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### Contactor Type Direct Starter.

In cases where remote control is necessary and the electromagnetic starter described above is unsuitable, a triple-pole contactor is used. Over-current protection is obtained either by thermal relays or by solenoid relays fitted with time-lag dashpots.

### Drum Controller-type Direct Starters.

The above types of direct starters are only suitable for single-speed motors, i.e., motors in which only one number of poles is obtained from the stator winding. For multi-speed or changeable-pole motors having squirrel-cage rotors, a drum controller is required to make the necessary combinations of the stator winding to obtain the various numbers of poles. Such controllers may have two, three or four "run" positions (according to the number of speeds) with intermediate "off" positions.

A typical controller, with four "run" positions, is illustrated in Fig. 21. This controller is mounted on the frame of a 2-h.p. four-speed motor driving one of the spindles of the multiple-spindle drilling

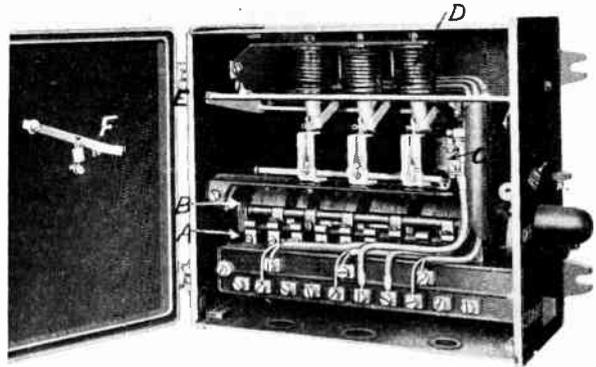


Fig. 22.—DRUM-TYPE STAR-DELTA STARTER.  
(Metropolitan-Vickers.)

This starter has an under-voltage release C, and instantaneous-type over-current releases D.

machine illustrated in Fig. 15, p. 825. The other motors are fitted with similar controllers, the operating hand wheels of which are mounted at the base of the controllers so as to be within easy reach of the operator.

Such controllers are not provided with automatic features, and, therefore, a circuit breaker with automatic releases must be connected between the supply and the controller. The small electromagnetic starter and circuit breaker illustrated in Figs. 15, 19 is eminently suitable for this purpose. These circuit-breakers may be mounted either on the frames of the motors or grouped together as shown in Fig. 19. In the latter case remote control from the drilling machine is possible by "on"-"off" push-buttons mounted on the controllers.

### TYPES OF STAR-DELTA STARTERS.

#### Hand-operated Starters.

These starters in the smaller sizes are usually of the air-break drum type, i.e., connections from the supply and motor are made to fingers (A, Fig. 22), which are interconnected by segments fitted to a drum (B, Fig. 22) so as to give the required star and delta combinations. In the larger sizes oil-immersed switches are used, the drum type being used in intermediate sizes and the cam-operated contactor type in the largest sizes.

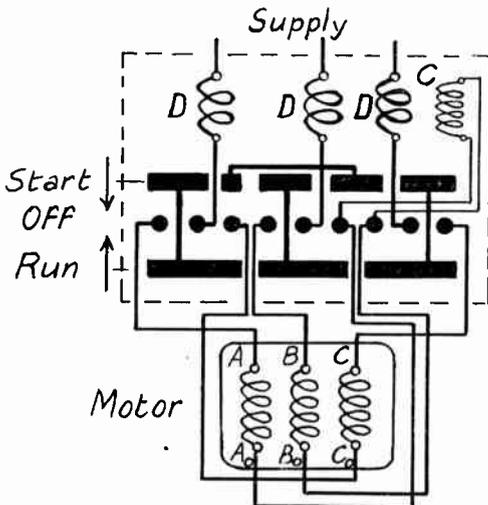


Fig. 23.—CONNECTIONS OF THE DRUM-TYPE STAR-DELTA STARTER ILLUSTRATED IN FIG. 22.  
(Metropolitan-Vickers.)

### Air-break Drum-type Starter.

A typical modern star-delta starter is shown in Fig. 22. The drum B has a spring return to the "off" position, and is retained in the "run" position by an electro-magnetic catch, the operating coil C, of which is shunt excited and forms an under-voltage release. The catch may also be tripped automatically by the action of any of the over-current solenoid releases, D, the plungers of which, when lifted, engage the tripping bar, E. This bar is connected with the catch and

quickly to the "run" position where it is retained by the catch previously referred to.

To stop the motor the catch is tripped by turning a knob mounted in the cover. This knob is attached to a lever F, Fig. 22, inside the cover, which engages the tripping bar E. Stopping from remote positions is effected by a push-button switch connected in series with the under-voltage release coil. In both cases the handle returns to the "off" position under the action of a spring.

A mechanical sequence device is fitted to ensure correct operation, and the operating mechanism is so designed that the over-current releases are in-operative during the starting period in order to prevent tripping of the starter by the starting current.

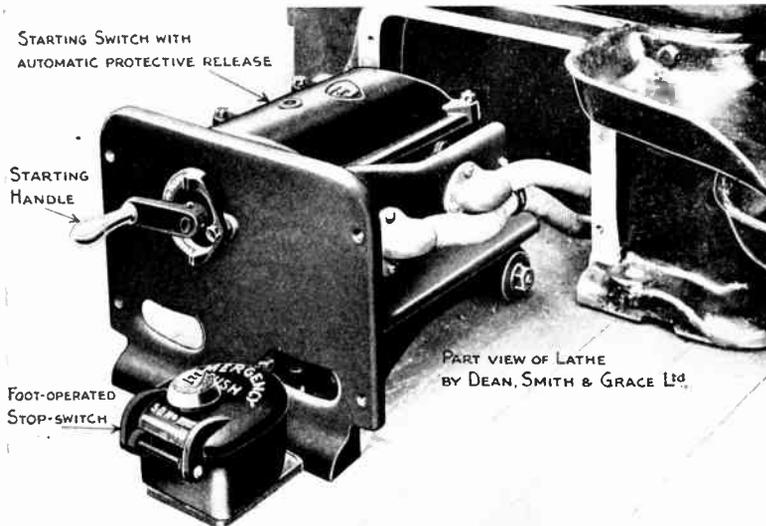


Fig. 24.—STAR-DELTA STARTER BUILT INTO LATHE BED.

The starter is of the Ellison type with under-voltage and time-lag over-current releases. It is fitted to a frame, with wheels, which is normally bolted flush with the lathe bed.

The foot-operated push switch is connected in series with the under-voltage release coil. (George Ellison.)

normally (i.e., when the drum is in the running position and the under-voltage release is excited) occupies a position lower than that shown in the illustration.

The internal and external connections, and the development of the contact drum, are shown in Fig. 23.

### How the Starter Operates.

To start the motor the operating handle must first be placed in the "start" position and held in this position until the motor has run up to about half or higher speed, when the handle must be moved

duty involving 10 starts per hour. The larger oil-immersed starters are suitable for currents up to 125 amperes.

Fig. 24 shows how a star-delta starter is built into the frame of a large lathe. In this case the motor is also built into the lathe. The starter is mounted on wheels so as to be easily withdrawn for inspection and the cables between the starter, supply and motor are enclosed in metallic flexible tubing. Over-current and under-voltage relays of the solenoid type are fitted to the starter, and a foot-operated push-button

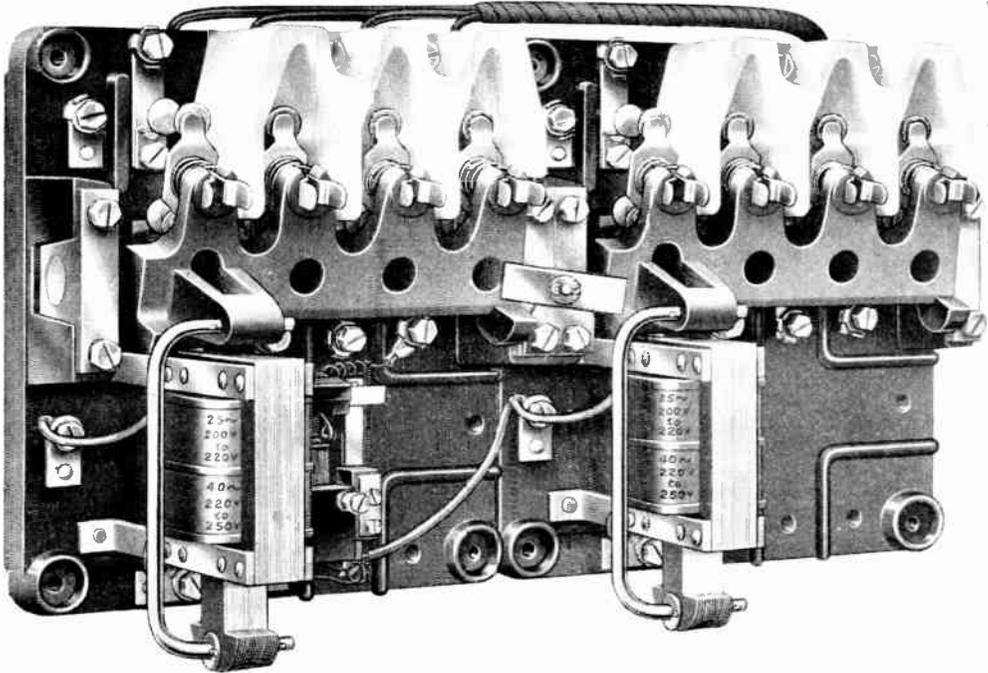


Fig. 25.—CONTACTOR-TYPE STAR-DELTA STARTER FOR SMALL MOTORS. (B.T.-H. Co.)

This illustration also shows clearly the construction of an A.C. electromagnet. Similar (smaller magnets are also used for the under-voltage releases of face-plate starters (see Fig. 44).

switch is connected in series with the under-voltage trip.

**Contactor Star-delta Starter for Small Motors.**

Fig. 25 illustrates a recent type of contactor starter developed specially for small motors (up to 7½ h.p. at 400 volts). It is built up of two "units" which, singly, may be used as direct starters (non-reversing).

Owing to the small size, and with the object of reducing the cost of the starter, a type of construction is employed

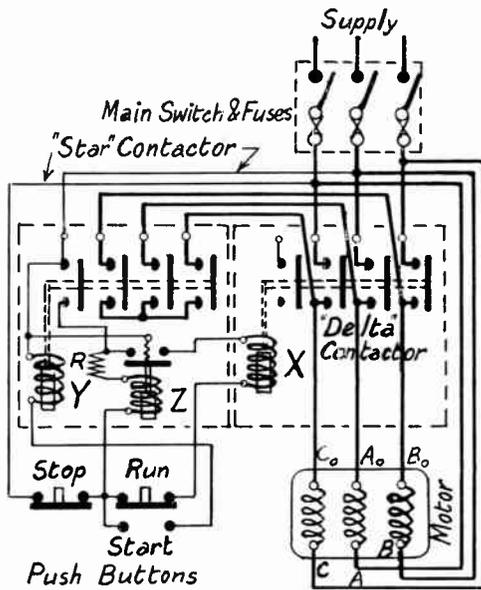


Fig. 26.—CONNECTIONS OF THE CONTACTOR-TYPE STARTER ILLUSTRATED IN FIG. 25. (B.T.-H. Co.)

which is radically different from that of larger contactor starters. Thus, the contacts are of the button type and consist of convex silver buttons welded to a hinged pressed steel frame which is linked to the plunger of the operating electromagnet. Silver is used instead of copper because the arcing with silver contacts is much less than that with copper contacts, and therefore no magnetic blow-outs or arc chutes are necessary in this case. The main contacts are

shrouded with porcelain to prevent the possibility of short circuits.

The base is of a moulded insulating material and the operating electro-magnet and linkwork are of much lighter and simpler design than that ordinarily used for contactors.

### How the Starter Operates.

The starter illustrated in Fig. 25 is controlled by push-buttons, and the connections are shown in Fig. 26. The "start" button has a double set of contacts. When this button is pressed the operating coil, Y, of the left-hand contactor is energised, and the closing of this contactor completes the "star" connection of the stator windings. An interlock (viz., the contacts to the left of the porcelain shroud) also completes an auxiliary circuit through the coil of an under-voltage relay, Z, which when energised closes an auxiliary switch connected in the circuit of the operating coil, X, of the right-hand contactor. This contactor, however, cannot close until the "start" push-button is released, as the normally closed contacts of this button are also in the circuit of the operating coil. When the "start" button is released, the "star" contactor, Y, is opened and the "delta" contactor, X, is closed.

Thus, the procedure in starting is: (1) Press the "start" button and hold it depressed for about three seconds or until the motor has accelerated sufficiently (i.e., the speed has reached about half normal speed); (2) release the "start" button.

To stop the motor, press the "stop" button.

### Under-voltage and Over-current Protection.

Under-voltage protection is obtained by a relay Z, Fig. 26, the operating coil of which, together with a series resistance, is connected across the supply so long as the auxiliary switch on the relay is closed. This auxiliary switch also controls the operating coil of the "delta" contactor X. Hence, if the supply fails, or the voltage becomes abnormally low, the auxiliary switch of the relay and contactor X open. The motor cannot restart, however, until the "start" button is pressed, as when the auxiliary switch of the relay is open the relay can be energised only through the auxiliary contacts of the "star" contactor Y.

Over-current protective devices are not incorporated in the starter, and, therefore, over-current protection must be obtained either by fuses or by a circuit breaker with over-current trips.

### Applications.

The starter is suitable for motors having full-load currents equal to or below 16 amperes and momentary starting currents not exceeding 80 amperes.

## TYPES OF AUTO-TRANSFORMER STARTERS.

### Hand-operated Starters.

The change-over switch in smaller sizes of these starters is usually of the air-break drum type and is similar to, but not identical with, that of a corresponding star-delta starter. In these sizes the auto-transformer is air-cooled and is fitted into the same frame or case as the switchgear.

The larger sizes have an oil-immersed change-over switch, the drum type being

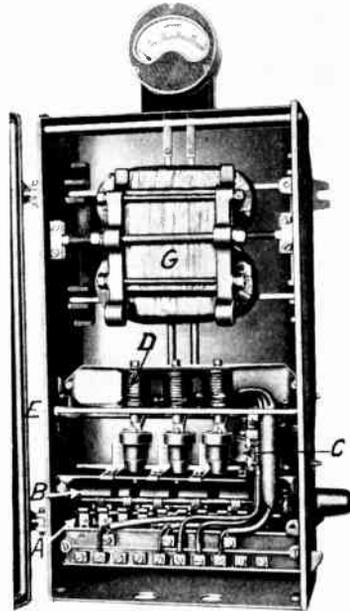


Fig. 27. — AUTO-TRANSFORMER STARTER WITH DRUM-TYPE AIR-BREAK SWITCH. (Metropolitan-Vickers.)

This starter has an under-voltage release, C, and time-limit type over-current releases, D. The general arrangement of the change-over switch and automatic releases is similar to that of the star-delta starter in Fig. 22.

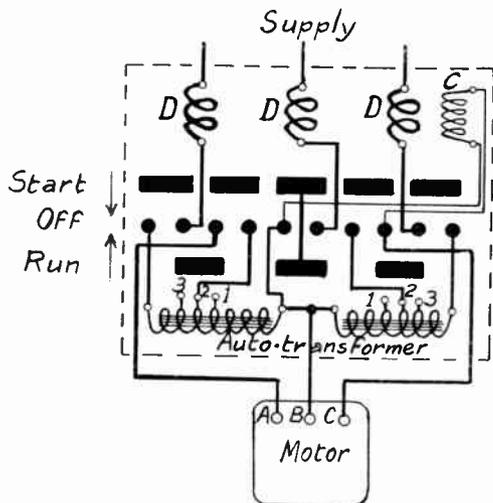


Fig. 28.—Connections of Auto-transformer Starter Illustrated in Fig. 27. (Metropolitan-Vickers.)

Transformer tap No. 1 gives 50 per cent. of line voltage; No. 2 gives 60 per cent.; and No. 3 gives 75 per cent. By changing over the connections to each auto-transformer 40 per cent. of line voltage may be obtained from tap No. 2, and 25 per cent from tap No. 3.

used for the intermediate sizes and the cam-operated contactor type being used for the largest sizes. In some of the intermediate sizes of these starters the auto-transformer is air-cooled and is mounted in the same frame as the switchgear, but an alternative practice is to use an oil-immersed auto-transformer contained in a separate case. For the largest sizes, the auto-transformer and switchgear are mounted in separate cases.

**Air-break Drum-type Auto-transformer Starter.**

A typical modern starter for small motors (up to 25 h.p.) is illus-

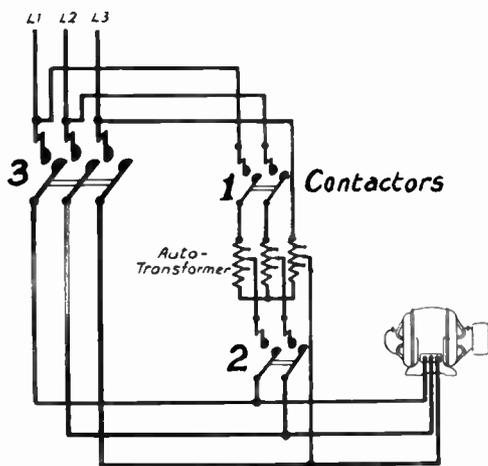


Fig. 29.—Main Circuit Connections of Contactor-type Auto-transformer Starter for Large Motors. (B.T.-H. Co.)

trated in Fig. 27, and the internal and external connections are shown in Fig. 28. The drum-type switch is arranged on a similar principle to that of the star-delta starter illustrated in Fig. 22, but the number and arrangement of the fingers and segments are different in the two cases.

The auto-transformer G consists of two single-phase shell-type transformers with the windings V-connected to the three-phase supply system. Two V-

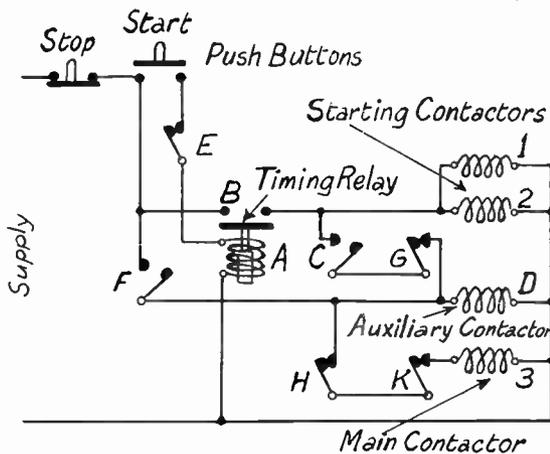


Fig. 30.—Control-circuit Connections of Contactor-type Auto-transformer Starter for Large Motors. (B.T.-H. Co.)

connected transformers are used in these starters in preference to three star-connected transformers or a three-phase transformer on account of simpler connections, fewer windings and fewer contacts for the drum-type switch. Three windings are brought out from each winding so that the voltage applied to the motor at starting

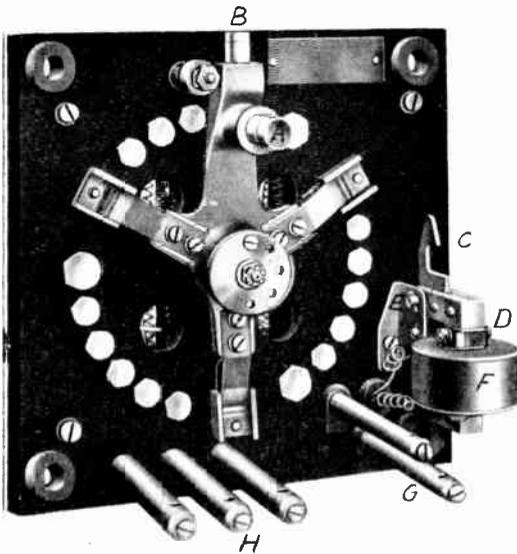


Fig. 31.—FACE-PLATE TYPE ROTOR STARTER. (Metropolitan-Vickers.)

A, pin engaging fork on operating lever (not shown); B, roller engaging catch C of under-voltage release D; G, terminals of under-voltage release coil (F); H, terminals of starter.

may be 25, 40, 50, 60, or 75 per cent. of the line voltage (see note in connection with Fig. 28).

The over-current and under-voltage releases are identical with those of the star-delta starter illustrated in Fig. 22, with the exception that the plungers of the over-current solenoids are fitted with non-adjustable time-lag dashpots.

**How the Starter Operates.**

To start the motor the operating handle must first be placed in the "start" position and held in this position until the motor has run up to about half or higher speed, when the handle must be moved quickly to the "run" position where it is retained by a catch mechanically connected to the under-voltage release.

To stop the motor the catch is tripped by turning a knob mounted on the cover. The switch then returns directly to the "off" position under the action of a spring.

A mechanical sequence device ensures correct operation and a quick change over from "start" to "run," and a spring

prevents the handle being left in the "start" position. Moreover, the over-current releases are inoperative in the "start" position of the switch.

**Applications.**

The starter illustrated in Fig. 27 is suitable for currents up to 40 amperes (continuous service), and for a maximum service of 10 starts per hour provided that the intervals between the successive starts are not less than 50 times the starting period. If two starts at maximum rating are made in quick succession an interval of 100 times the starting period must elapse before another start can be made. For example, if the starting period is 21 seconds, only 3 starts per hour are possible, but if it is 7 seconds 10 starts per hour are possible.

The starting period in seconds should not exceed  $(15 + \frac{1}{4} \times \text{rated h.p. of starter})$ , and the tapplings used should be such that this starting period is not

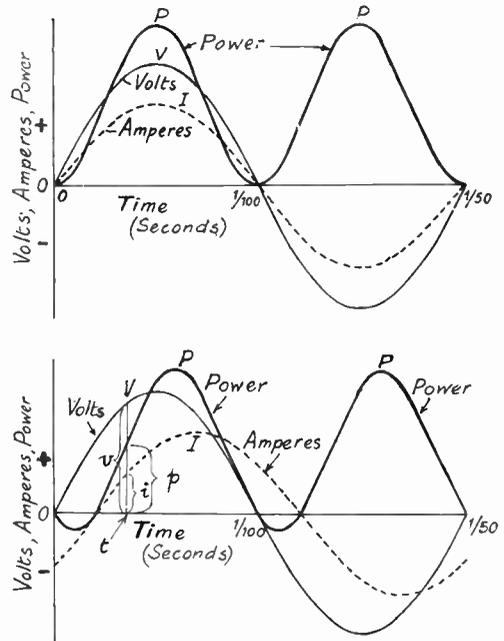


Fig. 32.—SHOWING HOW THE VOLTAGE, CURRENT AND POWER VARY FROM INSTANT TO INSTANT IN A NON-INDUCTIVE CIRCUIT (UPPER DIAGRAM), AND AN INDUCTIVE CIRCUIT OF 0.8 POWER FACTOR (LOWER DIAGRAM).

exceeded. For example, with a 25-h.p. motor, the maximum starting period is  $(15 - \frac{1}{4} \times 25) = 21\frac{1}{4}$  seconds. If, then, on a trial with the 50 per cent. tappings the starting period is greater than 21 seconds, the 60 per cent. or, if necessary, the 75 per cent. tappings must be used for permanent service. On the other hand, if the trial starting period is, say, 10 seconds, the lower (40 per cent.) tappings could be used.

### Contactor-type Auto-Transformer Starters.

A contactor-type starter must be used when automatic operation or remote control is desired. The switchgear in this case consists of a triple-pole contactor and either a 4-pole contactor or two double-pole contactors, together with a relay and its associated auxiliary switches.

Fig. 29 shows the main connections when a triple-pole contactor and two double-pole

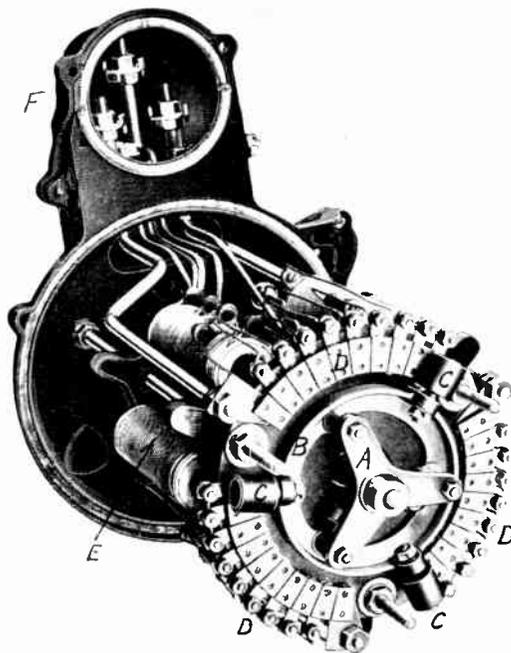


Fig. 33. — INTERIOR VIEW OF ELLISON ROTOR STARTER. (George Ellison.)

This view shows the face-plate and resistances removed from the oil tank. The terminals of the starter are at F.

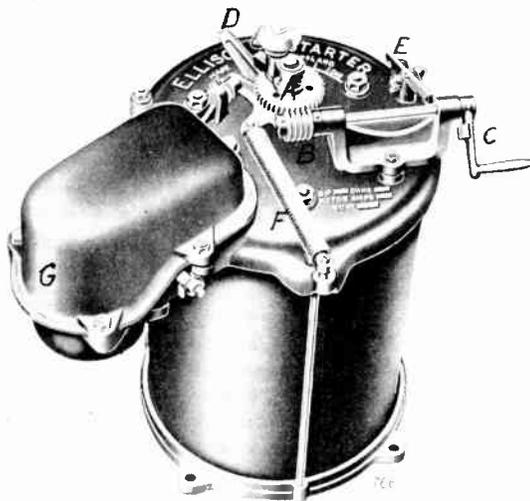


Fig. 34.—EXTERIOR VIEW OF ELLISON OIL-IMMERSED ROTOR STARTER.

The face-plate switch is operated by a worm and worm wheel.

contactors are used. The auto-transformer is of the three-phase type, and three tappings are provided to give voltages, for the motor, of 45, 65 or 80 per cent. of the line voltage.

Fig. 30 shows the control connections for push-button control. In this case a special time-delay relay is used to give a definite time interval between the closing of the "start" contactors (Nos. 1 and 2) and the "run" contactor (No. 3). The relay is of the plunger type with a time-lag oil dashpot operative only in the downward direction. Thus, the plunger lifts immediately the operating coil is energised, but does not drop until a definite time interval has elapsed after the operating-coil circuit is opened.

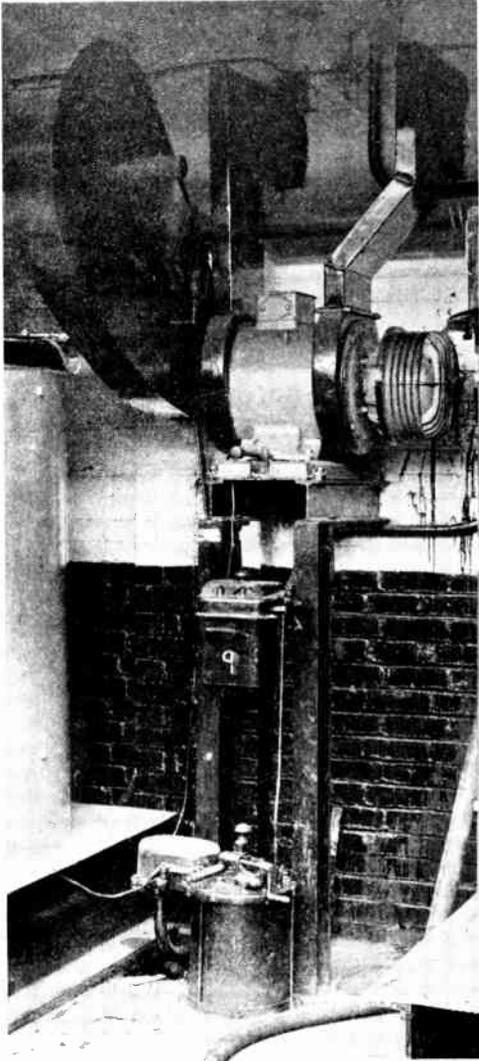


Fig. 35.—AN INDUSTRIAL INSTALLATION OF A PIPE-VENTILATED ENGLISH-ELECTRIC THREE-PHASE SLIP-RING MOTOR AND ELLISON CONTROL GEAR.

The rotor starter is similar to Fig. 34, and is mechanically interlocked with the circuit breaker. (*George Ellison.*)

### How the Starter Operates.

The main-circuit operations at starting are as follows: To start, contactors Nos. 1 and 3, Fig. 29, are closed simultaneously, which operations connect the auto-transformer to the supply, and the motor to the auto-transformer. After a short time

interval—which is determined by the setting of the timing relay—these contactors open and the main contactor No. 3 immediately closes.

The control-circuit operations are as follow: The pressing of the "start" push-button completes the operating-coil circuit of the time-delay change-over relay (which controls the time interval between the closing of contactors Nos. 1, 2 and contactor No. 3). This relay, A, closes its auxiliary switch, B, which completes the operating-coil circuits of contactors Nos. 1 and 2. An auxiliary switch, C, on contactor No. 1 closes simultaneously with the main contacts and completes the operating-coil circuit of a small auxiliary or pilot contactor D. This contactor operates a number of control switches (some of which close when the contactor closes, and others open) which effect certain changes in the control-circuit connections. Thus the operating coil of the timing relay is opened at E; the circuit of the pilot contactor coil, D, is made independent of both the "start" button and the auxiliary switch, C, on contactor No. 1, this operation being effected by closing auxiliary switch F and opening G. Switch F also prepares the operating-coil circuit of the main contactor No. 3 for closing when contactors Nos. 1 and 2 open, this circuit containing auxiliary switches H, K, on these contactors. Therefore, when the contacts, B, of the timing relay, A, open after a predetermined time interval, the operating-coil circuit of contactors Nos. 1 and 3 is opened, and that of contactor No. 3 closes immediately these contactors open.

To stop the motor the "stop" push-button is pressed, which operation opens the operating-coil circuit of the pilot contactor. This contactor cannot reclose until the "start" button is again pressed.

### Applications.

Contactor-type starters are suitable with appropriate contactors and auto-transformer for any size of motor and for any starting conditions; but usually the number of starts per hour are limited to 15, and the starting period in seconds should not exceed  $(15 \div \frac{1}{4} \times \text{rated h.p. of starter})$ . The time interval between successive starts should not be less than

50 times the starting period.

### TYPES OF ROTOR STARTERS FOR THREE-PHASE MOTORS.

#### Faceplate - type Starters.

These starters consist of three sets of star-connected starting resistances—one for each of the rotor phases—and a faceplate-type switch for cutting out the resistance sections equally

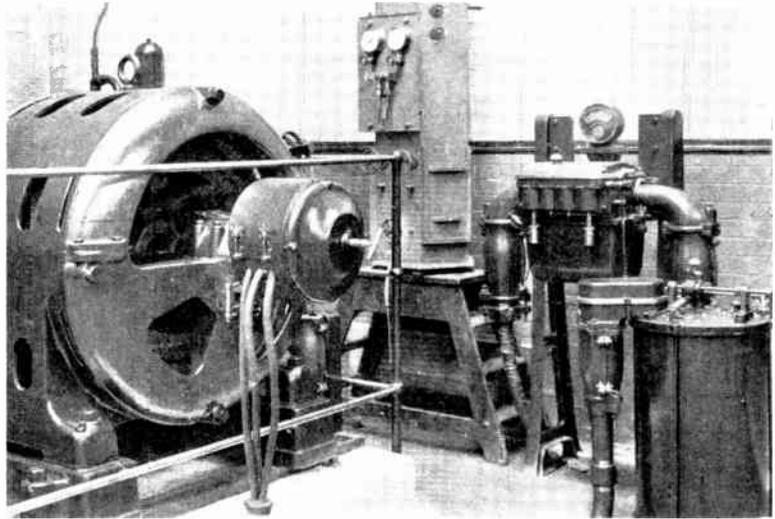


Fig. 36.—THE CONTROL GEAR FOR A LARGE SLIP-RING INDUCTION MOTOR. The rotor starter is of similar type to that illustrated in Fig. 33 and is mechanically interlocked with the circuit breaker. The terminal boxes for the supply, stator and rotor cables are clearly shown. (George Ellison.)

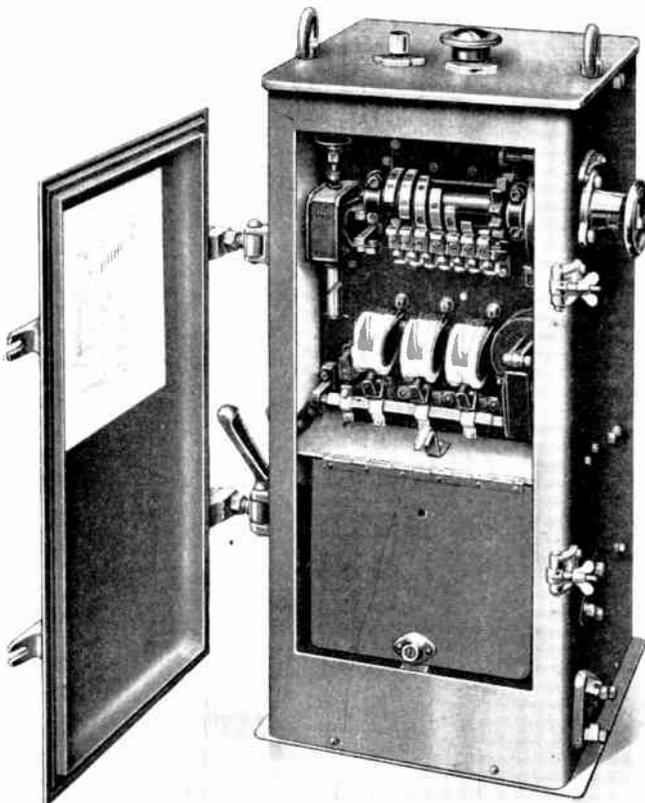


Fig. 37.—SELF-CONTAINED STARTER AND CONTROL PILLAR. (B.T.-H. Co.)

from each phase so as to maintain balanced phases on all steps. The starter switch is of the three-armed type, having three contact arms radiating from a central hub at 120 degrees to one another.

Some of the smaller sizes of three-phase slip-ring motors have two-phase rotor windings instead of three-phase windings. For these cases the rotor starter requires only two sets of starting resistances and a double-arm faceplate-type switch.

#### Air and Oil-cooled Starters.

The starting switch and resistances may be either air-cooled in the same manner as those of D.C. starters, or the whole starter may be oil-immersed. The latter is the common practice for

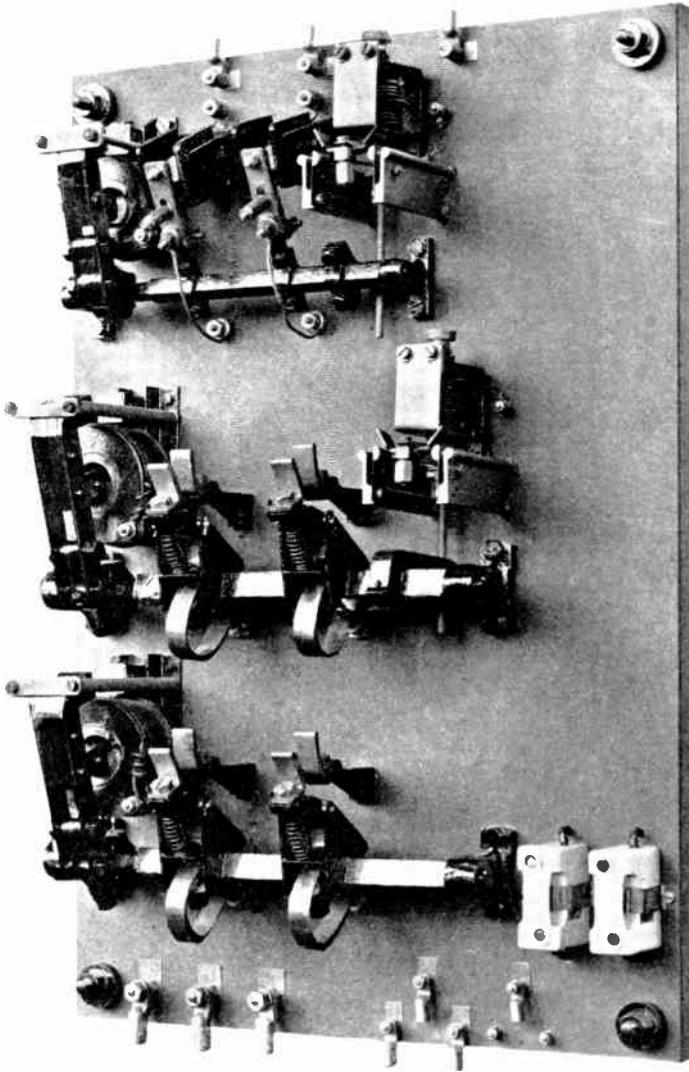


Fig. 38.— CONTACTOR PANEL FOR SMALL THREE-PHASE SLIP-RING MOTOR.  
(G.E.C.)

The top contactor controls the stator circuits, and the two lower contactors control the rotor circuits.

industrial works, as oil cooling possesses a number of advantages over air cooling for this type of starter. Thus the thermal capacity of the oil-cooled starter is much higher than that of the air-cooled starter, and, therefore, the resistances can be worked at a higher

current density than those of the air-cooled starter for the same duty; the wear on the switch contacts is minimised and these contacts are maintained in a clean condition by a washing action which occurs each time the starter is used.

**Why Oil-Immersed Starters can be Used with A.C. Motors and not with D.C. Motors.**

Oil immersion can be used with A.C. switchgear because the rate at which energy is supplied to maintain an arc formed at the switch contacts when a circuit is broken pulsates between zero and a maximum value. This is shown graphically in Fig. 32, in which the sine curves  $V$  and  $I$  show one cycle of the voltage and current in the circuit (i.e., these curves show how the voltage and current change during each  $\frac{1}{50}$  second, which is the time of one cycle for a 50-cycle system).

The rate at which energy is supplied to the circuit—i.e., the power—is, at any instant, equal to the product of the values of voltage and current at that instant. Thus at the instant  $t$ , shown in Fig. 32, the voltage is  $v$  and the current is  $i$ . There-

fore, the power is  $v \times i$ , and is represented by the ordinate  $p$  on the power curve  $P$ . Because of the alternating voltage and current the power varies periodically, and, in general, is zero four times for each cycle of voltage or current, as obviously when either  $v$  or  $i$  is zero,  $p$  must be zero.

Hence if the switch is oil immersed, any arc at the contacts will go out when  $p$  approaches zero, and if the contacts are cooled and conducting vapours removed during the brief interval of time when  $p$  is passing through zero, the arc cannot re-form.

On the other hand, with an oil-immersed switch on a D.C. circuit the power at the arc is maintained; which causes the oil to become carbonised and to form conducting vapours which facilitate the maintenance of the arc. Thus oil-immersed switchgear is not practicable for D.C. circuits.

**Examples of Rotor Starters for Three-phase Motors.**

Figs. 31, 33, 34 show typical

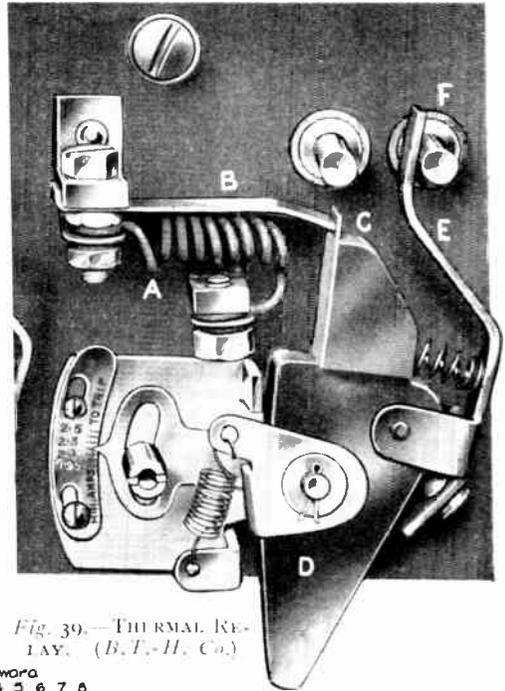


Fig. 39.—THERMAL RELAY. (B.T.-H. Co.)

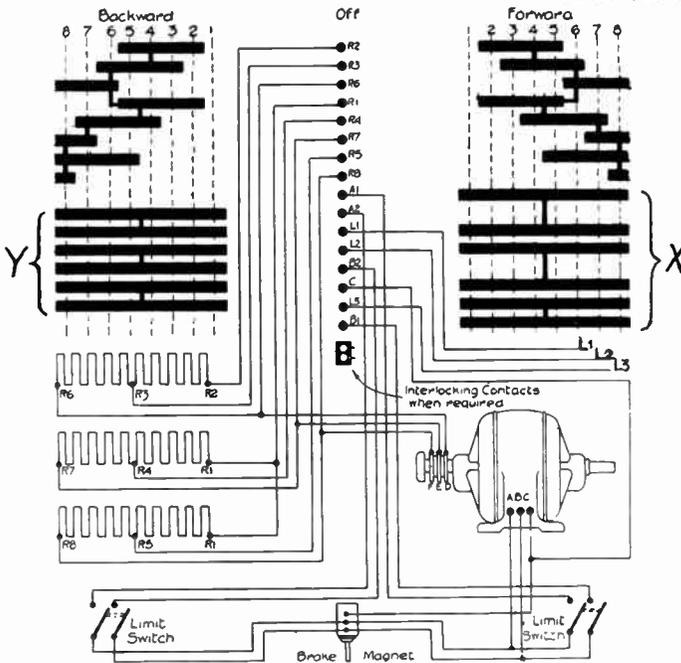


Fig. 40.—CONNECTIONS OF REVERSING DRUM CONTROLLER FOR THREE-PHASE CRANE MOTOR. (B.T.-H. Co.)

The "limit switches" open the stator circuits in the event of over-travel. The segments X, Y, together with the appropriate fingers, control the stator circuits and the direction of motion.

examples of oil-immersed face-plate rotor starters. The face-plate shown in Fig. 31 is fixed at the upper part of a welded steel case (which contains the oil). The switch is operated by a forked lever (which is connected by a short spindle to the operating handle) engaging the pin A, and is biased to the "off" position—shown in Fig. 32—by a spiral spring in the hub. The switch is retained in the "running" position by a roller B engaging the latch, C, of the under-voltage release, D. This release is an A.C. electromagnet with a laminated core and armature, the latter being hinged at E. The operating coil, F, is excited from the supply.

The starter illustrated in Figs. 33, 34 has the face-

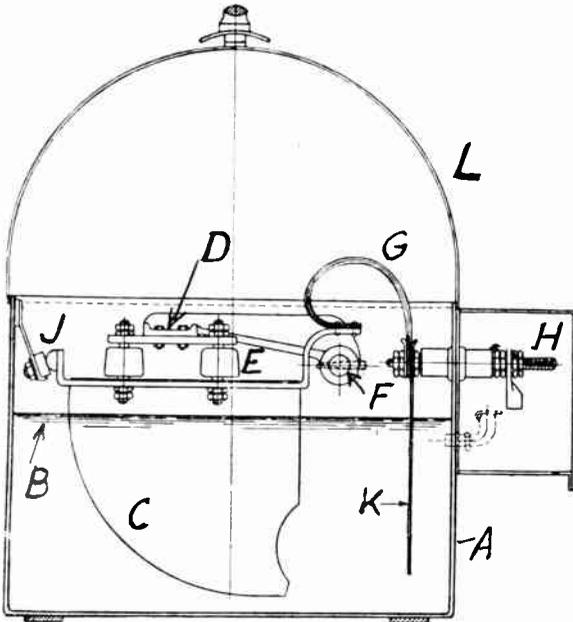


Fig. 41 - ARRANGEMENT OF LIQUID STARTER FOR LIGHT DUTY. (Metropolitan-Vickers.)

plate located at the *bottom* of the oil tank, which is cylindrical, as shown in Fig. 34. The moving contacts, C, consist of copper rollers, which are supported from an angle ring, B, as shown clearly in Fig. 33. This ring is connected to, but insulated from, a three-armed spider, A, which is pinned to the operating spindle. The top end of this spindle is fitted with a worm wheel which engages with a worm and operating handle as shown in Fig. 34. The pitches of the threads and teeth in the worm and worm wheel, however, are not the same, but are so chosen that a quick motion is obtained when the contact rollers move over the gaps between the contact segments on the face-plate. The rotation of the worm wheel in the clockwise direction (which moves the switch towards the "running" position) applies a tension to the spring, E, which returns the switch to the "off" position if the operating handle is released, as the frame, B, carrying the operating handle, spindle and worm is not rigidly fixed, but is hinged to the cover. The switch is retained in the

running position by a detent D engaging the latch E. This latch is usually interlocked mechanically with the circuit-breaker controlling the stator circuits. The starter switch may be released by pressing the knob on the top of the starter, which operation disengages the detent D from the latch E.

**Interlocking and Protective Features of Face-plate Rotor Starters for Three-phase Motors.**

With the face-plate starters illustrated in Figs 31, 34, which control only the rotor circuits, precautions must be taken to prevent the stator switch being closed unless the rotor starter is in the "start" or "all resistance in" position.

Moreover, the opening of the main switch or the failure of the supply should both cause the automatic return of the starter switch to the "start" position.

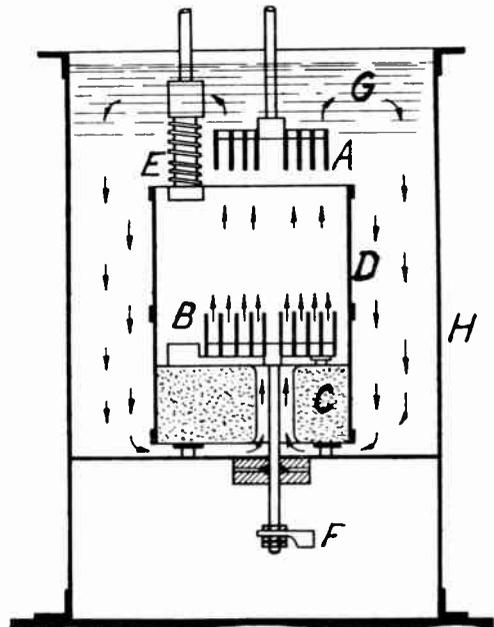


Fig. 42.—ARRANGEMENT OF LIQUID STARTER FOR HEAVY DUTY. (Metropolitan-Vickers.)

With the starter illustrated in Fig. 31 the first-mentioned feature is obtained by interlocking contacts on the starter which are closed in the "start" position, and are connected in series with a shunt-excited electromagnet on the stator switch or circuit breaker. The arrangement is such that the circuit breaker cannot close unless this magnet is excited, i.e., the starter must be in the "start" position. An auxiliary switch is necessary on the circuit breaker to short-circuit the interlocking contacts on the starter when the circuit breaker closes. The automatic return of the starter to the "start" position is effected by an under-voltage release as explained above.

With the starter illustrated in Fig. 34, mechanical interlocking is employed between the stator circuit breaker and the rotor starter.

#### Applications.

Faceplate starters of the types illustrated in Figs. 31, 33 and 34 are available for motors up to 500 h.p. They are intended for *infrequent* starting; the normal service rating allowing two starts per hour against full-load torque and the starting period in seconds being  $(5 + \frac{1}{2}) \times$  h.p. rating) of starter for motors up to 50 h.p. The starting period is 30 seconds for motors 50-200 h.p., and 1 minute for motors above 200 h.p.

In emergencies, four successive starts from the cold without cooling periods may be made, but in such cases at least an hour must elapse before another start is made, in order that the oil may become thoroughly cooled. Figs. 35 and 36 show industrial applications of the oil-immersed type of starter illustrated in Figs. 33 and 34. In each case an oil-break circuit breaker, with solenoid-type over-current and under-voltage releases, is used to

control the stator circuits, and the over-current releases are fitted with time-lag dashpots of the type shown in Fig. 13. Also in each case the circuit breaker is mechanically interlocked with the rotor starter. The interlocking rod may be observed in each illustration.

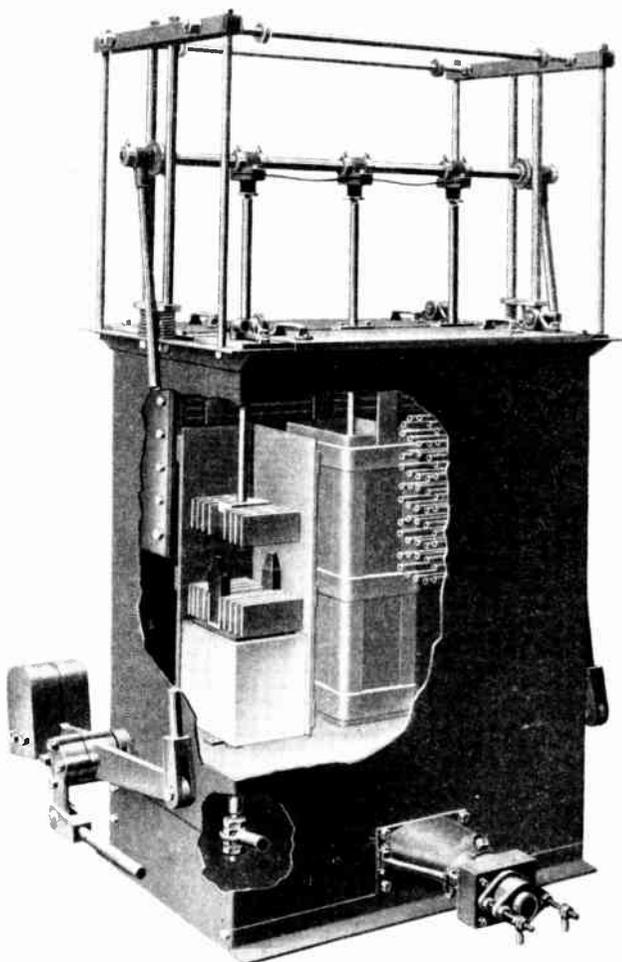


Fig. 43.—VIEW OF LARGE LIQUID STARTER FOR HEAVY DUTY. Showing the electrodes, compartments, cooling-water tubes, operating gear, etc. (Metropolitan-Vickers.)

#### Drum-type Rotor Starters.

An alternative to the combination of a faceplate starter and separate circuit breaker is a self-contained control pillar, having a drum-type rotor starter and an interlocked triple-pole contactor for the

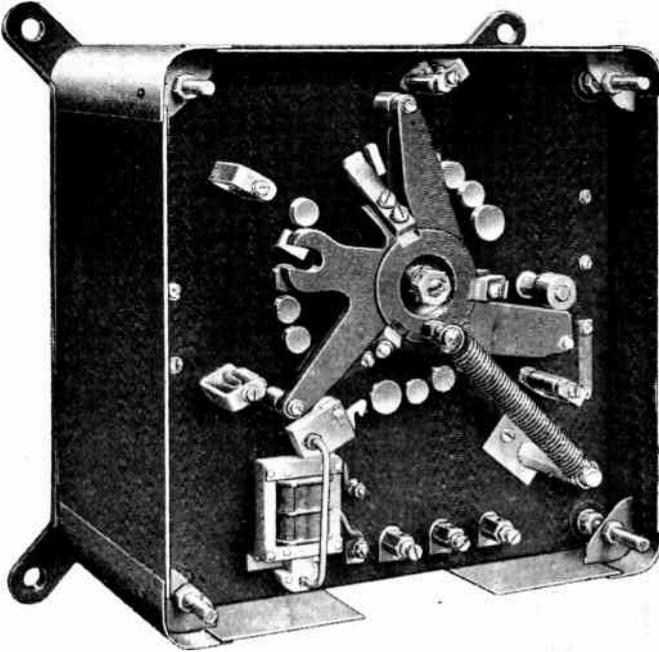


Fig. 44.—FACE-PLATE TYPE STARTER FOR SINGLE-PHASE SQUIRREL-CAGE INDUCTION MOTOR. (R.T.-H. Co.)

This switch is adapted from a rotor-starting switch for a three-phase motor. The connections are shown in Fig. 45.

stator circuits. Such a pillar is illustrated in Fig. 37, and the arrangement possesses a number of advantages over the use of separate pieces of apparatus.

For reversing service (e.g., cranes, hoists and haulages), and also for all cases of frequent starting, drum-type controllers may be used. These controllers are similar to those for D.C. circuits, except that no magnetic blow-out is provided and that the arrangement of the contact drum is different. Moreover, for heavy service, an oil-immersed controller may be used.

An important feature in all drum controllers for three-phase rotors is that the resistances are cut out *successively* from the rotor circuits instead of simultaneously, as with faceplate starters. Thus on some steps the rotor circuits are unbalanced. This arrangement is adopted in order to reduce the size and cost of the controller, and in practice the unbalancing does not affect the operation of the motor.

Fig. 40 shows the connections and development of a typical controller for a

reversing motor. The contact drum controls both rotor and stator circuits.

For large motors a separate contactor-type reversing switch is necessary.

### Contactor-type Rotor Starters.

These starters are used for heavy starting duty, for frequent starting and reversing, and for either automatic or remote control, or both. The rotor circuit resistances are cut out symmetrically from each phase by either double-pole or triple-pole contactors, and the closing of these contactors is governed by current-limit or notching relays, the operating coils of which are connected in the stator circuit. By arranging that each rotor-circuit contactor closes

at a predetermined current input to the motor, uniform acceleration may be obtained with a minimum number of sections in the starting rheostats, provided that these sections are correctly designed.

When only two or three sections of resistance are necessary the relays are incorporated into the contactors, as shown in Fig. 38. In this starter the top contactor controls the stator circuits. (Observe that this contactor has lighter main contacts than the other contactors, and that magnetic blow-outs are provided.) The relay adjacent to this top contactor controls the middle contactor, which cuts out the first section of rotor resistance. The relay adjacent to the middle contactor controls the bottom contactor, which cuts out the second section of rotor resistance.

With starters for larger motors in which several rotor-circuit contactors may be necessary, these contactors are all controlled by two relays which operate alternately, suitable auxiliary switches

being provided on the contactors to give the correct sequence of operations.

### Protective Devices.

Under-voltage protection is an inherent feature of contactor equipments on account of the shunt excitation of the operating coils from the supply system.

Over-current protection is obtained by either two or three over-current relays, according to whether or not the neutral point of the supply system is earthed. On all systems with earthed neutral point, three relays are essential to obtain complete protection. The relays may be of the solenoid type with time-lag dashpots, but recently a thermal type of relay has been developed, the characteristics of which give better protection to the motor than electro-magnetic relays.

### Thermal Over-current Relay.

This relay is shown in Fig. 39. It consists of a heater A, which carries either the full motor current or a proportional current. This heater is located underneath a bi-metal strip B, the free (outer) end of which on becoming heated moves upwards and trips the latch C. This operation opens the contacts E F, which are connected in the operating-coil circuit of the stator contactor. The relay is not self resetting, which must be effected by hand (usually by a bar engaging with the lower end of D). Three relays are, of course, necessary for a three-phase motor.

These thermal relays give the ideal inverse time-current protective characteristic against normal or small sustained over-currents on all phases of the motor. They can be set to give protection against prolonged over-currents just above the normal current of the motor, and yet allow the motor to carry overloads of 50 per cent. for brief periods, provided that such overloads are followed by periods of light load.

## TYPES OF LIQUID STARTERS FOR THREE-PHASE MOTORS.

### Their Advantages over Metallic Rheostats.

Under favourable conditions of installation these starters are ideal as rotor starters for three-phase motors. They are non-inductive and the starting resistance may be reduced continuously. Thus perfectly

uniform torque may be obtained throughout the starting period, and heavy loads, such as cement mills, compressors, etc., may be started slowly and without shocks.

### Applications.

Liquid starters are best suited for medium and large-size motors which require to be started *infrequently*, as the cost of the starter is then lower than that of the corresponding starter with metallic resistances.

With forced cooling they are suitable for starting and controlling the largest motors (such as pit winders and the motors of large flywheel motor-generator sets for reversing rolling mills), and in these cases a large amount of power can be dissipated. The industrial types of liquid starters are not suitable for cranes, owing to the liability of the liquid being spilt.

### The Electrolyte.

The resistance solution or electrolyte is a solution of washing soda (carbonate of soda). In general, the strength of the solution should be about one part of washing soda to twenty parts of water (by weight). The strength, however, must be adjusted to suit the starting conditions. For example, for motors starting heavy loads with full-load torque, two parts of soda to twenty parts of water may be necessary. Under working conditions the water evaporates slowly, and fresh water must, therefore, be added periodically to maintain the original level and strength.

### Liquid Starter for Small and Medium-size Motors.

The smaller sizes of liquid starters consist of an iron tank, containing the requisite amount of electrolyte, and three moving electrodes or dippers, which are connected to the slip rings of the motor. The dippers are quadrant-shaped and are attached to, but insulated from, a cross frame, which can be raised or lowered slowly by screw gear so as to immerse more or less of the dippers and thus control the resistance between the terminals of the starter. When the dippers are fully immersed they are short circuited by special contact fingers in order to avoid current passing continuously through

the electrolyte which would cause unnecessary losses and evaporation of the electrolyte.

These features are shown in the diagram of Fig. 41, which is a cross-section of a typical starter. The dippers C are shown in the full-on position, and the short-circuiting contacts are shown at J. The cross frame D, from which the dippers are supported by the insulators E, is fixed to a shaft F, which is carried in bearings fitted into the ends of the tank A. One end of the shaft is extended and is fitted with a crank to which the screw-operating gear is attached. The fixed dippers, K, attached to the terminals H of the starter are for the purpose of preventing the opening of the rotor circuits when the movable dippers are raised above the level of the liquid.

#### Liquid Starters for Large Motors (Natural Circulation).

Large liquid starters for infrequent use differ considerably from the smaller starters considered above. Due to the large amount of energy which has to be dissipated in the electrolyte during starting, special arrangements have to be provided for circulating the electrolyte to prevent overheating during the starting period. In these starters the neutral point of the rotor circuit is not formed by the tank, as in the smaller starters, but by the moving electrodes or dippers A, Fig. 42. These are suspended by copper rods fixed to a common crossbar which has a vertical motion. The three fixed electrodes, B, are each located in separate rectangular tubes D, of insulating material, each electrode being supported on a block of insulating material C, as shown in Fig. 42. Both sets of electrodes are of the multiple plate type, and in the full-on position the plates of the moving electrodes mesh closely with those of the fixed electrodes in order to give a minimum resistance of electrolyte in this position. The residual resistance is cut out in two or three steps by auxiliary contacts, E, which close in succession when the moving electrodes reach their lowest position. This step-by-step reduction of the residual resistance of the electrolyte is effected by metallic resistances connected between the auxiliary contacts.

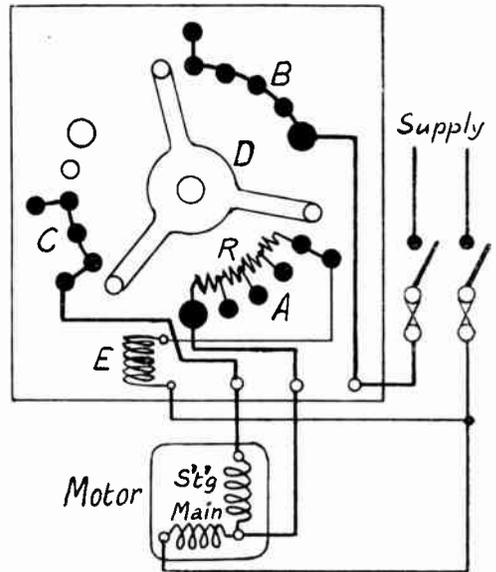


Fig. 45.—CONNECTIONS OF STARTER (FIG. 44) FOR SINGLE-PHASE SQUIRREL-CAGE INDUCTION MOTOR. (B.T.-H. Co.)

The three insulated tubes which contain the electrodes are fixed in a large tank which contains a large amount of electrolyte. In service, the electrolyte circulates in the directions of the arrows in Fig. 42. Thus the heated liquid in the tubes rises to the top of the tank and its place is taken by cool liquid which enters the tubes through the bottom insulators and fixed electrodes.

#### Large Liquid Starters for Frequent Use.

These starters are used for controlling large reversing motors driving winders and haulages in coal mines. They are also used for starting and regulating the speed of flywheel motor-generator sets (induction motor, heavy flywheel and D.C. generators) for supplying power to D.C. reversing rolling motors. All these services involve practically continuous duty, and, therefore, special cooling of the electrolyte is necessary. A typical cooling arrangement is shown in Fig. 43.

The general arrangement of the electrodes and insulated tubes is similar to that of the large starters with natural circulation, but in the present case the upper portion of the tank contains a large

number of thin tubes through the interior of which cold water is circulated. Thus the heated electrolyte discharging over the tops of the resistance tubes is effectively cooled by the water tubes before being used again in the resistance tubes. Approximately 3.3 gallons of cooling water are required for each h.p. dissipated per hour.

The largest size of liquid starter—which is designed for large A.C. winders, and is capable of dissipating 900 h.p. continuously—has a separate external cooler and forced circulation of the electrolyte by a centrifugal pump.

### Protective Devices for Liquid Starters.

Liquid starters cannot be arranged with automatic protective features, and, therefore, the over-current and under-voltage releases must be fitted to the stator circuit breaker. It is most desirable, however, that the liquid starter should be fitted with an auxiliary interlocking switch in conjunction with the under-voltage release on the stator switch, which will ensure that the stator switch cannot be closed unless the starter is in the "start" position.

## STARTERS FOR SINGLE-PHASE MOTORS.

### How Single-phase Repulsion-type Motors are Started.

Repulsion motors, repulsion-start induction motors and repulsion-induction motors in fractional-h.p. and small sizes (2 to 3 h.p.) are started by direct switching on to the supply. Larger motors are started by inserting resistance in the stator circuits.

### How Single-phase Induction Motors are Started.

Split-phase *squirrel-cage* motors (i.e., motors having a "main" winding and a high-resistance "starting" winding, displaced 90 electrical degrees from the main winding) in fractional-h.p. sizes are started by direct switching on to the supply. No changeover or special switch is necessary, as a centrifugally operated switch is built into the motor for the purpose of automatically cutting the starting winding out of circuit when the speed reaches the normal value.

Larger split-phase *squirrel-cage* motors, up to  $7\frac{1}{2}$  h.p. (which are also wound with a high-resistance starting winding), require a starting rheostat to limit the starting current and a cut-out switch for the starting winding. At starting, the rheostat is connected in series with the supply to the main winding, and the starting winding is connected directly to the supply. The rheostat is cut out in steps and finally the starting winding is disconnected from the supply.

Split-phase *slip-ring* motors usually require an external phase-splitter with change over switch for the stator, together with a starting rheostat for the rotor; the latter being of similar type to the rotor starter for a three-phase motor.

The phase-splitter consists of a fixed resistance, a fixed reactance and a change-over switch. In the "start" position of this switch the supply is connected to both main and starting windings, but the fixed resistance is connected in series with the starting winding, and the reactance is connected in series with the main winding. In the "run" position the main winding is connected directly to the supply and the starting winding is cut out.

At starting, the full starting resistance is connected in the rotor circuit, and the change-over switch is placed in the "start" position. The starting resistance is then cut out in steps in the same manner as when starting a three-phase motor, and finally, when all this resistance is cut out, the change-over switch is thrown to the "run" position.

### Rheostatic Starter for Split-phase Squirrel-cage Motor.

Fig. 44 illustrates a starter for a split-phase *squirrel-cage* motor of  $5-7\frac{1}{2}$  h.p. In these motors the starting winding is designed with a sufficiently high resistance and reactance that an external phase-splitter is not required. The starter, therefore, consists of a suitable faceplate-type switch and a graded rheostat which at starting is connected in series with the main winding. The switch is fitted with auxiliary carbon roller contacts at points where circuits are broken, so that any arcing may occur at these contacts instead of at the main contacts. An under-

voltage release and a return spring (to return the starting switch to the "off" position) are fitted.

The connections are shown in Fig. 45. The contact buttons are arranged in three groups A, B, C, as in a rotor starter for a three-phase motor. (In fact, the faceplate of a three-phase rotor starter is adapted to meet the present requirements.) The starting resistance,  $R$ , is connected to the buttons of group A. The whole of the buttons in group B are connected together, and a number of buttons in group C are similarly connected.

#### **How the Starter Operates.**

When the three-armed switch D is operated the starting winding of the motor is connected directly to the supply, the whole of the resistance  $R$  is connected in

series with the main winding, and this circuit is also connected to the supply. The resistance  $R$  is cut out in steps, and just before the last section is cut out the starting winding is disconnected from the supply by the switch leaving the contact C.

#### **Applications.**

Rheostatic starters of the type illustrated in Fig. 44 are intended for infrequent light-duty starting. The starting period, in seconds, should not exceed 5 seconds plus half a second per h.p. of starter rating. A maximum of four starts per hour may be made, and at least fourteen times the starting period should be allowed between successive starts so as to allow the rheostats to cool thoroughly.

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## QUESTIONS AND ANSWERS

#### **What is an auto-transformer ?**

A transformer in which a portion of the turns are common to both primary and secondary circuits.

#### **Why is an auto-transformer used for starting three-phase squirrel-cage motors ?**

Because with the low ratios of transformation required, it is very much cheaper than an ordinary transformer, due to the power output of its secondary winding being only a portion of the power supplied to the motor.

#### **What is rheostatic starting ?**

The method in which the reduced voltage applied to the motor is obtained by means of resistances connected in series with the stator windings. This method is occasionally used with small motors.

#### **How are three-phase slip-ring motors started ?**

By means of resistances connected in the rotor circuits, the full supply voltage being switched on to the stator windings,

Either metallic or liquid rheostats may be used according to circumstances and starting conditions.

#### **What method would you use for starting a synchronous motor having a squirrel-cage winding in the pole faces ?**

By supplying the stator at reduced voltage by means of an auto-transformer. The field winding on the rotor is usually short-circuited. When the motor has run up to speed the short circuit across the field winding is removed and D.C. excitation is applied which causes the rotor to lock into synchronism.

#### **Describe a thermal over-current relay as applied to a three-phase motor circuit ?**

The essential parts are (1) three heating elements, one in each supply line; (2) a bi-metallic spiral, which when sufficiently heated untwists and operates a tripping bar which opens the contacts of the "off" push-button switch. The necessary time lag is obtained by adjusting the air space between the heating element and the bi-metallic spiral.

# L.F. AND H.F. RADIO TRANSFORMERS

By A. E. WATKINS

## LOW FREQUENCY TRANSFORMERS

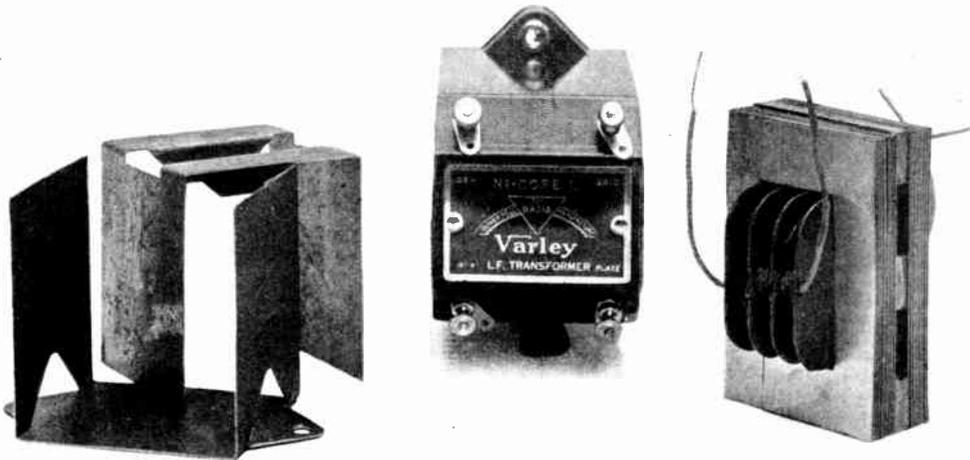


Fig. 1.—CONSTRUCTIONAL DETAILS OF THE VARLEY NICORE TRANSFORMER.

On the left are the screening plates, while on the right can be seen the bobbin construction and the core which is subdivided by the packing pieces. The curve of the transformer is shown in Fig. 2.

**P**RACTICALLY every modern radio receiver uses a low frequency transformer. If not correctly designed, this component will make or mar the results almost more than any other.

The position it usually occupies in a receiver is a vital one, for it forms the link between each valve following the detector, and upon the low frequency transformer depends the correct functioning of the valves. Particular attention should therefore be paid to the selection of the low frequency transformer.

The electrical and magnetic properties of a low frequency transformer are far more complicated than those particular to any other part of the receiver, and its operation is exceedingly complex.

### What a Low Frequency Transformer has to do.

In the position which the transformer

usually occupies in the receiver it has to take the low frequency impulses from one valve and pass them on to the next for further amplification. That sounds rather simple, but it is not, for it endeavours to get that energy passed over without any loss or any distortion. The early design of low frequency transformers was an elementary affair. It consisted of a simple core of iron with two windings, the primary and secondary, and little attention was paid to the correct proportions of these three components, but now particular care has been taken in the selection of the material for the core, and also the size in proportion to the windings.

There are two materials generally used for the production of the core—silicon iron and nickel iron. Silicon iron is used on the larger of transformers, and the nickel iron is used in the case of small transformers which are usually parallel fed, that is

to say, the high tension direct current to the anode of the valve does not directly pass through the windings.

### The Core.

The core of a low frequency transformer does not consist of a simple rod of metal, either solid or divided. It has a definite form of design and generally assumes the shape of a rectangle with a bar across the centre, the bobbin holding the winding being placed upon this central bar. The purpose of making the core this shape is

### The Magnetic Core.

The same applies to the magnetic core. The greater the permeability, the more easily are the lines of force carried through it. In the early days, transformers had cores made of ordinary soft iron. It was found later that an alloy of silicon iron had a still higher permeability, and now only the very cheapest of transformers still contain soft iron. It must be remembered that the greater the permeability of the core on which the transformer is built, the greater will be the inductance

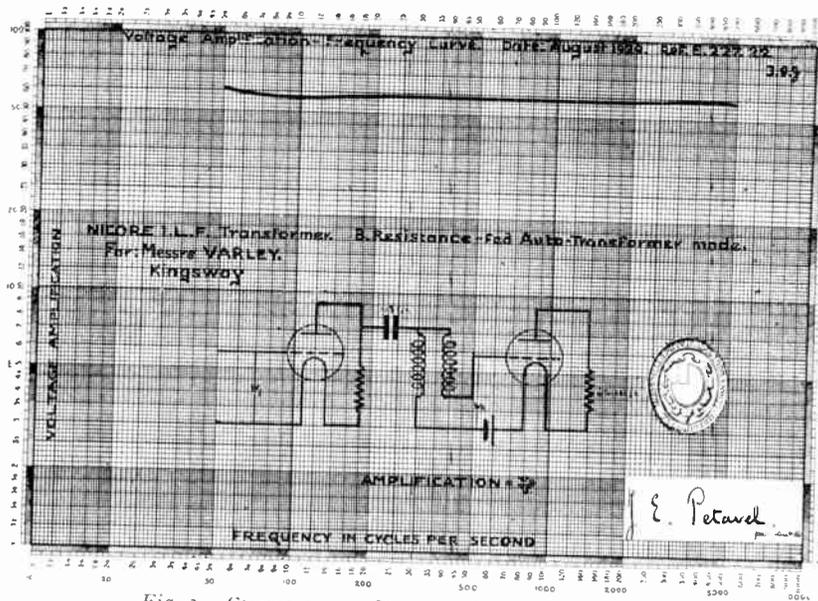


Fig. 2.—CURVE OF THE VARLEY NICORE TRANSFORMER.

to confine a line of force to a definite magnetic surface and air gaps are reduced to a minimum so as to obtain a high efficiency of the core as a whole. Therefore we find these stampings or laminations arranged so that the stampings are insulated from one another and clamped together tightly to prevent any air gaps.

### The Importance of Permeability.

Permeability is to the lines of force more or less what conductance is to an electrical current. Conductance is the direct opposite to resistance. The higher the resistance of a wire, the less its conductance, or the more easily it conducts the electricity.

of the primary for a given number of turns, and the less the number of turns, the greater the advantage, for it means that there will be less self-capacity and the resistance of the primary will be lower; therefore a greater voltage will be supplied to the anode of the valve.

Nickel iron alloy has a very much higher permeability than silicon iron, and nickel iron is used on the very small transformers which have trade names given to their cores, such as "Nicore."

### Advantages and Disadvantages of Small Transformers.

The advantage of these small transformers is that the inductance of the

primary is high with small bulk of winding. This reduces self-capacity and eddy losses, and gives a better performance.

There are, however, certain snags with these transformers. The cores are very small and, therefore, the windings are also small and usually of fine wire and cannot carry very heavy current. Also, if a transformer of this description is called upon to carry heavy current, the saturation of the core will tend to spoil the result.

### Choosing a Transformer.

When selecting a transformer it is essential that one should consider the anode current which will be passing through the primary. That is why it is an advantage, when high anode current is required on the preceding valve, for it to be fed by a resistance and coupled to the transformer by a condenser. The primary is then not called upon to carry the direct current which would be the principal cause of saturation.

There is one other important point in connection with transformer design. This concerns the losses due to leakage or inductance. The job of the core is to concentrate the magnetic field set up round the primary winding and make it

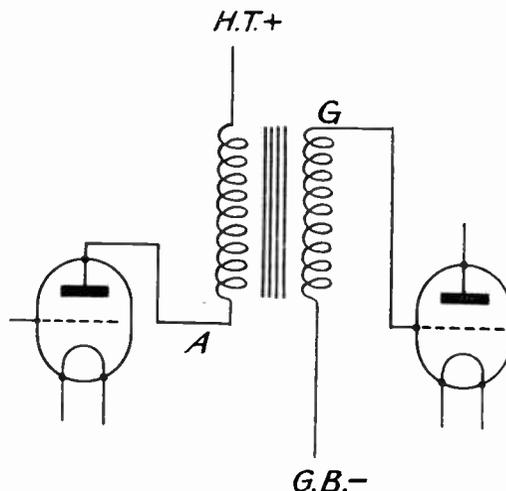


Fig. 3.—THE STANDARD CONNECTIONS FOR AN L.F. TRANSFORMER WITH THE HIGH TENSION PASSING THROUGH THE PRIMARY.

flow through the secondary without loss, but 100 per cent. efficiency cannot be obtained, and in the present transformers there will be a loss of the lines of force, or "leakage lines," which do not link the primary and secondary together. The smaller this leakage the greater the efficiency of the transformer, and this is where a carefully designed core, with little air gap, carefully assembled, counts.

### The Primary and Secondary.

These are usually wound at various ratios, such as 2-3, 1-3, 1-5 and 1-7. For all-round general results a 1-3 is most suitable, although where two stages of low frequency transformer coupling are used, it is also advantageous to use two different ratios, the higher ratios being used in the second position. The reason for this is that the lower the ratio, the bigger the primary impedance, as the difference of ratio is obtained by sacrificing the turns of the primary. That is to say, if there are 1,000 turns on the primary and 7,000 turns on the secondary for 7-1, on the 3-1 there will be, approximately, 2,700 turns on the primary.

### Impedance.

As the valves are of higher impedance at the earlier stages it is important that

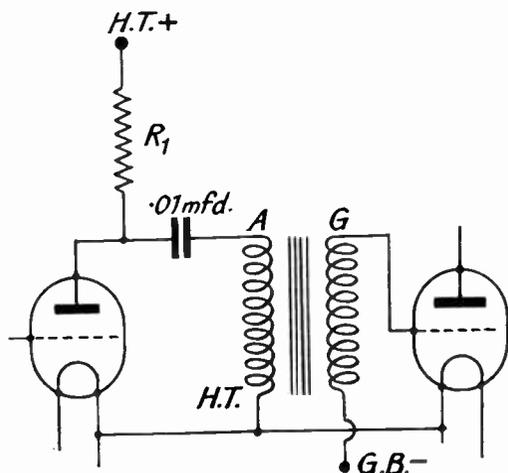


Fig. 4.—RESISTANCE FEED METHOD OF CONNECTING UP AN L.F. TRANSFORMER.

This is the best method to use for small transformers of the Nicore type. No direct current passes the primary.

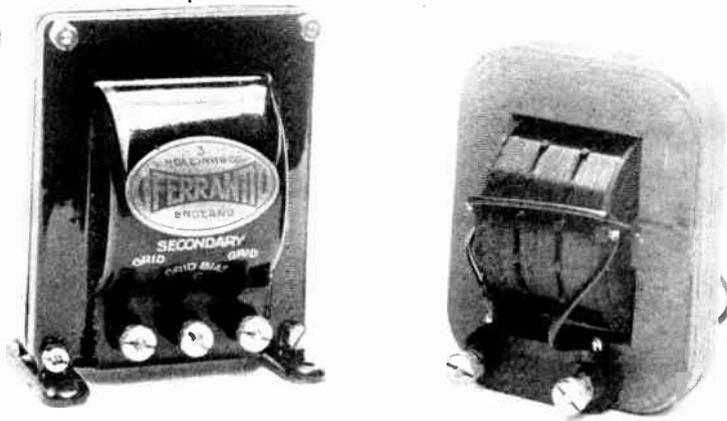


Fig. 5.—CONSTRUCTIONAL DETAILS OF FERRANTI TRANSFORMER. On the left can be seen the centre tap for push-pull. The construction of the formers can be seen on the right, also the subdivided windings.

the transformer impedance should also be higher, an average rule being for the transformer primary impedance to be twice that of the valve impedance, and often a lower ratio transformer will give better results than one of a greater ratio, due simply to the fact that the impedance of the primary is more suitable to the valve.

The design of the primary and secondary winding is most important, as the self-capacity between these windings has a great effect upon the higher frequencies. Should there be a high capacity between the windings, the transformer will act similarly to a condenser and by-pass the low frequency impulses directly away without affecting the secondary.

#### How a Low Capacity Winding is Obtained.

The method of achieving a low capacity winding is carried out in various manners. The most commonly used method is to subdivide the bobbin, winding the primary on one bobbin and the secondary on two others, and spacing them apart with a small air gap. The "Ferranti" method, in which the windings are carried out on skeleton formers, and the winding subdivided on each former, is a still better design and results in a very low self-capacity winding, and is why, in the first

stage following the detector, it is advisable to have a small condenser between the primary winding.

Another advantage of having a transformer with low self-capacity, such as the Ferranti, is that the value of the condenser across the primary can be altered to obtain the exact degree of capacity that is necessary, and so balance the low frequency circuit without any loss of the higher frequency.

#### Design of Ferranti Transformers.

On examining Fig. 5, showing the component parts of the Ferranti transformer, it will be seen that great care has been expended on the design and the construction. This particularly applies

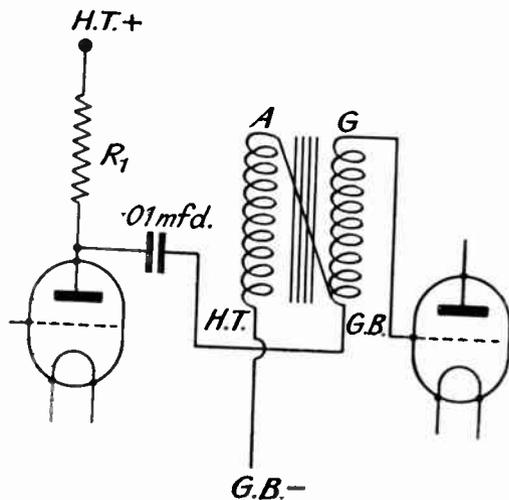


Fig. 6.—CONNECTIONS FOR RESISTANCE COUPLED AUTO TRANSFORMER.

The resistance of  $R_1$  should be approximately twice the impedance of the valve.

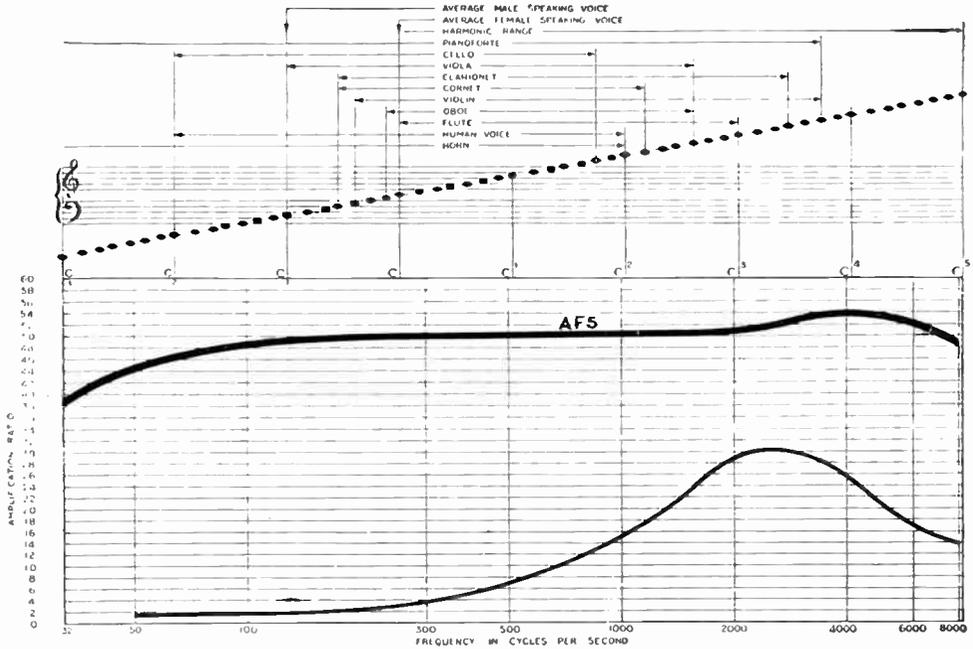


Fig. 7. — COMPARATIVE CURVES OF A FERRANTI A.F.5 TRANSFORMER, AND A BADLY DESIGNED TRANSFORMER.

The lower curve is that of a badly designed transformer.

to the design of the formers for carrying the windings. Again, the design of the core is such as to obtain as little magnetic leakage as possible. The whole design of this transformer has been so carefully proportioned that it gives practically a straight line from the lowest frequency, without any resonant peaks, and it is in this connection that the difference in performance with a good quality transformer scores over that with a cheap make.

low frequency transformer should be as that shown on the graph. Therefore, when deciding on the purchase of a transformer, see the makers' amplification curve. If they do not publish one, do not buy the transformer because, unless they show this curve, it follows that they have little idea of the performance of the transformer in question. It is essential to know these facts, and also the impedance of the primary, so as to know whether the transformer and valves are suitably matched.

**What the Makers' Curve Shows.**

If the curve of a cheap transformer were taken it would probably show very little low frequency amplification with a high peak round about the middle register rapidly falling, whereas the curve of a

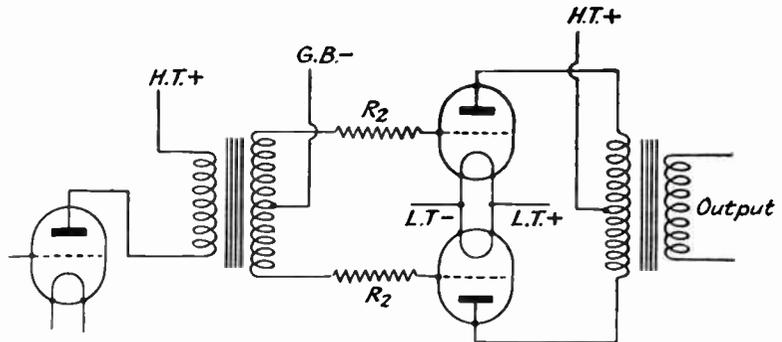


Fig. 8.—CONNECTIONS FOR PUSH-PULL TRANSFORMER. The resistances  $R_2$  are decoupling resistances of 50,000 ohms.

### Types of Low Frequency Transformers.

Low frequency transformers can be divided into the following classes :—

Transformers for single intervalve coupling, such as one primary and secondary.

Transformers which have divided primaries and divided secondaries, that is, the transformer preceding the output valve, has the secondary tapped in the centre, and the output transformer has the primary centre tapped or two windings for push-pull amplification.

In some circuits, two output transformers are used, but this is not necessary unless a heavy anode current is used.

Another type is the output transformer and output choke. Output transformers usually have their secondaries and primaries with various tappings so that they may be used to suit the valves and the loud-speaker.

### Connecting up Transformers.

The circuits for connecting transformers are shown in Figs. 4 & 6, which will show the various alternative methods of connecting transformers other than the usual practice of passing the direct current directly through the primary as in Fig. 3.

### IMPORTANT POINTS IN L.F. TRANSFORMER DESIGN.

An example of good transformer design, showing the attention which has been paid to the particular points, is the Ferranti

transformer, which has a core of large cross-section—in the AF5 transformer it is 1.07 sq. in. The stamping has no appreciable air gap and the number of primary turns of wire is large—in the AF3 and the AF5, 7,600 turns. Points to watch for are :—

#### Self-induction.

(1) That the inductance of the primary winding should be as great as possible.

#### Magnetic Leakage.

(2) That the magnetic leakage of the transformer should be as small as possible. The magnetic field created by the primary is not completely passed on to the secondary ; this is magnetic leakage.

In the AF3, AF5 and AF7 transformers this is attained by interleaving the secondary between two half-primary windings. This is quite important if the high notes are to be reproduced properly.

#### Self-capacity.

(3) That windings unfortunately possess another property besides "self-induction," that is "self-capacity" due to the close proximity of turns with voltage differences acting as condenser plates. To reduce this self-capacity and yet retain the large ratio of  $3\frac{1}{2}$ , fine enamel wire of .002 in. diameter is used for the secondary winding and the bobbins are of skeleton form, in order to get as much air space as possible. The windings are also subdivided. Fig. 5 shows the bobbins.

## HIGH FREQUENCY TRANSFORMERS

High frequency resonance radio transformers are used to couple the valve preceding the detector valve, so as to pass the energy from the H.F. valve on to the next and so amplify the high frequency currents that they are powerful enough to give a good swing to the grid of the detector valve. As it is well known, a detector, to function at its best, must have a certain grid swing.

The H.F. transformer differs considerably from the L.F. transformer.

In the first place there is no iron core, for this would be useless in an H.F. trans-

former. Secondly, one of the circuits is usually tuned by means of a variable condenser, for resonance between the primary and secondary is only obtained when the circuit is correctly in tune, and at that point the greatest transfer of energy will be obtained. It does not matter whether there are one or two windings in a transformer, exactly the same thing will occur.

#### Why One Circuit Only is Tuned.

It is unnecessary to tune both for the act of tuning one will also tune the other,

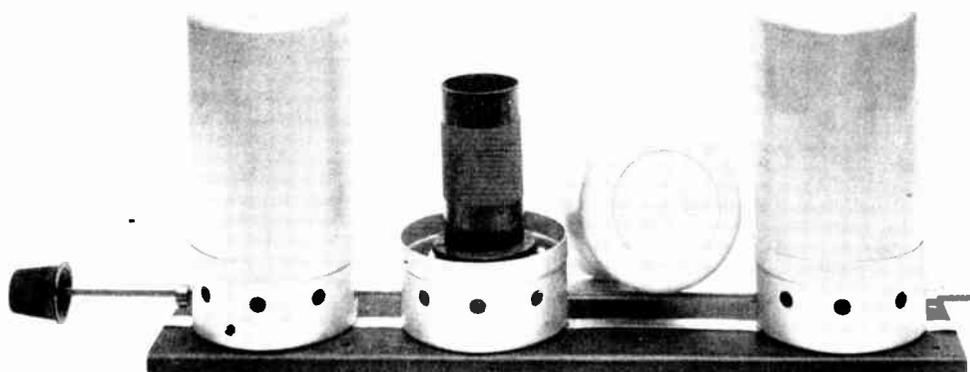


Fig. 9.—A MODERN GANGED H.F. TRANSFORMER.

Showing the screens mounted with earthing strip as it is essential that the screens are efficiently earthed.

and as the primary is usually partly aperiodic, the maximum resonance will be obtained only when the secondary is tuned. Therefore, any slight advantage which may be obtained by tuning both windings is negated by the extra complications and difficulties of balancing and ganging tuning condensers together.

#### Position of the Windings.

The two windings are placed apart at such a distance as will give maximum coupling effects, so that there is as little leakage of the flux as possible. In some transformers they are deliberately placed apart to loosen the coupling and, therefore, give a high peak resonance, but if windings are placed too far apart, resonance may not be obtained throughout the whole wave band. The reason for this is that the act of tuning one winding would have very little effect upon the other, therefore, it is readily understood that the secondary circuit has an effect upon the primary, and vice versa, which is clear from the fact that there is energy transferred from one circuit to

the other. In the transfer of energy from one circuit to the other the leakage flux goes to waste. It is the mutual flux only which determines the energy transferred, and it is necessary to have this as great as possible.

#### Mutual Inductance.

There is a limit to the amount of mutual flux, this being determined by the other constants of the circuit, the size of the coil and other matters. If the mutual inductance is too great, the circuit will tune to the same wavelength frequency at two different settings of the condenser. It is necessary to keep the mutual inductance so low that for all practical purposes these two settings of the condenser come together. This phenomenon is well known and is known as "double hump resonance."

The first position for the primary and secondary is obtained by adjusting the distances till the desired results are obtained, for to determine these differences on paper would involve taking into consideration a great many things and

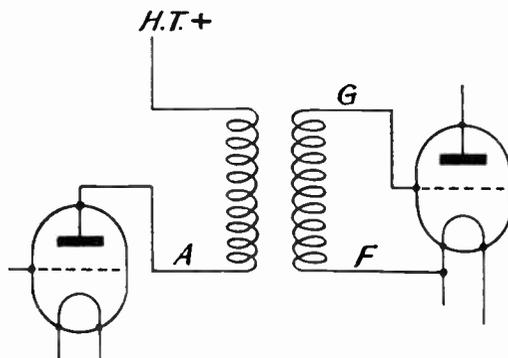


Fig. 10.—CIRCUIT FOR H.F. UNTUNED TRANSFORMER.

would then not work out satisfactorily. It is better to determine these differences by actual experiment.

**The Single Winding.**

We now come to the single winding ; that is to say, one common coil is used to take the place of primary and secondary.

This is actually an auto-transformer and the ratio of the winding may be 1-1 or, by taking a tapping at any of the intermediate turns, the ratio can be varied.

This type of H.F. transformer is commonly called " tuned anode " or " tuned

on a single coil too low down, sharpness of tuning will be obtained, but at the sacrifice of cutting the side bands, resulting in poor quality.

**Causes of H.F. Transformer Losses.**

Losses in an H.F. transformer are due to badly designed coils, poor insulating material and self-capacity. Poor design, where the useful energy is not transferred and may result from using the wrong gauges of wire ; poor insulation, absorption or damping due to poor design of screen, unsuitable material for winding the inductances upon and losses due to the condensers used to tune one of the circuits.

**How Damping is Introduced.**

Under present day conditions, however, a certain amount of damping is deliberately introduced. This is to obtain stability, for, if the ideal of efficiency of coupling was obtained, the receiver would be uncontrollable, due to its bursting into oscillation.

Under present practice it is accepted that it is better to design the coil with a small diameter and use wire of a fairly fine gauge usually round about No. 30 or 32, and in some cases No. 36 and 38, the finer gauges being particularly applied to the higher wavelengths. A satisfactory diameter for the inductance is approximately 1¼ in. or even 1 in.

**Use Silk Covered Wire.**

There is, however, no question at all that silk covered wire is the best for the insulation of the wire itself and paxolin

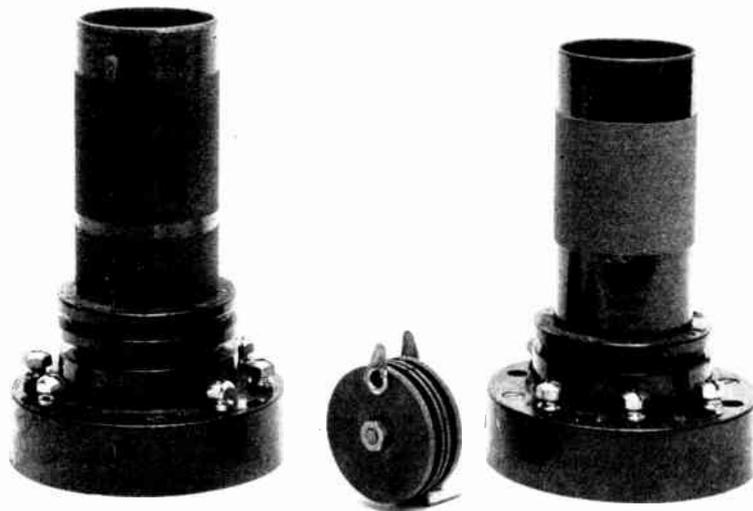


Fig. 11.—THREE MODERN H.F. TRANSFORMERS.

Left, a two-circuit winding ; centre, an aperiodic untuned transformer as used in portable receivers ; right, a single winding tuned anode or tuned grid transformer.

grid," but of course this actually serves exactly the same purpose as that of transferring the energy from one valve to the other and passing it on without loss or distortion.

**Distortion Troubles.**

Distortion troubles do not occur quite so badly in an H.F. transformer as in the L.F. transformer, for unless the curve is made too sharp, so as to cut off the side bands, little trouble is experienced, but if the coupling between the primary and secondary is made too small or the tapping

is one of the best materials for winding the inductance upon successfully.

**Types of H.F. Transformers.**

We will now consider the various types of transformers and describe the various circuits of which each type is most suitable.

1. The untuned primary and secondary.
2. Untuned primary and tuned secondary.
3. Tuned primary and secondary.
4. Tuned single winding.
5. Tuned single winding with auto-coupling.

**1. The Untuned Primary and Secondary.**

The untuned primary and secondary is

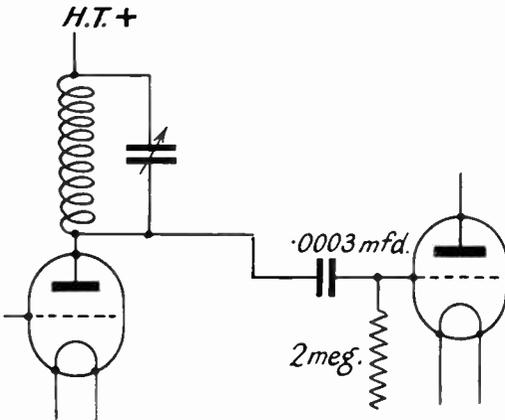


Fig. 13.—CIRCUIT FOR TUNED ANODE H.F. COUPLING.

usually used in sets of the portable type in which high stage gain is sacrificed to simplify construction, bulk and tuning. The windings of these transformers are aperiodic; that is to say, the primary will transfer its energy to the secondary at any frequency. The disadvantage of this type of transformer is that it is not of very high efficiency and it has a very flat tuning curve. Therefore, it does not assist in obtaining selectivity and is practically useless on any receiver using an outside aerial or where a high overall efficiency and degree of selectivity are required.

**2. Untuned Primary and Tuned Secondary.**

Untuned primary and tuned secondary is universally used in most of the American

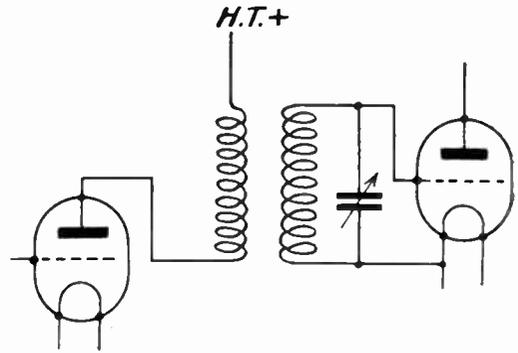


Fig. 12.—CIRCUIT FOR TUNED SECONDARY H.F. COUPLING.

receivers and is particularly suitable for receivers which are designed to work over a narrow wave band, such as between 200 and 600 metres, as the primary can be so proportioned as to give a fair degree of selectivity with a reasonable degree of efficiency. The usual ratio of the windings is 3-1. That is, the primary has the lower number of turns and the secondary usually three times that of the primary. The primary to the secondary are coupled as closely as possible to obtain the greatest transfer of energy.

In both these types of transformers it will be seen that the anode current passes through the primary to the anode of the valve. One end of the secondary is connected to the grid and the other to the filament. The variable tuning con-

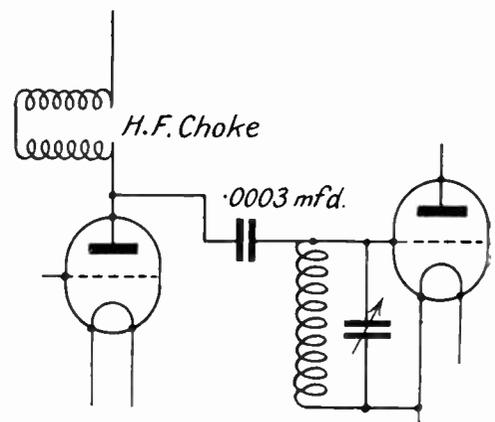


Fig. 14.—CIRCUIT FOR CHOKE CAPACITY TUNED GRID H.F. COUPLING.

denser is connected across the secondary in the case of the tuned secondary winding.

### 3. Tuned Primary and Secondary.

Tuned primary and secondary is usually employed as the intermediate frequency coupling transformer in superheterodynes. In this type of transformer, the primary and secondary are usually of equal ratio, and both are adjusted by a small capacity across the primary and secondary, so that they are each tuned to a definite wavelength. The wavelength to which they are designed to be tuned varies slightly, but usually it is round about 110 kilocycles, but some designers even work to 40 kilocycles.

The distance between the primary and secondary is adjusted to obtain the highest degree of coupling, consistent with good

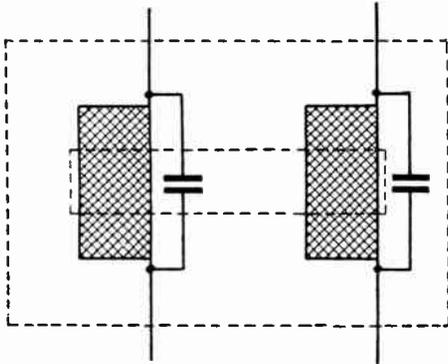


Fig. 15.—H.F. TRANSFORMER SHOWING PRIMARY AND SECONDARY WINDINGS TUNED BY A FIXED CONDENSER, AS USED FOR SUPERHETERODYNE RECEIVER.

quality and adjusted to such a position as to obtain a sharp resonant peak, for it is particularly desired in this type of transformer that it should only pass the correct wavelength for which it is designed.

### 4. Tuned Single Winding.

Tuned single winding is what is commonly called the "tuned anode" or "tuned grid" and consists of only a single inductance tuned by a condenser. The value of this inductance is determined by the waveband which it is to cover. In the case of a coil to cover 200 to 600 metres a suitable size would be as follows: Diameter of former, 1½ in., wound with 90 turns of No. 32 double silk covered

copper wire; long wave coil, 190 turns of No. 36 double silk covered copper wire. Tuned by a .0005 variable condenser.

The value has been determined to allow for screening, for an H.F. transformer must be suitably screened, as otherwise the energy will be transferred to other parts of the circuit. For efficient screening the coil should be totally enclosed in a screening box, and for a coil the size as above a suitable diameter would be 2½ in. with an allowance at top and bottom of at least ¾ in.

### 5. Tuned Single Winding with Auto-coupling.

Tuned single winding with auto-coupling is similar to Type 4. The only difference is that a tapping is taken at a particular position in the coil. By feeding the energy to the tap, the ratio between the primary and secondary can be determined to increase the selectivity, for although this is only a single coil, it is an auto-transformer when used in this form, the coupling taking place between the lower part of the coil and the upper, but the whole circuit is tuned right across from top to bottom of the coil by means of the variable condenser.

### Circuits for H.F. Transformers.

Four different circuits are shown for connecting this type of intervalve coupling. Fig. 14 is probably the most commonly used to-day, and is termed the "tuned grid," the reason being that the tuning condensers can be ganged as the moving plates are at earth potential, and this greatly simplifies the construction of the receiver for all the moving plates of the condenser can be connected together without any difficulty, whereas, in the case of the circuit in Fig. 13, both the fixed and the moving vanes of each condenser must be insulated from one another. In the case of circuit Fig. 14, the energy is fed to the grid coil through a fixed condenser, an H.F. choke being included in the plate circuit to prevent the high frequency impulses passing directly to the H.T. battery and then to earth. This acts as a stopper and forces the energy through the fixed condenser, being the easiest path. The H.F. choke should have a great number of turns of wire.

# SWITCHES, CABLES AND CONNECTORS

## FOR CAR ELECTRICAL EQUIPMENT

By E. HILL

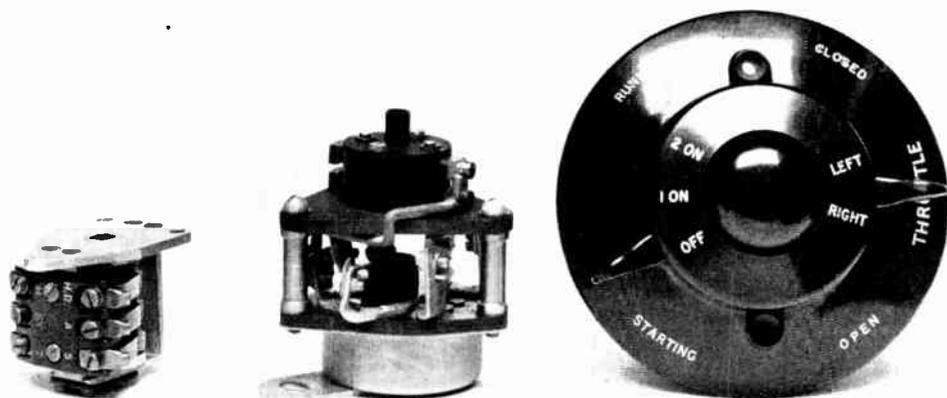


Fig. 1.—TYPICAL SWITCHES AND CONTROL GEAR FOR A MOTOR-CAR.

On the left, base of column switch, barrel type. In the centre, base of column switch, disc type. On the right, head of column control.

**T**HE design and construction of switches for the electrical equipment of motor vehicles of all descriptions are different in many respects to the conventional switchgear as used for house lighting and other stationary electrical plants. For cars and motor cycles, space, appearance and adaptation for a variety of purposes have imposed conditions on designers which have resulted in the production of switches of remarkable ingenuity and effectiveness.

### Use of Stampings and Moulded Insulating Parts.

By the use of stampings and moulded insulating parts, switches controlling 3 or 4 circuits such as head lamps, side and tail lamps, ignition, and generator output have been evolved and which occupy very little space. The single hole mounting, as popularised for radio sets, has been adapted for switches mounted direct to a facia plate, and simple screwed bracket mountings are employed when the switch is fixed in a switchbox or at the bottom of

the steering column. There has recently been a tendency to mount as many of the electrical controls as convenient on the steering column so that they can be operated by a driver without the necessity of moving the hands from the wheel. The horn push, head lamp control and dipping switch, dynamo output control, direction indicator controls and starter remote control switch have all been embodied in one or more devices attached to the steering column. Ignition switches and main starter switches are usually mounted on the dashboard and are often combined with a lock which makes them inoperative when the key is removed.

### Concealed Lighting.

Concealed lighting is generally employed for dashboard illumination, lamps being mounted behind the facia board and controlled by a tumbler or pull-push switch.

### Ammeter Connections.

An ammeter, of the moving-iron type, centre zero, may be mounted on the head

lamp of a motor cycle or on the switch-board of a car, to indicate the charge to, or discharge from, the battery. The current required for ignition, regulation lamps, and dashboard lights is tapped off on the dynamo side of the ammeter, whilst intermittent circuits such as starter, control, horn, screen wiper, and direction

instrument is connected in the dynamo circuit and does not indicate the charge to the battery.

### Maintenance of Car Switchgear.

Little maintenance is necessary on car switchgear. Where the moving contact is of the moulded disc type with brass inserts, tracking may occur after considerable use and cause partial shorting between contacts. Scraping and polishing the surfaces of the disc will remedy this. Spring contact fingers should be made of hard springy phosphor bronze, and when found to be soft, or cracked at a bend, they should be replaced without delay, as no attempt at rectification is likely to be successful. Sweated connections should not be made directly to contact blades, as the soldering operation will soften the contacts and make them ineffective.

### Precaution to Take After Soldering.

After soldering to a fixed contact the surfaces should be thoroughly cleaned, as the flux may have spread and formed an insulating film over the contact. Tension or compression springs, either spiral or flat, when forming part of a switch, should not carry current, as this may soften them and diminish their springiness. Where they are in the circuit, an alterna-

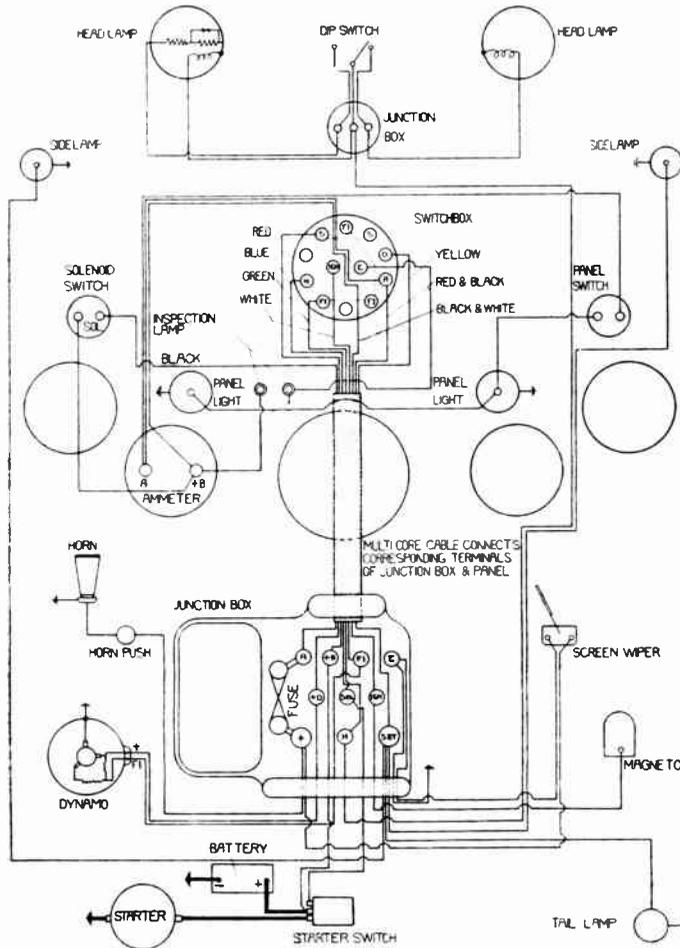


Fig. 2.—TYPICAL WIRING DIAGRAM FOR MOTOR-CAR ELECTRICAL EQUIPMENT.

Showing position of switches and their connections,

indicators are connected directly across the battery and are not indicated on the ammeter.

It should be noted that c.p. equipments on commercial vehicles do not as a rule include an ammeter, but when used, this

path should be provided by means of a flexible copper wire or other conductor. Switch contacts on car circuits are usually of like polarity, but when a terminal or contact of opposite polarity is adjacent, the insulation should be arranged so as

to prevent accidental bridging between it and the switch contacts.

**Size and Position of Switches.**

Contact surfaces should be proportionate to the current to be carried and high conductivity metals employed; for instance, assuming a current density of 200 amperes per sq. in. and a circuit current of 10 amperes the surface of the switch making contact should be

$$\frac{10}{200} = \frac{I}{20} \text{ sq. in.}$$

Barrel type switches, similar in conception to drum controller switches, require accurate positioning owing to the small angular movement between each step. Contact fingers bent out of position may cause open circuit, or make contact out of step and complete the wrong circuit. A spring ball device provides accurate loca-

tion of the barrel for each position, and if no check is felt during movement of the switch handle, this device requires adjustment.

**Loose Connections.**

Loose connections at switch points are a frequent source of trouble, and this can be minimised by occasional inspection and tightening of screwed terminals.

On motor cycles and cars recent practice has shown considerable improvement in the method of laying out the wiring of the electrical equipment. This has been effected by harnessing groups of cables in a loom of cotton braiding.

**Size of Cable.**

Single-pole wiring has been adopted extensively for cars and motor cycles, especially with coil ignition, but double-pole wiring is more general for commercial vehicles. The Standard Specification for automobile cables, published by the British Engineering Standards Association, gives particulars of cores and coverings of cables for various purposes, such as dynamo, battery, starter and lamp connections, and these sizes should be adopted for cable layouts wherever possible. Lamp cables for instance should be single or twin 14 .012 in. (or equivalent section of finer wires), insulated with vulcanised india-

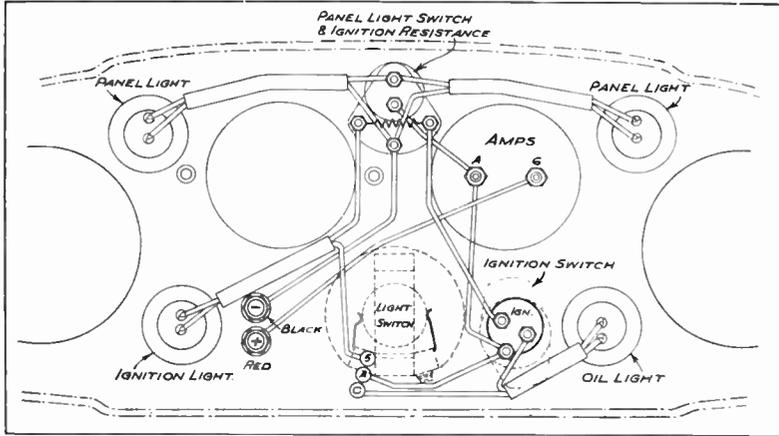


Fig. 3.—BACK OF BOARD CONNECTIONS ON SWITCH PANEL.

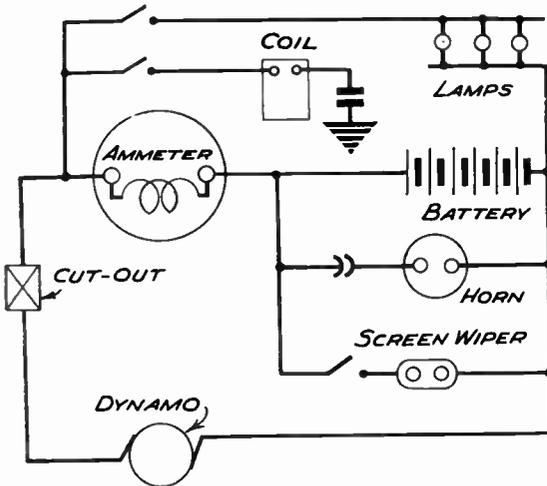


Fig. 4.—DIAGRAM OF CONNECTIONS SHOWING TAPPINGS TO LAMPS AND COIL ON DYNAMO SIDE OF AMMETER AND TAPPINGS TO HORN, ETC., ON BATTERY SIDE OF AMMETER.

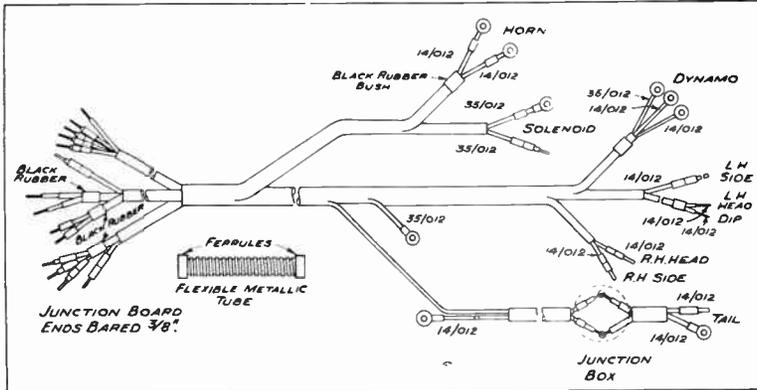


Fig. 5.—DIAGRAM SHOWING METHOD OF HARNESSING CABLES.

rubber of not less than .025 in. thick, lapped with oil and water resisting varnished cambric tape with 50 per cent. overlap, braided with cotton and protected with oil, water and fire resisting compound. Dynamo and switchboard feed wires should have 35 .012 in. cores with similar covering. It is of course necessary on 'buses and other vehicles having a high lamp load to employ larger cables than those specified for cars, and the ratings and grades of cables employed for house wiring are usually adopted for this class of vehicle, although it is preferable for the cores to be made up of .012 in. copper strands to obtain the requisite flexibility.

**How Multi-core Cables are Made Up.**

Multi-core cables for connection between switchboard, distribution box and steering column switches are made up of rubber covered cores, of different colourings for easy identification, all taped together with cambric tape and then braided to within a few inches of the terminals. Intermediate connections to points between the switches and junction box are brought out through the braiding and either separately braided or enclosed in sistoflex. The ends of the braiding are bound round with cotton and the covering is then doped with water, oil and fire resisting varnish. The ends of cables

are made to suit the particular terminal to which they are to be attached. Tags should be used wherever possible to prevent the ends of the wires from fraying out and shorting on to other terminals.

**Earth Return Systems.**

On earth return systems, every unit of the electrical equipment must be effectively grounded. The flange or other mounting of the dynamo and starter should be free from paint or rust, and the two surfaces in contact quite clean. An earthing lead will be required from the battery to the chassis and the same precaution regarding contact is necessary at the chassis terminal end. This terminal should have a large area of contact surface where bolted to the frame and the cable lead must have as large a section as the starter cable. Inter-battery cables must also be of this section when the battery is split up into two units, and it is advisable to use rubber sleeving

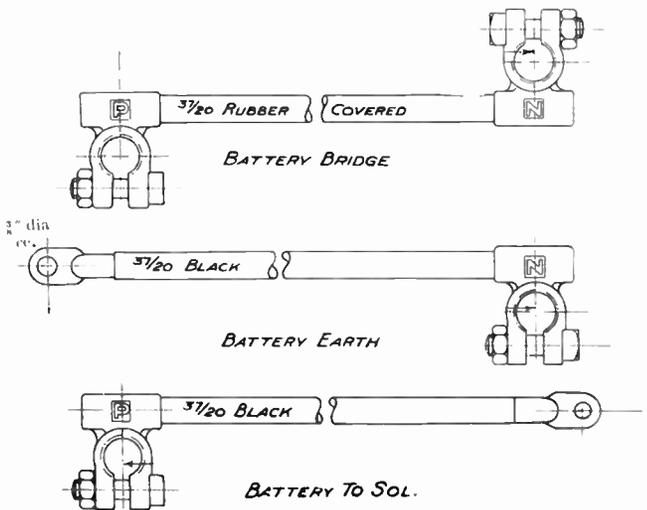


Fig. 6.— BATTERY AND STARTER CABLES.

on all cables attached to or adjacent to batteries, to protect the cables from damage by acid fumes.

### How to Fix Starter Cables.

Starter cables should be as short as possible and the weight of the cable taken by cleats so that there is no drag on the terminals. Cables taken through holes in the frame, scuttle, or body, should be protected by flexible metallic tubing, especially at sharp bends or between parts having relative movement. Rubber bushings should be used to prevent rattle at the points where the tubes go through the frame. Metal ferrules at the ends of the tubes prevent the edges from fraying the cable. Cable harness and cables should be cleated to the frame, the separate cleats being spaced so as to avoid relative movement between cables and frame. Exposed wires leading to head, side, tail, spot, fog, or other lights, should be enclosed in flexible metallic tubing.

Providing one end of this tubing is fixed to the body of the lamp and the other end to the chassis and makes good metallic contact, then single pole wiring to these points can be used satisfactorily, the metallic tubing acting as the earth return wire.



Fig. 8.—A TWO-WAY CONNECTING BLOCK.

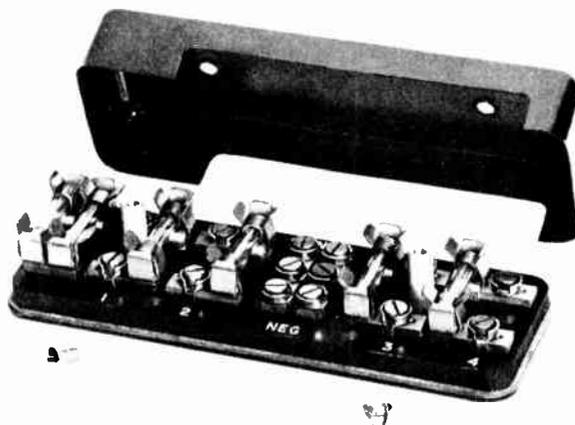


Fig. 7.—A TYPICAL FOUR-WAY FUSE BOX.

### Braided Cable for Exposed Lamp Connections.

Where braided cable is used for exposed lamp connections, a 3-point junction box at either side of the chassis for side and head lamp cables will make it possible to employ double pole wiring from the junction box to each lamp. This not only gets over the difficulty of obtaining a satisfactory earth connection from the wings and lamp brackets to the chassis, but also enables the lamp wires to be easily disconnected when the wings have to be taken off or should there be a break in the leads. Tail lamp connections can be easily made adaptable for either English or Continental conditions by the provision of a lamp bracket on the near side in addition to the usual one on the off side.

By using a small junction box at the rear end of the chassis, alternative leads to either bracket position can be wired up as required.

### Use of Fuses.

Mounting the cut-out directly on the dynamo will reduce the amount of cabling required and when a shunt field fuse is embodied in the cut-out housing a further reduction can be made. On earth return systems particularly it is advisable to fuse any circuit on which it is possible for extensive damage to occur through a short. As the whole of the chassis frame acts as one pole of the system, it is only

necessary for the insulation of any wire on the battery side to be pierced and permit contact between the cable and the frame, for the battery to be short circuited and cause extensive damage through overheating.

The introduction of fuses into these circuits will, of course, prevent damage, apart from blowing the fuses, should a cable become earthed. By using a well designed distribution and fuse box located

much more accurately calibrated than the odd pieces of wire which may be used to substitute plain wire fuses.

The fusing value of fuses used on car circuits is twice the normal current, that is, on a 5-ampere circuit the fuse should blow at 10 amperes. The fuse marking in this instance will be 10 amps., i.e. the fusing rating. The distribution box terminals are usually numbered, lettered, or coloured, to correspond to the various circuits and with

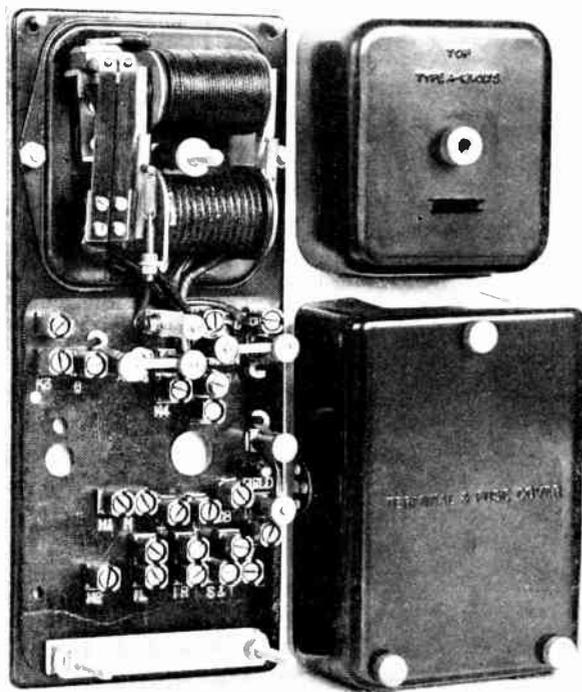


Fig. 9.—CUT-OUT AND JUNCTION BOARD WITH FUSES.

on the scuttle and conveniently placed relatively to the switchboard, steering column, and dynamo, the length of cables can be minimised, each circuit can be conveniently traced, and the location of faults on the system considerably simplified.

#### Type of Fuse to Use.

When spares are readily obtainable, the cartridge type of fuse is to be preferred as it is more easily detachable and is probably

the aid of a wiring diagram no difficulty should be experienced in making the correct connections. When any doubt arises regarding the disposition of any disconnected lead, the other end should be traced through, by means of the colour, or with the aid of a test lamp, and the connection made to the terminal having the like number, or letter, to the one at the fixed end.

#### Points to Remember When Wiring a Chassis.

When wiring a chassis it is essential to test each circuit for earths and continuity, to have each terminal connection clean and tight and to avoid cutting through the cable insulation with cleats or sharp bends. At points where adjacent terminal sockets are liable to be pulled into contact with each other, or with the frame, it is a good plan to provide rubber sleeving over the cable and socket, as close up to the terminal as possible, or to cleat the cables so as to prevent side movement of the sockets. Although the cables are flexible they are not elastic, and sufficient slack must be left at any part of the wiring where relative movement may occur between the points at which the cables are fixed. This should be particularly noted on cars where the wings are attached to the steering gear and not to the frame.

# REPAIRS TO DOMESTIC ELECTRICAL APPLIANCES

## HAVING MICA WOUND HEATING ELEMENTS

By BLYTH LAWRENCE

**F**ROM the standpoint of repairs electric kettles and similar appliances may be classified into three groups: (a) Those that are not worth repairing, owing to the excessive expense that would be incurred or to the nature of the damage; (b) those that can be satisfactorily renovated by retail electricians; and (c) those that can most economically be returned to the makers for repair. This grouping is obvious; the allotment of a particular kettle or appliance to its proper class according to the damage done is not always quite so simple.

### First Make Sure the Repair is Worth While.

In general the cheap continental makes of domestic appliances, such as are extensively sold in this country and brought home by holiday visitors to European countries, are not worth repairing at all. There are two main reasons for this. First, such appliances, being cheap, are usually light and flimsy. Consequently damage due to their boiling dry—a common source of trouble—generally results in the bottom or base

plate being distorted. When that is the case a really satisfactory and reliable repair job is very difficult to ensure. Secondly, spare heating elements for continentally made appliances generally have to be obtained from abroad. That means delay and expense, even if the maker's name and address can be traced, which is by no means always the case.

### Making a Special Element.

Alternatively, an element has to be made specially to fit the appliance. Mica sheets have to be obtained and cut to form. The size and length of resistance wire or ribbon

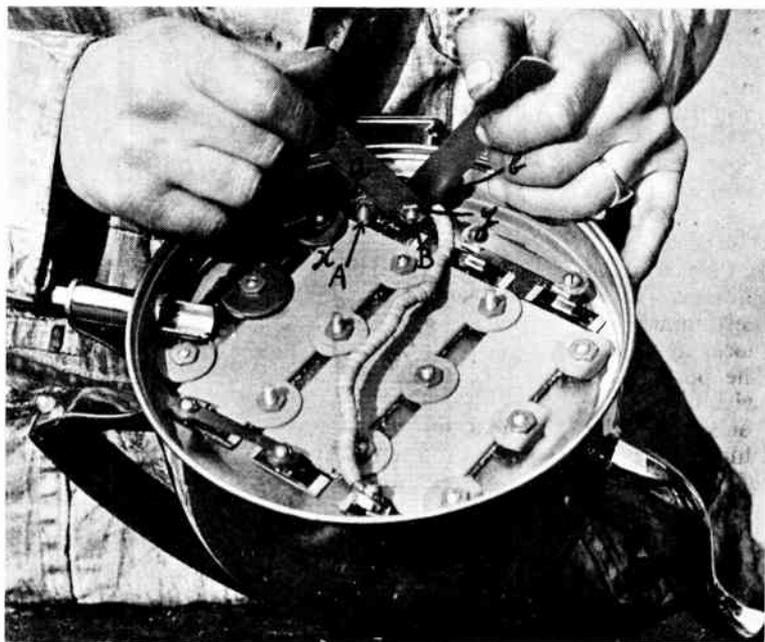


Fig. 1.—UNDERSIDE OF AN ELECTRIC KETTLE WITH BOTTOM COVER REMOVED. (Sunray Tricity.)

Showing method of loosening nuts holding the element tails in position.

must be carefully calculated to obtain the correct wattage at the voltage on which the appliance is to be used. Then the wire must be wound on the mica former in such a way as to secure uniform distribution, and end leads and mica cover sheets provided.

Making up single elements in this way is notoriously expensive. It may even be found that by the time the new element is made and fitted the aggregate repair cost—taking into account all legitimate charges such as materials and labour, overheads, and a reasonable profit—may equal or exceed the price paid for the appliance when new. At best the repair bill is likely to be out of all proportion to the value of the appliance. In such circumstances even a good repair job will leave the owner of the appliance annoyed and dissatisfied.

The advice—leave the repair of cheap continental makes of electric appliances severely alone (and some of the lower-priced British-made products may be included)—is supported by general experience. Some customers may be occasioned initial disappointment, but an estimate, and explanation thereof, will as a rule readily induce them to see the matter from the correct angle. In any case if they still insist on the repairs being executed no grounds then exist for subsequent complaint on the score of excessive cost.

### Likely Faults to Look For.

Casual examination of an appliance brought in for repair will generally determine straight away whether it is necessary to return it to the makers for the purpose or not; i.e., whether it falls within group (b) or (c) of the classification set out at the commencement. If anything more extensive than the replacement of a burnt-out element is required it will normally be a job for the makers. That is because more serious damage usually means that the appliance has been badly overheated, as the result of some misadventure such as current being left switched on when it is empty.

Probably the solder holding the clamping studs in place, and possibly the bottom plate of the appliance also, has melted and

run out, with the consequence of loose studs and leaks; the bottom plate may even have fallen right out. Furthermore, the body of the appliance will have become discoloured by the excessive heat and the lacquer finish burnt off in places. Damage of this nature can, of course, be put right by anyone skilled in the use of a soldering iron, polishing and lacquering, etc. But generally the manufacturers, with their greater facilities and experience, can handle repair jobs of this magnitude more effectively, and, what is just as important, more economically, even taking into account postage charges to and from the factory.

### See that the Bottom Plate is Flat.

And there is one other point to note. It is of the utmost importance that the appliance bottom against which the elements are clamped should be absolutely flat. Overheating to the extent indicated above is very likely to produce distortion, and if this is not removed before a new element is fitted a speedy burn-out is the probable result. An incidental advantage of sending the appliance back to the makers in such a case is that they will most probably regard it as more satisfactory, and cheaper, to fit a new bottom plate, rather than attempt to straighten out the damaged one, as would be done if the repair were handled locally. And that, as indicated, makes for reliability and satisfaction to all concerned.

### SIMPLE REPAIRS.

Having defined in some detail groups (a) and (c) of the classification, group (b) is arrived at by a process of elimination. It embraces appliances worth repairing but not sufficiently badly damaged to necessitate them being sent to the manufacturers. Many of the commonest troubles are associated with split terminal pins. These may have become pressed together by careless fixing and removal of the connector, resulting in loose contact; the pins may have been damaged mechanically; or they may be loose due to the fixing nuts having slacked back. Then the principal electrical faults include—the element wire being broken off close up to the terminal; breakdown of the insula-

tion—broken beads or faulty mica—resulting in the body of the appliance becoming “alive”; and the resistance wire burnt out. Repairs of any of the above groups of faults are comparatively simple and straightforward.

The work involves one or other or both of two operations. (1) Removal and refixing of the split pin terminals; and (2) Removal and replacement of the heating element. Both these operations need only care and common sense. The procedure is described below in detail, an ordinary type of electric kettle having been selected for the purpose of providing a concrete example. But, as will be made plain later, the instructions given are in principle applicable to practically any class of appliance having mica-wound clamped-on elements.

### Dismantling the Appliance.

Fig. 1 shows the underside of an electric kettle, the bottom cover plate having been removed. A and B are the split pin terminals. They are insulated from the side of the kettle by the mica washers shown and clamped in position by the nuts *a* and *b*. The nuts *x* *y* connect the element tails (or end connections) to the terminal pins; these tails are commonly bead insulated as shown. The first step in removing a terminal pin is to disconnect the element tails, for which purpose nuts *x* and *y* must be slacked back or removed. Do not attempt to do this with a pair of pliers, because the nuts may have become

tightly fixed owing to the heat to which they are exposed in use and if the pliers slip there is the probability of breaking the beads insulating the element tails.

### Loosening the Nuts.

For loosening nuts *x* and *y* a spanner of the correct size should be used. Another precaution that it is advisable to take is to hold nuts *a* and *b* with a second spanner



Fig. 2.—REPLACING A HEATING ELEMENT IN AN ELECTRIC KETTLE. (Sunray Tricity.)

Showing how a box spanner is used to unscrew the nuts holding clamping plate.

before applying pressure to *x* and *y*. If the second spanner is not used there is a possibility of the terminal pin screwing round in its seating, with resultant damage to the mica insulation washers. For the same reason when it comes to slacking back nuts *a* and *b*, the terminal pin should be firmly held in a pair of pliers to prevent rotation when pressure is applied to the spanner.

Again, care must be taken that the jaws of the pliers do not cut or other-

wise damage the pins, as that would lead subsequently to bad contact between the pins and the connector sockets. To protect the pins strips of lead, brass or similar soft metal should be inserted between the jaws of the pliers and the pin. Furthermore, if the pins are split they should not be gripped in such a way that the two halves are pressed together, but with the slit at right angles to the jaws of the pliers.

### **Don't Damage the Insulation Materials.**

The precautions cited above should, of course, be taken in exactly the same way when replacing a terminal pin and/or connecting up the element tails. The guiding principle is—avoid all risk of damaging the electrical insulation materials. And an obvious corollary is—do not lose any of the insulation beads off the element tails. A useful precaution in this connection is to twist a loop in the end of the tail as soon as the wire has been disconnected from the terminal pin, no beads can then drop off and be accidentally lost. Should, however, any beads be broken or lost they must be replaced by new ones before the tails are reconnected up. Do not on any account neglect that point.

With any section of the connecting tails bare of insulation there is always a possibility that the jolts and jars to which the kettle is subjected in everyday use may result in accidental contact to the body, thereby making the kettle "live," or of "shorts" between the tails, or from the bare tail to the adjacent terminal pin. If there is enough slack in the tail it is permissible to take up the bare length exposed by one or two broken beads when making off at the terminal pin. The guiding principle is that the tail must be to a degree flexible and must be insulated by beads throughout its length.

### **Replacing a Heating Element.**

The first step to replacing a damaged heating element is to disconnect the tails from the terminal pins as described above. The nuts holding the clamping plate in position must then be slacked back. For this operation the use of pliers should again be avoided; the proper tool to use is a box spanner (see Fig. 2). Do not un-

screw one nut completely, and then the next, and so on. All nuts should first be slacked back about a quarter turn, and they should be dealt with in such order that opposite points on the clamp plate are relieved of stress alternately.

This procedure avoids the risk of the element and its mica insulation being damaged during removal. That may not appear to be of much importance if the element is subsequently to be scrapped, but sometimes it may be feasible to repair it; and the right way is always the best way of doing any job. Having slacked back the nuts until the clamping plate is relieved of all pressure they can be removed from the studs and the plate lifted off. If the plate shows any tendency to stick, lever it up slightly at the four corners in succession until it is free. Similarly, if the mica encased element sticks, prise it off carefully and when lifting it away see that the mica does not catch in the threads of the studs and pieces flake off.

### **Precautions in Reassembling.**

The new element, or the old one repaired, should be fitted in position with meticulous care to avoid damaging the mica insulation. The clamping plate should then be fitted and one nut (near the centre) screwed up just sufficiently to hold it in position. The rest of the nuts should then be screwed down on to the clamp plate, but not sufficiently tightly as to apply pressure. Next, using a box spanner, tighten up the nuts by one half or quarter turn at a time, first those in the centre and then those on the outer edges in the reverse order to that in which they were removed. The "feel" of the spanner will indicate that the pressure applied to every nut is approximately uniform.

### **Tightening the Nuts.**

By following the procedure indicated the element will steadily be gripped more and more tightly between the kettle bottom and the clamping plate, and under uniform pressure over the whole area. That is the factor that is of vital importance to the subsequent life of the element. If, for instance, the nuts on one side of the

clamping plate were first tightened up to their full extent, then those on the opposite edge and in the centre, the resultant unequal pressure would "nip" the element at some points and leave it comparatively uncompressed at others.

### Connecting Up the Element Tails.

Thus, the expansion and contraction that takes place on alternate heating and cooling during normal use of the kettle would produce unequal movements of the parts of the element tightly and loosely clamped—a condition which quickly results in the element burning-out, or rupture of the insulation media. It is not too much to say that, apart from the quality of the materials used, the one factor on which the long life of mica-wound heating elements depends is the tightness and uniformity of the pressure by which they are clamped in position. The final operation in fitting a new kettle element is, of course, connecting up the element tails to the terminal pins—taking similar precautions to those described in respect of disconnection as discussed earlier on.

### A Note on Supply Voltages.

When a new element is to be fitted to a damaged appliance a point to watch is the supply voltage—not necessarily what it is at the moment but what it may be in a few weeks' or months' time. As is well known, all over the country to-day supply voltages are progressively being brought into line with the standard pressure authorised by the Electricity Commissioners, viz. 230 volts. In an area where the present voltage may be 210, 220, 240 or 250 volts but which may be standardised in the near future, it is better to fit an element which will be correct for 230 volts when it arrives. Of course, this suggestion should not be carried to an extreme. Running a 230-volt element on 250 volts represents rather a heavy strain, and if continued too long will lead to the element breaking down comparatively soon. The overloading might not have any markedly adverse effect over a period of, say, three months. But if the advent of standard pressure (230 volts) is much further ahead than that then an element appropriate to

the existing supply pressure should be fitted. A broader licence in time can be allowed where the variation from standard pressure is only, say, 10 volts, i.e., 220 or 240 volts.

### Variations in Design.

It is but natural that the detail construction of individual makes of electric kettles and similar domestic appliances differs widely. Not all, even, are equipped with mica wound clamped-on elements; heating elements may be of the immersion, sheathed wire, or other types, fitted actually inside the water space. Then, again, the methods of fitting clamping plates are diverse; porcelain bushes in place of mica washers may be used for insulating the terminal pins; bare strip or rod connections may be used between the element and the terminal pins in place of flexible bead insulated tails; and so on. But the foregoing notes have been compiled primarily to bring out the points in respect of repairs to kettles and similar appliances that should receive most attention. The detail instructions given may be applicable in only a proportion of the appliances that have to be dealt with, but the guiding principles are the same in every instance. Follow these and with common sense there is no reason why a good repair job should not be effected no matter in what respect the detail construction and arrangement of the elements may differ from those discussed.

### "Safety" and "Automatic" Kettles.

Nothing so far has been said about "safety" and "automatic" types of electric kettles. These are quite common nowadays and their distinctive feature is the incorporation of a protective device which functions automatically to cut off current if the kettle should accidentally boil dry, or if it should be plugged on to the supply current when empty. In general such devices are a great boon. But individual makers' designs differ fundamentally in operating principle, design and construction. Most require a rather delicate adjustment. When they go wrong it is perhaps best that the manufacturer handles the repair job.



these give a tougher moulding. High-temperature mouldings use ground mica, asbestos or a clay. Asbestos gives mechanical strength, as its fibrous character tends to knit the moulding together. Mica, on the other hand, is flaky even when finely powdered, and the resin does not adhere well to the particles, unless shellac or glyptal be used.

Colouring pigments or dyes are not essential electrically, but are put in generally for the sake of appearance. Earths, metallic oxides, etc., are used for colouring purposes, just as for oil paints.

### Types of Moulded Compositions.

*Shellac* is used as the binder in many mouldings of best quality. It will reproduce complicated shapes very faithfully, and has great durability. The most commonly known non-electrical shellac-base mouldings are gramophone records, the manufacture of which absorbs most of the world supply of shellac. A small acquaintance with the physics of sound will enable the reader to realise the wonderful accuracy of the minute irregularities on the record which permit the sound to be reproduced. If necessary, the same accuracy and durability can be attained for electrical ends. A moulding composition containing pure shellac as a binder is rather expensive. Where possible, the shellac is adulterated with copal or bitumen. A shellac-copal-wood flour and a shellac-bitumen-asbestos mixture are common. Shellac demands a hot moulding process for the same reason that micanite is moulded hot; shellac softens with heat. This fact prevents shellac being used for heat-resisting mouldings.

*Bitumen* with a drying oil and asbestos filler, moulded when cold, is commonly used for cheap mouldings, such as plugs for electric flat-irons. It resists heat and is fairly tough, but does not take a good finish. It is recognisable by its brown-black colour and slight tendency to fibrous crumbling.

*Rubber* as a binder has been known for nearly a century. The use of sulphur with a filler for vulcanization can actually be used as a moulding and hardening process. The fillers used with rubber are chiefly zinc oxide and French chalk, with certain

other ingredients to soften the "dough" and make it conform more closely to the sides of the mould. Litharge and lime are used to reduce the time of vulcanization. Although rubber mouldings do not attain a good surface directly, they can be easily machined and will take an excellent polish. Telephone receiver parts are commonly made from vulcanized rubber mouldings.

*Portland Cement* is a cheap and useful binder. Mixed with asbestos fibre and moulded into sheets, tubes, etc., it serves as an excellent material for arc and fuse shields. In many cases the tube enclosing the fuse wire in small fuse carriers is a cement-asbestos product. Its insulation value is low, but its resistance to damage by arcing renders it valuable for this purpose and for flash guards. Another use is for lining cast-iron switch cubicles.

*Synthetic Resins* are more reliable than natural products, for their manufacture and constituents are under complete control, whereas natural substances have to be taken as found. Mouldings of synthetic resin base are superior to most others in strength and especially in finish. They will take complicated shapes and can be produced to resist all the conditions likely to be encountered in electrical uses, with the exception of resistance to arcing.

Resins are usually supplied to the moulders by the manufacturers as moulding powders, ready mixed with the filler and pigment. A common composition is equal parts of bakelite "A" and wood flour.

Stainless steel moulds are used. These have to be very carefully designed to avoid sudden changes of section, sharp corners, holes, etc., avoiding, especially, the use of loose core pieces. With simple moulds the process becomes a quick one. The moulds are charged with powder and moulded under pressure at a temperature of 175° C. for a few minutes.

### Another Method of Moulding.

Another method is to press the powder into shape first by a cold pressing process, and then to transfer the block to the hot mould for the conversion of the resin to its final form.

When a synthetic resin is heated, it melts and liquefies. With rising tempera-

ture the liquid becomes sticky and viscous and finally hardens permanently. It can no longer be melted on account of chemical change in the material: it will now withstand high temperatures without damage. A great deal of ingenious chemical research has been prosecuted to obtain various qualities and characteristics, particularly that of rapid moulding. In modern processes the time is 45 seconds upwards to a few minutes.

#### **Mouldings Made From Bakelite.**

Mouldings of synthetic resins of the bakelite class have become so commonplace in all branches of engineering production that a summary of their admirable properties would not be out of place.

To begin with, they reproduce the surface of the mould with complete fidelity. Thus the high polish of the moulded surface as it comes straight from the mould is only limited by the finish of the mould itself. Steel moulds are capable of taking a mirror-like surface and the bakelite moulding acquires

the same high finish automatically.

All mouldings from the same mould are identical in size, finish and quality. Metal inserts (e.g., small screwed holes in brass parts) can be moulded in, and the moulding can be taken from the mould quite ready for use, except for removal of the "fin" left at the junction of the two halves of the mould.

#### **Screw-threads.**

Bakelite mouldings can be drilled, tapped and machined: but these processes can very often be done in the mould itself, for bakelite will take excellent screw-threads.

Mouldings can be manufactured to withstand large electrical stresses and high temperatures. For this purpose they may be stoved after moulding at 130° C. for 2 to 4 days.

Finally, bakelite mouldings are light, strong, non-hygroscopic, unaffected by immersion in water, uniform and homogeneous, and durable for an indefinitely long period.

## COMPOSITION OF PASTE FOR POSITIVE AND NEGATIVE PLATES OF A LEAD STORAGE BATTERY

#### **Positive Plates.**

The following ingredients are required:

4 parts by weight red lead ( $Pb_3O_4$ ).

1 part by weight litharge ( $PbO$ ).

1 part by weight sulphuric acid (1.12 specific gravity).

Add the acid gradually to the mixture of red lead and litharge, stirring well until a fairly stiff paste has been formed. Thorough mixing is essential, and care must be taken not to make the paste too thin.

#### **How to Apply.**

Place the grid on a flat board and use a scoop to place the paste in the grid. A wooden spreader should then be used to force the paste into the pockets of the grid. A piece of newspaper is then placed on top of the plate, and another flat board on top of that. This enables the plate to be turned over so that it can be pasted on the opposite side.

#### **Drying.**

Stack the plates carefully in a warm

room to dry. After three or four days dip the plates in sulphuric acid 1.25 specific gravity and redry.

#### **Paste for Negative Plates.**

Use the following ingredients:—

5 parts by weight litharge.

1 part by weight of 1.10 specific gravity sulphuric acid.

Mix, apply and dry as for positive plates.

For a high rate discharge cell the paste for the negative plates can be varied as below:—

Litharge 99.96 per cent.

1 amp black .03 per cent.

Wood flour .01 per cent.

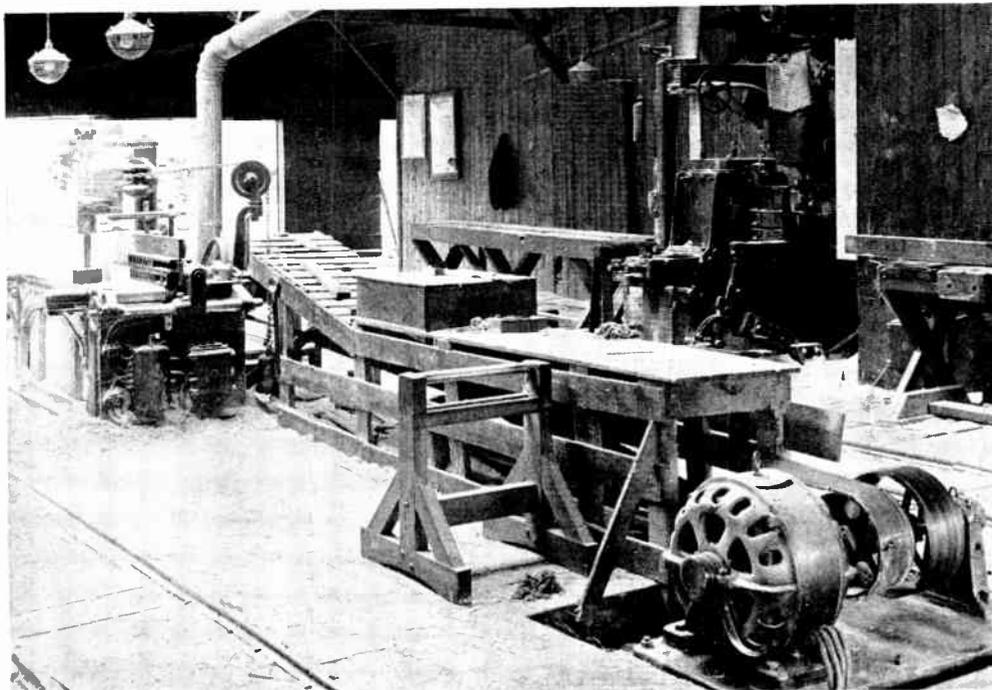
One-sixth of the total weight of the above of 1.10 specific gravity sulphuric acid.

#### **Forming the Plates.**

Use acid of 1.12 specific gravity, charge at the rate of about .02 amp. per square inch of the plate area, counting both sides of the plate.

# CARE AND MAINTENANCE OF ELECTRICAL MACHINES

By ROBERT RAWLINSON



*Fig. 1.—A MOTOR-DRIVEN CARPENTER'S SHOP.*

This is an out-of-date arrangement but is typical of many drives which still exist in small shops. It shows the conditions which the maintenance engineer must combat. Note particularly the dust. (*Metropolitan-Vickers.*)

**A**FTER an electric motor has been properly installed and set to work it requires very little attention to keep it in good working order. Given periodical cleansing and lubrication, together with an occasional inspection to ensure that all is correct, a motor of efficient design will work for many years without trouble, and the only vital point regarding the maintenance of electrical machinery is that every operation and adjustment should be carried out along

approved lines. This is essential, because of the fine clearances and delicate insulating material which it is necessary to use in the manufacture of efficient machines.

## **Cleanliness is Essential.**

Let us consider the steps which should be taken to maintain the driving motors of a factory in good working order.

To begin with we may say that cleanliness is one of the first essentials for trouble-free service and long life. Insulation failure

can nearly always be traced to the presence of moisture, oil, grease, dirt or dust, and the same injurious matter is also responsible for many mechanical troubles, as in the case of bearings to which grit has gained access.

### Remove Any Deposit of Dirt or Dust Immediately.

It follows, then, that any deposit of dirt or dust should be removed immediately and that every precaution should be taken to prevent water dripping on to a protected type motor from a leaky roof or from the condensation of steam or atmospheric moisture on a glass or iron roof; any oil leakage or grease which exudes from the bearings should also receive prompt attention.

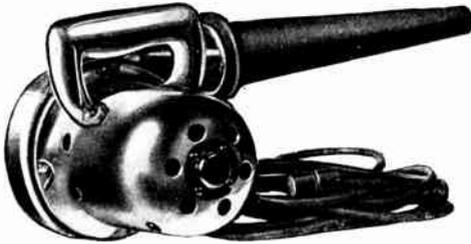


Fig. 2.—A PORTABLE BLOWER FOR MAINTENANCE WORK.

This little machine delivers a strong blast of air for blowing out motors and generators, and it is rapidly superseding brushes and bellows for routine maintenance work. When blowing out a machine with a compressed air hose, special care should be taken to see that any water which has condensed in the air piping is blown away before the blast is directed on to the motor; if this is not done the water deposited on the insulation may be sufficient to cause a breakdown. (*Martindale Electric Co., Ltd.*)

### Dismantle Periodically for Thorough Cleaning.

Every machine should be dismantled from time to time and thoroughly cleansed, and, although conditions vary, it will pay to do this every 12 months at least, while motors working under dusty and dirty conditions should receive more frequent attention.

### Time Between Dismantlings.

In any case, the time between dismantlings will have to be regulated by experience of the actual site conditions, but it may be taken as a fact that the

motor cannot be kept too clean and that the periodical cleansings cannot be carried out too often, within reason.

### An Example of Periodical Maintenance Procedure.

The present practice in this important matter, as applied to their power-station motors by most large electricity authorities, is as follows. Once a week the motors are freed of all loose dust and dirt, this being blown out by means of a compressed air hose, an electrically driven blower, or a pair of bellows; care is taken to direct the air stream so as to blow all dust out of the motor and not further into it, and at the same time any oil or grease leakage is removed.

### What the Weekly Procedure Does.

This weekly procedure serves to keep the machine in a reasonably clean state so that when the times comes for the annual dismantling and thorough cleaning, there is very little loose dust in the motor, that which remains being in the ventilating ducts and passages.

### Removing Loose Dust by Means of a Pipe Brush.

This may easily be removed by means of a pipe brush, together with compressed air, etc., as before, and all interstices between the windings may be thoroughly cleansed at the same time. The annual cleansing period is also taken advantage of for mechanical and electrical inspection, adjustment and repair.

### Precaution to Take when Using Compressed Air.

A word of warning regarding the use of compressed air hoses will be in order at this stage. *When blowing out a machine with a compressed air hose, special care should be taken to see that any water which has condensed in the air piping is blown away before the blast is directed on to the motor; if this is not done the water deposited on the insulation may be sufficient to cause a breakdown.* The air hose itself should supply air at not more than about 25 lb. per sq. in. pressure; any stronger blast will tend to blow the dust into, rather than off, the windings. A hose of about  $\frac{3}{4}$ -in. diameter is usually sufficient and a

flexible length of about 8 to 10 ft. attached to the end of the air piping will allow the operator to reach every part of the motor in the case of all except the very largest machines. When blowing out a motor, any other machines in the vicinity should be protected against the flying dust by means of sheets or other suitable shields.

### The Weekly Cleaning of Ventilated Motors.

The weekly blowing out of a ventilated motor is a perfectly straightforward job; it is only necessary to remove one or more of the covers which are screwed or hinged to the end brackets of the motor and access is gained to the end windings and ends of the core. The air blast should be directed on these portions and its use should be continued until no more flying dust is observed to be issuing from the motor and until all visible parts appear clean. If there is any leakage of oil or grease from the bearings, it should be carefully removed and if the motor is of the slip ring or D.C. type the brushgear should be inspected and cleansed in line with the instructions given later.

### Cleaning Totally Enclosed Motors.

A totally enclosed type motor need not be opened up every week for cleaning the windings since there will be little or no dust within the motor casing providing the covers fit reasonably well and the dust is not abnormally fine. The weekly cleansing should be confined to removing any deposit of dust or dirt which is adhering to the outside of the motor, and attention should be directed, as before, to any grease or oil which is leaking from the bearings. The brushgear should receive weekly cleaning, even when it is totally enclosed.

### Totally Enclosed Fan-cooled Motors.

This type of motor is becoming increasingly popular since it has definite advantages over the plain T.E.-type—due to its special form of ventilation—being smaller, cheaper and lighter; at the same time, all windings and vulnerable parts are completely enclosed from contact with dusty or fume-laden air, and in this respect it resembles a normal T.E. machine. In the latest designs of this

type of motor there are two ventilating fans and two flows of cooling air. One fan drives the external (or local) air through a series of cooling passages in the stator core, and this fan is usually situated at the driving end of the motor and picks up the air from that end, exhausting at the far end of the machine. Interlinked with this flow of cool local air, but entirely isolated from it, is a circulation of the air which is enclosed within the motor casing proper and a fan is fitted on the rotor shaft which drives this interior air through a circuit consisting of ducts in the rotor



Fig. 3.—BLOWING OUT A LARGE MACHINE.

The blower shown in Fig. 2 is here seen at work cleaning the brushgear and windings of a large machine. (*Martindale Electric Co., Ltd.*)

and a series of air passages between the back of the stator punchings and the outside casing of the machine. By these means, the heat dissipation of the motor is increased to a considerable extent and its output is, in consequence, much greater than that of a normal totally enclosed motor of the same dimensions.

### Cleaning T.E.F.C. Motors.

It will be clear from the above that

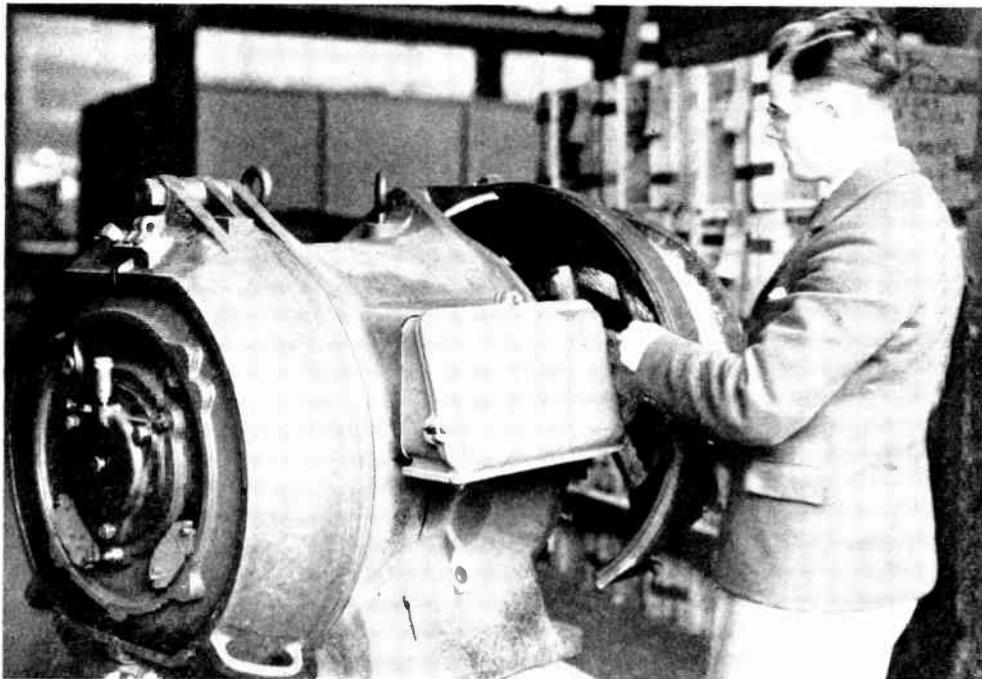


Fig. 4.—SWEEPING OUT A DUST EXTRACTOR END-SHIELD.

The majority of the dust which is suspended in the cooling air is trapped in the specially shaped endshield which is arranged to swing outwards for easy cleaning, as is shown here. (*Metropolitan-Vickers*)

so far as cleaning is concerned, the T.E.F.C. motor is intermediate between the ventilated types and the T.E. form, and it follows that the cleansing procedure should be adapted accordingly. The outer air circuit which carries the contaminated local air should be cleaned out each week and at the same time the brushgear should be looked to. The internal parts of the motor need not receive any greater attention than a normal T.E. machine; that is to say, an annual inspection will be quite sufficient providing other conditions, such as fineness of dust, have not a preponderating influence.

#### Opening up a T.E.F.C. Motor for Cleaning.

In the latest design of T.E.F.C. motor developed by the Metropolitan-Vickers Electrical Co., Ltd., special and novel arrangements are made to assist the maintenance engineer. The end guards are hinged so that they may be lifted and brushed out, and in addition to this the

guard at the fan end is so shaped that it forms an efficient dust extractor which serves to clean the local air of any suspended matter. The dust which is separated by this dust extractor action is deposited in a special groove in the fan guard, and to remove it, it is only necessary to sweep the groove with an ordinary hand brush. This feature serves to keep the outer air ducts clear of all except the very finest dust, which is too small to be affected by the extractor and which passes through the passages in the stator core where some of it is deposited. Since only a very small proportion of the dust passes the extractor and as only a portion of that which passes is deposited in the stator ducts, it is unnecessary to clean these more often than once a month, and easy access is gained to every stator duct by lifting up the hinged guards and working from both ends with an air hose, portable blower or brush. The method of cleaning these machines is clearly demonstrated in the photograph

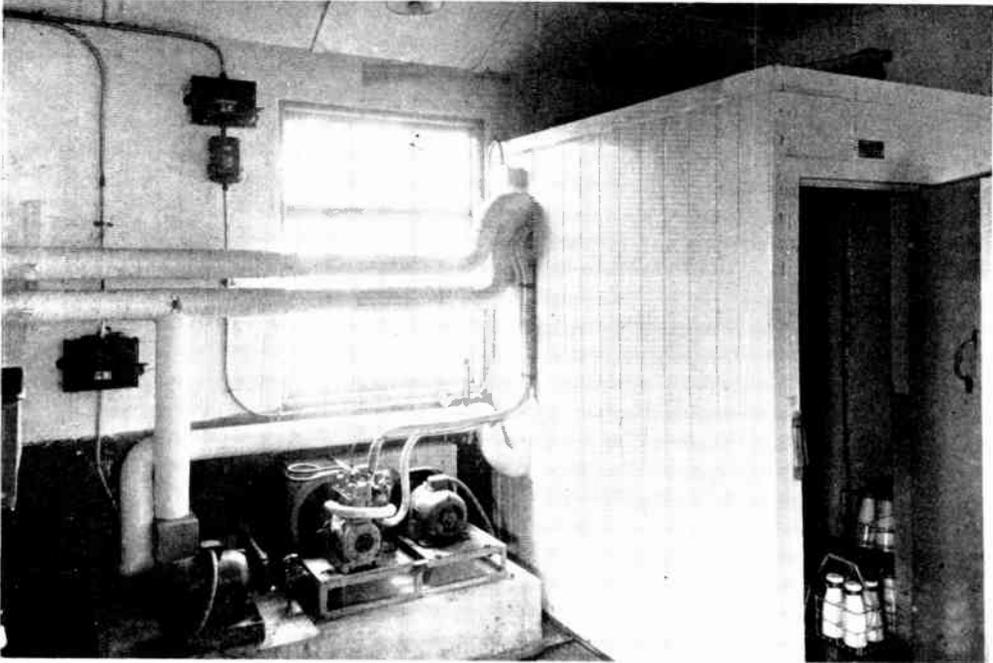


Fig. 5.—A REFRIGERATOR DRIVE IN A DAIRY.

When a drive of this type is under review special precautions should be taken against moisture and the motors should be specified to be specially gum-impregnated. This type of insulation is applied as standard to the motors shown. (*Metropolitan-Vickers.*)

### The Weekly Superficial Cleaning.

To summarise the foregoing notes, the following maintenance procedure should be applied to every ventilated type motor once a week.

(1) Remove all loose dust and dirt by means of an air hose, portable blower, bellows, or brush.

(2) Clean away any oil or grease which has exuded from the bearings.

(3) Inspect any brushgear, sliprings, or commutator, remove all dust and clean the contact surfaces if necessary, as described later under "Brushgear."

The above rules are also to be applied as regards cleaning to the dust extractor end shields of T.E.F.C. motors and to the entire outer air circuits of motors without extractors. All brushgears should receive weekly attention.

### Every Four Weeks.

The above rules should be applied consistently and at regular weekly intervals.

At every fourth inspection, however, the following points should be attended to in addition to the routine weekly items which have already been enumerated.

(4) Measure the insulation resistance by means of a "Megger" or similar instrument as described on page 717. This should not be lower than 75 per cent. of the value given in Table 1, page 718.

(5) Measure the radial air gaps by means of a feeler gauge as described later under "Check the Air Gap."

(6) Remove all dust from the stator outer air ducts of T.E.F.C. motors which are fitted with dust extractors.

### THE ANNUAL CLEANING.

Once every year the motor should be completely dismantled and every part should be thoroughly cleaned and inspected. There is nothing difficult or worthy of note regarding the actual dismantling procedure, except that when the ball and roller bearings are contained in

separate cartridges or housings (which is the latest and best practice), they should not be opened up or disturbed in any way. Cartridge type ball and roller bearings will be fully discussed when we consider lubrication, but when the bearings are not so protected it will, of course, be necessary to separate them from the end brackets when the motor is dismantled, and they should then receive annually the attention which is described to be applied every three years to cartridge enclosed bearings.

When the internal leads from the motor windings are removed from the terminals (if this is necessary) great care should be taken to mark each lead and its terminal with a distinctive mark so that when the motor is reassembled the lead may be returned to the terminal it originally occupied, so avoiding troublesome cross connections.

#### **No Excessive Force Necessary to Dismantle.**

All modern motors are made to an elaborate system of gauges and jigs and the correct fits are thereby obtained for all parts. It should be unnecessary to employ any large force during the dismantling and subsequent reassembly, and hammer blows should be dispensed with as much as possible. When it is necessary to use a hammer a suitable wood or soft metal driver must be employed to deaden the blows, and all driving should be directed with due regard to the comparative weakness of cast iron under shock loading and bending.

#### **Clean Every Part Thoroughly.**

When the motor is completely dismantled each part should be carefully cleaned of all dirt, oil or grease. Petrol may be used to remove hardened grease and its use on windings is quite permissible, providing it is quickly and thinly applied so that it cannot soak in and damage the insulation.

All air ducts in both stator and rotor should be carefully cleaned out, and the exposed portions of windings and slot openings must receive the same attention. Radial or interlaminar ducts should have special cleaning since they are very liable to choking, and after the cleaning process has been completed every particle of dirt

should have been removed from each component of the motor.

#### **Inspect Every Part.**

When each part is thoroughly cleansed a careful inspection should be made to ensure that there are no signs of excessive wear or damage; the bearings, if of the sleeve type, should be examined for signs of scoring and all cast parts should be inspected for cracks or signs of damage. Ball and roller bearings and brushgear should be inspected as described later; every part should be kept in good order; if any damage is found steps should be taken to repair same and to rectify the fault which causes it.

#### **Re-enamel the Windings.**

If it is found that each part appears undamaged and if the insulation resistance of the cleaned stator is not less than given in Table I, page 718, a coating of good quality insulating varnish or enamel should be applied to the end windings and all exposed insulation. This varnish must be bought specially for the purpose and should be ordered as "black brushing air drying insulating varnish," "glossy insulating air drying enamel," "anti-acid insulating varnish, air drying," or "anti-sulphuric enamel." Ordinary varnish or black enamel is quite unsuitable and will damage the insulation. When varnish is required for this purpose it should be bought from a reputable varnish manufacturer and the orderer should state the purpose for which the material is required. It will be found that shiny enamel or varnish does not allow dust to adhere and it assists, therefore, in the weekly blowing out; for this reason all internal parts, except the stator bore and outside surface of the rotor laminations, should receive a fresh coat of enamel once a year.

#### **When the Insulation is Low.**

When the stator and all its connections, terminal boards, end windings and other parts have been thoroughly cleansed the insulation resistance should be not less than is given in Table I, page 718, and if it is found that the appropriate minimum figure is not obtained the stator must be dried out as is described for complete

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