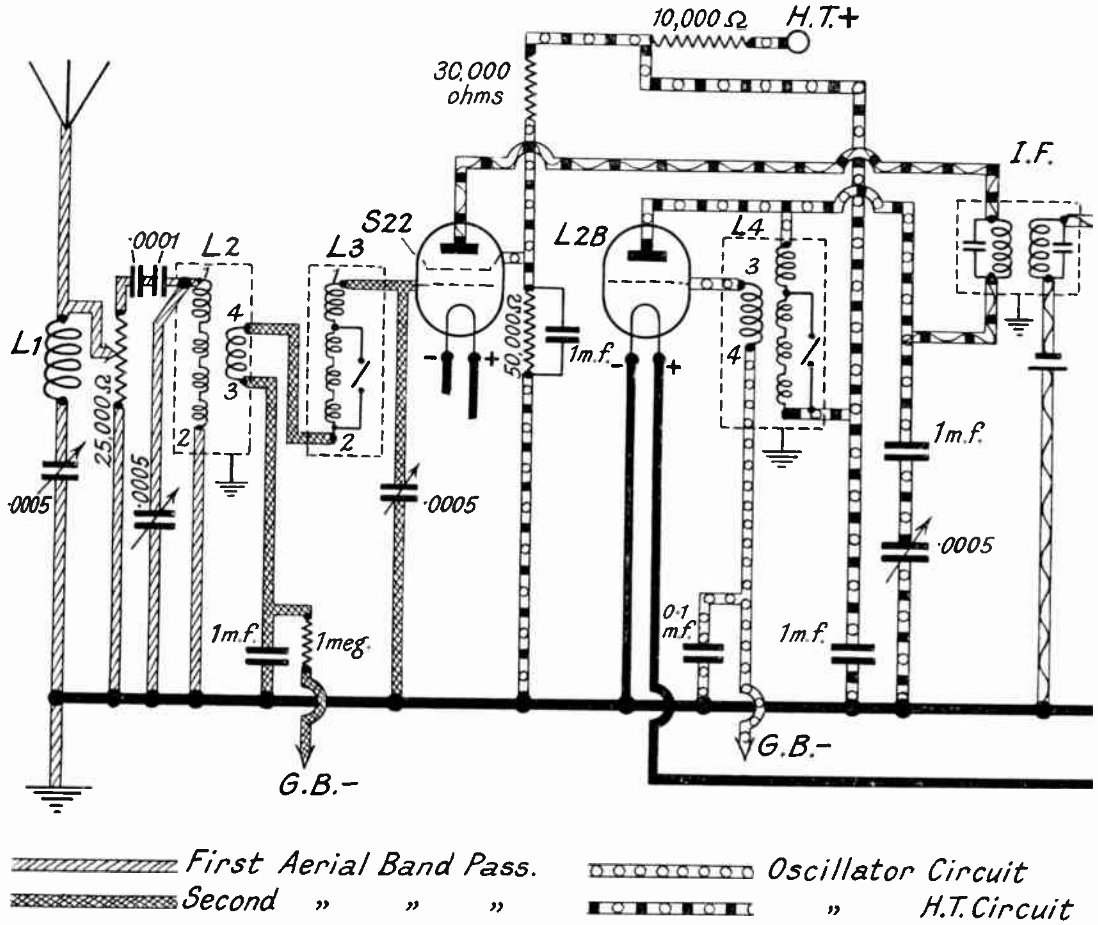


Fig. 19.—CIRCUIT DIAGRAM OF THE BAT

In this illustration the filament negative and positive of the first valve is connected the same as the ot

circuit als

that this condenser be adjustable, so that for various sized aerials tuning will be correct.

In every case in a band pass tuner it is necessary that each inductance is independently screened, as otherwise the coupling between the two inductances will spoil the result.

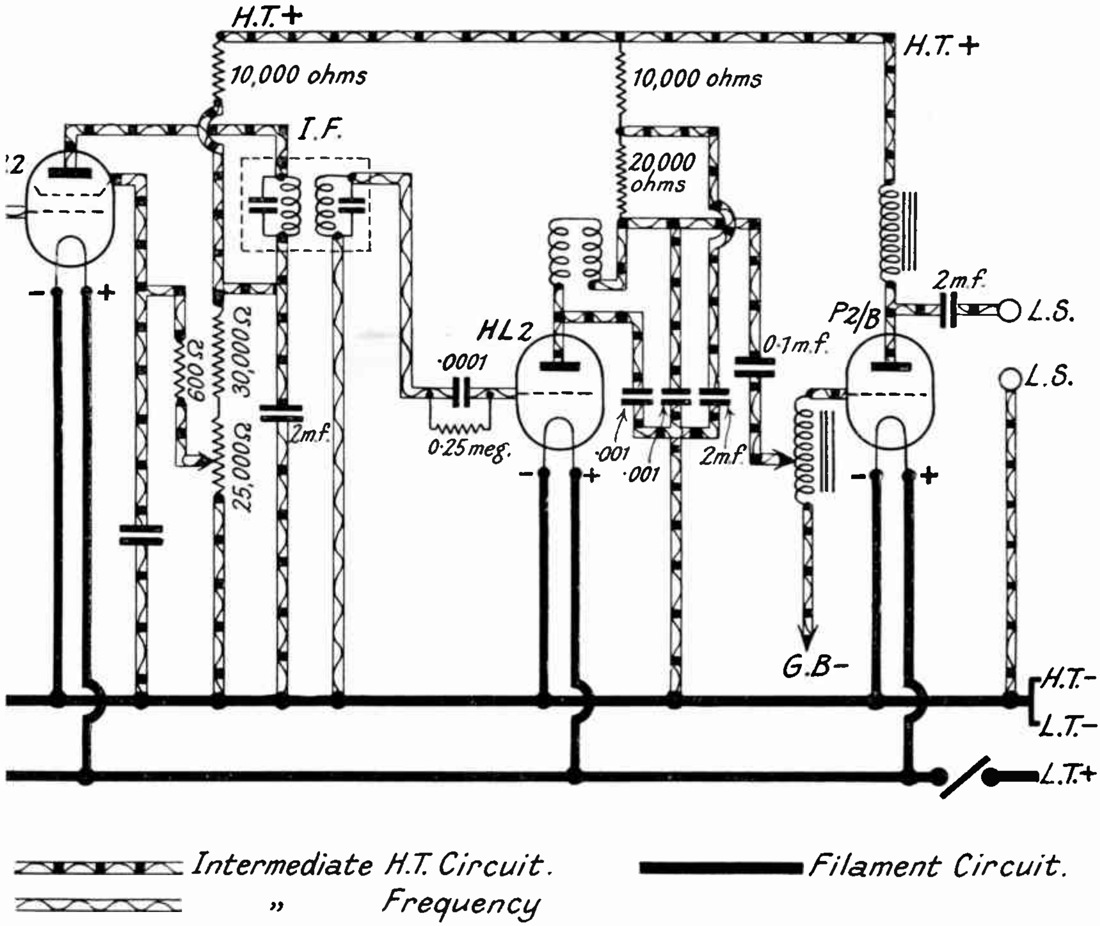
Loose Coupling Gives Selectivity at the Expense of Signal Strength.

There is one other method of obtaining high selectivity, and that is by means of a loosely coupled aerial, that is to say, the aerial is fed through a small inductance loosely coupled to the grid coil, as shown in Fig. 18, the selectivity being obtained by the looseness of the coupling. The looser the coupling, the higher the selectivity, but also with a decrease in the signal strength.

Having now described the simple detector and L.F. receivers and receivers with H.F. amplification, the next most important receiver to describe is the superheterodyne.

THE BATTERY-OPERATED SUPER-HETERODYNE RECEIVER.

The interference to which the ordinary receiver is subject, due to stations working with only a small separation, is well



OPERATED SUPERHETERODYNE RECEIVER.
lves, but is not shown for the sake of clearness. The symbols used to denote the different parts of a
to Fig. 20.

known. This interference is the only point considered in the design of ordinary receivers, but with the superheterodyne other forms of interference have to be considered, therefore careful design is necessary and it must be built with specially designed parts.

The most satisfactory receiver of this type, also the one which is the easiest to construct, is that designed by W. T. Cocking, and published in *The Wireless World*. Specially designed components, such as the band-pass filter, oscillator coils and the intermediate frequency transformers are manufactured by certain firms, but details of their construction will be given for the benefit of those readers who wish to make their own components.

The Band Pass Tuner.

It is essential that band pass tuning is used with a superheterodyne receiver, particularly when an outside aerial is used, for this system of tuning prevents, to a certain extent, re-radiation. The most suitable system is the inductance coupled.

The Superheterodyne Receiver.

Referring to Fig. 19, the aerial is connected to inductance L1. This is a flat-wound coil of approximately 550

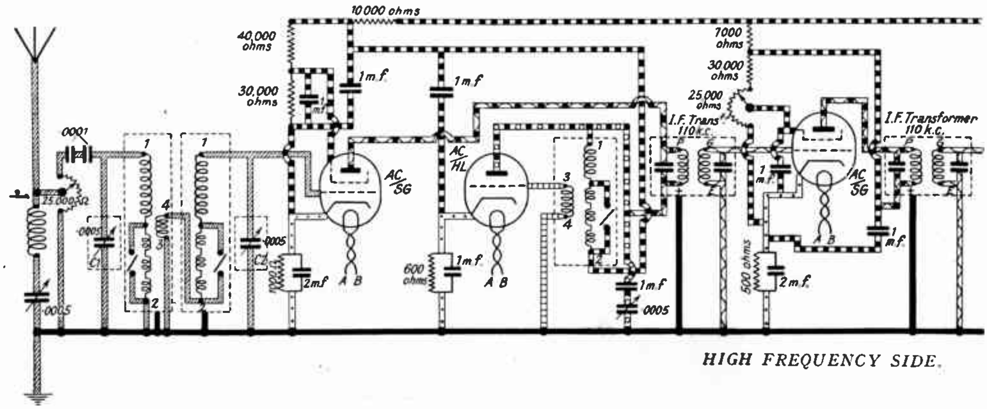


Fig. 20.—CIRCUIT DIAGRAM OF THE SUPERHETERODYNE

The general layout of the first part of the circuit is very similar to that of the battery operated of obtaining grid bias. See Fig. 19 for

turns of 36 double silk-covered wire, wound on a bobbin, and it is termed a "slab coil." The other terminal of this slab coil is connected to a .0005 prefixed condenser to earth. This is called the acceptor circuit, and prevents stations working on a similar frequency to that of the intermediate frequency causing interference.

The 25,000-ohm potentiometer, which should be wire-wound, controls the aerial input acting as a volume control.

The Feed Condensers.

These are two .0001 in series connected to one end of the potentiometer and No. 1 terminal of the first band-pass filter. The No. 1 terminal is internally connected in the tuner to the top end of the winding.

The Tuning Condensers.

Each of the tuning condensers is .0005 fitted with adjusters completely screened and ganged together.

Construction of Coils.

All the coils are of standard design except that the winding details are different and those manufactured by the Watmel Company are as follows :—

The medium wave winding is wound on a paxolin former $1\frac{1}{4}$ inches in diameter and approximately $2\frac{1}{4}$ inches long. This is wound with silk-covered wire, with the number of turns given in Fig. 21.

The long-wave winding is wound on a slotted former moulded to the base, with the number of turns as stated in Fig. 21.

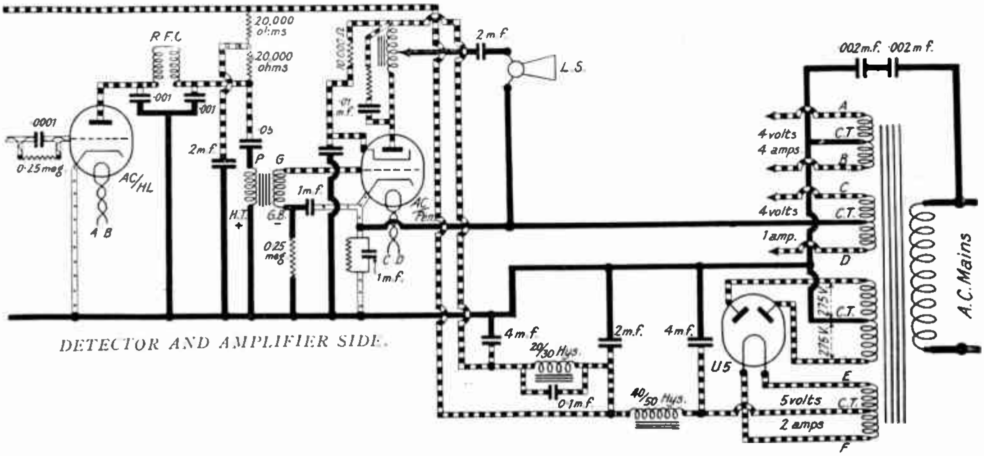
Inside the base is fitted the switch which has gold and silver contacts. The reason for the contacts being of these metals is that it does not oxidise and therefore form bad contacts. These are operated by a cam through which passes the operating rod so as to gang together the whole set of coils, so that by one turn of the knob the three switches are changed.

The screens are of aluminium, the size being approximately $2\frac{1}{2}$ inches in diameter, this being the most suitable size for a coil of the diameter of $1\frac{1}{4}$ inches. The size of the screen, relative to the size of the coil, is important to obtain effective screening. The height of the screen is 5 inches.

Matching the Coils.

It is important in the manufacture of coils, to match the winding together; that is to say, each inductance tuned by the condenser must be exact, as otherwise the tuning will not hold true over the whole scale reading of condensers.

Therefore, each coil must be adjusted on an oscillator to see that it is of the same reading at all settings of the con-



RECEIVER FOR A.C. MAINS OPERATION.

set, excepting that there are various modifications of the value of the resistances, also the method explanation of symbols used in this circuit.

denser. Details for matching coils will be dealt with later in an article on components.

The Frequency Changer.

This is a screen grid valve biased at 1.5 volts to act as an anode-bend rectifier, which is the first rectifier or detector.

In the anode circuit are included the primary of the first intermediate frequency transformer and the tuned anode winding of the oscillator coil. This makes the circuit non-radiating and prevents interaction between the tuning controls and simplifies the wave-change switching.

The Oscillator Valve.

This second valve is of the three-electrode type, the grid being connected to the reaction winding of the oscillating coil. If, on first connecting, the oscillator does not operate, reverse the connection, for it is important that the direction of circuits to the primary of the oscillating coil is correct.

Intermediate Frequency Transformers.

These consist of two inductances placed about 1 inch apart and tuned by two condensers. The details of the winding will be seen from the sketch, and the fixed condensers are approximately .0003.

To balance each of these inductances and condensers correctly, two small trimer condensers are placed parallel with the fixed condensers, for it is important that these are in exact tune and also slightly adjustable so as to balance out the stray capacity.

Coils and Condensers Should be Screened.

Both coils and condensers should be screened, and it is important that the screen should enclose the whole unit.

The efficiency of the intermediate frequency transformer depends upon the correct matching of the two inductances, and also upon the distance which they are apart. If they are too close together, the quality of the receiver will suffer. Usually at a distance of 1 inch apart, they give the best results, but this is a matter of experiment and is usually adjusted after the receiver is completed.

It will be noted that there are two intermediate frequency transformers, and after this comes the detector valve, which is the second detector and is very similar to ordinary L.F. circuits.

After this detector valve the circuit is exactly the same as an ordinary receiver.

Resistances and Condensers.

Further examination of the circuit will reveal a number of various resistances and condensers. These are very necessary and have been calculated to

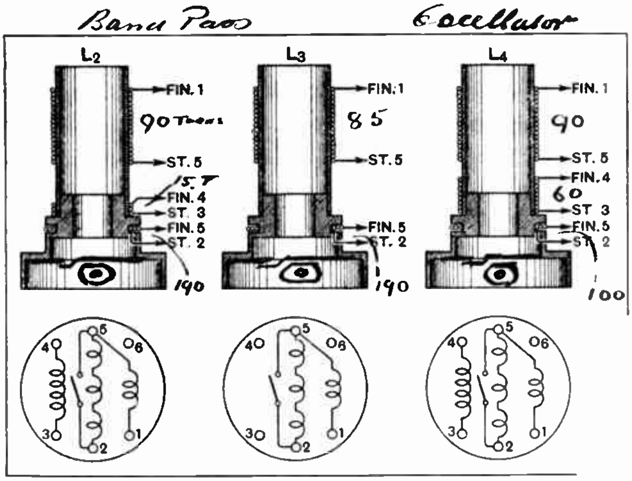


Fig. 21.—How the Coils are Wound.
It is important in the manufacture of coils, to match the winding together; that is to say, each inductance tuned by the condenser must be exact, as otherwise the tuning will not hold true over the whole scale reading of condensers.

give the best results. It will also be noticed that the choke filter output is arranged at the last valve. This is very important and must be used in the superheterodyne receiver. Any good L.F. choke will be perfectly suitable providing that it has an inductance of approximately 50-70 henries.

Using an Auto Choke.

In place of the ordinary transformer between the detector and output valves, an auto-choke coupling is provided. This gives very much better quality than a transformer. The position of the tapping is 3—1. This grid choke should have an inductance of from 50-75 henries.

Layout of the Receiver.

The components of the receiver should be laid out very similarly to those in the diagram. That is to say, each circuit should follow in rotation, and it is very important that the H.F. side should not be mixed with the L.F. side. The various tuning condensers are placed in front of the tuning coils; that is to say, the band-pass tuning condensers are in front of the band pass coils, and the oscillating condenser is in front of the oscillating coil.

Keep the Wiring Short and Well Spaced.

The intermediate frequency transformer should be placed at the back of the receiver so that the distance between the oscillating coil and the intermediate transformers is as great as possible. The wiring should be both short and well spaced so as to prevent interaction; but little trouble will be experienced providing that these components have proper screens. Those, of course, which are supplied by manufacturers are correctly screened but each screen must be properly earthed.

The various by-pass condensers and resistances should be laid out similar to the diagram, for the more direct each circuit the better. This then reduces the wiring to a minimum.

The volume controls are mounted on the panel.

Use First-class Components and Care.

It is also important that only first-class components should be used in the construction of the superheterodyne receiver; cheap transformers and L.F. choke should be avoided at all costs.

SUPERHETERODYNE RECEIVER FOR A.C. MAINS OPERATION.

The cost of running mains sets is much less than that of battery sets. Even a large mains set would not cost more than ½d. per day for the power consumed.

Although the superheterodyne receiver is one of the most complicated, it nevertheless can be operated from A.C. mains with every satisfaction.

The general layout of the first part of the circuit is very similar to that of the battery-operated set, excepting that there are various modifications of the value of the resistances, also the method of obtaining grid bias. The circuit is shown in Fig. 20.

In mains-operated receivers it is usual

to obtain the grid bias by means of the voltage drop across a resistance which is in series with the filament or the cathode of the indirectly heated valve.

The Importance of Screening.

The first three valves of this receiver must be totally screened, while the band-pass tuner, oscillator coils and intermediate frequency transformers should also be screened, and all screens connected to earth. Particular attention should be given to the effective earthing of the screen or otherwise mains hum will result and satisfactory results will not be obtained. The same applies to the tuning condensers of the band-pass tuner. These two condensers must be screened and earthed in the same manner as the coils. It is not important to screen the oscillator condenser although this can be done.

The Oscillator Circuit.

At first sight, the oscillator circuit looks complicated, but if this is carefully followed by the wiring diagram, the simplicity will be seen.

The grid of the second valve is connected to the primary winding of the oscillator coil and connected straight to earth.

Parallel with this circuit is the intermediate frequency transformer's primary. The H.T. terminal is connected to Terminal No. 1 of the oscillator, the H.T. passing through the primary of the transformer to the plate on the first valve, but it will be noted that the primary of the intermediate frequency transformer is really in series with that of the secondary of the oscillator coil for the H.T. supply.

The second intermediate frequency transformer is connected in a similar manner to an ordinary transformer, and the diagram shows the circuit quite clearly.

After the detector valve No. 4, the ordinary L.F. circuit is used, excepting that in this instance, instead of the primary being in series with the H.T. it is connected from the plate to earth, but between the plate and the primary of the transformer is an .05 fixed condenser.

The H.T. current to the plate of the valve is fed through resistances. This is what is termed "resistance feed coupling" and by this means, no H.T. current passes through the primary of the transformer.

Grid Bias Connections.

Secondly, as we are obtaining free grid bias from the mains, the grid bias secondary is not connected direct to earth, but through a .25 grid leak. This is called a "de-coupling circuit." Between the grid bias terminal of the transformer and the cathode of the valve is a 1 m.f.d. condenser. This is to complete the secondary circuit of the transformer and allow a free path for the L.F. current.

The L.T. and H.T. Supplies.

This is really an ordinary H.T. and L.T. eliminator and is perfectly simple. As will be noted from the drawing, for clearness sake the filaments of the valves of the receiver and that from the transformer are not shown connected in the drawing, therefore, they are connected to the respective filament terminals, as lettered.

As it is alternating L.T. supply it is advisable to twist these leads together as this prevents any hum. Use heavy gauge wire, well insulated (at least 16 gauge). Separate L.T. filament leads to the transformer terminals are advised, that is to say, a pair of leads taken from each valve direct to the terminals as, owing to each filament taking a heavy current, and the voltage being low, the resistance of the leads is important.

The H T. Rectifier.

The connections of the rectifier valve of the transformers are very straightforward and simple, but there is a point of warning here which must be emphasised. The filament supply of the transformers and also of the leads must be well insulated because this is the positive H.T. supply, and if the insulation is bad, a short-circuit to earth is likely.

The L.T. smoothing choke should be, approximately, 40-50 henries and, of course, low resistance suitable for H.T. smoothing circuits.

The condensers should be suitable to withstand at least 500 volts on test.

More Advanced Sets.

In a later article details will be given of more advanced circuits such as: The A.C. power detector and pentode; A.C. 3-valve band pass tuning, screened grid high frequency; a power detector pentode circuit; and a D.C. mains superheterodyne.

ELECTRO-MEDICAL APPARATUS

By E. M. Sutton.

In this article we propose to deal mainly with apparatus in which the electric current is applied directly to the patient. Before doing so, however, we will briefly refer to some apparatus in which electricity is used to provide the motive power for massage purposes.

Vibratory Massage Apparatus.

A suitable electric motor, generally of about $\frac{1}{4}$ h.p., is mounted on a cast-iron base incorporating the starting resistance. This resistance is heavy enough to regulate the speed of the motor under working conditions. Mounted on one of the end plates of the motor is a screw attachment which clamps a flexible shaft in position. The method of attachment is shown in Fig. 1. Mounted on the other extremity of this flexible shaft is a rotating weight fixed eccentrically on a spindle. This is enclosed in a hollow metal sphere, known as the "vibrator head." The vibrations can be applied to the patient direct from the vibrator head, or through the medium of different shaped applicators.

Sometimes the vibrator is built up in portable form, in which case the flexible shaft is dispensed with, the applicators being fixed direct into an eccentrically revolving spindle, fixed on an extended portion of the motor shaft.

Care and Maintenance of Vibrators.

The brushes of the motor require attention from time to time. The method of securing the brush in position is shown in Fig. 2. These brushes wear down gradually and have to be renewed. The commutator of the motor should be kept clean and free from oil. If it gets in a very bad condition it may be cleaned with some very fine glass paper. Trouble may occur on the regulating resistance of the motor. The sliding contact here should be cleaned and adjusted occasionally. The remaining points to be attended to refer to the lubrication of the motor, flexible shaft and vibrator head. Oil holes are provided on all bearings and these should be kept well oiled, always taking care to keep the oil off the brushes and commutator.

Pantostats.

The Pantostat or Universal Machine is designed to work from the main supply and will give earth-free currents for Galvanism, Faradism, Cautery and Light.

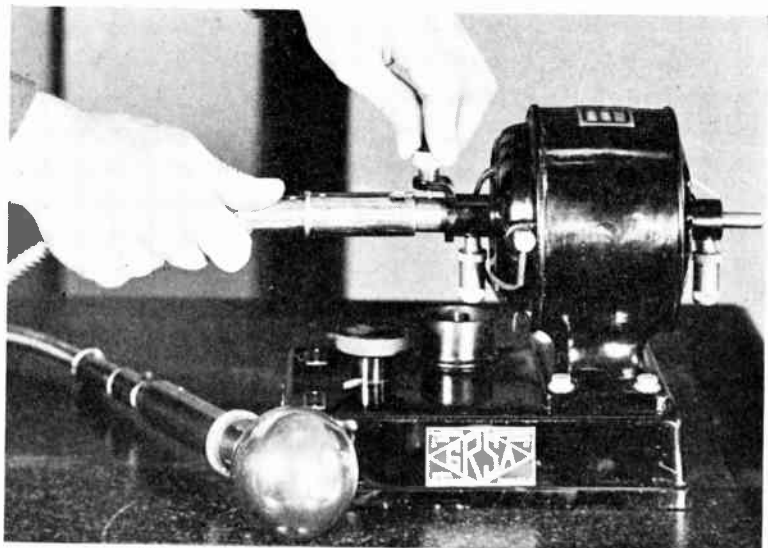


Fig. 1—Attaching Flexible Shaft to Motor.
Mounted on one of the end plates of the motor is a screw attachment which clamps a flexible shaft in position.

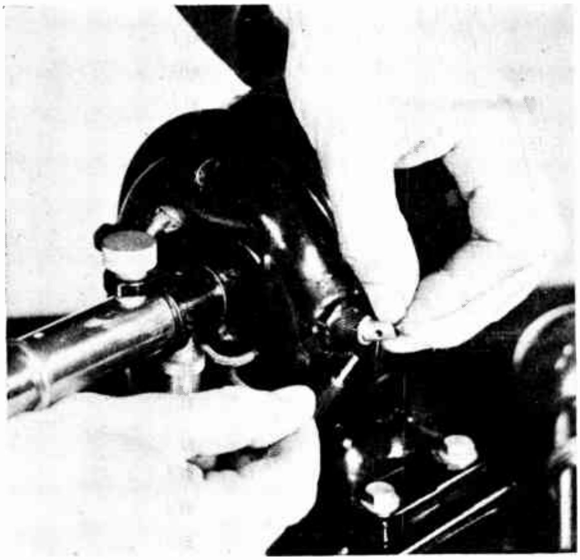


Fig. 2.—Method of Securing Brush in Position.

The Pantostat working from D.C. mains consists of a motor, a direct current generator and a pair of A.C. slip rings connected to the windings of the generator. All these are mounted on the same shaft. The current from the direct current generator is led through suitable regulating resistances to the patients' terminals for Galvanism, and also to feed the faradic coil through its interrupter. The alternating current is led to a step-down transformer, which, in turn, supplies current for cautery burners and also for surgical lamps. All controls (five in number) are actuated by push and pull rods on the front of the apparatus.

A.C. Pantostat

In the case of the Pantostat working from alternating current mains, the cautery and light transformer is fed direct from the main supply. An A.C. motor and D.C. generator are wound on the one spindle. The circuits otherwise are the same as for the D.C. machine.

The motor of the Pantostat is fitted with the same attachment as the vibratory massage motor previously described. It can, therefore, be used for this purpose in addition to its other duties.

Points Requiring Attention.

The motor bearings must be kept oiled, the brushes and brush gear in correct adjustment and the commutator and slip rings must be kept clean. The platinum points in the interrupter of the faradic coil must be kept clean and occasionally smoothed over with some fine emery cloth. The sliding contacts inside the apparatus require attention at times. These are easily accessible after the bottom of the Pantostat has been removed. This is held in position by four screws.

When to Use the Valve Pantostat.

Where A.C. mains are available the Valve Pantostat may be employed. This makes use of a thermionic rectifying valve and smoothing condensers to give the

Fig. 3.—Adjusting the Apparatus for Varying Intensity of Vibration.

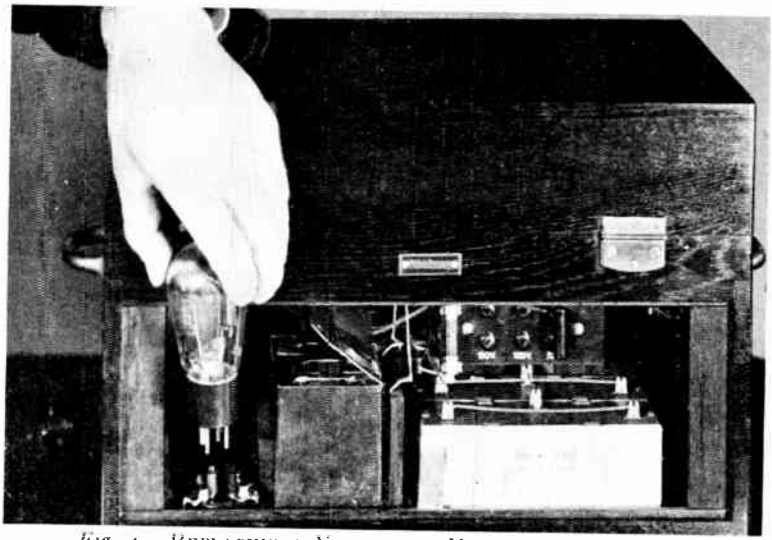


Fig. 4.—REPLACING A VALVE IN A VALVE PANTOSTAT.
The back of the apparatus is easily removed in order to adjust the contacts and renew the valve and battery. Note the faradic battery which can be seen next to the valve holder.

galvanic current. The main supply is used to feed the primary of a transformer. It is only the induced currents which are connected to the patient. The cautery and light circuits are the same as for the Pantostat. The Galvanic current is taken through a bi-anode valve, the filament of which is heated from a subsidiary winding on the main transformer. Two condensers of 12 microfarads capacity each are connected across these leads and a choke coil placed in series. Regulation of this current is by a potentiometer, which enables the output to be controlled from zero up to its maximum. The current is measured by a milliammeter fitted with a two-scale reading.

A faradic coil is also embodied in the apparatus and this is worked from a dry battery. This battery is merely placed in position inside the apparatus and then automatically makes contact with its respective terminals by means of spring contacts.

Adjusting the Contacts.

In order to adjust the contacts and renew the valve and battery when necessary, the back of the apparatus is easily removed. (See Fig. 4.)

The Battery Pantostat.

Where no main current supply is available, the Battery Pantostat is often used. This consists of a box, inside which are two dry batteries. One is arranged to give a tension of 90 volts for the galvanic current, and the other provides a tension of 4.5 volts for feeding the faradic coil.

Above the batteries is fixed an ebonite panel on which are mounted the necessary controls and a milliammeter for measuring the galvanic current.

Renewing the Batteries.

The only points requiring attention here are to see that all contacts are kept clean and to renew the batteries when they are run down. The method of performing the latter operation is similar to that already described in connection with the Valve Pantostat. That is to say, the back of the box is removed and the batteries placed in position. They then make contact with their respective spring terminals.

A Cautery and Light Transformer.

There are many other types of electro-medical apparatus, such as the cautery and light transformer apparatus, which will be dealt with in later articles, but nearly all of them follow on the lines of those already indicated. It will be noted that all of them protect the patient against any accidental shock by utilising induced currents only. Care should always be taken to see that all exposed metal parts are connected to a good "earth."

PRACTICAL
ELECTRICAL ENGINEERING

Intended for Electric Lighting and Power Engineers. Electricians and Wiremen. Wireless Dealers. Students, Apprentices and Improvers in all Branches of the Electrical and Wireless Industries

General Editor

EDWARD MOLLOY

VOL. I

Contributors to Vol. I

SIR RICHARD TETLEY GLAZEBROOK, K.C.B., D.Sc., F.R.S.
H. W. JOHNSON
H. E. J. BUTLER
A. W. JUDGE, A.R.C.Sc., D.I.C.
M. L. MATTHEWS, A.I.E.E.
K. BINYON
T. LINSTEAD
H. GRISBROOK, A.M.C.T.
E. M. SUTTON
H. PARSONS
SIR AMBROSE FLEMING, F.R.S.
S. PARKER SMITH, D.Sc., M.I.E.E.
A. T. DOVER, M.I.E.E.
E. H. FREEMAN, M.I.E.E.
W. R. LAMBERT
H. J. BALDWIN
A. E. WATKINS
LIEUT.-COL. D. J. SMITH, M.I.Mech.E.
A. H. BRACKENSEY
M. G. SAY, Ph.D., M.Sc., D.I.C.
A. C. BARKLIE

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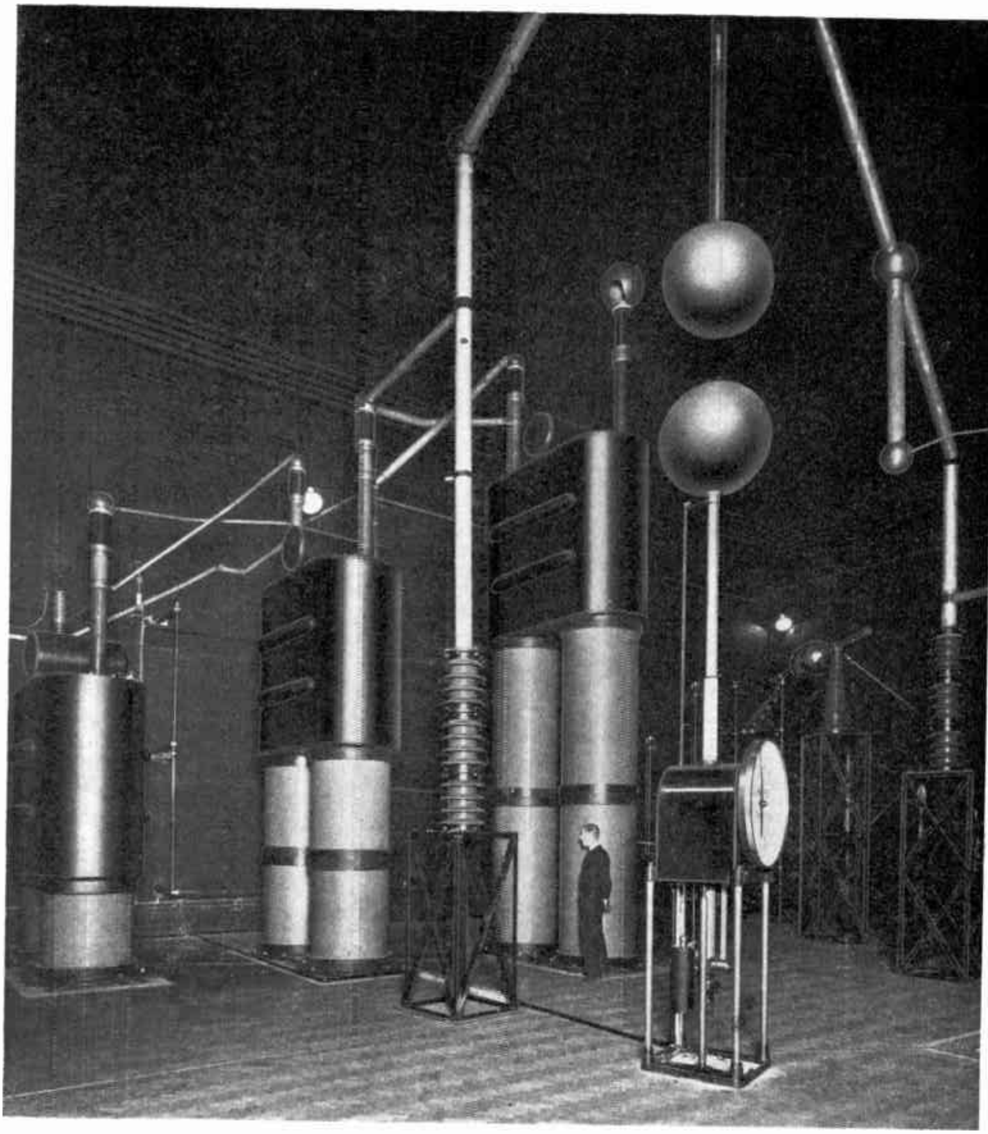

AN EXTRA HIGH VOLTAGE TEST ROOM. *(G.E.C.)*

PREFACE TO VOLUME I

THERE are very many excellent textbooks on all branches of electrical engineering. The first volume of PRACTICAL ELECTRICAL ENGINEERING is not intended as a textbook. Readers will not find in it any of the theoretical definitions and formulæ which occupy considerable space in the textbooks. These fundamentals will be treated in a later part of the work.

Every engineer realises that sound theory is the basis of sound practice. Many people, however, find it difficult to understand abstract theory whereas they may be very good when it comes to doing the practical work. Without good practitioners the electrical industry, like any other industry, would very quickly die. The most brilliant theories can only be rendered of practical use to humanity providing there are craftsmen sufficiently skilled to do the practical work necessary to put these theories into operation. This is the viewpoint which has been adopted in the compilation of the present work. It has been planned with the requirements of the practical man always in the foreground. The theory underlying practical operations will be explained in its due sequence, but the compilers of the work quite definitely do not subscribe to the idea that a man cannot be an electrical engineer unless he can understand the differential calculus or solve simultaneous equations.

Several very eminent electrical engineers have contributed articles to this volume. In particular we would draw attention to Sir Richard Tetley Glazebrook's contribution, which forms a fitting opening to the work. The brief, but masterly, exposition of present-day knowledge as to the nature of electricity which forms Sir Ambrose Fleming's contribution is well worth careful perusal by every reader.

It will be seen that the subject of Electric Wiring occupies a good portion of this work. The planning of wiring circuits and the detailed methods of erecting wiring installations in small buildings are each fully treated.

The important subject of Electric Motors has also been given prominence. Methods of rewinding small motors, and the characteristics of direct current motors are two articles worthy of special note in this connection.

Other present-day applications of electricity, such as wireless reception, electric traction, medical electricity, have also been dealt with, in a manner which it is believed will be specially appreciated by readers with a practical turn of mind.

E.M.

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