

→ SEE SPECIAL ANNOUNCEMENT INSIDE FRONT COVER

# NEWNES PRACTICAL ELECTRICAL ENGINEERING

PRACTICAL ELECTRICAL ENGINEERING

IN THIS PART

CARE AND  
MAINTENANCE OF  
ELECTRICAL  
MACHINES

ELECTRIC  
CIRCUIT  
CALCULATIONS

LOW VOLTAGE  
LAMPS

TELEGRAPH  
SYSTEMS

1/-

PART  
29

A PRACTICAL WORK WRITTEN BY EXPERTS

## IMPORTANT EDITORIAL ANNOUNCEMENT

**D**URING the progress of this Work the Editor has received many requests from readers for information on various subjects not included within the original scope of the work. Here are a few typical questions:—

“What are the practical methods used for recording sound electrically?”

“How is the frequency of an electricity supply synchronised so that electric clocks can be run from the supply mains?”

“Why is power factor correction apparatus necessary?”

“How can I qualify for membership of the Institution of Electrical Engineers?”

“I have a small electrical contracting business. Is there any trade association which I can join?”

“I want to design a large amplifier for a concert hall. Can you give me practical details?”

“Can you tell me if there are any Board of Trade Regulations governing the use of electrical machinery in a spinning mill?”

“Will you please supply tables and data which will enable me to design transformers of different outputs, say, from 10 volt-amperes to 1,000 volt-amperes?”

“I should be very interested if you could publish any basic rules governing the design of dynamos and motors.”

In view of the numerous requests received and the variety of subjects suggested for treatment, the Editor feels that he will be meeting the general wishes of readers in expanding the Work to incorporate most of these subjects. He has, therefore, decided to complete the Work in 40 parts, which will permit him to deal with the wide variety of new subjects suggested, thus enhancing the usefulness of the complete Work.

Further particulars will be published in next week's issue.

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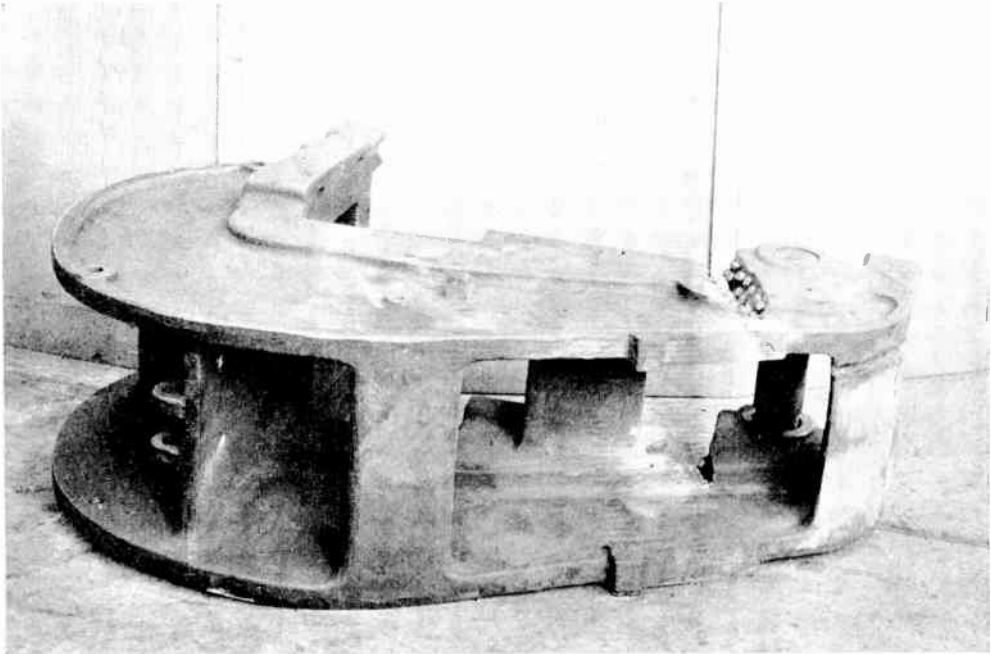


Fig. 6.—A BROKEN MACHINE FRAME.

This part is broken, as may be seen, and it is shown prepared for repairing by welding. (*Metropolitan-Vickers.*)

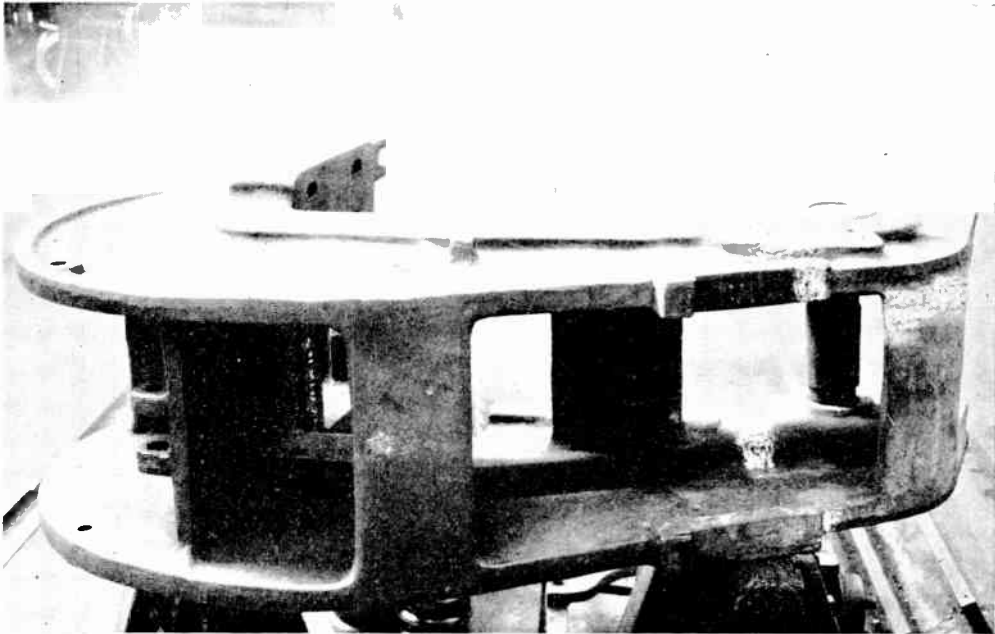


Fig. 7.—THE MACHINE FRAME REPAIRED BY ARC WELDING.

The frame shown in Fig. 6 is here seen completely repaired by arc welding. These two illustrations show the saving which may be effected in maintenance by the salvage of damaged parts by arc welding. (*Metropolitan-Vickers.*)

A

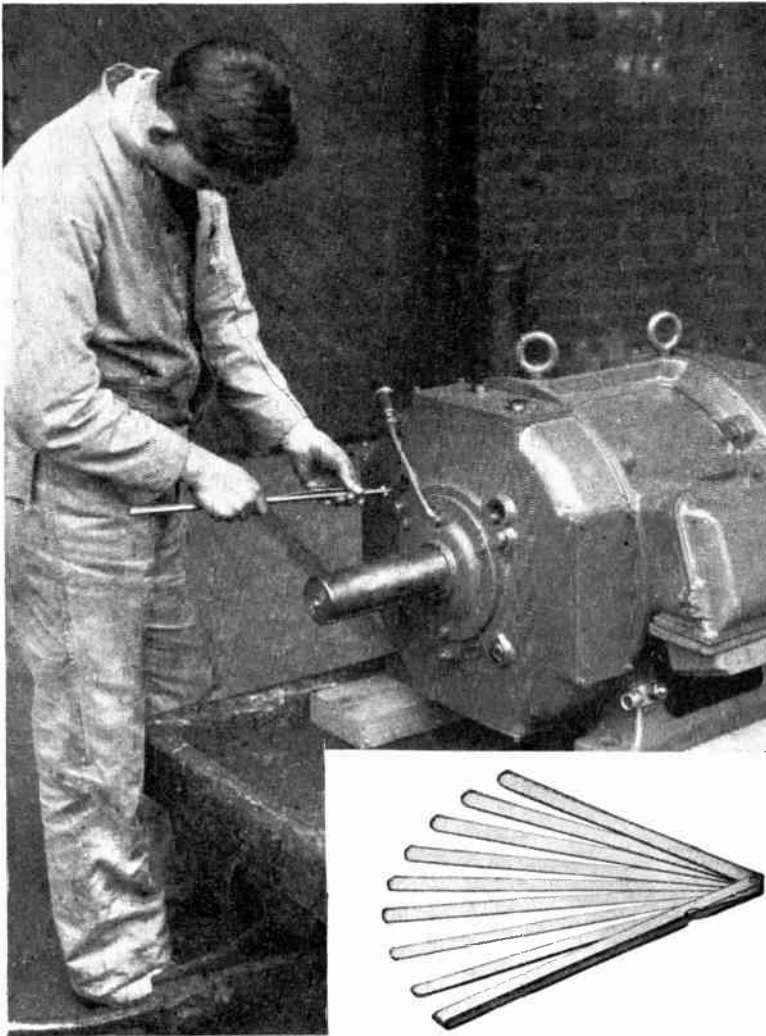


Fig. 8.—MEASURING THE AIR GAP OF AN INDUCTION MOTOR.

This operation is an essential part of the maintenance procedure and must always follow reassembly. The operator is shown using a long feeler gauge which is inserted through the specially provided plugged apertures in the motor end bracket. Two of the gapping plugs are shown removed. (*Metropolitan-Vickers.*) Inset, a specially long and narrow type of feeler gauge which is suitable for measuring fine air gaps. (*Martindale Electric Co., Ltd.*)

motors on pages 717 and 718. Since it is probable that the rotor insulation will be similarly lowered due to moisture, it is good practice to dry out both stator and rotor together and this should be done in every case where the stator resistance is found to be low; the insulation being undamaged, dry and clean when the

"Megger" reading is taken. After drying out as directed in the above-mentioned article, the parts should be varnished or enameled before being put into service.

#### When Any Part Shows Damage.

If, upon inspection, any mechanical damage or excessive wear is noticed, steps should be taken immediately to have the part repaired or to obtain a new one. The various types of mechanical damage and the degrees of same are so diverse that no ruling can be given here as to what is better replaced and what better repaired, but it can be said that many parts which a few years ago would have to be scrapped are now given a new lease of life by means of welding. This process can be applied with equal success to cracked castings

and to worn shafts and it will pay to consider its use before deciding to scrap a part.

#### When the Insulation is Damaged.

It will sometimes be found that the insulation on one or other of the motor windings has been damaged, and sometimes

slight damage is done accidentally during dismantling; in certain cases also a terminal base or bar, or some detail of the brushgear, may have suffered damage to its insulation. When the part is a composition moulding, a simple tube or a strip of insulating material, it is best to fit an entirely new insulation rather than attempt a repair, but in those cases where damage has been done to end winding or coil insulation a quite satisfactory repair can often be effected by carefully lifting the damaged wires and applying fresh insulation. This new insulation should be of the same material and not

### The Question of Repairs.

It should always be borne in mind that a machine repaired by the maker is, to all intents and purposes, equal to a new motor, and it will certainly pay to have a complete rewind in preference to a series of breakdowns and patchings up with consequent loss of operating time. Repairers other than the original motor manufacturer should not, in general, be relied upon, although there are a *few* very excellent and capable repair firms. In any case, the jobbing repairer is to be avoided if at all possible.

### When Ordering Replacement Parts.

When it is decided that a part cannot be satisfactorily repaired a new one must be ordered from the manufacturers and when doing this, care should be taken to quote *in full* all the particulars given on the motor name-plate. If this is done and a clear description given of the part which is required, there will be little difficulty or delay in the despatch of the replacement, providing, of course, that the motor is of a standard type. If the name-plate details

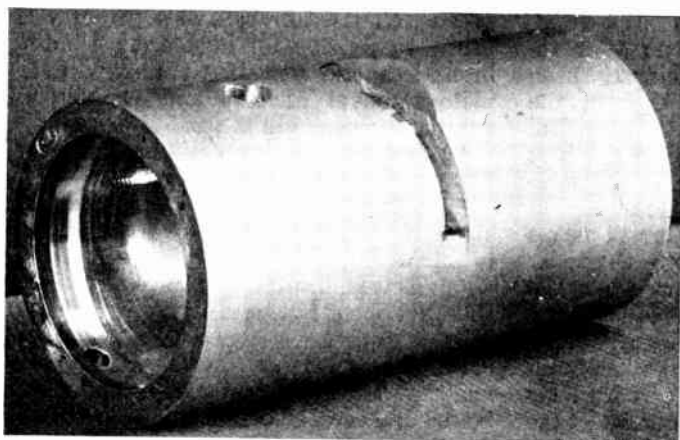


Fig. 9.—THE PHOSPHOR BRONZE BEARING OF A SMALL MOTOR.

This solid bearing bush shows the oilring groove and lubricating passages. When a detail of this type is excessively worn, it must be replaced since it cannot be relined. (Metropolitan-Vickers.)

less than the same number of layers as the original damaged insulation; it should be carefully applied, due care being directed to keeping each layer (of tape, for instance) tight, and when the repair is completed the new insulation must be liberally soaked with the insulating varnish previously mentioned and the whole repaired part dried out until the varnish is hard. The insulation resistance must then be measured, and if it is up to the specified figure the part may go into service again. If the insulation is still low, an inspection for further damage should be made, and if necessary the machine should be rewound by its maker.

are not given the manufacturer will nearly always write asking for them and this may mean a delay of at least three days.

### Reassembling.

After all the parts have been cleaned, and when it is ascertained that they are all in good order and repair, reassembly can proceed. As in the dismantling stage, excessive force and hammer blows are to be avoided and a suitable driver should always be employed when a hammer is used; no difficulty should be experienced in the purely mechanical refitting together of all the parts and when this has been accomplished all internal leads and cables should be replaced on the terminals which

they originally occupied. Great care should be taken regarding this, otherwise there will be trouble when the restarting stage is reached.

### Test the Insulation Again.

When the motor is reassembled, the insulation should be tested again and it should not be less than 75 per cent. of the Table I values previously mentioned. This figure will be easily attained providing the foregoing notes have been followed, and when it has been ascertained that this is so, we may now check the air gap.

### How to Check the Air Gap.

This should always be done after re-assembly, and, as has previously been mentioned, it should form part of the routine monthly maintenance. A special narrow and long feeler gauge is the best tool to employ in making this measurement and the plugged apertures which are provided in the end brackets of most makes of motor should be used to give the feeler access to the gap. If it is found that the length of air gap at one point is less than three-quarters of that diametrically opposite, the machine should be inspected for lack of alignment in the end brackets or bearing housings. The inequality of the air gaps may also be due to the bracket fixing screws being loose, or the bearings may be worn. Steps must be taken to correct the discrepancy and eliminate its cause, and the motor should not be set to work until the minimum air-gap length is not less than 90 per cent. of the value of the maximum. If this is neglected, rubbing between stator and rotor may occur and this will cause extensive damage.

### Putting Back to Work.

Having attended to all of the above points, we may now place the motor back in work with every confidence that it will perform satisfactorily. Before starting up, make sure that the drive is running freely and is in good alignment, that the connections are correct, and that all brushes are in contact with and well bedded on to their commutator or slip-rings. The reader is referred to "Install-

tion and Erection," page 715, for full details of the precautions which should be taken when starting up a motor for the first time; these precautions also apply after the annual maintenance inspection.

### Summary of Annual Maintenance Procedure.

The rules given above for the annual maintenance inspection may now be briefly summarised as follows:—

- (1) Dismantle without using excessive force and without hammer blows, if possible; do not open up bearing housings.
- (2) Clean every part, removing all dust, oil, grease and dirt; use blower, compressed air blast or bellows together with brush to remove all dust from winding interstices and ventilating ducts. Complete removal of dirt and clearing of ventilating passages is *most essential*.
- (3) Inspect all parts for damage or wear, and repair or replace as necessary.
- (4) Measure insulation resistance and stove, if necessary, until correct insulation is obtained.
- (5) Repair insulation if necessary and thoroughly varnish and dry any repaired coils.
- (6) Re-enamel or revarnish all end-windings and internal parts except stator bore, and rotor outside iron surface; dry thoroughly.
- (7) Reassemble without using excessive force or hammer blows; ensure that machine leads are on correct terminals and that everything is well tightened up.
- (8) Retest the insulation.
- (9) Check the air gap.
- (10) Check all connections, etc., and apply the same rules as for the initial starting. If all is correct put the motor back to work.

### Control Gear.

We have now dealt with most of the problems which will arise in connection with the cleansing of the motor and its routine maintenance, and it only remains to refer to those details which require special attention, such as brushgear and bearings. Before we leave the question of the routine maintenance, however, it should be stated that any control gear should be inspected and maintained at the

same time as the motor receives attention. All contacts and connections must be kept clean and tight and the gear must be kept free from dust and dirt. Trip gear should be operated once a week to ensure that it remains free; arcing at contacts must be reduced to the absolute minimum and the oil in all immersed gear should be filtered, centrifuged, or entirely replaced from time to time depending upon the amount of operation and service which the

are not so commonly employed nowadays, and, except for certain drives under peculiar conditions, ball and roller bearings hold the field so far as industrial motors and generators are concerned; we must, however, consider both types and the older variety will be dealt with first.

### Types of Sleeve Bearing.

Sleeve bearings consist of a bush made of some type of anti-friction metal which is accurately fitted to the shaft and which is lubricated to prevent over-heating and seizure. In the smaller types of bearing the bearing bush is usually made of brass or phosphor bronze, and die-cast white metal is sometimes employed; these forms are usual in motors up to about 20 h.p. output; above this figure a cast-iron shell lined with white metal or babbitt is employed, and when the shaft diameter is over about 3 to 4 in. the bearings are usually split across a horizontal diameter into upper and lower halves. Whichever construction is adopted the aim of the maintenance engineer is to keep the bearing well lubricated and as free from friction as possible.

### Lubrication.

The most usual method of lubrication for sleeve bearings on electric motors is by rings running on the shaft and dipping into a well of oil; rotation of the motor shaft causes the rings to revolve and to pick up a certain quantity of oil and convey same to the shaft and bearing bush. The maintenance of this type of bearing consists in keeping the oil well replenished with fresh clean lubricant and ensuring that the

gear is called upon to perform. The control gear makers should be consulted for definite details.

### BEARINGS AND LUBRICATION.

There are two types of bearing which we must consider, viz., sleeve bearings and the ball and roller type. Sleeve bearings

rings revolve and convey sufficient oil to the bearings. The lubricant used should be of good quality and most of the large oil refiners list a grade of "dynamo oil" which will be suitable, although a somewhat heavier oil than this grade may be necessary when the local temperature is high.

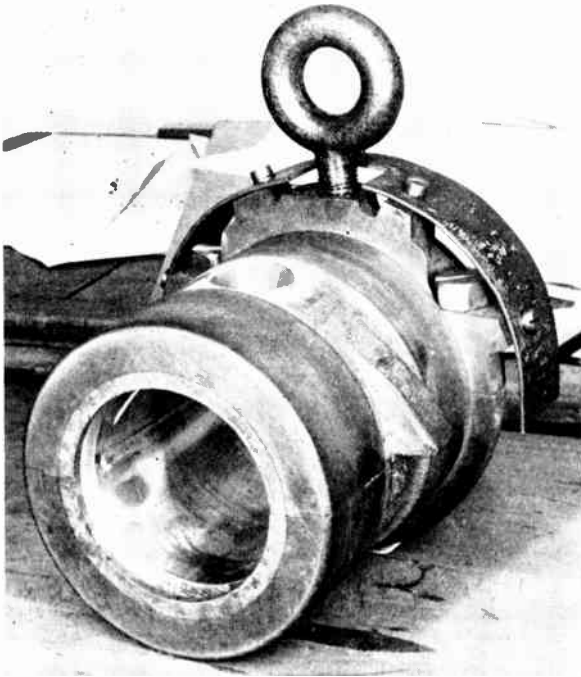


Fig. 10.—A WHITE METAL LINED BEARING.

This bearing is of the split type lined with babbitt metal and is suitable for relining. It is intended for a heavy duty mill motor and is split in halves across a horizontal diameter. The two halves are held together by the screws underneath the oil guard and an eye-bolt is provided for lifting the armature out of the split frame. (Metropolitan-Vickers.)

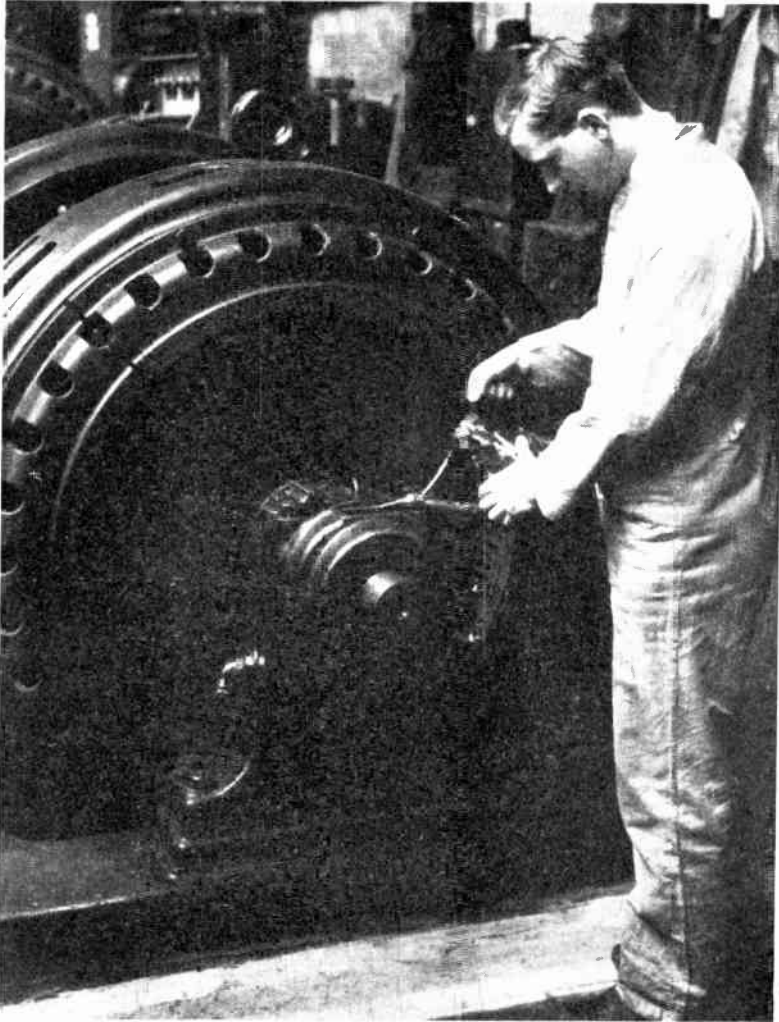


Fig. 11.—FILLING A BEARING OIL WELL.

Note the drain pipe on the left and the oil gauge on the right of the pedestal bearing. The oil well should be filled to the level as shown on the gauge or by the overflow. (Metropolitan-Vickers.)

### Beware of Grit.

It is essential that the bearings and oil wells be kept clean and free from dirt and grit, and special care should be taken that the oil is quite clean and free from any suspended matter. The oil wells should be filled to the correct level as shown by the oil gauge or overflow; an excess of lubricant will creep along the shaft and may be thrown on to the windings or brushgear.

This should be avoided since it may cause a bad breakdown.

### Clean the Bearings Annually.

At the time of the annual overhaul the bearing shells and oil wells should be cleaned out, being swilled with petrol to remove all old oil, and fresh oil should be supplied; the rings should be inspected to ensure that they are running freely and that they are picking up plenty of oil. The surface of the shaft and the bore of the bearing shell should show no signs of rubbing or scoring but should be highly polished and smooth.

### Another Method of Lubrication.

Some small motors are fitted with "oil and waste" lubricated bearings, and in this case,

as the name implies, oil soaked textile waste is used to effect the lubrication. Motors having this form of lubrication will be supplied with the bearing housings already packed with waste, but it is good practice to replace the waste every three years and for this purpose a good quality *woollen* waste should be used; this should be packed closely round the bearing bush and into the grooves in



same through which the shaft is visible. Poor quality wool waste or cotton waste soon becomes "soggy" and settles down away from contact with the shaft, giving rise to lack of lubrication and bearing trouble. Before packing the housing the waste should be soaked thoroughly with oil, and immersion for about 48 hours in "dynamo oil" will give satisfactory saturation. The surplus oil should be allowed to drain from the waste for about 12 hours before the bearing is packed.

### Maintenance of Waste and Oil Lubricated Bearings.

The bearing should be inspected each month to ensure that the waste is carrying sufficient oil to give satisfactory lubrication, and if it appears rather dry a small quantity of oil should be poured on to same at the points where it makes contact with the shaft. It is only necessary to add a little oil—just sufficient to saturate the waste which is in direct contact with the shaft—and care should be taken not to flood the bearing. Every year this type of bearing should be inspected for scoring

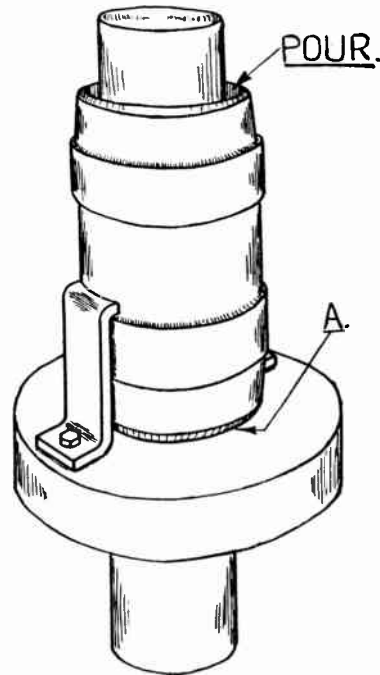


Fig. 12.—A SOLID BEARING SHELL AND ITS MANDREL.

The bearing shell should be mounted with, and clamped to, the mandrel as shown, and the corner A between the bottom of the shell and the collar should be sealed with clay to prevent the escape of the molten babbitt. The metal should be poured into the space indicated until it stands above the top of the shell.

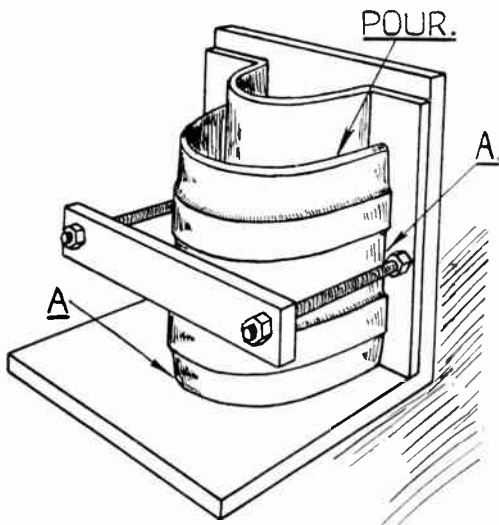


Fig. 13.—A SPLIT BEARING HALF SHELL SET UP FOR RELINING.

The clamps, angle plate and sheet iron mandrel are here shown. Clay sealing should be applied to corners A and the molten babbitt should be poured between shell and mandrel as indicated.

or wear, as has been described above for ring-lubricated bearings.

### When the Bearing is Worn.

If it is found, at the annual inspection, that:—

(A) The bearings and shaft are rough or scored;

(B) There appears to be excessive "play," "lift," or clearance between the shaft and bush;

(c) The air gaps cannot be made equal, although all parts are tight and truly in place;

then the bearings require relining or replacing. On small sized motors with phosphor bronze, brass or die cast white metal bushes the complete bearing should be replaced and new bushes should be obtained from the manufacturer for that

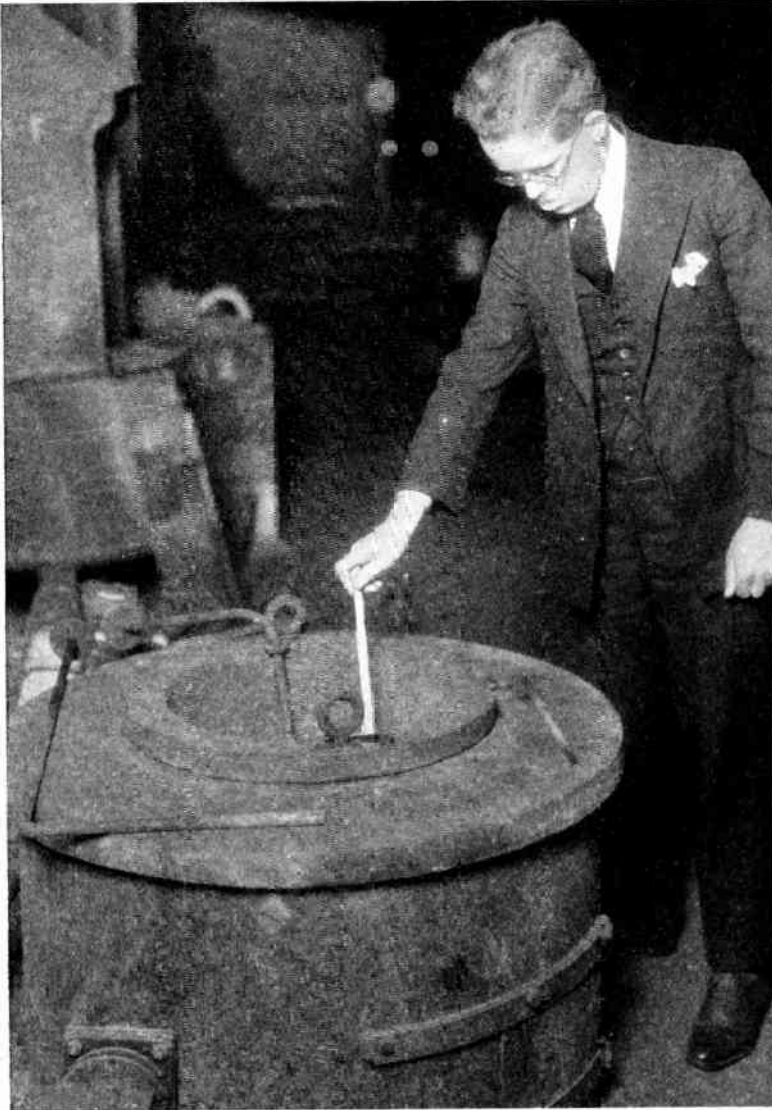


Fig. 14.—TESTING THE TEMPERATURE OF MOLTEN BABBITT.

The operator is shown gauging the temperature by the wood strip method. Note the used strip of wood on the right-hand side of the melting pot and the pyrometer head on the left. (Metropolitan-Vickers.)

purpose. When the shaft is scored it will be necessary to true it up and to give it a smooth surface with a high polish; this may be done in a lathe, due care being taken to keep the shaft bearing parallel and free from ridges, and when the truing up has been completed the shaft diameter

at the place where the bearing bush fits should be measured by means of a micrometer, the dimension obtained being passed forward to the maker of the replace bearing bushes so that details having the correct dimension for a good bearing fit may be supplied.

#### Large Bearings.

When the bearing bushes consist of cast-iron shells lined with babbitt, re-metalling should only be attempted when proper equipment and an experienced fitter is available. When this is not so the bearing bushes should be returned to the motor maker for relining, although in certain cases where return is impossible local repair firms or general engineers can be relied upon to make a good job. The firm must, however, be chosen with dis-

crimination. In those cases where it is decided to reline the bearings on site the following notes should be observed.

#### Rebabbitting the Bearings.

The old white metal must first of all be melted out of the bearing shells and the

tinuing of the insides of the shells should then be inspected to ensure that it is clean and adhering properly. While the shell is still hot (after the old babbitt has run out), the tinning should be swabbed with a rag dipped in flux and if it is found that any portions of the interior of the shell are bare where they should be tinned, special care must be taken to complete the coating of solder (or tin), since, without this, the lining of bearing metal cannot adhere and trouble due to a loose lining will result.

#### **The Correct Flux and Tinning Alloy.**

In those cases where the tinning has to be attended to a good quality "Tinman's Solder" of at least 50 per cent. tin content must be employed, and it will be found that this alloy will give satisfactory results providing the shell is kept at a good soldering temperature and the correct flux is used. A suitable flux may be made by dissolving zinc shavings in hydrochloric acid, or "spirits of salts," until all bubbling ceases. The mixture should then be strained to remove all small pieces of zinc and the resulting zinc chloride, or



*Fig. 15.—POURING A HALF BEARING.*

The lining of a half bearing is being poured here. Note the clay around the feeding holes and the specially spouted ladle. The type of mandrel is an alternative to that shown in Fig. 13 and is suitable for shop production. (*Metropolitan-Vickers.*)

"killed spirits," will be found to give very good fluxing. In certain cases, powdered sal-ammoniac will be found advantageous, especially when the bearing shell is oily and stubborn in tinning. It may be said that the fluxes mentioned will cover nearly every case although proprietary fluxes will give equally satisfactory results providing they are not greasy.

### Ring the Shell.

After all superfluous tin has been wiped off the shell faces, leaving a smooth bright silvery coating, and when the shell is cold, it should be suspended in the air by means of a piece of string or wire and when it is so suspended it should be struck sharply on the outside with a mallet or hammer to ascertain if it "rings true." The ring of a bearing is the only indication of whether or no the babbit lining is adhering properly, and unless the bearing rings properly before it is lined with babbit it is clear that it cannot do so afterwards. Providing the shell rings true, we can proceed ;

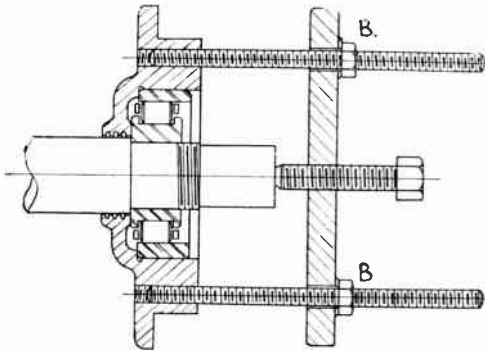


Fig. 16.—Using the Housing as Part of the Withdrawal Gear.

Note that the bearing nut has been removed. The bearing will come away easily if nuts B-B are tightened *equally*, but it will bind and the housing may break if the nuts are not tightened to the same extent.

otherwise an inspection for cracks or flaws should be made, and if any are found a new shell should be employed, the faulty one being scrapped since it is dangerous.

### The Mandrel.

Having now obtained a perfectly tinned and true-ringing shell, which, by the way, should be quite clean and free from oil, we must consider the provision of a suitable mandrel, and this may be made of steel or iron rod or tubing, or sheet iron, depending upon the dimensions of the bearing and whether it is a solid bush or of the split type. For one-piece bearings up to about 4 in. shaft diameter a mild steel bar or tube is usually used, turned and polished on the outside surface and tapered

about  $\frac{1}{8}$ -in. in diameter per foot of length.

A mandrel of this type must be securely clamped on end to a faceplate, or a large collar may be placed over the lower end to form a base for the metal lining. The mandrel for the half shells of a split bearing may consist of a cylinder of suitable diameter, split in half along its axis, the half cylinder being clamped to a plate which will form shoulders on which the sides (splitting surfaces) of the bearing shell may rest. The half cylinder may be solid but it is more usually made from sheet iron or boiler plate bent to the correct shape.

It should be clamped to the inside surface of a right-angled bracket as shown in the sketch and the base of the bracket will then serve as a casting surface for the lower end of the bearing. The dimensions of mandrels of both types should be about  $\frac{1}{4}$  in. less in diameter than the shaft for which the bearing is being relined and the mandrel must project about 2 in. above the top of the bearing shell ; suitable clamps must be provided so that the bearing shell may be rigidly secured and held during both pouring and cooling.

### Preparing to Pour.

Having tinned the shell and ascertained that same is ringing true, and having made a suitable mandrel, together with its clamps and casting faces, we must now prepare the bearing shell. All oil ring grooves and oil relief or supply holes should be plugged with dry, well seasoned, white wood, and the shell should then be clamped in place on the mandrel support, the mandrel having previously been given a light coating of clay wash or whitening suspended in water. Care should be taken that the space between the inside surface of the shell and the outside of the mandrel is equal all round and at both ends. Having ascertained that this is so and that all the clamps are tight, steps should be taken to ensure that no white metal can escape when it is poured into the space between the shell and the mandrel, and to this end all joints between the bottom of the shell and the faceplate or collar, and up the sides in the case of half shells, should be sealed with clay or putty ;

asbestos string is sometimes used for this sealing and it will prove quite satisfactory if kept damp and held securely in place.

### Heat the Shell and Mandrel.

The shell and mandrel, assembled as one unit, may now be evenly heated by means of a blow lamp directed on to the back of the shell and inside the mandrel if this is tubular. The heating should be evenly applied and carefully controlled so that no part becomes overheated while another remains comparatively cold, and it is best, if possible, to use at least two blow lamps (and more on large jobs) and to so move them about as to keep the heating uniform all over the complete job. This heating should be carried out while the babbitt metal is melting and it should be so controlled that when the babbitt is ready to pour, the shell and mandrel are both evenly heated to the correct temperature. This is about  $130^{\circ}$  C. ( $265^{\circ}$  F.) and it should be measured by pyrometer or thermometer if either of these instru-

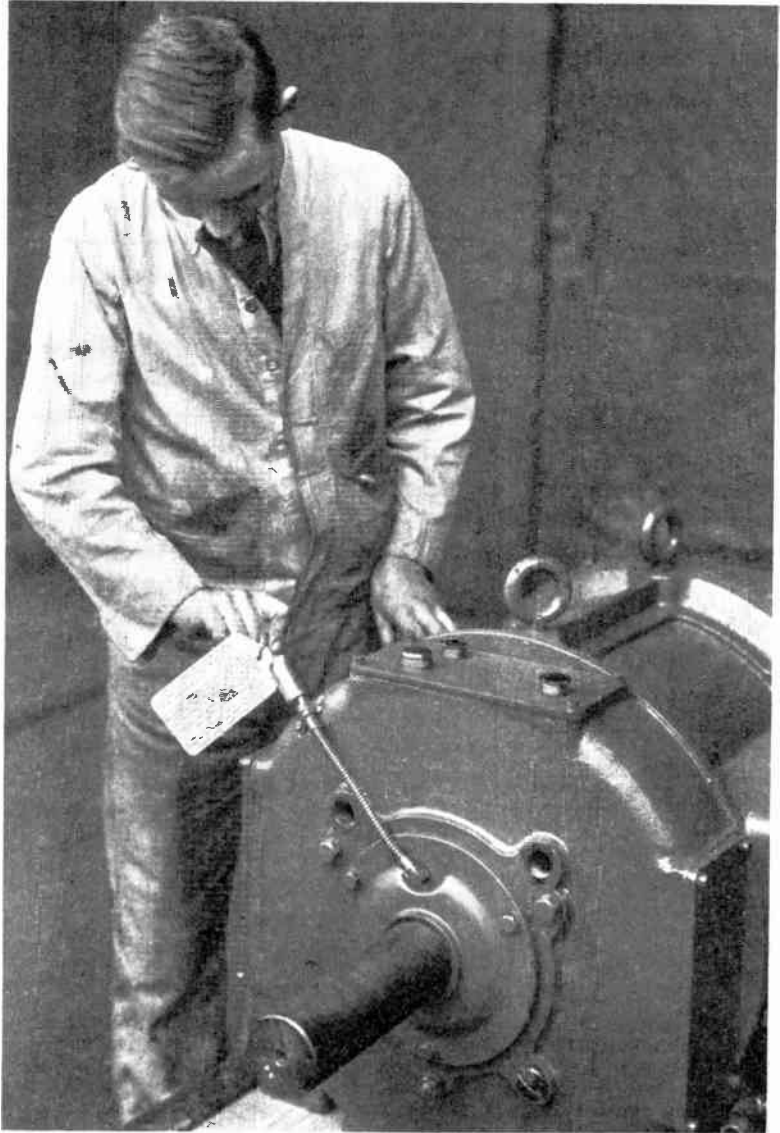


Fig. 17.—REPLENISHING THE GREASE CHARGE.

The operator is here shown replenishing the grease charge, using the special key with instruction tag attached. This tag is shown in detail in Fig. 20. (Metropolitan-Vickers)

ments is available. If not, the correct temperature may be gauged by holding a piece of dry cotton cloth in contact with the heated bearing shell. When the temperature is correct the cloth will not be singed at all, but any further heating

ments is available. If not, the correct temperature may be gauged by holding a piece of dry cotton cloth in contact with the heated bearing shell. When the temperature is correct the cloth will not be singed at all, but any further heating

of the shell should result in singeing. In other words, the shell should be just below the singeing temperature.

### The Correct Babbitt to Use.

Only the very best white metal must be used for lining the bearings of electrical machinery and for this reason scrap metal must not be employed. Care should be

taken, due to oxidation, etc., of the more susceptible elements, and after about two melts the babbitt requires reconditioning by the addition of some of the material which has been lost.

### Effect of Overheating.

Overheating, as will be appreciated, results in very rapid loss of nature and in

addition the crystal structure of the metal is impaired. Overheated metal can sometimes be restored to normal, but it is unreliable unless the restoration has been done by a very experienced melter; for this reason it must be avoided and returned to the metal maker for reconditioning if any large quantity is affected. The metal maker will also be able to deal with over-melted metal. Scrap babbitt should be avoided because it frequently contains impurities such as filings or borings, and the only way to be sure that the correct babbitt is being used is to purchase it from the original maker of the motor or from a reputable firm of bearing

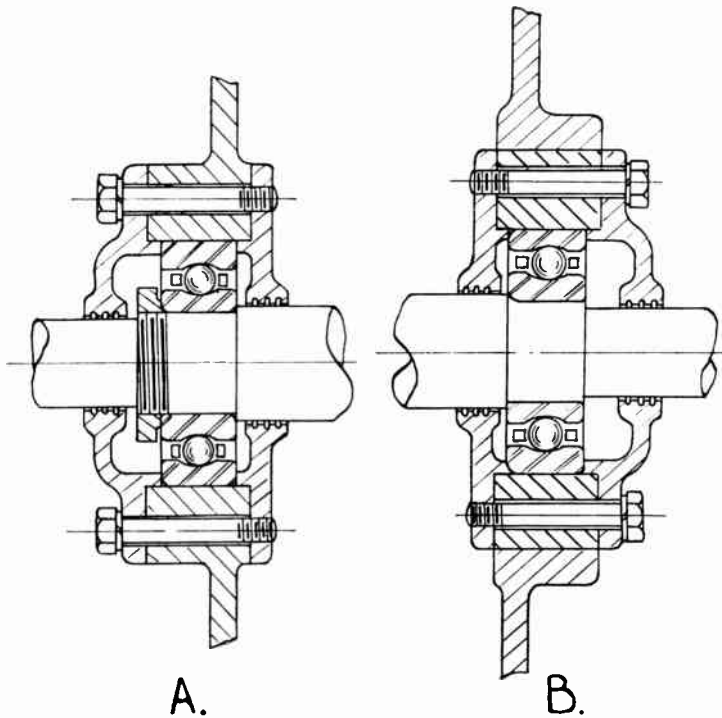


Fig. 18.—MOUNTINGS OF BALL BEARINGS.

In A we have the older arrangement with the bearing mounted directly in the motor bracket, while B shows one form of cartridge housing mounting. Note that A is shown with a locknut for the bearing, whereas no such detail is incorporated in the cartridge arrangement. The locknut is frequently omitted on small motors, but the best practice includes it on machines of any reasonable size.

taken also to avoid all metal which has been melted more than once since it was in ingot form and any babbitt which has been overheated at any time must be rejected as unsuitable. These precautions are necessary because, although a bearing alloy will contain the correct proportions of its various constituent metals when it is first bought in ingot form, every melting up results in an alteration of the propor-

metal manufacturers. In the latter case, it should be stated that the metal is required for the bearings of an electric motor.

### Melting the White Metal.

We must now proceed to melt the babbitt and special care should be taken in this operation so as to avoid overheating or burning. It is best to use a gas or

electrically heated melting pot, as this minimises the danger of contamination of the metal, but if this is not available the babbitt may be melted in a ladle over a coke fire, care being taken to avoid dropping small pieces of coke into the molten metal. Having obtained a suitable ladle or melting pot, it should be placed on the fire to become heated. It should be noted that the pot must be absolutely clean and free from all dross or remnants of previous melts. Just sufficient metal (in ingot form) to remetal all

that this will cause it to melt rapidly, forming a pool of molten metal in the pot. As soon as a pool has been formed in this manner a new ingot should be taken and laid flat in the already molten metal, and when this also has been melted, a further one or two ingots may be introduced, until the whole amount of the metal is in the molten state. On no account must the pot be stacked with ingots standing on end and then placed on the fire to melt all at once; if this is done the metal will be burnt at the bottom and melting be slow

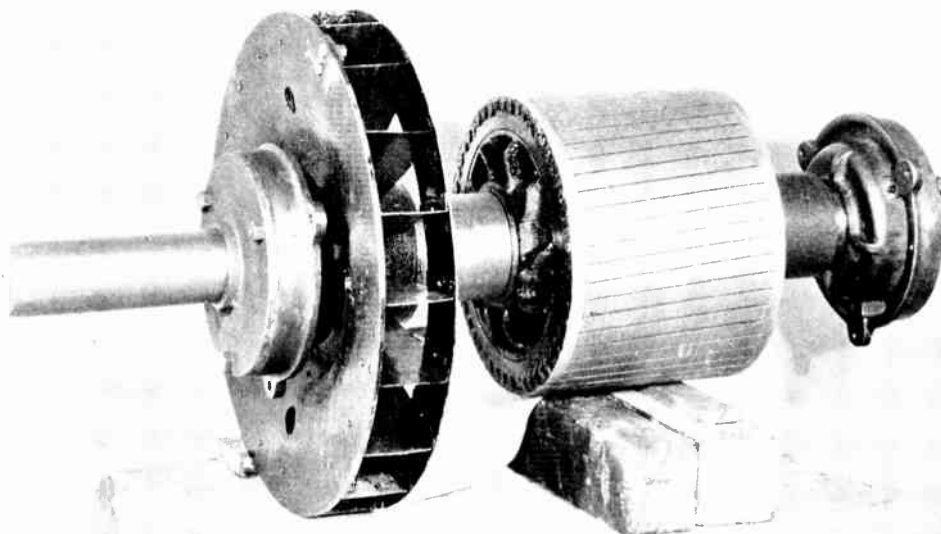


Fig. 19.—ROTOR OF AN A.C. MOTOR COMPLETE.

This complete squirrel cage rotor shows the undisturbed cartridge housings left in position on the shaft while the rest of the machine may be dismantled. Note also the fan for the circulation of cooling air through the motor. (*Metropolitan-Vickers.*)

the bearings which are being worked on should now be taken. Too much metal should be avoided since it will have to be left over and remelted, with consequent deterioration as has already been explained.

### Melting Procedure.

As soon as the pot becomes hot enough to melt an ingot of metal when it is pressed against its inside surface, we may proceed with the actual melting. The first step is to take an ingot of the metal and to rub it against the inside sides and bottom of the pot, and it will be found

because of the small surface of each ingot which is exposed to the heat.

### The Pouring Temperature.

In order to produce a good bearing, great care is necessary in order to see that the metal is at the correct pouring temperature and this should be measured by pyrometer or thermometer (high temperature type), when either of these instruments are available. When this is not the case, the temperature may be roughly judged as follows. When melting the metal a number (about a dozen) of strips of white wood (white pine) should be

prepared. These should be made of well seasoned wood and should be quite dry ; they should be about  $\frac{1}{8}$  in. thick by  $\frac{1}{2}$  in. to 1 in. wide, and about 6 in. to 12 in. longer than the depth of the pot. As soon as all the metal in the pot is liquid the temperature should be measured ; the use of the pyrometer varies with the

perature one of the wooden strips mentioned above should be taken and, the operator holding one end, it should be thrust vertically downwards into the pot, immersing it in the molten babbitt and, if possible, reaching the bottom of the pot. The strip of wood should be held in the metal for about five seconds and it should

then be withdrawn and examined. With the majority of white metals which are suitable for electric motors it will be found that the correct pouring temperature is attained when the wooden strip becomes light brown in colour when immersed in the molten metal. On no account should the strip be charred extensively, since charring indicates overheating, and when this has taken place the surface of the molten metal will be covered with a bluish film of oxide or dross. In any case, great care must be taken to avoid overheating ; it is advisable to ask the metal maker what the pouring temperature for his product should be, and the same source can also give definite advice on the appearance of the wooden strip.

**ASSOCIATED ELECTRICAL INDUSTRIES LTD**  
**TRAFFORD PARK**  
**MANCHESTER**

**INSTRUCTIONS FOR LUBRICATION OF BEARINGS**  
*Carefully clean away all grit, dirt & moisture to prevent entry of the slightest trace into lubricator. Remove dust cap of lubricator, insert attached key and give 10 complete turns. Replace cap.*  
*Lubricate ONCE each January and July. Too much grease is harmful.*  
*To recharge lubricator, withdraw inner screw cap, fill it with our BELVIC grease and replace in position. See over.*  
*At intervals of three years wash all dirt etc. from exterior of bearing housings, remove housing caps, clean out all old grease with petrol, and dry. Press BELVIC grease into bearings and fill housing caps with new grease seven eighths full. Refill labyrinth grooves. No dirt or moisture must enter bearings or caps. See instruction booklet supplied with motor.*  
*When dismantling the motor, do not remove bearing caps, as the end brackets can be withdrawn without disturbing the bearing housing. See over for sketch of cartridge housing.*  
*To remove bearings from shaft, see instruction booklet supplied with motor*

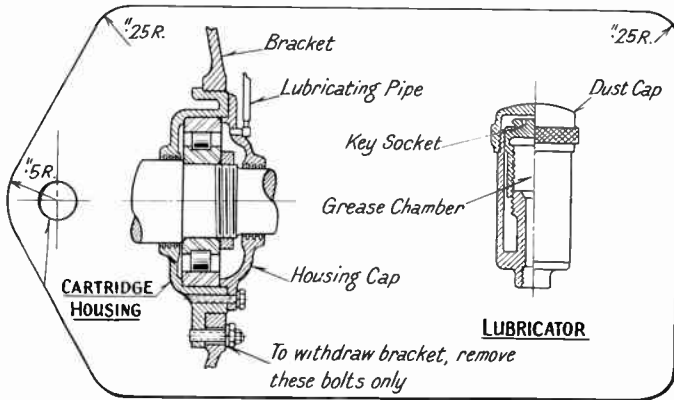


Fig. 20.—LUBRICATION INSTRUCTION TAG.

On the front of this tag we have instructions for the operation of the lubrication system, while the reverse side gives details of the special lubricator and bearing housing. This tag is attached to the lubricator operating key. (Metropolitan-Vickers.)

type of instrument ; while the method of measuring by thermometer needs no description. In cases where the wood strip method is to be used, however, the following procedure should be followed.

**Gauging the Temperature by a Wooden Strip.**

When it is required to gauge the tem-

perature, to the correct metal at the pouring temperature, we may proceed to pour the lining. A clean ladle should be taken which will hold sufficient metal for the complete pour. If the bearing is of large size two ladles operated by two pourers should be used since the flow of metal must not be interrupted or else the bearing will suffer. The



white metal should now be skimmed so that it shows a white silvery surface, and it should be stirred thoroughly, care being taken to stir well down to the bottom of the pot. A ladle full of the molten metal should now be taken, all dross or oxide being carefully avoided because clean metal is absolutely essential, and the lining may be poured, care being taken to maintain a steady flow of the molten metal and to

employed to keep the top metal molten until the bottom has solidified and settling is complete. When this has happened the bearing may be left to cool off, and as soon as it is cold enough to handle the mandrel should be removed and the lined bearing should be suspended as before and "rung." If, upon striking it with a hammer, it does not ring, the babbitt lining is not adhering properly, and it must

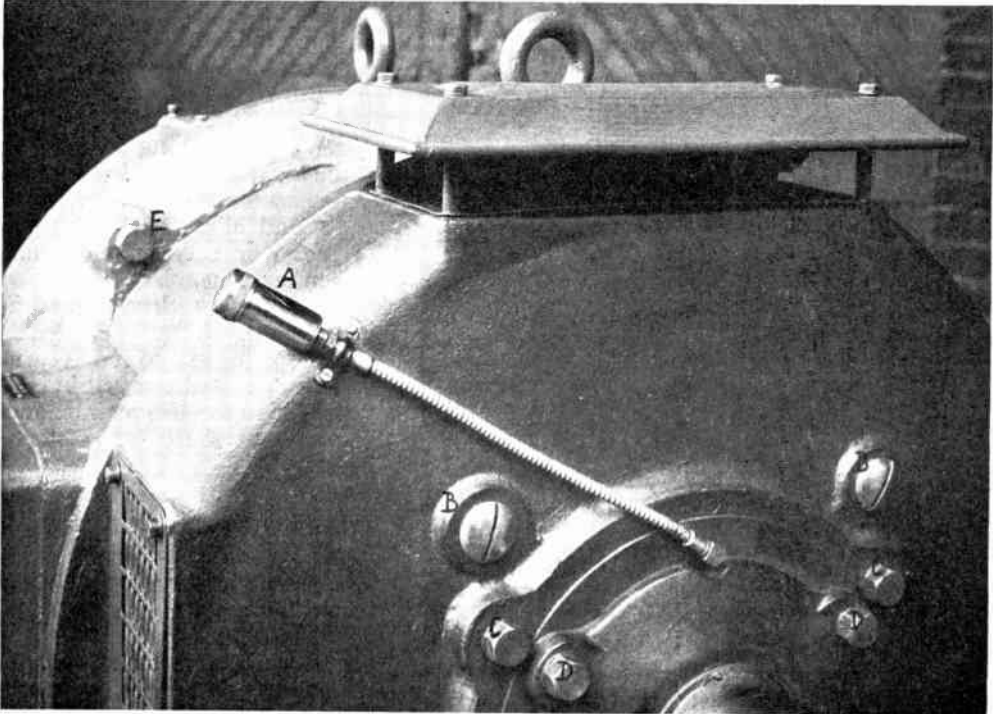


Fig. 21.—DRIVING END DETAILS OF A MOTOR.

The various details are as follows : A, lubricator complete with pipe. B, plugged apertures for gap checking. C, bolts holding bearing housing to motor bracket. D, bolts holding on housing cap. E, bolts fixing bracket to yoke. To remove the bracket, take away bolts E and C only ; do not disturb D. (*Metropolitan-Vickers.*)

avoid lifting the ladle spout more than  $\frac{1}{4}$  in. above the top of the shell. The metal should be poured from one point only and the space between the shell and mandrel must be filled so that the molten metal stands above the top of the shell.

#### While the Lining is Setting.

If the metal settles down during solidification, more must be added to make up the deficiency and a blow lamp should be

be melted out and re-run, otherwise much trouble will ensue. Providing the lined shell rings true, it can be machined, the oil grooves and passages cut and drilled, the bearing surfaces scraped to a good fit, and returned to service.

#### After Relining the Bearings.

When a motor with relined bearings is put back to work the bearings must be carefully watched for the first few hours,

care being taken that the lubrication system is functioning correctly and that the bearings are not overheating. It is good practice to let a motor run light for a few hours after the bearings have been relined, the machine being closely watched for any signs of trouble.

#### Points to Watch Regarding Bearings.

A sleeve type bearing is usually safe if its temperature never exceeds 100 C. (212 F.) when the motor is on full load; the temperature should also be constant

may overheat due to any one or more of the following causes:—

- (1) Excessive belt tension.
- (2) Insufficient lubrication due to—
  - (A) Low oil level;
  - (B) Oil rings sticking;
  - (C) Waste dry or out of contact with shaft (in waste-and-oil lubricated bearings);
  - (D) Poor quality waste—see text.
- (3) Lubricant of low grade or wrong consistency due to—
  - (A) Wrong grade of oil—consult oil refiners;
  - (B) Wrong type of oil—consult oil refiners;
  - (C) Surrounding temperature too high, thus thinning oil down—consult refiners for heavier oil.
- (4) Bad alignment of bearings of motor or between motor and driven machine.
- (5) Motor or driven machine out of level.
- (6) Rough or scored bearing surface due to dirt or grit in oil or waste, or to careless maintenance.
- (7) Bent shaft or distorted bearing.

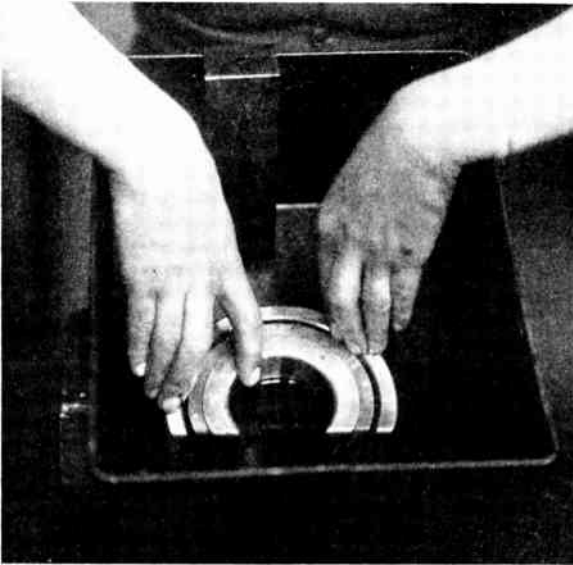


Fig. 22.—WASHING AND INSPECTING A BALL BEARING.

The bearing is shown being washed in petrol, the races being rotated while the washing is proceeding so as to dislodge any hardened grease or dirt. (*Metropolitan-Vickers.*)

below the above limit and any sudden rise should be taken as a warning sign. If a thermometer is not available a hot bearing can be detected by the smell of burning oil and the smoke which issues from the bearing housing; the hand is unreliable as a gauge of temperature and a bearing which is hot enough to burn the hand may be quite safe, so it is best to obtain a thermometer and be sure of the actual temperature. The main point to watch is that the lubrication is ample and the oil of good quality. A bearing

#### When the Bearing Overheats.

An overheating bearing will almost invariably be detected when the motor is running at full speed on full load, and it is essential to correct the fault immediately; otherwise, a seizure, causing grave mechanical damage or a fire, may result. In these cases proceed as follows: Remove all load and slacken off the belt or chain (if any); if possible reduce the speed and pour large quantities of oil directly on to the bearing shell and into any lubricating passages. On no account must the motor be allowed to stop revolving until the bearing can be touched by hand; if this is done, a seizure will ensue, necessitating turning or melting off the bearing. As soon as the machine can be stopped, dismantle the bearing and inspect shaft and lining for damage. If necessary true up and polish the shaft and reline the bearing. If the babbitt has run out,

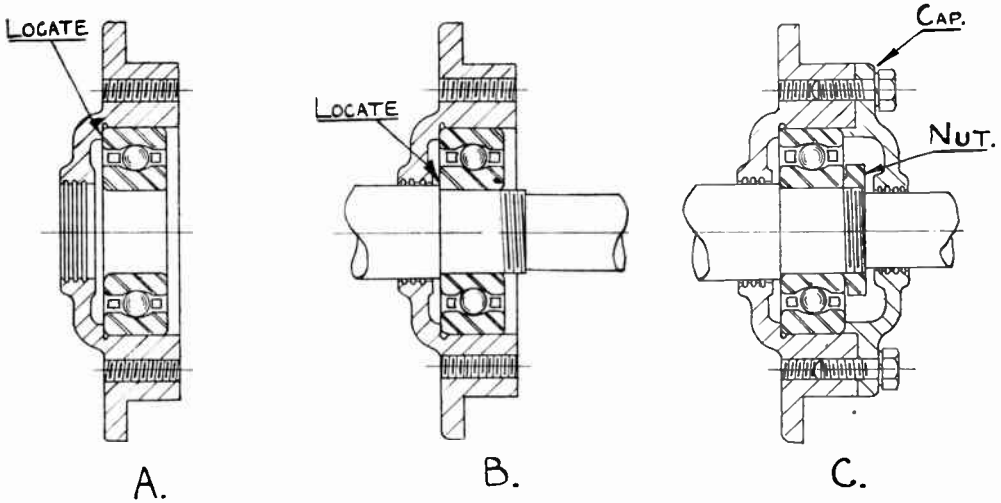


Fig. 23. - REASSEMBLING A CARTRIDGE MOUNTED BALL BEARING.

The first stage, A, shows the bearing inserted in the housing and locating its outer race against the housing shoulder. At B the complete unit of housing and bearing is pressed on to the shaft, locating the inner race on the shaft shoulder. The final stage, C, shows the bearing nut fitted, holding the inner race in place, and the housing cap in position.

examine the stator and rotor for damage due to rubbing and repair if necessary. Always repack a waste and oil-lubricated bearing when it has been running hot.

**Ball and Roller Bearings.**

Ball and roller bearings are amongst

the most robust and reliable equipment manufactured. They will withstand overloads and shocks many times larger than those which can be imposed on a sleeve-type bearing for the same shaft diameter. The very precision of manufacture which is the basic source of their superiority

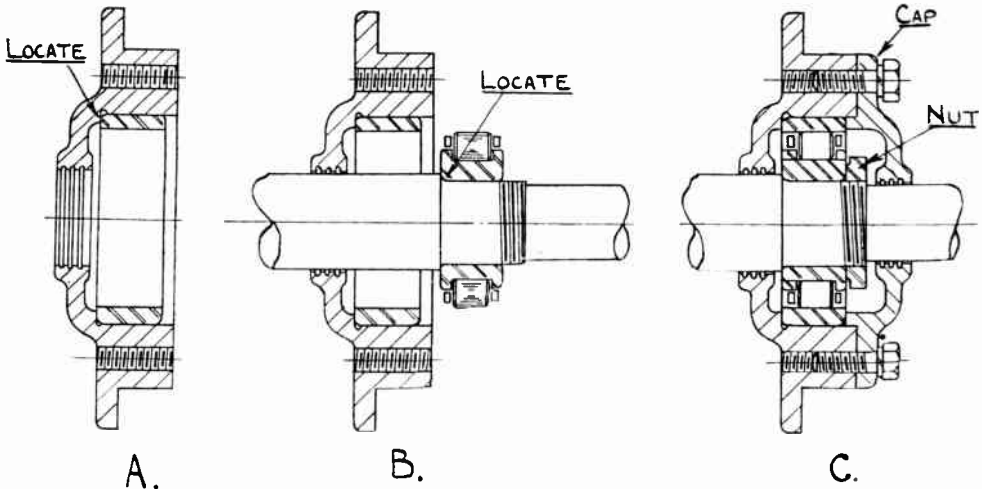


Fig. 24. - REASSEMBLING A CARTRIDGE MOUNTED ROLLER BEARING.

Stage A shows the outer race only pressed into and located in the housing. At B the outer race and housing are threaded over the shaft, while the inner race, complete with rollers and cage, is located against the shaft shoulder. The final stage, C, shows the outer race drawn back over the rollers, the bearing nut in place and the housing cap fitted.

renders them somewhat sensitive to abuse, however, and it follows that the essential conditions for satisfactory operation of these bearings are scrupulous cleanliness, thorough protection and adequate lubrication with the correct quality of lubricant.

### The Correct Ball-bearing Grease.

The experience of manufacturers and

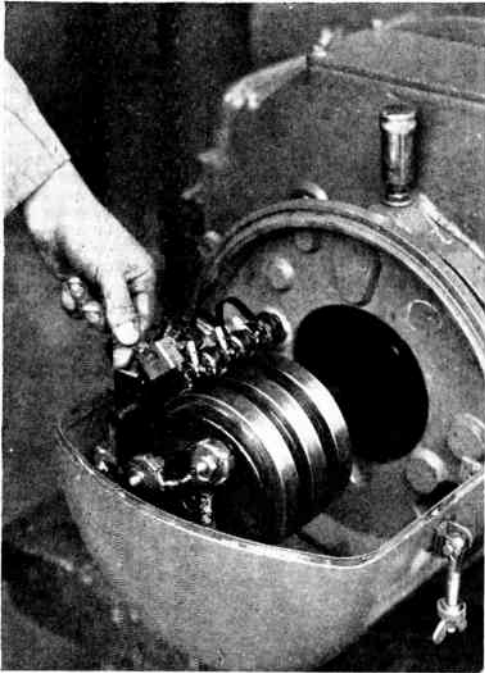


Fig. 25.—TESTING A BRUSH FOR FREEDOM OF MOVEMENT.

When the brush is lifted as shown, against the spring pressure, it should slide freely in its holder and when it is released it should return smartly to its position on the contact face. This operation should be carried out on each brush during the weekly cleansing. (*Metropolitan-Vickers.*)

users of ball and roller bearings has indicated that grease is the cleanest and most reliable lubricant for use in general cases. Special applications involving very high speeds may involve the use of oil, but all normal industrial electric motors employ grease lubrication. The grade of grease used should be free from acids or alkalis and it should be kept scrupulously

clean because grit, which may easily be introduced via the grease, will quickly ruin the bearing.

Most oil refiners list a suitable ball-bearing grease and some motor manufacturers supply a special grease for use with their products. Where a special grease is specified by the motor maker it should be used.

### Storing the Grease.

*The grease must be kept clean* and for this reason it should not be removed from its original container until it is transferred to the bearing housing; the lid of the grease tin should always be kept in place, being removed only when it is necessary to withdraw lubricant for use. Even with these precautions dirt may find its way into the grease during its transference from tin to bearing, and to avoid this the grease must be handled only by means of a *clean* spatula, spoon or strip of wood kept specially for this purpose inside the tin with the grease. Special care should be taken that the grease is not applied by means of the gritty or dirty fingers of a maintenance fitter. Grease must not be kept too long in stock since it is apt to deteriorate, a safe rule is to reject all grease which has been in the stores more than three years.

### Replenishing the Grease Charge.

There are two processes in the lubrication of ball and roller bearings which need explaining. First, by "replenishment" we are to understand adding a small quantity of grease to that which is already in the housing; this is to make up for leakage, etc., and it is usually introduced by means of a screw-down lubricator or a grease gun. The second term is "replacement" and this means that all grease is completely removed from housing and bearing and that new and fresh grease is used to repack same—this process will be described later. As regards replenishment, we can say that the average motor will run at least 2,500 hours—say one working year—before the grease charge needs adding to, and that after the first year replenishment should be carried out every six months, not oftener.

### Bearing Mountings.

There are two methods in common use at present for mounting and enclosing the ball or roller bearings and as these affect the maintenance procedure, we must now consider them. In the older method the outer race of the bearing is seated in a machined housing integral with the motor end bracket, and the ends of this housing are closed by caps which also serve to locate the bearing in an endwise direction. This has obvious disadvantages since when the motor end bracket is removed, it is necessary to expose the bearing with the consequent risk of the entry of grit and dirt; the close fit which is essential between the outer race and housing must also be disturbed and will become slacker each time the bearing and bracket are separated.

### The Cartridge Housing.

To overcome these disadvantages a "cartridge housing" mounting has been devised in which the bearing proper is enclosed within a separate housing or cartridge which is sealed by end caps as in the previously described arrangement. The sealed cartridge is, in turn, seated in a machined housing which is integral with the motor bracket and the whole is constructed in such a manner that it is unnecessary to open up the bearing housings when the motor is dismantled. By this arrangement the bearing is protected at all times, it being unnecessary to open the housing unless it is required to inspect the bearing itself, and we thus prevent dirt getting in and preserve the correct degree of fit between bearing race and housing.

### Difference in Maintenance for Different Mountings.

The cartridge-type housing is the very latest refinement in the application of ball and roller bearings to electrical machinery and it is incorporated only in the latest designs. Since all manufacturers will undoubtedly take the opportunity of making their motor bearings cartridge enclosed when they redesign their standard lines, it follows that the number of

bearings of this type will steadily increase, and we therefore propose to deal with this arrangement only in the following notes. The only difference in procedure when the old type of mounting is incorporated is that the instructions given later for the cleaning, bearing inspection and grease charge replacement should be applied annually during the maintenance

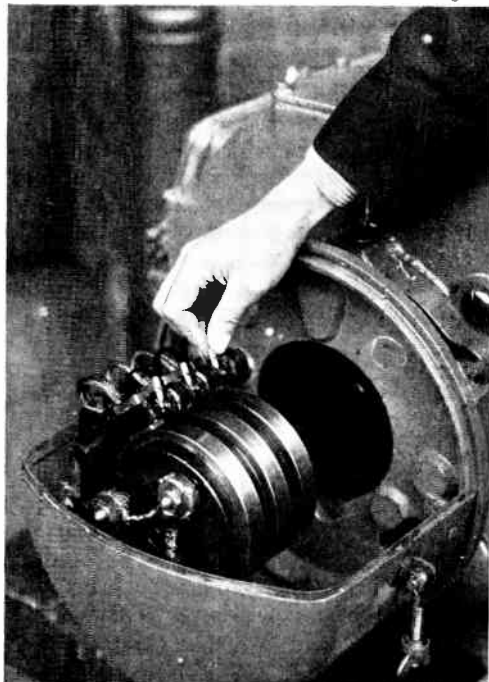


Fig. 26.—ADJUSTING THE BRUSH PRESSURE.

From time to time it will be necessary to adjust the brush pressure, and a lever is usually provided on each brush holder for this purpose. The operation is shown being performed on an A.C. motor; the levers show up white, being plated for rust proofing. (*Metropolitan-Vickers.*)

overhaul and not every three years as for the cartridge protected detail.

### An Example of Lubrication Maintenance.

As an example, we cannot do better than take the instructions issued by the Metropolitan-Vickers Electric Co., Ltd. This firm have done a large amount of research work on ball and roller-bearing

lubrication and they fit a special lubricator which is so arranged as to prevent the thoughtless screwing down which often applies when unprotected screw-down lubricators are fitted and which results in overcharging and bearing troubles. The instructions mentioned are engraved on an ivorine tag which is attached to the lubricator operating key. This key is intended to be kept by the maintenance engineer who will attend to the lubrication of the motor, thus taking this important duty out of the hands of machine operatives and labourers who can do a lot of harm by unintelligent interest. The reader is referred to Fig. 20, which shows the tag, and from which the instructions may be read. It should be mentioned that the grease grade mentioned on this tag—"Belvic"—is the result of the research referred to previously, and it is recommended for machines by this maker and for ball and roller bearings in general.

#### **How to Tell if the Bearing is Working Correctly.**

Climatic conditions and environment may affect the lubrication, and it is advisable to ascertain from time to time that the bearing temperature is neither too high nor too low. A comfortable warmth to the hand when placed on the housing or cap indicates that the bearing is running under the best conditions. This can be taken as a rough guide, although somewhat higher or lower temperatures are, in themselves, not dangerous; however, if the temperature begins to rise, or if the bearing becomes noisy, an inspection should be made immediately.

#### **Replacing the Grease Charge.**

The complete grease charge should be renewed every three years. All dirt, etc., should be cleaned from the bearing caps, housings and adjacent parts. The caps should be separated from the housings, and the bearings, housings, and caps should be washed with petrol—removing all old grease in the process—and thoroughly dried. The labyrinth grooves in the cap bore at the driving end should be scraped out and filled with fresh grease. *The necessity for absolute cleanliness cannot*

*be too strongly impressed upon those instructed to carry out the operation of recharging the bearings, and all parts which have been removed and washed should be covered with clean material, such as paper, to prevent foreign matter adhering and subsequently entering the bearing.*

#### **Examination of the Bearing.**

After washing, the parts should be carefully examined. Providing the grease charge has been regularly replenished, and the bearing has not been subjected to any form of excessive loading, no undue wear will be observed and the bearing will be in good condition. In this case, fresh grease should be pressed well between cage, races, and balls or rollers. Merely placing the grease on the end faces of cage and races is not sufficient. The grease is required inside the bearing. After packing the bearing, any superfluous grease should be wiped off.

#### **The Correct Quantity of Grease.**

It has been found that 85 to 90 per cent. of the space available in the housing and cap should be occupied by grease if the best results are to be obtained; since grease expands when heated and as a certain amount is thrown off the bearing by centrifugal action if the housing is crammed full of grease, churning, overheating and disintegration will occur; while less than 85 per cent. grease is apt to lead to starving, cage wear and breakdown. Care should be taken to see that the spatula or stick by which the housing is filled does not introduce any foreign matter into the grease.

#### **Removal and Replacement of Bearings.**

If the bearing appears worn, or if the grease has become hard and dirty, the bearing should be removed from the shaft, withdrawn from the housing, washed and inspected for wear. Special precautions are taken by all motor manufacturers to ensure a correct fit between the bearings and their housings and shaft. *Bearings should never be removed if this can be avoided, and, in any case, they cannot be removed without damage unless adequate and suitable withdrawing gear is used.*

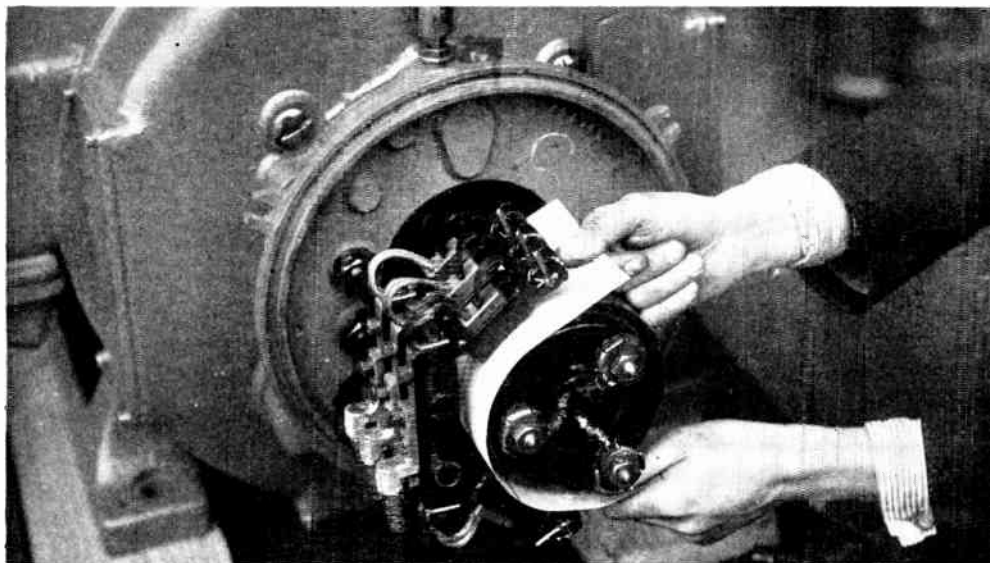


Fig. 27.—BEDDING A.C. MOTOR BRUSHES.

Note that the glasspaper is fitted with the rough side outward and that the hands are held as close together as possible. This is to avoid cutting away the brush edges and to give good bedding over the whole brush face. (*Metropolitan-Vickers.*)

### Dismantle the Housing.

To remove a bearing from the shaft, the cap should first be taken off and the bearing nut (if any), which is screwed and locked on the shaft, completely removed. The withdrawing gear should then be placed behind the housing, or the housing itself may be used as part of the withdrawing gear providing every precaution is taken to prevent undue strain, since it is usually made of cast iron. If the housing is used for this purpose the tapped holes *nearest* to the bearing must be employed and a stud should be used in each hole, care being taken to tighten the studs equally. The most important point to observe during this operation is that the pressure is evenly distributed all round the bearing; it must never, in any circumstances, be exerted more on one side than the other, otherwise the bearing and its seatings will be damaged. Having removed the bearing and its housing from the shaft, the housing and bearing may be separated by employing hook bolts inserted through the bearing bore; the above-mentioned precautions as to equally distributed pressure

should be strictly observed in this case also.

### Inspect the Bearing.

The inspection of the bearing should now proceed. First, the complete bearing should be washed in petrol and every trace of grease should be removed. The races and balls or rollers should then be closely examined and if the slightest crack or chipping of their surfaces is found, the complete bearing should be replaced immediately. If it is impossible to observe any flaw during the visual inspection, the outer race should be revolved slowly by one hand while the inner race is held by the other; any noticeable increase in the force required for rotation, or any sharp check in the movement (however slight), indicates either dirt in between the races and balls or rollers, or surface defects in same.

If this condition is observed, the bearing should be rewashed in clean petrol, the races being revolved by hand while the bearing is in the petrol bath in an effort to displace and remove any particle of grit which may be present. If after drying the bearing still exhibits defects in its

running, it should be rejected. Any roughness of operation indicates the probable presence of worn races or cage, and the bearing should be inspected for these defects and immediately rejected if they are found.

### How to Tell if a Bearing is in Good Condition.

If in good condition the bearing will revolve smoothly and without jerking, catching, or clacking; it will not show any cracks or chipping of its surfaces, and while a certain amount of endplay will be present, there will be no appreciable radial clearance. Furthermore, all

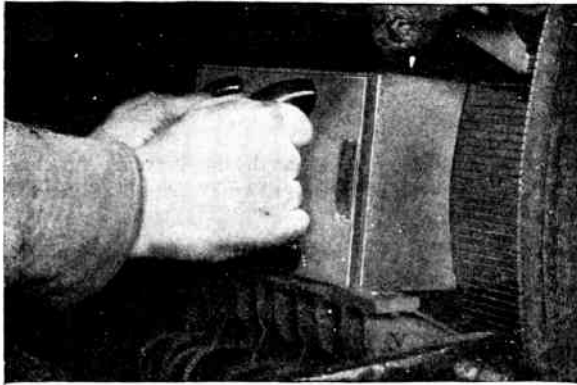


Fig. 28.—USING A COMM. STONE.

A large comm. stone is here shown in use cleaning a large commutator. Note that it is unnecessary for the machine to be "dead" since the stone is a good insulator. (*Martindale Electric Co., Ltd.*)

surfaces will be bright and will show the original distinctive grinding marks on the outsides and edges of the races.

### Creeping of Bearing Races.

If those portions of the race which come into contact with the housing or shaft show signs of having been rubbed or polished by a burnishing action in a circumferential direction, creeping of the race is indicated. While this is not a defect of the bearing itself, it is an indication that all is not well with the fit, either on the shaft or in the housing, as the case may be. Creeping should not be tolerated, since it is cumulative and may necessitate new bearings together with a built up or

new shaft, or new housings. Creeping is usually started by drive vibration of a periodic nature (such as a heavy belt fastener or badly aligned gear) or by the driven rotating masses being out of balance. When these sources of disturbance are removed the creeping generally stops, and if these measures are taken in time it will not be necessary to fit oversize bearings. In investigating a complaint of this nature it should be remembered that all motors of reputable make are dynamically balanced at the works, and should, therefore, not give rise to any unbalanced forces.

### Remounting the Bearing in the Housing.

Having decided, from the inspection, whether the original or a replace bearing must be fitted, reassembly of the various parts may be undertaken. The first operation is to fit the bearing in the housing. Ball bearings require the whole unit, roller bearings the outer race only, to be inserted. After housing and bearing have been wiped clean the bearing should be greased well; the back of the housing as far as the outer race locating shoulder should be filled with grease and the bearing, or race, should then be placed in position and pushed into the housing by pressure applied gradually and evenly to the *outer* race. Care must be taken to ascertain that the bearing remains

square with the housing bore from the very start of this operation and if these instructions are followed it will be found that the bearing or race will easily enter the housing, and may be pressed down until it makes contact with the locating shoulder. It is essential that the bearing beds on this shoulder, and having ascertained that this has been achieved the fitting of the combination of bearing and housing on to the shaft may be proceeded with.

### Fitting on to the Shaft.

With roller bearings, the housing carrying the outer race is threaded over the shaft first, followed by the bearing proper. In the case of ball bearings the bearing



and housing, assembled together, are fitted as one unit. The shaft should be clean and lightly greased, and the bearing should be forced on to its seating by pressure applied evenly to the *inner* race, as close to the shaft as possible. The application of the pressure close to the shaft is very important, particularly with roller bearings, since otherwise the flanges forming the sides of the race are liable to be distorted or broken. The pressure *must* be even all round the race and the bearing *must* remain square with the shaft from the very start of the operation, otherwise a damaged shaft will result. If a tube is used to force the bearing on, it should be a reasonably close fit over the shaft; its face should be square and its outside diameter should not exceed the diameter of the bearing nut face which makes contact with the inner race. *In no circumstances must pressure be applied to the outer race when fitting a bearing on the shaft.*

#### Completing the Reassembly.

Remounting is completed when the inner race is in contact with the locating shoulder on the shaft and this should be checked before proceeding with the fitting of the bearing nut. The nut should be replaced, well tightened up, and relocked. A complete grease charge should be given as previously described; the cap should be refixed to the housing, the lubricator filled, and the bearing is ready for running.

#### SLIPRINGS, COMMUTATORS, BRUSHES AND BRUSHGEARS.

The function of these parts is to provide a path for the current between the stationary conductors, or cables, and the rotating armature or rotor; the combination of slipring (or commutator) and brush constitutes a sliding contact, being subject to the same general rules as govern any surface contacts which are called upon to carry current. We will first of all discuss those details which are common to all types of motors, such as brushes and brush holders; sliprings and commutators will be considered later.

#### Always Keep the Brushgear Clean.

As has already been mentioned the brushgear should be cleaned every week, being wiped down with a clean cloth free from fluff or down. All carbon or metallic dust, oil and grease must be removed and care should be taken that all recesses and particularly insulating surfaces are quite clean. At the same time as this is done all dust should be removed from the spaces between the sliprings and from the ends of the slipring, bush or commutator vee rings as the case may be. This periodical and scrupulous cleansing is essential if breakdown is to be avoided.

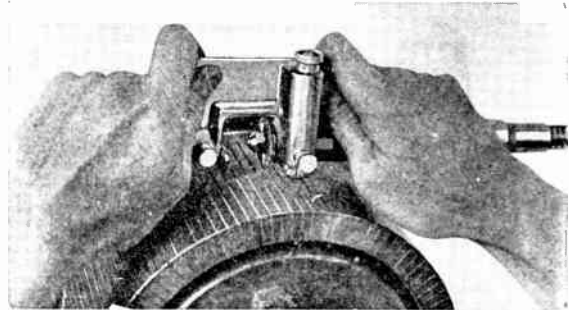


Fig. 29.—AN UNDERCUTTING HEAD IN USE.

Observe the method of holding and guiding. This is to avoid cutting or scratching the copper segments. (Martindale Electric Co., Ltd.)

#### Brushes Must Move Freely.

When the weekly cleaning of the brushgear is being carried out, each brush should be lifted up against the spring pressure and then released. Any sluggishness of movement of the brush towards remaking contact must be corrected immediately, otherwise destructive sparking and burning will set in and spoil the contact surfaces. It will generally be found that the seizure is due to dust in the brush box or hinge bearing of the brush-holder and removal of this will free the brush; sometimes, however, oil may be the cause, and cases have been known where the shellac bond in intersegment micas oozed out when the motor became warm and was flung off

by centrifugal force, causing most stubborn and perplexing brush seizure. These latter cases occurred on very old motors and this trouble would never occur on a machine of modern design by a reputable manufacturer.

### Measure the Brush Pressure.

At intervals of about three months the brush pressure should be measured by means of a small spring balance. The hook of the balance should be attached to

according to the type of brush which is in use.

Carbon brushes—2 to 2½ lb. per sq. in.

Metal mixture—3 to 3½ lb. per sq. in.

If it is found that the brush pressure exceeds or is less than the above figures, the spring tension must be adjusted accordingly. All brushes on the same motor *must* be at the same pressure, as nearly as possible.

### If there is Sparking due to Vibration.

Sometimes the driven machine gives rise

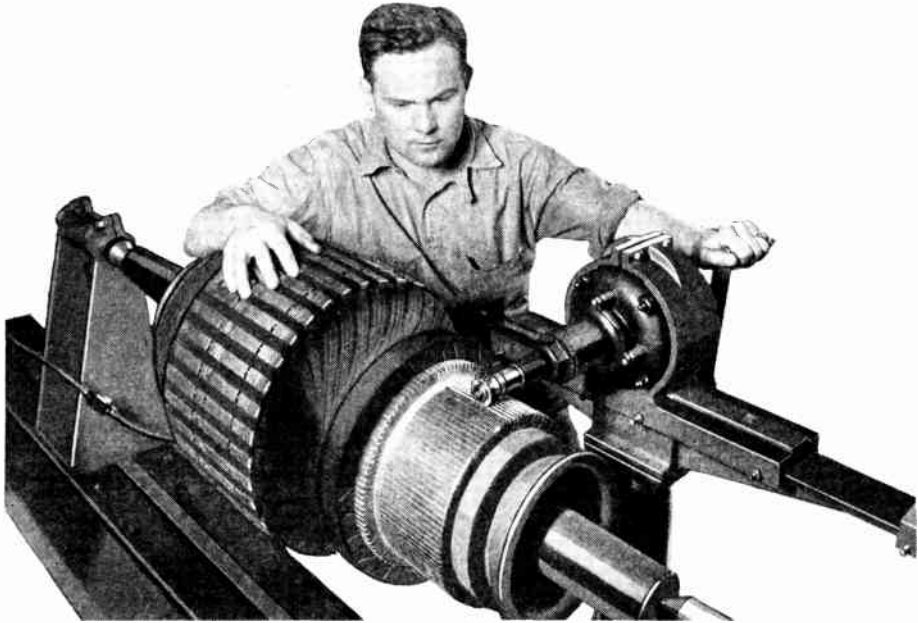


Fig. 30.—AN UNDERCUTTER FOR WORKSHOP USE.

This mica undercutter is suitable for the large maintenance shop or factory. It is so constructed that the mica slot is milled truly parallel to the shaft axis. (*Martindale Electric Co., Ltd.*)

the end of the pressure finger, as close as possible to the point of contact with the brush top, and the balance should be held along a line parallel to the brush centre line. The spring balance should now be gradually moved away from the brush by pulling on the ring at its end, and the reading at which the end of the pressure finger is lifted from the top of the brush should be noted. This is the spring pressure and it should be converted into pounds per square inch of contact surface and checked against the following figures, ac-

to general or periodical vibration, causing brush dancing and violent sparking. In these cases the correct cure, of course, is to remove the vibration; when this cannot be entirely accomplished, it may be necessary to increase the brush pressure over the figures given above, this being done at the expense of brush and commutator (or slipring) life, of course. This increase of pressure must not be carried too far, however, certainly not above about 4½ lb. per sq. in. for carbon, or 5½ lb. per sq. in. for metallic mixture (copper

graphite, etc.) brushes, and when it is found that this extent of pressure increase will not affect a cure it may be necessary to fit a brush of lighter weight which will be more easily controlled by the brush-holder spring. The motor manufacturer and brush maker must be consulted on this point however.

### When to Fit New Brushes.

Even with the very best running conditions the brushes will gradually wear away and have to be replaced, but it is impossible to say how long a set of brushes should last because conditions and machines differ so much. However, the brushes must be replaced if any one or more of the following conditions have been arrived at due to wear.

(A) When the height of the brush measured from the commutator or slipping surface to pressure finger is  $\frac{1}{2}$ -in. or less.

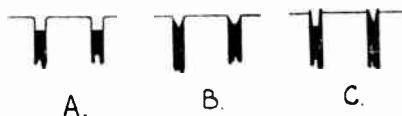


Fig. 32.—MICA GROOVES.

At A we have square grooves with the edges of the segments bevelled, and B shows vee-shaped grooves. Either of these shapes are satisfactory. In the case of C we have the condition when the mica has been carelessly reduced—giving flake mica standing above the copper segments. This is a condition of "high mica" and gives commutator blackening and much trouble due to sparking.

(B) When any metal figments inserted in or attached to the brush approach to within  $\frac{1}{16}$  in. of the commutator or slipping face.

(C) When the brushes have become so short that no further spring pressure is available.

The new brushes should be ordered from the maker of the motor, full nameplate particulars being quoted and one of the old worn brushes being sent as a sample if possible; if a worn brush cannot be spared the orderer should quote the letters or figures which will be found stamped at the top of the brush sides or edges. This is the brush grade designation.

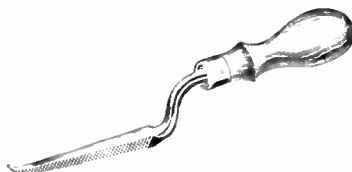


Fig. 31.—AN UNDERCUTTING FILE.

This little tool is useful where only a few commutators have to be maintained; with careful use it produces good work, although its operation is somewhat tedious. (*Martindale Electric Co., Ltd.*)

### If the Brushes Wear Unequally.

Sometimes it will be found that the brushes wear away rapidly but at unequal rates, one brush being practically full length when the next is worn away, although both have been in service the same length of time. This trouble may be due to many causes, such as unequal brush pressures, bad bedding, vibration, etc. The best procedure is to ensure that the pressure, bedding and vibration questions are beyond reproach, and if these are made correct the trouble will usually cease, so long as there is not anything inherently wrong with the design. If the trouble cannot be overcome the motor makers should be informed.

### How to Fit the New Brushes.

When the new brushes are received they should be carefully unpacked and examined to make sure that they are unbroken and are of the same size and grade (or its equivalent) as the old ones. If everything is in order the old brushes should be removed and the holders cleaned of all dust before the new brushes are inserted. Care should be taken that every brush slides freely in its holder and the copper flexible which is moulded into or attached

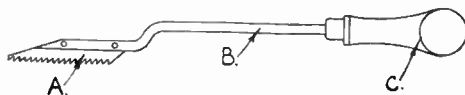


Fig. 33.—A HOME-MADE MICA UNDERCUTTER.

The small piece of hack saw blade A is screwed, rivetted, or soldered, into the slotted rod B, which is in turn fitted into the handle C. The use of this tool is similar to that of the file shown in Fig. 31.

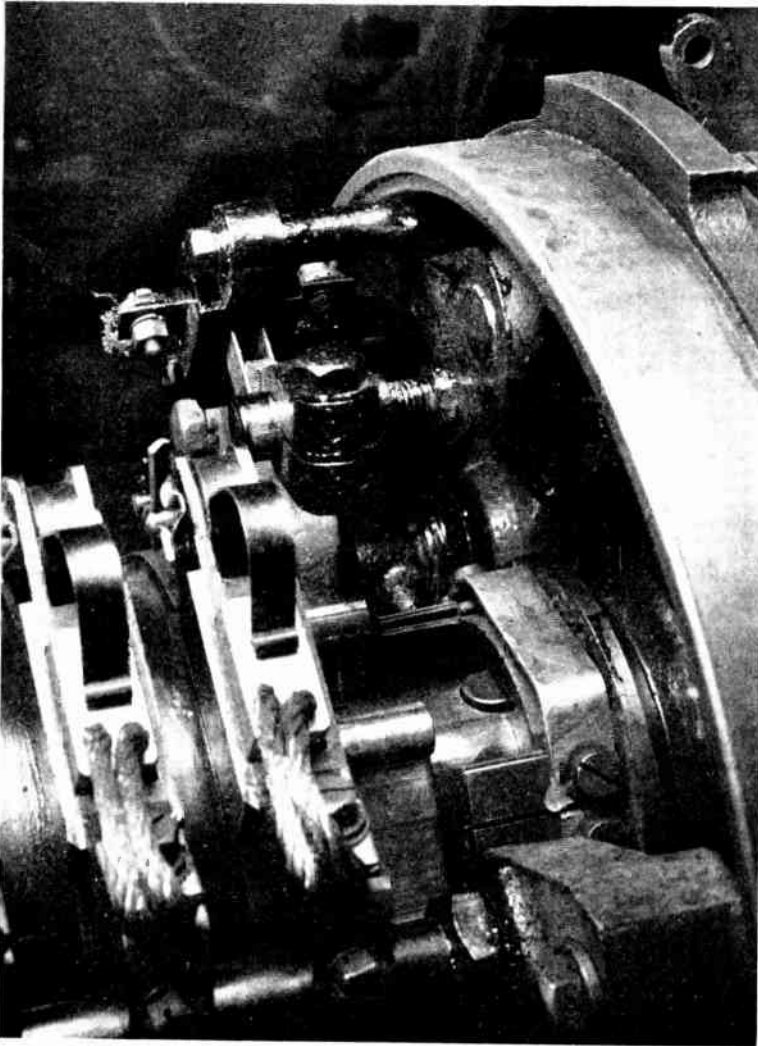


Fig. 34.—ARRANGEMENT OF A.C. MOTOR BRUSHGEAR.

This shows clearly the brush with its flexible lead clamped under the screw provided for it. The brush spring and its adjusting lever may also be seen, and the topmost detail is the interlock switch with its terminals and contacts. The gear shown is fitted with short-circuiting mechanism, and the shorting sleeve and its contacts are clearly visible on the right of the illustration. The contacts must be kept clean and tight and the sleeve and its mechanism should be lightly lubricated every six months. (*Metropolitan-Vickers.*)

to the brush should be secured to the brush holder by the terminal or screw provided for it.

The spring tension must now be adjusted to the correct amount with the new full length brush, and having ascertained that this is so for each individual brush, we

may proceed to grind in, or "bed," the brushes.

### Bedding Brushes.

The procedure is as follows: A strip of glass-paper or sand-paper (not emery paper or cloth) should be taken and placed in between the brush contact face and the commutator or slipring, the rough side of the glasspaper should be outermost, i.e., in contact with the brush, and the strip should be drawn backwards and forwards so as to cut the brush face to a radius which will be the same as the radius of the commutator. This procedure should be gone through until every brush has been shaped on its contact face to the radius of the commutator or slipring on which it rests. When every brush is fully ground in, all

dust should be scrupulously removed, the brushes should be lifted to ensure that they are moving freely and the spring tension should be checked.

### The Care of Sliprings.

When a slipring is in good condition, it is

smooth and highly polished on its contact surface, the colour being rather of a bronze tint in the case of brass or similarly coloured sliprings. All rings and their supports and insulation must be kept very clean so as to avoid leakage, flashing, or creeping trouble with consequent breakdown. If the rings become roughened or scored they may be cleaned up by means of sand or glasspaper when the damage is only slight, while a suitable commutator stone will be capable of dealing with greater roughening. When the rings are badly pitted, it will be necessary to turn them down in a lathe to a smooth, highly polished surface, although a "cutting grade" of commutator stone is available which may be used if the pitting is not very deep; these commutator stones are referred to later.

If the brushes are noisy, giving high-pitched squeaking noises with a slipring in perfect condition, a piece of rag on which a few drops of oil have been placed should be run once round each ring.

#### **Commutator Maintenance.**

The commutator has been developed from the most troublesome detail on a motor to one of the most reliable parts, and given proper maintenance, it will give excellent service. As in all other cases, cleanliness is most essential. It is, in fact, definitely dangerous to permit even the slightest accumulation of dirt on a commutator or its supports because of the potentials which exist between closely adjacent surfaces. In order to keep the commutator clean it is only necessary to wipe the contact surface and end with a clean cloth which is free from fluff, and a few drops of oil may be placed on this cloth to provide the necessary *very slight* lubrication, as has been described for sliprings. It is most important that any lubrication should be very sparing and no grease, dust, oil or dirt must be allowed to accumulate on any portion of the commutator.

#### **Using a Commutator Stone.**

The use of sandpaper (on no account must emery paper or cloth be used) has certain disadvantages for com-

mutator cleaning and a better method is to use a commutator stone. This is a shaped stone of special abrasive material which is also an insulator, and it may thus be used while the motor is alive. The stones are available in almost any size and in a variety of grades suitable for cutting or finishing, and they can be relied upon to produce a good job.

#### **When the Commutator is Badly Worn.**

If the commutator is badly worn, being ridged or burnt, its surface must be trued up, and for this purpose it is usual either to turn same in a lathe or to grind it up. Turning the commutator necessitates the removal of the armature unless a special turning fixture is available to carry out the job where it stands; if it is desired to avoid removal of the armature, grinding can be used, a portable grinding attachment being *rigidly mounted* upon a traverse head which is, in turn, securely fixed to some portion of the motor or its foundations.

#### **Undercut the Mica.**

It is usual nowadays for the mica intersegment insulation to be undercut or reduced below the level of the copper commutator surface, and this should always be done when the original arrangement of the commutator incorporated reduced micas. It should be noted that it is not usual to reduce the micas on motors which are to run very silently, and certain other exceptions occur, such as high voltage generators, and some rotary converters. On industrial motors and generators, however, reduced mica is the common modern practice, and it is usual to cut back the mica so that the slot between the segments is between  $\frac{1}{16}$ -in. and  $\frac{3}{16}$ -in. deep; deeper undercutting is dangerous since it may be filled up with carbon dust and result in a short circuit between segments.

#### **Undercutting Must be Thorough.**

The different appliances used for this purpose are shown in the sketches and illustrations, and very little need be said regarding the operation of them since the method of use is obvious.

After the mica has been removed and all dust cleaned from the commutator surface

and mica grooves, the edges of the segments should be very slightly bevelled with a smooth piece of hard steel so as to remove the sharp edge of the copper which is left when the mica has been undercut.

### Scrape Out the Grooves Yearly.

An undercut commutator will operate quite satisfactorily providing the brush grade is suitable and when the reservations which have been previously mentioned do not apply. During the annual overhaul the grooves should be scraped clean, using a piece of hard fibre or close-grained hardwood, and beyond this slight extra attention the undercutting of the mica gives rise to no additional maintenance work. Oil and grease should not be permitted on any commutator, and when the mica is recessed the presence of these, together with dust, is particularly objectionable; care should, therefore, be taken of this point and should the local air carry oil fumes or vapour it may be necessary to varnish the grooves. The motor maker or brush manufacturer will advise on this point.

### Causes of Sparking and Remedies.

(1) Motor is overloaded—reduce load or install larger motor.

(2) Brushes out of position—set to marked position or move rocker *slowly* until sparking becomes a minimum.

(3) Brushes are not making perfect contact, this may be due to:—

(A) Dirty commutator or brushgear—clean.

(B) Brushes may need grinding in—see “Bedding Brushes.”

(C) Brushes sticking in holder—free same, by sandpapering if necessary. Brushes must slide easily but not be too slack.

(D) Brush pressure too light—measure and increase same if necessary.

(4) Commutator requires cleaning or smoothing—see previous notes.

(5) Brush “pigtails” or shunts may be loose or detached—fasten same.

(7) Defect in armature, such as:—

(A) Earthed conductor—shows up on “Megger Test.”

(B) Short-circuited coil or conductor—

heats up rapidly and burns commutator by very violent sparking.

(C) Open-circuited coil—sparks seem to go all round the commutator and commutator is burned at the bars to which the open-circuited coil is connected. This trouble may be due to bad connection between armature conductor and commutator.

All the above faults will necessitate either return of the armature to its maker, or the attention of a skilled winder.

(8) High bars—one or more commutator bars stand up higher than the rest when motor is running, due to loose or distorted commutator. Brushes “click” and jump. Tighten commutator nut or studs, if necessary, and true up the surface by turning or grinding.

(9) High mica—as for “High bars”—commutator blackens quickly—true up as for (8) and undercut mica if case is suitable (see previous notes).

(10) Low bars—one or more commutator bars low in level, shown up by blackening of low bars—true up.

(11) Flat spot on commutator—caused by a blow, periodic vibration or violent periodic sparking due to some other cause. Brushes jump and several bars close together are blackened and burnt. True up.

(12) Bent shaft—commutator runs eccentric—straighten shaft or replace.

(13) Brush arms may not be spaced equal distances apart. Only likely to occur when motor has been dismantled. Check by counting commutator bars between rows of brushes. All numbers should be equal; if not, adjust position of displaced brush arms.

### Brushgears Generally.

When there is any brush lifting and short-circuiting mechanism on A.C. motors this should be lubricated every six months with a little grease. Do not use too much or it may be thrown off on to the brushes and holders. Any short-circuiting blades and jaws must be kept clean and in good contact and all connections should be kept clean, tight and in good repair. Cleanliness of brushes, holders, sliprings or commutator and all adjacent parts is essential and will amply repay attention.

# ELECTRIC CIRCUIT CALCULATIONS FOR LIGHTING, HEATING AND D.C. POWER

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

IT is not often that the electrical engineer has occasion to calculate the resistance of conductors in the course of his everyday work, as there are many conveniently arranged tables giving the resistance of wires of standard sizes. Every electrical engineer should, however, be able to calculate resistances when necessary, and there is no reason why everyone who can divide and multiply should not be able to do this.

The resistance of a wire depends on three things :—

(a) Its length. *The longer the wire the greater the resistance.* A wire 10 yards long offers twice as much resistance to the flow of current as a wire 5 yards long.

(b) The cross sectional area of the wire. *The greater the area the less the resistance.*

For example, a wire or cable with a cross sectional area of  $\frac{1}{10}$  square inch would have only one half the resistance of a wire of equal length with an area of  $\frac{1}{20}$  square inch.

(c) The material of which the wire is made. Some metals, e.g., copper and silver, have high conductivity, whilst other metals such as platinum have low conductivity. *The resistance between the faces of an inch cube of metal*

*is called the specific resistance of the metal.* The value of this specific resistance is given in tables which have been found as a result of experiments. The specific resistance of copper is about 0.66 millionth of an ohm, i.e., 0.66 microhm per inch cube. The above facts have been put into a simple formula, viz. :—

$$\text{Resistance} = \frac{\text{Length of conductor} \times \text{specific resist. of metal}}{\text{Cross sectional area}}$$

Using the well-known symbols, this is expressed briefly as :—

$$R = \frac{l \times \rho}{a} \dots\dots\dots(1)$$

Where :—

*R* is the resistance,  
*l* is the length of the conductor,

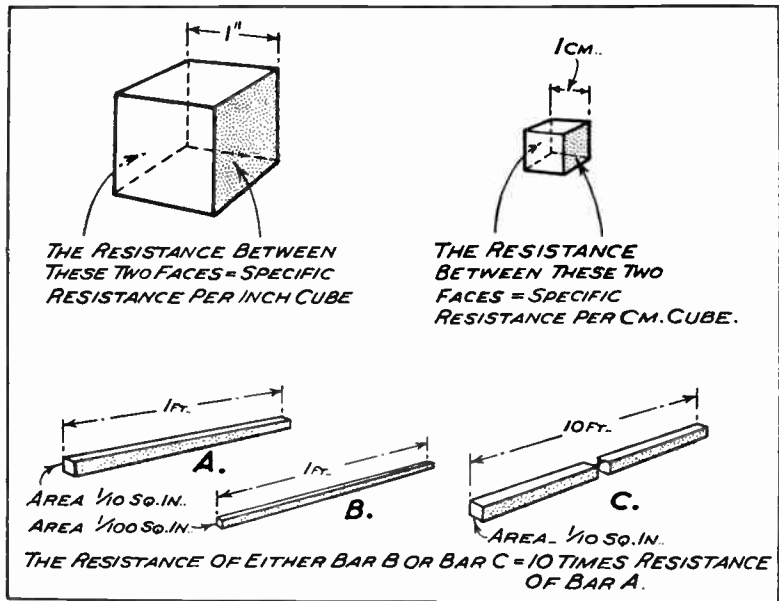


Fig. 1.—PICTORIAL REPRESENTATION OF SPECIFIC RESISTANCE AND LAWS OF RESISTANCE.

$a$  is the cross section of the conductor,  $\rho$  (Greek letter, pronounced rho) is the *specific resistance*, or resistivity of the material of the conductor.

The length and cross section must be expressed in a common system of units (i.e., length in inches, cross section in square inches; or length in centimetres, cross section in square centimetres). The specific resistance must be expressed in

Specific resistance is usually expressed in ohms, or microhms (1 microhm = 1 millionth of an ohm =  $10^{-6}$  ohm), per inch cube, or per centimetre cube, according to the system of units adopted for length and cross section. But this method of expression must be considered as a shortened form of the more correct expression:—ohms per inch length per square inch of cross section.

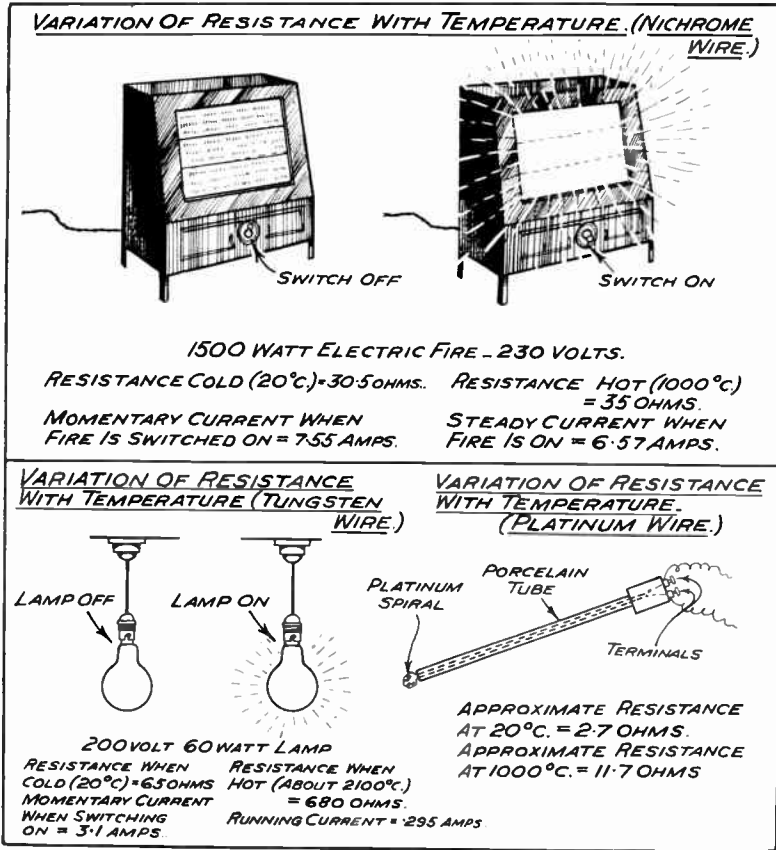


Fig. 2.—VARIATIONS OF RESISTANCE WITH TEMPERATURE. Showing variations with nichrome, tungsten and platinum wire.

the same system of units as that employed for length and cross section.

**Specific Resistance or Volume Resistivity.**

As already mentioned, this is defined as the resistance of a conductor having unit length and unit cross section. Thus, if in the above formula we make  $l = 1$ ,  $a = 1$ , then  $R = \rho$ .

When expressing the specific resistance in “ohms per inch cube” we do not imply that this quantity is the *resistance per cubic inch* of the material. This point must be very carefully remembered in calculations of resistance, as in such calculations the ratio of length to cross section is involved, and not the product of these quantities (which would give the volume). To avoid such ambiguity specific resistance is frequently expressed shortly as ohm-inches or ohm-centimetres.

**Values of Specific Resistance.**

These values, for metals, depend upon the chemical purity, hardness, temperature, etc. Average values (which may be used in the majority of calculations) are:—

	Microhm-	
	inches.	
ANNEALED COPPER	..	0.68 (20° C.)
ANNEALED COPPER	..	0.666 (60° F.)
HARD-DRAWN COPPER	..	0.69 (60° F.)



	Microhm-inches.	
ANNEALED ALUMINIUM..	0.96	(60° F.)
IRON (pure) .. .. .	3.8	(60° F.)
TUNGSTEN .. .. .	2.4	(60° F.)
NICHROME (alloy of nickel and chromium; used for electric heaters)	35	(20° C.)
EUREKA (alloy of copper and nickel; used for shunts and series resistances in instruments, resistance coils, etc.)..	18.5	(20° C.)
MANGANIN (alloy of copper, nickel and manganese; used for standard resistance coils, etc.) ..	20	(20° C.)
CARBON (non-metal) ..	1,600 to 4,000	(Varies with grade of carbon, method of manufacture, etc.)

amount  $R_1/254$ . Hence the temperature rise in degrees Centigrade is :—

$$T = \frac{R_2 - R_1}{R_1/254} = 254 \left( \frac{R_2 - R_1}{R_1} \right) \dots\dots(2)$$

If the cold resistance had been measured at a temperature  $t_1$  instead of at 20° C. the resistance  $R_1'$  at 20° C. would have to be calculated, and the increase in resistance from this value obtained. Thus :—

$$R_1' = R_1 \left( 1 + \frac{20 - t_1}{254} \right) \dots\dots(3)$$

Hence the temperature rise from 20° C. is :—

$$254 \left( \frac{R_2 - R_1'}{R_1'} \right)$$

and the actual temperature rise is :—

$$254 \left( \frac{R_2 - R_1'}{R_1'} \right) - (20 - t_1) \dots(4)$$

**Change of Specific Resistance with Temperature.**

The specific resistance of pure metals increases as the temperature increases, but that of certain alloys (e.g. eureka, manganin) remains almost constant over the normal range of air temperatures in electrical works and test rooms.

The specific resistance of copper (of the purity used for electric wires and cables) changes  $\frac{1}{254}$ th of its value at 20° C. for each degree change of temperature from 20° C. Alternatively, in the Fahrenheit temperature scale the change in specific resistance per °F. from 60° F. is  $\frac{1}{410}$ th of the value at 60° F. These values are called the *temperature coefficient of resistance*.

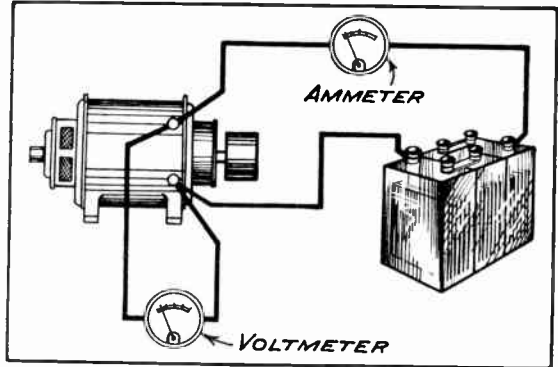


Fig. 3.—CALCULATING TEMPERATURE RISE OF A MOTOR. The resistance of the machine when cold is measured with an ammeter, voltmeter and battery as shown. Immediately after running the machine, the resistance is again measured, and from the two readings it is easy to calculate the temperature rise of the windings.

**Estimation of Temperature Rise by Change of Resistance.**

The temperature rise of armature and field coils may be estimated by measuring the cold and hot resistances, and using the above values of temperature coefficient. Thus, if  $R_1$  is the cold resistance at a temperature of 20° C., and  $R_2$  is the hot resistance, the increase in resistance is  $R_2 - R_1$ . For each degree rise in temperature the resistance increases by the

**DATA OF RESISTANCE OF COPPER CONDUCTORS (ANNEALED).**

**Useful Rule.**

The resistance at 60° F. of a uniform copper conductor of 1 square inch cross section is 0.024 ohm per 1,000 yards, or 0.042 ohm per mile.

The resistance at 60° F. per 1,000 yards of solid circular wires of standard sizes used in electric installations is given in Table I.

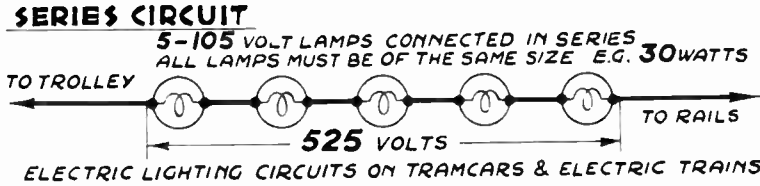


Fig. 4.—RESISTANCES OF SERIES CIRCUITS.

The total resistance is equal to the sum of the resistances of the several parts of the circuit.

TABLE I.  
DATA OF SOLID COPPER WIRES.

Diameter of Wire (inch).	Size S.W.G.	Cross Section (square inch).	Resistance per 1,000 yards at 60° F. (ohms).
0.0076	36	0.00001539	529.2
0.01	33	0.00007854	305.7
0.012	..	0.000113	212.3
0.018	26	0.000254	94.35
0.020	..	0.00036	36.35
0.036	20	0.00102	23.59
0.044	..	0.00152	15.79
0.052	..	0.00212	11.3
0.064	16	0.00322	7.46
0.072	15	0.00497	5.9
0.083	..	0.00541	4.38
0.093	..	0.0079	3.53
0.103	..	0.00833	2.88

material and cross sections are *proportional to the respective lengths*; (2) the resistances of conductors of given material and lengths are *proportional to the reciprocals of the respective cross sections*.

Thus :—

$$\text{Resistance of 1 mile of } 0.044'' \text{ wire} = 15.8 \times \frac{1,760}{1,000} = 27.8 \text{ ohms.}$$

$$\text{Resistance of 1 mile of } 0.064'' \text{ wire} = 27.8 \times \frac{0.00152}{0.00322} = 13.13 \text{ ohms.}$$

Alternatively, the calculation may be carried out in a single step. Thus :—

$$\begin{aligned} &\text{Resistance of 1 mile of } 0.064'' \text{ wire} \\ &= \text{Given resistance} \\ &\times \frac{\text{Length of } 0.064'' \text{ wire}}{\text{Length of } 0.044'' \text{ wire}} \\ &\times \frac{\text{Cross section of } 0.044'' \text{ wire}}{\text{Cross section of } 0.064'' \text{ wire}} \end{aligned}$$

**Numerical Examples on Resistance.**

(1) If the resistance of 1,000 yards of copper wire 0.044 inch in diameter (0.00152 square inch in cross section) is 15.8 ohms, what will be the resistance of 1 mile of copper wire 0.064 inch in diameter (0.00322 square inch in cross section)?

This problem may be worked by simple proportion, using the following rules: (1) the resistances of conductors of given

(2) What will be the resistance of 1,000 yards of copper wire 0.4 inch in diameter if the specific resistance of copper is 0.68 microhm per inch cube?

$$\text{The length} = 1,000 \times 36 = 36,000 \text{ inches.}$$

$$\begin{aligned} \text{The cross section} &= 0.785 \times (\text{diameter})^2 \\ &= 0.785 \times 0.4 \times 0.4 = 0.1257 \text{ square inch,} \end{aligned}$$

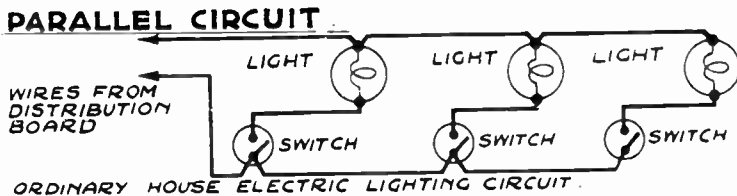


Fig. 5.—RESISTANCES OF PARALLEL CIRCUITS.

The reciprocal of the equivalent or joint resistance is equal to the sum of the reciprocals of the resistances of the several parallel parts of the circuit.

[Note.— $0.785 = \pi/4$ , where  $\pi$  ( $= 3.14$  approx.) is the ratio (circumference/diameter) for a circle.]

Hence :—

$$\text{Resistance} = \frac{36,000}{0.1257} \times \frac{0.68}{10^6} = 0.195 \text{ ohm.}$$

(3) A shunt for a moving-coil ammeter is required to have a resistance of 0.01 ohm and is to be made up of a single strand of Eureka wire 0.104 inch in diameter. What length is necessary? Specific resistance of Eureka = 18.5 microhms per inch cube.

Rearranging the formula  $R = \rho l/a$ , we have :—

$$l = Ra/\rho.$$

Now  $a = 0.785 \times (0.104)^2 = 0.0085$  square inch.

Hence :—

$$l = \frac{0.01 \times 0.0085 \times 10^6}{18.5} = 4.6 \text{ inches.}$$

(4) The cold resistance of the field winding of a motor is 120 ohms at an air temperature of 15° C. The hot resistance measured at the end of a heat run is 142 ohms. What is the temperature rise?

From formula (3) the resistance at 20° C. is :—

$$R_1' = 120 \left( 1 + \frac{20 - 15}{254} \right)$$

$$= 120 (1 + 0.0197) = 122.2 \text{ ohms,}$$

and from formula (4) the actual temperature rise (from 15° C.) is :—

$$254 \left( \frac{142 - 122.2}{122.2} \right) + (20 - 15) = 46.1^\circ \text{C.}$$

### Resistances of Series, Parallel, and Series-parallel Circuits.

*Series circuits.* The total resistance is equal to the sum of the resistances of the several parts of the circuit. Thus :—

$$R = R_1 + R_2 + R_3 + \dots \dots \dots (5)$$

where  $R$  is the total resistance and

$R_1, R_2, R_3 \dots$  the resistances of the several parts.

*Parallel circuits.* The reciprocal of the equivalent or joint resistance is equal to the sum of the reciprocals of the resistances of the several parallel parts of the circuit. The reciprocal of resistance is called *conductance*. Hence with parallel circuits, the equivalent conductance is equal to the sum of the conductances of the several parts. Thus :—

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \dots \dots (6)$$

With two circuits in parallel, we have the simple form :—

$$R = \frac{1}{1/R_1 + 1/R_2} = \frac{R_1 R_2}{R_1 + R_2} \dots \dots \dots (7)$$

*Series-parallel circuits.* The equivalent resistances of the series and parallel portions are calculated separately, and are

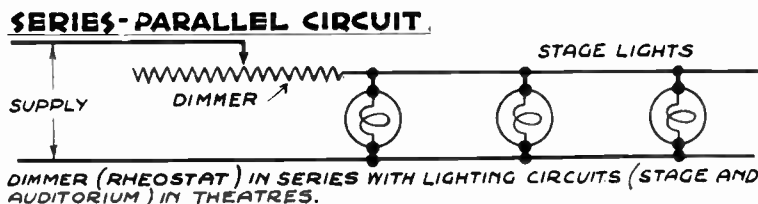


Fig. 6.—RESISTANCES OF SERIES-PARALLEL CIRCUITS.

The equivalent resistances of the series and parallel portions are calculated separately and are then added to give the equivalent resistance of the whole circuit.

then added to give the equivalent resistance of the whole circuit.

### Numerical Example.

Three conductors of resistances 3.5, 3, 1.5 ohms are connected in parallel. What is the equivalent resistance?

The separate conductances are :—

$$\begin{aligned} 1/3.5 &= 0.286 \\ 1/3 &= 0.333 \\ 1/1.5 &= 0.667 \end{aligned}$$

Hence the equivalent conductance = 1.286 and the equivalent resistance =

$$\frac{1}{1.286} = 0.778 \text{ ohm.}$$

### Law of Electric Circuit.

The relationship between the e.m.f.,

current and resistance is given by Ohm's Law. Thus :—

$$\text{Current} = \frac{\text{E.m.f.}}{\text{Resistance}}$$

or :—

$$I = E/R \dots\dots\dots(8)$$

If the circuit contains other internal e.m.f.'s, then :—

$$\text{Current} = \frac{\text{Applied voltage} - \text{Sum of counter e.m.f.'s}}{\text{Resistance}}$$

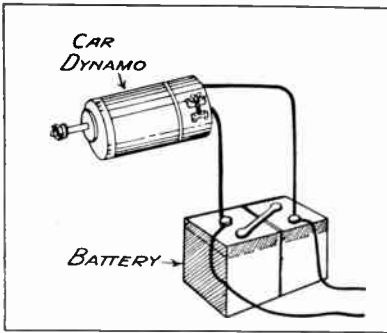
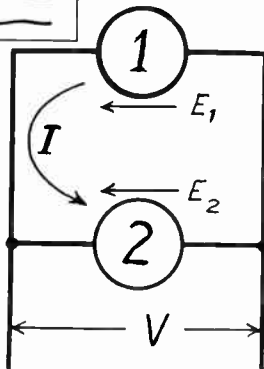


Fig. 7A.—PICTORIAL REPRESENTATION OF TWO E.M.F. SOURCES IN PARALLEL, NO EXTERNAL LOAD (E.G., A CAR LIGHTING DYNAMO AND STORAGE BATTERY).

Fig. 7B (right). — CIRCUIT DIAGRAM FOR TWO E.M.F. SOURCES IN PARALLEL.



tion : (1) when no external circuit is connected (i.e., no load) ; (2) when current is supplied to an external circuit.

For the *first case* (i.e., no load) the calculation of the common terminal voltage, when the e.m.f.'s have not exactly the same value, is not difficult, but it involves determining the circulating current, or currents. Thus with two sources, having e.m.f.'s  $E_1, E_2$  ( $E_1$  being the greater), and internal resistances  $R_1, R_2$ , respectively, the circulating current,  $I$ , Fig. 7B, is given by  $(E_1 - E_2)/(R_1 + R_2)$ . The common terminal voltage,  $V$ , is given by  $V = E_1 - IR_1 = E_2 + IR_2$ .

With three sources, e.g., storage cells, having e.m.f.'s  $E_1, E_2, E_3$  ( $E_1 > E_2, E_2 > E_3$ ), and internal resistances  $R_1, R_2, R_3$ , respectively, the circulating currents  $I_1, I_2, I_3$ , are best determined by first calculating the *fictitious* currents shown as  $I_a, I_b$  in Fig. 8B. These currents are calculated by equating the resultant e.m.f. in each circuit to the voltage drops produced by the circulating currents. Thus :—

$$E_1 - E_2 = R_1 I_a + R_2 (I_a - I_b)$$

$$E_2 - E_3 = R_2 (I_b - I_a) + R_3 I_b$$

Solving for  $I_a$  and  $I_b$  we have :—

$$I_a = \frac{(E_1 - E_2) R_3 + (E_1 - E_3) R_2}{R_1 R_2 + R_2 R_3 + R_3 R_1} \dots\dots(10)$$

$$I_b = \frac{(E_1 - E_3) R_2 + (E_2 - E_3) R_1}{R_1 R_2 + R_2 R_3 + R_3 R_1} \dots\dots(11)$$

Hence the common terminal voltage,  $V$ , is given by  $V = E_1 - I_a R_1$ , or  $V = E_2 - (I_b - I_a) R_2$ , or  $V = E_3 + I_b R_3$ .

For the *second case* (i.e., when the sources supply current to an external circuit) the calculation is more involved, and is best treated by the principle of fictitious currents circulating in the parallel circuits—an extension of the method employed in the no-load case. Thus with two sources (having e.m.f.'s  $E_1, E_2$ , and internal resistances  $R_1, R_2$ , respectively) connected to an external circuit or load of

**Voltage Drop.**

The voltage drop due to the current  $I$  passing through a resistance  $R$  is equal to  $RI$ . Hence if a source of e.m.f. has an e.m.f.  $E$  and an internal resistance  $R$  the terminal voltage ( $V$ ) will be :—

$$V = E - IR \dots\dots\dots(9)$$

**E.m.f. Sources in Series and Parallel.**

*Series.* The resultant e.m.f. is equal to the sum of the separate e.m.f.'s. The resultant terminal voltage = resultant e.m.f. — sum of voltage drops due to internal resistances of e.m.f. sources.

*Parallel.* Two cases need considera-

resistance  $R$ , the fictitious currents  $I_x, I_y$ , Fig. 9B, are determined from the equations:—

$$E_1 - E_2 = R_1 I_x + R_2 (I_x - I_y)$$

$$E_2 = R_2 (I_y - I_x) + R I_y$$

giving:—

$$I_x = \frac{E_1 R_2 + (E_1 - E_2) R}{R_1 R_2 + R_1 R + R_2 R} \dots\dots(12)$$

$$I_y = \frac{E_1 R_2 + E_2 R_1}{R_1 R_2 + R_1 R + R_2 R} \dots\dots(13)$$

Whence:—

$$V = E_1 - I_x R_1$$

and  $I_2 = I_y - I_x =$

$$\frac{E_2 R_1 - (E_1 - E_2) R}{R_1 R_2 + R_1 R + R_2 R} \dots\dots\dots(14)$$

**Numerical Examples.**

(1) A separately excited dynamo giving a no-load e.m.f. of 110 volts is connected in parallel with a 55-cell battery of accumulators, each cell of which gives an open-circuit e.m.f. of 2.01 volts. The internal resistance of the dynamo is 0.2 ohm and that of each cell is 0.005 ohm. What is the common terminal voltage?

The open-circuit e.m.f. of the battery is  $55 \times 2.01 = 110.5$  V., and the internal resistance of the battery is  $55 \times 0.005 = 0.275$  ohm.

Hence the circulating current

$$= \frac{110.5 - 110}{0.2 + 0.275} = 1.05 \text{ A.}$$

(discharge from battery) and the common terminal voltage =  $110 + 0.2 \times 1.05 = 110.21$  V.

(2) If in the preceding example the dynamo and battery supply a load of 2 ohms, what will be the common terminal voltage if the no-load e.m.f. of the dynamo is raised to 112 volts? Neglect the effects of armature reaction in the dynamo. Also, what will be the currents in the dynamo and the battery?

The circulating current  $I_x$ , Fig. 9B, is calculated from formula (12). Thus:

$$I_x = \frac{112 \times 0.275 + 1.5 \times 2}{0.055 + 0.4 + 0.55} = 33.6 \text{ A.}$$

Whence the common terminal voltage is:—

$$V = 112 - (33.6 \times 0.2) = 105.28 \text{ V.}$$

The current supplied by the battery may be obtained either from formula (14) or by calculating the load current and subtracting the dynamo current. Adopting the latter method, which is the simpler one, we have:—

$$\text{Load current} = 105.28 / 2 = 52.64 \text{ A.}$$

$$\text{Battery current} = 52.64 - 33.6 = 19.04 \text{ A.}$$

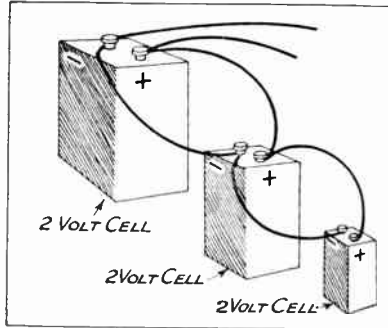


Fig. 9A.—PICTORIAL DIAGRAM OF THREE E.M.F. SOURCES IN PARALLEL.

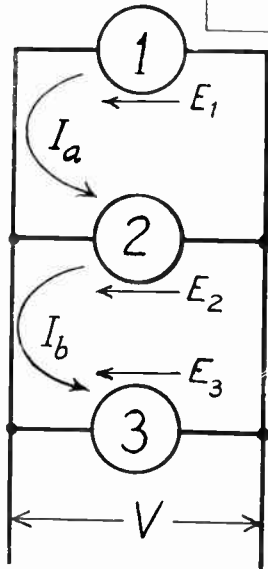


Fig. 9B (left).—CIRCUIT DIAGRAM FOR THREE E.M.F. SOURCES IN PARALLEL.

**Currents in Parallel Circuits.**

The division of current between simple conductors connected in parallel is easily calculated by the application of Ohm's Law. Thus because the same voltage,  $E$ , exists between the ends of the conductors, the currents are given by:—

$$I_1 = \frac{E}{R_1} \text{ in conductor No. 1,}$$

$$I_2 = \frac{E}{R_2} \text{ in conductor No. 2,}$$

and so on.

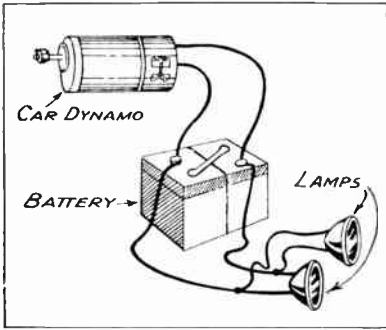


Fig. 9A.—PICTORIAL REPRESENTATION OF TWO E.M.F. SOURCES IN PARALLEL SUPPLYING AN EXTERNAL LOAD (E.G., A CAR LIGHTING AND STORAGE BATTERY SUPPLYING THE CAR'S HEAD-LIGHTS).

Whence:—

$$I_1 : I_2 : I_3, \text{ etc.} = \frac{I}{R_1} : \frac{I}{R_2} : \frac{I}{R_3}, \text{ etc.}$$

or, in the special case of two conductors:—

$$\frac{I_1}{I_2} = \frac{R_2}{R_1} \dots \dots \dots (15)$$

The total current,  $I = I_1 + I_2 + I_3 + \dots$

In the special case of two conductors, the ratios of the total current to the currents in each conductor can be expressed very simply in terms of the resistances of the conductors. Thus:—

$$\frac{I}{I_1} = \frac{I_1 + I_2}{I_1} = 1 + \frac{I_2}{I_1} = 1 + \frac{R_1}{R_2}$$

$$= \frac{R_1 + R_2}{R_2}$$

$$\frac{I}{I_2} = \frac{I_1 + I_2}{I_2} = 1 + \frac{I_1}{I_2} = 1 + \frac{R_2}{R_1}$$

$$= \frac{R_1 + R_2}{R_1}$$

Whence:—

$$I_1 = I \left( \frac{R_2}{R_1 + R_2} \right) \dots \dots \dots (16)$$

$$I_2 = I \left( \frac{R_1}{R_1 + R_2} \right) \dots \dots \dots (17)$$

These formulæ are very useful and should be noted.

The division of current between dynamos or batteries connected in parallel is calculated by the method given in the

preceding section, and the formulæ there given are directly applicable.

**Numerical Examples.**

(1) Two feeder cables having resistances of 0.05 ohm and 0.08 ohm are connected in parallel to carry a total current of 800 amperes. What will be the current in each cable and the voltage drop?

Applying formulæ (16), (17) the currents are:—

$$I_1 = 800 \left( \frac{0.08}{0.05 + 0.08} \right)$$

$$= 492 \text{ A. in the } 0.05\text{-ohm feeder.}$$

$$I_2 = 800 \left( \frac{0.05}{0.05 + 0.08} \right)$$

$$= 308 \text{ A. in the } 0.08\text{-ohm feeder.}$$

The voltage drop =  $I_1 R_1 = 492 \times 0.05 = 24.6 \text{ V.}$

(2) An ammeter having a range of 1 ampere and a resistance of 0.1 ohm is required to have its range extended to 10 amperes by means of a shunt connected in parallel with the instrument. What must be the resistance of this shunt?

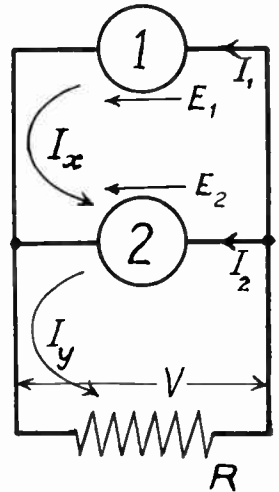


Fig. 9B.—CIRCUIT DIAGRAM FOR TWO E.M.F. FORCES IN PARALLEL SUPPLYING AN EXTERNAL LOAD, R.

The current in the instrument for full scale deflection is 1 ampere and the voltage drop is therefore 0.1 volt. Hence the shunt must carry  $(10 - 1) = 9$  amperes, and therefore its resistance =  $0.1/9 = 0.0111 \text{ ohm.}$

(3) Two cables having resistances of 0.2 ohm and 0.35 ohm are working in parallel. The current in the 0.2-ohm cable is 120 amperes. What is the total current?

The current in the 0.35-ohm cable is determined from formula (15). Thus:—

$$\frac{I}{120} = \frac{0.2}{0.35}$$

Whence  $I = 68.6$  A.

The total current =  $120 + 68.6 = 188.6$  A.

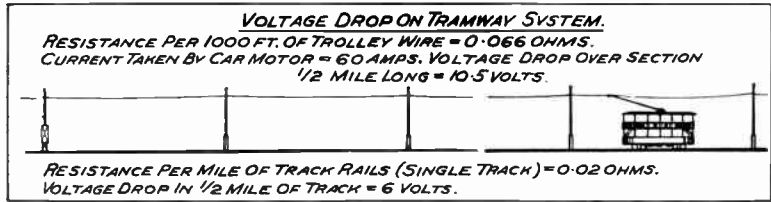


Fig. 10.—PICTORIAL REPRESENTATION OF VOLTAGE DROP ON A TRAMWAY SYSTEM.

**Current Density.**

This quantity is equal to (current/cross section of conductor), and is usually expressed in amperes per square inch. It is an important item in calculations of conductors for electric power distribution and electrical machines.

**Power and Energy.**

Electric power is the product of current and voltage; it is expressed in watts (or kilowatts, 1 k.W. = 1,000 watts).

Thus  $P = E I$ .

Energy (watts) is the product of power and time; it is usually expressed in kilowatt hours (k.W.h.).

Hence power is the rate at which energy is expended, since energy/time = power.

**Relationship Between the Units of Electric Power and Mechanical Power.**

The unit of mechanical power is the horse power which corresponds to the expenditure of energy at the rate of 33,000 feet pounds per minute.

1 horse power = 746 watts.

**Power Loss in Conductors.**

The voltage drop  $E$  in a conductor of resistance  $R$  carrying a current  $I$  is equal to  $R I$ . Hence the power supplied to the conductor is equal to:—

$$P = E \times I = R I \times I = R I^2 \dots (18)$$

Alternatively, the current,  $I$ , may be expressed in terms of  $E$  and  $R$ , in which case the power is given by:—

$$P = E \times I = E \times \frac{E}{R} = \frac{E^2}{R} \dots (19)$$

Of these alternative expressions the former is more convenient for calculations on series circuits and the latter is more convenient for calculations on parallel circuits.

**Current Density and Heating of Conductors.**

The power loss in a conductor tends to raise its temperature, the temperature rise being approximately proportional to the power loss per unit of cooling surface. This quantity is dependent



SIZE	B.Th.U	CALORIES	THEOR'L WATT SECONDS.	ACT'L. WATT SEC'S. @ 78% EFFICIENCY	IN PRACTICE
1/2 PTS.	285	72,000	300,000	385,000	500 WATTS FOR 13 MINS..
2 PTS.	380	96,000	400,000	512,000	800 WATTS FOR 11 MINS..
4 PTS.	760	192,000	800,000	1024,000	1000 WATTS FOR 17 MINS..
8 PTS.	1520	384,000	1600,000	2048,000	1300 WATTS FOR 26 MINS..

Fig. 11.—CONVERSION OF ELECTRICITY INTO HEAT.

Formulae: Actual Watt Seconds =  $\frac{\text{Pints} \times 1\frac{1}{4} \times \text{Temperature rise } ^\circ\text{F} \times 1058}{\text{Efficiency}}$

on both the diameter of the wire and the current density. Thus:—

$$P = I^2 R = I^2 \frac{l \rho}{a}$$

External surface =  $\pi dl = 4 l a/d$   
 Whence:—

$$\frac{P}{\pi dl} = \frac{I^2 l \rho d}{4 a^2 l} = \left(\frac{I}{a}\right)^2 d \frac{\rho}{4}$$

Hence for a given temperature rise, small conductors may be worked at a higher current density than large conductors. This point is very important with rubber insulated cables as overheating causes rapid deterioration of the rubber insulation.

TABLE II.

DATA OF COPPER WIRES AND CABLES USED FOR ELECTRIC LIGHTING AND POWER CIRCUITS, GIVING PERMISSIBLE CURRENT DENSITIES AND POWER LOSS FOR RUBBER INSULATED CABLES.

Number of wires and diam. of each wire (inch).	Nominal cross section (square inch).	Current (amp.).	Current density (amp. per sq. in.).	Power loss per 100 yards (watts).
1 .030	0.001	4.1	4,100	396
1 .04	0.0015	6.1	4,060	588
1 .004	0.00322	12.9	4,100	1,240
7 .044	0.01	31	3,100	2,200
19 .004	0.06	83	1,380	2,760
19 .083	0.1	118	1,180	3,330
37 .083	0.2	184	920	4,140
91 .103	0.5	332	664	5,320
91 .103	0.75	461	614	6,860
127 .103	1.0	595	595	8,140

**Numerical Examples.**

(1) Determine the cross section of a cable 200 yards long to carry a current of 100 amperes if the power loss in the cable is to be 500 watts.

From formula (18) the resistance of the cable is  $R = P/I^2 = 500/100^2 = 0.05$  ohm.

Whence the cross section—from formula (1)—is:—

$$a = \frac{200 \times 36 \times 0.66}{0.05 \times 10^6} = 0.095 \text{ square inch.}$$

(2) A 460-volt motor taking a full-load current of 300 amperes is supplied from a

power station 250 yards distant. Determine the cross section of the cable and the voltage at the power station if the efficiency of transmission is to be 98 per cent.

Power input to motor at full load =  $460 \times 300 = 138,000$  W.

Power supplied from station:—

$$= \frac{138,000}{0.98} = 140,700 \text{ W.}$$

Power loss in cable (by difference) = 2,700 W.

Voltage drop in cable =  $2,700/300 = 9$  V.

Voltage at power station =  $460 + 9 = 469$  V.

Resistance of cable =  $9/300 = 0.03$  ohm.

Length of cable =  $2 \times 250 = 500$  yards.

Cross section of cable

$$= \frac{500 \times 36 \times 0.66}{0.03 \times 10^6} = 0.395 \text{ square inch.}$$

**Conversion of Electrical Energy into Heat.**

Heat energy is expressed either in calories or in British Thermal Units. One calorie is the heat required to raise the temperature of 1 gramme of water 1° C., and 1 British Thermal Unit (B.Th.U.) is the heat necessary to raise the temperature of 1 pound of water 1° F. The relationship between these heat units and electrical units is as follows:—

1 calorie = 4.2 watt-seconds.

1 B.Th.U. = 1,058 watt-seconds = 0.29 watt hour.

Hence the heat produced by a current  $I$  passing through a resistance  $R$  for a time  $t$  seconds will be:—

$$I^2 R t / 4.2 \text{ calories} \dots\dots\dots(20)$$

$$I^2 R t / 1,058 \text{ B.Th.U.} \dots\dots\dots(21)$$

**Water Heating.**

The electrical energy supplied to the heater must be greater than the heat energy required for the water because of heat losses occurring during the heating process and losses in the heater itself. To allow for these losses we include the heat efficiency in the calculations.



# LOW VOLTAGE LAMPS

## FOR CAR AND OTHER PURPOSES

By E. HILL

**L**OW voltage lamps are used for a great variety of purposes, such as the lighting of motor vehicles, cycles, motor and steam boats, aeroplanes and trains, for hand, pilot and mine lamps, and for temporary lighting circuits.

The lamps range from 2-volt screw cap bulbs to 25-volt, 60-watt bulbs of the S.C. or B.C. type.

### Flash Lamps.

Everyone is familiar with the flash lamp made up of one or more dry cells in a container of rectangular or cylindrical shape, a press or sliding switch and a cover in which is mounted a lens, reflector and lampholder. Miniature screw cap bulbs are almost invariably used for this type of lamp, and as primary cells are relied on as the supply source the current consumption is kept down to a minimum, and the effectiveness of the light depends largely on the brightness and efficiency of the reflector and lens. The screw cap forms one terminal of the bulb and is connected to one end of the filament, the other end being connected through the vitrite to the centre contact consisting of a bead of solder. The top half of the bulb is usually obscured by frosting or opal glass so that there are no direct rays and all the light is reflected. Similar bulbs are used for hand inspection lamps having either dry cells or accumulators as the power supply. The same type of bulb is used on telephone exchange switchboards as a pilot lamp, to indicate whether a circuit is alive. On car switchboards the screw cap bulb may be used as a pilot lamp for direction indicators, and in the ignition circuit as a warning lamp.

### Bayonet Cap Bulbs.

Similar use for hand lamps, pilot lamps, switchboard lighting, etc., is made of small bayonet cap bulbs of 2, 4, 6 or 12 volts. B.C. bulbs are made with centre contact for single pole wiring or double contact for double pole wiring. Either screw cap or bayonet cap bulbs may be used for temporary circuits such as table lighting, shop window and sign illumination and indoor or outdoor exhibition lighting; being connected in series when

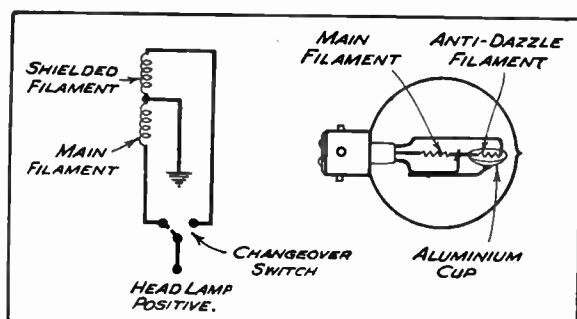


Fig. 1.—GRAVES BULB, SHOWING METHOD OF CONNECTING.

run off the mains or in parallel across accumulators.

### How the Lamps are Connected.

For general use lamps connected in series are unsatisfactory, as the failure of one lamp will put the whole circuit out of action. This principle is utilised in the connection of a visible pilot lamp in series with a remote lamp or instrument so that a breakdown of the circuit is indicated by the pilot light going out, or failing to light when the circuit is switched on.

### Electric Headlights for Cycles.

Electric headlights for cycles are similar

**SOME TYPICAL CIRCUITS USING LOW VOLTAGE LAMPS.**

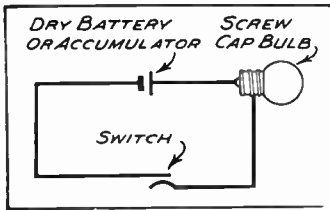


Fig. 2.—Circuit of Flash or Hand Lamp.

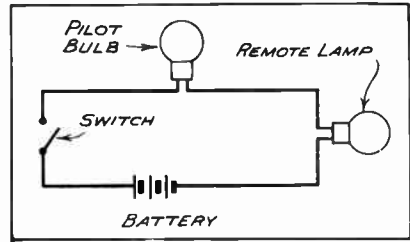


Fig. 3.—Circuit Showing Pilot Lamp in Series.

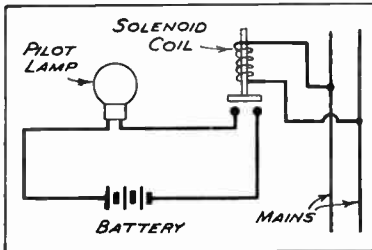


Fig. 4.—Circuit for Pilot Lamp Arranged to Indicate Failure of Mains Circuit.

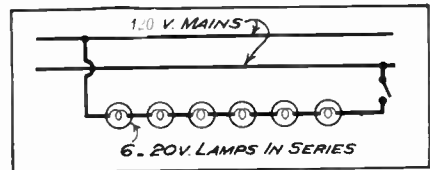


Fig. 5.—Connections for Sign or Decoration Lamps in Series.

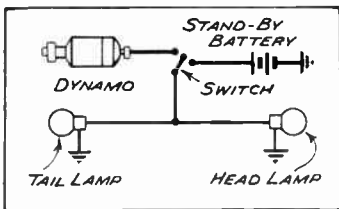


Fig. 6.—Connections of Dynamo for Cycles.

Showing auxiliary battery for lights when the machine is stationary.

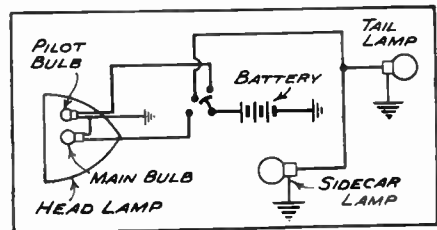


Fig. 7.—Connections of Battery Lighting Set for Motor-cycles.

in construction to flash lamps and are provided with a mounting for fitting to the lamp bracket. Electric lamps for motor-cycles, motor-cars, coaches, omnibuses and vans differ only in details of construction.

**Regulation Lights for Cars, etc.**

The regulation lights consist of a

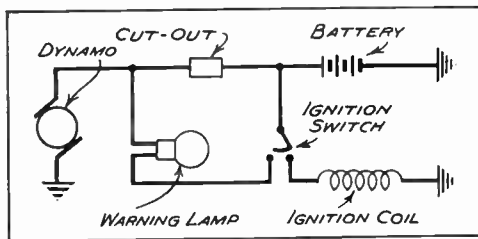


Fig. 8.—Connections for Warning Lamp for Coil Ignition.

The lamp glows when switch is left on with engine stalled. When the dynamo cuts in, the E.M.F. of the dynamo is opposed to the E.M.F. of the battery through the lamp and no light is shown.

tail lamp showing a red light to the rear, a head light for motor-cycles, and two lamps indicating the width of three or four-wheeled motor vehicles, showing white lights ahead. In addition most motor passenger vehicles carry two head lamps, the two regulation lamps being termed side

lamps. The latter may be combined with the head lamps providing these are fixed within 12 inches of the outer edge of the wings. Side and tail lamps are usually fitted with 6-volt, 3 or 6-watt or 12-volt, 6-watt s.b.c. bulbs.

**Bulbs for Car Head Lamps.**

Suitable bulbs for head lamps having an aperture of up to 6½ inches are the 6-volt, 12-watt or 12-volt, 24-watt s. b. c. Above that size 6-volt, 18-watt or 12-volt, 36-watt are usually fitted. For extra powerful lamps 48-watt or even 60-watt bulbs may be used, although the new regulations may limit these to 36 watts.

**The Problem of Dazzle.**

The problem of providing an adequate

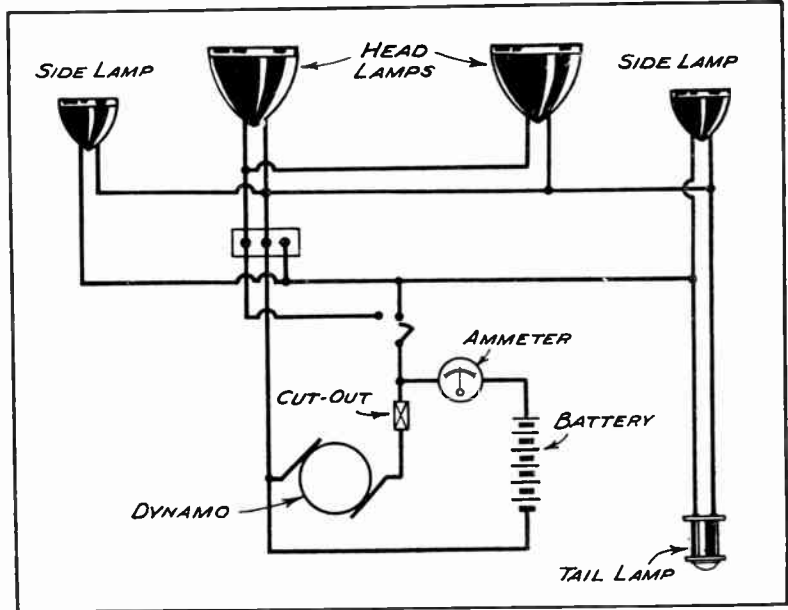


Fig. 9.—CONNECTIONS FOR A TYPICAL FIVE-LAMP CAR LIGHTING SET. Suitable bulbs for head lamps having an aperture of up to 6½ inches are the 6-volt, 12-watt or 12-volt, 24-watt, s.b.c. Side and tail lamps are usually fitted with 6-volt, 3 or 6-watt, or 12-volt, 6-watt s.b.c. bulbs.

driving light without interference by dazzle with oncoming traffic, has exercised the minds of many inventors, and numerous devices have been tried and manufactured with this objective. Many of these devices are successful in cutting off the top rays of light, and thus preventing dazzle on a level road, but in most instances there is a pronounced falling off of the intensity and range of the beam. Dipping the beam by movement of the reflector, or lamp body, or displacement of filament, definitely shortens the effective lighting range and limits the safe driving speed of a car at night, especially on unlit roads or on roads with a switch-back contour.

**“Dipping.”**

As an anti-dazzle device “dipping” is probably the most effective and is applicable to most makes of head lamps in one form or another. The Graves type of bulb, which has two filaments—one for the main beam and the other shielded so as to give a horizontal “cut off” of the beam—is also satisfactory from the anti-

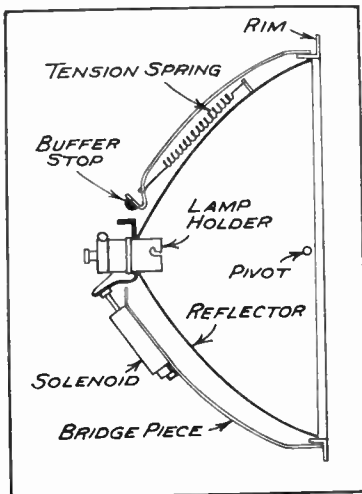


Fig. 10.—SECTION OF DIPPING REFLECTOR.

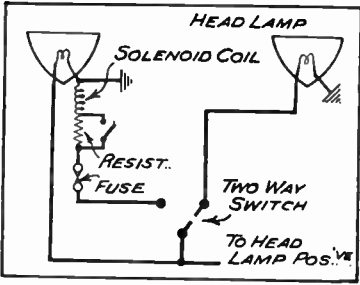


Fig. 11.—Connections of Dip and Switch Arrangement for Car Head Lights.

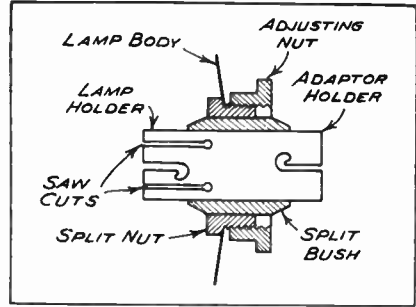


Fig. 12.—External Focussing Type of Lampholder.

dazzle point of view and gives a longer range of lighting, thus permitting a rather higher safe driving speed. Dimming or blacking out of lamps is unsatisfactory and is liable to cause the driver behind the lamps to lose sight of the road temporarily, with consequent danger to other road users.

**How to Counteract Dazzle.**

The chief source of dazzle is the inaccurate focussing of bulbs in relation to the reflectors. This is demonstrated by the large number of side lamps which have a dazzling effect, owing to the inadequate means of focussing provided. The proposed regulation stipulating that all side lamps should have frosted lenses, will, if enforced, reduce the glare problem considerably. The setting of lamps also has a bearing on the subject and a safer and better driving light will be obtained if

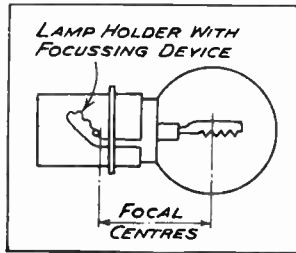


Fig. 13.—Lampholder with Focussing Device.

the axis of the lamp and bulb is set parallel to the road surface and to the wheel base of the car, or set over slightly towards the near side. Many experiments have been made by means of coloured bulbs, or discs of amber and blue in front or behind the lens, to obtain better lighting in fog, but no conclusive evidence has been produced that a more penetrative light is obtained by these means. It has been established, however, that amber or blue lights do not reflect back from fog to the same extent as white lights, and surrounding objects are therefore more visible when seen through these coloured lights.

**Parabolic Reflectors.**

Parabolic reflectors are used on most car head lamps and the lighting efficiency depends largely on their accuracy and polish. Reflectors are made of brass or

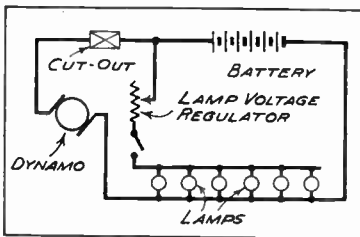


Fig. 14.—Single Battery Train Lighting System with Regulator.

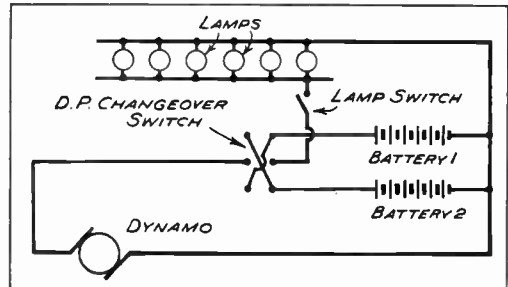


Fig. 15.—Double Battery Train Lighting System.

bright steel sheet drawn up to shape, planished, polished, nickel or copper-plated, silver-plated, and then highly polished. To protect the polish some manufacturers make a practice of coating the polished surface with colourless lacquer.

**Type of Bulbs for Reflectors.**

The type of bulb is also of importance and should be suitable for the particular head lamp in which it is used, in regard to contacts, cap fitting, focal centres and size of globe. Standard bulbs are gas filled and have s.b. caps, single or double contact, and may have single or double filaments. The main filament is a short spiral tungsten wire fixed axially in the lamp so that the light centre is 28.5 mm.  $\pm$  1.5 mm. from the bayonet pins, and the diameter of the globe is 38 mm.

**How to Obtain Correct Focussing.**

It is important that the axis of the bulb should coincide with the axis of the lamp reflector and a slack fit between the lampholder and the bulb is sufficient to prevent accurate focussing. Holders are now made to close limits, and additional saw cuts at right angles to the bayonet slots ensure that the holder fits snugly round the cap of the bulb. Various focussing devices are in common use on head lamps, the most efficient type consisting of a lampholder which can be adjusted forwards or backwards in a sleeve and locked in position by a nut, screw or collar.

The pressure of the contact plungers in lampholders, against the bulb contacts is

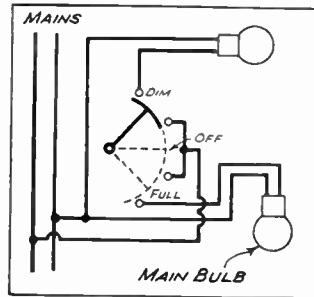
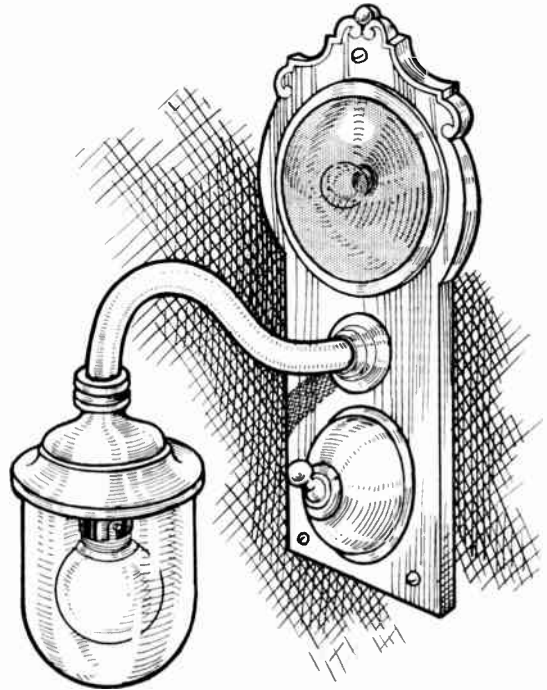


Fig. 16.—THE "NIGHT MAIL SAFETY LIGHT," SHOWING WIRING CIRCUIT.

also of importance and has been standardised for automobile lamps at 4 pounds per plunger. Spiral springs as used for lampholders quickly lose their resilience if employed as conductors for the current, and in well-designed holders the plunger connects directly between the external circuit and the bulb and is of sufficient cross section to carry the current without overheating.

**When Flat Spring Contacts are Used.**

On many modern car lamps, especially roof lamps, tail and stop lamps, plungers are replaced by flat

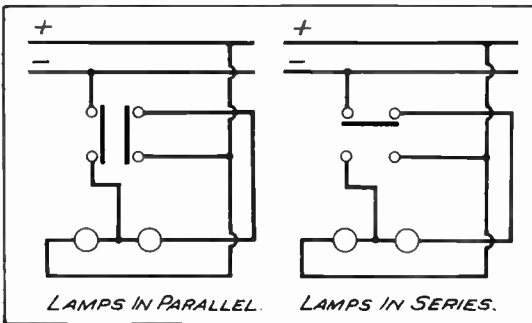


Fig. 17.—CONNECTIONS OF SERIES PARALLEL SWITCH FOR COMPARTMENT LIGHTING OF TRAINS.

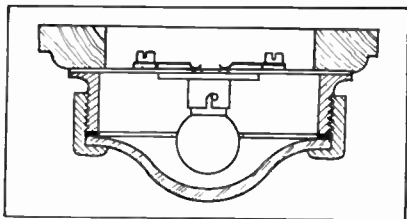


Fig. 18.—SECTION OF ROOF LAMP FOR CAR, BUS OR MOTOR-BOAT.

spring contacts bearing directly against the bulb contacts. These are easily adjusted if bent out of position, but should they become softened by overheating the only remedy is to replace them.

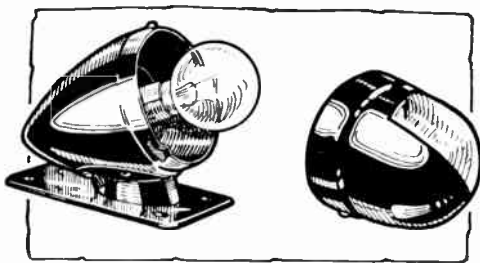


Fig. 19.—A TYPICAL NAVIGATION LIGHT.

### Fitting Lamp Fronts and Lenses.

The fitting of lamp fronts and lenses, for car use, can materially affect the efficiency. A badly fitted front may allow moisture to tarnish the reflector and reduce the effectiveness of the lighting. A cork or rubber ring interposed between the front and the lens will make a good watertight joint, but when the joint is made against the reflector rim, cork is the more suitable as rubber will adhere to the reflector and may damage the bulb or the reflector when the front is removed.

### How to Connect Up Head Lamps.

Connections to head lamps are made in several ways, e.g., lamps with hollow bolt fixing are wired through the bolt to a connecting block or direct to the lampholder in the interior of the lamp. Other lamps are wired from the lampholder

to an adaptor fixed in the lamp body and the external leads are connected to the adaptor by means of a plug.

### TRAIN LIGHTING LAMPS.

Gas-filled or vacuum b.c. bulbs of 16, 22 or 24 volts and 15 or 20 watts are used in lamps for train lighting purposes in this country.

Compartment fittings may be of the well glass type with one, two or three lampholders, or may be simple lampholders without other fittings and having exposed bulbs which utilise the white painted ceiling for reflecting the light.

Corridors are lit by single-bulb well glass lamps. For dining cars and saloons ornamental side bracket roof and table lamps are used.

### Regulating the Voltage Across the Lamp.

A high proportion of maintenance costs for the lighting of omnibuses and trains is allocated to lamp bulb renewals and some form of regulation to keep the voltage across the lamps within reasonable limits, is adopted on most systems, in order to

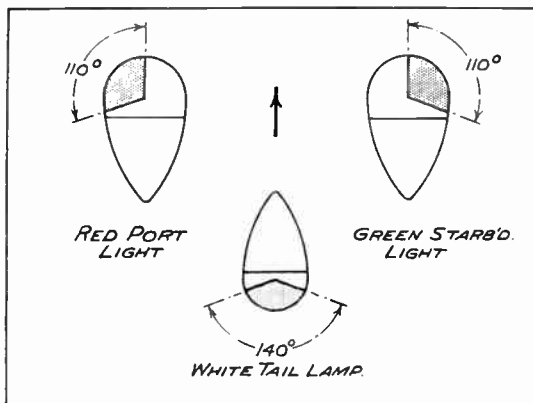


Fig. 20.—DIAGRAM OF AEROPLANE NAVIGATION LIGHTS.

minimise failures through over-volting.

On a double battery system, for instance, one battery is being

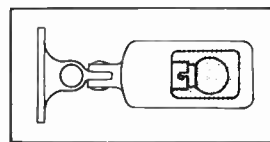


Fig. 21.—COCKPIT LIGHT WITH UNIVERSAL ACTION.

charged whilst the other supplies the lamp current at the normal battery discharge voltage.

On a single battery system a voltage regulator may be employed which interposes resistance in the lamp circuit when the charging voltage is above normal and cuts out resistance when the voltage drops.

For night travelling means are provided on some coaches for dimming compartment or sleeper lights. This may be done by putting resistance in the lamp circuit with a dimming switch or by changing the connections to the lamps from parallel to series by means of a special series-parallel switch.

**MOTOR BOAT LAMPS.**

Cabin and dashboard lamps are similar to those employed for car and omnibus interior lighting. Regulation navigating lights consist of a port, a starboard and a mast-head light. The port lamp shows a red light with a definite cut off, the light angle being  $110^\circ$ . The starboard light is green with a similar angle of cut off. The colour and transmission value of the red and green glass used in these lamps must conform to the specification issued by the Board of Trade.

The mast-head lamp shows a white light forward. Small searchlights may be carried, and these have a drum-shaped brass body mounted in trunnions on a bracket, which in turn may be given rotary motion on a vertical axis, thus allowing universal movement to the

direction of the light. Silvered glass reflectors are used and bulbs of 12 volts, 60 watts fitted. The searchlight front may be either hinged or detachable and fastened with swing bolts and wing nuts. A watertight joint is essential and this is provided by means of a rubber gasket between the front and the body of the lamp.

**AEROPLANE LAMPS.**

The regulation lamps for an aeroplane employed for night flying are similar to those of a ship. A red port-light with an aperture giving a cut off dead forward, and  $110^\circ$  round on the port side, is carried on the left-hand wing tip. The starboard green light on the right-hand wing has a similar angle of cut off on the starboard side. The tail lamp shows a white light through an angle of  $140^\circ$ , and an ahead light (shown by seaplanes at moorings) also shows a white light forward, through an angle of  $220^\circ$ .

**Special Bulbs for Aeroplanes.**

Special bulbs are necessary for these lamps, having a horizontal filament in the plane of the vertex of the angle of cut

off. For port and starboard lights, which should be visible at a range of five miles on a clear night, 12-volt gas-filled s.b.c. or b.c. bulbs are employed, rated at 24, 36, 48 or 60 watts according to the thickness and transmission value of the glass. Gas-filled s.b.c. 12-volt, 10-watt bulbs are fitted in tail and ahead lamps.

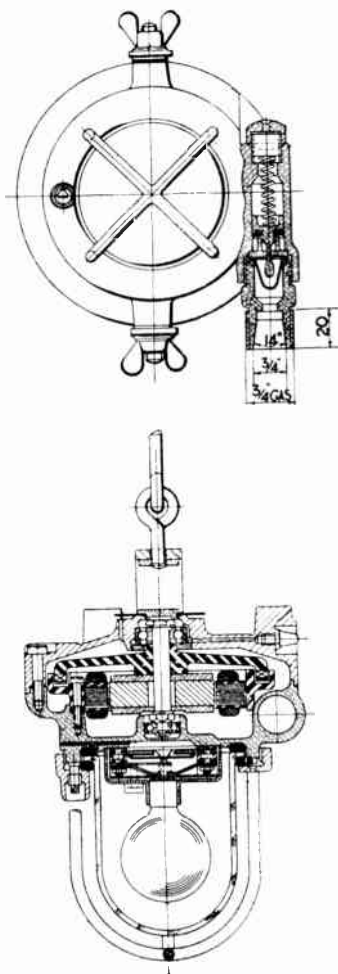


Fig. 22.—A PORTABLE PNEUMATIC ELECTRIC LAMP FOR MINES.

The metal casing contains an electric generator driven by a compressed air turbine working at a pressure of 40 lb. per square inch.

### Navigation Lamps for Aeroplanes.

In the design of navigation lamps, weight is of primary importance, and as sea air and spray have a detrimental effect on aluminium, light brass pressings and bakelite mouldings are utilised in the manufacture of lamps weighing only a few ounces each. A central navigation lamp may be used for aeroplanes having a wing span not exceeding 60 feet. Two of these lamps are required, one fitted above and one below the fuselage. Port, starboard and tail lamps are incorporated in this central type of fitting, which is cylindrical in shape and has one bulb only, mounted centrally. Red, green and white glass form the periphery of the lamp body and give the correct lighting apertures; the angle of cut off being determined by partitions inside the lamp body.

### Lights for Cockpits.

Cockpit lighting is effected by pillar type or tubular dash lamps, which may have universal mountings, allowing the light to be directed on any of the instrument dials. Concealed switchboard lighting is adopted on some of the larger air liners. Single bracket and roof lamps are used for cabin and other interior lights.

### MINE LAMPS.

Portable electric hand lamps for use in mines must conform to the special regu-

lations issued by the Home Office, and special precautions are taken to prevent any firedamp penetrating into contact with the lamp bulb or terminals. The accumulator is enclosed in a container, a vent being provided for the cell gases at a point outside the lamp casing. Two-volt, 2-watt vacuum bulbs are usually fitted and may have either peg top or small Edison screw caps.

### Pneumatic Electric Lamps.

Pneumatic electric lamps have been designed to minimise the danger from explosive gases in mines where firedamp is prevalent. This type of lamp is a stationary, self-contained unit coupled to a compressed air main. The metal casing contains an electric generator of the revolving field pattern, driven by a compressed air turbine working with an air pressure of 40 pounds per square inch. Safety devices are incorporated which cut off the current should the air supply fail or the lamp guard glass be broken or removed. Leads from the generator are attached to a cut-out on which is mounted the lampholder and bulb. A glass dome protects the bulb and this is secured to the body of the lamp with a gas tight locking ring. The range of bulbs used for lamps of this type are: 6-volt, 24-watt s.b.c., 12-volt, 36-watt s.b.c. and 25-volt, 60-watt b.c., all double contact and gas filled.

## QUESTIONS AND ANSWERS

### How does a warning lamp in a motor-car ignition system work?

The lamp glows when the switch is left on with engine stopped. When the dynamo cuts in, the E.M.F. of the dynamo is opposed to the E.M.F. of the battery through the lamp and no light is shown.

### What means are provided for dimming the lights on a train for night travelling?

By putting resistance in the lamp circuit with a dimming switch or by changing the connections to the lamp from parallel to series by means of a special series-parallel switch.

### What bulbs should be used for a typical five-lamp car lighting set?

Suitable bulbs for head lamps having an aperture of up to 6½ inches are the 6-volt, 12-watt, or 12-volt, 24-watt small bayonet cap. Side and tail lamps are usually fitted with 6-volt, 3 or 6-watt, or 12-volt, 6-watt small bayonet cap bulbs.

### How would you obtain correct focussing?

By seeing that the axis of the bulb coincides with the axis of the lamp reflector. A slack fit between the lamp holder and the bulb is sufficient to prevent accurate focussing.



# TELEGRAPH SYSTEMS

By T. E. HERBERT, M.I.E.E.,

*Superintending Engineer of South Lancashire District of Post Office Engineering Department.*

## FOUR KINDS OF ELECTRICAL COMMUNICATION.

THE subject of electrical communication comprises four main divisions, each with a technique of its own. They are: (a) the ordinary electric telegraphs used within the Kingdom and on Continental circuits; (b) submarine telegraphy; (c) telephony; and (d) radio communication. All these branches are interconnected and interdependent to a remarkable degree.

### Plant Required for Telegraphy.

The line plant required for telegraphs is similar to that used for telephones. There is, however, this difference: that all the earlier telegraphs used the earth as the return path for the current, whereas a metallic circuit is essential in telephony. Since telegraphs seem destined in future to be carried wholly in telephone

cables, the use of the earth return will have to be abandoned.

### Railway Telegraphs.

The railway companies use a single needle instrument (Fig. 1) in which the dots and dashes of the Morse code are represented by deflection of the needle to the left and right respectively. At rest, the needle dial is connected to line through the springs (Fig. 2). The movement of the handle to the side sends out currents in a direction corresponding to the direction in which the handle is moved. It will be observed that the battery is connected to the upper and lower insulated halves of the contact arm.

The substitution of shaped pieces of tin for the stop pins on the needle dial enables the instrument to be read by sound, the dots and the dashes being distinguished

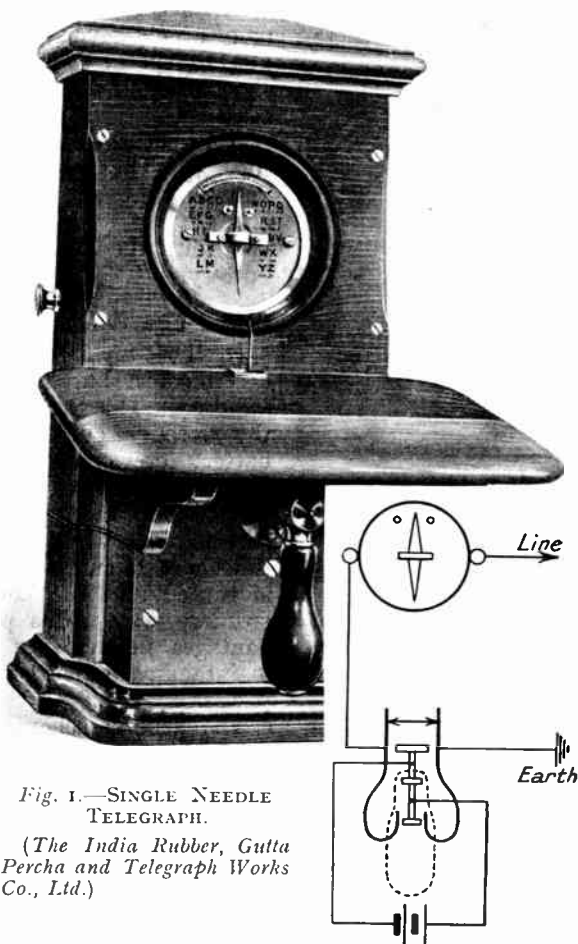


Fig. 1.—SINGLE NEEDLE TELEGRAPH.

(The India Rubber, Gutta Percha and Telegraph Works Co., Ltd.)

Fig. 2.—CONNECTIONS.

by the different pitch of the sounds made at each stroke of the needle on the sounding pieces.

### Double-plate Sounder.

In a large and necessarily noisy telegraph instrument room this proved inadequate. By substituting a neutral relay for the dial and providing different toned sounders this problem was solved. The

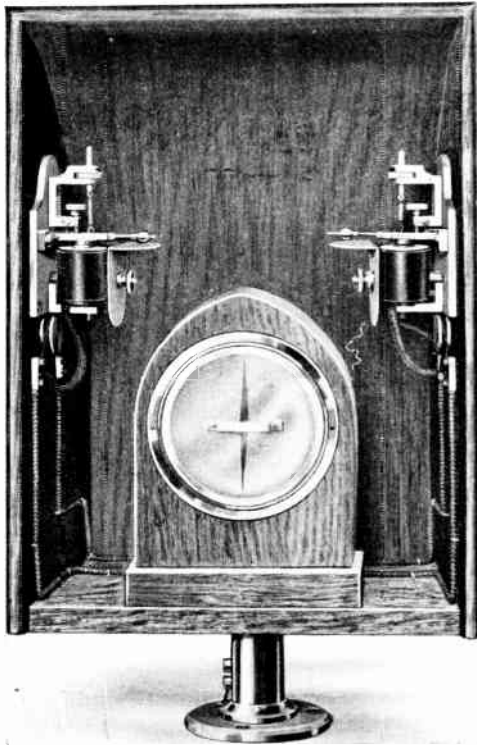


Fig. 3.—DOUBLE-PLATE SOUNDER. (Siemens.)

instrument was known as a double-plate sounder (Fig. 3).

### Morse Sounder.

The Morse code nowadays is, in principle, familiar to everyone. It consists of permutations of short and long signals as set out in Fig. 4. The dash is three times as long as the dot.

The ordinary sounder (Fig. 5) consists of an electro-magnet with a soft iron armature carried on a heavy brass bar held to the upper stop by an antagonistic spring. It is wound to a resistance of 20 ohms or

900 ohms according to whether it is to be operated by a primary battery or from the 24-volt power lead.

The dots and dashes of the Morse code are produced by the brass bar striking the stops, and here it may be remarked that the ear in recognising the dots and dashes of the Morse code really measures the interval of time between the downward click and the upward click of bar returning to rest, and this is perhaps why some difficulty is experienced in reading wireless signals where the dots and dashes are made by continuous sounds lasting for the duration of the signal.

### The Key.

The key calls only for the comment that its contacts are either of platinum or of a gold-silver alloy to avoid troubles due to sparking and to secure reliable signals by avoiding oxidation of the contacts.

A direct sounder circuit is shown in Fig. 6. The sounders are connected between line and earth when the keys are at rest. The depression of a key cuts out the sounder and applies the battery.

### Closed Circuit System.

In the simple form of sounder circuit described, a battery at each station is required. This necessity is avoided by the closed circuit system, in which the battery for working the circuit is located at the main office. Current continuously flows along the circuit through all the sounders and when it is required to signal the short circuit switch about the key is turned and the key operated in the ordinary way. This plan has some advantages in avoiding the necessity for maintaining primary batteries in remote places.

The general scheme will be apparent from an examination of Fig. 7.

### Post Office Teleprinter Circuit.

This system is used by the Post Office on some teleprinter circuits to avoid the provision of a battery at the outstation. But, in this case, the signals are made by disconnections instead of by transmitted currents.

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## *Our National Humorist at His Best*

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# THE BISHOP'S CAT

By P. G. WODEHOUSE

"Cats are not dogs!"

There is only one place where you can hear good things like that thrown off quite casually in the general run of conversation, and that is the bar parlour of the Anglers' Rest. It was there, as we sat grouped about the fire, that a thoughtful Pint of Bitter had made the statement just recorded.

Although the talk up to this point had been dealing with Einstein's Theory of Relativity, we readily adjusted our minds to cope with the new topic. Regular attendance at the nightly sessions over which Mr. Mulliner presides with such unflinching dignity and geniality tends to produce mental nimbleness. In our little circle I have known an argument on the Final Destination of the Soul to change inside forty seconds into one concerning

the best method of preserving the juiciness of bacon fat.

"Cats," proceeded the Pint of Bitter, "are selfish. A man waits on a cat hand and foot for weeks, humouring its lightest whims, and then it goes and leaves him flat because it has found a place down the road where the fish is more frequent."

"What I've got against cats," said a Lemon Sour, speaking feelingly, as one brooding on a private grievance, "is their unreliability. They lack candour and are not square shooters. You get your cat and you call him Thomas or George, as the case may be. So far, so good. Then one morning you wake up and find six kittens in the hat-box and you have to reopen the whole matter, approaching it from an entirely different angle."

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