ELECTRIC LIGHTING, STARTING AND IGNITION FOR MOTOR CARS

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A PRACTICAL EXPLANATION OF THE MOST MODERN METHODS OF MOTOR CAR LIGHTING, STARTING AND IGNITION, WITH GUIDE TO INSTALLATION, CONTROL, MAINTENANCE, FAULTS AND REPAIRS

BY

HAROLD H. U. CROSS

ELECTRICAL ENGINEER, FORMERLY WITH THE UNION OF SOUTH AFRICA GOVERNMENT, LATE OF THE SYDNEY TECHNICAL COLLEGE

AUTHOR OF "AUTOMOBILE BATTERIES," ETC.

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BLE GUIDE.—Faults at a Glance.

TABLE OF DYNAMO FAULTS

(Dynamotor used as Generator or Two-unit Systems.)

Dynamo not Charging.

Charging switch off.
Fuse on switchbox blown.
Slipping belt.
Battery not connected up.
Broken cable from dynamo.

Dynamo Output Low or Unsteady.

Belt slipping.
Loose fuse at switch-box, cut-out (broken winding, dirty contacts), loose back connections.
Loose connections at battery.
Loose terminal nuts.
Brush trouble (greasy, dirty, or worn too short, tight in holders, no spring tension), shunt brush position altered.
Commutator trouble (greasy, dirty, or worn rough), copper dust between the segments.

Dynamo Output too High. Dynamo Output too Low.

Trouble in shunt circuit (brush position altered, brush not bedding on commutator).

TABLE FOR LAMP FAULTS

Insufficient Light.

Bad bracket adjustment (see page 210).
Out of focus (see page 206).
Discoloured or blackened bulb.
Dirty reflector (see page 213).
Battery exhausted.

Varying Light as Car Speeds.

Loose or broken battery connection.

Light Fades Gradually.

Battery exhausted.
Dynamo polarity reversed.
Battery connected the wrong way round.

Flickering Light.

Faulty contacts at lampholder or adapter.
Loose connection.

TABLE OF STARTER FAULTS

(Dynamotor Operating as Starter or Two-unit Systems.)

Starter Fails to Turn Engine Over, or Very Weak.

Engine seized (partially or entirely).
Oil too thick for winter use.

IF ENGINE IS NORMAL TO HAND-CRANKING.

↓

Loose terminal nuts, brush trouble (worn, greasy or dirty, tight in holders, no spring tension). Commutator trouble (worn, greasy [illegible] Switch trouble (loose terminal connections), c[illegible]

TABLE FOR GUIDANCE IN BATTERY INSPECTION

Acid and Gravity Tests.

Has the acid level fallen below the tops of plates ?
Are vent plugs loose, cracked, or broken ?
Are there any indications of broken plates ?
Is the temperature above 105° F. ?
Is the acid dirty ?
Is the gravity below 1,150 ?
Is one cell " dead " or much below the others in S.G. ?

Terminals and Case.

Are the terminals dirty ?
Are the terminals loose ?
Are the connectors loose ?
Is the battery loose in its carrier ?
Is the top wet or fouled ?
Are there any badly protected wires connected to or near the battery ?
Are the main cables so short that they are tight ?
Is the wooden box rotted ?

After a Visit to Service Station.

Were the separators allowed to dry out when taken from the acid ?
Have separators been turned rib side towards the negatives ?
Have any separators been left out ?
Are there any signs of broken or loose jars, connectors, or posts ?
Is the sealing of covers and posts satisfactory ?
Are the connections correctly made ? (i.e. polarity, fit, etc.).
Has vaseline been applied ?
Is everything clean ?
Is the " earth " connection perfect ?

Loading and Charge Rate.

What is the capacity of the battery ? Is it too small ?
Are any of the following overload conditions present ? Stiff engine, cranking period unduly long, too frequent use of the starter, too many accessories attached to the electrical system, over-use of lamps.
Is the charge rate too low ?
Is the charge rate too high ?

Fixing of Battery.

Is the battery fitted near the exhaust pipe or too close to the engine ?
Is the battery secured by the handles or otherwise, so that an air space is provided around the outside of the case ?
If resting on the bottom, is it supported on cleats ?

N.B.—Further and more detailed information will be found on page 300.

To

GEORGE SULLY STOWE, Esq., M.I.Mech.E.

IN ACKNOWLEDGMENT OF MUCH UNSELFISH HELP

AND IN REMEMBRANCE OF THOSE HAPPY DAYS

SPENT ON THE WITWATERSRAND

PREFACE TO THIRD REVISED AND ENLARGED EDITION

In offering this edition to the motoring public, it has been the Author's aim to present the most salient features of Electric Lighting and Starting for Motor Cars in such a form as to be interesting to and readily comprehended by the average motorist.

It is hoped that the technical reader will bear this in mind when criticizing the book, as it is intended to be little more than a popular handbook. There is, however, a great deal of practical information scattered throughout its pages for the benefit of those directly concerned in the motor industry. The explanation of the technicalities is, according to most of the critics of former editions, adequately done; doubtless the Author's experience as lecturer on applied electricity at the *Eclectic College*, Los Angeles, California, has proved a fitting apprenticeship for such a task.

A considerable portion of the text appeared serially in the pages of *The South African Motorist*, and Chapter XII first saw light in the columns of *The Motor Trader*. These are reproduced by courtesy of the respective editors.

In the gathering of the material the Author has been ably assisted by Mr. Chas. J. Webb, A.I.A.E., and the painstaking way the publishers have set this out has made the book attractive to a wide circle of readers. In connection with the illustrations the Author would acknowledge his further indebtedness to those firms who have allowed reproduction of their copyright material, and have in many cases placed machines and other apparatus at his disposal for testing purposes.

Suggestions for incorporation in the subsequent editions will be gratefully received by the Author.

H. H. U. C.

TECHNICAL COLLEGE,
SYDNEY, NEW SOUTH WALES,
1922.

PREFACE TO FOURTH EDITION

IN deference to the wishes of numerous correspondents, besides a section on the latest design and practice, a short treatise on the principles of modern ignition has been included in this new edition. This originally appeared in the *Motor in Australia*, and the Author's best thanks are due to the Editor, Geoffry Goodge, Esq., in this connection.

Fuller details on the subject of Ignition will be found in the Author's forthcoming work on that subject to be included in "Lockwood's Manual" series.

H. H. U. C.

CONNAUGHT LODGE,
WESTENHANGER.
1926.

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PROLOGUE

THE TENDENCIES OF MODERN PRACTICE

Present Practice and the Trend of the Future—To-day and To-morrow

At the present day electricity plays a still more important rôle in connection with the modern automobile, whether designed for pleasure purposes or for commercial enterprise. Some years ago the author drew attention in detail to the remarkable advances that electricity had even then made in connection with the car. Most of his prophecies have been more than justified, and to-day in so far as the electrical department is concerned, there seems little gross improvement possible. Improvements that in the natural course of events are bound to occur will be chiefly concerned with important details in connection with the points about to be set forth.

There is, however, one phase of electrical endeavour in which the author apparently "backed the wrong horse," and that is in connection with the electrical gear-shift apparatus. This appears to be the one avenue for automobile improvement that has not been fully exploited. In this association, the words of Roger W. Griswold, the President of the Vulcan Motor Devices Company, in a recent letter to the author, will prove distinctly illuminating, carrying as it does the weight of authority and experience in that precise field under review. "The writer is unable to understand just why the electrical or mechanical gear-shift has not met with a more cordial reception by automobile manufacturers; probably the cost had a great deal to do with their failure to adopt the electric shift.

"Every driver of a gear-shift-equipped car becomes an enthusiast over the device and realizes its many advantageous features, but the manufacturer hesitates to adopt it as standard equipment because it adds somewhat to the cost of his car and requires possibly slight changes in the clutch connections, transmission, and steering-wheel. In America, with business so good, manufacturers have been able to sell their output without changing to pre-selective gear shifting."

Most of the large manufacturers are really interested in this subject and are experimenting in the direction of pre-selective gear-changing. They are anxious to "clean up" the foot-board, and earnestly desire better and more improved gear-changing than is possible at present with the "wobble stick."

Many think, with the author, that pre-selective gear-changing is not far off. There is not the least doubt that when one reputable large manufacturer takes the initiative universal use will quickly follow his lead. Certainly it is a logical refinement and a marked advance on the present hit-and-miss principle of to-day.

THE BATTERY

Naturally, the basic source of all car-electrical vitality is the battery. If Faure and Planté were living to-day they would still be able to recognize the emblems of their genius in the car battery of our times. They would be quite astonished at the millions of their batteries now in use; indeed, even in far-off Australia the Clyde Engineering Company are manufacturing some seven hundred batteries per week to supply only a portion of the local requirements! The improvements in "black boxes" during the last few years have not been particularly striking or dramatic; they have, with one single exception, been confined to structural details such as the formation, support, connection and insulation of the elements.

A point which strikes one when comparing the practice of America and Great Britain in regard to the battery is that in the former country the accepted standard of voltage is six, in contra-distinction to the 8-volt and 12-volt batteries frequently used on British cars. Many reasons have been given to account for such a fundamental discrepancy, but among the most probable are: (1) The fact that American engines are, generally speaking, of larger bore and shorter stroke, and lower compression ratio than those of British manufacture. This is due to the R.A.C. method of H.P. rating for taxation purposes which is in force. There is the very significant fact following upon the foregoing, that the American starter need not have such a big starting torque as that needed for the corresponding British one, so that a 6-volt battery and starter can be utilized in an American car, which in virtue of electrical considerations would be all but impossible on many of the British productions. (2) When the dynamo is driven at engine speed (a common practice in American cars) it must have a low cutting-in point, and it is much easier to build a 6-volt dynamo to run at engine speed than a 12-volt one. As the initial engine speed on British cars is higher, the 12-volt construction enables a satisfactory operation to be provided so far as the cutting-in speed is concerned, and in addition some further advantage is gained on the score of decreased weight (unfortunately offset by that included in the additional battery cells required), and a better all-round efficiency from an electrical point of view—windings, cables saved, incidental losses saved, etc. (3) The almost universal use of the 6-volt coil in the United States of America. Hence it may be assumed that until some drastic change is made in the engine design the 6-volt versus 12-volt will still remain a problem for the designer.

Improvements in Design

The one exception in battery improvement is the provision of an "all-rubber" case fabricated in one piece, and even more recently an all-metal case ! thus abolishing the "seepy" wooden box with its separate cells. The hard rubber (or ebonite or other similar composition) is much easier to keep decently dry ; its insulation coefficient is consequently much higher, and naturally the corrosion of terminals, connectors, etc., is much reduced. Providing one does not drop the battery or hit it with a sledge-hammer, the case may now be assumed to have reached the dignity of an enduring unit.

Regarding the important minutæ connected with a battery, there has been some revision in connection with the insulation and isolation of the elements. At the present time practically all experts are agreed that a wood separator is the last word in separation materials. The use of hard rubber diaphrams permeated by linen threads is also widely used, but the capillary function of the little wicks is open to the destructive influence of the acid, and the subsequent carbonization of the oxidized product would assume the nature of an impurity in the electrolyte that could hardly be styled benign.

In many batteries the connectional straps from cell to cell have been lowered, and are now almost on the top of the sealing compound. In this new position there is less risk of fracture by injudicious handling, also the amount of corrosion is less, as the new type of top can be maintained in a much cleaner and drier condition with considerably less labour.

In the plates themselves there has been some minor improvements in the building of the grid, and in one case at least in the method of preparing the active material.

In the alkaline battery some of the difficulties in connection with its internal resistance have been overcome, and this has enabled a type of cell to be developed that will meet the greedy demands of the starter.

Overcoming Battery Troubles

Batteries still are to be debited with the bulk of electrical derangements in the electric system of the car, in fact of the car failures 78 per cent. are of an electrical nature and 95 per cent. of these are connected with the battery. It has been found on careful statistical examination that nine-tenths of this inherent battery weakness is due to two main causes: (1) **being insufficiently large for their work,** and (2) **not being looked after properly.** Under the first heading the small size supplied is due to the cost and to the weight limitations imposed by the car manufacturer. The manufacturer increases the draw on the battery, too, by admitting to the chassis a light-weight starter. Strange though it may appear to the lay mind, a large starter may take less current from the battery than a small one, and in virtue of its superior starting torque turn the engine faster. Another factor in the longevity of the battery is the amount of voltage drop produced by the starter during its performance. It may be considered that with the average small battery the voltage drops between one and two volts per 100 amperes of current supplied to the motor. With a given load the effect of this voltage drop is to cause the motor to run slower, thereby increasing the current consumed with a corresponding increase in voltage drop in the battery. With a large battery, on the other hand, the voltage drop would be much less, and the ultimate balance point between the voltage drop and the turning speed of the motor would be much higher in the revolution scale. With a dynamotor [dynamo and motor combined in one unit (page 248)] the battery size is of even much greater moment as the dynamotor starting torque is low, and its current when functioning as a motor comparatively heavy.

Another important factor in battery life is that connected with its working temperature. The highest temperature advisable for a battery is 104° F. At temperatures inferior to this the capacity of a battery falls in amount according to a straight line law, until at – 43° C. the battery becomes inert. In the standard commercial battery the capacity is rated as 100 per cent. for a temperature of 52° F. at a 10-hour rate of discharge, so that under the usual motoring conditions the full money's worth is always on tap.

Some advances have been made in the direction of restricting the charge put into the battery after it has become fully charged by the dynamo. In a recent test of electrical equipment under load conditions over some 25,000 miles, the battery required ten "drinks" of distilled water to keep the acid up to the correct level. This shows how very desirable it is to have a reliable method of staying the charge from time to time in order to prevent undue evaporation; amongst the newer methods of meeting this difficulty is an electrolytic apparatus introduced by the British Lighting and Ignition Company. The device consists of an electrolytic controller which is connected across the mains leading from the dynamo to the battery, being thus in parallel with the latter. In construction we have a number of small steel cells containing sheet steel plates and immersed in an alkaline solution. These plates are connected in positive and negative groups, and the groups of the various compartments are joined in series.

When the current is passed through such an apparatus the effect is to decompose the water, but the voltage required for the process is 2 volts in each cell, or for a regulator of six cells as used for a 12-volt battery, 12 volts. It follows that if the voltage of the car battery is below

12 volts, the electrolysis will not take place and the whole of the current will go into the battery; but when in the progress of charging the voltage rises above 12 volts, electrolysis takes place in the little control cells and absorbs some of the current that would otherwise "boil" the life out of the battery. When the battery is fully charged the majority of the current from the dynamo is diverted into the electrolytic cells.

In this way the over-charging problem is solved and the battery's life increased. The controller needs little attention beyond the addition of water to make up for decomposition losses, and indeed it will continue to function so long as a reasonable area of the steel plates remains covered. The plates themselves are not acted upon.

In summer it is desirable so to alter the setting of the third brush of the dynamo that the output is reduced somewhat.

Slowly but surely the motoring public is being taught the use of the hydrometer, and the increasing demand for that instrument augurs well for the life of the battery.

If the owner cannot himself undertake the testing of the battery he should take advantage of some such service plan as that described on page 302, or a coupon scheme such as the following might fill the bill—a book of coupons to be issued by the service station, and available over a stated period, or containing a number of tickets, for an agreed sum the owner on presentation of a coupon being entitled to have the following attentions paid to his battery: Testing the state of the acid, including individual reading of each cell and replenishing as and when necessary; cleaning of terminals and the cell tops, and tightening of the fastenings which keep the battery *in situ*. In order to prevent the motorist from leaving the care of his battery until such an accumulation of work has resulted that the normal coupon charge would be quite inadequate, it would be necessary for each coupon to be dated, and to have a time limit of availability beyond which the coupon would be void.

DYNAMOS AND STARTERS

The Commercial Vehicle Set

Here again the march of progress compels us to speak of one or two notable improvements and emendations which have occurred in the details of both the dynamo and the starter. When one considers that every motor vehicle made in the United States and Canada has electric lighting and starting as a matter of course, and whilst in England and Europe generally it is still possible to find an isolated small car without a lighting set, practically every vehicle is so equipped from the smallest to the largest; but in Europe there are still many makes of small car that have yet to be fitted with an electric starter as standard, and if we turn to commercial vehicles we find that an electrical equipment is an exception rather than the rule. In this latter connection some recent heavy vehicle tests should prove interesting to the owners of all commercial vehicles. It has been demonstrated that in a year of 300 days a bus-type lorry engine running light will consume on the basis of 1 gallon per hour nearly £20 worth of fuel, assuming only ten idle spells of five minutes each per diem. In addition to the foregoing sum paying a generous interest on the cost of electrically equipping the vehicle with a plant of adequate capacity, there is the fact of the saving of engine wear and tear and the reduction in its carbonization.

Until quite recently in this country the position in regard to the standardization of the more mechanical portion of the car's electrical apparatus was deplorable; but at the present juncture a schedule of standards has been provided in conformity with the other component parts of the chasis.* That its appearance has been somewhat tardy is mainly the fault of car designers calling for special types of equipment or drastic modifications of existing standard dynamotive apparatus. Here is an actual case, by way of illustrating the scotching of the wheels of electrical progress. Messrs. X listed no fewer than twenty-nine types of dynamo and seven additional creations combining ignition gear! And moreover the manufacturers explicitly stated that they were prepared to supply special designs to order of their customers—the car-builders.

The consensus of electrical opinion is that at the most four types of dynamo will meet the exigencies of all ordinary cars. Actually the generator armatures on this basis would need to be of only two diameters—the length alone being subject to variation to meet the differences of output. These four models would be offered to the designers in a choice of mountings—attached end-plates for flange mounting or the necessary appendages to suit strap mounting. The latter method, though very popular, is not so satisfactory as the former, and manufacturers should impress the fact on the car designers.

For bus and heavy requirements a line of two only, specially large dynamos, would meet the requirements.

The starter is in the same invidious position, and the numerous—too numerous—models of electric cranker could be reduced to a series of three only, and offered to the car manufacturer with the alternative mounting as mentioned above; one large motor alone being required for the case of a specially large-sized engine. In connection with starters it must be realized that—as in the case of buses where many types have comparatively small engines—the fact that a large dynamo is required by no means postulates the provision of a large starter.

* See British Engineering Standards Publications: *5002—1924*, Electric Lighting and Starter Cables for Automobiles—specification for; *5031* to *5034—1925*, Dynamos, Distributor Mountings, Starting Motors and Dynamotors for Automobiles—dimensions for.

The Working Voltage.

We have previously touched upon this subject from the point of view of electrical design, and all that need be added is to indicate that in starter operation the use of 12 volts is to be preferred; and in this country, as the magneto is still popular, the use of 6 volts for ignition purposes does not apply here. The voltage drop in the cables—a most important desideratum with the starter—is less apparent when functioning on a 12-volt circuit, whilst the machine itself can be designed more neatly when it is intended for 12-volt operation.

The Earth Contact.

Another source of loss of a similar nature to the above cited, is that which occurs through the relatively high resistance of the earth return circuit of the starter-battery. The best plan in cases where the starter is attached to the aluminium crank-case is to make a good earth for the battery on to the aluminium, a conductor of electricity second only to copper.

Drives.

This problem has received considerable attention, and the co-operative efforts have now been productive of much improvement; and although as will be apparent from the examples furnished in Chapter X that here at least was a weak spot, the latest models show marked advance in this respect, particularly in regard to mounting the dynamo.

In former times manufacturers had to place the dynamo where they could get it in, and drive it as best they might. Mostly the drives were by means of whittle belting with—in many cases—short centre distances and with no effective provision for adjustment. The triangular section belt employed had too little grip on the driving pulley after a short term of service. This was due to the angle of wrap being two small. Nowadays the engine design shows that the electrical experts have to an extent been considered, and the ultimate purchasers find that they are free from drive and general dynamo trouble owing to this fact. There is following from the above the increasing tendency to adopt the flange fit, as was alluded to on a previous page. A silent chain has taken the place of the whittle belt; and on all orthodox cars the dynamos can be placed at the rear of the timing-gear case, preferably on the side opposite to the camshaft, the chain being either the main chain or a lighter one alongside it. Adjustment of the driving chain is secured by means of having the dynamo so that it can swing about one of three bolts or studs, by which it is attached to the crank-case.

To-day most dynamos are driven at engine speed by direct drive.

Concerning the starter, there are two positions which are favoured at the present time, and in either of which it can be made quite get-at-able. (1) Attached to the forward side of the fly-wheel housing, or occasionally in a split socket with a clamping bolt. Such a plan permits of easy removal. (2) Fitted to the rear of the fly-wheel housing, mounted fairly high and alongside the gearbox. A word of caution is necessary in this connection, as one sometimes finds with this method of mounting that the position is *too* high, and consequently an unsightly mound is necessary in the ramp of the floor in the driving compartment, which may in addition to the æsthetic consideration be subject to injury in view of the constant exposure to the percussive effect of numerous feet upsetting the brush-gear!

The bendix drive, like the third brush control, has, of course, come to stay, and calls for little comment except for a plea for better protection (in some cases) from the road dirt. There would be some advantage gained by the substitution of graphite (dry) on the teeth for the running in oil that obtains in many designs. The gear ratio is now limited to 10–15 to 1. With dynamotors the ratio is restricted to 2 to 1 or 2·25 to 1, but dynamotors find employment only on small power cars, as a rule, as they reach their practical limit on an engine of about 12 H.P.

Switchgear.

There is little changed in the switchboard and control department, except that simplification has been generally adopted, and we now find a central zero ammeter and a single rotating switch completing the visible part of the switching equipment. Some clever ideas in relay control have come into use. This plan enables the car to be started by the slightest pressure of a small button on the dash, similar to a bell-push. The relay then operates the main switchgear automatically. In at least one new car the starting switch is dispensed with altogether, the brush on the starter, which is operated by a bowden cable, acting as a switch on the commutator itself. The idea is somewhat similar to that which was employed as far back as 1911 on the Delco system for placing the starting brush of the commutator. The more expensive cars have a voltmeter fitted, but this is not so good a plan as having a portable 3-volt cell starter for the battery. The "lead-ins" of the cables are now much neater than they were, and the universal adoption of impregnated colour schemes makes for greater facility in repairs or alterations.

The Future.

As we indicated at the commencement of this review, there is in the main little to be accomplished. Workmanship and quality of materials, especially insulating materials, are in a few instances not first grade. Quite recently the author inspected a hundred or so dynamos and starters that were all very badly machined.

Future developments of lighting and starting sets must depend very largely on the battery; but apart from this there is much scope for the exercise of designing skill still left in the design of the dynamotor, with a view to increasing its motor efficiency. Regulation of the current is still open to further improvement, so that in practice as well as theory the energy supplied shall at all times be suited to the ruling requirements of the battery. Again, the production of a dynamo that will regulate really satisfactorily *without a battery* would prove a boon to many users of motor vehicles.

Finally, and without usurping the functions of "Old Moore," the author is convinced that the brilliant recent optical research work that has been carried out in Australia by Cassels and in Germany by Zeiss will provide the solution to the anti-dazzle and glare problems of head-lights.

IGNITION PRINCIPLES SIMPLIFIED *

In response to numerous inquiries, it has been deemed desirable to draw the motorist's attention to the fundamental principles of the electrical ignition system used upon his car.

Whilst making no pretensions of delving into the details of so intricate a subject as modern magneto-generator construction, or to setting forth in correct scientific sequence the various laws and principles that modify the effects of electro-magnetic induction, it is hoped that we shall be able to give a glimpse, at least, of the differences between the several systems of ignition now in vogue.

It will be necessary rigidly to eschew all appearance of dogmatism in dealing with our theme, as opinion as to what constitutes the best system of internal-combustion engine ignition is by no means unanimous.

* A separate volume by the same author is shortly to be produced by the same publishers giving detailed information on modern ignition systems simply explained for motorists.

Times have changed during the last few years, and designers have witnessed the reappearance of the once-despised battery. The modern battery is a triumph of electro-chemistry, and its present design is such that car builders can rely on a certain length of definite good service under fixed and known conditions. This alone has caused them to view the battery in a less prejudiced light than heretofore. Again, clever adaptations to the dynamo which *has* to be fitted for lighting purposes, have caused even the staunchest magneto "fan" to waver in his allegiance to his "dynamoid" divinity—the magneto "straight." This has, of course, eliminated one unnecessary machine from the chassis as a matter of evolution, just as soon as the memory of the unreliability of the battery of yesterday receded to the land of forgetfulness, hastened, no doubt, by the superimposing of the virtues of the battery of to-day.

The wonderful flexibility of battery and coil ignition has been brought out recently in connection with world's records that have been achieved by means of this system of ignition. Moreover the failure of magnetos in similar circumstances has still further impressed the discerning with the possibilities of the battery ignition system.

Ignition Systems in a Nutshell

Let us glance at the various ignition systems that are available to the motorist, with a view to sorting out their advantages and disadvantages.

Low-tension Coil System.

This is, except for low-speed stationary engines, now almost obsolete, as its clumsy make and break that has to take place in the cylinder itself is against its universal adoption. However, on some gas engines of the stationary type it still finds a place; also on some motor boats it is still retained. The main consideration for the retention of the low-tension ignition is the approximately constant speed at which the engine is to run, a condition fulfilled by the stationary and boat engine, and under these circunstances the low-tension ignition is quite practical and satisfactory.

Coil with Vibrator.

The disadvantage with the vibrator coil is generally conceded to lie in its tendency to miss : if the battery is weak, the coil will not operate—at least, not satisfactorily. Should the battery power be too great, the contacts will give trouble by fusing together and cause missing. Again, it is considered by many that the spark is insufficiently rapid to produce complete ignition of the compressed gases ; this statement is probably open to question. The consumption of current in a trembler coil is certainly too high to justify its employment in preference to alternative methods when other considerations are anything near equal.

The chief difficulty of the contacts is overcome on many systems, notably the Ford, by means of fitting what is known as a master vibrator, and screwing down the tremblers of the other coils, so that they will not work independently, but here again the extra work on the master contacts may possibly more easily cause them to stick, although the author used this method on his Ford with excellent results for some years.

Dry Battery Systems.

There have from time to time emerged from the laboratory coils of such delicate current-consuming characteristics, that they could be safely run from a dry battery, and thus eliminate the accumulator. This plan is all right in theory, but unfortunately there is one weak point, and that is the impossibility of finding a reliable battery of the dry kind. For intermittent work, such as for starting the Ford model that has not an electric starter incorporated, a dry battery set is ideal, and will last for two years or more, worked under those conditions. The author used two such batteries alternately, with success for awkward Ford starts. These cells (Hellesen's) were in service for three years, and a battery of five of them was used.

There were several systems of complete electrical equipment of American origin that furnished the purchaser with an auxiliary dry battery for ignition emergencies. Dry cells are, of course, only suited to intermittent work, but they will, on an emergency, run a coil for long periods, provided that they are fairly new, as the modern dry cell is a much more reliable article than the old-time production.

Storage Battery Systems.

The very oldest electrical ignition systems utilized storage batteries, or accumulators as they were then called. The older motorists will not want to be told the disadvantages of this form of ignition. Nowadays the inclusion of a dynamo has solved the problem, and cleared away all the past prejudices and difficulties that were well-nigh insurmountable without a carried generator to recharge the battery.

Battery, Coil and Magneto.

This is better known as the "dual ignition system," and was in vogue some years ago, but to an extent it dropped out when it was generally appreciated that the magneto could be depended upon, in spite of its complicated construction. Provided that especial reliability was desired, the system appeared justified, but for ordinary usage the magneto has always proved a fully satisfactory source of ignition current, although, as we said awhile back, for racing the battery offers advantages, and when crawling along through heavy traffic many prefer a battery "sparker."

Low-tension Magneto and Separate High-tension Coil.

At one time it was customary to employ a low-tension magneto working in conjunction with a high-tension coil, the "maggie" only displacing the battery as a producer of primary current. This system was abandoned because it was soon realized that the coil could readily and satisfactorily be wound on to the magneto armature itself, hence the production of the H.T. magneto.

High-tension Magneto.

This form of ignition is the best known to the European motorist, and rightly has the name for reliability of service. The high-tension magneto produces a hot, and at the same time a voluminous, spark. The weak point in many makes of magneto, though not in all, is that at low speed of the engine the spark is somewhat weak and anæmic in character. To overcome the initial starting, the well-known Bosch Company produced a special form of magneto, which was so arranged that a specially fat spark could be produced at very low speed of the armature. We shall have more to say about this apparatus a little later.

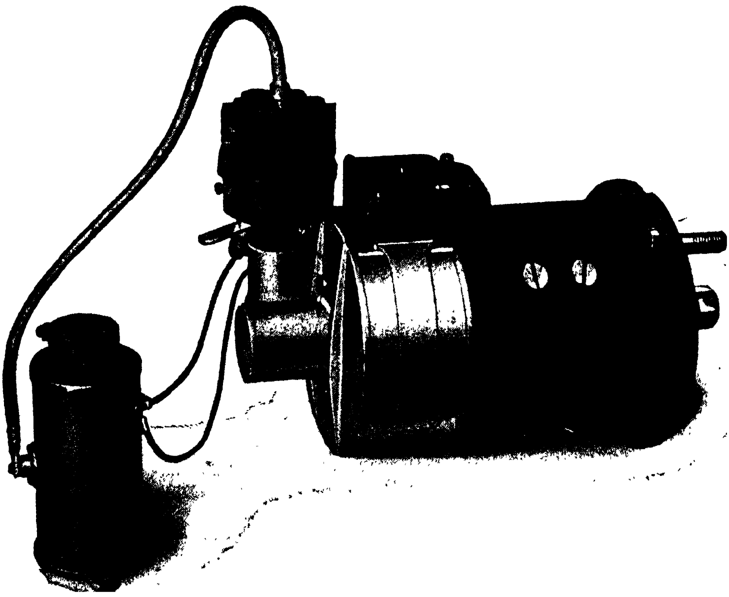
In general, we may say that the spark of the high-tension magneto at its critical value is better, hotter, and exists across the gap of the spark plugs for a longer time than the spark attached to other systems. Thus it fires all of the gas in each of the cylinders, and the fact that the spark is hotter causes the gas to ignite more quickly.

The speed of combustion has been further enhanced by what is known as the double system of ignition, a system that provides for two separate sparks simultaneously in each cylinder.

The New Dynamo-Battery Ignition.

The illustration shows an English representation of the new ignition. It will be observed that the apparatus is essentially an ordinary lighting dynamo, plus a coil on the left of the photograph and a distributor on the left end of the dynamo itself.

It has been designed in order to meet the rapidly growing demand for a simple and reliable battery ignition apparatus, which can be used to replace or merely, as in the case of the large Rolls-Royce, to supplement the



The New C A.V Dynamo-Battery Ignition.

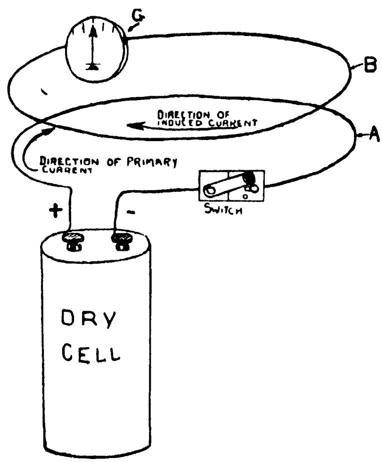
magneto ignition system. The distributor and contact breaker, which are mounted as shown in the left of the photograph (they may be attached to the other end equally well), is driven from the armature shaft by spiral gears. The coil is fixed to the dynamo in some types, notably in the B.L.I.C. set. Here, again, the matter is subject to modification, as in many other English and Continental systems the coil is mounted in some other location as a separate unit. The distributor and breaker mechanism are usually spoken of as the "igniter," and the whole machine as the "dynamo-igniter."

The advantages of the dynamo-battery system are principally the great ignition flexibility, and the fact that the power is available at slow speeds of engine. The current supply is taken from the storage battery or the generator, if the latter is running, then passed through the primary winding of the coil, which is of the non-trembler type. The breaker and distributor then takes care of the secondary or induced current furnished to the plugs.

The Principles of Induction

In addition to the principles enumerated and expounded in connection with the elements of the dynamo in Chapter IV, it is necessary to emphasize the special part that induction plays in the development of the ignition apparatus, whether coil or magneto. To effect our purpose we have prepared the following experiment.

In the sketch on the next page a loop of wire A is joined up to a battery—a single dry cell will do—above this is seen another loop of wire B, which has no electrical connection with A: notice that particularly. When the current is switched on or off in coil A a sympathetic electrical flow occurs in coil B, and will be apparent to the experimenter by the deflection of the needle on the galvanometer G, which is included in loop B. As a matter of strict accuracy we may postulate that *any* variation of the current flow, such as increase or decrease in addition to the first conditions we laid down, will cause a corresponding fluctuation in coil B. So also would a variation in the distance and other movement of the coils in respect to each other. The arrow in the coil A shows that the flow of current from the cell is from the positive or carbon terminal (the centre one) to the negative or zinc connection. Actually the circuit, as shown, would be a short circuit when the switch was closed, as practically no resistance would be included in the path of the current. If we used a battery like that found upon the car, upon closing the switch we should find that the insulation would be rapidly burnt off the wire, and the wire would in all probability melt. Such occurrences should always be avoided when using car batteries, and for such an experiment as illustrated it is better to use a single dry cell, and thus avoid all risk of unpleasant consequences.



Experiment to illustrate inductive phenomena applied to ignition devices.

There is yet one other important effect of induction currents that we have indicated in our sketch, and this is the fact that the direction of flow with the induced current in B circuit is opposite to that which is shown to be the case with the inducing or primary current, which flows out of the cell. Similarly if we had a third loop of wire held over the top of B we should get an inductive impulse from B in this new loop, and this would again be in the reverse direction to the current inducted in B from A. Such a circuit would be spoken of as a tertiary circuit, and the current as a tertiary current. In the ordinary ignition field our coils and magnetos do not deal in tertiary windings, but stop short at the secondary. To prove the direction of the current in loop A we need an additional galvanometer in the battery circuit, and when the switch was closed we should note that the needle of the meter went to the right hand, say, and at the same instant an observer watching the instrument in the upper circuit B would remark that the needle of the galvanometer deflected to the left. He would also learn another important electrical fact, namely, that the deflection was of the most momentary character, and he would assume, no doubt, that the operator had switched off the battery current in circuit A, but on glancing below he would see that such was not the case, and upon switching off the current in order to check things up, he would (if he were quick enough) notice a further kick in the needle of the galvanometer included in circuit B, and if he were especially observant or had taken a memory-training course he would be puzzled to note that this final flutter was in the opposite direction to that which occurred on first switching on the battery current.

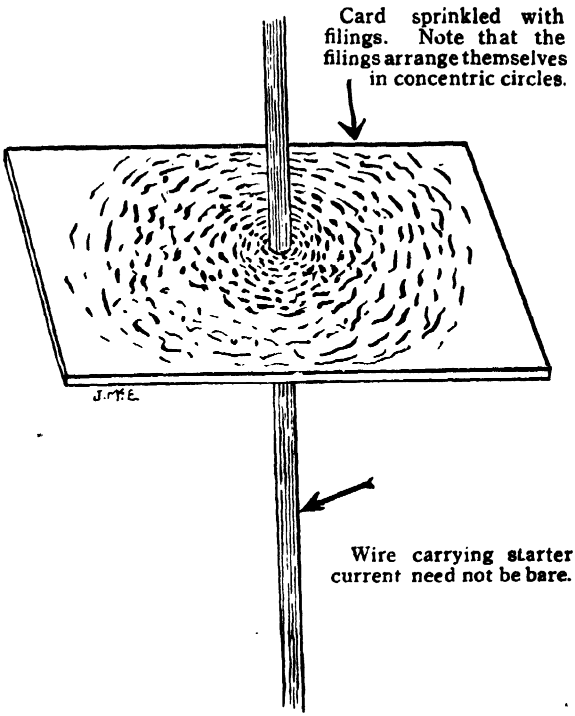
By the above simple experiment we have learnt several basic points about induction, which will stand us in good stead in our study of magneto and battery ignition problems.

Summary of Inductive Effects

Summarizing these we have first of all seen that the current flowing in loop A can, at the moment of commencing and finishing, induce a current in loop B, although there exists no electrical connection between these two coils; second, we have noted that the direction of the inducing and induced currents are opposite to one another. We further noticed that every time the circuit of A was closed the current in B was an inverse, or opposite, directional current to the primary current in

A, but when the A circuit was opened we noted that the current was a direct one; that is to say, it flows in the same direction in B as that which the original current flowed in A.

This statement may at first reading appear at variance



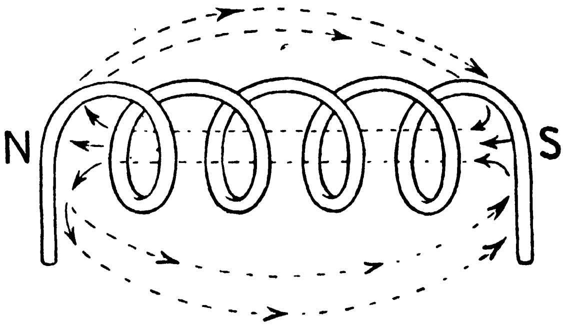
Card sprinkled with filings. Note that the filings arrange themselves in concentric circles.

to that previously made in reference to the opposite character of induced and inducing currents, but actually the discrepancy is apparent, not real, as the inductive impulse which produced the second "kick," i.e. when A circuit is opened, did not result from the steady current flowing in A until we opened the circuit, but from the back flow of the current, due to the inertia, so to speak, leaving a little trapped in the wire. In ignition coil practice, as we shall see a little later on, this is the impulse that gives the first hot spark so much sought after ; however, this is due principally to other considerations.

The next step is to appreciate the fact that around every wire carrying a current there exists a sort of aura, or atmosphere of magnetism. Certain persons called "clairvoyants" claim to be able to see this field of magnetic force that surrounds a wire, but so far orthodox science has not established this as fact, and many persons have been shown to be suffering from an hallucination, and quite unable to establish their claim. However, the reader can "see" this field in a solid, convincing way, by causing a wire carrying the starting current to pass vertically through a card held horizontally, and sprinkling a few very fine iron filings on the portion surrounding the wire. Now by gently tapping the card with a pencil, the filings will arrange themselves in concentric circles around the wire as their common centre, as shown in the diagram opposite.

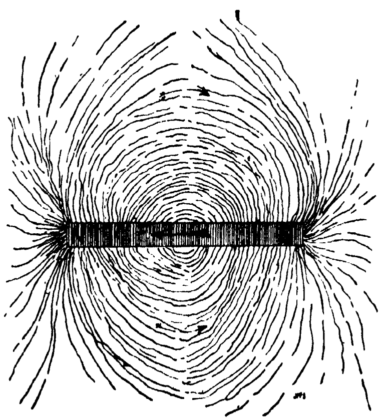
In every circuit carrying a current, weak or strong, their exists this invisible magnetic field surrounding the conductors. When we have two or more conductors adjacent their respective magnetic fields re-act on one another, and as is the case with magnets, they attract or repel each other according to whether their polarity is dissimilar or similar respectively. In the class of electric conductors used on ignition coils and magneto armatures we find that the wire takes the form of numbers of convolutions, or turns close together. In such cases the magnetic field, due to one turn, is more or less neutralized by the turns on each side of it. The sketch depicts a wire conductor wound into a simple helix and electrically known as a "solenoid."

The arrows in the drawing show that the general direction of the magnetism is similar to that found in a bar magnet; this will be evident on glancing at the



Field of a solenoid.

lines of force for the bar magnet shown in the sketch, which are produced by the same process as that used in the demonstration of the field around a wire.



Magnetic field due to a bar magnet.

Notice that the lines of force in the coil illustrated in the previous sketch proceed from the N end of the solenoid and pass outside the coil to the S end, where they turn in and pass back through the inside of the coil to N, and so on *ad infinitum* until the current ceases, when all the magnetic effects disappear. So that just so long as the current is passing the helix will form a magnet, and as we shall see later, is capable of magnetizing iron or steel. The importance of the arrangement illustrated may be imagined when we say that it forms the basis of all electrical machinery, to say nothing of its wireless importance. Ignition is a mere side-issue by comparison.

The Magneto Simply Explained

We shall now apply the knowledge gained to the elucidation of the magneto.

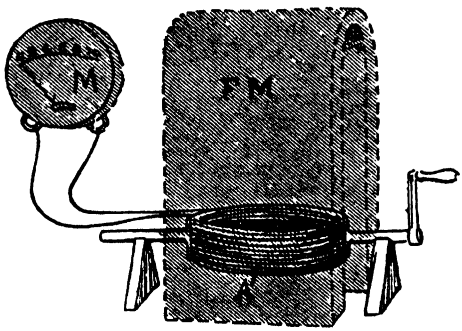
Many writers have endeavoured to make plain to the reader ignorant of electrical phenomena how it comes about that the magneto generates the sparks without which the explosive mixture in the cylinders could not be fired, and the car could not move.* Their explanations, however, have generally run into a book, or at least into a series of illustrated articles, which quite overcame the pure novice. In these days life hastens, and for those who want a post-impression of this complex subject we reproduce two little cameos in black and white, which tell the story succinctly and graphically.

The next drawing shows a hank of wire (A) used in the last experiment, mounted on a spindle to which is attached a handle, and arranged so that it can be rotated between the poles of the horse-shoe field magnet FM. We already know that it is an elementary principle that if a loop of wire is moved in a magnetic field—that is, near the poles of a magnet as well as the magnetic fields produced by currents themselves flowing in conductors—a current

* We are not unmindful that cars have been moved successfully (?) by non-spark ignition (hot-tube, spongy platinum acting on the "radio" gas lighter principle), but this was in the dark ages of motoring.

of electricity will start to flow through the wire. We may here add that the greater the number of loops in the wire, the faster its motion, and the stronger the magnetic force of the magnet, the greater will be the current produced in A. The meter M will register the current as we turn the handle. This is the basic principle of the low-tension magneto used on motor boats and stationary engines.

In the same drawing also we have a representation of the most modern type of dynamo ignition, if we picture to ourselves the low-pressure current there produced

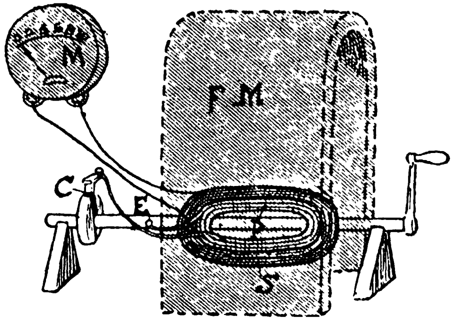


A post-impression of a dynamo-igniter.

going into a separate and extraneous induction coil which acts as a transformer and steps up the low voltage of the armature A sufficiently high to spark across the plugs of the engine.

The similar sketch on the opposite page shows us the general run of magnetos in use to-day—the high tension —here the induction coil we have just spoken of is wound on the armature itself, P representing the winding A on the previous illustration, but now known as the *primary*, and S denoting the coil part or high-tension winding known as the *secondary*. Remember that the generation of current in the primary winding P is just the same as in the former experimental circuit illustrated on page xxxii at circuit B.

FM is the *field magnet,* made from hard steel ; P is the primary winding, S is the secondary wire (the fine winding). E indicates the position at which the part of the circuit is "earthed" or grounded. One end of the primary coil P (the thick wire) is earthed at E on the shaft, while the other end of this winding is connected to the contact-breaker brush C, as indicated in the sketch. The brush bears on a metal disc having an insulated segment (shown black). In this way for the



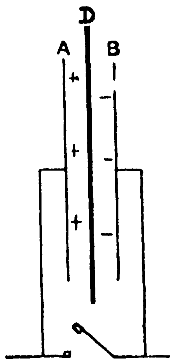
The High-tension Magneto.

greater part of the time the current is short-circuited in the primary winding P, and only allowed to attain its power during the time the brush is on the insulated piece. At that instant the current flowing in the primary induces a current in the winding S, the secondary. (Note that there is no electrical connection with this winding ; it is purely a matter of induction, which in principle is shown in the sketch on page xxxii.)

The Condenser

This apparatus is not shown in the sketch, but it is placed across the primary winding at the make and break. The method of function will be made clear from the diagram and the description which follows.

We note that the plate A is insulated from B, but as yet these plates are in close proximity to each other. These two plates are connected one to each side of the contact breaker in the manner shown in the coil diagram on page xlii. Of course, in actual practice, there are more than two plates in a condenser, and every alternate one is connected together on one side of the condenser, a wire or clip being attached to the two groups of tags for connection to the contact breaker.



Principles of the Condenser in Magneto and Coil.

When the contact breaker is closed the condenser takes no part in the proceedings; but when it opens, the current instead of jumping across the points and so causing a destructive sparking, uses up the energy in charging the plates of the condenser, as indicated by the above diagram. Actually it is the mica or dielectric which is the seat of the electric storage. This was proved by having a Leyden jar made so that its coverings could be removed and tested. Each was found to be uncharged apart from the dielectric. When the primary current connection is re-made the plates discharge themselves.

For our purpose the condenser acts as a device for storing the inverse or "extra" current in the primary winding.

This extra current is due to the fact that the primary winding is coiled up into many turns, so that one loop of the circuit can induce lines of force through another loop of the same. It must be realized that when a current is made and broken in any circuit, it neither attains its full strength nor becomes reduced to zero instantaneously, but a finite time is required for the change to be effected, and it is during this small interval of rapid change that these induction currents are produced.*

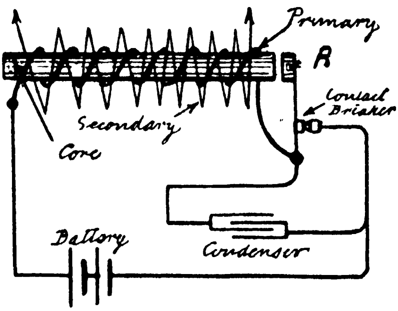
The following may assist the reader to a clearer understanding: When the current is "made," as in the position of the contact breaker shown in the right of the coil diagram, the condenser is at the same time charged (actually charged with electricity from the battery), and thus the current in the primary takes a comparatively long time to rise to full strength. This lessens the inductive effect on the secondary at the make of contact. Further, we recall that the self-inducted current also charges the condenser, as it cannot jump the breaker contact at the time of separation. This stored electricity at once discharges round the primary coil, but *in the opposite direction* to that of the primary current—that is, in the opposite direction to that it would have taken had it been able to spark over the separated points. This extra current at the opening of the primary circuit serves only to intensify the effect of the "break" on the secondary winding, while the "make" impulse is practically unfelt in the secondary circuit on account of the absorption of current by the condenser.

* Adapted from the author's work, *Electro-Therapy and Ionic Medication*, by permission of the publishers, Chas. Griffin & Co., London.

The Coil

Finally we come to the coil that is used in connection with the modern ignition system operated off the dynamo battery circuit.

The drawing below shows a diagram of the kind of apparatus termed a "coil"—induction coil for full. Here it will be seen that our loops of wire, in which we observed inductive phenomena on page xxxii, are now wound over an iron core made up of a bundle of very soft iron wires. As in our experimental circuit there is no contact between the primary and secondary windings.



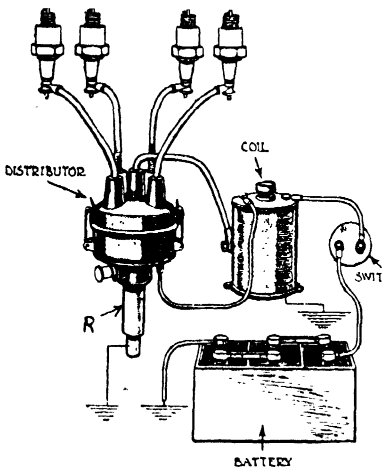
Schematic representation of the Coil.

The switch is now an electro-magnetic spring device, termed "contact breaker" in the diagram.

Notice also that the condenser is connected to the primary circuit across this contact breaker, as shown in the above diagram.

Our next diagram depicts the commercial arrangement of the coil circuit for ignition circuits. The contact breaker is no longer attached to the iron core to disrupt the flow of current in the primary, but it is now operated purely nechanically by means of an interrupter fitted in the driving train of the dynamo shaft itself. See photograph on page xxx.

Further simplification is made possible by dispensing with one of the secondary connections of the coil and bringing the beginning of the secondary winding to the same terminal as that used for the end of the primary. As these two points are always at the same electrical potential there is nothing lost in efficiency by adopting this plan, and furthermore the inductive effect in the



Ordinary dynamo-battery lay-out.

windings is in no way affected by this equi-potential contact.

Modern Magneto Design

In former times it was customary to have the armature of the magneto rotative, but at the present stage of magneto evolution it is the field that rotates much the same as in the Ford magneto. In the newer rotor type of magneto, as it is called, the windings are stationary, the field alone comprising the moving member, thus giving greater security in the matter of windings.

ELECTRIC LIGHTING AND STARTING FOR MOTOR CARS

CHAPTER I

INTRODUCTION—THE EXPLANATION OF TECHNICAL TERMS

OVER two decades have run their course since motor cars were by any means a novelty. The improvements that have been manifested during that time have been both many and important. Manufacturers soon began to realize that if the new method of locomotion was to be rapidly advanced, it would be necessary to divide the industry into various specialized departments. That this method has been productive of great efficiency and brilliant achievement will be patent to every reader of the motoring Press, both British and Foreign. If any further evidence be required, let a visit be paid to the next Motor Show. As we are to deal with a particularly wide field of autocar activity in a comparatively small volume, it is quite impossible to do justice to any other sphere of development than that enumerated upon the title page, therefore the author begs to be excused from attempting to do so. In dealing impartially with our particular subject, reference must be made to the pioneer of efficient automobile lighting—Acetylene Gas. Motorists in the early days of the movement dared not drive fast, after daylight hours had passed, because oil and candle lamps, although excellently adapted for horse-drawn vehicles, were scarcely safe illuminants for automobile speeds, more especially upon infrequently traversed thoroughfares. It was upon the want of a better light being keenly felt that manufacturers turned their attention to the production of suitable road searchlights, employing the best-known optical aids to add to their efficacy. Success was practically assured, as by this time calcium carbide had become a commercial article. It will be recollected that in the earlier types of lamps the carbide—which upon the addition of water evolved acetylene gas—was housed in the base of the lamp itself, whilst in the later acetylene systems it was more usual to have the generator, as it is called, separate from the lamps, and fixed to the footboard of the car.

It cannot be denied that acetylene gas has done much for the popularity of the car, but its success was, even in the very heyday of its fame, overshadowed by the possibility of electric lighting, and its promises of cheaper running costs, and much greater convenience in manipulation. There can be little doubt that the death knell of carbide systems has already sounded, but there are very successful systems of acetylene gas lighting, employing what is known as dissolved acetylene.

The process consists of dissolving acetylene gas (under pressure) in acetone, wood alcohol, etc. These liquids are found to absorb very considerable quantities of the gas; indeed, in one well-known system, which has many special features, a bottle whose dimensions are 6 inches by 22 inches, is made to contain sufficient gas to supply two ½-cubic foot burners for forty lighting hours, and the gas can be turned on or off at will, without the slightest waste.

The manufacturers of this system also recommend a system of electrical ignition, costing but little, and one which enables the driver to have the same lighting and extinguishing facilities as are enjoyed by the possessors of the electric system. To many minds this method of making extremes meet will appear little better than accepting help from the enemy. The running cost of the carbide system of acetylene lighting works out at several pounds per annum, even when the lights are used on the average three nights per week only. This large expenditure has been found necessary, owing to the fact that it is uneconomical to use the carbide more than once on the average, as when the moisture comes into contact with the carbide, it resolves it into a half-spent material of very uncertain utility. With the dissolved systems the running cost for the gas works out somewhat cheaper. In addition to this high running cost it is necessary to take into account the fact that, should the flame deviate from its optical centre, through the choking of a burner, a very frequent occurrence with the carbide systems, nine times out of ten it will crack the lens mirror at the back of the projector. This apparatus is a most expensive item to replace, as it is constructed out of a peculiar quality of glass, and ground to accord with certain optical formulæ. It will, of course, withstand considerable heat, but cracks instantly upon the direct application of the acetylene flame, and the light given by a cracked mirror is distorted and spoilt by shadows almost invariably. To mitigate this evil makers have much improved the design of their projectors, also the lens mirror has in one case at least been fitted with a provision for taking up any expansion that may occur. In effect, it consists of an arrangement whereby the lens mirror is mounted in expansion rings.

However, after all points of improvement have been duly considered, even to the point of indulgence, electric lamps can be obtained that surpass these for efficiency, and obliterate them for simplicity and economy of up-keep. Electricity is so obviously the most fitting agent to employ for autocar lighting that, sooner or later, it was bound to come by its own. The oil lamp will still have its uses, though not to the large extent it once had. Many makers have realized this fact, and have fitted the innocent oil lamp with an up-to-date electric attachment, so that it can consume oil or electricity at will, or rather as occasion demands.

Before seriously entertaining the subject of automobile lighting installations and their accessories, necessary and otherwise, it will not be amiss to consider for a moment the most salient feature of Electric Lighting progress, apart from the jurisdiction of the motor car. Those who are not directly interested in the electrical industry—and for such this book is written—will hardly credit the difference the modern electric glow lamp, with tungsten filaments has made to the use of electricity for lighting purposes. It will be no exaggeration to state that the difference between the old carbon and new metal lamps in light and running cost is even greater than that between the fish tail or bat's wing burner and the latest incandescent mantle. The least appreciative of the difference are generally those who have never made close acquaintance with electric light, although the author must confess that he was not a little surprised when a Red Indian confided to him that he preferred to sit in the red glow of his rude camp fire, than to stay beneath any of the "pale face's pots of magic," as he described the most recent departure in high candle power half-watts. In the same way there will always be motorists who tolerate, and even enjoy, paraffin and acetylene after giving electricity a trial. However, it is hoped that the vast majority have been favourably impressed with the modern method of motor car lighting.

The advent of the tungsten filament lamp is *the* one great factor that has made the application of electric light to an automobile commercially possible.

With the foregoing introductory remarks we will at once pass on to the fundamental electrical *desiderata* necessary for an intelligent grasp of such a subject as the electric lighting of a motor car. Other terms and principles of scarcely less importance will be dealt with as they appear in the text.

Technical Terms Explained

Most motorists have doubtless felt at a decided disadvantage when remonstrating with an "electrical expert" during the early stages of their motoring career, owing to the vast amount of strange electrical terms he had at his command, rightly calculated to overwhelm the innocent car-man who knew little or less of matters electrical. At the present time, however, a dispute with an electrician is a more equal struggle, as the continual handling of batteries, coils, magnetos, and other electrical equipment, has created a sort of "sixth sense"—or electrical instinct to aid and abet the possessor of a motor car. Now that the use of electricity has spread to such an enormous extent, it is very necessary to have more than a mere contact knowledge of the subject, and the motorist should possess a definite conception of ohm, volt, ampere, ampere-hour, and the like terms used in connection with the mechanism of the car; hence no apology is offered for the inclusion of the following important definitions.

We can speak of the quantity of heat, light, etc., without in the least implying a mass or volume of anything actually present. In this sense we refer to relative magnitude only. However, since whenever we employ the term "quantity" we almost unconsciously signify the motion of more or less, we must be prepared to answer more or less than what? Therefore for calculation we must perforce employ a unit.

The Ohm

When an electric current is used to light a lamp, work a coil, sound a horn, or for whatever purpose one desires, its progress along the conducting wire is to a greater or lesser extent opposed. This opposition to its passage is called *resistance* (one of the few self-explanatory terms used in the profession). In other words (and more completely) Resistance implies that quality of a conductor, in virtue of which more than a certain amount of work is prevented from being done in a given time by a given electrical pressure. Like most things, this property requires a unit or standard. The practical unit with which the motorist should be acquainted, is called an *ohm*. The *ohm* is the resistance of about 300 yards of ordinary copper telegraph wire. It would be naturally concluded that the longer a wire is, the more resistance it will present to the flowing of the current, because the electricity has to travel a greater distance; and that the thicker the wire the less will this opposition evidence itself, as the path is wider in a thick wire than in a thin one. The water analogy may help us to understand this point. In the case of a pipe carrying water, the longer this pipe is, the greater will be its opposition to the flow of water, while the greater the diameter of the pipe the less will be the resistance to its passage. The precise relation the resistance of a wire bears to its length and thickness is expressed by the following theorem: The resistance of a wire or other conductor varies in *direct proportion* to its length, and in *inverse proportion* to its cross section, that is, the area of the face of the wire (or conductor) when cut straight through. It is also very important to note that the resistance of a conductor depends upon the material of which it is composed, also upon its shape; for example, a length of copper wire of a certain gauge will have a different resistance to the same length and gauge of German silver. Furthermore, if the thickness of a conductor be not uniform throughout its length, it will be of different resistance to a conductor of similar material and length that is of uniform construction.

The Volt

The volt is undoubtedly the best known electrical unit; it is the unit of electrical pressure, and is approximately one-fourth as great as the difference of potential or pressure between the terminals of the familiar 4-volt ignition accumulator. The *Electro-Motive Force*, or E.M.F., as it is written for the sake of brevity, of which the volt is the unit, is clearly then that which moves or tends to move electricity from one place to another in any circuit. In this connection it is highly important to guard against the error of supposing that voltage or electro motive force can be adequately expressed as *Electric Force*, which is that force with which electricity tends to move *matter* in contradistinction to *Electro-Motive Force*, which tends to move *electricity*. Potential, therefore, implies that function of electricity which directs its movement from one part of a circuit to another, and the difference of potential or pressure, which determines the magnitude of this motion, is expressed as "*the voltage.*"

The term E.M.F. is generally used in preference to voltage, when speaking of the specific origin or the source of a current. For example, we speak of the E.M.F.'s of various cells, but we say the voltage of lamp because the lamp terminal potential difference is not the same as the E.M.F. induced in the generator at the station. Custom, however, has caused these distinctions to be rather loosely observed.

The Ampere

The Ampere is the other electrical unit known to all motorists, although it is to be feared that there are still a few who have only the vaguest conception of what the unit represents.

To elucidate the definition of the ampere, let us have recourse again to the familiar water analogy. Suppose we were told that 10 gallons of water has passed through a pipe, this of itself would give us no idea of the force of the flow, or, in other words, the strength of the current. It might have taken a month to trickle its way through, or the total quantity might have passed in a minute. It will be obvious, therefore, that as the time taken to pass is short or long, so is the force of the flow greater or less. To get a concrete conception of the strength or density of current, then, we must not only know the total quantity that has passed ; the time taken in its passage must also claim our attention. It is not, however, necessary that the observation should be an extended one ; if the quantity that passes each unit of time, say an hour, a minute, or a second be noted, it gives a clear idea of the strength, or rate of flow of the current. In electrical science the term *current* is that quantity of electricity that passes any part of a given circuit in a *unit of time*, the unit of time employed being one second. The practical unit * of *quantity* of electricity is the *coulomb*.

Now it will be evident from what has been stated, that the *current*—whose practical unit is the ampere—

* The unit is not the same as the "Board of Trade" unit for which the electricity consumer has to pay, although, strictly speaking, it forms an integral part of it.

is the number of coulombs that pass any point of an electric circuit per second. In general terms we should speak of it as the "rate of flow." It follows also from the above definitions, that in order to produce a current density or strength of one ampere, it will be necessary to apply a pressure of one volt to a conductor whose resistance is one ohm. This is, of course, a fundamental case, with all the terms expressed as unity.

Current, which is the apparent transference of electricity from one point to another to produce equalization of potential, is presumed to flow from the point of high potential to the low. Hence, as the positive terminal of the car battery is the point of high potential, and the negative the lower, the current flows from the positive terminal to the negative.

Ohm's Law

We have now considered more or less fully the three important terms which form the foundation of all practical electrical calculation and application, but before proceeding to the explanation of other scarcely less important terms and phrases, it is necessary to consider Ohm's Law, which is expressed as a simple algebraical equation, for ascertaining the value of any one of the three important terms when the other two are known quantities. The equation is expressed as follows :—

$C = E/R$, where C stands for Current or amperage,
,, E ,, E.M.F. or voltage,
,, R ,, Resistance expressed in ohms.

Suppose, for example, it is wished to find the quantity of current in amperes that would flow through the filament of a head lamp bulb. To work out such a problem as this, first ascertain the voltage given by the supply, and then note the resistance of the lamp (the resistance is not infrequently marked on the plaster of Paris lining of the cap inside the lamp), and divide this latter into the former, the result will be the current that lamp requires in amperes.

It may be desired to find out the resistance of a tail lamp that is unmarked. In such a case it is necessary, as previously, to ascertain the voltage of the supply battery, also the current should be checked by means of the ampere meter, or ammeter, as it is more usually called. Having arrived at the two known quantities of the $R = E/C$ equation, all that remains to be done is to divide the figures denoting the current into those representing the E.M.F., and the resulting quotient will be the resistance in ohms.

Finally, for the sake of completeness, let us take the case of a lamp whose resistance and current consumption rate are known, but not its voltage. To find the missing factor of the electrical data, it is a very simple matter to solve the equation $E = C \times R$, since we have only to multiply the current consumption by the resistance of the lamp, to obtain the required result.

There are two little points in connection with these calculations that ought not to be passed over without a brief reference. Firstly, when ascertaining the voltage, either use a volt-meter, or, in its absence, count the number of single cells and multiply by two, thus in a four-volt battery * one would find two cells, in a six, three cells, and so on. If one take the figures on the lamps, an error is likely to creep in, as some circuits are "over-run," i.e. have an E.M.F. in excess of that

* They might be, as in the case of the smaller sizes, one cell in appearance as the separation takes place inside the case. The cells are assumed to be of the ordinary lead type.

for which the lamps are nominally rated. The second point concerns the resistance of the lamp leads or wiring. This, if efficiently carried out, should have such a low value as to be almost negligible as the "run" is so short, nevertheless, theoretically, an error has been permitted to enter our calculations by its inclusion, in spite of this fact.

Other Terms

The Ampere-Hour very largely concerns the motorist, as it is a term that is very extensively employed in connection with the accumulators used on the car. It refers to the current whose strength is one ampere, and maintained for one hour, and is the unit of the capacity of an accumulator. For instance, the capacities of accumulators are always rated at so many ampere-hours, hence a battery of 20 ampere-hours' capacity means that if it is used to light a lamp taking one ampere, it will maintain that light for twenty hours. This unit will be explained further in the chapter on Accumulators.

The Watt is the technical term for the measurement of electrical energy. It is equal to one *volt-ampere*, which is equivalent to the work done by a current of one ampere, at a pressure of one volt, and is represented by the formula $E \times C$. If we are told that a car-lighting dynamo can supply 8–16 candle-power lamps, we cannot form an idea of the voltage, but we *can* form an idea as to its output in watts, and therefore we know its power; since car lamps require 1 *Watt per candle-power*, and a 16 candle-power lamp consumes, approximately, 16 *Watts*, and as the machine enunciated can light eight such lamps, it needs must have an output of 128 *Watts*. Most makers state both the watts and volts and amperes a machine will give out. Providing one or other of these two methods is adopted, the proper cost of a machine can be arrived at. However, cases are not unknown where a dynamo has been listed in candle-powers—a more or less unknown quantity unless, of course, one knows something of the lamps upon which the candle-power was rated.

Previous to passing to more interesting branches of the subject, it will be advisable to remind the reader of a few practical "shop" terms which are the every-day expressions of the electrician, and frequently upon

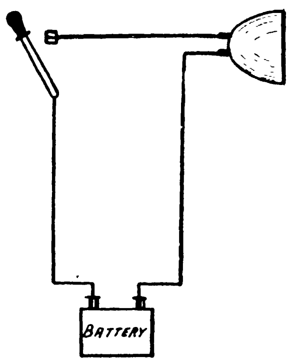


FIG. 1.—An Open Circuit.

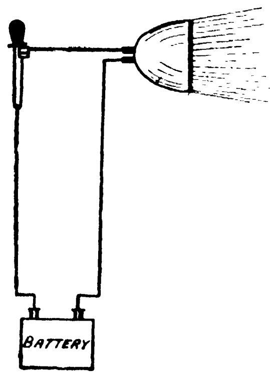


FIG. 2.—A Closed Circuit.

the lips of motorists ; the following are some important ones :—

Open Circuit, or "Dis" (THE ABBREVIATION FOR DISCONNECTION)

By this term it is meant that no current can pass, owing to the conducting wire being at some point or points interrupted, either by means of a disconnected battery wire, faulty connector, broken filament, etc., or by having the switch "off" as shown in Fig. 1.

Closed Circuit

This naturally is the state of affairs existing when the switch is in the "on" position, or in some other way arrangements are provided (accidentally or otherwise) for the passage of the current. Fig. 2 gives a clear idea of a simple closed circuit.

Short Circuit, or "Short"

This is a term to express that some conductor has become accidentally connected with the wires from the dynamo, battery, or lamps, so as to shorten the

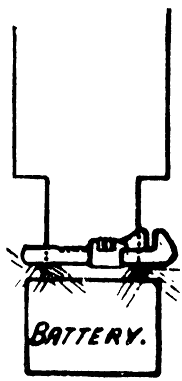


Fig. 3.—A "Good" Short.

path of the current to such an extent that a great wastage of electrical energy takes place. For the sake of an example, let us suppose a spanner has been carelessly shut up in the accumulator box, and it has fallen across the terminals, as depicted in Fig. 3. Practically the whole of the energy in the accumulator will expend itself in warming up the spanner, and the portion available for the legitimate circuit is practically nil, as electricity has no desire to wend its way through the wiring or lamps—the path of greater opposition, or resistance—when it has an easier, and less resistive path open to it, via the spanner. **Short circuits must always be avoided.**

Safety Fuse

This refers to a piece of wire composed of lead, tin, copper, or other metal of such a gauge that its current-carrying capacity is very limited, so much so, that it fuses or melts directly the strength of current in any circuit has exceeded a certain safe amount. Such a provision as this adequately protects the wiring, battery, and dynamo against all the usual forms of short-circuits or over-loads, but not in the case of Fig. 3, as, obviously to guard against such a contingency, the fuse would have to be inside the battery. Copper wire forms the most reliable fuse, but lead and tin wires are preferred by many on low voltage work, as they melt or " cut out " at a lower temperature.

"Earth" or "Earthed"; "Ground" or "Grounded"

This is the term employed to denote that the frame of the engine, etc., is used as one conductor. No *real* earth connection, however, can exist, as the tyres effectively prevent any electricity travelling via the earth. In automobile work the employment of " earth returns," though increasingly practised through motives of simplicity and economy, is inferior to two-wire practice. It might happen that a wire passing near the engine may suffer from impaired insulation, and so render the engine an unintentional conductor. Subsequently a further wire of opposite polarity might also become affiliated to the frame, with the result that short-circuiting takes place. If one conductor is already purposely earthed, it is more easy for a " short " to develop. The risk of such an occurrence is reduced to a minumum by the employment of armoured cables. In America a wire that is "earthed" is also spoken of as "grounded."

The Electric Circuit

In order to dissipate a little mystery that sometimes surrounds the use of electric cables, Fig. 4 has

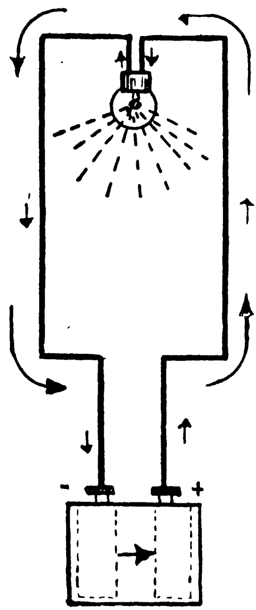


FIG. 4.—The Lighting of a Lamp.

been prepared, to show why *two* wires or conductors are necessary in order to complete the electric circuit. The lower portion of the diagram represents an accumulator cell; the dotted lines inside are supposed to be the plates, positive and negative, two alone being shown, for the sake of clearness. Now, in order to light the lamp, the current has to travel from the positive terminal of the cell, along the wire in the direction of the arrow, and through the lamp, and back to the negative terminal. *Inside* the cell the current, in order to complete the circuit, and to light the lamp, has to pass *from* the negative plate *to* the positive, hence the need for acid. Just the opposite to what is taking place *outside* the cell.

The outside circuit is the centre of the motorist's interest, and it is doubtful whether he troubles one whit about what goes on inside his accumulator.

"Parallel" Circuit

When the current has more than one path open to it, such as the paths afforded by the wiring of the ordinary car lighting circuits, it is said to flow in "parallel" or "multiple" circuit. It is also alluded to as flowing in circuits joined "abreast." This method of grouping the various circuits is shown in Fig. 5A. It will be seen that the lamps shown are quite independent of each other and may have very different strengths of current passing through them.

"Series" Circuit

Fig. 5B depicts what is known as the "Series" method of wiring. It is used to a large extent in the running of "Ford" head lights from the "Ford" Magneto (see Fig. 65), also used to some extent in connection with tail and dash lamps, to enable the driver to know when his tail light is extinguished. It will readily be understood that the current density is the same in all portions of any "series" circuit independently of the number of lamps that may be included in the circuit. The various lamps are dependent upon one another for their current, since the failure of one lamp will put the others out too, as the flow of the current is interrupted as effectually as if the switch were opened. It is a bad plan to have a large number of lamps joined

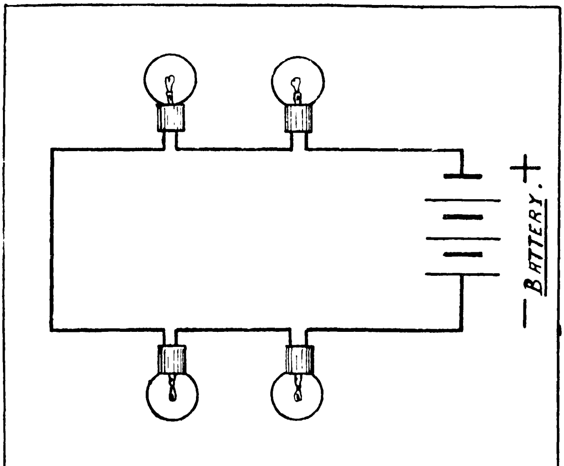


FIG. 5B.—“Series” Circuit.

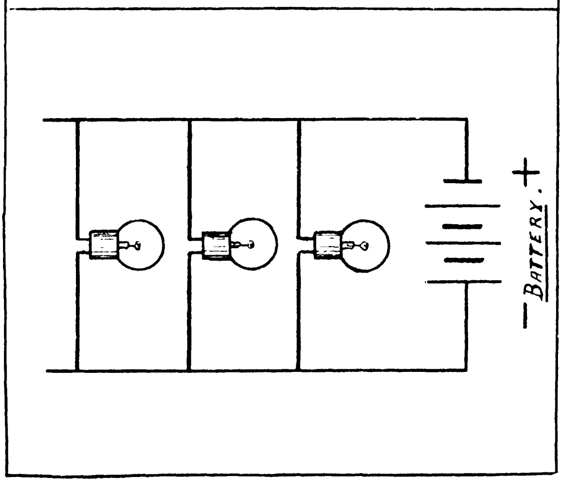


FIG. 5A.—“Parallel” Circuit.

in “series” circuit, as it sometimes happens that a fault will occur in one of the lamps which alters its resistance and so allows the circuit to be thrown out of balance, with the result that its companion lamps are also damaged. For example, suppose the tail lamp goes "short" through any cause; this will certainly spoil its accompanying dash lamp, as full circuit pressure will be experienced at its terminals, which nine times out of ten will cause the filament to "burn out."

The Live Wire

This is the name usually given to the positive wire —the outgoing portion of the circuit, and in the ignition system it will be remembered as the one that is most carefully insulated.

The Negative Wire

This is the term applied to the incoming conductor; it for some reason has a less awe-inspiring claim to the motorist's attention than its confrère.

Bad Contact

This takes place when the wires and terminals of electric appliances are dirty, or imperfectly tightened; in the latter case local heating may result, as in the case of a badly fitting head lamp bulb. In most cases the light is considerably dimmed thereby, and in some instances, if not quickly remedied, imperfect connection may cause the cessation of all light, just when the night is pitchy black all round, and when a fair speed is being maintained. Only those who have actually experienced the situation can fully realize the awfulness of it. The prevention of such an event is simple—have none but secure connections; especially does this apply to accumulator terminals, and the main connectors.

Automatic Switch—(alias the "Cut-out")

This is a device for effecting the closing and opening of various circuits by mechanical or electrical means. A detailed description will be found in the section on that subject (see p. 61).

The many special terms used in dynamo and battery work will be found in the chapters dealing with these parts of the system.

Before leaving the subject of fundamentals, it is necessary to draw attention to the only satisfactory mode of technically thinking. In viewing any particular electrical term or unit, it is essential for the motorist to cultivate the habit of creating a mental picture of its precise relation to the other units with which it is correlative, as only then will it be possible to acquire the power of keeping his mind properly in focus, when dealing with the many little problems that from time to time beset him. It should be also borne in mind that the laws that govern the distribution of electricity can really be depended upon just as much as the laws that govern heat or light. Their action does not admit of exceptions—even to prove the rule!

The following problem will serve to illustrate the need for having a due regard for perspective in dealing with the simple problems of car lighting: A correspondent recently wrote asking why it was that his 8-volt head lights did not give the same light as his friend's 12-volt head lamps, although, he was careful to state, they consumed the same current (4 amperes). "Was it the fault of the lamp bulbs?" he suggested. It would appear that in such a case as this, the writer was so saturated with the conception of the term "ampere" that he seemed quite oblivious to resistance and E.M.F., or he would have seen that greater work is done in the 12-volt circuit than in the 8, and to make it possible for the circulation of 4 amperes only, through the lamps of his friend's car, needs a much greater resistance in circuit than in his own case, since the pressure is 4 volts higher ; consequently as the conducting leads and conditions are in both cases essentially similar, it follows that the lamp filament, which is the light-giving portion of the bulb, needs to supply the additional required resistance, hence the filament needs must be greater in length, as it cannot vary in cross section, since it has to carry 4 amperes in both cases, and the material of which it is composed is of the same metal in either case.

It follows from this, as a *sine qua non*, that its brilliancy must be increased proportionately.

CHAPTER II

THE REQUIREMENTS OF CAR LIGHTING

THE fundamental technicalities of our theme having been dealt with in the previous chapter, we shall now be in a position to more easily grasp the succeeding practical propositions, and to understand their significance. It is proposed in the present chapter to examine in a very general way the precise requirements of electric car lighting, viewing it from a necessitous rather than a luxurious point of view.

All motor cars have certain peculiarities that render the adaptation of complete lighting plants a matter for great forethought, and the employment of considerable ingenuity; more especially is this so with the dynamo portion of the equipment, as the ordinary type of dynamo is quite inadequate to supply the power for lighting a car. The chief reason for this inherent unsuitability is the fact that all ordinary dynamos, whether large or small, require to be run at a constant speed to ensure a steady output of current. It will be readily seen upon a moment's reflection, that with the car engine as the motive power, the dynamo would hardly fulfil this condition for even two consecutive minutes. Its output would be such that one minute the lights would just glow, and the minute after, perhaps, they would be fed with such a quantity of current that their filaments would be fused. It is the purpose of this volume to show how the electrician has ingeniously adapted the dynamo to the needs of the car. For some years past their serious attention has been engaged upon this problem.

The struggle—for the pathway of its solution has been beset with innumerable obstacles—has been bravely maintained, and now the motor car is not deemed complete without its electric lighter and starter. The problem presented is, strictly speaking, a threefold one concerning the design and equipment of special electric lamps, the generation and regulation of current, and last, but not by any means least, its successful distribution. The greatest setback to the success of the earliest attempts was accountable to the fact that there were no suitable electric lamps then in existence, as until the metal filament lamp was materialized the old-fashioned carbon lamp was the only electric glow lamp obtainable. The unsuitability of this lamp was not so much due to its greed for current as to its peculiar personal equation; for example, when a current is passed through the cold carbon filament of the lamp it finds its passage one of high resistance, and as the tiny carbon thread warms up due to the current's effort in struggling through, as it were, its resistance gets less and less, and when the filament is fully incandesced the lamp's resistance is very much reduced. This in itself is of little importance to the automobilist, but should the voltage of the battery or dynamo rise above its stated value the ensuing rush of current becomes too much for the poor little carbon filament, and it fuses under the strain. If, on the other hand, the electric pressure should fall below its standard amount the filament grows cooler, as, of course, the current density is now much reduced for two reasons: firstly, the obvious—the drop in electro-motive force, and, secondly, the increase in the filament's resistive power to the passage of the current. The combined effect of these factors is to reduce the light to an almost useless value even though the pressure dropped but a single volt. It will now be evident from what has been said that unless the electric supply was absolutely constant, or, at the worst, varied only by a mere fraction of a volt, the problem was insurmountable. With the metallic filament the position is exactly reversed, as when the filament is cold, its resistance is at its *minimum*. As the current passes, its temperature is raised, and, simultaneously its resistance becomes greater. It will be seen, therefore, that any small difference in the circuit's E.M.F. is rendered of little consequence, as the lamp resistance rises or falls in unison with the current supplied. Although this regulatory factor is in this case in the desired direction, it must not for a moment be imagined that herein lies the solution of the problem of automatic regulation,* for although the hot resistance of the metallic filament is some ten or eleven times as great as the cold, its sensitiveness to pressure variation is most marked when candle-power is considered ; as an illustration, let us take the case of a certain 4-volt metal filament tail lamp rated as a "4 C.P." At exactly 4 volts this 4-candle lamp gave 3·6 candle-power ; at 5 volts the candle-power increased to 8. Other tests carried out on 8 and 12-volt lamps showed even greater variation than this.

Below the scheduled working voltage the variation does not appear to be so great or, rather, so sudden. In the case of a carbon lamp of the same voltage as the tail lamp taken as an example, if the voltage were to drop to two, there would be no hope of reaching one's destination, as the filament would be only just red hot, but in the case of the metallic, it would still give a useful light, of some 0·25 of its original candle-power. In the case of an 8-volt or 12-volt lamp, the light would

* A system of regulation was recently developed by Dufty which was based on this difference of filament resistance (see page 100).

be proportionately greater, as there is a great deal more filament in these lamps.

The earliest attempts to solve the problem of car lighting were almost invariably storage battery installations, which enabled their users to successfully cope with the side, tail, and interior lamps of the car, but it was found that to produce the necessary candle-power for the head lights was impracticable owing to the very large amount of current they consumed, and the consequent weight of the storage battery. (It must be remembered that the efficiency of the new metallic lamp is about four times as great as the old carbon lamp, therefore the battery carried need only be one-quarter of the weight of its predecessor.) To run such a system as the above necessitated the employment of two separate storage batteries, of no small size, one to be charged at the garage whilst the other was in use. As accumulators are not the paragon of simplicity that some makers would have us believe, it was easily possible for the battery to "fall sick." When this happened the unhappy motorist seldom did much beyond blame the makers, or the proprietors of the charging station. Consequently the battery soon became practically useless. Ultimately it occurred to an inventive few to construct a dynamo of such dimensions that it could be readily stowed away upon the chassis of the ordinary car, and in such a manner as to allow of an easy direct drive being obtained.

One of the very first successful attempts to incorporate an automatic dynamo upon the chassis of a motor car was the "En Route" dynamo, not as it is manufactured to-day, but in its original form which, although it bore some features of external resemblance to the modern "En Route" (see Fig. 40), it did not pretend to any of its refinements. The old type virtually consisted of a totally enclosed shunt-wound machine, without any elaboration, save its automatic cut-out switch, which connected the dynamo to the battery when the correct speed was arrived at for charging purposes.

The lights were not intended to be used whilst charging was in progress, as the voltage was of course by no means sufficiently constant at any period to work the lamps direct from dynamo, and whilst the accumulators were under charge they, too, would fluctuate. The charging was done during the day-time, so that the lamps were run from the almost constant battery voltage at night. The great difficulty with such systems as this, is their inability to be of service should the battery become "discharged to the dregs," as may often happen if the daylight charge be forgotten. It was therefore felt that such lighting sets as the above were a long way short of the ideal. However, in spite of this yearning after better things, little, if any, improvement was effected until the perfected metallic filament lamp was well in sight; and then a host of makers took up the subject, and succeeded in solving the problem of automatic electric lighting. At the present time there are some two hundred odd distinct makes of car installations, and it is quite safe to state that the majority of these can be relied upon to perform useful and prolonged service, although, of course, there is still a little to be done before the ideal state of simplicity and perfection is attained—especially does this apply to lamp design, and the standardization of the plant. The larger engineering feats of an electrical nature (starting, etc.) that manufacturers attempt leave much to be desired in some cases.

Providing one has a satisfactory charging dynamo, installed under capable supervision, one need have no fear that the light will be unavailable at any moment, even if the daylight charging be forgotten.

Doctors, and professional men generally, have found electric lighting well worth the expense of the plant and its instalment. Should a call have to be made after dark, no delay will be occasioned in lighting the lamps. The motorist should in all cases consult an experienced firm with regard to the fitting of the dynamo, if he would gain the best possible result, as there are several awkward little jobs to be done on the majority of old cars ; indeed, the author has known cases where it was quite impossible to fit a dynamo at all, so that a satisfactory drive could be obtained. In such cases the owner is advised to buy a new car, as the only solution to the problem. A further point for consideration is the fact that the makers of equipment are, owing to their constantly handling various makes of cars, and fitting one set to them all (the set in which they are interested), necessarily able to suggest practical ways of driving the dynamo, which would not occur to the ordinary motor mechanic. Of course, as time goes on, there will not be the need for this extensive display of talent, as *all* engine makers will put a place on the engine as they do for the magneto, or fit the engine with a motor-generator as an integral part, to enable the engine to be mechanically started by electricity as well, and thus by doing this two very important birds are killed with one stone.

The principal advantages of the electric system hardly need stating, as they are so very obvious ; however, attention may be drawn to the following good reasons for the universal adoption of electric car lighting : (*a*) The necessary power required to drive the dynamo is present upon the car, and can be requisitioned without the slightest risk of seriously detracting from the horse-power of the car, as in the majority of cases the total power absorbed, when the dynamo is giving its full output, does not exceed one-sixth of a horse-power ; and should the generator not be required for charging or lighting purposes, a switch is usually provided to enable the windings to be disconnected, thereby reducing the power absorbed to the smallest fraction only—merely that required to overcome the friction of the bearings and brushes. (*b*) The great convenience at lighting-up time, as all the lamps can be lighted without descending from the car, or even reducing the speed, by the simple process of pressing a button or turning a switch. (*c*) Absolute safety from fire, even if petrol vapour should be found under the bonnet or down in the undercasing, where inspection may perhaps be requisite. (*d*) Perfect cleanliness, as the sooting of burners is impossible; and beyond merely dusting they require no attention whatever by way of cleaning. (*e*) When changing a tyre or detaching a wheel when one is five miles from the nearest station, and the night is particularly rough and wet, it is consoling to note that the "elements'" have no effect on electric light. (*f*) As a final point, probably the natural fascination of an electrically lighted car is a most convincing argument for its adoption.

The Modern Installation

The essential parts of the modern set comprise (1) a dynamo to produce the current; (2) a storage battery to supply the lights, when the car engine has stopped, or is running too slowly for the dynamo to do the work. A further point in connection with the storage battery, which seems to have been overlooked in the earlier treatises on this subject, is its regulating effect upon the *dynamo*; very nearly all the dynamos used upon lighting sets would forfeit their good name if it was not for this little-understood fact. (3) An automatic cut-out switch, or other controlling device; this part is really the brain of the system, as it has to direct the supply and demand of the electrical energy—this is probably the least ideal component of any existing outfit; indeed some of the leading fims have replaced it by other apparatus. (4) The necessary wiring, switches, meters, lamps, bulbs, etc. It is commonly thought that all the above apparatus *must* be fool proof, so that it will perform its functions with equal accuracy in the hands of its designer, or a person lacking intellect. It is pleasing to note that many firms are now assuming a little common sense on the part of the much maligned motorist. The ideal set, of course, is that set that performs its operations with as little looking after as possible, and all these independently of the driver, then, and only then, will the ideal set be recognized. However, it is *most* desirable that the owner or driver should know as much anent the lighting set as he does about the engine—that is to say, he should at least possess a broad idea of how it works. It has been the author's experience that where firms show a willingness to answer intending customers' queries in an intelligent and ample manner, they will in the long run obtain the preference over those that state almost to the point of discourteousness that all the necessary information will be found in their particular catalogue. Many of the largest English and American firms have special departments for dealing with the thousand and one obscure points raised by interested inquirers. Many of these queries are printed together with their answers, and issued in booklet form ; this is an excellent plan for the enkindling of the motorist's interest. The exact type, size, and power of one's equipment, will, to a great extent, depend upon the sum one is prepared to expend upon the complete plant. For example, it is quite possible to have 50 candle-power bulbs in the head lamps, and 12 candle-power globes in the side lamps. The interior may also be required to be brilliantly illuminated as well as the necessary tail and dash-board lights of from 6 to 9 candle-power. A dynamo sufficiently powerful to supply such a comprehensive, and at the same time luxurious installation, would naturally be of much greater weight and cost than a machine to furnish the necessary lamps for safety only.

Whilst dealing with the question of the luxurious, and the absolutely necessary amount of illumination for safe driving purposes, it may be as well to draw the reader's attention to what was recently a common practice among motorists who had just become the proud possessors of an electric set. Financial and other considerations decreed that their set should be a moderate output one. The plant as fitted by the makers, and equipped with suitable lamps, and what is even of more importance, suitable lamp bulbs, gave complete satisfaction. The owner has shortly afterwards, however, acquired an infatuation for a pair of 50 candle-power head lights, and has had them fitted by the local garage mechanic, who, however well versed in the art of cleaning and repairing motor cars, knows little about matters electrical. In one or two cases the motorist has just exchanged the *bulbs* of his headlamps for those of the higher denomination. Such a procedure as the above, always results in trouble, unless in very experienced hands—trouble arising from the disturbed balance of the outfit. The makers had already supplied lamps of the maximum power for the set under observation, thus, when the exchange is made, the output from the battery far exceeds the input by the generator ; this, in itself, would be of little importance, if the car were run mostly during the daytime, but even so, the regulatory effect of the storage battery just referred to would be lost and the light consequently unsteady to a large extent. To be quite safe then, one should have their dynamo of such a size (or rather capacity) that its current is quite equal to the usual lamp load, when all the lamps are lighted. As a matter of strict accuracy, it is ideal to have the lamp load just a little in excess of the dynamo's supply to the storage battery. In this manner the regulating effect of the battery has its maximum dominion. The case we have considered is, of course, an extreme example, when contrasted with the generality of instances; but many complaints of a minor nature are really traceable to this cause, and not to any remissness upon the part of the manufacturer. For practical electric lighting the following particulars may prove of assistance to the motorist who has not yet installed electric light upon his car.

Type.	Number.	Candle-power.*
Head lamp	2	16 to 32
Side lamp	2	4 to 9
Tail lamp	1	3 to 4
Speedometer or dash lamp	1	3 to 4
Interior lamp	1	4 to 9

* This refers to the candle-power of the bulbs alone.

The above table gives a rational allowance for a small to moderate size of car. It will be understood, that where an extra powerful head light is required the size of the lamp, and the power of the bulb should be increased. The same remarks apply with equal force to the side lights. To meet special exigences one should not hesitate to install a plant of ample capacity. It should be specially noted that the head lights should be wired and controlled independently. In the average case, it is usual to assume that, when the car is running, the total candle-power output working within the limits of the above table would be from 48 to 90 candle-power. Whilst the car is standing in the public highway, such as waiting at a theatre, the output would be approximately 16 candle-power.

One hears little if anything nowadays about the disadvantages of electric lighting—except perhaps that it "ruins the eyesight." It is not unusual to place the disadvantages of a subject right at the tag end of the story, but in this case there is no need to hesitate in bringing them to the forefront. The only really inherent disadvantage in connection with electric systems of car lighting was mentioned when explaining the technical terms, under the heading of "Bad Contact." With other illuminants than electricity a failure is premonitioned by a gradual dimming of the light, but with electricity the light may suddenly be extinguished owing to a loose connection in any part of the entire system (comprising dynamo, battery, switchboard, and lamps). To banish such an occurrence even from the sphere of a remote contingency is a simple matter if one tightens all the connectional terminals with a pair of pliers, and not merely have them "finger-tight." Many of the modern terminals are designated as "vibration proof," as they are secured in their positions by simple but effective locking devices. In one or two instances the stem of the terminal is expanded towards the top, so that it is impossible for any terminal nut to be entirely removed. This method, however, is not so good as many others. The few remaining weak points are all to do with badly made and inefficient lamp fittings, and are not now very serious; indeed, quite 95 per cent. of the few failures in practice are due to there being no provision for fixing the dynamo upon the chassis.

With the small car owner the question of supreme importance is always: "What will the cost be?" so we will deal with this before passing on to more detailed study of the actual components. It is not, of course, always possible in every case to arrive at a reliable figure, as so much depends upon its use. However, if the car is used to any extent for regular night work, there is not the least room for doubt that electricity can hold its own ; for example, the cost of an electrical installation is on the average about £40 to £45, although one can spend considerably over £100 upon an equipment *de luxe.* There are some firms who undertake to convert one's old magneto into an up-to-date lighting dynamo for a few pounds only ; this plan, if satisfactory, would bring an installation within the limits of £25, or possibly less. In both cases the figure includes the charge made for fitting by the firms that manufacture the apparatus. If one buys the set and have it fitted at one's own garage it usually costs, in normal cases, from five to ten guineas for fitting.

To purchase a couple of acetylene head lights and generator, a couple of side lights and a tail lamp will not usually need an outlay of more than half the above amount.

The cost of the outfit seems at first unusually high for so small a dynamo ; however, one must bear in mind that a large output is asked for at a minimum of space and weight, also provision has to be made for a wide range of speed variation. Furthermore, the workmanship must be of the highest possible order, in order to withstand the extraordinary running conditions. The choice of the fittings allows of a wide range of prices, but the dynamo does not, as it costs a great deal more to manufacture than the average motorist would think, simply because it contains much more work than he credits it with.

In connection with the output of the generator, it is of first importance to arrange that the lamp load will not exhaust the battery, even if discharge is in progress during the whole time the dynamo is working. Several otherwise successful installations have been handicapped through failure to observe this important point. To make the matter quite clear, let us take an actual case. Suppose our dynamo can supply a steady current of five amperes into the battery, and the car runs exclusively at night, we have to be careful to adjust the power of the lamps, so that they consume not more than four and a half amperes, to be on the safe side. If they consume five and a half amperes it will cause the battery to be slowly discharged, and the lights will ultimately grow dim.

Under such treatment as this the battery will be speedily spoilt, with the result that the system will not work satisfactorily owing to the loss of its prime regulator—the battery.

It is quite possible to obtain a dynamo with a greater output than the discharge rate of the battery ; indeed, in some systems this is the working hypothesis. The advantage of this arrangement is, that in the event of the car running exclusively at night, it will be impossible to discharge and injure the battery. Modern practice has established the fact that whatever type of generator is employed, its rate of charging the battery should "tail off" at high speeds rather than increase if the best all-round service is to be obtained.

A motorist's choice of equipment should be governed by a process of selective reasoning, as there are so many excellent sets upon the European and American markets ; nevertheless, after giving the matter careful consideration, circumstances will be the ultimate guide in his choice of a set that will relieve him of the irritating struggles between matches and wind in which the latter sometimes came off victorious, and that will make lighting-up a pleasure. The choice of starting equipment is a matter of great importance, and the motorist would do well at all times to approach the manufacturers of his car for their advice. Upon all modern cars the manufacturer has put *his* standard equipment.

CHAPTER III

REQUIREMENTS OF CAR STARTING

Electricity has so completely ousted every other form of starter from the motor car that it seems superfluous even to state that a new car minus an electric starter would be somewhat of an anachronism. The only car that will be tolerated in the future is the one that will start without shocks, bangs, or grindings. Motor engineers spent years in perfecting the engine so that it should run noiselessly—as it does to-day. So with the starting—that wonderful invention known as the Bendix drive adopted by practically all of the starting firms has to all appearances eliminated the imprisoned mangle effect that so conspicuously told one's friends that one had an electric starter in the car. For commercial vehicles there is still to be had other types of starting gear; the impulse starter is probably the best known—perhaps the sole survivor. Two impulse couplings were on view at a recent motor show. In these devices a trip gear is automatically cut out, setting itself again as soon as the engine stops ready for the next operation. Of course it will be realized that unless one has an extra large battery aboard a lorry delivering beer in a back street in Birmingham for instance, where the public houses are unusually numerous, the energy could not be "put back" into the battery between the calls, and so the battery must inevitably become discharged.

The above requirements have not to be met with in pleasure vehicles, but here, too, we find a fly in the designer's ointment, as we cannot escape from the stiff initial starting difficulty. Let us take some figures to indicate what is in store for the Ford battery for instance. The Ford starting motor without load takes 70 amperes; on a good loose engine 140 to 200 amperes. On a stiff cold morning sort of engine the current consumption is no less than 225 to 300 amperes. Blocking the motor so that the armature cannot turn consumes 300 amperes. Running without load this motor consumes 373 watts, or ½ horse-power: the current was 65 amperes at 5·75 volts.

Tests on a Typical New Engine.—Motor turning at 900 R.P.M. engine at 75 R.P.M. motor takes 275–300 amperes at 4·5 volts, giving a maximum power consumption of 1,350 watts or 1·8 H.P.

Tests on a Typical Run-in Engine.—Motor turning at 2,200 R.P.M., engine at 183·3 R.P.M. Motor taking 140 amperes at 5 volts giving 700 watts, or 0·93 H.P.—Tests of the American Bureau of Engineering, Chicago. From the above the first requirement of car-starting is undoubtedly a remarkable storage battery.

The average engine of $3\frac{3}{4}$-inch bore by $5\frac{1}{4}$-inch stroke and 60 pounds compression can be spun at 100 R.P.M., a speed in excess of what is required for starting, with a current of 95 amperes. Some makers claim to start an average engine with 50 amperes of current at 12 volts in one second, given accurate spark and carburation adjustments. The exact power required varies as the size of engine to crank and the speed at which it must be revolved. Loss of power in the motor itself, and in the reduction gear where this is fitted, may add as much as 75 per cent. to the pull required of the motor. In general the initial rush of current when switching on is double that which will subsequently keep the engine turning over. Engines of from 20 to 40 H.P. require at the moment of switching on 1 to 1½ H.P. of electrical energy. This drops to about half when away. High turning speed is desirable for ignition and carburation reasons, also it minimizes backfire. The second requirement for the starting system is a series wound motor small enough to be accommodated on the car, and sufficiently robust to stand up to its work. There are many starting motors that answer these requirements; a detailed description of some of them will be found in Chapter XI. There is no very great

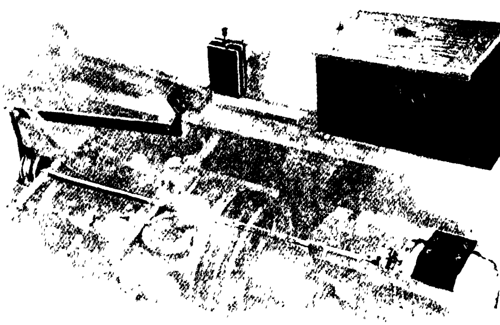


FIG. 6.—The C.A.V. Friction Drive Starter.

difficulty in designing an electric starting motor: it is far simpler than the car dynamo, as it is free from all "funny business" in its fields—being a plain honest series wound motor with extra heavy windings. In the armature of many types wire is replaced with rectangular conductors, so as to get more copper into the slots. In one type a special shape of slot is used in the armature core. The motor is usually 4 pole and not 2 pole like most of the dynamos used on cars. The cables to convey the energy to the motor have to be enormously thick or the "lost volts" * will be conspicuously high. The switch gear has to be so designed that it will handle large currents without getting burnt and worn. The contacts must be massive and positive in action.

As the length of time for which the motor is in operation is extremely small, all the windings can be operated at high-current density.

The greatest problem has been to devise a sufficiently simple and yet efficient way of automatically coupling

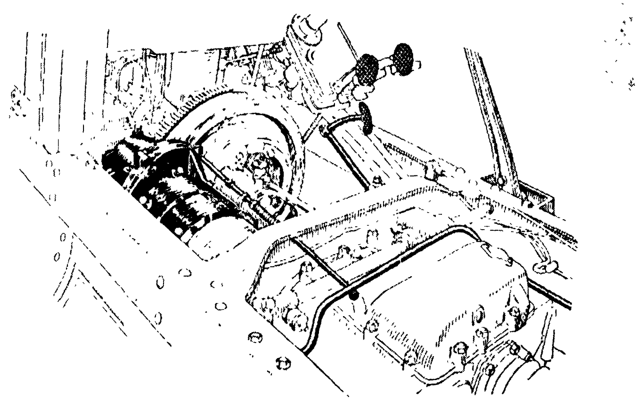


FIG. 7.—Sketch showing how the simple series type is geared up to engine.

and uncoupling the motor to the flywheel. In the past many systems have been evolved, and among them one of the most widely used was the friction drive. A high-speed motor was housed at the back of the chassis, and its power was transmitted to the engine flywheel by means of a long propeller shaft with a universal joint coupled up through an epicyclic 5 to 1 gear and fitted with a friction pulley. One of the earliest

* See note on p. 190.

friction drives is shown in the illustration Fig. 6, from which the general scheme will be apparent.

This and other systems of drive have been given up in favour of the geared flywheel drive. In outline we now have a comparatively slow-speed motor fitted close up to the flywheel, the periphery of which has been cut to form teeth, or when added to an old car, fitted with a toothed rim, so that the shaft of the motor, which also is equipped with a pinion can engage into the teeth of the flywheel (see Fig. 7). When the engine fires, arrangements are provided so that the pinion can move out of mesh. This automatic meshing and demeshing has troubled the brains of many motor engineers. A consideration of the prize-winning efforts must be left over to Chapter XI.

In brief, what is sought after is an apparatus which will give us all of the following features : (*a*) Automatic engagement, (*b*) positive engagement, (*c*) automatic disengagement, (*d*) positive disengagement, (*e*) small motor pinion, (*f*) proof against backfire, (*g*) no jambed pinions, (*h*) shockless, (*i*) noiseless, (*j*) light-weight, (*k*) economical with the current, (*l*) cold weather ability, (*m*) harmless to press starting switch when engine is running, (*n*) no intermittent ticking of pinions against the flywheel.

CHAPTER IV

THE DYNAMO AND ITS CUT-OUT

In the last two chapters we discussed car lighting and starting in a general way; in the present one, it is proposed to deal with the first principles of the dynamo itself, and to give a glimpse of the *modus operandi* of the specific units with which the dynamo is correlative.

The Lighting Dynamo simply explained

The automobile dynamo differs in no essential from the ordinary dynamos of commerce, such as are used for lighting our houses and streets. However, in detail, it is widely different. There are nowadays comparatively few persons who think that the electricity used for lighting purposes is obtained from the electricity present in the atmosphere. However, the author quite recently overheard a lady motorist explaining to a gentleman friend that the dynamo on her car generated the current by means of the friction caused by the brushes rubbing on the commutator of the machine. To support her statement she removed the dust cover of the dynamo and asked her friend to contemplate the brilliant array of sparks that surrounded each brush, at the same time telling him in a reminiscent sort of way of the wonderful strides electrical science had made since the days when her grandfather used to electrify the family with a certain plate-glass electric machine. Now, of course, it is a well-known scientific fact that friction under certain favourable conditions does produce electricity, but if car lighting depended upon such charges as those, many of the statements made by advocates of acetylene systems would be nothing less than the literal truth. When visiting the local power station, many people are puzzled to know why such a powerful engine is required to pull round a dynamo machine, which to the eye has no apparent resistance to motion. To explain this point, let us for a moment consider the little magneto used upon a motor car for ignition purposes. Upon rotating the spindle one cannot fail to notice that at certain periods in its revolution, the armature (the part one is rotating) seems to be held back or resisting an invisible force which is trying its level best to stop it turning. This, then, is precisely where the power is required—in overcoming this unseen power—magnetic attraction, as it is known to the profession. Fig. 8 gives a rough idea of what form this magnetic force apparently takes, in the case of a simple form of machine. The thick dotted line between the poles—the projecting pieces marked N and S—is supposed to indicate the rotating part of the generator called the armature. It will be noticed that the lines of magnetic force pass through this without reluctance, it being mainly composed of soft iron; it is therefore said to be a good *magnetic* conductor; other substances, such as wood, copper, paper, etc., are all no better than air for the conveyance of these magnetic lines, as they are usually called, which form the magnetic field or area. The arrows in the sketch indicate the direction in which these lines are assumed to flow. This supposition is, of course, an arbitrary one, but, for purposes of definite calculation and design, it is necessary to fix a standard course to these lines of force, so that scientific statements shall be generally intelligible. They first leave the magnet at the north pole and enter it (after permeating the air space or the iron armature) at the south pole, wending their way back again to the north pole through the material of the magnet ready to start out again. These lines of force, as indicated in Fig. 8 by the finer dotted

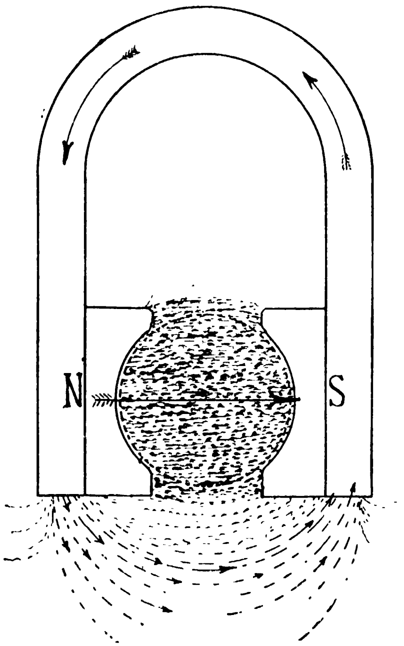


FIG 8.—A Magnetic Field: the arrows denote the direction of the lines of force.

lines, are not finite in number, but are infinite. To realize this, take a piece of stout drawing paper or thin cardboard and sprinkle a few very fine grade iron filings thereon. Now take a large bar magnet, hold it in a vertical position, and let one of its poles be held underneath the card that has been besprinkled with iron filings. It will be noticed that the filings immediately take up a definite position and arrange themselves in a ❋ shape. Let the magnet be rotated round its own axis, *no displacement will occur in the position of the filings.* One conclusion alone can be drawn from this experiment, namely, that the *lines of force are infinite in number.* If they were finite the filings would perforce follow the rotation of the magnet. We have now arrived at a most important conclusion, viz. that the whole of the space surrounding the poles of any magnet is pervaded by magnetic force. Further experimentation has demonstrated that no matter how strong or how weak the magnetization is, the above holds true, neither does it make the least difference how the magnetic field is produced—permanently, as in the case of magneto magnets, or, temporarily, as in the case of an electro-magnetic field (see diagrams in Figs. 10 and 12. Here, again, in order to make calculation and comparison possible, it is necessary to fix a unit (number of lines per square inch) to designate the intensity rather than—as the unit itself would lead one to suppose—the quantity of lines of force present in any given magnetic field.

If we place a conductor, such as a piece of copper wire, in the magnetic field of such a magnet as depicted in Fig. 8, the moment we place it in the active area an electro-motive force is set up in it, and if we bent the two extremities so that they were brought into contact, a current would flow through the circuit we had thus completed. When the wire was withdrawn from the field the same effect would occur. If the reader were to take a large coil of insulated wire several yards long and arranged so that the wire forming the conductor was in a large number of turns, each end of the wire being joined to a sensitive galvanometer, and drop this coil through the polar space, i.e. between the poles marked N and S in Fig. 8, the needle of the galvanometer would indicate by its movement the presence of an electric current flowing through the wire. The above is a modification of Faraday's great experiment whereby he discovered what he called "induction" (the current in our wire owes its presence to this phenomenon of induction). It will be noticed that unless the wire is actually moving no current is set up, hence we conclude that one of the first principles in the production of electric currents by dynamos is to have some means of constantly varying the magnetic influence. It makes little difference which way this is accomplished, but for purely mechanical reasons it is more usual to impart the motion to the system of conductors (called the armature). In car lighting and starting machines, we have ample evidence of all possible systems of varying the magnetic influence, the most frequent practice being to rotate the conductors upon an *iron* drum, in order to increase the inductive effects. In some types the armature is stationary, and the field magnet rotates, and in other cases where the permanent magnetic field is helped by an additional electro-magnetic field, the field coils which excite the electro-field remain stationary, so also the armature, the sole rotating part being the permanently magnetized steel mass which also forms the fly-wheel of engine (see Fig. 170, p. 276).

It must be always borne in mind that the part that produces the magnetic force or "flux," as it is more usually called, is always alluded to as the "field-magnet," and the apparatus that carries the conductors in which the electro-motive force is set up is always spoken of as the "armature" irrespective of its capability of rotation. In the magneto the armature is of the simple coil type wound upon an iron mass so as to increase the magnetic inductive effects of the field-magnet; this simple arrangement is known as an **H**-type armature, owing to its similarity to that letter. Being of one coil only, the current, as might be gathered from the simple experiments mentioned earlier in this chapter, would be of a very unsteady and unsatisfactory character; indeed, it would be much too unsteady for car-lighting purposes In order to render the current more constant and less intermittent, also suitable for charging purposes, several separate coils of wire are employed upon a modified form of armature core or drum; the arrangement and appearance is shown in Fig. 9; the coils are wound into an almost tunnel-shaped slot, so as to minimize the centrifugal strain and so lessen the risk of the coils being displaced during their rotation at

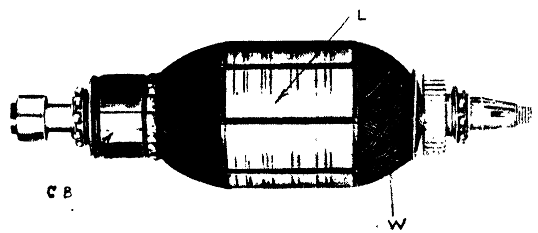


FIG. 9.—A Dynamo Armature.

high speeds. Most firms have adopted this form of armature as the most suitably constructed for car-lighting machines. The armature core (L) is built up of thin laminations * of soft iron, and upon this are wound several coils of insulated copper wire—each coil consisting of many turns of wire (W). The part (CB) is termed "Commutator"; its function is to collect the current that flows round the armature coils, and to deliver it to the brushes (not shown), which are generally two or more carbon blocks that

* If the core of the armature were not laminated the armature, owing to what are known as "Eddy currents" (no relation to Christian Science), would become very hot.

are so ground that their ends coincide with the periphery of the commutator, and are pressed well down upon its surface by means of springs which are concealed in the brush gear. The brushes in their turn convey the current to the storage battery. A word or two upon the subject of commutation may prove of interest to the motorist. The E.M.F. generated in any armature is always alternating in character ; it could well be otherwise, as will be shown.

We have already seen that the electro-motive force is only generated by a conductor cutting the lines of force. The flux is streaming mainly across the polar gap, as indicated by the arrow in Fig. 8, so that, when the conductor's position, in the course of its rotation, is such that the motion is almost parallel to the lines of force, little E.M.F. will be induced in it, for the simple reason that practically no "cutting" is taking place. Let us assume this to be the starting point of our conductor. As it moves away from this position it gradually cuts the lines of force, until eventually it takes up a position at right angles to the main body of the flux ; such a position as is shown by the tail of the arrow in Fig. 8. In this region our conductor is cutting the maximum amount of flux, and therefore has the highest E.M.F. It will now pass out of this maximum area, and cut less and less lines, until it finally finds itself in a position at right angles to the arrow in Fig. 8 ; and midway between the poles of the magnet, the path traced out by the conductor is indicated by the dotted circle described between the poles. In this place it is diametrically opposite its starting point, and is cutting no lines of force again. When it moves away from this position, it comes under the influence of the opposite pole of the magnet, which will produce a change in the direction of the E.M.F., and by the time it has arrived at the point of the arrow in the diagram, a maximum E.M.F. of an opposite sign to the previous maximum will be induced in the conductor. Moving on again towards its first position, the E.M.F. will gradually die away until it disappears altogether upon the conductor reaching its starting point. After passing the starting position it again begins to build up an E.M.F. of an opposite sign or polarity. As will have been gathered from the foregoing description of the process, this cycle takes a relatively large time with one single coil such as is found upon a magneto's armature, and, limited as it is to speed of rotation, the current must needs be very pulsating or intermittent. To reiterate a former statement, this condition would be intolerable for lighting purposes. In order to allow of a steady current being obtained from the armature, it is necessary to have a number of coils wound upon the armature as may be seen upon any existing electric starter or lighter. By this means it is possible to have always some coils in the best generating position; when one is just passing out of the vicinity of maximum flux the next is coming into it, and also the E.M.F. induced in the coils is the sum of all the separate E.M.F.'s in each coil joined in series. Thus, although from their individual positions in the magnetic field, it is quite impossible for all the coils to contribute equally to the total E.M.F., the induction of one coil is added to the induction of the next, and so on; by this means the effect is cumulative, and provided the brushes are placed in the best position, the maximum E.M.F. will be always available.

The fact of having a number of coils in series does not in any way rectify the current. To do this it is necessary to fit what is known as a "commutator." It consists of a number of bars of hard drawn copper arranged in a circle and carefully insulated from the shaft and each other by means of a mica bush and mica strips respectively. To these bars are connected the beginning and ends of the armature coils. They are so arranged in respect to the commutator and brushes, that at the critical instant, when the direction of the E.M.F. is reversed in any particular coil, the brushes cross the insulation of the commutator that is between adjacent bars, and so reverse the connections to the brushes. In this way a continuous, or, at least a current free from alternations is obtained. The evenness or continuity of the current will depend upon the number of coils (not turns per coil) upon the armature. This current is suitable for lighting and charging purposes. The brushes of a machine are of such vital importance that upon all the best makes of machine they are duplicated. It is essential for the brushes to have sufficient angular width so that they can bridge two adjacent segments over the insulation; this for various reasons insures sparkless commutation (always assuming the design and proportion of other factors are correct.)

The results of which we have been speaking only take place when the armature is moving in a magnetic field. To produce such a field in a car-lighting dynamo three methods can be used: (*a*) by the employment of permanent magnets of a horse-shoe type such as motorists have been familiarized with in the ignition magneto; (*b*) by the employment of an electrically excited field; (*c*) by the employment of a mixed field, i.e. partly formed with permanent magnets and partly by means of electro-magnets. The permanent magnet, to take the first method, is needless of description, it will be remembered that the magnetic force is permanently resident in the steel of which the magnet is composed. The electro-magnet is, perhaps, new to some motorists, therefore, let us perform a little experiment that will be indicative of its special properties. Suppose we take a soft iron rod and place one end into a tin of "tacks," we shall find that it possesses none of the attractive powers common to all magnets. Let us now wind a length of insulated copper wire round it, as shown in the accompanying Fig. 10. The ends of this wire are to be joined to the terminals of a dry cell, as shown in the illustration. Now, upon dipping the end of the rod into the tin of tacks it will be found that it has become strongly magnetized, and that if the rod is withdrawn carefully, some tacks adhere to it. It will further be

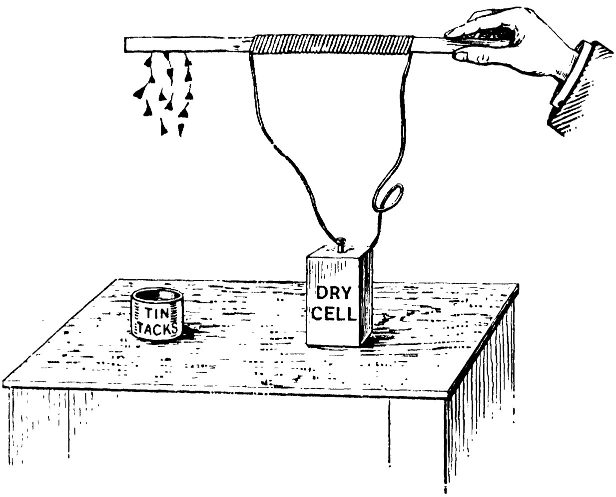


FIG. 10.—Electro-magnetism.

found that upon disconnecting the dry cell, and so stopping the exciting current, the tacks instantly fall to the ground. The above experiment shows us quite clearly the difference between the electro-magnet, whose magnetic properties cease upon the cessation of the current, and the permanent magnet whose effects are always with us. Electro-magnets are used in preference to permanent ones, for many reasons, chiefly, however, because one can obtain a greater amount of magnetic force from the electrically-excited magnet of equal size and weight; also with the permanent magnet it has been found that the vibration of the car, coupled with what is known as "armature reaction," * tends to demagnetize the steel after some years of use, whilst, in the case of a soft iron or mild steel electro-magnet these improve with use and age if anything. The mixed magnet suffers the worst of any from demagnetization, as in most cases this phenomenon is purposely called into being, in that the electro-magnetic effect is deliberately set to oppose the permanent flux, for the purposes of output regulation. In the majority of machines which rely upon the creation of an opposing magnetic field to the main permanent one, the end is obtained by means of winding one or more coils of wire over the permanent magnets and connecting them up to the brushes in such a manner that the flow of current through them will create a south pole just in the region of the main magnets' north pole, and so nullify its effect to a greater or lesser extent, depending upon the strength of the current passing round the coil. In some instances, however, a soft iron core is provided in order to still further increase this nullifying effect. It will be found, upon experiment, that if we pass an electric current round one of the coils illustrated in Fig. 11, and bring a piece of iron near it, the magnetic effect will not be very strongly marked, but, if we place the coil upon a bar of soft iron which fits it tightly, and then try with our piece of iron, we shall notice a very considerable degree of magnetization in evidence. Of course, the difference here is very noticeable, as we have the two extremes compared, an air

* The neutralizing effect of the magnetism acquired by the armature owing to the circulation of the current in its coils upon the magnetism of the field; these two magnetizations are in opposition to each other, therefore the field developed by the armature is wasteful and parasitic. The necessary position of the brushes upon a dynamo tends also to induce a further wasteful magnetic field in the armature, and still further reacts upon the field magnet.

core and a soft iron core. In the case of the same coil mounted upon the permanent magnet as is intended for the coils shown in Fig. 11, the core, although not of soft iron, is fairly efficient. The commonest type of field magnet is shown in Fig. 12, which represents an electrically excited magnet composed of mild steel. In common with the majority there are two exciting coils, one placed at the top and the other at the bottom of the casting. The apparatus in the front of the picture is the armature, which has just been removed

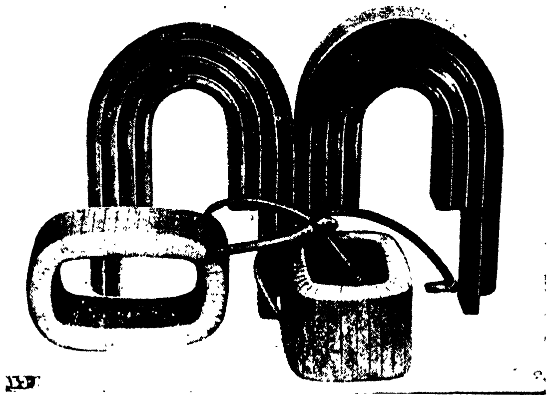


FIG. 11.—The "Mixed" Magnetic System.

to show the arrangement more closely. The windings used upon electrically excited machines are not always alike in character; in some they form what is known as a "shunt" machine, in others they cause the machine to be designated as "compound," and in starting motors they may be so arranged as to produce a "series" machine. In the case of the shunt machine, the field coil is connected across the brushes, one end to the negative brush, and the other to the positive pole; in this way full terminal pressure is fed into the field. First of all, as soon as the armature begins to rotate, a very weak current flows through its windings and into the field. "Where does this current come from ?" asks the interested motorist. Every iron mass, after being subjected to the filing, drilling, boring, turning, hammering, etc., in order to make it into a dynamo shell, acquires a little magnetism in the process produced in it by the earth's field. The molecules of the metal, being much vibrated, are then in the right condition to accept the influence just referred to. This initial magnetism is always spoken of in electrical circles as "residual" magnetism.

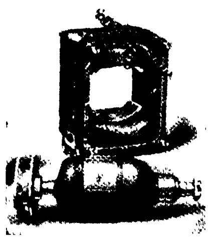


Fig. 12.—An Electrically Excited Magnet.

Hence, at the outset of the dynamo's career we have conductors moving in a magnetic field—a very weak field it is true, but sufficient under normal conditions to send a small current round the field coil. Consisting, as it does, of many turns of wire, the cumulative magnetizing effect of even that very small current is very great, and it quickly raises the magnetization of the iron to a high degree ; this, in its turn, acts upon the conductors of the armature with the result that the subsequent field current is very much augmented, and so the operation goes on until the maximum magnetization is reached possible with the permissible speed of the armature. It will be remembered that, if the rate at which a conductor cut the lines of magnetic force were increased, the E.M.F. induced in that conductor would also be increased. In the case of the "compound" winding used upon several makes of dynamos (although for battery charging purposes the best machine is the simple shunt-wound outlined above) the compound is cut out, unless the lights are burning, except it is used for regulatory purposes, in which event it is called a "bucking coil," and produces magnetic effects that are in opposition to the main shunt field. The winding itself consists of a number of turns of thick wire wound over the shunt coils so that the winding is part of the outer circuit, and, therefore, the current consumed by the lamps is made to assist or detract (depending upon the way the winding is connected up) from the magnetizing force of the current flowing through the shunt winding.

In the series wound machine we have the same current passing through the field as through the armature, as one end of one field coil is joined to one brush of the machine, and the end corresponding of the other coil is connected to the outer circuit. The two free ends of the field coils are connected together, the other main is joined to the unconnected brush. This machine is seldom used as a dynamo for car-lighting purposes, but as a powerful motor for electric starting gear. We have already seen that the electrical output of a dynamo is, to a large extent, dependent upon the speed at which the armature is rotated, and it follows from this that when the rotation is high, considerably more power is required to drive the dynamo as more work is being done. The E.M.F. will in normal cases reach its highest value only at maximum speed. Now, suppose instead of taking electrical energy out of a dynamo we put electrical energy into it; the dynamo at once begins to "motorize" (run as an electric motor); the greater the current we send through the windings the greater the power of the available mechanical energy. In certain complete equipments intended for lighting and starting this is the principle followed, and the machine for the sake of distinction is referred to as a "dynamotor," and will perform both the function of a dynamo and motor as occasion demands.

The Principles of the Starting Motor

If we take an ordinary dynamo of the simple shunt-wound type and send a current into it at its normal output voltage, it will at once run as an electric motor. Let us take the ammeter reading in order to note its current consumption; this being carefully noted, put a load upon the dynamo in order to make it run slower (this can be done sufficiently well for the purpose of this experiment, by merely pressing upon the driving pulley with a duster), we at once observe that the amperes now flowing are considerably more than when the machine was running freely. It must be admitted that the opposition to the passage of the current has considerably diminished—we must say opposition, and *not* "the resistance," has become lessened, otherwise we may fall into the error of supposing that the "ohmic" resistance (see page 6) of the wire has in some mysterious and inconceivable way decreased. If the resistance of the conductors has not altered, how then the apparent difference? To answer this question is not difficult, if the reader remembers that the armature rotating (no matter how) in a magnetic field produces in its conductors an E.M.F., and that this E.M.F. must be in direct opposition to the E.M.F. supplied by the current for running the machine as a motor, as it is ordinarily used for driving the current through the outer circuit into the battery or lamps, and naturally it follows from what we have already seen that this opposing electro-motive force will be at its maximum value when the machine is running unloaded, and therefore it is impossible to send much current through the armature under these conditions. However, when we put a load on the motor, the speed goes down, and simultaneously the E.M.F. in opposition drops considerably, and as the E.M.F. of the supply current does not also drop, more current is as a *sine qua non* forced through the armature and more mechanical power is available in consequence of the increased electrical energy. Shunt-wound motors are of use where the load keeps well within prescribed limits and does not vary but little. In the case of starting the engine, especially on a cold morning after a week's rest and a good compression, the power required is by no means small, and the amount required is not taken as a regular load, but more or less the motor has to perform a series of irregular jerks as the engine encounters compression. The only motor which has this necessary starting torque is the "series" motor: such powerful currents can flow through the field windings and at the same time (as armature and fields are one and the same circuit) through the armature that very powerful magnetic effects are set up in the machine which ultimately resolve themselves into mechanical power of no mean order. Indeed, the starting torque of even a moderate-sized series cranking motor may amount to well over $\frac{3}{4}$ brake horse-power: this huge effort is best explained by stating that the current taken by the motor may be anything up to 200 amperes!

Output Control

There still remains one important consideration to be dealt with, namely, "the *elements* of output control"—the term "elements" is used advisedly since this is only an elementary manual, and it would therefore be beyond its scope to deal with the abstruse problems that beset the dynamo designer in detail; also the correct explanation of many of the existing phenomena which occur in dynamos is more a matter of theory than of absolutely definite knowledge. Nevertheless it is to be hoped that the motorist will not be merely content to know that the output of his set is controlled by a "patent in the dynamo." Although we may very roughly divide car lighters into three groups according to whether their field magnet is a permanent, electro-magnet, or mixed type—a cross between the other two, combining as it does to some extent the good points of each type—this general classification does not, however, differentiate between the peculiarities of each maker's system of controlling the output of the dynamo, so it is necessary to give somewhat fuller details of these different means to an end. The most popular control is the electrical control; indeed, many first-class firms who had previously placed upon the market machines whose output was governed by other means, have long ago changed to electric control. For the sake of completeness let us consider briefly all the practical methods of output control likely to confront the motorist at large. In passing we must state that the majority of machines, in addition to their output control, need a further provision for allowing the automatic coupling or uncoupling of themselves to the battery; this branch will be dealt with in due course.

The speed at which a motor car normally travels is in every case the basis of all makers' regulatory calculation. It has been found that for touring purposes and general country running the best figure that can be given as a safe calculating basis is the engine speed when the car is doing 18 miles per hour, hence it is necessary to have the dynamo so geared that it will take full load at that speed. When the speed falls below 18 m.p.h. the battery must supply the deficit, and, of course, when the dynamo falls below the arranged critical speed for generating current the battery has to supply the whole load. If one does much driving about town or hill climbing with low engine speed, it is well to adopt either of two courses: (*a*) have a special slow-speed dynamo of large output, or (*b*) dispense with the headlamps except when absolutely essential for one's safety. Taking the other extreme into consideration, a car whose dynamo was geared to give full output at a car speed of, say, 20 miles per hour, when the car speed reaches 40 or even 60 miles per hour in some cases, a dynamo not properly protected will be forced to generate current far in excess of its rated capacity, and serious damage to the windings of the machine will result, as they will almost inevitably become "burnt out" (name given to the charing of insulation). The battery unless protected, too, would receive considerable overcharge and subsequent possible damage. Considering, first, the purely mechanical types of control, which as the evidence of modern design shows is rapidly becoming extinct as a general method (although with certain modifications this plan has many welcome advantages), we have slipping clutches of different designs. For example, one maker uses a clutch composed of two members, one being attached rigidly to the dynamo shaft and the other to some convenient drive shaft. These two members are held in contact by means of a spring, and as the speed of the driving shaft rises, centrifugal governors neutralize the spring pressure, and slippage dependent upon the speed of the shaft's rotation occurs. This method allows of a fairly constant speed drive, and works well with an ordinary shunt-wound machine. A regulator adopted by another inventor has in it a centrifugal governor also, which turns at the same speed as the armature, and moves under the centrifugal influence a small sliding contact arm, over a number of contact pieces, to which are connected various steps of a resistance. The idea being to insert more or less resistance in the field of the dynamo, which has the effect of reducing the strength of the magnetic field, and subsequently weakening the armature E.M.F. At low speeds this resistance is cut out so as to obtain full field strength. This method, however, does not appeal to the engineer as thoroughly reliable in practice, as the sliding contacts would be too liable to wear badly, and so defeat their object. The resistance itself was a hot-bed of complication; in one type a resistance was made of small carbon discs arranged in a tube and connected in series with the field coil. Normally, a spring pressed against these discs of carbon and so kept their resistance negligible. The device was so arranged that the armature current of the dynamo passed through a series winding embodying an iron core, and its influence was exerted to weaken the pressure of the spring. At high speeds, when the magnetic pull was strong, the resistance of the discs was considerably increased, and so the output was kept constant. The author could not conscientiously recommend any one to purchase a dynamo thus controlled. The provision of a compound winding to oppose the shunt-winding is quite successful in practice, and reference has already been made to this method of regulation. Some manufacturers have employed double field windings, one portion arranged to oppose the flux generated by the other portion; the opposing or bucking coil being thrown into action at the right instant by means of a series relay inserted in the armature circuit. One magneto type dynamo has an auxiliary electromagnetic field which is disconnected after a certain current has been reached. If the speed is increased beyond a certain point, the field is reconnected, so that its flux opposes that of the permanent magnet field (see p. 79). These regulating features have been used under slight modifications in some systems to regulate the dynamo's maximum voltage instead of its maximum current. In another widely used system (see p. 96), a few inches of iron is used to improve the regulating effect of a "bucking coil," by being joined in parallel with the latter, and owing to the peculiar properties of iron as an electrical resistance, unusually good regulation is obtained. Another well-tried scheme of regulation is that modelled upon the lines of the Rosenberg machine, known to motorists as the old C.A.V. type (see p. 111). In brief, the principle involved is as follows: A bi-polar shunt-wound dynamo is arranged with a pair of unwound poles at right angles to the wound ones. These poles are magnetized by means of cross-magnetization from the wound poles. Two brushes are placed in the neutral position relative to the main poles, and are sufficiently wide to short-circuit several coils of the armature during the period of commutation. This short-circuit current is proportional to the speed of the dynamo, and acts in such a direction as to demagnetize the wound poles, and so the regulation of output is obtained. Among other well-known types of automobile dynamos is the inter-brush type, such as the Smith dynamo, the Lucas and the Rotax. One ingenious system is fitted with a separate regulating resistance for each circuit. This resistance permits of the passage of a certain current only. If more current is induced to flow the resistance increases up eight or ten times its nominal value, and so protects the lamps. Several systems work upon the sliding armature principle, an arrangement whereby the armature at high speeds is automatically moved out of the most active magnetic area into one less so, and thus regulation is experienced. Still another type automatically increases and decreases the proximity of a magnetic screen to the armature.

In the subsequent chapters we shall consider a few examples of some of the more utilitarian methods of output control taken from this list.

The Automatic Cut-in and Cut-out

The majority of controlled dynamos do not provide a means for joining themselves up to the battery at the right period and conversely disconnecting themselves.

To do this most important operation, several methods are in vogue; pre-eminent among these are the following:—

(*a*) A mechanical switch of the centrifugal governor type; this is usually incorporated in the dynamo itself or, rather, in its driving arrangements.

(*b*) A method is introduced which allows the dynamo to "motorize" (see p. 116) in such a noisy fashion that the driver cannot fail to heed it and disconnect it by means of a switch upon the board for the purpose.

(*c*) A double solenoid switch, operating on the tug-of-war principle, the battery being in opposition to the dynamo.

(*d*) An electrical cut-out switch operating against an adjustable spring.

In order to illustrate the principle of the automatic cut-out switch the diagram shown in Fig. 13 has been prepared. This switch is of the most simple and satisfactory type. The particular adjustments and finish are special to the Lodge system of car lighting, although the windings and principles are common to many systems. It scarcely needs any explanation, but in case there should be any reader who cannot follow the connections it may be advisable to just "go over them." When the dynamo starts generating, the current passes through the shunt winding of the cut-out, and renders the iron magnetic, slightly at first, but increasingly so as the speed increases. At

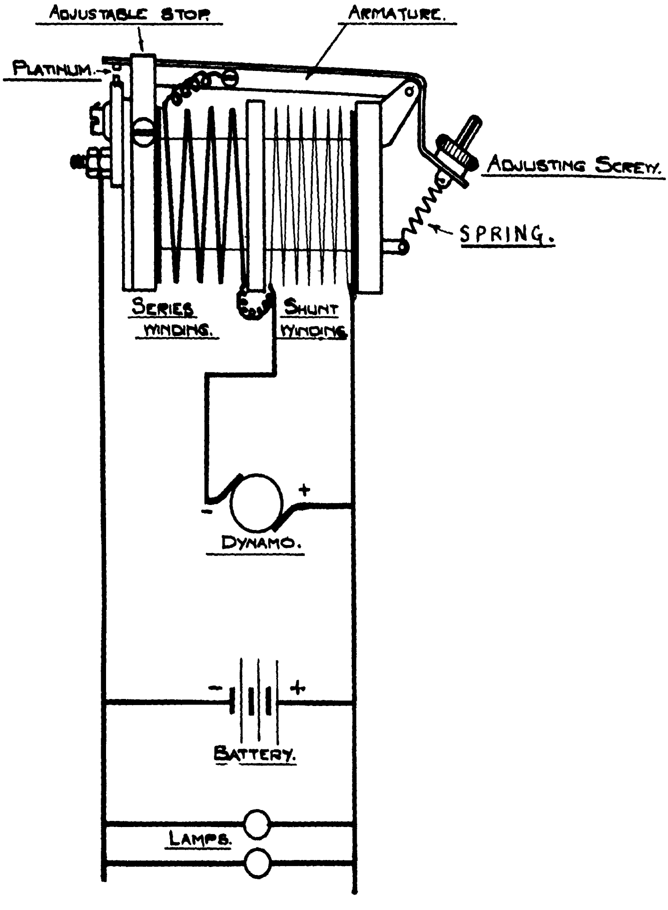


FIG. 13.—An excellent type of Cut-out.

last the magnetic attraction is sufficiently strong to draw down the armature of the cut-out, and the contacts marked platinum are brought together. By this means the dynamo is placed into connection with the battery, as the current can now go from the positive terminal of the dynamo through the battery and out at the negative terminal, up through the platinum contact, round the series coil, thus holding the armature of the switch down with great force, and back to the negative terminal of the dynamo. If the current should fail for any reason, not only does the holding down effect upon the armature decrease owing to the weak pull exerted by the shunt winding, but the dynamo voltage falling below that of the battery causes the battery to send current round the series coil in a reverse direction to that sent out by the dynamo. This, of course, instantly brings the magnetic effects to zero, and the spring at once opens the switch and disconnects the dynamo, thus preventing any damage.

The Analogy System of Teaching Electro-Technics.

For those who find a difficulty in comprehending the mysteries of electrical apparatus, a few analogies may prove useful. It is not difficult to remember in connection with the dynamo used upon a car or elsewhere, that the field magnet corresponds to the boiler of a steam engine, whilst the armature is equivalent to the steam cylinder. There is also one error into which the unwary may fall, and that is, the practice of assuming a dynamo to make electricity; this it certainly does not; it must be regarded more in the light of a pump, which raises water from a well; the water which has been raised can be made to do work in flowing back again, and so with the dynamo, the balance of potential is disturbed by the work done in it, and this potential in its efforts to equalize itself once more can be said to do work in the same way.

A Complete Water Analogy

Fig. 14, which is reproduced from *The Autocar* (England) represents the most comprehensive water analogy devised by the makers of the Lodge Dynamo for the enlightenment of non-electrical motorists. In substance it depicts the engine of the car driving a water pump (the dynamo), the water is being pumped up

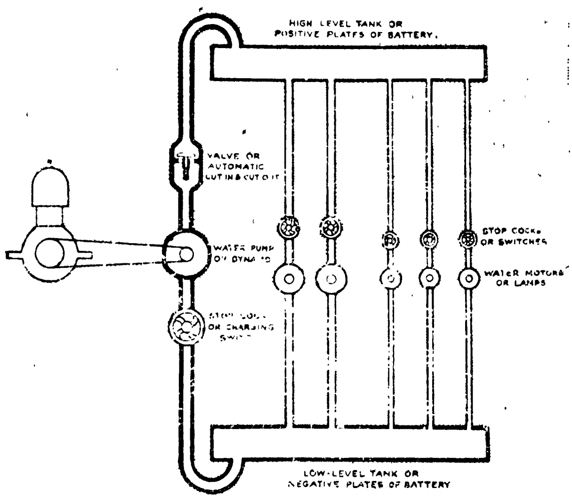


FIG. 14.—A Complete Water Analogy.

from the low-level tank (negative plates of storage battery) into the high-level tank (positives of battery). The water that is being pumped from the lower tank can be shut off by means of the stop-cock (charging switch). It should be noted that if the stop-cock is turned off, no power is required to drive the pump except that required to overcome the friction ; this is equivalent to the dynamo running idle on the car. In the main circuit of the pump there is a valve ; this exactly fulfils the function of an automatic cut-in and cut-out, since when the pressure of the pump is greater than that produced by the difference in levels of the two tanks, the valve opens. Conversely, when the pressure of the pump is below that of the two tanks (the battery) the valve closes and prevents a wasteful flowing back through the pump. In the case of the lighting system, it will be recollected that the automatic cut-out prevents the battery from discharging through the dynamo, when the dynamo's pressure is less than the battery. The high-level tank can be discharged through the water motors (the lamps) by turning on the stop-cocks (the switches). The two big water motors shown in the diagram are to represent the head lamps, and the three smaller ones the two sides and the tail lamp. The pressure of water is expressed in pounds per square inch, whilst electrical pressure is expressed in volts. The water current is expressed in cubic feet per second; electrical current for commercial purposes, in amperes. Both hydraulically and electrically the product of the pressure and the current gives the power. It will be seen that the same power either in the water or electric system can be obtained by a high pressure and a small current, or by a low pressure and a large current.

CHAPTER V

DYNAMOS WHICH EMPLOY PERMANENT MAGNETS

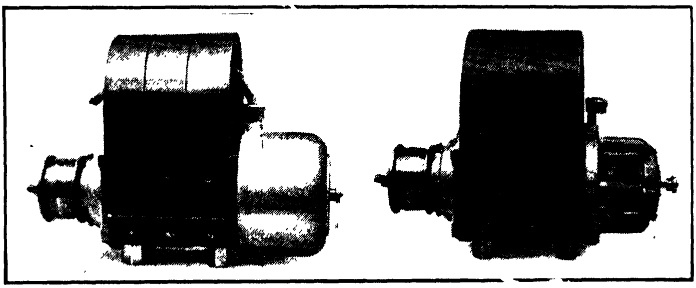
HAVING touched upon the general principles of car-lighters in the previous chapter, we shall now turn our attention to one or two choice examples of the various types. We saw that there were two schools of thought, those who believed in permanent magnets for their machines, and those who did not.

The term "dynamo" is used indifferently by most makers of equipment, whether they use permanent magnet machines, or not. Strictly speaking, this is quite correct, but as the motorist, who has long been accustomed to magnetos for ignition purposes, would instantly proclaim their similarity to his igniter, it would seem to the author a better plan to apply the term "dynamo" to the true, or rather, generally accepted conception of dynamo only. Many makers in Europe and America have adopted this plan. Some well-known English and American makers who originally called their productions by a name strongly suggestive of Magneto have, however, brought their machines into line with the other types and styled them "dynamos."

Among the names which appeal to the author as being better fitting to the class of apparatus they cover, are the following:—"MAGNETOLITE," AUTO-LIGHTER," "MAGNETO LIGHT," etc.

Let us for a moment consider the precise application of the terms "Lighting Dynamo" and "Lighting

Magneto." We can at once dismiss from our minds all parts except the magnets which produce the magnetic field. The dynamo's field magnetism is dependent upon some source of electricity which must be continuously applied in order to maintain the magnetic properties of the iron magnet. This current may come from an outside supply, as in the case of an alternator's field magnet belonging to such machines as those used to supply electric power, or it may come, as is usually the case with the general run of dynamos, from the armature itself (see Chapter IV). As has been implied, the cessation of magnetism is concurrent with the stoppage of the exciting current. The magneto's field, on the other hand, is in no way directly dependent upon a continuous flow of exciting current for its magnetic power ; it certainly, at the commencement of its career, obtained its supply of "power" indirectly from an electric current, as practically all large permanent magnets are magnetized from a large powerful electro-magnet, but, after this indirect application, it requires no electrical stimulus to keep it in the proper magnetic condition. However, after several years the output of the machine falls off a little, as the steel gets "tired," and consequently the magnets lose their power. Heat and vibration are two other prominent causes of magnetic losses. When this happens it is quite a simple matter to re-magnetize the magnets, and can be done at any garage where ignition magnetos are dealt with. The method employed is to magnetize the tardy magnets from a powerful electro-magnet. Great care has to be exercised that the dissembled magnets are not left lying around loose without a keeper (i.e. a bar of soft iron short-circuiting the poles), or some of the magnetism will surely be lost. In re-assembling it is all important to have all the "norths" and all the "souths" of the magnets together and on separate sides of the armature. For instance in Fig. 15 there are two sets of three magnets shown which give six poles on *each* side of the armature. These poles which might be well represented by the six screws, as this is about their theoretical location, must all be of the same kind, for if one or more are dissimilar, they will of course detract from the resultant field and also cause serious heating of the armature owing to magnetic distortion. "Why not employ one solid horseshoe magnet and avoid all this risk?" the reader may well ask. The reason is because the majority of the magnetism appears



Front view of Lodge Machine. End Cover removed to show Commutator

FIG. 15.

to reside near the surface of a magnet, and by the use of laminated magnets the surface is obviously much increased and correspondingly this power. In dismantling a permanent magnet field, always be sure to mark the magnets (with paint or chalk) before removal, so that a mistake is impossible.

An Indian reader recently wrote asking how many magnetos he could re-fill from a six-volt accumulator! As will be gathered from what has been said, one cannot re-charge a magnet like a storage battery. However, with a suitably wound 6-volt electro-magnet it is possible to re-energize from 75 to 100 magnetos with one charge of a 75-ampere hour 6-volt battery. It does not take anything like so long to "charge" a magnet as it does an accumulator. Furthermore, one does not need a hydrometer or a voltmeter to ascertain if "fully charged." All one does is to test the pull of the individual magnets against a piece of iron attached to a spring balance. Test the magnet before contact with the magnetizing source and note its pulling power, then after magnetizing for a few moments try the test once more. Should the magnet show an improvement, keep on with the magnetizing for some five minutes, until it is found that no increase in pull is apparent. At this stage the magnet is said to be "saturated" or more loosely "fully charged." To-day it is extremely difficult to obtain magnets for the construction of lighters, and makers like Lodge Bros. —who now occupy themselves exclusively with "plugs" —have given up the manufacture of permanent magnet dynamos. However, in America there are firms who still manufacture such commodities, also of course there are a sufficient number of sets already in use to justify the retention of this section of our subject. Attention is called to Fig. 16, which gives a clear idea of the lighting magnetos in section. It will be noticed that as in ordinary dynamos, the armature is laminated and rotates between the poles of the field—permanent in this case. The armature core is slotted in practice and overwound with a suitable gauge of insulated wire. Except in details the armature differs not from that used in the ordinary dynamos. Upon glancing at the end view in Fig. 16, it will be observed that to change the polarity of the machine, all that is needed is to drive it in the reverse direction—not so with the other types, as we shall presently see, because with a regular dynamo special arrangements have to be made for running it in the reverse direction to that specified by the maker, as complications arise which do not

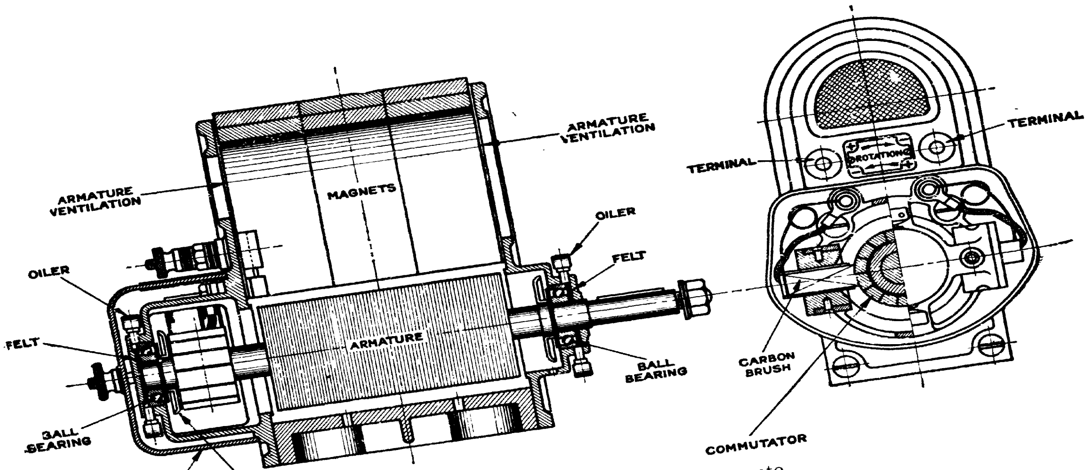


FIG. 16.—Section of Lighting Magneto.

occur in the "magneto" species. To reverse the polarity of a true dynamo is not a matter of just running it backwards. The great and obvious advantage of the magneto for car lighting is, of course, its extreme simplicity of design, as no provision is required for regulation of speed and output as with the other type of generator. The field being constant in value and armature reaction increasing its restricting effect on the output as the speed rises, a nice range of output is thus assured over a wide range of speed. Moreover, 25 per cent. of the magneto-dynamo's output is not consumed in excitation of field windings as is often the case with the other type. This means a saving in weight for small output machines. Heating, too, is less prominent. The speed at which the current is produced is another point in favour of the lighting magnetos; it is indeed possible to illuminate an 8-c.p. lamp by simply turning the armature with the fingers. The speed at which the full output is obtained in these machines is about 1,500 R.P.M. From an average-sized generator of this class one can draw some 100 watts, which is ample for all car needs. In the case of certain U.S.A. machines, it will be noticed they do not produce anything like this output, indeed in the case of the "Deaco" the maximum output does not reach 50 watts!

Under normal conditions, assuming the pulley of the machine to be 2½ inches diam., it would be necessary to fit a driving pulley of 7½ inches if rotating at the crank-shaft speed of the average engine. The power absorbed at full output would be about ⅛ H.P. only, as no current is used for the field. In an ordinary dynamo of the same output which of course supplies its own field current, it is usual to assume about twice this figure for the power taken from the engine.

The Mira Magnetolite.

Fig. 17 shows a section of the apparatus manufactured by the High Tension Co., Hungerford Works, Westminster. The governing principle is armature reaction upon the permanent magnetic field, which is clearly shown in the cut. The current is delivered at a fairly low armature speed (1,200) and its maximum output

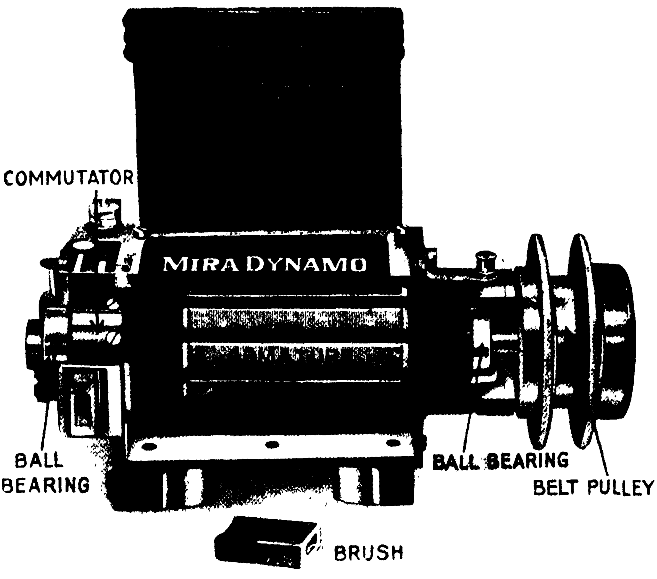


FIG. 17.—The Mira Machine, sectional, to show its construction.

is 12 amperes at 12 volts' pressure with the machine illustrated. In a smaller size only three laminated permanent magnets are utilized and the maximum output is 10 amperes at 8 volts only. The armature is of the laminated drum type parallel wound, as is customary. The bearings are of course "ball" type, and one of the bearing end-plates carries the brushes which collect the current, the other bearing plate carries an insulated slip ring which serves to carry the current from the negative brush to the cut-out, which is of a mechanical design.

Fig. 18 gives a sketch of the rather neat way the circuit to the storage battery is opened and closed. This essentially consists of a live contact in connection with the negative brush, and a small balance weight pivoted in the centre. One end of the latter carries a metal contact stud, and at the other extremity a flat steel spring is fixed. Normally, the spring keeps the contacts apart when the dynamo is at rest, but

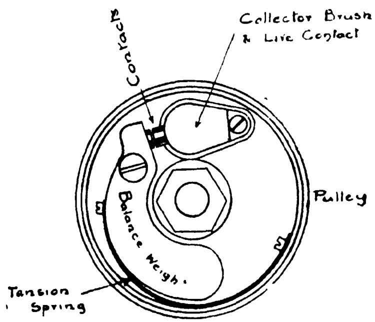


FIG. 18.—The Mira Auto-Switch.

when sufficient speed is attained the weight flies out by centrifugal force, and prevents the pressure of the spring from keeping the contacts open, and so they close the circuit and connect the dynamo to "earth" on the negative side. The machine is now in circuit with the battery, providing the charging switch is closed. The cut-out is situated in the aluminium pulley on the right of Fig. 17. When the speed of the dynamo is insufficient to generate enough current for the cells, or to light the lamps, the balance weight of the governor is forced inward by the spring; this causes the contacts to open and interrupts the flow of current to "earth."

The governing apparatus is covered by a brass dust-cap, and a small spring pressing on the spindle forms an efficient earth return. At the present time, largely owing to the difficulty of obtaining a plentiful supply of large magnets, the Mira people are supplying sets for motor-cycle use principally.

The drive is a detail that requires careful consideration. In some types of machine chain-drive is advised as being the only reliable method of drive; where this is done one would be wise to adopt that counsel—personally, the author has found nothing to equal a good running belt for lighting dynamos. In

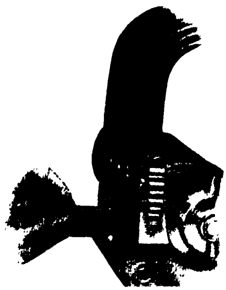


FIG. 19.—Removing a Brush.

other systems friction-drive is advised; however, many have found this method unsatisfactory (the author amongst them). The Mira outfit requires to be belt-driven, so one has only to select a choice belt. This should be as long as possible, and, as ample width of pulley surface is provided, the belt should not be stretched—it should slip on to the big pulley comfortably and leave no sag. This avoids straining the armature spindle.

Fig. 19 indicates the way to remove the brushes for inspection or other purposes.

It is next proposed to set forth the claims of the electrically regulated type of lighting magneto, this class being a combination of the "magneto" and "dynamo." There are two ways in vogue for effecting this electrical regulation of the magneto—(*a*) by opposing the permanent magnetic field of the steel magnets as the engine speed rises; (*b*) by *helping* the magnetism of the permanent magnets at low speeds and detracting from its influence at high speeds. Theoretically, it is not conducive to the longevity of the permanent magnet to bring an opposing magnetic field into its immediate vicinity, as the molecular "tug-of-war" then ensues is likely to impair the retentive property of the steel, if prolonged for any great length of time. However, in practice the demagnetization is sufficiently slow to enable this type to achieve appreciable success. The effect of the demagnetization of the steel is no doubt retarded to a very considerable extent by the fairly high temperature * at which these small generators operate, although above a certain heat the steel would very rapidly lose its magnetic powers. Of the several types of generator, this combined machine is theoretically the least advisable; nevertheless, good results are obtained in spite of its theoretical handicap.

THE SIMPLE REGULATED MAGNETO DYNAMO, (*a*) METHOD

Fig. 20 gives a general idea of a French type of machine that owes its regulating power to the first class of control we spoke of. It is known as the "Ducellier Dynamo," and is, as will be apparent from the illustration, a totally enclosed machine, thereby fitting it for a dusty atmosphere. The enclosing cover

* This is not necessarily due to bad design or workmanship, but is quite common to all species of generators, and is purely an electrical effect. However, an *excessive* rise in temperature is indicative of serious defects. (See also footnote on page 51.)

is kept in position by a steel strap, which is capable of adjustment in order to provide a means of keeping the cover tightly in position, and at the same time the catch action renders it possible to remove the cover quickly. The machine is best driven by belt, although it can be run by gear, or by friction drive. Underneath the cover we should find 16 plain bar permanent magnets, separated from the armature by means of a soft iron distance piece, around which is wound a coil of insulated copper wire ; this part of

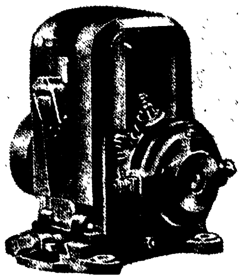


FIG. 20.—The Ducellier Generator. A represents the Output Controller.

the equipment forms the electro-magnetic field, which is wound on the differential plan—that is, part of the coil assists the permanent magnets and a part which is connected to brush A on Fig. 20 is so arranged that it opposes or " bucks " the field at high speeds and thus curtails the dynamo output. The main field winding draws its supply from the main brushes. The brush A is not fixed, but is adjustable, so that the " bucking " effect can be increased or decreased according to the position it occupies upon the commutator with respect to the main brush, to which is connected the other end of the bucking coil. The maximum counter current is induced in the opposing coil when brush A is adjacent to the terminal on the machine which is opposite to the side towards which the top of the armature is turning. In this position, of course, the output of the dynamo is re-

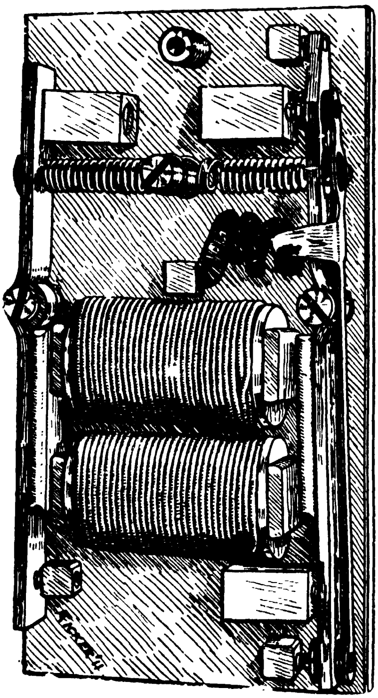
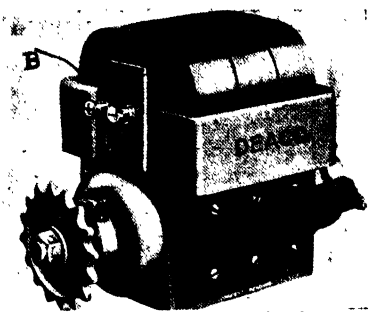


FIG. 21.—The Deaco Automatic Switchgear for Fields.

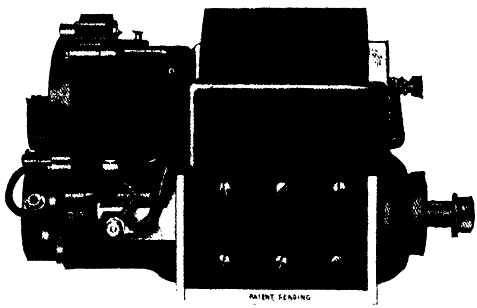
stricted to the maximal degree. Attention is drawn to the slide rail equipment fitted to this generator. This is a refinement that could be well copied, as it does away with the necessity of cutting the belt in order to tighten the drive. Unfortunately, the Ducellier generator is no longer obtainable in this form, a later type having superseded this method of control, with a mechanical governor device.

THE COMPLEX REGULATED MAGNETO DYNAMO, (*b*) METHOD

To affect the addition of flux at low speeds and its subsequent subtraction at high speeds needs a somewhat



Old type.



Newer model for electric lighting and ignition.

FIG. 22.—The Deaco Magneto-Dynamo.

complex piece of switchgear. The sketch in Fig. 21 shows its general arrangement. The current flowing in a field winding directly connected across the brushes of the machine is made to open and close the various contacts of an apparatus which reminds one of the domestic electric bell. The appliance itself nestles in between the magnets as shown in the Deaco dynamo in Fig. 22 (see B). Precisely what takes place at the various speeds will be made clear by the progressive sketches. The alterations in connection are done absolutely automatically by the regulator referred to above. The first sketch in Fig. 23 shows the state of affairs that exists at the beginning of a run when the machine is running slowly. The electric field is connected in such manner that it helps the permanent field to the fullest possible extent. As the speed rises we arrive at condition of Sketch II. Here the electrical

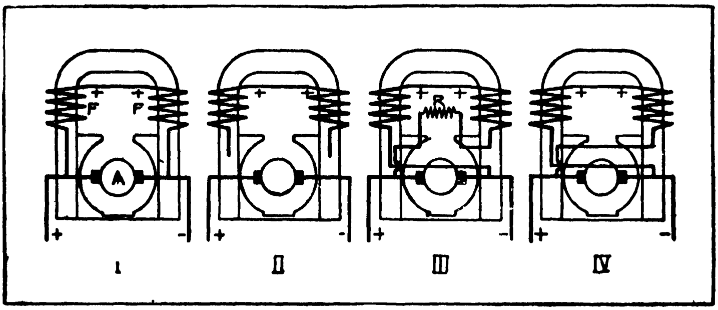


FIG. 23.—Key Chart for Deaco Field Controller (Fig. 21).

field is cut out, and the machine is running on the permanent magnetism alone. The car having got well under weigh, Sketch III is arrived at ; here the regulator has changed over the electro-magnetic field's connection, and so has considerably detracted from the magnetic influence of the permanent field. However, a small resistance has been introduced into the circuit, which prevents the change in flux density from being too keenly felt by the armature. Sketch IV illustrates the disposition of the machine at very high speeds ; here we see that the resistance R has been short-circuited so as to enable the full opposition to be realized. The above machine will give a very constant output, as the makers have practically guarded against every possible contingency. Any desired output up to the maximum can be obtained from this generator by simply adjusting the springs controlling the regulator. The net effect of the regulator is to render the current constant at *all* speeds beyond the critical speed, so that if the regulator were adjusted to give a maximum current of 8 amperes the following table gives the performances of the machine :—

Revolutions ..	250	350	450	550	650	750	1,000	All over 1,000
Amperes ..	$\frac{1}{4}$	2	3·8	5·2	6·6	8	8	8
Volts	6	6	6	6	6	6	6	6

For reasons already stated the magneto machine is not very prominent in these now happily post-war days. Readers who have an old magneto and who wish to experiment with a view to converting it to an electric lighter may find the following particulars of use to them :

In the first place one will need to substitute a cogged drum armature in place of the magneto one. Twelve slot drum stampings will answer quite well for the purpose. These should be built up to form a core of the maximum possible length, taking care that room is left for the accommodation of the end wire and commutator. The armature should be wound with No. 20 S.W.G. copper wire, as much as each slot will take. In case a 12-volt output is required it would be a better plan to wind the armature with No. 22 S.W.G. instead. The amperage that would be obtained in this case would approximate at the maximum to 5 amperes. These particulars are of necessity very crude, as the actual output will depend upon the strength of the field magnets ; nevertheless, they will serve as a rough guide. The brush gear will have to be of superior construction, and the brushes employed will need to have a cross section of $\frac{3}{8}$ by $\frac{3}{8}$ inch. The best material for brushes is either Morganite or copper-carbon ; the latter is preferable in many ways.

The commutator will need to have ample width to take the brushes just alluded to, and it must be finished quite clean and smooth. It should be the aim in designing a dynamo, even of the simple type, to provide for adjustment, as the lack of this necessary provision is a weak point with many of the existing machines.

CHAPTER VI

ELECTRO-MAGNETIC TYPES OF GENERATOR

HAVING discussed in the previous chapter the principles that govern the working of the lighting magneto, and of its modified competitor, we shall be able at the present juncture to turn the knowledge thus acquired to useful account now that we come to the third and last type of "electric lighter"—the dynamo proper. It is with this class of generator that the cleverest work has been done. Especially does this apply to the purely electrically regulated types, which are truly representative of the electrician's art. A big factor in the satisfactory running of a dynamo-lighting system is the relation between the time during which a car is used by day and the time it is used for night driving. It is quite possible to obtain a dynamo with an output greater than the rate of discharge of the necessary storage battery in conjunction with which it has to work. With the former types of machines reviewed the output was in practically every case almost equal to the maximum discharge required from the battery; so also in many of these dynamos the principle followed is that of "floating" the battery, i.e. to have the dynamo's *input* the same as the battery's *output*; the advantage gained by this method is considerable, as the first cost of plant is low, also the regulative effect of the storage battery is at its best when working under these conditions. This is a most important point; indeed, the success of many well-known systems depends principally upon the floating of the battery in the manner just alluded to.

Anent the other school of thought which indulges in larger machines of greater output, these are no doubt better suited to the man who drives 95 per cent. at night, as the battery cannot become discharged, no matter how long he uses his car. However, the continued overcharging that may ensue is detrimental to the battery in the long run. In obtaining this advantage, one pays a higher price than would otherwise be necessary, the dynamo's weight is greater, also its location will in many cases be restricted to less convenient methods of drive owing to its large proportions. To the author's mind the possibility that the small output machine would not meet an extreme case like the above has no detracting value when contrasted with the satisfactory light one gets in the normal case. Hence, the ideal set is not necessarily that of largest output.

The representatives of the class of dynamos we are to consider are so exceedingly numerous that it is impossible even to mention them all, so we must confine ourselves to a few representatives of the most practical types used in British territory. For purposes of classification we can group them under two headings : (*a*) the mechanically controlled ; (*b*) the electrically controlled. There are, too, some few which utilize both controls in conjunction with each other. The first class alone was in pre-war days sufficiently numerous to fill all the available space in this volume. Nowadays the mechanical control has lost out, and it seems difficult to find a widely used example extant. It is a striking coincidence that, as in the early days of the car-lighting set, manufacturers staked their good names upon the mechanical regulation, only a year or so later to adopt the electrical system ; so to-day, in what may be termed the early days of motor-cycle electric lighting, mechanicians are still advocating mechanical controls for cycle lighters ! Will they, too, be compelled to change over at a later date.

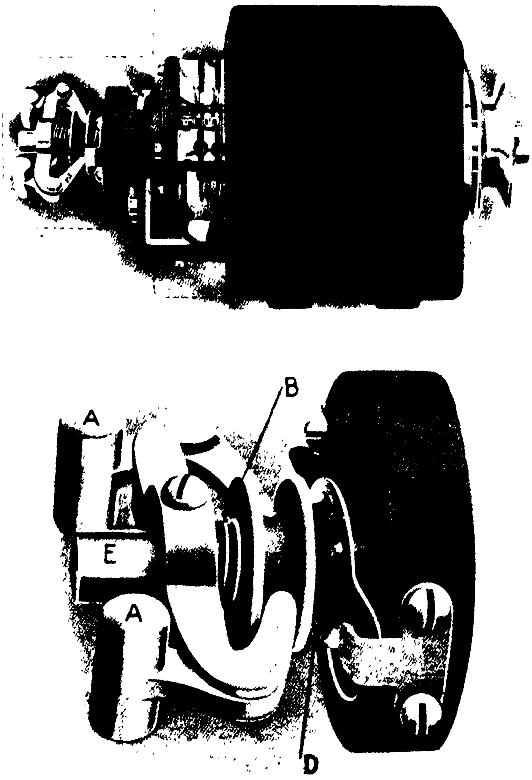


Fig. 24.—The Polkey-Jarrott Dynamo and its Governor.

The dotted line in the upper figure indicates the position of the protective cover.

MECHANICAL CONTROL

On account of the large number of mechanical sets upon existing cars and a few recent productions, it will be advisable to outline one or two principles of mechanical government. The very earliest types of mechanically controlled dynamos were almost exclusively based upon the simple steam-engine governor and had no finesse of regulation after contact was once made.* The later patterns embody some rather special features, as will be evident from what follows.

The lower portion of Fig. 24 represents the cut-off that was used on the Polkey-Jarrott dynamo, a machine that employed a reversed series winding connected to a third brush for its regulation. A represents the

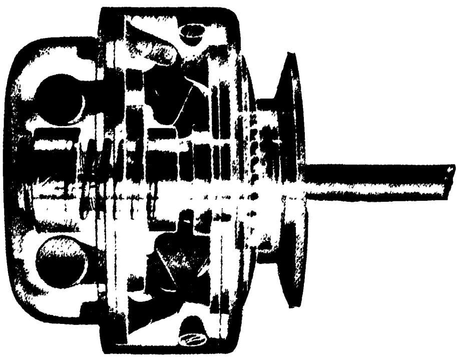


FIG. 25.—The P. & R. Governor situated in the pulley.

governor weights; whilst B is the spring that works in conjunction with them; C is a sliding sleeve on the dynamo shaft; D is a fibre insulating washer, to keep the current from going to "earth"; E represents the armature shaft; F is the contact spring, which is self-acting, and makes contact with G, which is the fixed contact of the dynamo; H is the fibre insulating

* It is on record that one manufacturer did fit an extra contact on his device which at a certain high speed (4,000 R.P.M.) opened the circuit between the dynamo and battery so that an overcharge could be avoided. However, in his later models he dispensed with this *refinement* as unnecessary!

block, to keep the contacts from "earthing" to the frame or dynamo casing.

Sometimes the governing mechanism was integral with the driving pulley. Fig. 25 illustrates one such that was fitted to the Peto Radford dynamo to control its output. The ghost illustration shows that it was entirely enclosed, and ran in oil ; further, when governing, it ran on ball bearings. It was controlled entirely by one strong compression spring which seldom required adjustment, as the wear on the gripping surfaces was extremely small, owing to the material employed. The surfaces were of the same area, and opposed to each

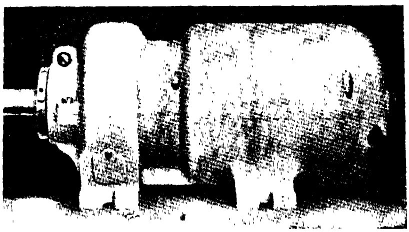


FIG. 26.—Gray & Davis Dynamo.

other, the end thrust was equal, and was, therefore, practically eliminated.

If the dynamo was required to be friction-driven off the engine fly-wheel, the above construction was adapted for friction contact with the fly-wheel.

To vary the generating speed there was an adjustable collar which pressed, more or less as the case may be, against the spring which provided the cohesion between the driving member and the driven portion. The actual opening and closing of the battery-dynamo circuit was carried out by an electro-magnetically operated cut-out of the usual design.

The dynamo just outlined is a typical example of a mechanically controlled machine, and would be classed as governed by means of " a centrifugal slipping pulley."

In Fig. 26 we have a further example of mechanical control upon what is termed the "slipping clutch

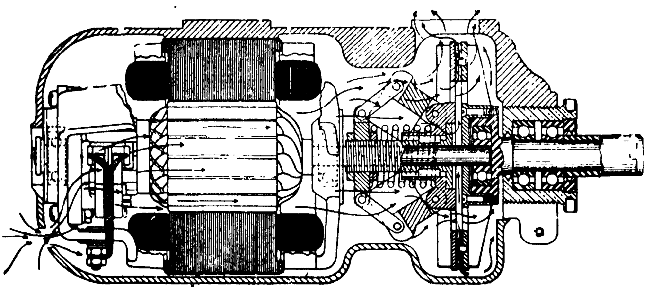


FIG. 27.—Section of old Gray & Davis Dynamo.

principle." It is a widely installed but now obsolete type of the Gray & Davis dynamo.* The section of the two best-known types are given in Figs. 27 and 28,

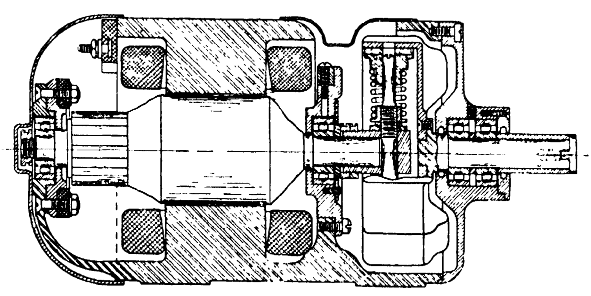


FIG. 28.—Section of a Gray & Davis Dynamo which superseded type shown in Fig. 27.

that in Fig. 28 being the more recent of the two. In so far as the control itself was concerned, it virtually consisted of an aluminium disc secured to a shaft positively driven from the engine, and faced with an

* New type Gray & Davis dynamo wiring is given on p. 299.

asbestos fabric $\frac{1}{8}$ inch in thickness, against which was pressed a second disc of cast iron by means of a vanadium steel spring. The contact pressure was controlled by a centrifugal governor (see right of Fig. 27) which, in broad principles, bears a relation to the other centrifugal ones illustrated. Under normal conditions the clutch was always slipping more or less, consequently considerable heat was generated. This feature of the problem was solved by the provision of fans, so arranged that they caused a considerable draught of air to be circulated through the clutch gear, and, in fact, through the entire machine. The path of these currents of air is indicated by the arrows in the figure. To aid the efficiency of the machine, a connection changing device was included in the switch gear that controlled it. This change-over switch enabled the machine to be run either as a compound or shunt dynamo. The compound winding, of course, was intended to be utilized only when the generator supplied current to the lamps.

The later pattern machine is shown in section in Fig. 28 ; essentially it differed but little from the one illustrated in Fig. 27, except that one member of the clutch control consisted of a cast-iron shell, finished smooth on the inner surface, and was driven direct by silent chain or gearing from the engine. Within this shell was the second member, consisting of two friction shoes faced with a woven fabric of asbestos and brass wire, which were pressed against the containing shell by two vanadium steel springs. The pressure of these springs was still, of course, under the control of the centrifugal governor weights. As soon as the speed of the outer shell exceeded a speed of 1,000 R.P.M. (car speed 12 M.P.H.), the rotating governor weights caused the shoes to release their hold upon the shell, so that the dynamo shaft could not over-run its set speed. The weights were so proportioned that the pressure of the springs at normal speed drove the dynamo with a 50 per cent. overload, but released the armature completely at about 5 per cent. overspeed. When the speed of the outer shell exceeded 1,000 R.P.M. the clutch slipped sufficiently to maintain an armature speed of 1,000 R.P.M. independently of the engine speed. An extrinsic electrical cut-out switch was employed in connection with the above clutches.

The Powell and Hanmer Dynamo

When the renowned Joseph Lucas, Ltd., of Birmingham started making dynamos, they came to the conclusion that mechanical control was *the* thing. However, as time went by they were attracted by the lure of distorted fluxes and extra brushes. And now we have another celebrated Birmingham lamp manufacturer, Powell and Hanmer, taking up the cudgels upon behalf of mechanical control! First let it be said that the P. and H. people are out for simplicity of construction, and they have brought out several sizes of dynamo to fit from large motor cars down to small motor cycles,* and whose outputs for car use range from 12 volts 8 amperes to 6 volts 8·5 amperes for light cars. Their aim has been to eliminate everything of the hypertechnical which, though excellent in the hands of skilled users, is apt to come to grief when left to the tender mercies of the busy motorist. The brush gear is more substantial than that found on many machines, and as the dynamo is only a simple shunt-wound one the commutator troubles are nil. Fig. 29 gives a sketch of the patented governor which controls the destiny of the dynamo's output. A simple Ferodo-faced single-plate clutch is employed, because lengthy

* See author's work, *Electric Lighting for Cycles and Motor Cycles* (Spon, 3s. 6d. net).

tests have proved, the Ferodo is practically unwearable and will not require replacing until many thousands of miles have been covered. The clutch is not a cumbersome affair, and combined with the ordinary V-shaped pulley increases the bulk to a small extent only. To explain this clutch on paper is by no means a simple matter. Firstly, to try to make it clear, it must be explained that the armature of a dynamo as its speed increases experiences what is known as a magnetic drag, that is to say, the magnetic field both of the armature and the field magnets tends to prevent the dynamo increasing its speed. This is obvious on all machines, for if the belt is slack the drag at certain

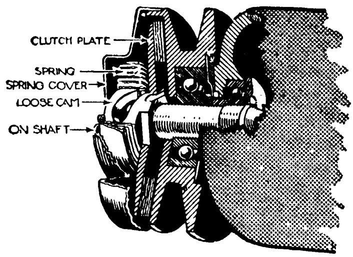


FIG. 29.—Section of P. & H. Clutch Control.

speeds prevents the armature from speeding up, and of course the proper output cannot be obtained. This type of friction clutch makes use of the magnetic drag on the armature opposing its rotation. As the speed tends to increase, a small helical slot cam comes into operation and forcibly, though very slightly, separates the two faces of the clutch, one of which is inside the driving pulley, this by the way running on a large ball bearing, the other part of the clutch being in effect keyed to the shaft. The detailed action of the cam cannot very well be explained, but it is sufficient to say that it comes into action at a certain predetermined speed. A flat spiral spring forms practically the whole control of the clutch. Means are provided for obtaining the correct tension. As the speed increases, the armature drag brings the cam action more and more into operation and provides proportionately more slip.

Fig. 30 illustrates an ingenious form of cut-out of the mercury type. It consists of an insulated drum carrying two contacts attached to open ends of the dynamo circuit. These contacts can be joined up by means of the spraying of some mercury which, at rest, is situated at the base of the drum. Centrifugal force causes the mercury to spread itself around the periphery

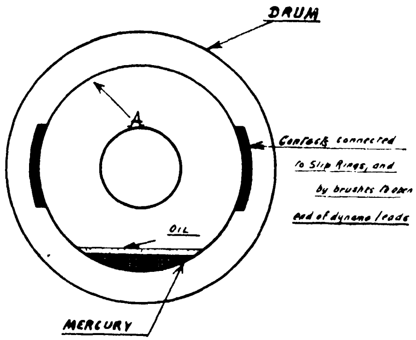


FIG. 30.—A Mercury Centrifugal Cut-out.

of the drum on the surface indicated by the arrow marked A on Fig. 30. The oil shown in diagram is there to prevent arcing at the contacts.

It may be urged against the mechanically controlled machines, as a class, that a certain unsteadiness of action is more or less inherent to them all when observed at their critical speeds.

In the slipping clutch variety, just when the slipping occurs, if the clutch design does not incorporate a proviso for special lubrication of the surfaces, the voltage is likely to rise unduly until actual slipping is achieved. After it has once been accomplished, the machine behaves perfectly at all superior speeds of the driving member. The result just alluded to is attributable to the difference between static and kinetic friction, and a drop in speed is often experienced at the instant when slipping begins; in other words, the clutch can continue to accelerate the speed of the armature, beyond the maximum speed for which the clutch is adjusted. As soon as slipping actually takes place the speed is constant.

ELECTRICAL CONTROL

We are now to consider what may be aptly termed the finesse of dynamo design. It will be evident upon the perusal of the following outlines—since space does not permit of more than a glimpse of the underlying principles—that magnetic action and reaction have been reduced to a fine art. This, as was pointed out on page 56 *et seq.*, includes every conceivable device, from damping resistances to flipping flaps; but they all depend for their action upon some form of electrical apparatus as distinct from those of which we have been speaking, which are governed by purely mechanical contrivances innocent of any electrical stimulus. Here again we can divide them into two classes: (*a*) that class of apparatus which controls extrinsically and *need not of necessity* be situate in the magnetic area; and (*b*) that class of dynamo whose regulation is inherent and *operates of necessity* inside the dynamo.

There is at the present time a series of dynamos known as the "Tredelect" which forms an electrical analogue to the earlier type of mechanical dynamos we referred to, only in the Tredelect dynamo we have some excellent workmanship and a rather uncommon type of cut-out device which has no "shunt" winding, cutting-in being accomplished by the field current of the dynamo, which is taken through one winding of the electro-magnet of the cut-out. It has the usual "series" winding as well for reinforcing the connection. The dynamo is shunt wound and proportioned in such a way that, at average speed, about 50 per cent. of the total current generated is taken by the field. The iron in the field is so proportioned that as the speed rises the "permeability"* decreases rapidly, thus increasing the "reluctance,"† and the armature winding is arranged so that the "back ampere turns" ‡ increase rapidly, all of which prevent too high a current being generated.

It will be understood that these principles and conditions can only be taken advantage of in small dynamos, and the parts have been carefully proportioned so as to obtain the best results.

The ratio of driving pulley and belt recommended make it impossible to drive at more than about 4,000 revs. In considering the speed, it must be remembered that the armature is extremely small, viz. *only* $1\frac{1}{16}$*-inches diameter.*

It must also be borne in mind that this machine will stand a tremendous amount of overload, due to the construction of the armature and commutator. All the connecting wires on which the working of the system depends are inside the dynamo itself, doing away with the liability of these wires becoming "shorted" by wear and tear, and so causing a breakdown, which is especially liable to happen when any ordinary repairs are being done to the car.

Tredelect dynamos, although made for 6 volts, will

* The property possessed by iron of being able to increase or multiply the magnetism of any magnetic field.

† The resistance which iron offers to the magnetic flux somewhat analogous to "resistance" of electrical conductors.

‡ Those conductors on the armature which, consequent upon giving "lead" to the brushes, oppose the current flowing in the coils contributing to the total E.M.F. This is a field distortion cross-magnetization effect common to all dynamos.

work quite satisfactorily without any alteration whatever on 2, 4, 6, 8, 10, or 12 volts. This is an advantage which is very convenient should one or more cells of the accumulator become damaged or "shorted" from any cause.

Of the (*a*) class we have several examples by types. They include those machines whose regulation is thermostatic—i.e. dependent upon the *heating* of resistances in some form—and dynamos that are equipped with electro-magnetically operated field rheostats of various kinds.

As machines on this principle are more easily understood, we will consider a few choice examples of these first.

The Hot Wire Regulation

It is a well-known fact that if we pass an electric current through a wire certain heating effects are produced in obedience to a strange and wonderful formula (C_2R), which when interpreted means that the current in amperes multiplied by itself, and the product again multiplied by the number denoting the resistance of the wire in ohms, will give the rate at which heat is produced by that current. As a sort of corollary, it may be stated that if we increase R and keep the E.M.F. (voltage) the same, the current is bound to decrease in amount. This, of course, is familiar to even the most casual user of electricity.

However, it is a fact that all metals when under the influence of heat increase in ohmic resistance, and the case of iron is unusually interesting. The increase under the stimulation of a little heat is in no way different from that of any other metal in general characteristics, but at what is known as the "critical" temperature the resistance increases out of all proportion to the normal range, as will be made clear upon glancing at the curve of German silver resistance wire and that of iron wire shown in Fig. 31.

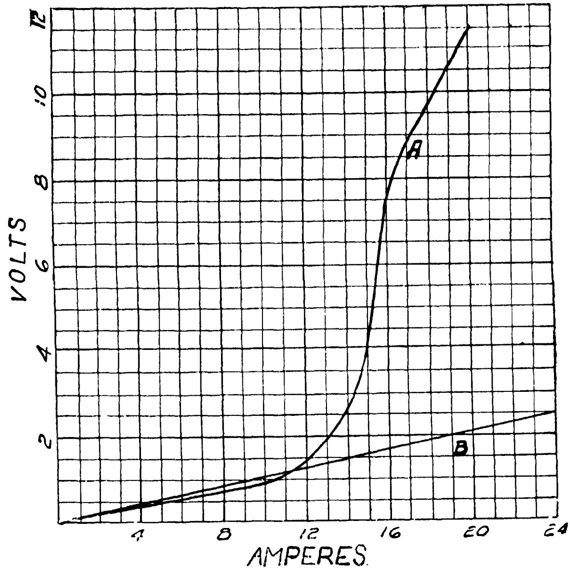


FIG. 31.—Curve B shows performance of German silver or other material whose resistance does not increase abnormally with an increase of temperature. Curve A shows how the resistance of an iron wire remains constant up to a "critical" point, after which practically no more current can be made to pass through it.

The Rushmore Dynamo.

At least one well-known dynamo is indebted to this fact for its regulation, and the necessary iron wire is wound around the spool shown in Fig. 32. Its location is in a ventilated box at the base of the switchboard. It is described by the makers (Rushmore) as a ballast coil, and operates in a rather unusual manner. The shunt field coil is connected beyond the ballast coil, so that it receives current at all times at the constant voltage of the battery, and another winding is added to the field, and so connected that it opposes the main shunt field coil. This bucking coil, as it is called, the effect of which, it will be recollected, is to reduce the field excitation, is connected in parallel with the iron ballast coil. Its resistance is considerably greater

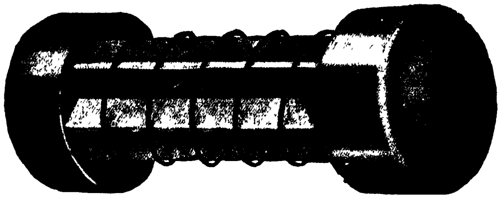


FIG. 32.—The Rushmore Regulating Device.

than that of the ballast coil, when the latter is cold, or only warm. At low engine speeds the whole of the current passes into the battery and lamps, and the machine acts as a simple, unhampered shunt dynamo. However, owing to the peculiar property of the iron wire used upon the ballast coil, as soon as its temperature has risen to a certain critical point, its resistance

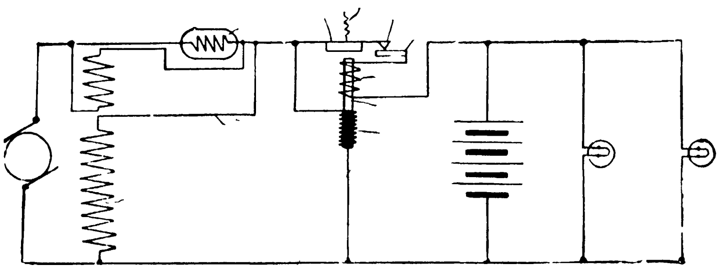


FIG. 33.—Circuit Connections of Rushmore Dynamo (with the automatic cut-out switch) occupying the central portion of the diagram.

increases many times its original value, and thus prevents the passage of the current, therefore the current has to travel by the other route—the bucking-coil—and in doing so serves to regulate the output.

The general scheme of regulation is sketched out in Fig. 33. The dynamo is so designed that at a car speed of about 15 miles per hour the current delivered at this speed corresponds to the "critical" temperature of the ballast coil. This current is 12 amperes in the smaller dynamo.

The automatic switch which is used in connection with the Rushmore dynamo is shown in Fig. 34. It is housed upon the dynamo carcass, and is no larger

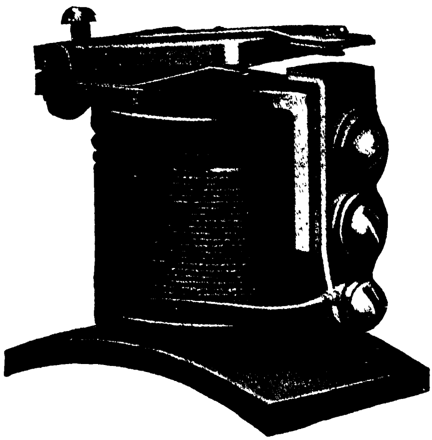


Fig. 34.—The Rushmore Auto-Switch; the base is rounded and drilled for screwing on to the carcass of the dynamo.

than illustrated. It is of the usual construction, but is rather more compact in design than most other makes.

The general arrangement of the dynamo is given in Fig. 35.

The Lithanode Dynamo.

The regulation of the Lithanode dynamo was even simpler than the foregoing, as in that machine the ballast coil was simply included anywhere convenient in the main circuit—indeed, it often took the form of a foot-warmer! It merely consisted of a waste resistance composed of two or more strands of suitable wire that prevented more than the maximum charging current from passing. The surplus current was dissipated as heat.

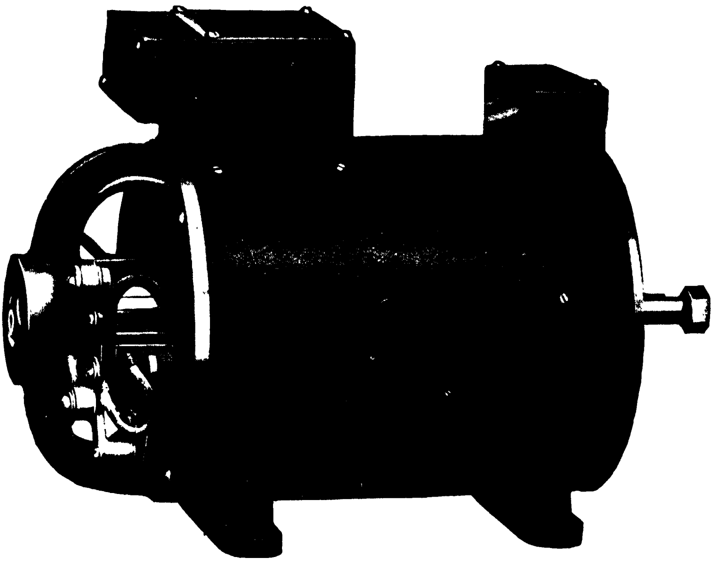


FIG. 35.—The Rushmore Dynamo, showing accessibility of brushes.

The Dufty Regulation.

If the reader will turn back to page 22 he will find a discussion upon the regulating effects of carbon and metallic filament lamps, which will serve to introduce the ingenious method of thermostatic regulation patented by Dufty, which is one of the cleverest methods yet been put forward. Fig. 36 will at once remind the technical reader of the old familiar lozenge figure of the Wheatstone bridge, for that is what is depicted.

There are two field windings, a main shunt coil, and an additional winding which Mr. Dufty calls a "pilot" winding (see centre of the lozenge). Carbon and metal filament lamps are connected, as shown by letters C and M, as the arms of the Wheatstone bridge and the ends of the pilot coil to opposite corners (*b* and *b′*) of the bridge.

When the normal speed is reached the resistance of the lamps is equal, and no current passes through the pilot coil. At high speeds the carbon lamps have

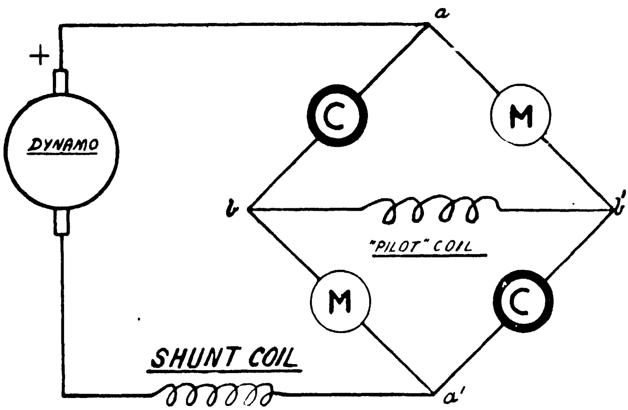


FIG. 36.—The Dufty Method of Regulation.

a lower resistance, and consequently the current is reversed in the pilot coil, and this opposes the main flux produced by the regular shunt winding. At low speeds the resistance of the metal lamps is less than the carbon ones, hence the path of the current in pilot winding would be from *b′* to *b*. It may be urged against the efforts of Mr. Dufty that the delicate metal filaments will surely break; however, one may use iron wire instead of the lamps, and the *modus operandi* is the same.

The Remy.

There is still another type of thermostatic control to consider, and that is the widely used Remy apparatus, which is illustrated in Fig. 37.

This thermostat resistance serves the double purpose of reducing the charging rate and acting as a protective fuse to the generator in case the battery or generator charging circuit should ever become disconnected, either from accident or neglect, as the resistance wire would then burn out and prevent the generator windings from being damaged.

Loose or corroded battery terminals are very often the cause of high resistance in the charging circuit.

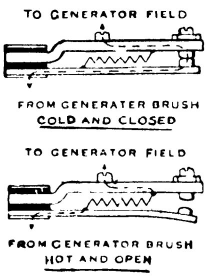


Fig. 37.—Remy Thermostatic Switch.

This condition produces high voltage at the generator, and therefore high voltage is impressed across the thermostat resistance at the time the points open. The excessive current forced through the resistance unit will cause it to burn in two and open the field circuit. This reduces the generator output to zero, and thereby prevents damage to the generator windings.

A burned thermostat resistance will be indicated by the ammeter dropping to zero, then returning to maximum when the generator is cool. Further, a burned thermostat resistance is an indication of high resistance in the charging circuit, and this condition should be corrected before installing a new resistance unit, as such an installation will offer no relief unless the original cause is eliminated.

Resistance unit trouble should be corrected immediately, as the thermostat points are apt to burn and possibly stick, due to the heavy arcing at the time they open.

The thermostat is substantially made to withstand the most excessive vibration without impairing its operation, but its accuracy would surely be destroyed by prying the contacts apart.

To some extent the dynamo just described comes within the following category too, as the actual resistance is not primarily due to heating effects.

The C.A.V. and Rotax.

The C.A.V. and Rotax dynamo, too, have a thermostatic switch which automatically shuts off the battery ignition in case it has been forgotten by the driver when shutting down the engine. In short, it is an "electrical thinker." The thermostatic portion consists of a long **T**-shaped member of bi-metal, a homogeneous composition consisting of two strips of metal of different coefficients of expansion welded together. This strip is wound with a small heating coil, which actually forms part of the ignition circuit. When the engine is running, the passage of current through the switch and also through the heating coil is intermittent, and therefore the coil remains cool. If, however, the engine stops with the ignition switch on, the current passing is continuous, and in these circumstances the coil begins to heat up. In doing so, it causes the blade of bi-metal to bend to the right, and this action releases the push switch on the left side, and allows the two contact points to spring open, and so disconnect the battery. The time that elapses between letting the engine stop with the switch on and the switch automatically releasing itself is about two minutes, so that only an infinitesimal amount of current is lost.

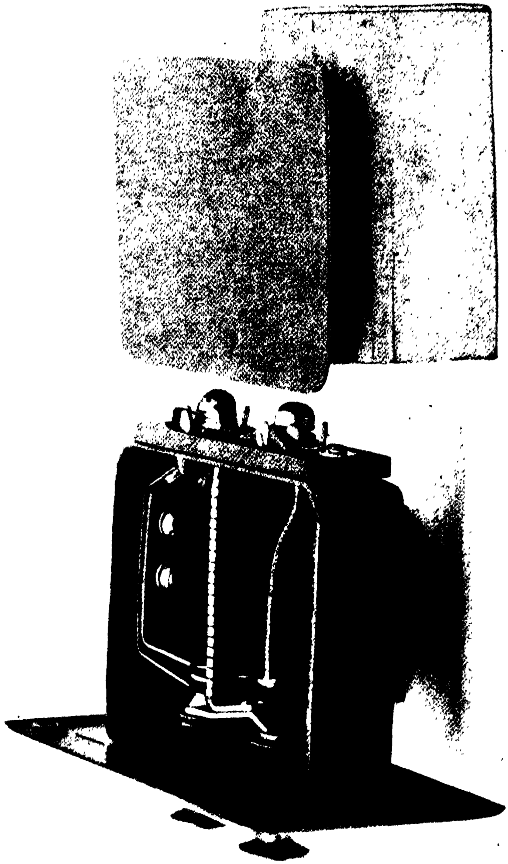


FIG. 38.—English Thermostats as used on C.A.V. and Rotax sets.

The photograph reproduced in Fig. 38 shows the type of apparatus used on the C.A.V., the Rotax and

Smith sets, whilst the sketch in Fig. 39 gives the principles of its action. Essentially the apparatus consists of an iron armature *a* carrying a winding *b* which is supported on a spring over a permanent magnet *c*. The free end of the spring carries a contact *d*, which, when the ignition system is switched on, touches a second contact *e* attached to the terminal *f*. At *g* is fixed a "compound strip," formed of a strip of brass rivetted to a strip of iron, or other suitable combination. This strip has the property of curving itself

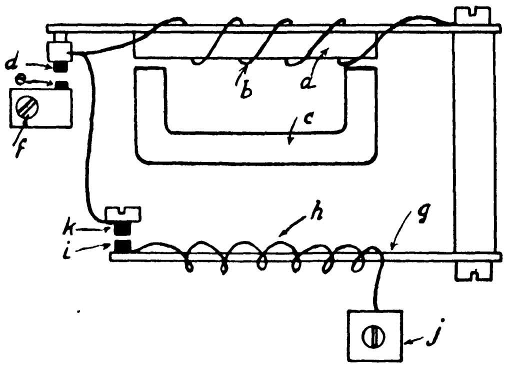


FIG. 39.—Arrangement of thermostatic device for opening the ignition circuit.

when heated. The strip *g* carries a heating coil *h*, one end of which is connected to a contact *i* and the other end to the terminal *j*. The contact *i* is normally touching the contact *k*.

When the system is working current enters at the terminals *f*, and passes by way of contact *e*, *d*, *k*, *i* and heating coil *h* to terminal *j*. Very little of the current takes the path through the winding *b*.

If the contact breaker should stop "on contact" the comparatively large current then passing heats up the coil *h* and causes the strip *g* to bend, thus separating the contacts *i* and *k*. This allows all the current to pass through the winding *b*, magnetizing the armature in such a way that it is repelled by the permanent magnet *c*. The spring then lifts the armature and separates the contacts *d* and *e*, thus completely breaking the circuit, and protecting both coil and battery.

The heating coil *h* is so designed that it takes nearly a minute to heat the strip *g* sufficiently to cause it to separate the contacts *i* and *k*. This gives plenty of time to get to the front of the car and start the engine cutting off the ignition.

Automatic Field Resistance Control

We now come to a class of regulation which is based upon the use of an electro-magnetically operated rheostat.

The Facile Dynamo.

A very simple device of this sort is used upon Ward and Goldstone's "Facile" dynamo. It consists of a machine shunt wound and without any complication, but before the current is allowed to pass into the battery and lamp circuit it has to negotiate an electrical regulator, generally fixed upon the dash of the car. The controlling action is as follows: The current is made to pass round an electro-magnet which is so placed that it can, when energized to a certain degree, attract a pivoted armature—like the armature of an ordinary electric bell—to it, and so close the circuit between the dynamo and battery, thereby allowing the battery to "charge." This circuit-closing action is arranged to take place when the average car is travelling at 10 to 12 M.P.H. As the speed increases full charging rate is attained, and should the speed increase to such an extent that the charging rate would be too heavy for the battery to stand, the magnet automatically inserts a resistance in the dynamo field winding, so that the amount of current which can circulate is thereby reduced, owing to the choking effect of the resistance. Beyond the simplicity of such regulatory expedients there is little to admire in them, therefore it is not surprising that the majority of makers are sacrificing undue simplicity for a greater constancy of output. Later on we shall meet with a more recent invention in which the excess load is made to regulate the dynamo output.

The Bosch.

This famous Hun product contains an electro-magnetically operated field resistance. It is operated by means of a voltage regulator carried in the switch-board casing. The winding of the regulator is connected to the terminals of the dynamo, and when the terminal voltage rises the electro-magnet causes the insertion of more resistance in the field circuit, and so keeps the output down.

The B.R.C. "Dynauto."

The current obtained from this dynamo was unusually steady, thanks to the automatic field resistance increase. The resistance unit was in series with the shunt coil, but short-circuited normally by an induction coil vibratory device, so that in ordinary usage the coil blade was always buzzing. This was arranged for by having the coil part of the device connected as a separate shunt circuit across the brushes of the dynamo. When the voltage rose to what was considered a safe amount, the core of the coil would attract the iron bob on the trembler blade, and in doing so include the extra resistance. This of course immediately curbed the output, and the attraction of the blade would cease, thus allowing the resistance to be short-circuited again. The other end of the coil magnet was wound with a series coil, so as to perform the usual functions of an automatic cut-out.

The Bijur.

In the Bijur dynamo, which also regulates on these lines, the wear on the contacts is compensated for by allowing the current to reverse its polarity periodically.

There are one or two other machines which regulate on the above principle, but those cited will more than suffice.

*   *   *   *   *

We now pass on to the (*b*) class of electrical regulation, with which most of the widely advertised sets are concerned. It will be recalled that we said that under this heading we should have to deal with dynamos that were inherently regulated only. By types these include such schemes as "Reversed series regulation," "Extra magnet poles," "Third brush regulation," "Triple field windings," and an unlimited number of "freaks" which embody such ideas as movable magnets, sliding armatures, rocking brushes, automatic magnetic screens, etc. As most of these latter methods have met with disaster, we shall not, under the present high cost of paper, allude to them in detail. In general it may be said that all modern dynamos which embody inherent control are regulated by armature reaction *—manufacturers have by this time found it to be the one "safe card." However, for the sake of simplicity, we will begin with an example of the first method noticed.

Reversed Series Regulation

Several attempts have been made to construct machines in which a series compensating winding is utilized, the idea being to diminish the strength of

* See footnote on p. 51.

field progressively by the flow of current in such a series winding after the normal voltage is produced, in the reverse direction to the main exciting current. The latest of these machines is that manufactured by Bottone and Co., Wallington, Surrey. All these dynamos are more or less open to the criticism that the regulation is imperfect over a wide range of speeds. However, given a proper balance of design, the fluctuation when running through a battery is of no great consequence to the motorist.

The Bottone Dynamo.

Fig. 40 gives the general appearance of the well-

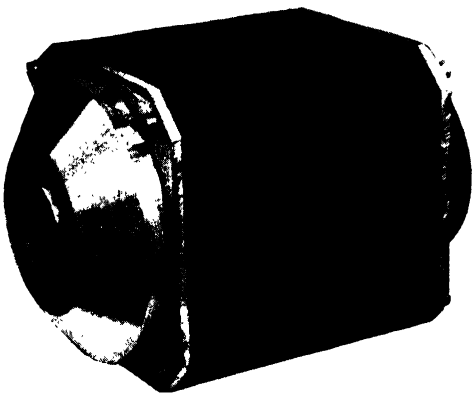


Fig. 40.—The New Bottone Dynamo.

made dynamo furnished by Bottone and Co., which regulates on the above principle. Its output is 100 watts at a voltage of 12, the speed is 1,800 R.P.M., whilst it scales $5\frac{3}{4}$ inches by $5\frac{3}{4}$ inches and 9 inches long only. In Fig. 41 we have a view of the inside construction. The reader's attention is directed to the little cupboard-like structure that is attached to the right side. This is the magnetically operated cut-out mechanism, which works upon the following plan : When the machine is running up to speed and is generating, the armature field attracts a little iron flap which is carefully pivoted at its upper extremity. The upper

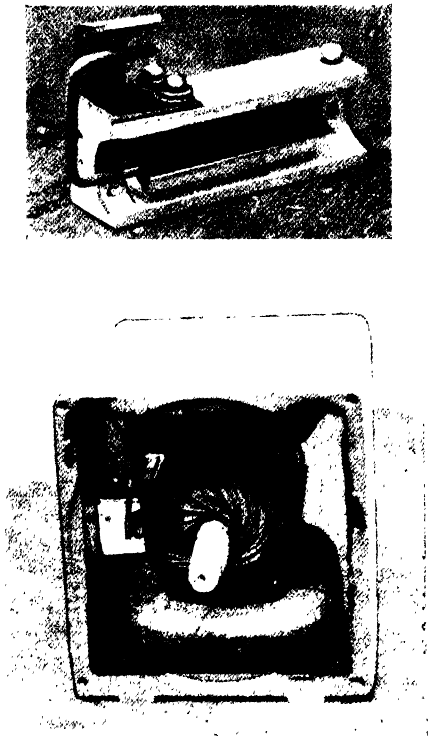


Fig. 41.—Internal Construction of Bottone Dynamo.

photograph in Fig. 41 will make this clear to the reader. Enough attraction is manifested to pull the little flap up to a horizontal position, and a contact is thus made between the dynamo and battery. The contact is of a special rubbing nature, and thereby cleans itself, and being constructed from electrolytic copper it does not, owing to its generous proportions, "arc" away like the restricted platinum ones provided upon most cut-outs.

The other point of special interest in this new Bottone design will help us to appreciate better the succeeding types. We had better therefore illustrate it by means of an experiment.

If we take an ordinary bar magnet, the lines of magnetic force (if they were made visible) would be found to emanate chiefly from the ends of it. In a normal specimen we should further notice that these lines followed graceful and regular courses—in short, the distribution of the field, although of course more dense at the ends of the magnet, assumed a perfectly even and balanced field of activity (refer to Fig. 8).

Now if we, for some reason or other, wish to distort or to turn aside the majority of the lines from their accustomed path, we can do so within limits by coaxing them away, as it were, from the place we want freed from magnetic influence by placing a suitable sized and shaped piece of soft iron in an adjacent portion of the magnetic field. The introduction of this piece of iron causes the bulk of the lines to rush through the iron path thus provided in preference to the very high resistive path provided by the air or any other media.

If the piece of iron we put into the active field area be capable of movement, as is the case with the iron flap in the Bottone machine, a large proportion of the flux will be concentrated upon this pole, unwound though it be, and we shall have a distortion of the useful lines of magnetic force in such a manner and degree that the output of the dynamo will be decreased in proportion to the speed. This decrease will occur only at relatively high speeds. In the next type of machine wherein the distortion of flux is the *main* *factor of regulation,* we shall try and illustrate this more completely.

Extra Pole Regulation

The provision of extra poles (usually unwound) is by no means a new idea, and even in the well-known

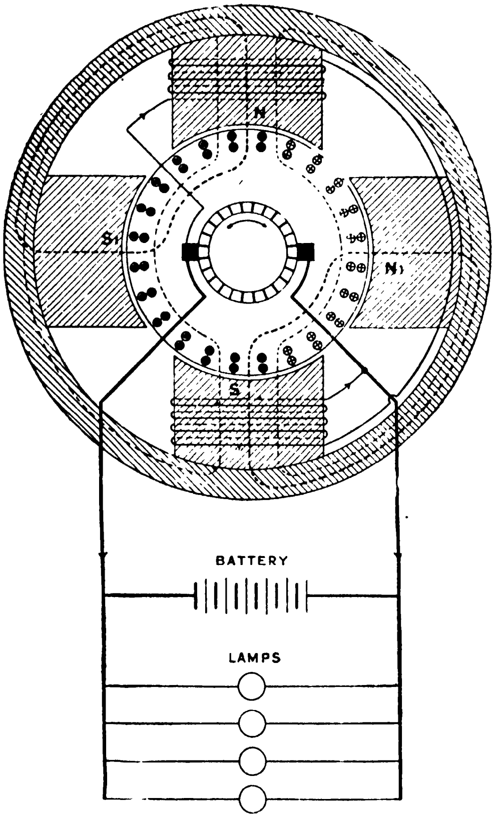


FIG. 42.—The old C.A.V. Principle of Self-regulation.

C.A.V. dynamo, which was a substantial improvement on the original scheme of Rosenberg, it has been given up for a more efficient multi-brush type of regulation. As there are some thousands of the extra-pole machines in satisfactory operation, we shall do well to retain this description along with the rest.

The C.A.V. Dynamo Extra-pole Type.

Fig. 42 clearly shows the dynamo's design, and will be easily understood by readers who have followed the previous chapters. Fig. 43 gives a view of the polar disposition of the magnet frame. It will be seen that in this machine there are two wound poles (N and S)

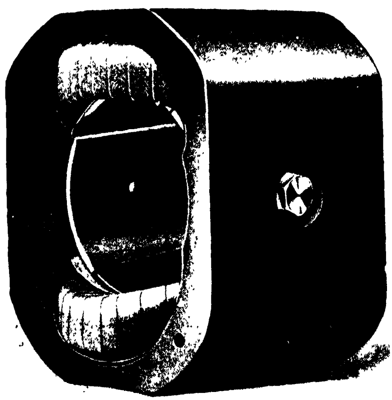


FIG. 43.—C.A.V. yoke.

at the top and bottom of the shell; at right angles to these poles are two other unwound poles (N_1 and S_1). These poles are really the main poles, as will be evident upon noting the position of the brushes, consequently the more usual wound poles are really only acting as subsidiary ones. The magnetic flux excited by the windings on the poles N and S normally passes straight through the armature diametrically from one of these poles to the other, and, dividing right and left, returns through the frame of the machine, thereby completing the magnetic circuit as shown by the *thin* dotted lines (Fig. 42). The poles which are placed in the familiar position have no winding upon them. Magnetism is produced in them by the reaction of the armature—*not* the whole armature—but the reaction due to certain currents which are generated in those coils which are, for the time being, short-circuited by the brushes that are collecting the current at the commutator. The position of the coils is depicted in the diagram by four black dots. The *modus operandi* of the generator is briefly as follows: The brushes being set in the usual neutral* position with respect to the unwound poles N_1 and S_1, the coils they short-circuit in the act of commutation are those which, for the time being, are not in any neutral magnetic zone (as would be the case in an ordinary dynamo), but are in an active zone where they are cutting the magnetic lines of force due to the subsidiary poles (N and S). Hence, during the period of short-circuit, they will be the seat of short-circuit currents. The currents cross-magnetize the armature and tend to set up a magnetic flux at right angles to the flux of the poles N and S, and this cross-magnetizing effect is greatly augmented by the iron masses adjacent, in the person of the unwound poles.

The net result of this is simply that the existing flux is distorted or twisted, and instead of traversing the armature diametrically as formerly from one subsidiary pole to the other, it now turns aside, passing through the armature quadrantally only, breaking up into two quadrantal paths, each of which includes only one-quarter of the frame, as is clearly shown by the *thick* dotted lines.

At this stage of magnetic condition the machine

* This is the position occupied by an armature coil when its two sides lie in the interpolar space, and are symmetrically placed in respect of the poles.

becomes self-regulating, since the cross-magnetization due to above reaction progressively weakens the field as the speed increases. This action proceeds to a limit beyond which under a given load the voltage and current are perfectly steady at all speeds. In the author's opinion, the two phases of magnetic excitation shown in Fig. 42 exist at all speeds concurrently, as long before a marked change in the disposition of the flux occurs, current is delivered to the external circuit. If the machine is now without a battery, its self-regulating property is absent, although a marked and abrupt change does occur in the machine's magnetic condition long before the voltage reaches its maximum. When run with its battery the change is not abrupt, and its auto-regulation is satisfactory.

It would appear from this also that not only do the two separate magnetic conditions exist concurrently at all times, but that they cannot be influenced by direct control. At a low speed, the C.A.V. dynamo working without a battery manifests a considerable increase of current and a comparatively slow increase of voltage; this is a most important point, and applies to practically all electrically self-regulating automobile dynamos when operating without a battery. Without this, self-regulation could not be obtained, for it is upon the production of a large increase of current with a comparatively small increase in voltage that these machines depend for their action —without it they would lose their characteristics. This regulating current flows in a circuit which is in communication with the external circuit, and unless a large increase of current can be discharged into the external circuit with the increase of voltage, too small a current is obtained in the regulatory circuit, and as a *sine qua non* the voltage of the machine rises rapidly on increasing the speed of the dynamo. This is the condition which prevails when the battery is disconnected and the lamps alone can take the current. As was pointed out in Chapter II, lamps do not provide a sufficiently accommodating load, as 100 per cent. increase in voltage at their terminals will only produce an approximate increase of 50 per cent. in the current that is flowing through them, owing to the particular nature of the metallic filaments (see Chapter II). To take a working example as an illustration, let us consider the lamps of a car as taking 5 amperes at 12 volts ; an increase of volts to 14 will only raise the current density of the circuit by 0·43 of an ampere (the above was an actual test case).

When the storage battery is connected in circuit, this increase of voltage is attended by a proportionately larger increase of current through and from the machine, and in consequence of this self-regulation can be obtained. This is a crucial point, as if at any time it was thought good practice to do away with the battery, machines of this type would become useless, and they would have to be then designed so that they would be able to regulate with a very slight increase of current, or incorporate some device that would enable a heavy regulating current to be produced in some part of the generator which is quite independent of the external circuit. Such a procedure is quite unlikely to become necessary, as reserve of light will always be a necessity, and the storage battery is the only known satisfactory means of providing this when the engine is stopped. The lower half of Fig. 42 shows the working conditions of the external circuit, and these are the same as in the majority of sets.

In all systems the regulating effect of the battery is important, but in the old type C.A.V. system it is the *alpha* and the *omega*, since the battery is "floated on the line" ; in other words, the *in*put is, at its maximum, no higher than the *out*put at its maximum, hence the battery just floats under load conditions. The best possible regulation is obtained when the amperes taken from the battery are slightly in excess of those put into it by the dynamo. This state of balance will not only save damage to the lamps by keeping the voltage constant, but will do away with the necessity of carrying a large battery in order to withstand the high charging rates that are a necessity of many systems. In short, experience has shown that there is no regulator to equal a "floating battery" for automobile work. It will be noted that if for any reason one requires an unusually large reserve of light, one must increase the size of one's battery and not alter the balance of input and output if the best regulating effect is demanded. Unlike most types of dynamos, the C.A.V. does not require an automatic cut-out, a fact that will appeal to many car-lighting engineers. A simple free-wheel is interposed between the pulley and the armature spindle, so that when the engine is stopped, or run too slowly for the dynamo to charge the accumulator, the armature can revolve freely or "motorize," thus over-running the driving pulley. Owing to the design of this machine, only a little over 1½ amperes are required to run it as a motor. In a day's run the actual amount of current wasted is generally less than that absorbed by the shunt and series coil of a cut-out. To leave the dynamo running as a motor when the engine is stopped was not the maker's intention, as they have made a free-wheel very noisy in its action to remind the driver to switch the dynamo off, a special switch being fitted upon the switchboard for the purpose.

There is, however, no need to switch off the dynamo for a momentary stop, as some users have apparently been led to believe.

EXTRA BRUSH REGULATION (FOUR-BRUSH TYPE)

The above caption represents the most widely used method of electrical control, and experience has proved it to be the best. As we shall see, there are several modifications, some using three brushes and others requiring four brushes to handle the situation.

The New C.A.V.

Figs. 44 and 45 are photographs of the inside and outside of the new Vandervell dynamo, the principle of

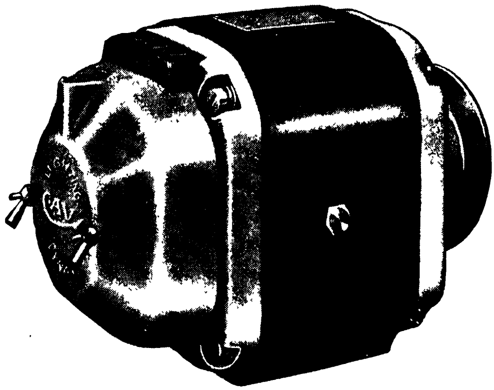


FIG. 44.—The present C.A.V. Dynamo.

which is lucidly expounded in the sketch (Fig. 46). A point of first interest to the lay mind is the fact that poles S_1 and N_1 of Fig. 42 have not only decreased in size, but have been transmuted into *brass*, a non-magnetic metal ; also they have taken unto themselves a winding. In the new dynamo these "poles" are really only bolts for the support of the auxiliary coils. It is upsetting to the action of the dynamo even to introduce an iron or steel bolt instead of the brass one used for holding the coils in position. The present dynamo represents one of Mr. A. H. Midgley's (the electrical genius of C.A.V.'s) greatest achievements.

The object of the invention is to increase the output of the machine, and to attain the maximum output at a lower speed and to obtain a satisfactory "drooping" characteristic, or a reduction of current at high speeds so that, contrary to what happens in the normally wound dynamo, the well being of the accumulators

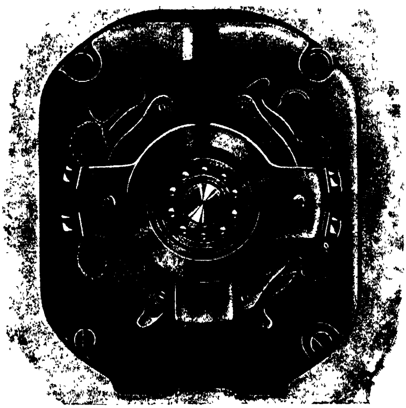


FIG. 45.—End view of C.A.V. Dynamo with cover removed to show brushgear.

and lamps would not be jeopardized with excessive current.

According to Mr. Midgley's scheme, the excitation windings of the main poles are connected in series with one another, and the two free ends of the windings thus connected together are connected to a main and an auxiliary brush respectively spanning the armature conductors under one of the main poles, and the regulating poles which are induced between the main poles by the armature cross field are provided with excitation windings producing a field acting in opposition to the armature cross field, such excitation windings being connected in series with one another and the two free ends thereof connected to a main and an auxiliary brush respectively spanning the armature conductors under one of the regulating poles.

Referring to Fig. 46, illustrating the invention diagrammatically, *a* is the armature, *b* the commutator,

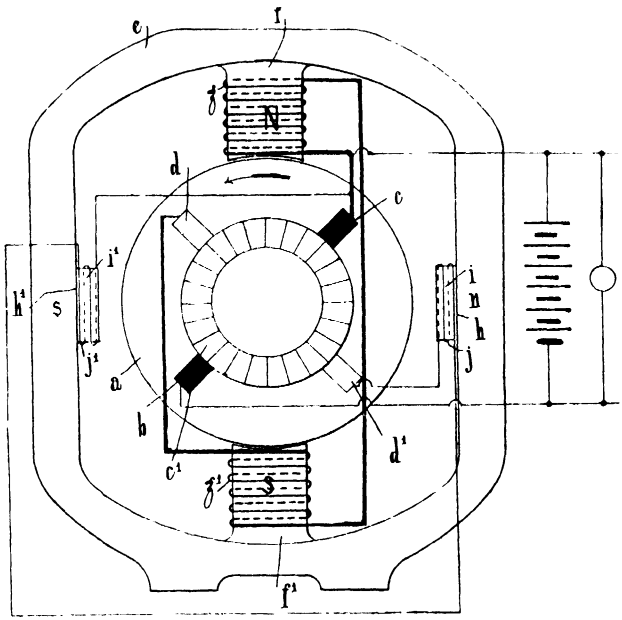


FIG. 46.—Sketch showing the principles of the present type of C.A.V. Generator.

c, c_1 the main brushes, *d*, d_1 the auxiliary brushes, *e* the magnet yoke, *f*, f_1 the main poles, and *g*, g_1 the excitation windings which are mounted on the main poles *f*, f_1 respectively, and are connected in series with each other, their free ends being connected to the main brush *c* and auxiliary brush *d* respectively, spanning the armature conductors under the main pole *f*;

h, h_1 are the portions of the magnet yoke e in which regulating poles are induced by the armature cross field; i, i_1 are two brass supports, mentioned above, attached to the portions h, h_1 respectively, and carrying excitation windings j, j_1 respectively, which are connected in series with one another and the free ends of which are connected to the main brush c and auxiliary brush d_1 respectively, the latter two brushes spanning the armature conductors under the regulating pole h. The flux produced by the excitation windings i, i_1 opposes the armature cross field and is smaller than the latter.

According to a test made with a 12-volt machine, the generating speed was attained at about 500 revs. and the maximum output of 12 volts at about 1,500 revs., the current in the excitation coils g dropping gradually from about 1·5 amperes at 1,000 revs. to about 0·9 at 4,000 revs., the current in the regulating coils j, j_1 increasing from about 0·5 at 1,000 revs. to about 3 amperes at 4,000 revs., and the current of the machine dropping from about 12 amperes at 1,500 revs. to about 9·5 amperes at 4,000.

The C.A.V. Igniter and Lighter Combined Unit.

There are several component parts to the C.A.V. coil ignition apparatus apart from the standard dynamo already fully described. The master patent for the combination of a constant voltage dynamo with a high-tension distributer is in the hands of C.A.V. and Mr. A. H. Midgley. As an alternative to the cube type dynamo there is to be had a machine of cylindrical design, which for this purpose makes a better job than the standard C.A.V. machine. However, it needs the co-operation of an engine manufacturer who is partial to cylindrical gear-driven generators, or it cannot be comfortably housed. To one of the end plates of either dynamo is attached a distributer and contact-breaker mechanism, driven by a vertical skew shaft. Half way up the shaft is a wick-type lubricator supplied with grease sufficient for several months of running. The contact-breaker is supported in a stationary housing, and is operated by a suitable form of cam, which varies, of course, according to whether the engine is four or six cylinder.

In order to allow the timing to be easily set, this contact breaker cam fits upon a taper shaft, and is readily placed in approximately the correct position. The adjustable platinum point is singularly accessible, and can always be easily inspected.

The high-tension distributor is of the "spark gap" type, the current being led to a shoe which revolves past a series of pins without quite touching them. These pins are embedded in the block of insulated material which forms the distributer cover, and contact between them and the high-tension wires is established by means of spike-ended screws, which pierce the cover of the wire, and secure it in position.

In the centre of the distributor rotor is a spring-loaded stud, which makes contact with another stud in the centre of the distributor block, through which the high-tension current is conveyed from the coil.

The distributor casing, and also that surrounding the contact breaker, are provided with a lever which allows them, for the purpose of advance or retard, to be moved through an arc of 30 degrees. In order to provide a fine adjustment in timing, the whole of the casing around the vertical shaft can be slightly rotated and then locked in position by a setscrew and locknut.

The induction coil used on this outfit is of unusual interest and strikes a new key in coil design. In order to reduce dimensions and maintain spark power, the secondary or *high-tension coil is wound directly over the iron core*, whilst the primary winding is wound over the secondary! Exactly the opposite to the time-honoured practice.

The inner high-tension terminal of the secondary coil is connected to the core, and, since the inner layer of the secondary coil and the core are substantially at the same potential, the thickness of insulating material required between the two is very small.

The same applies to the outer layer of the secondary coil and the inner layer of the primary coil, where, again, insulating material is considerably reduced.

The coil is enclosed in a cover of insulating material and is quite waterproof; at its base is a condenser, and at its upper cap, adjacent to the high-tension terminal, is a spark gap visible through a small mica window. The design of the coil is such that every part is readily accessible, and all parts can be made absolutely interchangeable.

The coil works at the ordinary lighting pressure of 12 volts, but it is claimed to be so efficient that it will give a spark sufficient for ignition purposes, even should the battery have become practically exhausted.

There is also available a fitment extraneous to the dynamo, which can be used in place of the magneto when conversion is desired. Obviously the better plan is to have all the gear in one place—at the dynamo shaft—and thus save an extra drive.

Magneto enthusiasts and "interested parties" will at once come forward with the objection, "How about if your battery breaks down, what then?" There are two rejoinders to the querist:

In the first place the coil, as already noted, is capable of giving an efficient spark on a very weak current indeed, and, provided a battery has not been left some miles down the road, it will be very strange if, even in the worst circumstances, it cannot be coaxed into giving enough current for starting up, *after which the dynamo will assume the ignition responsibility.*

The second line of defence is provided by the thermostatic ignition switch, which we described on page 102. This of its own accord opens the circuit when the human element has failed to do so, and thereby saves the storage battery.

* * * * *

It often happens that the dynamo so purchased "works the wrong way," i.e. its direction of rotation is opposite to that of the driving pulley on the car. The following instructions show how to change the directions either way for the C.A.V. dynamo.

Instructions for Changing Direction of Rotation

NOTE.—These instructions as regards connections and brushes should be followed when looking at the commutator end.

The direction of rotation is taken when looking at the pulley end.

If the brass bolts for holding the auxiliary coils in position get damaged or lost they must not be replaced with iron or steel bolts.

From Clockwise to Anti-Clockwise.

(1) Change over the regulating coils to the opposite sides of the magnet yoke, so that the sides of the regulating coils marked "anti" face the armature.

(2) Connect the end A of the regulating coils to the top left-hand brush. Connect the end B of the regulating coils to the bottom left-hand brush.

(3) Connect the end C of the main field coils to the top right-hand brush.

(4) Turn the main pole pieces round so that (looking at the pulley end) the chamfered sloping edge of the top pole piece is on the left-hand side

and that of the bottom pole piece is on the right-hand side.

(5) The top left-hand brush is now the main positive brush, and the bottom right-hand brush is now the main negative brush.

From Anti-Clockwise to Clockwise.

(1) Change over the regulating coils to the opposite sides of the magnet yoke so that the sides of the regulating coils marked "Clock" face the armature.

(2) Connect the end A of the regulating coils to the bottom right-hand brush. Connect the end B of the regulating coils to the top right-hand brush.

(3) Connect the end C of the main field coils to the top left-hand brush.

(4) Turn the main pole pieces round so that (looking at the pulley end) the chamfered sloping edge of the top pole piece is on the right-hand side and that of the bottom pole piece is on the left-hand side.

(5) The top right-hand brush is now the main positive brush, and the bottom left-hand brush is now the main negative brush.

The Brolt Dynamo.

This is an inter-brush type of machine which also employs four brushes, but no auxiliary windings, armature reaction alone being relied on. Fig. 47 diagrammatically indicates the arrangement of control.

In common with all dynamos, the two main poles N S are excited by a shunt winding connected to the brushes.

The sides of the magnet yoke are brought close to the armature, so that they form the equivalent of small unwound supplementary poles. These auxiliary poles carry no winding, but are excited by the cross magnetization caused by the working current in the armature.

Special double brushes are provided situated in the neutral position relative to the main poles N S, each pair of brushes being electrically connected together, the effect being to short-circuit a number of the armature coils during the period of commutation, as shown by black dots in the diagram. In order to adjust the output to suit the conditions under which the car is used, provision is made for inserting a resistance between

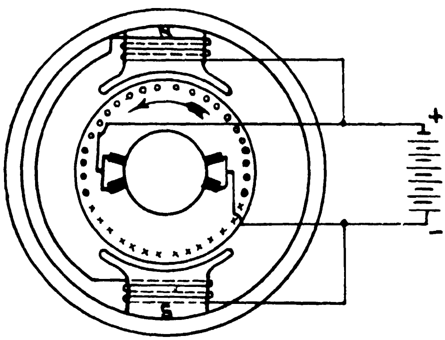


FIG. 47.—Sketch of Brolt Control scheme.

the short-circuited brushes, this having the effect of increasing the maximum output.

The operation is as follows :

When the armature is revolved a voltage is induced between the brushes exactly as in any ordinary dynamo, and the dynamo commences to charge the battery as soon as the necessary speed is reached. The load current in the armature exercises a cross-magnetizing tendency, which creates a magnetic flux in the auxiliary unwound poles provided by the proximity of the sides of the magnet yoke. The armature coils short-circuited by the brushes cut this cross flux, and in consequence have a short-circuit current induced in them which is proportionate to the cross flux and to the speed of rotation.

A few moments' thought will show that the direction of this short-circuit current is such as to directly demagnetize the main wound poles N S.

Any increase of speed is immediately accompanied by a proportionate increase in the short-circuit current, which demagnetize the main field, and keeps the output from increasing beyond the limits of a safe charging rate.

Again, if the output current should tend to increase, a larger cross-magnetization results, which in its turn increases the short-circuit current, therefore preventing any increase in voltage.

In order to keep the winding cool a centrifugal fan is fitted to the armature shaft, which draws in currents of air somewhat more efficiently than was accomplished on the old Gray and Davis dynamo (see page 88).

There is another well-made type of four-brush generator which in principle at least is similar to the others. It is manufactured by S. Smith and Sons.

The Smith Dynamo.

The construction of the machine is very similar to that of an ordinary two-pole shunt-wound dynamo, but it is provided with four brushes, viz., two main and two auxiliary brushes disposed equally round the commutator, the main brushes being connected to the auxiliary brushes half a pole pitch in advance through suitable resistances.

Fig. 48 shows diagrammatically the general arrangement and connections of the machine. It will be noticed that the field magnet windings S S′ are connected direct to the main brushes A B. The main brush A is connected through the resistance R to the auxiliary brush A′, and the main brush B is similarly connected to the auxiliary brush B′ through the resistance R′.

It is by the particular disposition and interconnection of the brushes that the required distribution of current in the armature winding at different speeds is obtained.

Not only does the distribution of current in the armature provide the armature reaction for regulating the machine, but it also greatly reduces the heating which occurs in the armature conductors.

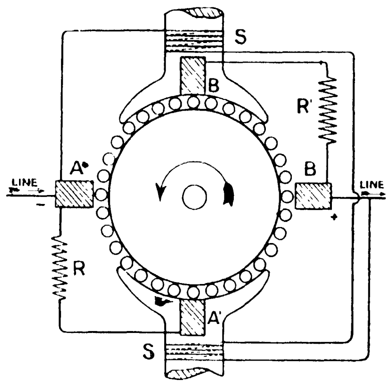


FIG. 48.—The principle of the Smith Dynamo.

The magnetizing forces produced by the armature currents, known as "armature reaction," on which the dynamo depends for its regulation, may be divided into two classes :—

(1) The magnetizing force which acts at right angles to the main magnetic field from the poles of the machine. This tends to distort the main magnetic field by sweeping it in the direction of rotation of the armature, and thus crowding the magnetism into one side of the pole shoe. This effect is known as distortion.

(2) The magnetizing force which acts directly to oppose or to assist the main magnetic field. This either weakens or strengthens the main magnetic field, and is known as " demagnetization " or " magnetization " as the case may be.

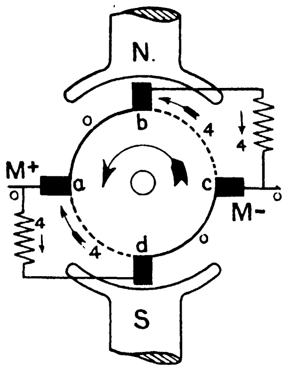


Fig. 49.

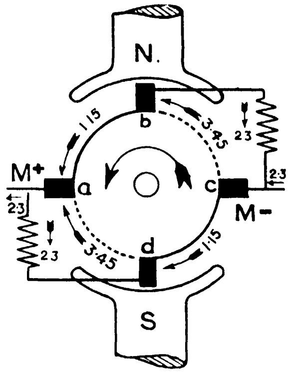


Fig. 50.

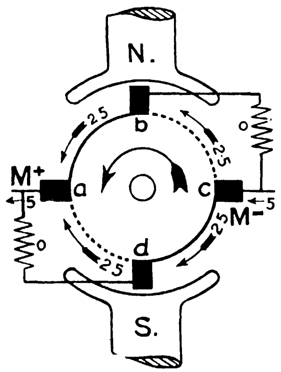


Fig. 51.

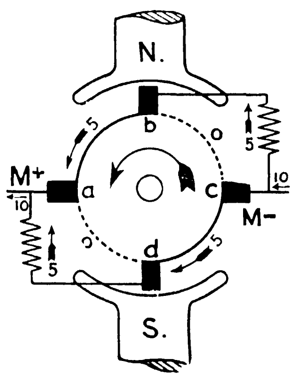


Fig. 52.

The regulation of the Smith Dynamo.

In order to understand how the armature reaction regulates the output of the machine, it will be well to consider the current distribution in the armature conductors and the resistances for the four most important speeds.

Referring to Figs. 49, 50, 51, and 52, it will be seen that the armature conductors are divided by the brushes into four sections, *ab*, *bc*, *cd* and *da*.

Two of these sections, *ab* and *cd*, are shown by full lines, and behave, so far as their magnetic effect is concerned, like a single coil of wire inclined at 45 degrees to the main field poles.

The other two sections, *bc* and *da*, shown dotted, also behave like another coil inclined at 45 degrees to the main poles on the other side.

When the current in the dotted sections, *bc* and *da*, is greater than that in the full line sections, *ab* and *cd*, it can be shown that the combined effect of the two coils tends to strengthen the magnetic field from the poles of the machine, and also to sweep the main field in the direction of rotation of the armature, the effects being those of " magnetization " and " distortion."

When the current in sections *ab* and *cd* is equal to that in sections *bc* and *da*, the joint effect of the two coils is almost entirely one of distortion, tending to move the magnetic field around in the direction of rotation of the armature.

Finally, when the current in sections *ab* and *cd* is greater than that in sections *bc* and *da*, the effect of the full line coil is greater than that of the dotted coil, and the resultant effect is one of " demagnetization " and " distortion," i.e. the main field is weakened and also swept along in the direction of rotation.

Consider now Fig. 49, which shows the current distribution when the dynamo is connected to the battery but has not commenced to supply any current. There is then no current from the main brushes, but a current of 4 amperes is flowing in the resistances. From what we have already seen, the effect of armature reaction is one of "magnetization" and "distortion." The field poles are thus being strengthened by the armature reaction.

Fig. 50 shows the current distribution when the currents in the resistances are just equal to the main output of the dynamo. It will be seen that the dotted coil is still more powerful than the full line coil, so that the effect of the armature reaction is still to strengthen the main field and to distort it. This causes the output to rise very rapidly, due to the strong main field.

In Fig. 51 is shown the current distribution when there is no current in the resistance, the current from the dynamo being 5 amperes. At this point the auxiliary brushes could be removed without affecting the working of the machine, which is behaving exactly as an ordinary shunt wound dynamo. The only effect of the armature reaction is one of "distortion," the main field being neither weakened nor strengthened to any appreciable extent.

The current distribution at full output is shown in Fig. 52, from which it will be seen that the full line coil is now more powerful than the dotted line coil, the effect of armature reaction is being "demagnetizing" and "distorting." This means that the main field is much weakened, and also swept across the pole shoes to such an extent that the conductors in sections *bc* and *da* are practically inoperative in generating any voltage.

If the speed of the machine is still further increased, the current in sections *bc* and *da* commences to increase again, but in the opposite direction. Both the full line and dotted coils now act to demagnetize and distort the field, thus effectually preventing any increase in the current output.

It will be noticed that in Fig. 52 only two sections, *ab* and *cd*, are carrying current, although the output is 10 amperes. This reduces the heating of the dynamo considerably, compared with what would occur in the ordinary shunt machine.

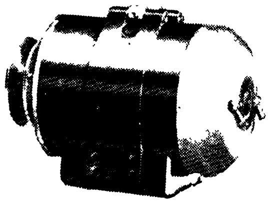


FIG. 53.

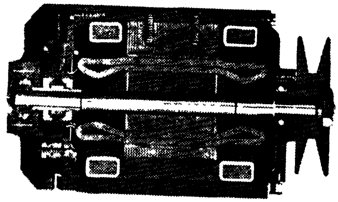


FIG. 54.

The Smith Dynamo.

Figs. 53 and 54 give an impression of the neat appearance of the Smith dynamo both inside and out, whilst in Fig. 55 we have a view of the well-constructed armature used in this generator.

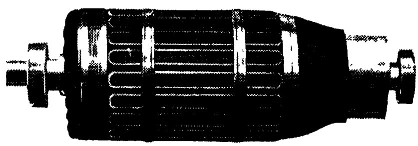


FIG. 55.- Armature of Smith Dynamo.

EXTRA BRUSH REGULATION (THIRD BRUSH TYPE)

We now come to consider the type of multi-brush regulation which is found upon the majority of modern car-lighting dynamos, and is known as the principle of "*third brush control.*" Opinions are divided as to whether this method is surpassed by the four-brush arrangement, with which it is basicly identical. For example, in the original Rotax dynamo four brushes were employed where to-day only three are used, and yet the method of regulation is the same.

The Rotax Dynamo.

The sketch in Fig. 56 shows the connections of the Rotax-Leitner generator, which is governed upon the third brush principle. Omitting all reference to the simple theory of current generation found in Chap-

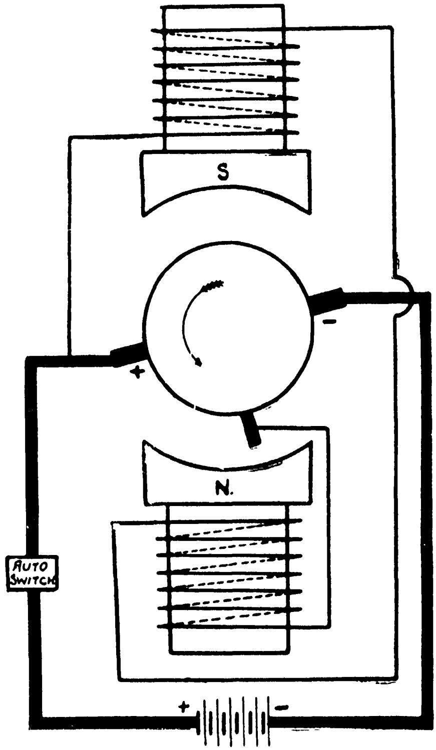


FIG. 56.—The Rotax Schema.

ter III, it will be sufficient to draw attention to the lowest brush upon the illustration, which is the control one or "third." Notice that it is connected to the end of one field coil, and that the field coils themselves are connected in simple series with each other. The other end of the top field coil is attached to the positive main brush. The thick wires shown are representative of the outside circuit to battery and cut-out.

Assuming the direction of rotation to be counter-clockwise, the *modus operandi* of the regulation is as follows : At starting, a potential difference is established between the left-hand main brush and the auxiliary brush, the former being positive to the latter as marked. The E.M.F., being in series with the field, adds itself, and therefore assists rapid excitation. However, when the current that passes out of the armature at the

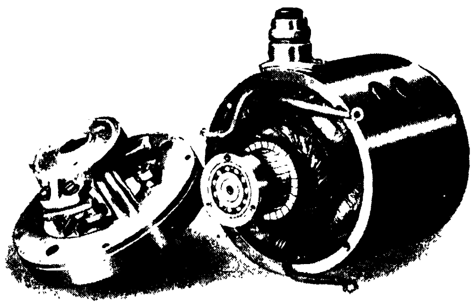


FIG. 57.—Construction of Rotax Machine.

main brushes increases, the armature flux reacts on the field flux to an increasing amount, and consequently the field flux is distorted in the direction of the armature's rotation. It follows that the voltage between the subsidiary brush is first reduced to zero, and then afterwards reversed in sign, becoming positive to the main brush. The condition existing at this stage is such that a counter-E.M.F. is introduced in circuit ; this condition continues so long as the speed is high, but directly the speed falls the counter-E.M.F. falls in strength until it no longer remains a counter-force, but assists the field at low speeds, as we saw at the beginning of the cycle of operation. This machine, in common with most others, is made in various sizes to suit all types of cars. The usual standard output is 10 amperes at 12 volts. It is possible to increase the output of the generator by altering the setting of the brushes, and under certain

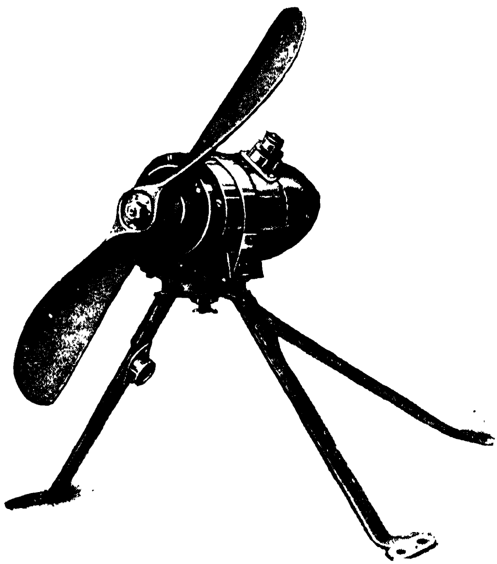
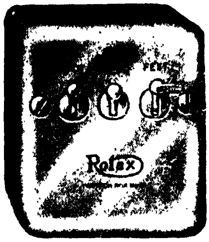


FIG. 58.—Rotax Aero Dynamo.

conditions it is advisable to do this. An automatic cut-out is needed to make the battery connection.

In Fig. 57 we have a dismantled view of the standard Rotax dynamo which illustrates its solid construction. The machine in Fig. 58 is used on aeroplanes and is wind driven. Its weight is 12 lbs. only for an output of 15 amperes at 12 volts, used for heating the aviator and lighting, wireless, etc.

The neat little switch-box for this air dynamo is shown in Fig. 59.



[Fig. 59.—The air type Switchboard.

The Rotax people have also a four-pole machine and a combined motor generator with third brush regulation. The principle is precisely similar to that of the two-pole type described, so we shall not take up time with another agonizing technical description. A

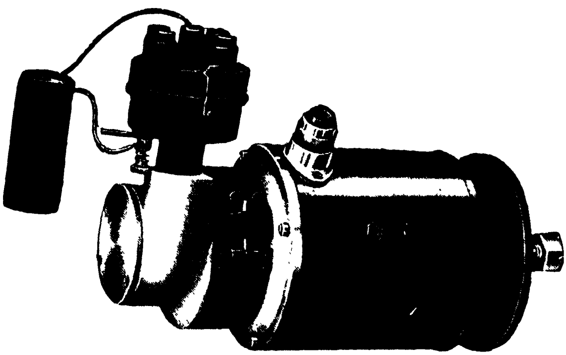


Fig. 60.—Rotax Ignition Dynamo.

combined unit for ignition and lighting is made by the Rotax Co. too. It is illustrated in Fig. 60.

The Lucas Dynamos.

The well known lamp makers of Birmingham have now an excellent series of machines, both straight dynamos, and dynamotors. Fig. 61 illustrates the dynamo which is standard in every way.

The armature is mounted eccentrically in order to allow easy belt adjustment by loosening the strap fly-nut and turning the dynamo round in its cradle.

The commutator is easily inspected by removing the dynamo end cover. It is desirable to do this occasionally and make sure that the brushes are sliding freely in their holders.

The springs (B, Fig. 61) which hold the brushes

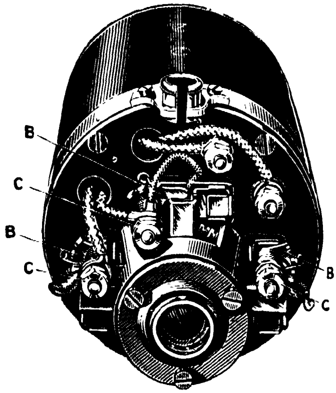


FIG. 61.—The Lucas Dynamo showing brush rigging, etc.

firmly to the commutator can be adjusted so that more pressure may be applied, if necessary, as the brushes wear in use. Worn brushes may be easily replaced in a few minutes, as follows: The brush terminal should be released by unscrewing the nut (C). The hold the spring lever (B) back out of the way so that the old brush may be withdrawn from the holder. Reverse these operations when putting the new brush into position.

The terminals are mounted on the commutator end frame and are numbered; the terminal eyes on the dynamo cable are also numbered, so that when the cables are disconnected there will be no difficulty in replacing them on their correct terminals.

Make sure that the terminals are all screwed down tightly—a loose terminal will give endless trouble.

The output of the machine is 7 to 8 amperes at 12 volts, and this should be attained at just under 20 M.P.H. when the car is on top gear.

In the diagram reproduced in Fig. 62 we have the electrical outline. A of course is the shunt coil proper, whilst D is a low-resistance regulator coil connected to

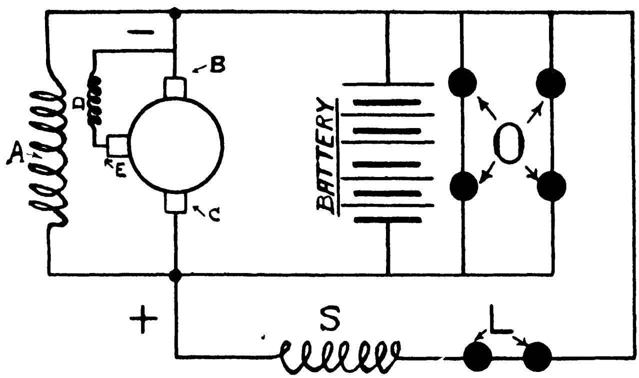


FIG. 62.—Diagram of Lucas Control.

the third brush E. B and C are the two main brushes. O represents the ordinary load, and L indicates another portion of the load which flows also through the coil S, a series coil which at heavy outputs elevates the voltage and keeps it up to advertised value. This is the principle point of difference in the Lucas regulatory scheme. The usual distortion flux is created, which assists of course at low speeds, and is neutral at higher speeds, and finally opposes at excessive speeds.

A Dynamo with Three Fields.

Sketch 63 depicts still another dynamo regulation scheme that can be worked with a third brush. At low armature speeds all three windings assist in the production of useful field flux. However, as speed rises flux distortion occurs, and the current in the coil which is connected to the third brush at T and the main circuit at P, reverses and detracts from the efforts of the main shunt winding. The lamp and battery current for the most part return through P instead of via the series coil. At highest speeds the series coil is de-

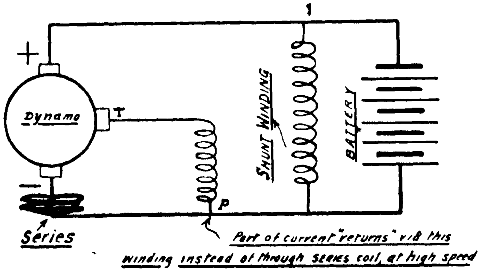


Fig. 63.—A dynamo with three windings on the field magnet.

energized, and there is a constant P.D. at the terminals of the machine.

The Ford.

We cannot close the subject of third brush regulation without a brief reference to *the* most widely used dynamo. As is doubtless known to the reader, this is fitted to the car for which so many firms had built up flourishing accessories businesses with the one idea of making the Ford look like a Rolls-Royce.

A friend of the author's, who revels in statistics, tells of how he found that the total weight of all the accessories one could get for a Ford—dynamos, starters, and twenty-seven other electrical attachments, including apparatus for rectification of the A.C. magneto current, amounted to two-thirds of the weight of the original

Ford. Further inquiry elicited the fact that one of the accessories included a camping-out trailer which was convertible into a two-roomed bungalow and could comfortably accommodate a family of four. Of course it is just possible that the weight of the family was included in the estimate—*revenons à nos moutons.* The Ford dynamo is not made as an accessory; it is sanctioned and standardized by the Ford Motor Company. It is accompanied by a starter extremely small in size and made by the same firm. The generator is located on the right side of the engine at the front end. It is bolted to the cylinder front end cover with three substantial cap screws. A piece of paper is placed between the generator and the cylinder cover to prevent oil leakage. The drive is accomplished by a spirally cut 16-tooth pinion which is engaged with the large timer gear. The dynamo is driven at one and a half times engine speed. The winding of the machine is four-pole, and the main brushes are set at 90 degrees, two alone being used. the "third" brush is smaller than the others. The regulation is accomplished in the manner common to this third brush system where the field is progressively weakened by the flux distortion, and does not need still further repetition. Provision for adjustment is made, and a slight shift of the third brush will vary the current from 8 to 12 amperes, according to whether the third brush is moved in the direction of rotation or the reverse. The recommended output is 10 amperes. This satisfies a normally used battery. The finish of the dynamo and the motor which are included in the Ford electric equipment is in keeping with the rest of the car. The battery is the famous Exide, with a twelve-months' guarantee, 6-volt, 13-plate type, 3—XC—13—1. The cut-out used on the Ford is extremely *chic*, and is housed on the generator or on right side of dash-board. This cut-out is usually the seat of any trouble and should always be looked at when the electric system fails to run smoothly.

There is one point about the Ford installation which it is important to note, and that is the fact that all the electrical equipment is of the earthed return construction—half the cables saved !

Blériot Phi Dynamo.

Fig. 64 gives a fair idea of the well-made Blériot

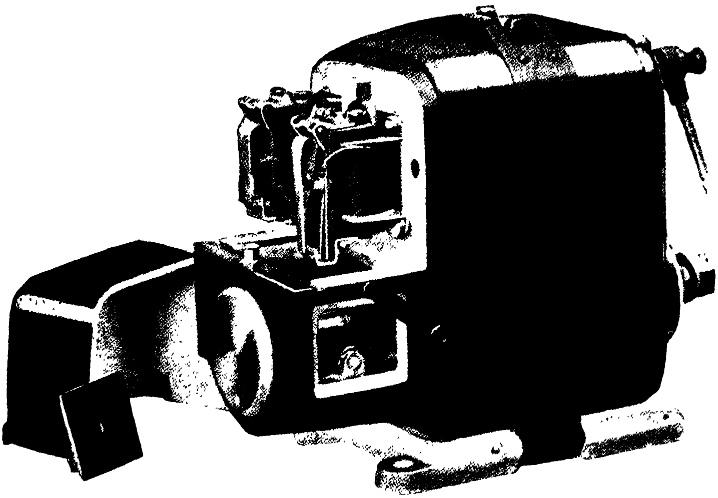


Fig. 64.—The Blériot Phi Dynamo.

generator. This has been developed for use on high-class cars where an equipment of more than usual refinement is required.

The principal points of interest centre around the method of control, and in the excellent design of automatic switch ; this latter apparatus is described on page 184.

The voltage is so controlled that the dynamo does not need a battery for regulatory purposes—this is an exceptional feature, as the lamps can be run direct from the dynamo.

The voltage of the dynamo below maximum is controlled by a reversed compound winding; the output is thus dependent upon the load supplied to the outer circuit. Additional control at other speeds is provided by a rheostatic voltage regulator operating on a vibratory plan, and by means of a tapping of the reverse series coil of the dynamo when the head lamps are in use, and thereby a reduction in its demagnetizing effect is accomplished.

HOW TO ADJUST THE OUTPUT

As a general rule we may postulate that to INCREASE the output of any of these multi-brush dynamos that we have considered, one needs only to advance the brushes in the direction of rotation. To DECREASE the amperes delivered by the dynamo, one moves the brushes in the opposite direction to rotation. An ammeter should be in circuit with the machine and battery to check the results of the various shifts. The brushes must remain equally spaced with regard to each other, but they will occupy different positions with regard to the poles of the field magnets. This causes the effect of the armature reaction on the field to vary. Moving the brush in the direction of rotation reduces this reaction, and so increases the value of the dynamo output, and vice versa.

DYNAMOS THAT REQUIRE NO BATTERY

Although there are one or two sets on the market that can be run successfully independently of the storage battery—that is to say, they do not include dynamos that *must* be connected to a battery before satisfactory regulation is possible—the majority of installations require a battery in order to maintain the lights when the engine is not running. There are, however, one or two sets, such as the " Ford " electric set (see Fig. 65) and the " Klersite dynamo," that

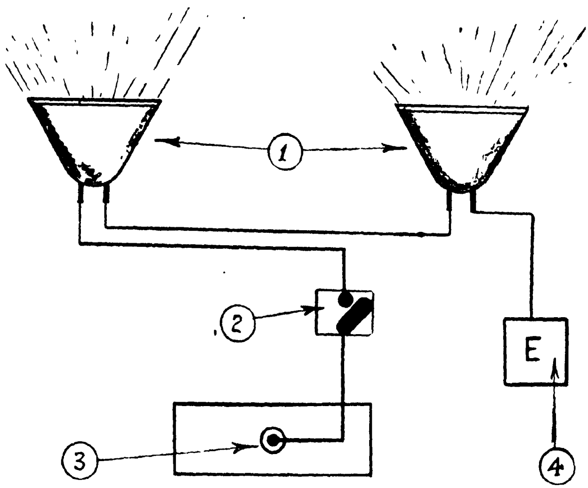


FIG. 65.—The "Ford" Electric System. (Unauthorized.)

(1) Headlamps; (2) Switch; (3) The Ford magneto terminal; (4) Any bolt of the chassis which will provide a satisfactory earth connection for picking up the return current.

cater for the headlights only, and therefore do not require a storage battery.

The Klersite Dynamo (Series Wound).

This machine is manufactured at Witton by the General Electric Co., Ltd., for commercial heavy vehicles. It is fitted with a special patent pulley, so arranged as to maintain the dynamo speed constant irrespective of the speed of the engine, once the latter has attained a fixed minimum.

The dynamo is a simple *series*-wound machine o robust construction, capable of generating current for one 18 candle-power headlamp, which has been found ample for commercial vehicles. A higher output can be obtained if so desired, in cases where two headlamps are required.

The dynamo is running at all times when the engine is working; but, if the lamps are switched off, the dynamo is unexcited and completely idle electrically, there being, therefore, no stand-by losses.

The dynamo may suitably be arranged to give its full voltage when the engine is running at about 350 R.P.M. As the engine speed increases, the patent pulley allows a certain amount of slip to take place, so that the speed of the dynamo itself remains constant, and therefore the brilliance of the lamps is unaltered. On tests, with a vehicle in which the engine speed was variable from 350 R.P.M. to 1,150 R.P.M., the terminal voltage remained constant within very close limits.

It will therefore be seen that no batteries are required with this system, which is a very considerable advantage, since batteries give so much trouble on solid-tyred vehicles.

The whole mechanism runs in oil, and consequently requires no attention, the lights being switched on at any required moment without any previous preparation whatever.

Even the higher power installation is extremely simple, consisting of dynamo (belt driven from any convenient pulley on the motor), a pair of headlights fitted with 4-volt 12 candle-power bulbs and wired in series, and a single tumbler switch for switching the lights off or on, and no accumulator, voltmeter, ammeter, or cut-out is used or required.

The dynamo is substantial, and should run for an indefinite period if kept clean and lubricated.

The author much regrets that he is not in the position to advise the reader which is *the* best set upon the market, as he is not interested in any set himself, but he would assure the reader that a post-card addressed to any manufacturer of car electric sets will bring by return of post full information as to the best dynamo yet produced !

CHAPTER VII

THE BATTERY

The familiar lead storage battery owes its conception to the endeavours of Gaston Planté. He it was who first turned his attention to the problem of "Storing electricity," although it must be insisted that the accumulator does *not* "store" electricity, but what it *does* store is chemical potential energy, which energy, under certain conditions, can be re-converted into electricity.

The well-known Planté positive plate is still used in a modified form at the present day. Camille A. Faure produced his famous pasted electrodes, which he patented in 1881. This date marks the real beginning of storage battery practice, as inventors in many countries vied with each other in working along the lines suggested by Faure, and hardly a week passed but a new pattern grid was registered at the Patent Office.

Considerable difference of opinion exists as to whether the electrically-formed Planté type plate excels the Faure or pasted type for car work. Many writers have suggested that the motorist should employ a battery containing Planté positives and Faure negatives, the positive plate being the one to suffer the greater strain, and so, if a plate of the Faure type were used, there is a slight risk of the paste, or active material, as it is called, falling out of its place and thus causing internal "short circuits" by lodging itself between adjacent plates. In the majority of instances, Faure type plates are used exclusively, as it is found that their capacity early in life is somewhat higher than in the Planté model, as the forming process can be accomplished more readily owing to the preliminary pasting.

Essentially, a storage battery* consists of the following parts: Plates, insulators, acid or electrolyte, and containing cells or boxes.

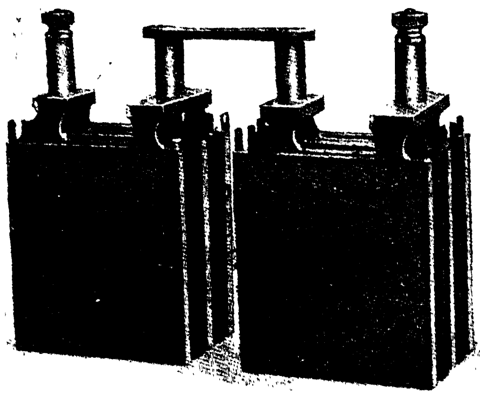


FIG. 66.—Peto Radford Plates, taken from a 4-volt lighting battery.

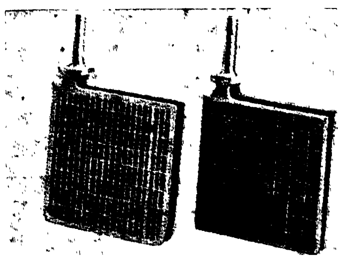
Fig. 66 gives a general idea of what an average accumulator would look like if we took it out of its case; the light coloured plates are the "negatives," and the dark ones are the "positives"; they are kept from touching each other by means of the insulators, which are placed each side of the dark plates. The rather ornamental pillars on top of the plates are known as the "lugs," and the two outside

* The term "Battery" must not be applied to a single cell. A battery is a combination of two or more cells.

lugs end in a terminal for making connection to the lamps, etc., whilst the two inside lugs are joined across by a bar or strip of lead, so as to connect one cell in series with the other, which, it will be remembered, adds the voltage together.

With the occasional exception of the terminals, all the metal work used in accumulators is of lead, to prevent the acid, or "electrolyte" as it is called, from attacking it and corroding it away.

The terminals sometimes, in spite of ordinary care, get slightly corroded or eaten away. This is due to minute particles of sulphuric acid settling on them.



Negative section. Positive section.
FIG. 67.

To prevent any acid doing harm, the terminals should be smeared (after wiping quite dry) with a little vaseline.

Although the plates of an accumulator differ in detail, they all bear a similarity to one another, and they all obey the same chemical laws of action and reaction. Fig. 67 shows two separate plate sections (C.A.V.), without insulators and terminals, etc. These are also dark and light; although manufactured by a different firm, there is a slight variation in appearance, however; it will be noticed that the squares or interstices of the negative plate are much finer than those on the former type. Plates, themselves, can be divided into two parts, (i) the support or "grid" (shown in Fig. 68), and (ii) the paste or active material let into the support either by mechanical means or by electrolytic methods, as in the Planté.

There are some accumulators which, although obeying the same laws, are quite distinct from the ordinary type; Fig. 69 is an example of this type. There is considerable scope for these batteries on all car

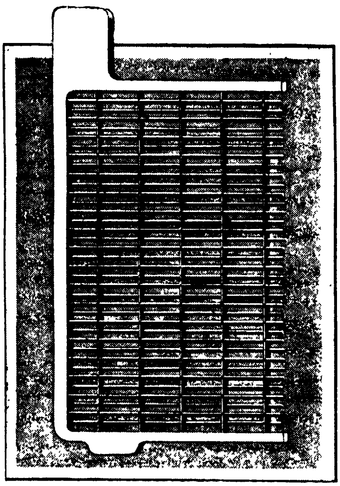


FIG. 68.—An "Exide" Grid for Starting and Lighting Cells.

installations, as they withstand great vibration, also high discharge will not injure them if not prolonged. The length of time that the "charge" is held is much in excess of the plate cell.

It must be stated at this juncture that to put a voltmeter across the terminals of a cell is no definite test as to its condition unless (i) one knows the particular meter or (ii) one takes the reading under load conditions, i.e. with the lamps alight; for if one does not do this, one may get a full voltage shown on a nearly discharged cell, provided the cell has been left to itself for a short time after use. This phenomenon has led meter manufacturers to construct a special meter for accumulator testing, which, instead of taking about $\frac{1}{20}$ of an ampere to work it (as in the case of the ordinary motorist's voltmeter), consumes about one ampere, and so indicates correctly whether the battery is charged or not, as no discharged accumu-

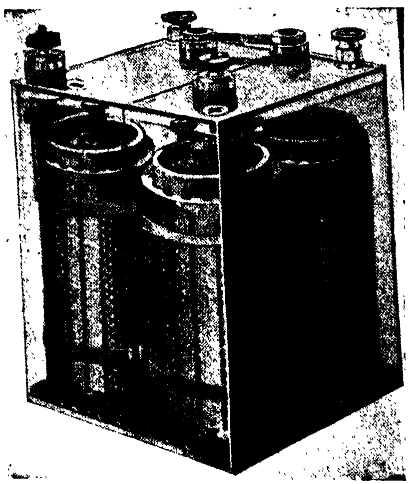


FIG. 69.—The "Fors" Accumulator.

lator could hold up for many seconds under such conditions. These meters were first introduced for testing ignition cells, and were designated "accumeters."

The only safe way of ascertaining whether an accumulator is charged fully or not is to take the specific gravity of the acid with an hydrometer. Several convenient forms of hydrometer can still be purchased for a few shillings. The method of using it is illustrated in Fig. 70, which shows its use in a large starting battery. A somewhat cheaper, though

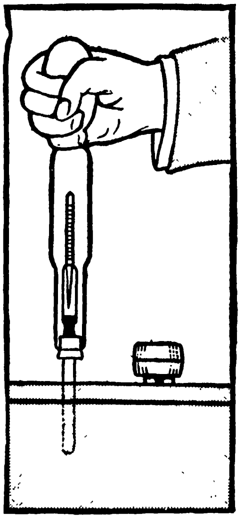


FIG. 70.—How to use the Syringe Hydrometer.

perfectly reliable type for use outside of the battery is illustrated in Fig. 71.

In practice, however, this test, although ideal, is very inconvenient, especially if required at night; hence, for all ordinary purposes, it will be a sufficient

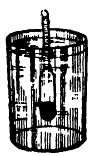


FIG. 71.—Hydrometer for external use.

guide to switch on the full complement of lights and note their brilliancy. The motorist will soon be able to tell whether his battery is in order or not by this method.

Judging by the note of the electric horn is another reliable guide for the practised ear. Even an amateur motorist will understand that if the note of the Klaxicon be like the bark of a dog suffering from bronchitis, the battery must be "down."

It has been found that when an accumulator is charged, the specific gravity of the acid rises to a maximum value, and, conversely, when discharged, the gravity falls to a minimum value, hence it is only feasible to suppose that if we knew the density of the liquid we could hazard an opinion as to the state of

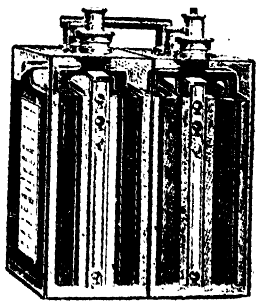


FIG. 72.—An Accumulator that indicates its condition at sight.

charge. It has been shown that very accurate results can be obtained by following this plan, as the density of the acid is in proportion to the "charge in the cell." However, it does not, unfortunately, bear a direct mathematical proportion, but is dependent upon a great many factors and causes which are constantly varying. Nevertheless, it does allow of greater accuracy than a voltmeter test.

Fig. 72 depicts an accumulator fitted with a density indicator, and constructed along the lines just set forth. There are four beads, red, blue, dark blue, and purple—all of different gravities. If all four float, the specific gravity of the acid has reached 1·220 or over, and the cell is fully charged. Should the purple bead be not floating, and the other beads floating, the cell is still charged, but not fully. Should the red and blue be floating only, then the cell is about one-quarter discharged. If a red bead alone be floating, it is about two-thirds discharged; and when this bead sinks down to join its comrades, the cell is discharged. In charging, the reverse occurs; but charging should not be discontinued until the plates have "gassed" freely for an hour, in order to keep the cells in fit condition. No adjustment can be correctly made to the specific gravity of the acid, except after the full charge has been arrived at.

Another interesting unconventional type of accumulator is the Fuller "Block" accumulator. This cell, whilst employing the same materials as the plate type, differs in that it has electrodes in the form of blocks, which are tapered in cross section. The chief advantages claimed for such a construction, are: (*a*) High current output per unit quantity of active material; (*b*) will not rapidly spoil if short-circuited; (*c*) durability much greater than the plate type under adverse conditions. In this connection it may be stated that the cell cannot buckle, and is practically fool-proof. (*d*) Of lighter weight than the lead plate type.

At its minimum, the battery should be able to furnish 16 candle-power for fully ten hours.

It must be of such a solid construction that it is enabled easily to withstand the vibration inherent to a motor car; further, its solidity of construction, whilst not embodying too much weight, must be such that large overdrafts can be obtained without the plates buckling or disintegrating to any considerable extent. Furthermore, it must be able to withstand considerable overcharge.

The above are the outstanding features of the successful automobile battery, yet there are a hundred and one little details upon which the quality of the cell depends; we cannot, of course, go into such details in a treatise confined to the present limits.* Cells embodying ebonite boxes are infinitely to be preferred to celluloid, as although each maker is sure he has discovered a brand of celluloid which defies the action of the acid, and the general electro-chemical conditions, sooner or later the celluloid is attacked,

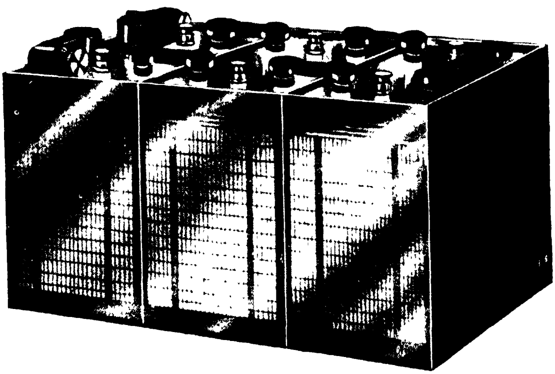


FIG. 73.—A 12-volt Battery Unit.

and in many cases is the unsuspected cause of the accumulator's output "falling off." The vibration an accumulator is subjected to upon a car is in some ways beneficial, as the acid is thus kept well circulated (an essential for best working conditions).

It is important to see that the acid in all accumulators is of correct specific gravity, viz. 1·20 to 1·225.

This can be made up by procuring a quantity of the pure yellow brimstone sulphuric acid of S.G. 1·843

* For detailed information concerning the treatment and use of automobile batteries, the reader is referred to the author's work, "Automobile Batteries" (E. and F. N. Spon, 2s. 6d.).

and adding it in a thin steady stream to four times its volume of *pure* water (which must not be kept in a metal vessel), take specific gravity readings only when the mixture is cool, and make any final adjustment (to bring the S.G. to 1·255) with pure water and stir well after addition before taking a fresh reading.

The kind of battery one requires for car-lighting and starting is shown in Fig. 73. This is a 12-volt one of ample size for the most powerful car. For export use the cases would need to be of ebonite, as in most tropical climates the deterioration of the celluloid is hastened considerably and the life of the battery is shortened proportionately.

It is quite a practical proposition to run the complete sets of automobile lamps with no other source of power than a storage battery. However, one needs two batteries to do this successfully—one to be charged whilst the other is in use. If one's car is only very infrequently used for night runs it is, of course, quite allowable to dispense with an additional battery. Some old cars are so out-of-the-ordinary that it is quite impossible to fit a dynamo upon any part of the chassis that will allow the dynamo's driving pulley to come within a drivable range of the engine. In such a case, should the owner wish for electric illumination, he can have it if he cares to depend upon a battery. Hundreds of cars are lighted solely by battery, through motives of economy in first cost, or in consequence of the inaccessibleness just referred to.

In the installing of battery-systems it is important to keep the voltage as low as possible for the following reasons: (*a*) It is more economical, less electrical leakage; (*b*) It is cheaper to install; (*c*) A spare 4-volt battery can be carried, so that the motorist in all eventualities can escape the unwelcome attentions of the police or the annoyance of having to put up for the night owing to having no light; (*d*) In the event of having no spare battery it is usually easier to obtain a 4-volt battery at the little country garages; (*e*) The breakage of bulbs is reduced to a minimum as the filaments of the 4-volt lamp are shorter and stiffer than those of higher pressures; (*f*) In

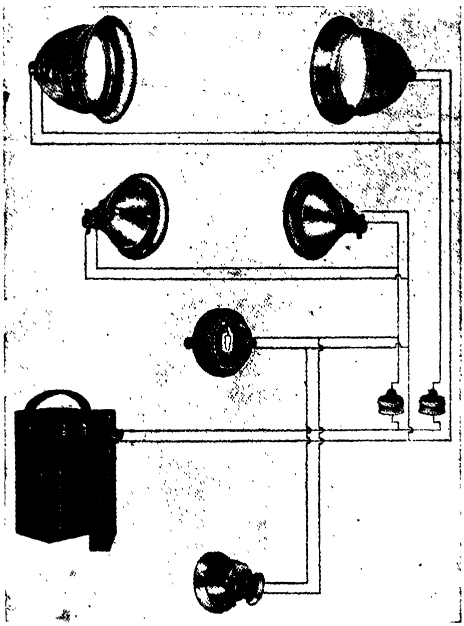


FIG. 74.—Double-pole Wiring.

repairs and accidents their cost is small compared with a large 12-volt battery with its six cells to the 4-volt's two.

In Fig. 74 is seen the scheme of a 4-volt double-pole wiring lay-out for the use of small cars. Fig. 75 shows the same, only single-wired. The former is the better of the two.

In fixing the accumulator into the carrying box, see that it fits tightly; if not, pack it up with rubber or wood strip. It is an improvement to carry them slung under the floorboards instead of on the running-boards, and this alteration has been carried out in some of the new designs. Perhaps the best arrangement seen is in the Angus-Sanderson, where a little com-

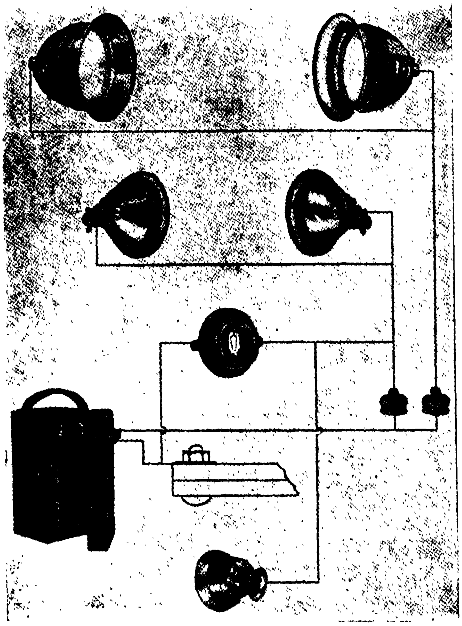


FIG. 75.—Single-pole Wiring.

partment is made for the battery on the floorboards just at the back of the front seats, and a sloping lid makes this compartment into a convenient foot-rest. Do not permit the lamps to burn until there is a sensible drop in their illuminating power, but be very careful not to confuse this drop with the falling off of their lighting power, owing to the traversing of tar-sprayed roads, as under this condition the finest head light appears inefficient, as the reflectory surface of the road is practically nil.

In determining the size of a car-lighting accumulator, consideration must be given to the fact that high efficiency electric bulbs of the half-watt type can now be obtained, but if ordinary globes are used it is advisable to limit one's head lamps to an 8-C.P. bulb, and side to about 4 C.P., while the tail and interior should not exceed 3 C.P. Under these conditions a 4-volt accumulator will suffice to run the lamps, all on together, for ten hours, if its capacity be not less than 80 ampere-hours. Running the lights w th the head lamps not always alight, and at short intervals, one might thus get a little greater output from one's battery.

It is very important in this connection to have the clearest understanding of the term "ampere-hour." If a lighting or starting battery is designated as 100 ampere-hours, it means that at a one-ampere rate of discharge that battery is guaranteed to furnish current for 100 hours. It does NOT mean that it is possible to withdraw a current of 100 amperes for one hour. Therefore, if we discharge it at any rate exceeding one ampere we must not expect to get our full 100 ampere-hours' worth of energy. However, if the discharge is under one-tenth of its capacity we should get the bulk of the stored energy as electricity. Some makers, in order to better explain their goods, state "capacity 100 ampere-hours on a 5-ampere (or other) discharge." Such an accumulator would supply more than its stated capacity when discharged at a lower rate than that specified.

Another very important point in connection with discharge is the question of its delay. For example, to obtain the maximum energy from a battery, it is necessary to commence discharging as soon as charging has ceased. If the discharge is left for a week or so after the charging has been stopped, no matter how good the cell's condition is, its output will be very considerably diminished—hence allowance must be made for this, if trouble is to be avoided.

The recharging of the motorist's accumulator will present no difficulty if left to a garage, as nowadays

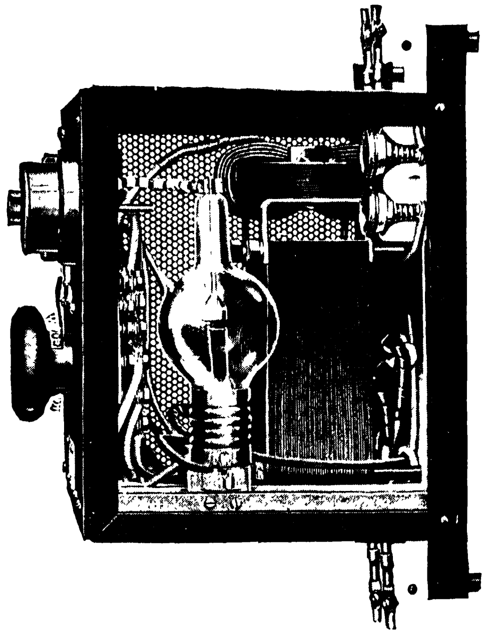


FIG. 75A.—The Tungar Rectifier.

most garages understand the charging of accumulators. However, if the user prefer to charge them himself from his house-lighting supply, he needs must attend to a few important details. In the first place the supply current must be "*direct*," and *not* "alternating," unless he possess a rectifier or converting set.

Among the number of rectifiers for the alternating current offered to the motorist and to the battery service station, the Tungar (probably so-called from "tungsten" and "argon") is one of the latest and certainly the most scientific. It will remind medical readers of the Coolidge X-ray tube.

One point of special importance with the Tungar is that it can be left unattended, as should the alternating current fail during the night or other time, the circuit with the accumulators is broken. Furthermore, when the current starts up again the rectified circuit is again made. The only precaution required is to ensure that the positive terminal of the rectified supply is connected to the positive of the battery, and the negative to the negative of the battery.

The Tungar Battery Charger is a simple, low-priced, highly efficient device for charging storage batteries from alternating current. It is made in various capacities. The main parts of any Tungar Battery Charger are as follows:—

One or two bulbs.

A transformer or auto-transformer.

A reactance.

The bulb looks much like an incandescent lamp, as will be seen from the illustration in Fig. 75A. In addition to the low-voltage filament (the "cathode") it has another electrode, the "anode." In the bulb is an inert gas—Argon. The combination of the heated filament and the gas makes it possible for current to flow in but one direction—from anode to cathode. Therefore, only uni-directional or direct current can flow from the battery charger.

No fixed life is guaranteed on the bulb. Laboratory and commercial tests over a period of three years indicate the average life is at least 600 to 800 hours, and many bulbs will run very much longer. Bulbs in commercial service, even overloaded at times to the extent of 30–40 per cent., have run 1,500 to 3,000 hours, so that the statement of average life is undoubtedly conservative. The high efficiency of the Tungar battery charger and the low price of bulbs make this item insignificant.

The transformer and reactance are to adjust the current and voltage of the alternating supply to the output voltage required by the battery or batteries.

All live electrical parts are enclosed in a steel case.

Assuming the supply to be direct, a cheap method of recharging one's accumulators is to place it in "series" with a lamp of the supply voltage. This operation is

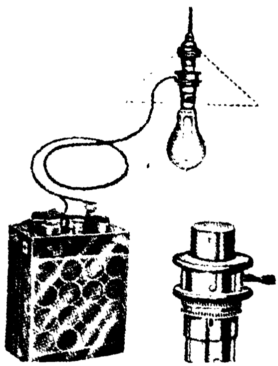


FIG. 76.—Recharging a small Accumulator through a Lamp.

accomplished with the aid of the special holder shown in Fig. 76, which almost explains itself. The only point to be guarded against is to see that the positive wire of the supply is connected to the positive terminal of the battery. To find out which wire is positive, either buy some pole-finding paper, or immerse the two wires in a glass of acidulated water; bubbles of gas will emanate from both wires after the current has passed for a few seconds. The wire which has the *lesser* quantity of bubbles is the *positive*, and must be connected to the positive terminal of the accumulator.

For convenience in handling, the special holder is fitted with a key switch, so that all connecting can be done with the current off. A somewhat neater arrangement than the above is that shown in Fig. 77. It

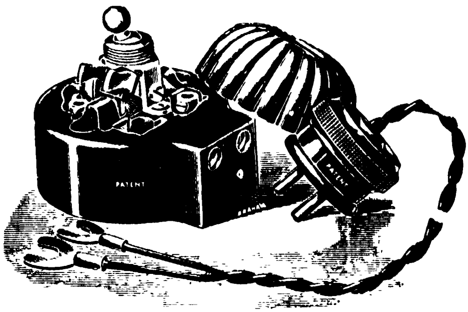


Fig. 77.—A Charging Switch for dealing with small car batteries.

virtually consists of a two-way switch, which enables the lights to be burnt as usual or when the plug is in to be connected in series with the battery. The connections are shown in the diagram (Fig. 78). The plug is so arranged that it will only fit in one way round, hence a reversal of polarity is impossible. As

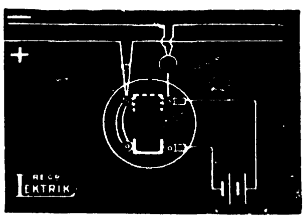


Fig. 78.—Diagram of Connections for the Switch shown in Fig. 77.

the existing switch has to be replaced with the one shown in Fig. 77, those who are quite unacquainted with electric practice would do well to call in the local electrician to advise them. He will then see that the positive main is connected to the right contact for the charging lead, to be in accordance with its marked polarity.

For recharging a large battery it is a good plan to place it in series with a radiator, and thus avail oneself of the cheaper power rate.

Before leaving the subject of the accumulator battery, it is necessary to refer to the work that is being done to promote the popularity of the alkaline type of accumulator cell. Up to the present all alkaline batteries have been handicapped by their low E.M.F. which ranges from about 0·75 to 1·25 volts. This does not of course contrast very favourably with the 1·9 to 2·2 volts furnished by the "good old lead cell." However, their general use is improbable, owing to their relatively high internal resistance, which prohibits their employment for starters. Neither the Edison Storage Battery Co. nor the Jüngner-Nife people enthuse about the use of their alkaline battery for starting sets, although the author knows of cases where success has been obtained. For lighting only, these batteries, on 6-volt equipments, are ideal, and will furnish 13 watt-hours per lb. of battery carried.

Advantages of an Alkaline Battery *

(*a*) They contain no acid, therefore give off no corrosive fumes, and can, therefore, be kept anywhere without destroying surrounding objects—including the battery attendants.

(*b*) They can be recharged at any time, regardless of the amount of charge left in ; and can be left standing idle and uncharged indefinitely without injurious results.

(*c*) Lighter and more durable (5 years of good service a certainty).

* Abstracted from "Automobile Batteries."

(*d*) May be discharged to utter exhaustion without harm, also a few "shorts" won't hurt any.

(*e*) No harm will result if cell is charged the wrong way round; however, it will NOT store when thus treated.

(*f*) No specific gravity readings are necessary and solution lasts good for one year.

(*g*) Within the limits of reason they cannot be hurt by overcharging.

(*h*) Do not run down to the same extent on standing idle.

Disadvantages of Alkaline Cells

(*a*) Voltage is very low, 1·2 per cell only can be counted as a working E.M.F.

(*b*) Internal resistance and first cost both too high!

(*c*) They have a tendency to rust their cases and grids if kept short of the 20 % caustic potash solution.

Here are some comparative figures for the two types of battery:—

Lead Type.—6-volt 50 ampere-hour (3 cell), weight 45 lb., gives 135 amperes with terminal voltage of 5·2 volts, watts for load = 702, or ·94 H.P.

Alkaline Type.—6-volt 50 ampere-hour (4 cell), weight 37 lb., internal resistance too high for load as above; it is therefore necessary to use a battery of the 80-lb. size, twice as heavy as the lead set, to obtain the required load.

Special Starter Batteries

In outlining the problem of electric starting, we saw that the battery had to be of unusual construction to stand the brunt of a balking starter. Makers usually give a two-year guarantee with a starter battery, and if one gets more than double the guaranteed life one cannot complain. Much improvement has taken place in the construction of heavy-wear batteries, but the greatest, no doubt, is the abolition of the celluloid separator and in many makes the celluloid case as well. The illustrations in Fig. 79 give the details of good, bad, and indifferent separation material. No. 1 is an ebonite one which, after considerable use, decays into a substance which powders quite easily and could not be of further use as an efficient insulator. No. 2 is the wood separator, and has done more for the

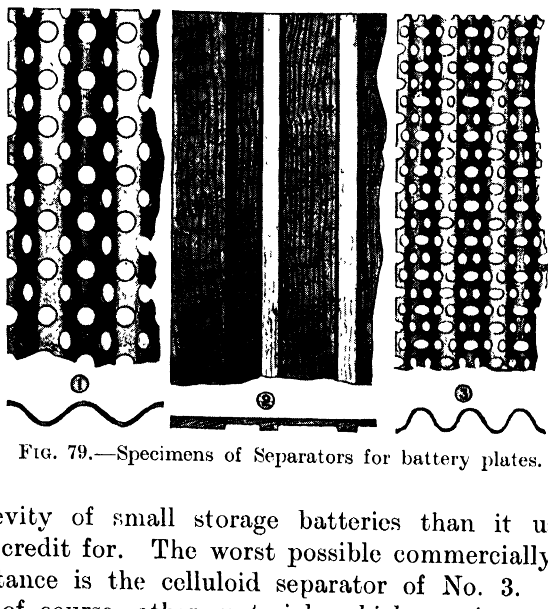


FIG. 79.—Specimens of Separators for battery plates.

longevity of small storage batteries than it usually gets credit for. The worst possible commercially used substance is the celluloid separator of No. 3. There are, of course, other materials which are in use, and in passing it may be news to some that Messrs. C. A. Vandevell & Co. have standardized their cells with a new woven fabric separator, for which they have acquired the sole rights for this side of the world.

In Fig. 80 we have another good point, which is used in the Van Raden batteries. This connexional method ensures positive contact and lowest resistance at the same time. In the make of cases we are able to report progress in the fact that it is now possible to obtain separate celluloid cells for a celluloid cased battery. Fig. 81 will illustrate an example.

The well-known Exide battery, in addition to being fitted on the world's most famous car, is now fitted with a special vent-plug, which is a marked advance on any of the older types. The plug fits into a socket in the ebonite cover of the cell by means of a bayonet joint. Below the joint the socket is provided with a

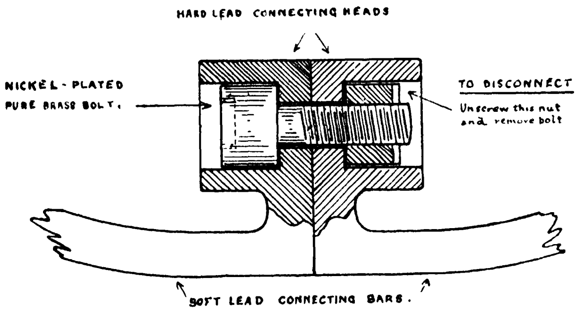


Fig. 80.—The Van Raden Connector.

rotatable ring, which, in one position, opens up the vent holes passing through the side of the socket to the interior of the cover, and in the other position closes the vents. There is, of course, right through the plug itself an additional vent-hole. When the plug is in position a key formation on its lower extremity engages with the rotatable ring, and holds the latter in such a position that the side vent holes are open. After the plug is withdrawn, by a semi-rotary movement, the rotatable ring covers these side vent holes, so that when distilled water is added to bring up the level of the electrolyte in the cell, as soon as this level reaches the bottom edge of the vent plug socket an air-lock is formed in the cover, and no more water can be added. Replacement of the plug rotates the ring, which uncovers the side vents, and allows the residue of water in the neck of the vent to escape into the cell, at the same time that the side vents are cleared ready to permit the escape of any gas when charging.

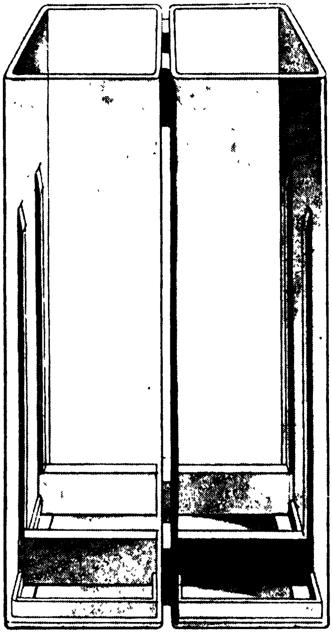


FIG. 81.—Celluloid Case with Isolated Cells.

Claimed to be better than the alternative, i.e. merely subdivided cell case.

It is possible to design special storage cells for many different duties, for example, a storage battery intended for lighting requires different types of plates from one used for starting, and the design of the battery both for starting and lighting will depend very largely upon the duty to which it will be put, i.e. whether it will have to do more starting than lighting, or more lighting than starting, hence the need, so far as the battery manufacturers are concerned, for more explicit and definite information than car manufacturers usually give.

As a final point it may be expedient to mention that with some makes of car dynamos, there is a likelihood of too much current being forced into the battery long after it has had enough, many a good battery has had the life boiled out of it by a non-regulated dynamo. Always check this up on a new car, especially as a trifling adjustment of the regulator will rectify matters. Most systems are calculated to charge the battery at a 10-ampere rate, and if at a little above cutting in speed the ammeter needle swings up to the 10-ampere mark and stays close to that mark, no matter how fast one drives, one will know that one's system is not only supposed to be a constant current system, but actually *operates* as such. Apropos of this, the author, through the courtesy of the U.S.L. laboratories, is able to reproduce, in Fig. 82, some charging curves which will doubtless be of great interest to members of the electrical profession, as well as to the less technical readers for whom this manual is intended.

Vertical distances in the chart are scaled in terms of amperes, as indicated on the left. The height at any point in a given curve above the bottom horizontal line shows the current output of the particular dynamo at the engine speed indicated directly below. Note that dynamo B cuts in at 300 R.P.M., and then gives an immediate output of 1½ amperes, increasing steadily until it generates and maintains a maximum and constant current of 13 amperes from 800 R.P.M. up. Note that D cuts in but produces zero current at 325 R.P.M., does not generate 1½ amperes until it attains 350 R.P.M., or 10 amperes until it reaches 850 R.P.M., or as much as generator B until its engine turns at 1,400 R.P.M. Take a good look at that curve D. A generator which behaves like that is hard for a battery to get along with. Note that curve D indicates a lower output at all speeds below 1,400 R.P.M., than all the other curves, and that at the right of the chart it is the steepest curve of the lot, indicating an increasing

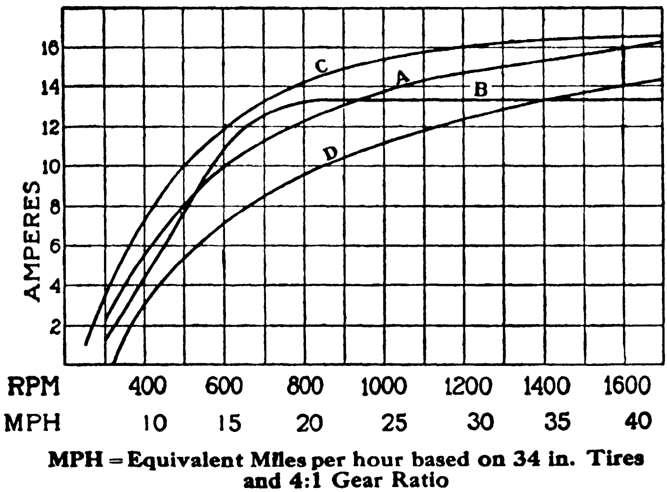


FIG. 82.—Some Generator Charging Curves.

output which will finally exceed that of generator A, likewise an offender.

If the generator behaves as indicated by curve D, unless the driver's speed habits happen to produce a generator output represented by a certain very short portion of that curve which is favourable to the battery, battery ailments are bound to occur. At habitual speeds *below* the favourable one, one will have a current starved battery and will call regularly at the service station for a " boosting " charge to keep it off the scrap heap.

In the well-known English sets, the makers aim at producing a satisfactory drooping characteristic, by which means the battery charge rate is materially reduced at excessive speeds. The inter-brush machines are perhaps the best ones for a satisfactory " droop." It is hoped that the reader will appreciate that it is not alone a question of size, capacity and voltage that ultimately counts. It is principally the service conditions. One prominent manufacturer of batteries advises his manufacturer clients in the following terms : " We could build you a battery which would see your present car in its grave, also your next car, and the same old battery would still be cheerfully doing its duty. But it would be altogether too heavy for practical use, and you would certainly balk at the price."

CHAPTER VIII

SWITCHBOARDS AND CABLES

We now come to deal with the nervous system of the car-lighting installation, viz. its wires and cables, which serve to distribute the current to the various points. The nerve centre of the system is, of course,

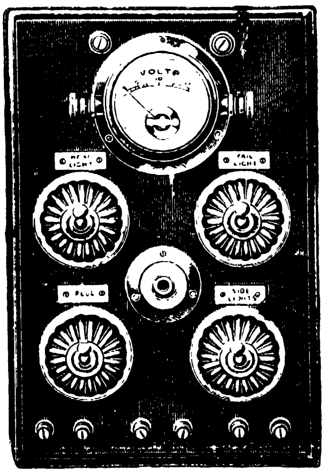


FIG. 83.—An elementary form of Switchboard.

the switchboard. In dealing with this important subject our attention must be given to general principles only, as reference to the maker's catalogue will furnish all the details and idiosyncrasies of any particular system in which the reader might be interested, However, in general principles, practically all switchboards or switchboxes follow the standard of simplicity, that is to say, their designers aim at surrounding two meters with "dinky" little switches, which are undoubtedly modelled after those used in house lighting over in the U.S.A. The early type of English board resembled that shown in Fig. 83, and later evolved, through foreign influence, to the creation exhibited in Fig. 84, which was wired up, as shown in Fig. 85.

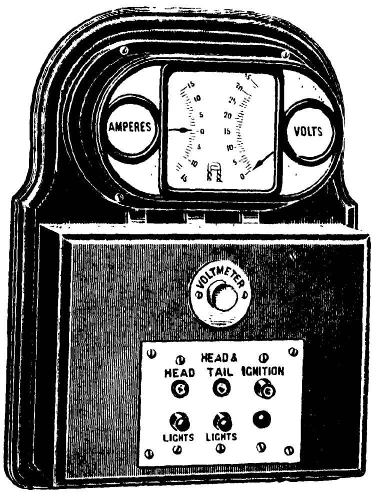


Fig. 84.—Front view of Switchboard.

Whether or not we should be favoured with a voltmeter or ammeter, or both, were debatable points, and even in these post-war days all makers do not think a voltmeter unnecessary—not that there is any special reason why they should, as a voltmeter is some sort of indication of the condition of the battery, it at least will tell the driver if it is still in the car. An ammeter is indispensable. It is better to be of the central zero type, as with this instrument one can read the discharge amperes as well as the charge ; the meter used on the board illustrated in Fig. 84 makes this quite apparent. Most of the English meters are of the left-hand zero pattern. As indicative of modern switchboards, we shall consider the arrangements of a few leading types of British board.

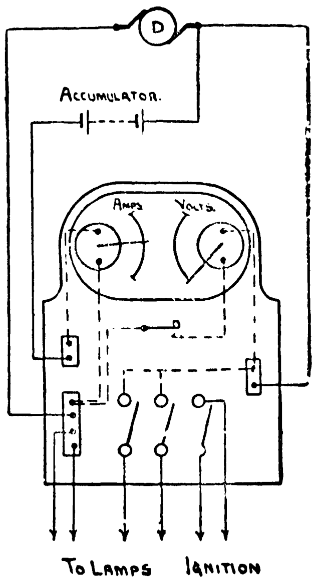


FIG. 85.—The back view of Switchboard shown in Fig. 84, giving Diagram of Connections.

The Rotax Switching Equipment is depicted in Figs. 86 and 87, which shows the general appearance and the board with its cover removed, so that we can get a glimpse of how the connections of the cables are accomplished. This board, in common with most of the others, is provided with a fuse (access to which is obtained by removing the front, held in position by two screws and switch-handle) which is interposed in the field circuit of the dynamo, so that, in the event of the battery becoming disconnected and the dynamo running on its own, the increased flow of current through the field circuit, which would occur owing to the

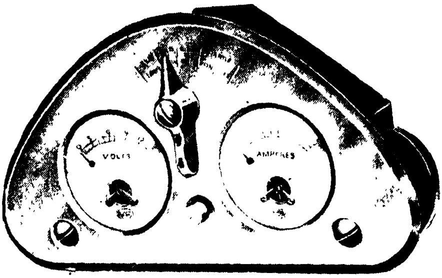


FIG. 86.—Rotax Switchboard.

absence of its prime regulator—the battery, causes the fuse wire to melt before the windings of the machine are damaged. Spare fuse wire, 3-ampere capacity, is

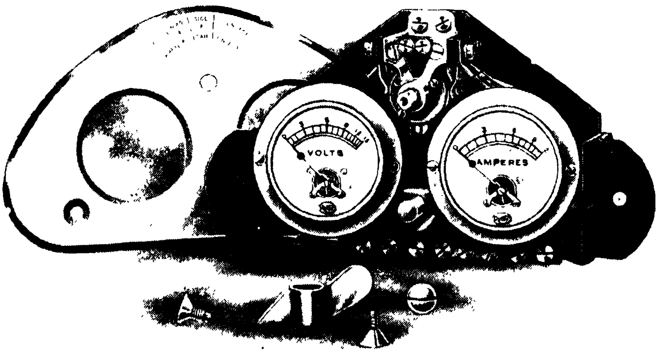


FIG. 87.—Rotax Board without Cover.

supplied inside the cover of the switchbox, which should always be used for replacement.

Fuses.—It has not been considered advisable in the majority of cases to fit fuses to the lamp circuits as there is always the possibility of a short circuit occurring which would then lead to the sudden extinction of the lamps with, perhaps, serious consequences. If no fuses are used, a short circuit will only dim the lamp whose circuit is affected, leaving enough light to steer by until the car can be stopped.

There are sets, such as the Blériot Scott for instance, where a fuse is included in the main circuit as well as the usual field fuse mentioned above. Some, indeed, have a fuse in circuit with each lamp. This is quite an unnecessary refinement.

N.B.—On no account should copper or iron wire be used.

The Charging Switch and Voltmeter.—This switch should always be kept in the charge position until there is no doubt that the battery is fully charged. If any doubt exists the battery should be given the benefit. OVERCHARGING WILL NOT HARM THE BATTERY BUT UNDERCHARGING WILL QUICKLY RUIN IT. Voltmeter readings should always be taken with the switch in the "all lamps" position, and the dynamo stationary, when if the battery is fully charged, it should read 13 volts with a 12-volt set and 6·5 with a 6-volt equipment.

Ammeter.—This instrument is the best indication that the set is in perfect order. Assuming its usual reading is 10 amperes at 25 M.P.H., and it is noticed to have dropped to 5 at the same speed, it will generally be found that belt slip is the cause of the trouble, and should be dealt with without delay. In the case of a dynamo which has been in use for a long period, worn carbon brushes may cause similar trouble, and these should be replaced by new ones immediately, otherwise damage to the commutator may result from excessive sparking, due to the brushes being worn so short that bad contact is made with the commutator.

The Lucas Switchbox is given in Fig. 88, showing switchbox without its cover. The switches marked H and S control the head and tail, and side and tail lamps respectively, by which arrangement the driver is assured that so long as any forward lights are on, the tail lamp will also be alight. The switch marked C controls the dynamo, and all the switches are so constructed as to be "on" when pushed in. In the Lucas arrangement there is, in addition to the dynamo

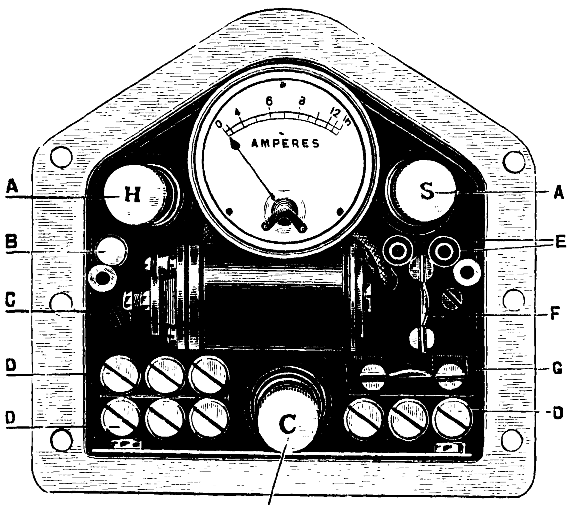


FIG. 88.—A, switches; B, spare fuse wire case; C, cut-out; D, terminals; E, inspection lamp adapter; F, control circuit fuse; G, main dynamotor fuse.

field fuse, a main dynamo-battery fuse, provided to obviate the serious consequences of a short circuit, such as burning out of switchbox and cable; it will "blow out" immediately excessive current flows.

The C.A.V. Switchboard (Fig. 89) is a widely used piece of switchgear and uses switches of the ordinary domestic pattern, so far as the action is concerned. The connections to the switches controlling

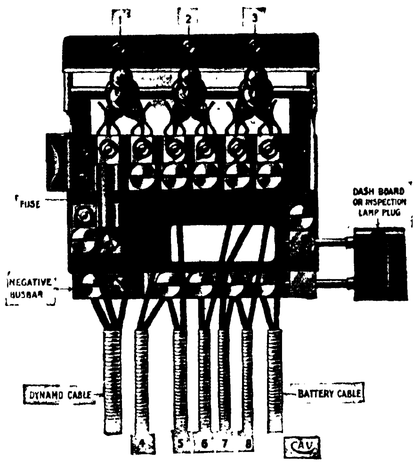


FIG 89.—The C.A.V. Switchbox. Internal wiring shown in Fig. 177.

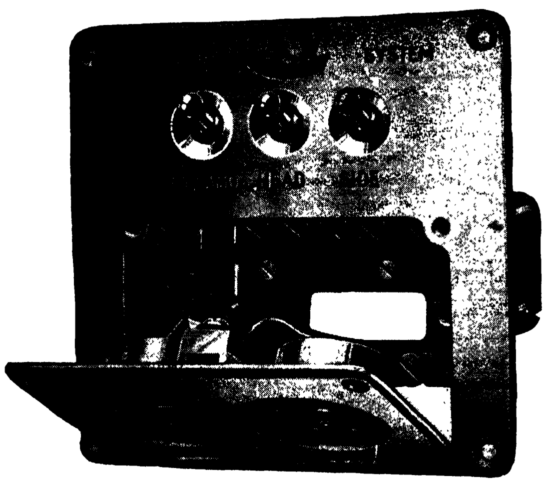


FIG. 90.—Showing C.A.V. arrangement for making easy inspections to connections.

the generator and various lamp circuits are clearly shown, also the position of the dynamo field fuse. It is important to see that the cables do not chafe on the terminal bars. Notice also that the metal

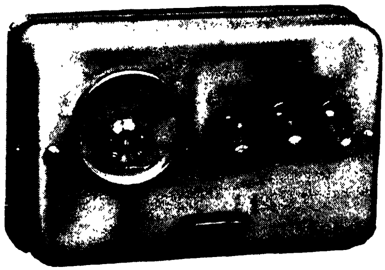


FIG. 91.—The Brolt Switchgear.

armour on the cables does *not* enter the board ; on no account must the armour enter the switchboard, as it is certain to become earthed in time if this is

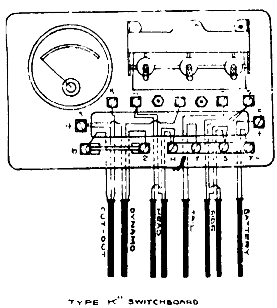


FIG. 92.—Connections to Cables of type "K" Brolt.

permitted. The meters are attached to the cover of the switchboard, which is hinged at the top as indicated in Fig. 90. This plan facilitates internal inspection.

The Brolt Switchboard.—This is a particularly well-finished and attractive-looking production, as will be gathered from Fig. 91. The firm make another type of apparatus to be fitted flush with dash. In both types three switches only are provided, one each for the dynamo, head lamps and side lamps, the tail lamps, as in the Lucas board, being automatically switched on when either the head or side lamps switch is operated.

A combined volt and ammeter is fitted in this type of switchboard, the meter reading amperes whenever the dynamo is charging. A very simple device has been evolved to obviate the necessity for a

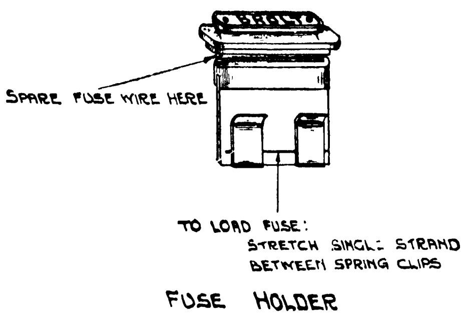


Fig. 93.—The Brolt Fuse-holder.

separate volt push, the dynamo switch being utilized for this purpose. When the dynamo switch is in the "off" position it is not at the extreme limit of its travel, but it is normally prevented from further movement by the pressure of a spring. To read the voltage of the battery it is only necessary to press the switch dolly a little beyond the "off" position and the meter at once indicates volts.

The fuse on the board illustrated is attached to the name plate block, which pulls outwards, and the fuse carrier and spare wire is brought away also with the one effort—a cute little scheme (see Fig. 93).

The Smith Switchgear.—We come now to a different type of controller in that the whole contrivance itself moves as a switch. It is known as a Bezel operated lighting switch, and matches the Smith clocks and speedometers. The switching operations are performed by rotating the knurled bezel of the instrument, and the combinations "ALL OFF," "SIDE," "HEAD," and "ALL ON" appearing in succession at the top of the switch dial as the bezel is turned. A high-class ammeter is mounted in the centre of the dial to indicate

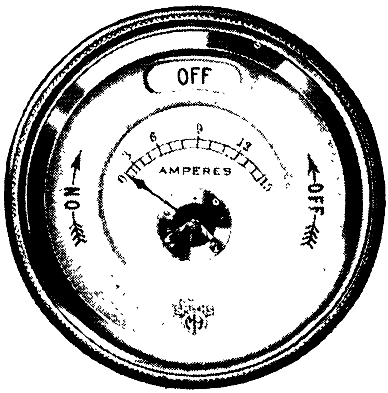


FIG. 94.—The Smith Switchgear.

the charging current and correct working of the system, and the terminals are neatly arranged at the back. They are clearly marked and easy to connect. It is fitted to the dashboard by means of the patented Smith spring, no screws being required. All this will be clear by looking at Fig. 94, which is a general arrangement of the switch, and its back view showing the fixing springs will be found in Fig. 95.

The charging switch (Fig. 96) for use in conjunction with the Bezel lighting switch, consists of a very small and neat button type switch, constructed for flush fitting on the dash or instrument board. It has two control positions: *Pull out*—dynamo on, i.e. charging the battery; *Push in*—dynamo off, i.e. out of operation. A dynamo switch is included in every set in which the Bezel lighting switch forms part of the equipment.

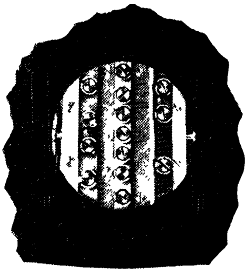


FIG. 95.—Back View of Smith Apparatus, showing the fixing springs.

The subject of charging switches is another moot point, as one is usually safer without any method of *preventing* the battery getting charged. The number of batteries ruined by over-charging on English sets is extremely small and, indeed, all makers after having

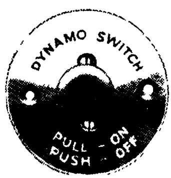


FIG. 96.—The Smith Charging Switch.

provided a dynamo switch, caution the customer to be sure and leave it on as much as possible—in short, don't use it! It is, of course, appreciated that the wear on the dynamo is greater when fully fluxed, and the author admits that power *may* be wasted, but a mere fraction surely? The dynamos made in the land where they do not include charging switches (U.S.A.) do occasionally show signs of the effects of long and arduous toil. The principle followed is to let the cut-out care for the battery.

Position of the Switchgear.

In practically every case this is fitted on the dashboard in a vertical position, so that the meters can be easily read from the driver's seat. It should be also fitted in such a position that nothing comes in the way to prevent inserting the plug for an inspection lamp into the socket which is provided in most of the switchboards for this purpose. A neat little inspection lamp is one called the "Stickalite," which, in addition to its light-giving functions, attaches itself on to any iron part of the car, for it has an electro-magnet in its base. As an instance of its usefulness it might be mentioned that when stuck on the under side of a mud guard it will throw the light just where the "tyre-changer" wants it. Or, again, in looking for electrical trouble it will stick conveniently to the folded-up bonnet. The device weighs only 3 oz. Most boards incorporate the cut-out when not fitted on or in the dynamo.

AUTOMATIC CUT-OUTS

Back on page 61 we discussed the theoretical considerations of electrical cut-outs, and pages 85 to 93 describe the mechanical types. We now have to cite a few examples by way of practical illustration. The function of the cut-out is to automatically connect the dynamo to the battery when the machine is charging and to disconnect the circuit when stationary, or when the generator is running too slowly for charging purposes. Fig. 97 illustrates the automatic switch used with the Rotax dynamo. This is usually mounted on the back of the dashboard, under the bonnet, and should not be tampered with, as it is adjusted before

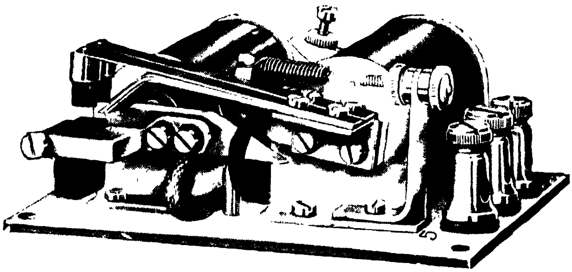


FIG. 97.—The Rotax Automatic Cut-out.

leaving the works. Any alteration to the spring adjustment will prevent the dynamo switching in until it reaches higher speeds, but will not affect its switching off. This part should never require attention, providing the

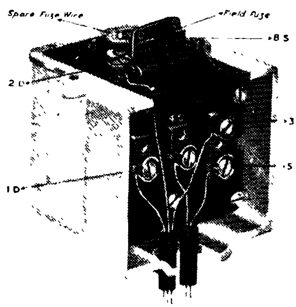


FIG. 98.—The Smith Automatic Cut-out.

connections are properly made to the three terminals (see illustration) in the first instance, and the set is not run on open circuit (i.e. with the battery disconnected) and a heavy fuse fitted, in which case, if the set is run for a considerable time, the shunt coil of the switch will become damaged.

In Fig. 98 we have the cut-out as fitted to the Smith machine. Its recommended position is preferably on the dashboard, under the bonnet, but it must be kept away from the exhaust pipe. Any other position would do equally well, but it should be easily accessible to enable the field fuse of the dynamo, which lives in the same house (see top of Fig. 98) to be inspected and replaced when required.

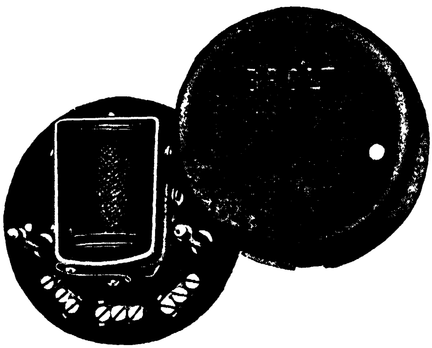


FIG. 99.—The Brolt Cut-out.

The Brolt Company have a neat little switch in their cut-out device, which is shown in Fig. 99.

The Blériot cut-out introduces a means to compensate for the air-gap variation which is unprovided for in all cut-outs of the usual type. Fig. 100 will illustrate the scheme employed. It will be seen that the resistance (*c*) is in series with the shunt winding (*b*) and is short-circuited by the subsidiary contacts *K.K.* when the cut-out is "out." When, however, the main contacts are closed the resistance (*c*) is inserted in series with the shunt (*b*); thus the shunt current is reduced, and provided a suitable value is adopted for the resistance winding (wound in opposite direction to shunt), the attractive force on the armature may be kept constant, irrespective as to whether the air gap is a maximum or minimum. The general appearance will be gathered from Fig. 100A.

Adjustments to Cut-outs

The weak points in most cut-outs are the contact points, which are usually made of a platinum alloy or tungsten, and silver in some cases. When they become dirty or worn unevenly, they may be cleaned by passing between them a piece of fine No. 00 sand-paper. Blow out all dust to allow clean, flat contact. Use care not to

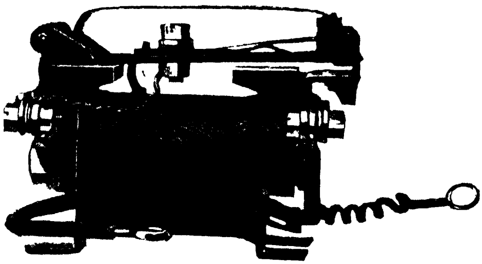


FIG. 100A.—General Appearance of Blériot Cut-out.

spring the arm or to change either the opening or the spring tension. The spring tension is correctly set to operate at the proper time for connecting and disconnecting the points, which should have a maximum opening of ·020 inch to ·025 inch.

Contacts Sticking.

Cut-out testing must be done with an ammeter in circuit and must not be set by guess-work. When in doubt how to adjust it refer to the makers. If, however, the cut-out should not open at the contacts, though engine has stopped, remove the wire from the battery terminal of the cut-out, then glance at the ammeter. If the needle now goes back to zero the fault is in the cut-out. Put back the wire and note what the meter tells. If the needle is still on the zero the answer is "stuck contacts," therefore, clean them well as first set forth above. If the ammeter still indicates a current flowing out of the battery, probably it will still be "stuck contacts." If so, prise them apart (do not push on the armature of the cut-out) and clean-up as recommended. Sometimes the whole

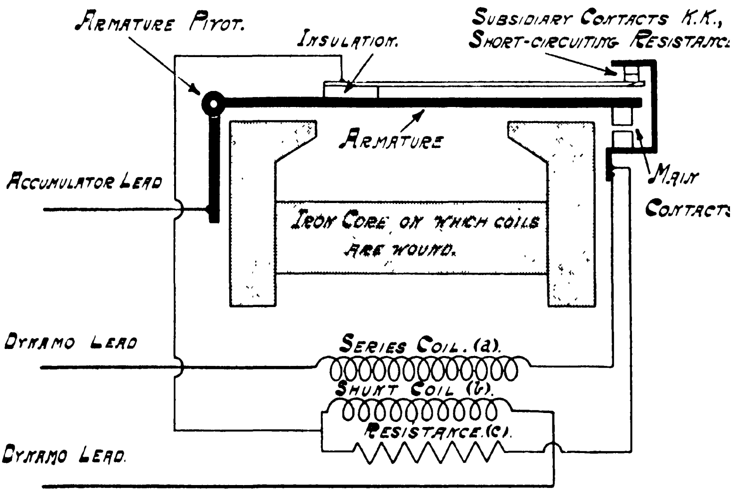


Fig. 100.—Blériot Compensated Cut-out.

armature will drop down and foul the actuating mechanism. Should this be the case screw into position carefully, adjusting the contacts as directed on page 185. Occasionally the snapping of a wire or the sticking of a brush, or other trouble which causes sudden interruption of the main current flow will prevent the cut-out from opening, because the battery is unable to send the needed opposing current round the series winding (thick coil) of the cut-out, while the armature is being held against the magnet through the shunt coil current obtained from the battery, which, of course, is in the same direction, as it is connected across the main terminals of the accumulator (see diagram on page 62).

Defective Insulation.

In the cheaper makes of cut-outs the insulation occasionally breaks down around the site of the terminals and contact connections. This causes "earths" and on a grounded system like that in the Ford short-circuits. The remedy is to renew the insulation.

Open Circuit.

Sometimes a wire will, through age and dryness, break under a terminal and cause a troublesome open circuit. Usually it is the fine wire coil which has this weakness. Soldered connections are another fruitful source of cut-out derangement. The remedial measures here are obvious. In making good broken wires, especially shunt wires, use a few strands of a piece of fine lighting flexible. The symptoms of an open cut-out are non-closure of contacts if in shunt coil, and no current through to battery if in the series or thick wire winding.

Damaged Windings.

These may occur through overheating and accidental injury; it is best to return the apparatus to the works, as to re-wind a cut-out is slightly beyond the province of the amateur electrician.

The electrical cut-out is to be considered by no means a troublesome piece of mechanism, as upon the average car if left untouched it will work indefinitely. It has one great feature of superiority over the mechanical automatic switch, in that to a large extent the contact is more positive as the weak initial shunt contact is heavily reinforced by the strong pull of the series coil. Furthermore, it is usual to introduce protective measures such as carbon or copper contacts to break the circuit first and thus the destruction of the expensive platinum contacts at the first contact is minimized. The Rotax cut-out on page 183 illustrates this point. There is also a co-operative action, a mutual dependency, as it were, between the dynamo and battery, which is theoretically an advantage, as if the voltage of the battery is low, the cut-out contact closes a little earlier than if it is high in value, as the back E.M.F. is, of course, greater in the latter case.

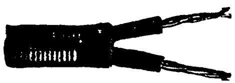
CABLES AND JUNCTION BOXES.

In turning our attention to the most important question of wiring, we must assume that a site for the dynamo and starter is already decided upon.

The cables to be used are primarily selected in accordance with the amount of current to be conveyed along the various circuits ; it is, of course, obvious that the heavy current required by the starting motor could not be obtained from a wire sufficient for the field wire of the generator. As the "run" is so short, the question of economizing in copper is not important, and so we find most makers generous in the cross-sectional area allotted to the cables. The following table gives an eclectic view of the cable practice now adopted.

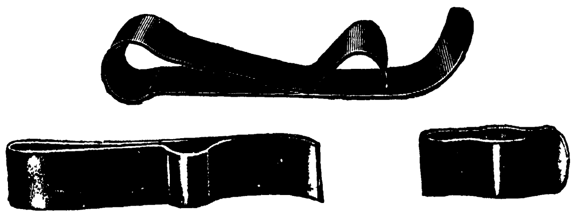
Use of Clips.

Notwithstanding the fact that no special difficulty is encountered in the fixing of the cables, there are several points which should be borne in mind. First of all decide not to use staples—insulated or otherwise ; both these types are uncertain and are most likely

Name of Circuit.	Contents of the Armouring.	Size of Conductor.	Carrying Capacity under I.E.E. Rules.*
		S.W.G.	Amps.
Starting Motor Leads	One conductor of tinned copper wires, insulated with vulcanized india rubber, oil taped, and armoured with metal strip. One cable is taken direct from the battery to motor, and a second from battery through the starting switch to the motor terminal.	19/18	59
		37/20	60
		78/25	48
		145/25	68
		260/25	102
		320/25	118
Dynamo Cable  Fig. 101.	Three conductors of tinned copper wires insulated as above and each conductor a distinctive colour. This cable goes direct to cut-out in the majority of installations (Fig. 101).	2 wires 7/23	12·4
		1 wire 3/22	7·2
		2 wires 70/36	12·9
		1 wire 14/36	2 5
		2 wires 110/36	19·0
		1 wire 23/36	4·0
Battery Cable  Fig. 102.	Two conductors as above directly connected to the switch-box (Fig. 102).	Twin 7/23	12·4
		Twin 70/36	12·9
Head Lamp	Two conductors as above, connected from switchboard to each lamp.	Twin 23/36	4·0
		Twin 3/22	7·2
Side and Tail, etc.	As above.	Twin 14/36	2·5
		Twin 3/22	7·2

* May actually carry from **50** to **500** amperes in starting circuits.

to damage the conductors, in the process of being "driven in." Cleats and clips are the usual and certainly a better means of attaching wires to the chassis of a motor car. Fig. 103 illustrates a few special clips for car use. The tunnel portion of the clips are for holding the cables, whilst the main portion of the apparatus bites on to the chassis and lamp bracket respectively. With this device the cables can be readily attached and detached without injury to their armour.



For the chassis. For the lamp bracket.

FIG. 103.—Cable Clips for use with Armoured Cables.

General Pointers.

Don't festoon the wiring near any moving part—it may catch.

If the headlights are very powerful use the thick cable in the above table, in fact it is always better to err on the side of too much copper than too little, since the "voltage drop*" is less with thick cables.

Take the greatest care that the connections to lamp holders and sockets, plugs, etc., are well made, and well insulated. Endless trouble is in store for the unwary on this one count alone. See that in all cases of wires running to and from terminals that the *rubber covering* runs right up to the terminal screw. Cables

* The fall in the electric pressure or voltage due to the resistance of poor or insufficiently thick conductors (lost volts).

passing through sheet metal, or in fact any metal part of the frame, require insulated bushes. The slack in cables must be neatly clipped up behind the dash. The "job" illustrated in Fig. 104 illustrates how cables should be run up to the switchboard. It is best always to start wiring **from** the switchboard **out** to the various points.

Do not run too close to the exhaust pipe, and avoid very sharp bends.

Do not twist the cables unnecessarily, especially close up to the lamps, as this is liable to cause short-circuits.

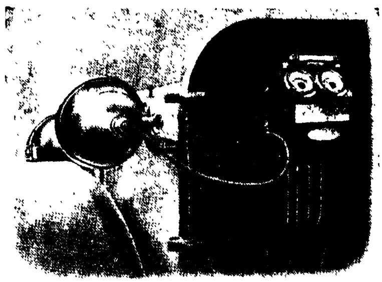


Fig. 104.—Method of running Cables to Switchboard.

See that the wires to battery are properly insulated and the ends fitted with round wire terminals to slip over the battery terminals.

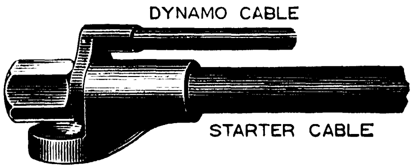
Above all, see that they are tight and held tight with spring washers under the nuts.

Starting Cables.

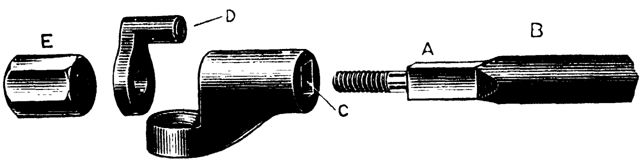
Always use a sufficiently heavy starting cable—the heaviest one in the table is the best for two reasons. First, the voltage drop, even with hundreds of amperes, is small, and, second, the heating of the thick cable is not so rapid to cause appreciable resistance. Messrs.

Lucas have solved the problem of attaching these heavy cables to the accumulator by means of the special terminal illustrated in Fig. 105. It is designed primarily to provide good contact, and great care has also been taken to ensure its resistance to the corroding effects of the acid solution. It is made of brass of sufficient strength to resist all vibration, and is thickly covered with lead.

The terminal is neat and accessible, and is easily detachable when required.



Terminal assembled.



Terminal adrift.

FIG. 105.—The Lucas Terminal for the Battery.

The square cable pin (A, Fig. 105), threaded $\frac{1}{4}$-inch B.S.F., is securely soldered on to the starter cable (B) and pushed through the square hole in the lead lug (C) on the battery. The dynamo cable is soldered to the lead eye (D), which is secured to the battery lug as shown in illustration. When assembled the whole is pulled up by the hexagon lead-covered brass nut (E). The hole in the lead lug is packed with vaseline before inserting the starter cable terminal. Care should be taken to ensure that nut (E) is screwed tightly home with a spanner.

Junction Boxes.

Where it is desired to tap off extra circuits for an electric horn, etc., it is advisable to use a junction box to obviate having to take a number of cables into the battery box. For this purpose a small fitting is provided, consisting of two bus-bars provided with terminal screws for extra circuits.

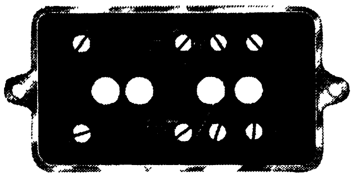


FIG. 106.—A typical Junction Box.

These are mounted on an insulated base, as shown in Fig. 106; the terminals there are connected on each side of the bus-bar to the battery wires through a fuse. Fig. 107 shows exactly how to connect up the

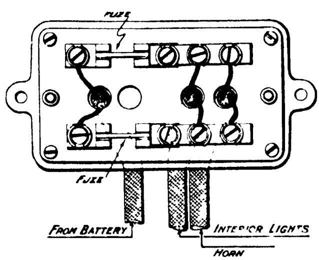


FIG. 107.—Connections for Fig. 106.

junction box. It should be fitted to some convenient part of the chassis, even affixed to the battery box itself, but never to the body work, as in the case of repairs, which necessitate the removal of the body, all the wiring would have to be pulled down. The chief object of the distribution box is to simplify the wiring and to prevent more than one wire being fitted to the positive and negative terminals of the battery.

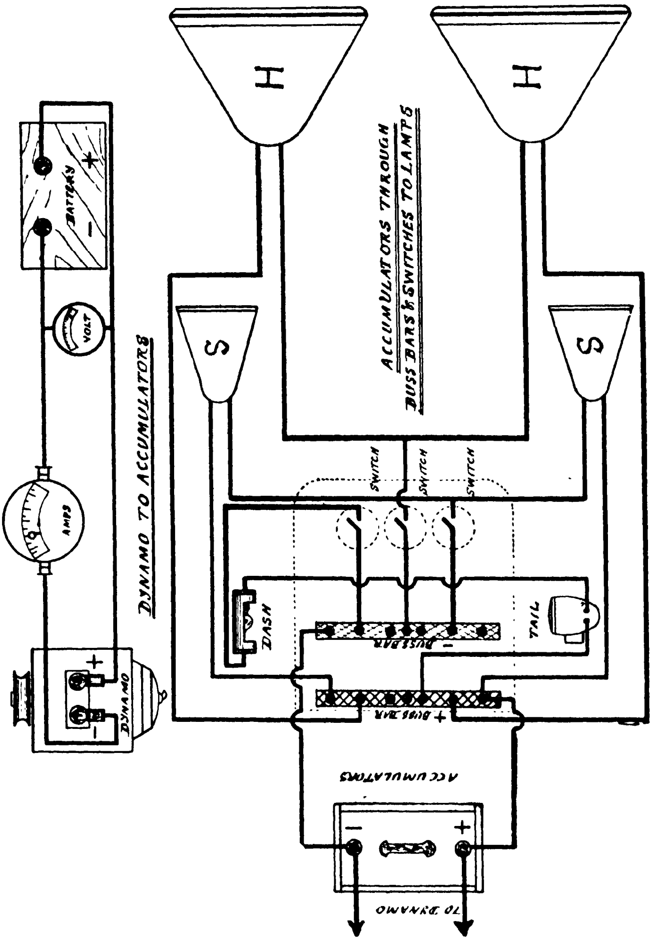


FIG. 108.—A complete Lighting Wiring Lay-out. Top part from dynamo to battery; lower portion from battery to lamps *viâ* switchboard.

There is no need to fit a distribution board if no extra lights or other appliances are required, as the general switchboard can comfortably handle the head, side, and tail lamps.

For the benefit of the beginner, attention is drawn to the wiring diagram to be found in Fig. 108. This is a simple lighting lay-out, which is divided into two portions and purposely kept free from cut-out and junction-box complications.

It is frequently necessary to wire up a tell-tale lamp upon the dash, so that, in the event of the tail or rear light failing, the driver is notified by the lighting of the lamp upon the dashboard. It works upon the relay

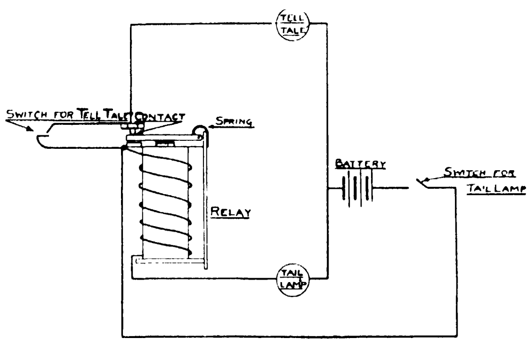


Fig. 109.—Lucas Tell-tale Diagram.

principle and the complete connections are sketched out in Fig. 109. A tell-tale relay bobbin is inserted in the tail-light circuit, and so long as current continues to flow, the armature is held away from the contact, but upon failure of the bulb, or from any other reason the circuit is broken, a light spring returns the armature against the contact, and the tell-tale light circuit is then closed, and remains so until the tail light is again put in proper order. Should, however, the tell-tale light be required for the purpose of inspecting meters at the same time as the back light is in use, the closing of the tell-tale switch will bridge the break, and bring the light into action.

Before leaving the subject of wiring, the author feels that he cannot lay too much emphasis in urging that the installation should be carried out in a very careful manner, strictly in accordance with the instructions and wiring diagram furnished with the set, as if this is badly done endless trouble is bound to ensue, which is oftentimes difficult to trace. See that all the wires are well insulated when connecting up, and that they are securely fastened in the terminals.

It must be particularly noted that the armouring should not be permitted to enter the interior of the switchboard, as it would be conducive to short circuits. It should be carefully turned off at the bottom of the board and held in place with a touch of solder so as to prevent it unwinding too far.

Loose wires, besides being unsightly, are dangerous, as, if they come in contact with the frame, short-circuits are almost certain to be brought about.

The final chapter in this book gives succinct directions and diagrams for location of faults, and is practically a sequel to the present one. The reader is invited to peruse this next should he be in need of more specific instructions.

CHAPTER IX

LAMPS AND LIGHTING

In considering the design of driving lamps, there are two points of first importance: (i) the provision of such illumination that the driver can see the road for at least 100 yards ahead; (ii) the provision of such a light that other people using the road have warning of the presence of the vehicle. Modern lamps of even moderate power are quite capable of lighting the way clearly for 100 yards ahead, and even to cast shadows at a distance of a quarter of a mile; such lights as these are adequately suited to the needs of all classes of cars, whether for commerce or for pleasure. The conditions for ideal lighting are as follows: First, the illumination should be such that a length of road should be in sight sufficient for any contingency; secondly, the road near to the car should be adequately lighted; this should be done with the side lamps; lastly, the light should not be rendered objectionable through glare to other users of the road—especially does this apply to pedestrians. It is of course more important to see the ditch near at hand, than to be able to read a signpost 100 yards ahead.

Dazzle and Dimming

The question of headlight dazzle is one of very great moment; in fact, legislation has been brought to bear upon the question of glaring head lamps. In some countries the law demands that head lamps shall be fitted with a hood projecting in such a manner that the beams which have a tendency to rise above the level of the lamp are deflected in a downward direction. Methods of avoiding glare may be divided into two classes: (*a*) Those that act directly on the lamp bulb and (*b*) those that deal with the light at its exit from the lamp itself. In the first class we find resistances and bulb screens the most popular. In the second class we have automatic shutters, hoods, vanes, opaque screens and particularly fancy lamp fronts in order to disperse the beam. The method adopted by many makers is to fit dual bulbs so that when the powerful bulb is not expedient it can be put out of circuit at the switchboard and a small pilot bulb switched in. The pilot bulb on some cars is fitted above the main bulb (as in the Locomobile), and in others below the main bulb (as in the Packard). The wiring for these double bulb projectors will be found in the Ford wiring diagram on page 289. The obvious disadvantage of this scheme is the fact that one has to train oneself to switch over on occasion without becoming perturbed. There is a less obvious disadvantage in the fact that a considerable portion of the reflecting surface is taken up with the extra bulb. However, in some types the extra light is cooped up separately and does not interfere with the main parabola. Another satisfactory device is the "Tulite" bulb which has a major filament of 20 C.P. and a minor of 4 C.P. A lamp of this type is extremely useful when the car is standing outside a theatre or other station at night, as these small lamps take little current and can be used as side lights. On many American cars the side lights are dispensed with and all that are used are the tail and these two small lights.

Another very popular anti-glare and current saving device is the "Headlight Dimmer." This is merely a resistance unit that is arranged to switch in or out of the headlight circuit. Occasionally a special switch and wiring is embodied to enable the headlights to be thrown in series and thus considerably dimmed. The writer well remembers an occasion when he lived in Los Angeles that he had to journey by night to Venice—a coastal town about 18 miles distant; it was a "Movie" festival, and that 18 miles was occupied with cars in one continuous stream returning to Los Angeles. The cars were proceeding so slowly that there could not have been a closed cut-out (electric) among them. All their headlights were dimmed by one means or another, mostly by the dimming resistance

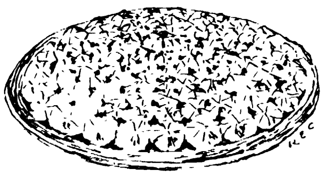


FIG. 110.—An Anti-glare Device.

method. No one meeting them experienced the least discomfort, and yet no collision occurred!

Special reflectors and deflectors are less popular means of dimming headlights. Fancy lens glasses (see Fig 110) for the front of the lamp are widely used and most effective in action. These are, of course, permanently in action and appear as a lamp with a fancy front. Fitting a yellow glass front is another method on similar lines to the English system of using amber bulbs—said to be good for fog penetration.

Another rather obvious method of doing the dimming trick is to paint the glass with a frosted paint or a semi-transparent paint, or even paper pasted on, leaving a clear space in the centre only. An astonishing number of American cars are treated in this fashion.

A cowl in front of the lamps is a method used widely on the Continent, and certainly serves to deflect the beam on to the road. Akin to this is the practice of fitting a metal shield to the lower half of the bulb so that the rays are reflected upwards, which causes them to bounce downwards on to the road. The inventors of this method say that no ray rises above 4 feet from the ground. The Star Dimmer is a device of Californian origin along the lines of shielding the bulb itself. It consists of putting a white fabric structure over the entire bulb except at the front. Imagine an inverted gas mantle fitted on the holder, clay side outwards, and the bulb put back, and the reader has the idea perfectly. A ray concentrator is a last example of this type of dimmer. A structure resembling a double egg-cup is suspended at three fixed points; it is cylindrical in form with slightly narrowed centre. The upper half of the interior surface is highly finished and reflects the imprisoned light rays directly on the roadway. The lower half of the interior surface is heavily darkened and absorbs all those rays which, were it a polished surface, would be reflected up to the eye level.

The application of this reflection control does not lessen the power of the light but directs it so that the road illumination is greatly improved and the dangerous glare—direct rays into the objective eye—is eliminated.

The English inventors seem to go in for the glass front methods such as the "Conaphore Anti-Glare" lens, whose glass is opaque (being tinted amber) and is, so to speak, horizontal louvred, while the centre is noduled or embossed. The black surface is plane, and the edges are chamfered so as to form a circular flange of about half the thickness of the rest of the surface. It is made of "Noviol" glass (a patented yellow tint glass), which absorbs the blue and violet rays. The beam of light transmitted by this glass eliminates back-glare and penetrates fog or dust. It gives headlight range of 500 feet when a standard bulb of 21 C.P. or more is properly focussed, and one can easily drive at 25 miles an hour under adverse weather conditions.

The " Diffusa " front glass for head lamps, by Lucas, Ltd., Birmingham, is a device diffusing and spreading

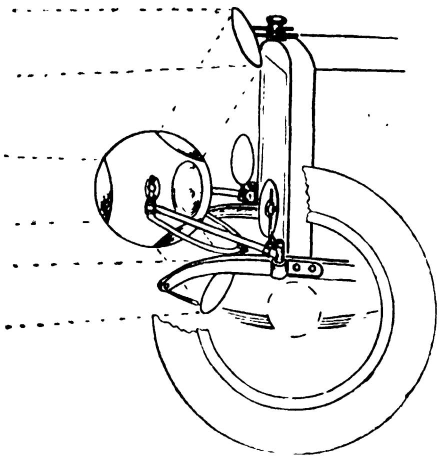


FIG 111.—The Diva Headlight principle.

out the light rays evenly, creating a very nice light to drive by.

The Diva Headlight Co. some years ago introduced a headlight upon the entirely novel principle which is illustrated in Fig. 111. Owing to its very unconventional appearance it gained but a small hold upon the automobiling public. There were many points in its favour, of which the low running cost was not the least important. In many respects this lamp was a masterpiece of lamp design, as the waste rays are practically *non est.* The illustration (Fig. 111) shows the general arrangement of the Diva lamp. The dotted lines indicate the distribution and projection of the rays on to the road. The four saucer-like discs shown in the neighbourhood of the radiator are four mirrors of either plain or fluted surface. With plain mirrors the beam is deflected forward, but its diffusion is slight ; however, this has been got over by fluting two of the mirrors which projected the light in a fan form. As will be seen in the figure, the projected rays could not affect the driver of an oncoming car, or even an adult pedestrian. Another type of lamp, somewhat on the lines of the Diva, has been developed on the periscope principle. The source of light, a 20-C.P. bulb, is passed through a plano-convex and a double convex lens and is focussed on to a 45° mirror placed at an angle in the bend of the periscope lamp body. The beam from this mirror passes into the outer world via a second plano-convex lens in order to counteract the colour distortion of the first one. The name of the lamp is "The Roffy." There are several other curious and ingenious mechanical devices, such as roller shades operated by the foot, and electro-magnetic vanes that close from a horizontal position to a vertical screen by the pressure of a button. All these are necessarily restricted in their use.

Before leaving the subject of dazzle and glare we must refer to the internal glare of the dash lamp which has in many cases proved a source of danger to the driver. To effect proper screening of the light it is necessary only to paste a single thickness of note-paper over the bulb. It is also an excellent plan to use a lamp of a bluish tinge if the ordinary series wiring as shown in Fig. 108 is used, as it is much less trying to the eyes than the ordinary white light.

The position of the lamps upon the car is an essential feature in connection with the solving of the above problem. They should invariably be placed as high up as possible, in order that the road may receive ample light ahead, and so that the resultant beam will be projected on to the road at a considerable angle. If the axis of the beam of light be nearly parallel to the road, it will cast black shadows into every small hole on the road's surface. It is a very difficult matter for the driver to discriminate between these small dips and really dangerous pot-holes. The foregoing point has an almost special significance to the foreign road user. The shaft of light should be also of considerable width, as if the road is of a winding disposition it is extremely difficult to spot every obstruction that may be loitering on it. To effect this wide illumination it is necessary to have the headlights placed as far apart as possible.

A further important difficulty in connection with car-lighting is the altered conditions of the road. The ever-increasing use of tar-spray on roads has caused many motorists to firmly assert that their headlights of to-day are not nearly so effective as those they possessed years ago. This fact, coinciding as it did with the increased application of the electric lamp, added to the prejudice of the user against this lamp—until he gave the question more serious consideration—or more probably found his acetylene lamp of yesterday also seemed to have lost its good form. Tests go to prove that the electric bulb can not only compete with the acetylene flame, but also effect a reconciliation between the lamp and the road.

A few years ago the majority of motoring roads at night gave the effect, in contrast with the hedges and banks on each side, of a white ribbon between dark borders. This being so, it will be easily understood that it was possible for the driver to pick out almost any dark object quite plainly for a considerable distance ahead, with headlights of only a very moderate power. Not only was this result obtained through the contrast, but the light-coloured road did not absorb all the rays, but deflected a portion of them forward in a manner somewhat similar to a cannon-ball ricochetting off the surface of the sea. The loose particles upon the road themselves tended to diffuse the light. With the beautiful black tar-sprayed road all this is changed, and we have to face a very difficult problem, as a dark object on the dark road surface

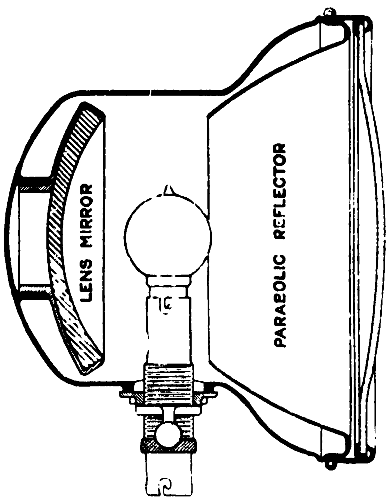


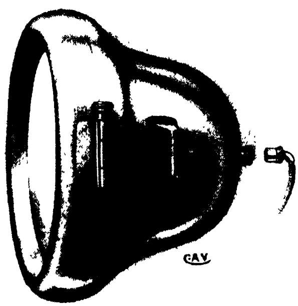
FIG. 112.—The Mangin lens type Head Lamp in section.

is not clearly defined, also the hedges and banks, where such exist, show as a light-coloured border, which is most confusing to the motorist. All this goes to show how imperative it is that every possible device of the lamp-maker's art should be requisitioned for the production of the modern driving lamp.

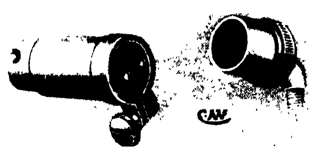
There are two distinct classes of lamp on the market, one class employing a reflector termed a "parabolic" reflector, the other species employing a lens mirror projector called the "Mangin" type. The majority of makers prefer the parabolic type of lamp.

The Projectors.

The two types are illustrated in Figs. 112 and 113. The parabolic lamp is relatively easy to focus, although



Lamp complete.



Detail of connector arrangement.

FIG. 113.—The Parabolic Head Lamp (C.A.V. model).

few of the many thousands of cars in service may be said to have their headlights properly focussed to give the best light for driving in the country. In the cities the focus does not matter so much, but it is in the country, especially on dark nights, that the motorist wishes he had better light. So he stops the car, bends the lamps and brackets a little this way and a little that, screws the bulbs in or out, and attempts to produce a better illumination. He does not accomplish much, for he has not gone about the job in a systematic, careful and accurate manner. One cannot properly focus the headlights and adjust them without measuring their light on a range.

The ideal method is to drive the car to a place where the lights can be focussed on a wall, and then adjust them so that each does its proper share of the illuminating in the correct way. Of course the head lamps in different cars vary, and probably distances and dimensions which would properly focus the majority of head-lamp installations might not do for every make of car. The best we can do here, however, is to give directions which ought to cover most cars which have lights of the usual size and reflecting possibilities.

The method given is that followed by the Hudson Company, and it covers the point in what seems to be the simplest way. Drive the car to a mark which is 40 feet from a wall. Best results will, of course, follow if the procedure is carried out in the dark. Throw the lights on to this wall, and adjust them so that the circle of light from each lamp will be about 3 feet in diameter, and the edges of these circles will just touch. They should also be $1\frac{1}{2}$ feet from the ground at the lowest point of the circles.

Without the use of special precautions, glare can be minimized by seeing that the centre of each projection of light is adjusted to strike the centre of the road 25 feet ahead of the car. This equals the optical distance of the most intense vision. It is also the place where greatest light is needed. When thus directed the glare evades the eyes of persons *in* approaching vehicles.

This adjustment can be obtained both by bending the brackets slightly and by moving the bulbs either towards or away from the reflectors. Fig 114 shows the method of focussing a C.A.V. lamp. By slackening the milled screw F, the complete bulb holder E and the adaptor C can be moved backward and forward as one unit, to obtain correct focus. To disconnect the lamp entirely, the milled screw D should be slackened and adaptor C withdrawn. Fig 115 depicts

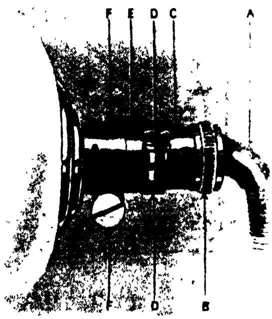


FIG. 114.—Focussing a C.A.V. Projector

the method used on the Gray and Davis lamps. By means of a small nut at the top of the reflector, the lamp bulb can be moved in or out of focus with the reflector, throwing the light on the road so that a wide ray or a pencil beam can be obtained as desired.

The adjusting nut is on the inside of the door, which is locked, and can be opened only with a screwdriver, so that the bulb cannot be stolen, or the adjustment tampered with. There are a number of ways of adjusting with different types of lamps, and the motorist undoubtedly has learned how to work them in his case. If the circle of light is too high or too low, bend the bracket up or down, as the case may be; also

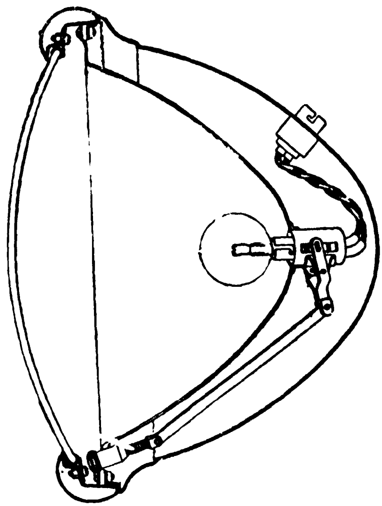


FIG. 115.—Diagram showing Regulation device upon Gray and Davis Head Lamp.

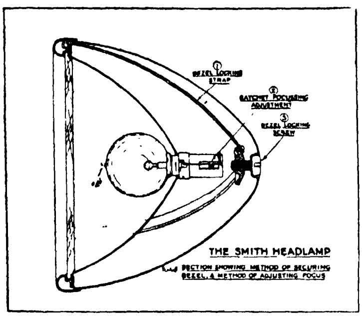


FIG. 116.—The Smith Method of Focussing.

bend it slightly to the left or right if the circles do not meet as they should.

The construction of the Smith Lamp is clearly shown in the sectional illustration (Fig. 116). The front bezel is held securely in position by means of three steel straps which pull the bezel against the main body of the lamp by means of a set screw located at the back of the body. To take the front off, this set screw must be slackened a few turns (use a coin), and the bezel given about ¼ turn in an anti-clockwise direction, when it will pull off quite freely.

The bulb may be correctly focussed by giving the bulb and holder a slight turn to the left and sliding it in or out as required.

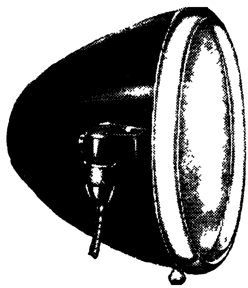


FIG. 117.—The Smith Headlight.

The cable is led in by means of a plug adaptor, mounted on one of the lamp brackets, and is held in position by a milled cap (see Fig. 117).

As the adjustment of brackets is a very important point the illustration in Fig. 118 has been prepared to indicate the deplorable results of badly adjusted lamp brackets, whilst in the lower half the converse is shown to advantage.

Where the plain parabolic reflector is utilized, it is necessary to have a method of focussing the lamp bulb filament, as no two lamps are made alike in regard to their filaments. If a maker recommends a particular type of electric lamp bulb, get it at any cost, as that lamp will be the one most suited to his type of projector. Messrs. Lucas have evolved a very neat scheme for adjusting the focus of their lamps. The bulb has a choice of four notches which naturally gives it four positions. The car is taken out on the road and then the bulb is tried in all positions and left in the notch that gives the best result. Fig. 119 shows the general arrangements of the Lucas device. Notice the excellent cable protection with these head lamps.

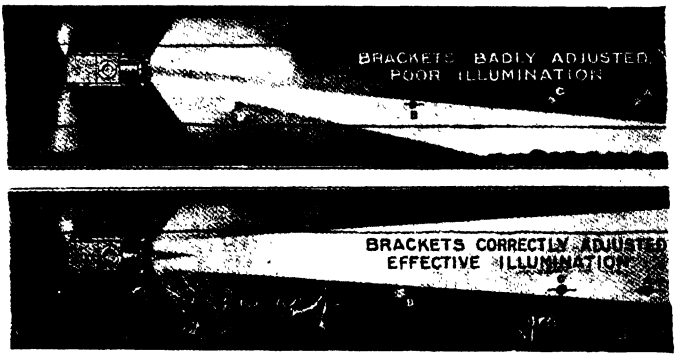
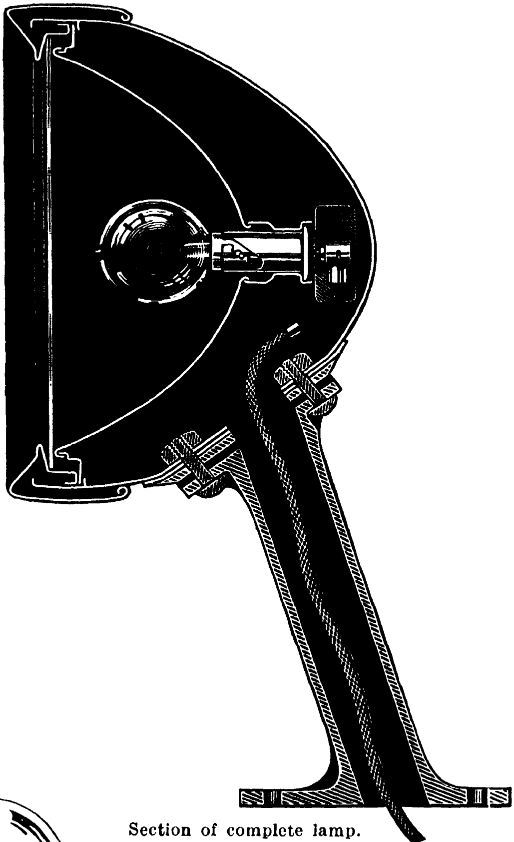


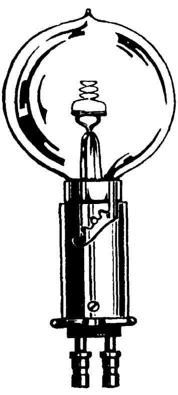
FIG. 118.—The importance of correct Bracket adjustment.

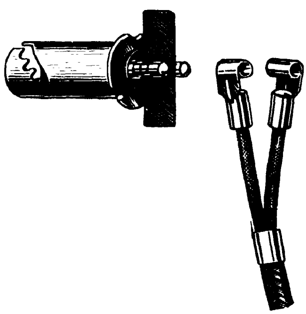
With the Mangin lens type of projector the lamp holder can be raised or lowered by loosening the adjustment at the bottom of the lamp, shown in Fig. 112. With this type it is necessary to employ a different position of filament from that used in the parabolic lamp. The light is vertical instead of horizontal. When we discuss bulbs we shall see that makers are allowing considerable leeway for adjustment purposes.

The great difficulty with night driving, from the driver's point of view, is the inability to see obstacles a medium distance from the car. When, say, a man with a basket upon his head is plodding his homeward



Section of complete lamp.





Details of lamp connector. Note focussing notches in holder.

FIG. 119.—The Lucas Headlamp.

way, a hundred feet or so away from the car, he can be distinguished with ease wherever he may be upon the road, but when he approaches the car he comes into a space lighted by the narrower portion of the beam, and then he passes out of this intense illumination of the headlight rays into a but *feebly lighted region*, if at all lit, by the side lights.

Again, a further great difficulty is experienced when one is about to turn a corner; with ordinary fixed headlights it is impossible to distinguish an obstruction at certain points of the newly entered bend. To overcome this condition of affairs it would be necessary to employ swivelling headlights,* which can be turned round in the direction of the anticipated bend.

The average headlight, however, is a sufficiently useful article to preclude an accident on the score of turning corners, as the side lights, if properly placed, would give the necessary lateral diffusion. These lamps should in all cases be placed so as to afford the general public who may meet the car on a dark night an accurate gauge of the car's extreme width. Many makers are manufacturing a neat little side lamp to fix upon the front mudguards; this is a very great asset to easy driving, as one does not want too much diffused light near one's eyes, and the extra foot or so that is obtained through moving the side lights from the accustomed position to the top of the front mudguard is very welcome. As the solution of effective lighting lies chiefly in the creation of sufficient contrast, it will be readily appreciated that to peer at a distant object, a hundred yards away from the car, through a sort of haze of light, as would be produced by inefficient head lamps, *plus* the diffusion from the side lamps (which, as we have already seen, is necessary), does not make for the acme of efficiency. To use a homely illustration, supposing we wish to look at night time

* These have been tried and found guilty of impracticability.

from our front room, across the street at a shop upon the opposite side. We can only distinguish the objects in the shop window with difficulty, although they may be brilliantly lighted—but switch off the room light for a moment, and we see the articles easily. This, of course, is only due to the contrast we have created. The same principle applies to road lighting from motor head lamps.

For the comfort and convenience of other users of the road it is specially desirable to allow a space a few yards *behind* the car to be lighted, but not too brilliantly. This is easily provided for by a good tail lamp giving not only its accustomed red glow and plate illumination, but also a little general illumination on the off side. Thus the abrupt passage from the brilliant light in the front of the car to the darkness behind is softened; also, it serves to indicate to the driver whether his tail lamp is all right.

Cleaning Reflectors

When lamp reflectors become tarnished, do not wipe reflectors. If only dusty, remove dust by blowing.

The reflector, being plated with pure silver, is very easily scratched, even with very soft material, unless great care is exercised.

If reflectors have become dull from long service, they can be polished by using clean chamois with red rouge.

Chamois should be soft and free from dust, and should not be used for any other purpose.

Red rouge or crocus is used by jewellers for cleaning watches.

To polish, first use chamois with rouge dampened with alcohol. This will remove any spots or heavy tarnish.

After this is wiped off, use a second piece of chamois, but with rouge dry. This will give a very high finish.

In polishing, use a rotary motion as indicated by arrows in Fig. 120, but do not press too hard. Unless a rotary polishing motion is used, reflectors will show marks.

Chamois used for this purpose should be kept in a dust-proof receptacle.

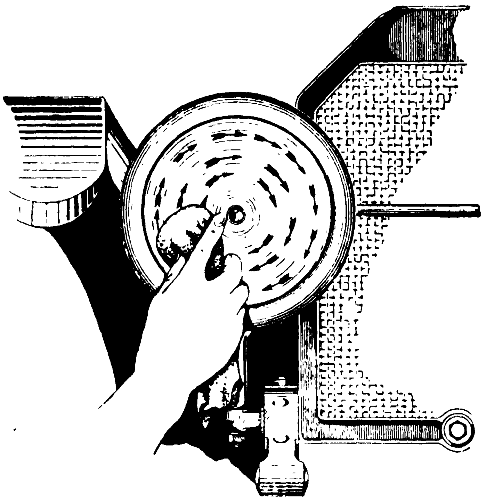


FIG. 120.—The art of polishing a reflector.

The efficiency of old reflectors will be increased if they are resilvered. This should be done by a lamp manufacturer, or a reliable silver-plater.

Lamp Bulbs and Their Filaments.

In an earlier chapter we saw what an important part the lamp bulbs played in the hastening on of the perfect lighting system that is available to-day, indeed, it is a significant fact that a 25-C.P. bulb will give better results when used in a suitable head lamp, than will a 50-C.P. if used in an unsuitable reflector. In America bulbs and head lamps are apparently more standardized than in this country (England). As a result the 21-C.P. 6-volt tungsten lamp has been adopted for use in a parabolic reflector measuring 10 inches across the opening. This choice was adopted upon many scores. For example, it was shown that with lamps of this description a 50-feet road could be perfectly lighted for at least several hundred feet in advance of the car. Objects on the road could be distinguished practically as far away as could be done in daylight, always in ample time to stop or turn aside. Another reason why these reflectors and lamps were used was because they did not necessitate extremely large headlights, which besides being costly would detract from the appearance of a motor car. The importance of having lamps properly focussed was brought into great prominence. The best results are only obtainable when the lamp filament is located exactly at the focus of the parabolic reflector, and this reflector should be so designed that the focus is well back from the opening.

A comparatively deep reflector makes the angle of the direct rays not intercepted by it rather small; consequently, a greater proportion of the total candle-power may be projected in a useful direction. The effect is particularly good when the lights are placed at least 3 feet from the ground. At this height the shadows caused by slight ridges and undulations in the road are not so apparent as when the lights are placed lower. The 10-inch parabolic reflector adopted measures about $5\frac{1}{2}$ inches in depth. This reflector has a focus of $1\frac{1}{8}$ inches, and, when properly focussed, a 21-C.P. lamp gives ample light on the road near the car, and at the same time has very good distance qualities. Very deep reflectors, both of the 8-inch and 10-inch diameter sizes, were tried; but it was found that these did not give satisfactory lighting near the car. Twenty-four-C.P. lamps were tried in the 10-inch reflector; but the difference in illumination was scarcely noticeable, and was more than offset by the fact that the 24-C.P. lamps required 14 per cent. more current than the 21-C.P. The side and rear lights, which are used only as signal lights, and have little value for road-lighting purposes, were equipped with 4-C.P. and 2-C.P. lamps respectively. Lights of lower candle-power than this would have been ample for the purpose; but in the smaller sizes of lamps the filaments were found to be too frail to give reliable

FIG. 121.—The standard "Osram" Filament (enlarged).

service under the conditions of severe vibration encountered on a motor car.

These were the views expressed at a recent meeting of the American Institute of Electrical Engineers, New York.

Returning once more to the design of the lamp filament, it must be obvious that in the parabolic reflector, the correct source of light is a point, but as in practice it is impossible to purchase points of light one has to be content to the nearest approximation to it. Fig. 121 shows the standard Osram filament for head-lamp bulbs. The filament is of course a drawn tungsten wire one, and is first formed into a fine spiral, this alone produces a light several times greater than could be obtained from a straight filament. It is then formed into a double helix, as shown in Fig. 121, further increasing the concentration, so that the complete source of light is confined to such a small area that it represents—as far as is practically possible to do so—a true point of light. The general appearance of the lamp is shown in Fig. 122. In motor-car bulbs the makers are compelled to put their trade-mark and other information on the cap of the lamp to eliminate shadows. In some lamps the pip is dispensed with for a similar reason. The manufacturing details

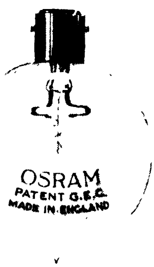


FIG. 122.—The modern Electric Bulb.

of a modern standard motor headlight bulb are given in Fig. 123.

The Half-watt Lamp.

In 1913, gas-filled (half-watt type) electric lamps were first introduced, it having been discovered that filaments of drawn tungsten wire coiled in a closely wound spiral burning in an atmosphere of nitrogen, gave an increased efficiency equal to about twice that of the ordinary vacuum type lamps.

Nitrogen filled lamps could, however, only be manufactured in high candle-power sizes, viz. 500 watts and above.

Manufacturing Details of Motor-Car Bulbs (Standard Type)

Contacts.—The accepted double, single, or screw caps of the Engineering Standards Committee are employed throughout.

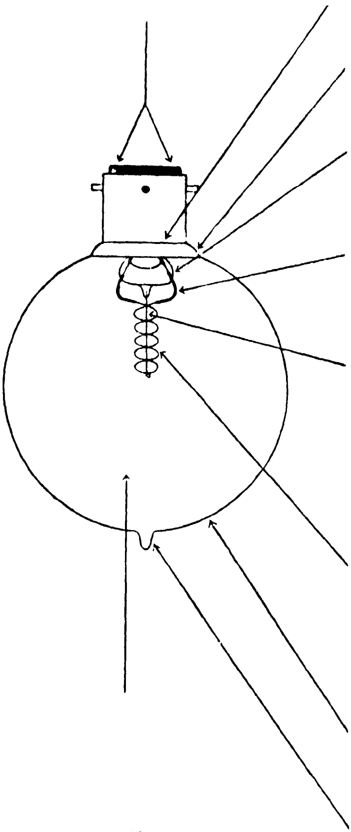


Fig. 123.

Vacuum.—A scientific method of exhausting obtains for all practical purposes an absolute vacuum which ensures long life, and retards the eventual blackening at the end of the useful life.

Capping.—Of stamped-out brass, the contacts and pins are uniformly positioned, carefully nickel-plated and polished.

Cementing.—A white cement is employed to assist the reflection of light, and gives a fast fixing unaffected by moisture or heat.

Glass Pinch.—Evenly formed it is substantially strong, and not calculated to snap off under excessive vibration.

Leading-in Wires. — These are well separated and carry the filament which is kept firmly in its original position.

Stem.—Formed of metal gives a strengthening support to the filament, and is carefully bedded into the "pinch."

Filament.—Of tough drawn-wire tungsten the close regular form prevents sagging, and gives, as near as possible, the ball of light essential for the diffused beam of the head lamps. In smaller bulbs of lower C.P., where the filament cannot be so arranged, a spring-like spiral bridge is substituted, and also in the case of interior lamps a wider illumination is obtained by a series of hairpin loops.

Glass Bulb.—The clarity of the bulb is imperative, for if unevenly blown ridges are formed which throw unpleasant shadows into the beam. The regular shaping of the focus bulbs will be noted, as also the festoon, squat, tubular, and mushroom types.

Pip. — The finishing operation must be carefully executed, and throughout the range the bulb sealing pipe is well formed and not likely to be knocked off.

Early in 1914 it was found that by the use of argon, serviceable lamps could be produced for much lower candle-powers, disintegration of the filament being retarded by its use, and the use of filaments of small diameter thus made possible.

The presence of argon in the atmosphere was discovered in 1894, as the result of experiments by Lord Rayleigh and Sir W. Ramsay, who found that it was much more inert than nitrogen. They called it argon (from the Greek, meaning " without work ").

Up to 1914, no commercial use was known for argon, and consequently no steps were taken for its production in quantities, and great difficulties—especially under war conditions—were at first experienced in obtaining even small supplies. Since then, however, an argon-producing plant has been erected (the first of its kind in this country), and is now working satisfactorily at the Osram Lamp Works, Hammersmith, London.

The air is compressed in stages until the various products are liquefied, when the liquid gases are removed, leaving the argon in a comparatively impure state.

The impurities are next removed chemically, and the argon compressed into cylinders ready for filling the bulbs, which is done after the latter have been exhausted to give a vacuum of a high order.

At the outset it was found that the drawn tungsten filament must be coiled in the form of a closely wound spiral, as it is necessary for the filament to be compressed into the smallest possible space, so as to limit the amount of heat given up to the gas.

The automatic machinery employed at the Osram Lamp Works for spiralizing these very fine tungsten wires is of a most ingenious kind. The wire is wound on bobbins which are fixed to a spindle capable of being revolved at a high speed. One end of the wire is then attached to a mandril, the size of which goveins the size of the spiral. A fixed number of turns, which are counted by an automatic counter, can then be wound on to the mandril, and a complete length for one lamp obtained.

The wire in this form is still pliable, and after it is attached to the lamp supports, current is passed through it in an atmosphere of "forming" gas which "sets" the filament in the desired shape.

The headlight half-watt lamp has an intrinsic brilliancy **eight times** that of ordinary metal filament

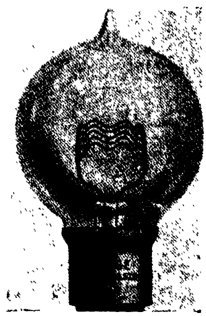


FIG. 124.—A Flame Bulb.

lamps. However, its life is not so long as that of the standard type.

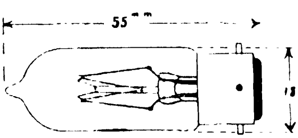
The exact shape of the filament used depends upon the type of reflector. For the lens mirror reflector the shape shown in Fig. 124 is desirable, as the lamp needs to sit vertically. For use in the parabolic reflectors, the half-watt lamp is constructed in the form shown in Fig. 125 which is known as the Atmos type lamp, because instead of the vacuum there is an atmosphere (of inert gas).

In order to meet focussing difficulties a new type of lamp is being developed, which has its filaments spread over a considerable area. The lamp is used in the customary horizontal position, but the arrangement of the filament is similar to that shown in Fig. 121. It is found that the resultant illumination is superior

FIG. 125.—The Half-watt Lamp.

with this arrangement, especially if the user is not clever at focussing.

Some other filament arrangements for car lighting are shown in Figs. 126 and 127.



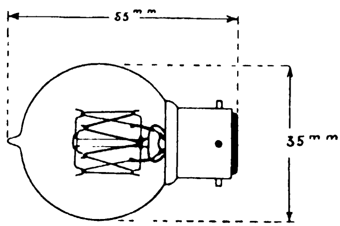


FIG. 126. FIG. 127.

Typical filament arrangements.

Lighting Effects

The course of the rays from a large C.A.V. reflector is drawn out in Fig. 128. It will be seen that the beam gradually diverges, and thereby is enabled to illuminate the major portion of the road. In this type of reflector, when everything is properly adjusted, there are not two distinct beams, but the powerful central rays gradually merge into the soft outer fringe, thus providing an immense range with the minimum of glare.

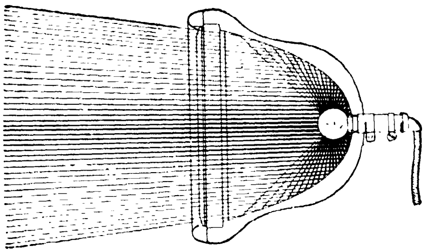


FIG. 128.—Parabolic Projection.

That the central core of light from a parabolic reflector is very pronounced will be evident from a photo taken by Professor Louis Derr, of Massachusetts. This photo, which is reproduced in Fig. 129, shows a view of the lighting effect broadside on. It shows the

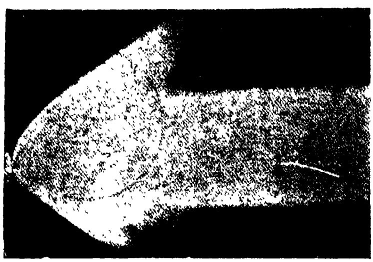


FIG. 129.—A photographic representation of the form the Light takes from a Parabolic Reflector.

remarkable combination of "pencil" and "fan" rays.

The light distribution from the other type of protector is shown in the illustration reproduced in Fig. 130.

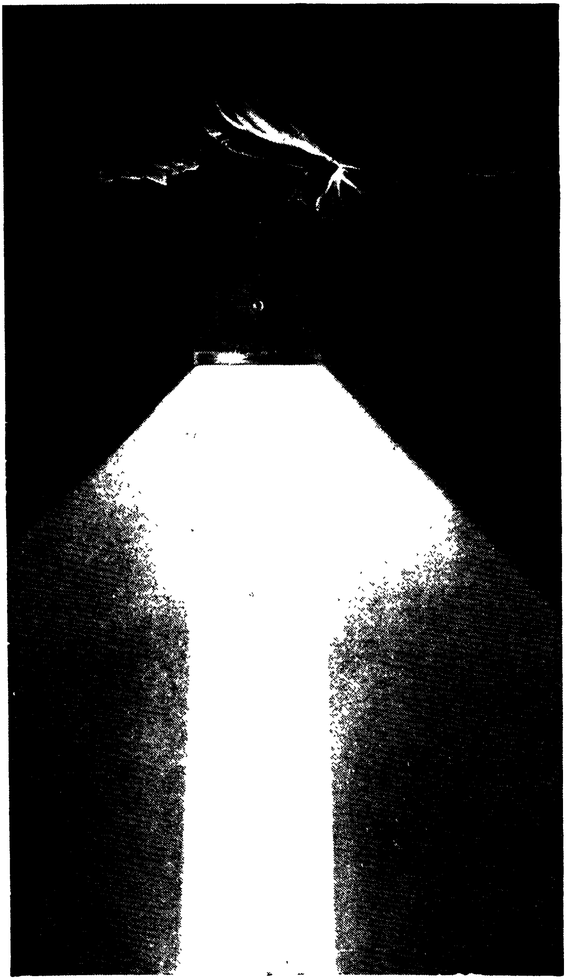


FIG. 130.—Light projection from lens-mirror lamp.

It will be seen that the distribution shows greater differentiation than it is possible to obtain with a plain parabola.

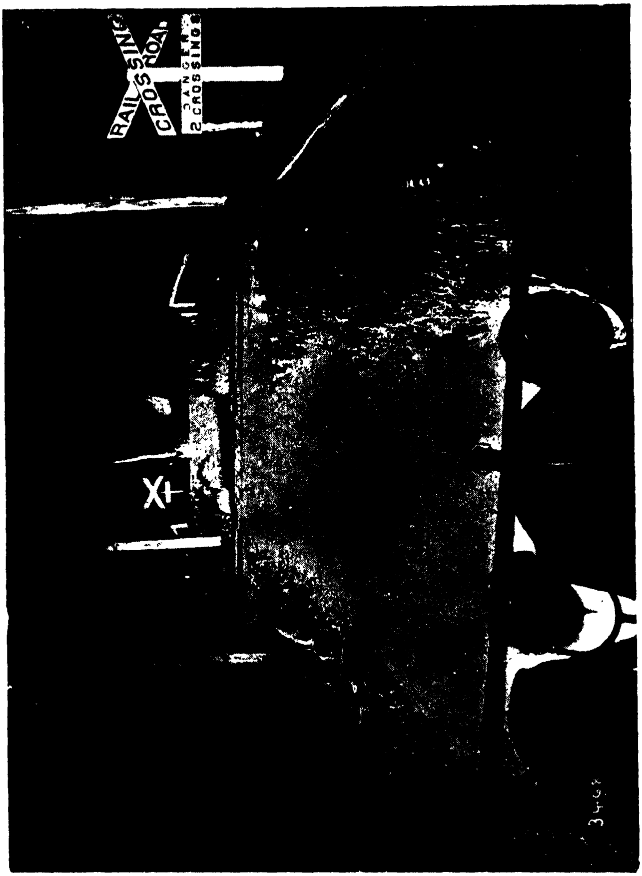


FIG. 131.—An American level crossing illuminated by motor-car headlights.

With the combination of half-watt lamps and correctly focussed projectors, and a pitch black night, it is possible to procure some good photographs of that desirable illumination which makes night driving a pleasure.

The photograph in Fig. 131 was taken by the lights of a Remy set with an exposure of 15 minutes. It depicts an American level crossing, way out in Indiana. The roads and the posts are white, being out of the tar-spray district. Notice that the second railroad crossing is plainly visible.

Fig. 132.—A road in Somerset, England, by night.

Messrs. Lucas sent the author the photograph reproduced in Fig. 132. It is a road in Somerset, England. Both the quality of the road surface and the night were ideal for photographing purposes. The bulbs used in the headlights were of 24 C.P. The charming little picture in Fig. 133 is a familiar scene to the motorist who chooses the byways of the Oxford Road, showing in bright reality Gerrard's Cross, Bucks. The car is standing on the railway bridge, showing, sharply defined, the building at the end of the road, which is 250 yards ahead. The broadly diffused beam picks out at considerable range, with certain safety, the hidden turnings which distress the motorist unfamiliar with the locality.

FIG. 133.—Gerrard's Cross, Bucks.

Fig. 134 is another C.A.V. view taken with a focus bulb in a 11-inch head lamp. It is a photograph of the Frensham Ponds Hotel, situated between the forked roads. The gradual merging of the more powerful central rays to the softer outer edge of the beam picks out the break in the hedges singling out the hidden turnings, and shows up clearly the forked roads at a safe distance of approach.

FIG. 134.—Frensham Ponds Hotel.

Bulbs for Commercial Motors

As a general rule the bulbs used with commercial dynamo lighting are of a somewhat lower efficiency; however, they have a much longer life. Fig. 127 gives the Edison and Swan lamp, manufactured for the firm of C. A. Vandervell. The main point to notice in connection with these lamps is the ample support of the filament which is designed to meet great vibration. A similar bulb is used by the London General Omnibus Co. for their interior lighting.

The illumination of advertising cars, although not widely done, is possible with the high efficiency lamps now obtainable. The Ardath Tobacco Co. uses an illuminated State Express Cigarette, also a group of three hand-painted panels on a delivery van. This illuminated publicity device uses forty 12-watt 10-C.P. bulbs.

The bulbs used even on commercial cars should be preferably of the small bayonet-capped sort, as although with the large bayonet-cap the mechanical strength is greater via the plaster filling to attach the glass to the cap, it cuts too much away from a vital part of the reflector to warrant its use.

The side lamps should be well focussed or they will throw unpleasant scattered rays. Coloured reflectors are a doubtful advantage, the coloured bulbs are better for commercial usage. In lamp designs the point of prime import is to see that there are no superfluous projections. The contour can be as pleasing as that found in the pleasure types of lamp if it is easy to clean—which is the main thing.

CHAPTER X

FITTING AND DRIVING

THE fitting of the installation is not so difficult a problem to-day as it was years ago, as about the only people who worry their brains as to where to fit the dynamo and starter or a dynamotor—the two functions in a single unit--are the car manufacturers. Various motives influence the choice of these gentlemen when they decide to go in for a Jones or a Green dynamo and a Brown's starter. Sometimes they consider that no one knows enough about the idiosyncrasies of *their* car properly to design a competent dynamo, so they do the job themselves. However, as this is the age of specialists most car manufacturers link up with one of those firms whose names indicate reliability, and set out in their design office to cram under an already well-filled bonnet a dynamo and a starter. The starter we can dismiss from our minds at once, as this apparatus must be linked up with the flywheel by a most positive drive. The dynamo certainly might be driven from almost any moving part of the car. In fact, in 1914-15 there were examples extant of every conceivable kind of drive, including replacement of the radiator fan with a fan-dynamo.

There are, of course, many cars which have not yet been fitted with a dynamo, and for such cases in particular we must consider a selection of the numerous fitting and driving arrangements. As a basic principle we may assert that all machines should, if possible, be fixed under the bonnet and driven from a pulley on the engine shaft. As an alternative it may be carried

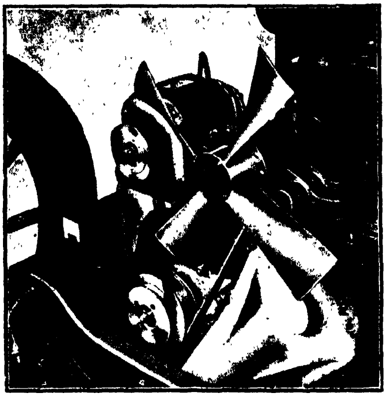


FIG. 135.—A very accessible arrangement. The dynamo is the slow-speed type, driven by "V" pulley mounted upon the magneto shaft.

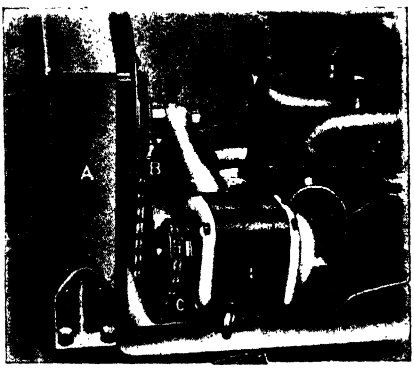


FIG. 136.—Crankshaft Drive on the 15-H.P. Napier cars. A double "V" pulley is fitted in place of the ordinary fan pulley.
A, radiator; B, fan belt; C, dynamo belt.

on the frame of the chassis and driven with success from the clutch shaft, but in this position it will slow down whenever the clutch is withdrawn, as in changing gear or slowing down in traffic. Unfortunately, with a clutch shaft drive the dynamo is apt to be neglected, also the universal joints are subjected to a side pull, for which they were not intended. Figs. 135 to 140 show excellent under-the-bonnet drives.

By far the most common method of driving dynamos fitted as after thoughts to an old engine, as all these are, is by whittle belt, which is illustrated in its com-

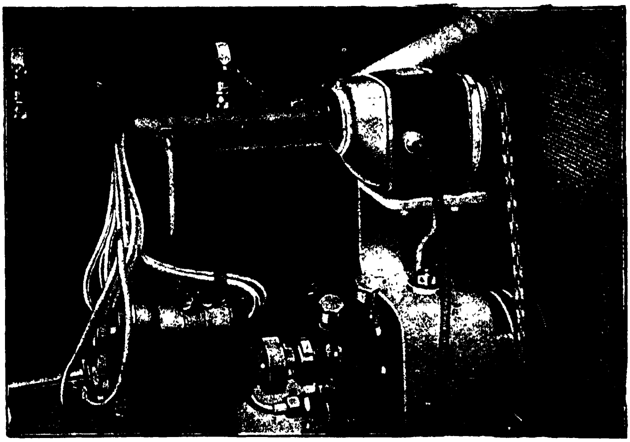


FIG. 137.—Dynamo Belt driven from magneto shaft. (Lucas.)

ponent parts in Fig. 139; the advantage of this device is the ease with which it is possible to alter its length by the insertion of extra whole or half links and vice versa. It offers a substantial drive, but is not so good as the drive shown with the Rotax dynamo in Fig. 140. This is a silent chain drive and is extremely popular in the United States also. There is less slip with this form of drive, as it runs over cogs which get a far better grip than the plain surface of a pulley. When laying out chain drive, the centre of the gear wheels should be kept as close together as possible.

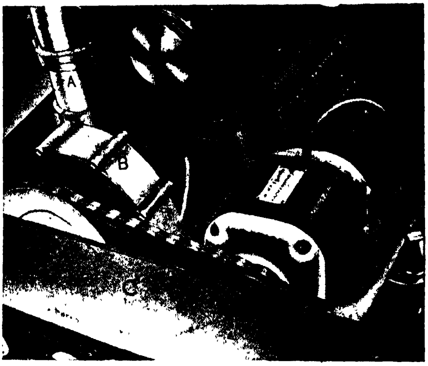


FIG. 138.—Standard Camshaft Drive for the C.A.V. Dynamo on Arrol-Johnston cars. For accessibility this arrangement cannot be improved upon. A slow-speed machine is necessary in this case, owing to the slow driving speed.

A, vertical exhaust pipe; B, timing wheel box; C, bonnet boards.

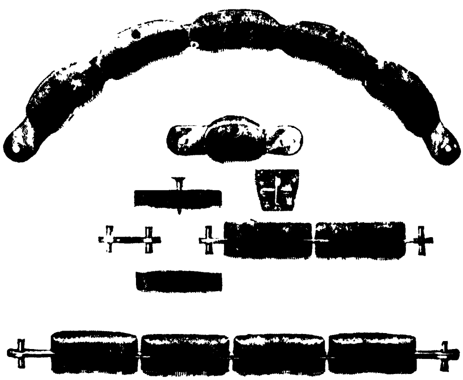


FIG. 139.—Whittle Belt and spare parts.

The nature of clutch shaft drives will be appreciated upon studying Figs. 141 to 143, which are typical of most cars employing this form of drive. Some engineers

FIG. 140.—Rotax Dynamo fitted to Belsize Car.

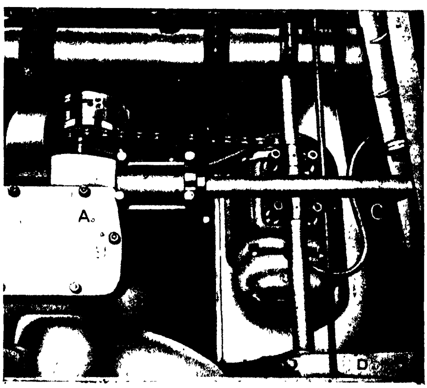


FIG. 141.—The Standard Clutch Shaft Drive arranged for in the Rolls-Royce Chassis, Series Nos. 1,700 and 1,800.

A, gear box; B, clutch shaft coupling; C, side of chassis; D, special bracket support.

maintain that the additional inertia which enters into the clutch shaft unit when gear-box drives are used

Fig. 142.—Dynamo Belt driven from pulley on clutch shaft. (Lucas.)

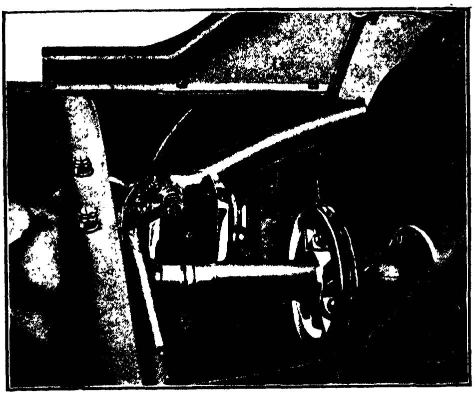


Fig. 143.—Clutch shaft drive on the 25–35-H.P. 1912 Renault. The outline of dynamo is shown in "ghost" behind the exhaust pipe, clutch fork, etc.

is prone to cause the gear changing process to become "heavy."

Fig. 144 shows the worst possible form of drive—the Cardan shaft position. The dynamo has to be driven from 50 per cent. to 100 per cent. in excess of crank speed to produce its proper output. The generator in Fig. 145 shows a footboard mounting and drive from the Cardan shaft. The length of the drive is in its favour.

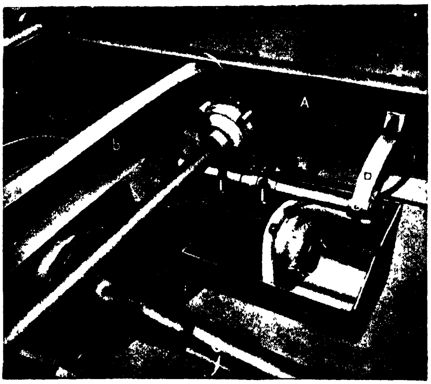


FIG. 144.—Driving from Cardan shaft, which is the only method possible in a few cars, including Rolls-Royce, prior to Chassis Series 1,700.

A, Side of chassis; B, cross-strutt; C, Cardan shaft; D, special bracket support for dynamo.

Points to be Borne in Mind in Fitting Dynamo

Positions Recommended.

(1) Under the bonnet driving off fan shaft, or from engine shaft direct.

(2) Under the driver's footboard, driving off clutch shaft.

General Points in Brief.

(*a*) The place should be clean and dry, non-magnetic for preference, and not too near the exhaust pipe.

If fitted to chassis frame take good care to stay the dynamo well to prevent vibration.

(*b*) Dynamo should not be driven from 2 to 1 gear if it can be avoided.

(*c*) Can be fitted before or behind the gear box. If fitted in front the variations of speed will be high, e.g. when engine is opened out on low gear for hill climbing. The wear and tear is great, but there are some advantages, for instance, the battery is always

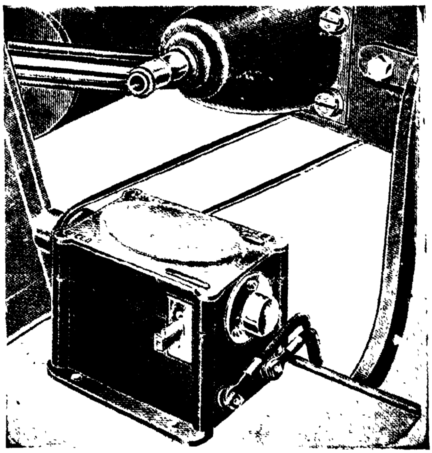


FIG 145.—Dynamo mounted on footboard and driven from the Cardan shaft.

under charge if engine is running. When driven from the rear of the gear box the drive is much steadier and the range of fluctuation is much smaller when engine is in low gear, therefore the wear is less.

(*d*) It is especially important when fitting to make sure that neither oil nor water is thrown up on to the belt—particularly water, as this injures the belt more.

(*e*) The best results from chains are obtained only when the length of drive is too short for a belt. Run chain a little slack and oil it at times, but keep free from dirt or gravel.

(*f*) Full consideration should be given to the question of "high" or "low" gear. Is the car used day or night? In the case of a touring car, for example, which is high-geared, it is necessary to gear the dynamo higher than a corresponding speed of town car.

(*g*) To get the best possible results from a fan pulley drive, it is best to have a triangular drive.

(*h*) The fly-wheel drive needs such a large pulley on

FIG. 146.—"Universal" Split Pulley for clutch shaft drives. Two or three alternatives as to diameter are given and the bore can be arranged to suit any size shaft. This type of pulley is suitable for many cars, including Metallurgique (all models), Berliet, 15-25 H.P.; Renault, etc.

the dynamo that it is quite out of the question. However, one may use a friction drive, either direct or through flexible shaft. Another method is to bolt a small pulley on to the side of the fly-wheel. It is easy to fit and provides a long steady drive, especially if dynamo is placed on the step of the car.

(*i*) Behind the gear box drive is usually either from the foot brake drum or the propeller shaft. The former is much to be preferred, but in many cases the shoes are outside and thus prevent a belt being fitted. With the propeller shaft drive the pulley should be situated as close to the gear box as possible, in order to render the vertical movements of the shaft caused by road inequalities as little as possible. This position has the advantage of allowing ample belt length. Care must be taken, however, that the torque rods and the silencer do not foul it. The problem of mud and water is important in this drive. The dynamo must be proof against these influences.

For fitting the driving pulley to the clutch shaft the special C.A.V. split pulley is of great service: it is illustrated in Fig. 146.

In all cases, no matter what drive is employed, always oil the dynamo periodically with a few drops of thin machine oil or dynamo oil once a week, or every 500 miles, taking care not to drop any on the commutator. **Do not over-oil.**

The cost of fitting must always be a variable quantity, as the charges made by firms for fitting include, more often than not, a bracket for carrying the dynamo, a special driving pulley, belt, armoured cable, insulators, and all the small clips, screws and cleats. The cost of this material, in most cases, amounts to half the total charge, and in many cases it is necessary to take down the undershield, and make alterations to it to suit the special exigencies of a case; hence it will be seen that in most cases the price charged would leave but little margin for time spent on the actual fitting.

Upon receipt of a new car equipped with starting-lighting system, inspect wiring and see if the terminals and connections make good contact. Be sure that wiring is in proper condition and insulation of wires is not injured. If insulation has become worn, wrap exposed wire with friction tape. See that battery is in good condition. Also see that dynamo, motor, and driving members are properly lubricated. *Be sure to make this inspection before attempting to use the system.*

The faults that occur upon any system can hardly be many, if the wiring be properly carried out; however, in Chapter XII we propose to outline in handy form all those likely to come within the range of the driver's experience.

There are a few methods of prevention which may be helpfully discussed here.

Commutator Condition and Correction.

It sometimes happens that the grooves between the commutator segments become clogged with brush dust, and tend to short circuit across to one another. This is easily rectified by carefully scraping out these grooves with a pin or other suitable instrument.

If the surface of the commutator is coated or dirty, cleanse it while in motion by holding a clean cloth slightly moistened with oil against it. **Do not leave oil on the commutator and do not put grease on it.**

If the dynamo develops sparking tendencies it usually indicates that the brushes want cleaning and re-fitting to the commutator, or perhaps they are sinfully short, in which case put in new ones. In fitting brushes take a strip of *sand*-paper, *not* emery-paper, the entire width of the commutator, and run this round the periphery of the commutator, business side uppermost. Put brush into one holder, or set of holders, and let spring come back to press brush well down on to the sand-paper. Now see-saw the strip of sand-paper under the brush until it can be seen that all the shiny surface of the brush has been worn away. *Be extremely careful to run the sand-paper well around the commutator surface in the process, and not, as so many people do, have the ends of the sand-paper parallel with the floor.*

Another point of commutator condition is brought out by the following experiment. Run the fingers round the commutator (stationary) and notice if the micas can be felt projecting. If so, they must be "cut down," because in time as the brushes strike the sharp edges of the micas, little pieces of mica will be chipped off and drawn underneath the brushes, which will inevitably cause arcing and burning of the commutator. To cut down "high micas," as electrical engineers call them, one needs two tools—a triangular file and a piece of hack-saw blade, mounted in a piece of wood to form a holder. The process is started with the file at the front of the commutator. When a good niche has been filed in the mica, proceed with the hack-saw blade to completely remove the proud portion of the mica, cut down for a fraction of an inch, say $\frac{1}{32}$, not more. The whole of the mica should be cut down; do not merely put a "V" in it and fail to remove the sides. It should be cut straight across, or the thin edges left will split off and cause the very trouble for which the remedy is designed.

Brushes.

These must be of ample cross-section and ample length for the spring to press down with a pressure of 16 to 20 oz. Always use the brushes supplied by the maker of the plant, as much experience has led to the adoption of that brand of brush.

Washing.

When washing the car do **not** wash the electrical plant, it does not improve with a bath! Electrical apparatus **must** be kept dry at all times. The windings of all car sets are overloaded at the best of times, and this fact, plus water, will break down the insulation completely.

Slipping Belt.

If the ammeter pointer shows a very low reading or violent oscillation, one can depend upon it that the belt is slipping. If loose it should be adjusted without delay.

Spares which should be Carried.

This represents the minimum electrical list :—(*a*) Length of fuse wire ; (*b*) spare brushes (dynamo and starter) ; (*c*) set of electric bulbs ; (*d*) a belt and one half-link of Vee belt ; (*e*) cut-out contacts.

CHAPTER XI

ELECTRIC ENGINE STARTERS AND GEAR SHIFTS

THE problem of electric self-starting, as it is called, is occupying the minds of all engine designers, and, indeed, motorists generally.

Electric starters can be divided into three important groups: (*a*) those that are of the dynamotor order—two functions, a dynamo and a motor, in the single unit; (*b*) the two unit system which employs a dynamo apart from the motor; of this class we have the greatest number of representatives; (*c*) that type of equipment that is built into the engine and acts, or, rather, takes the place of the ordinary fly-wheel, of which there is only one successful example extant.

So great is the enthusiasm of the motorist who has been emancipated from the manual "wind-up" of his engine that the large makers of car-lighting sets are now supplying electric starting motors as standard equipment. A number of starters, other than electrical, have eked out an impoverished existence, but now that the electric starter has been fitted with a standard and reliable method of drive, most of these have petered out—at least, so far as the pleasure car is concerned. An R.A.C. test of some years back already sounded their death-knell, when it was shown that the initial starts upon three cars could be procured in 4·2 seconds, 3 seconds, and 4·2 seconds respectively.

Each of the three cars was, after short intervals of rest, subsequently started 1,000 times with one charge of the battery. The ignition control was set in such a position as to be impossible to start " on the switch "—(the name applied to the process of starting the engine by throwing on the switch, producing a spark and igniting the charge still left in the cylinder, thus starting the engine). The very earliest types of self-starter used the above principle for their method of action. In order to use this type successfully it was essential for the engine to have stopped in a normal position, which, of course, it will do if in good running order. The successful devices of this ignition type starter use petrol and acetylene, and supply it to the cylinders in the form of an explosive mixture to be ignited.

The acetylene type of mechanical starter is not very satisfactory in practice, and is somewhat dangerous if incautiously handled. The spring and compressed air types, except for one or two minor details, are quite satisfactory. The term " self-starter " is a misnomer, and only adds one more glaring example to the already long list of terminological inaccuracies used in connection with the automobile industry.

All the devices we have been considering should be called " mechanical starters," and the cars embodying this feature should be alluded to as being " mechanically started." At present the nomenclature would lead one to suppose that the cars were in the habit of starting without their owners' volition.

Starters employing electricity as a power unquestionably go a long way towards furnishing the many requirements of the ideal starting device. When properly made and kept in good condition they are capable of rotating an engine for as long as an hour in some cases. Of course, no engine requires to be spun for more than five or ten seconds at the outside. The great advantage of the electric device is that it is able to rotate an engine that has stopped on centre. To gain these advantages needs some additional complicated and expensive mechanism, hence, except by mass production, it is not easy to fit cheap cars with electric starters. In the first place, there must be a source of electrical energy; this is usually obtained from the car-lighting set, as the dynamo employed for that work is easily able to provide sufficient energy for cranking purposes, since a well-running car of the average touring type used throughout a normal day's work does not require much more electrical energy for the starter than for the horn.

Secondly, one requires a battery of very large

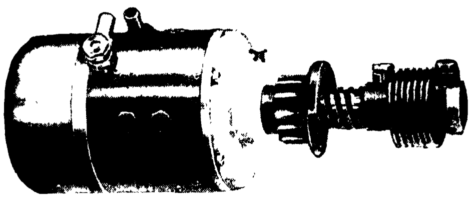


FIG. 117.—A simple Series Motor adapted to the starter.

capacity to store the necessary energy to cope with the starting torque of the motor, which reaches a very high value indeed in some sets.

The battery supplied with a lighting set is generally futile for starting work, as one requires a battery of sufficient size and capacity to furnish at least 175 amperes for a few seconds without damage to it. To obtain such an output requires the employment of a battery of 90 to 120 ampere-hours, depending upon the voltage, and of a special high discharge construction.

Regarding the motors themselves, it can be said that with the systems in use at present, these come naturally into two classes: (*a*) The simple series motor and (*b*) the motor-generator or dynamotor, as it is called. Fig. 147 gives the appearance of the simple series motor type, as made by Rotax, and Fig. 148 illustrates the dynamotor of Delco manufacture. The diagram in Fig. 149 gives a fair idea of the gearing and general internal arrangements of the Delco Dynamotor. Those who have followed the previous chapters on electric lighting dynamos will appreciate that a motor and a

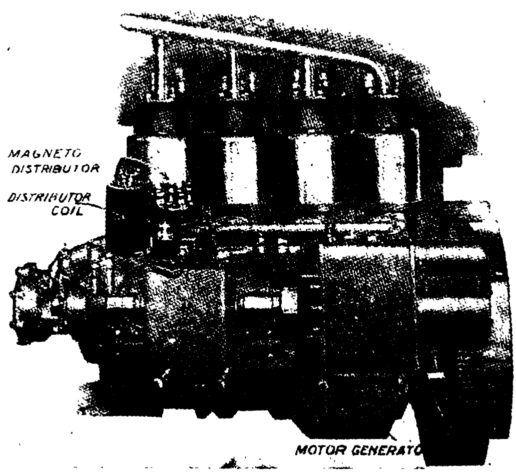


FIG. 148.—"Close up" of Dynamotor Starter.

dynamo differ very materially in their windings, and whereas we use a thick winding for a series field for use on a motor, it is necessary to have a fine shunt winding for a generator. This adds a complication which is not easily overcome.

The Delco Dynamotor.

In the Delco plant of the motor-generator type, a dual winding on the armature is used, also a dual commutator and two sets of brush gear; in addition to all this there are two separate field windings, a series and a shunt. With the Delco dynamotor the cycle of operation in getting the engine started is as follows: The ignition button on the combination lighting and ignition switch is pulled out. This completes the circuit from the storage battery through the ammeter, causing it to show a discharge. The current discharging during this operation is the amount required to slowly revolve the armature, and for the ignition.

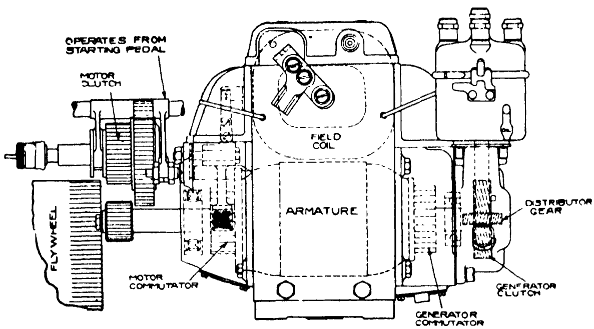


FIG. 149.—Delco Dynamotor showing general arrangement. Note that there is a commutator at both ends of the armature, one for the dynamo function and the other for the motor function. In other models these commutators are placed on the same end of the shaft arranged one above the other.

Part of this current flows through both the shunt field and the brushes and armature windings of the generator and causes the armature to slowly revolve. This motoring of the generator is necessary in order that the starting gears may be brought into mesh. Should trouble be experienced in meshing these gears, do not try to force them, but simply allow the starting pedal to come back, giving the gears time to change their relative position.

The clicking sound heard during the motoring of the generator is caused by the over-running of the generator clutch in the forward end of the generator.

The motoring of the generator is one of the most important operations for the mechanic to familiarize himself with, as the same wiring and parts of the generator are used during this operation as when generating. Therefore, if the apparatus will perform this operation properly, it is sure to generate when driven by the engine.

The cranking operation takes place when the starting pedal is fully depressed. The starting pedal brings the motor clutch gears into mesh with both the small gear on the end of the armature shaft and the teeth on the fly-wheel of the engine, and also withdraws a pin, allowing the motor brush to make contact on the motor commutator. At the same time the generator switch breaks contact, thus cutting out the generator element during the cranking operation. Cranking speed is materially reduced if the generator switch does not break contact. As soon as the motor brush makes contact on the commutator, a heavy current from the storage battery flows through the series field winding and the motor winding of the armature. This rotates the armature and performs the cranking operation.

BRITISH COMBINED LIGHTING AND STARTING SETS

The manufacture of combined lighting and starting sets has only recently been taken up by British firms. Several of the leading makers of electric equipment for petrol vehicles still produce only separate starting and lighting units, and the great majority of English cars that are electrically lighted and started are equipped with two machines. While it is perfectly true that any dynamo will work as a motor, and it appears at first sight bad practice to use more than one machine, it must not be forgotten that the conditions to be met in the two cases are very different. During the starting period the machine must be capable of drawing a heavy current and of developing a powerful starting torque, in order to set the engine in motion, whilst during the generating period it must produce a relatively small current at an approximately uniform voltage, irrespective of the driving speed. To satisfy such requirements is by no means a simple problem, and on the score of cost it is unlikely to prove cheap in its solution. Many United States firms who have turned out combined units are still undecided in their opinion as to whether or not a higher percentage of all-round satisfaction could be obtained by splitting the starting and lighting functions. About the only obvious advantage of the "dynamotor" is that *only one drive is required.* The fact that the apparatus is *permanently* in mesh with the driving gear is another, though perhaps less obvious, good point. The wear and tear, also the risk of fouling of the gears is obviated. Many sets across the water are driven by silent chain (they pooh-pooh the belt drive, even for dynamos, over there—say it is amateurish and crude). After the engine has been started, the machine automatically converts itself into a dynamo and "puts back" the current into battery. With this type of equipment all the electrical undertaking is concentrated at one spot, though as an offset to this we must hasten to add that a slight fault would render the whole equipment *hors de combat,* whereas with the two-unit system a fault on the motor would not affect the dynamo.

Whether we shall in the future find that the one unit is replacing the two unit so far as British enterprise is concerned it is difficult to say. In the author's humble opinion we shall *not,* because, firstly, we have too many cars with dynamos already fitted, and, secondly, makers have by this time produced great numbers of creditably efficient starting motors to fit upon these aforementioned cars. However, in the immortal words of Mr. Asquith, we must "wait . . ."

The Lucas Dynamotor.

This machine (see Fig. 150) is essentially for small engines, up to 11·9 H.P. In principle it is a machine equipped with three windings on the field. And although as in the American productions it has a thick winding for the series and a fine shunt winding for the generator element, a third regulating winding is employed in addition. It has two main brushes (A and B on Fig. 151) at right angles (being a 4-pole machine) and a third regulating brush (C) for regulating the voltage when the machine is acting as a generator,

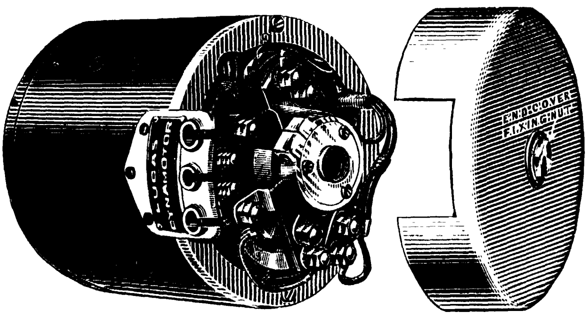


FIG. 150.—The general arrangement of the Lucas Dynamotor.

situated midway between the negative brush and the uppermost pole piece. One end of the series winding is connected to the positive brush, and its other end is connected to the starting switch, *and also* the charging switch. The ends of the shunt coil are connected one to the negative brush and the other to another terminal of the charging switch, which is connected through to the series winding and so reaches the positive brush. The low resistance regulation winding connected to the third brush is also taken to a third terminal of the charging switch. The accumulator battery is connected via the cut-out through to the main terminals of the motor-generator, provided that sufficient voltage is available and the charging switch has been closed.

The switches are fitted with simultaneously movable contacts, that of the charging circuit having four contacts while the starting switch has only two. The switches can be put up in a single fitting.

The closing of the starting switch puts the "dynamotor" into connection with the battery, and the

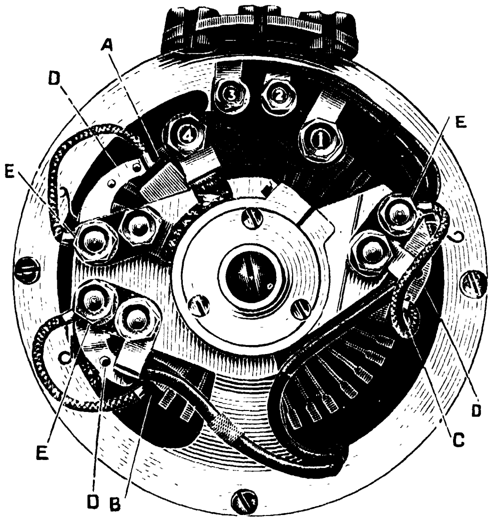


FIG. 151.—The Lucas Dynamotor Brush Gear.
A, B, main brushes. C, regulating brush. D, brush springs. E, brush terminal nut.

machine then operates as a series motor, the current in the other windings also assisting in producing the field. When the machine acts as a generator the charging switch is closed, but the circuit is not completed until the cut-out closes. During the time the machine is generating the series field opposes that set up by the main shunt winding, and thereby acts as a regulating winding in addition to the principal regulating winding. The auxiliary brush is placed on the commutator, so that the direction of the current through the regulating winding never reverses, and when a diminished output is required this winding can be utilized instead of the main shunt winding to provide the necessary excitation, which is then regulated by the other two coils. As an alternative plan, the regulating winding can be cut out when a diminished output is required.

The speed of the machine when in normal use determines which is the more preferable plan to adopt.

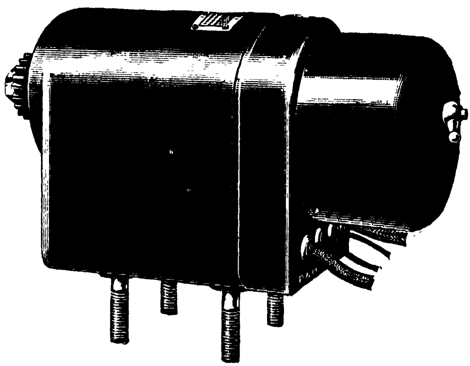


FIG. 152.—The P. and H. Dynamotor.

Fig. 151 gives an idea of the solid construction of the brush gear and commutator.

The Powell and Hanmer Mechanical Dynamotor.

We are now to consider a totally different type of combined unit—one that works upon a mechanical rather than electrical basis. Fig. 152 gives the general appearance of this machine, to which is attached the silent chain that drives the engine through the medium of the overrunning clutch, shown in Fig. 153, which is fitted directly upon the crank shaft of the engine, usually in the situation of the starting handle. The dynamotor is designed to start engines up to 20 H.P. One pole only is provided with a winding, arranged in two sections, a thick series for the starting function and a finer winding for the shunt when the machine is generating. In all other respects the electrical arrangement is that of a simple dynamo-motor construction. The commutator gives "central station" service, being of extra width and taking four brushes, so that the severe work thrown on the armature is unlikely

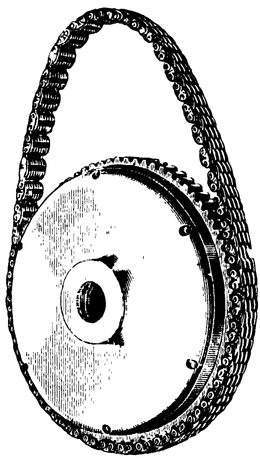


FIG. 153.—P. and H. Clutchgear.

to show signs of wear at the commutator or brushes. We will now try to expound what lies under the cover of Fig. 153—the patented clutch. In the first place be it noted that although this clutch is capable of transmitting the torque necessary for starting the engine, it slips at a pre-determined point when the machine is operating as a generator, thus creating a constant voltage dynamo.

To explain this clutch on paper is by no means a simple matter, but for any one who can see it taken apart, the action of it is at once seen to be both ingenious and thoroughly practicable. Firstly, to try to make it clear, it must be explained that the armature of a dynamo as its speed increases experiences what is known as a magnetic drag, that is to say, the magnetic field both of the armature and the field magnets tends to prevent the dynamo increasing its speed. This is obvious on all machines, for if the belt is slack the drag at certain speeds prevents the armature from speeding up, and of course the proper output cannot be obtained. This type of friction clutch makes use of the magnetic drag on the armature opposing its rotation. As the speed tends to increase a small helical slot cam comes into operation and forcibly, though very slightly, separates the two faces of the clutch, one of which is inside the driving gear, this by the way running on a large ball bearing, the other part of the clutch being in effect keyed to the shaft. The detailed action of the cam cannot very well be explained. It can be readily followed by seeing it, but it is sufficient to say that it comes into action at a certain pre-determined speed. A flat spiral spring forms practically the whole control of the clutch. Means are provided for obtaining the correct tension. As the speed increases, the armature drag brings the cam action more and more into operation and provides proportionately more slip.

When this clutch is considered from the starting point of view, the clutch acts as a driver and no slipping can take place, since the ferodo face of the one clutch member is held firmly in contact with a complementary member (the face of the gear wheel). The cam slides on its pin and locks these two faces, thereby transmitting the whole of the mechanical power developed by the rotating armature through to the silent chain and finally to the engine shaft. The moment the engine starts and tends to over-run the dynamotor, the reverse action comes into operation once more, and the armature speed is governed by the spring load, as before explained. The electrical output of the dynamotor is 8·5 amperes at 12 volts at 1,800 R.P.M. If the motor be geared 4 to 1, the initial torque for starting is 16 lb.-ft. This is more than ample for the purpose. As the speed cannot become excessive there is no risk of broken chains, which is sometimes a prominent feature with the single unit dynamo; no doubt the cushion drive effect with this clutch is also responsible for the lack of wear on the driving chain. The clutch itself is $7\frac{1}{2}$ inches in diameter and $2\frac{3}{8}$ inches wide.

Another British dynamotor is the Blériot-Scott, first shown in 1912. The machine is compound wound of the four-pole type. A vertical type of commutator is employed, which enables the maximum area of brush contact to be obtained for a given armature length.

The armature slots are distinctly novel also, in that they are not parallel but of tapered construction, which enables the iron section to be reduced at the root of the teeth where the flux density is greatest. Winding is difficult with thick conductors, but this has been overcome by the usual colonial practice (!) of using stranded conductors, which can be very easily deformed, to fill the whole of the available slot space.

Output control is due to the demagnetizing effect of the series starting winding.

In order to safeguard the accumulator when touring, the generator side is provided with a shunt resistance to cut down the battery current to 5 amperes. The charging switch never actually breaks the circuit, and provided the cut-out described on page 184 is able to close the circuit, a current of a few amperes is always flowing through the battery.

The equipment is made in three sizes with maximum outputs of 10, 12, and 15 amperes respectively at 12 volts. The speed is 1,200 r.p.m. except in the small machine which generates at 1,400 r.p.m. The motor function produces a starting torque of 275, 400, and 500 lb. respectively at 10 r.p.m. Fig. 154 gives a fair impression of a Blériot-Scott dynamotor.

BRITISH TWO-UNIT STARTING SETS.

We now come to the most popular type of starter—the simple series motor. With this apparatus there are also two forms: (*a*) those motors whose armatures are at once fully energized, and (*b*) those motors whose

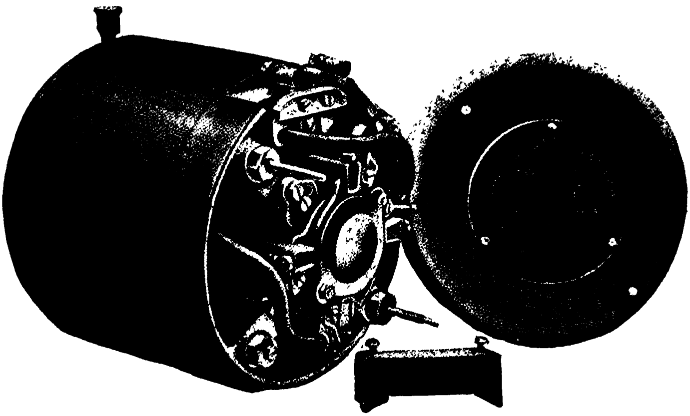


FIG. 154.—The Scott Starter Dynamotor.

energizing takes place in two stages, with a view to better enmeshment of gears. As was stated in Chapter III, the most difficult problem has been to find a way of satisfactory drive for these motors. One of the best of the earlier attempts embodied the use of an armature, capable of sliding axially when first the current was switched on, this axial transit put the geared pinion into mesh with the fly-wheel cogs.

The operating switch used in connection with this starter, when in the inactive position, was so designed that it almost short-circuited the armature winding through a limiting resistance grid; thus when the switch was closed a very heavy "series" field was built up. The magnetic stress consequent upon this was so great that the armature was pulled over into alignment with the fly-wheel gearing. Owing to the partial short, the armature at first turned over very slowly; this ensured that there would be no fouling through the teeth coming end-on. Upon a further movement of the switch arm the grid resistance was

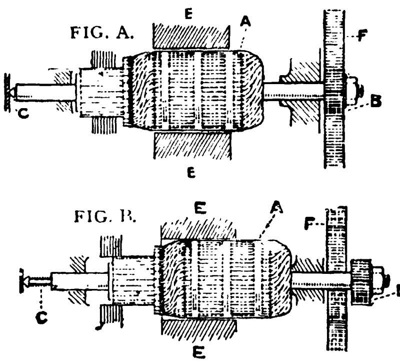


FIG. 155.—Arrangement for Gear Enmeshment. (Rushmore.)
Fig. A.—Running position of starter.
Fig. B.—Inactive position of starter.
A, armature; B, pinion; C, compression spring; EE, poles of field magnet; F, fly-wheel of engine.

shorted, and the armature was then placed in full series with its field. As soon as the engine started up, the load was released from the motor, and being wound as a series machine it immediately commenced to "run away." The field was thereby very considerably weakened, and the pull of the poles being insufficient to hold the pinion in mesh with the fly-wheel, it succumbed to the action of the spring, and was thus removed from danger. To avoid the short circuit being placed across the armature upon its return journey a simple "ride over" spring or clip was employed to "catch up" the switch arm until it had passed the short-circuit contact.

Fig. 155 will assist the reader to follow the above description.

The Bendix Drive.

This form of drive has now come into general use among all makers of starting motors. There are, naturally, different ways of applying this Bendix device, and some makers fit electro-magnetic and other contrivances to suit their individual requirements. The basic idea will be clear from a glance at Fig. 156,

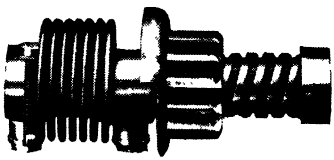


FIG. 156.—The Smith Bendix.

which shows the simple arrangement adopted by the Smith people. Starting from the right-hand end of the photograph we have first of all the driving stop, next the screw shaft for the pinion gear to run on. To this gear is attached an automatic weight, which is the highest projection on the illustration. The next important structure is the strong coil spring, which, as will be seen, is secured to the shaft. The last portion, the driving head, is farthest away from the motor. The action is as follows: The starting switch, on being closed, causes the armature to rotate, causing the screw-threaded sleeve to turn also. The pinion, which is weighted on one side and is normally in a de-meshed position, as shown in the general arrangement photograph, Fig. 157 (the left-hand

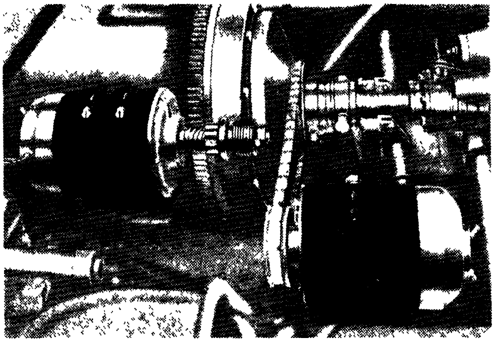


FIG. 157.—General arrangement of Smith Starter

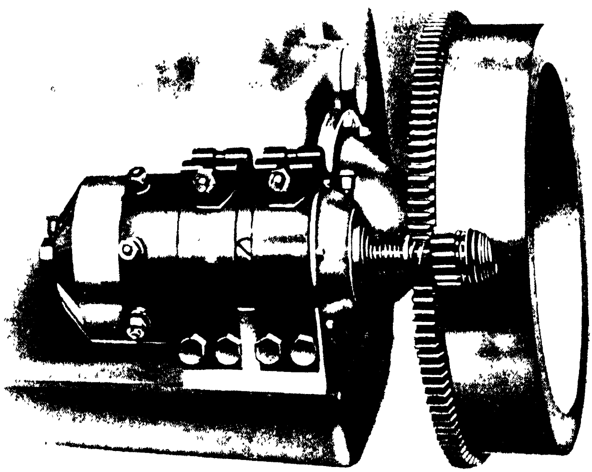


FIG. 157A.—Close-up of Smith Starter shown in previous photograph.

machine is the motor), tends to lag, by reason of its inertia, which causes it to move endwise along the screwed shaft until it enters into mesh with the fly-wheel gearing, and continues to travel until the stop collar at the extreme right of Fig. 156, is reached, when it commences to rotate with the shaft of the motor and turn the engine fly-wheel.

The spring acts as a cushion and absorbs all driving shock, and, moreover, should the teeth at the moment of meshing not enter properly or strike the teeth in the gear ring, the spring coupling gives and allows the pinion to mesh with the next tooth, without shock or binding.

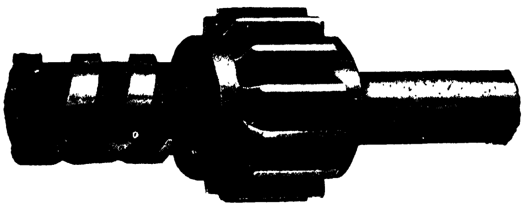


Fig. 158.—The Brolt-Bendix Drive.

When the engine starts firing the increased speed of the fly-wheel causes the pinion to rotate faster than the threaded sleeve, and consequently it travels endwise out of mesh, and the centrifugal effect of the pinion weight holds it out of mesh until the motor comes to rest, thereby completing the sequence of operations.

This method of drive is practically universal in the United States and is rapidly becoming the European standard, too.

Fig. 158 illustrates the Brolt-Bendix drive. This is a modification which also has the spring fitted as a buffer. However, it has some distinctive features.

The driving end of the armature spindle is enlarged and made hollow, and the interior of this spindle is screwed with a quick pitch thread. The pinion which drives the fly-wheel is cut from a solid piece of steel, with an extension which enters into and slides in the hole in the armature spindle. Two helically shaped keys are cut in this extension, forming a screw thread, and engage with the internal thread of the armature spindle. When the pinion revolves it therefore screws in or out of the starter spindle. The travel is so

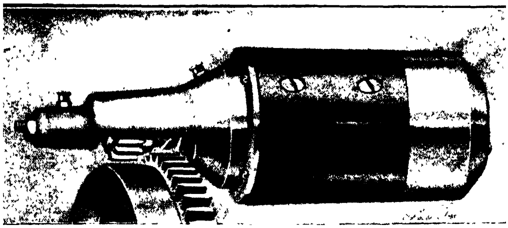


FIG. 159.—Showing Pinion out of Mesh

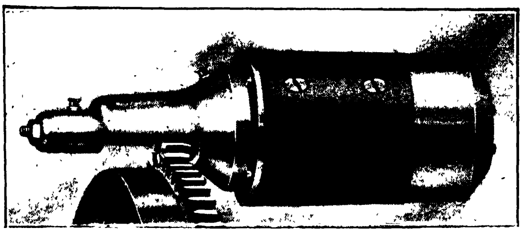


FIG. 160.—Showing Pinion in Mesh.

arranged that when the pinion is screwed home against the end of the spindle it is fully in gear with the teeth on the engine fly-wheel, and at the other end it is out of engagement and clear of the fly-wheel teeth.

The other end of the pinion has a plain extension, which runs in a bearing formed in the end bracket of the starter motor. The pinion is therefore supported on both sides of the gear teeth, and a true running, silent gear is thereby ensured.

The operation is essentially the same as in the last example, and depends on the inertia or fly-wheel effect, which causes the pinion to remain behind. Immediately the engine fires the fly-wheel overruns the pinion, which, on account of the threaded shaft, instantly flies out of mesh and resumes its former position, ready for the next start. The outer end of the pinion shaft now runs freely (as shown in the illustrations of the Brolt starter, Figs. 159 and 160), in a bearing situated in the motor housing, just under the lubricator shown on extreme left of the figures. However, at one time

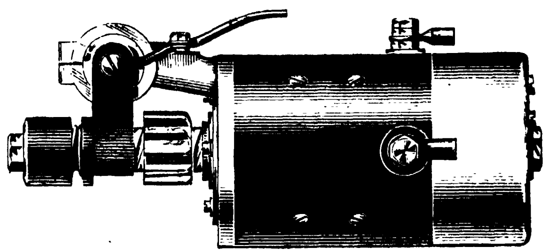


FIG. 161.—The Lucas Magnetic Damping Device for Starter Drive.

this shaft was coupled up to a small friction disc which rested on the fly-wheel.

The Lucas Co. have two very cute little schemes attached to their modification of the Bendix drive. In one arrangement the pinion is kept from turning with the motor shaft by means of the restraining powers of magnetic force. Fig. 161 gives a general impression of the Lucas device fitted to one of their single unit starters. As will be seen in the illustration there is a magnetic apparatus encircling the pinion. The teeth of the pinion can pass freely through the comb-like configuration on the magnet casting, and provided no lines of force are passing out of them it would easily rotate, but when the magnet is in circuit the concentration of the flux is sufficient to keep the pinion from revolving. It is therefore compelled to move along the threaded shaft and mesh with the fly-wheel teeth. Once the teeth are fully engaged the current in the magnetic coil is cut off and consequently the pinion turns with the armature shaft. To a large

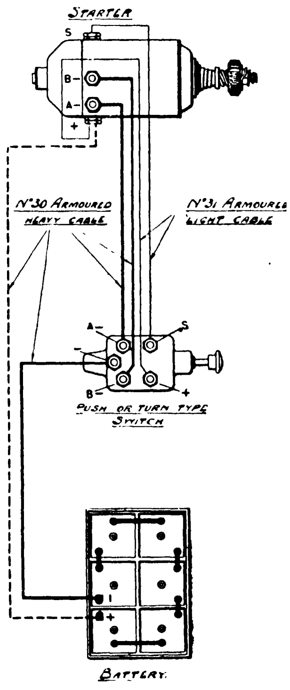


FIG. 162.—C.A.V. Starter Diagram.

extent the rush of current upon the first closing of the starter switch is mitigated by this magnet winding, and slower operation of the motor is possible until the coil is switched out as mentioned above.

The Lucas Electrical Co. have an alternative scheme bearing upon this magnet device, with the idea of preventing the low-starting torque, that is liable to occur when the magnetic coil is placed in series with the motor windings. The arrangement adopted is to connect the magnetic winding *across* the armature, instead of in series with it, so that when the starting switch is closed the current flows into the armature from the battery by way of the series winding, but at the armature the current divides, part going through the magnetic coil and part through the armature itself,

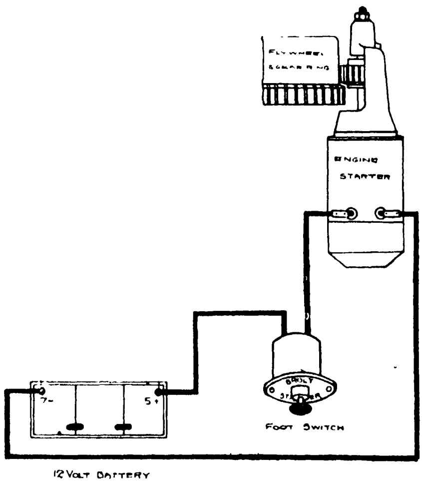
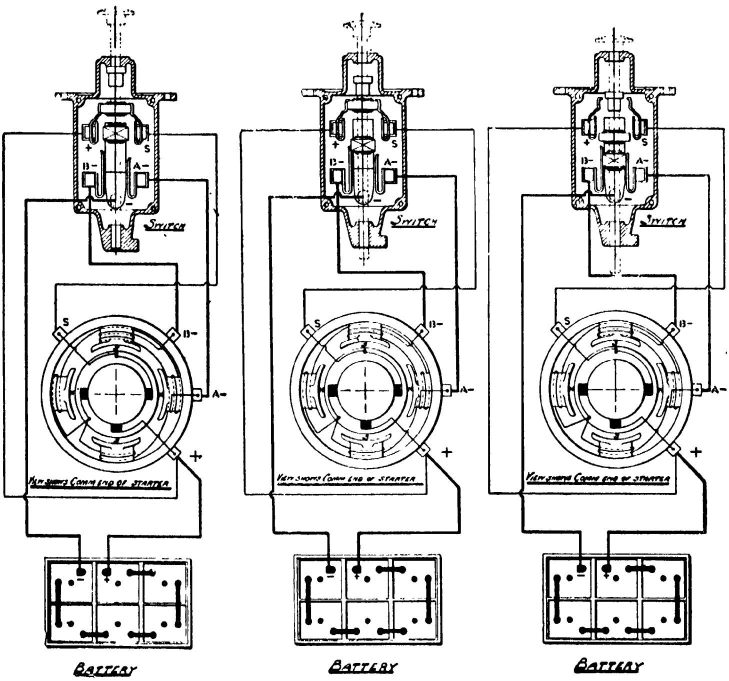


FIG. 163 —The Simple Series Starter with one position switch. (Brolt.)

the amount of current each branch will receive depending, of course, on their relative resistances. When the gears are fully enmeshed, the electro-magnet is, as formerly, cut out by a disconnecting switch, which is automatic in action.

The C.A.V. starter is another machine that employs a Bendix drive. The motor itself, though of 4-pole construction like the others of its class, is not of a simple series construction, but special additional field windings are provided, giving a weak field until the teeth of the pinion are properly enmeshed. The C.A.V. set requires a special two-position switch ; the circuit arrangement is shown in the drawing reproduced in Fig. 162. This diagram should be compared with that of Fig. 163,



First Position. *Second Position.* *Third Position.*

FIG. 164.—The C.A.V. Starter Principles.

and it will then be more clearly followed as in Fig. 163 we have the simplest possible series arrangement drawn out. In the C.A.V. the thin wiring indicates this special field winding. The motor is arranged to that alternate pole pieces carry the thin winding. There are two main brushes, and one auxiliary one called " the slow-running brush" ; this latter is capable of being cut out of circuit from the two-position switch, as will shortly be explained. The first part of the movement of the switch connects these windings and at the same time part of the armature is short-circuited. The effect of this is to retard the rotation of the motor, and due to the solenoidal action of the field magnets the armature moves slightly endwise (about ¼ inch), Fig. 165 mid. This ensures that the pinion does not foul the teeth on the fly-wheel. Once entered, as is usually the case, the threaded shaft draws the pinion right home. A further movement of the switch removes the short-circuiting block and puts the auxiliary brush out of action, and at the same time the fine field coils are put in parallel with the thick or main series coils, and the whole armature is in action. The armature now revolves in a dense field and produces a powerful starting torque. There is no difficulty in the operation of the switch, the only precaution necessary is to work it **slowly.** The diagrams in Fig. 164 show what actually occurs when switching on the starter.

(1st) Off position. In this position the spring controlled contact is short circuiting that part of the armature subtended by the main brush and the slow running brush, but no current is passing.

(2nd) In this position the short circuit is still on, but the "slow running" coils are connected to the battery, giving the initial engagement of the gears, and the armature revolving slowly pulls the pinion right home before the power is applied.

(3rd) In this position the short-circuiting block is held out of engagement by the pressure of the spring, while both the "slow running" and "power" coils are connected to the battery in series parallel. The particular diagram illustrated is that of the "Z.B." starter, clockwise rotation.

The respective positions for the starting pinion coinciding with these positions are illustrated in Fig. 165.

In-board and Out-board Types of Motors.

There are two principal types of Bendix gearing, one in which the pinion comes towards the motor and

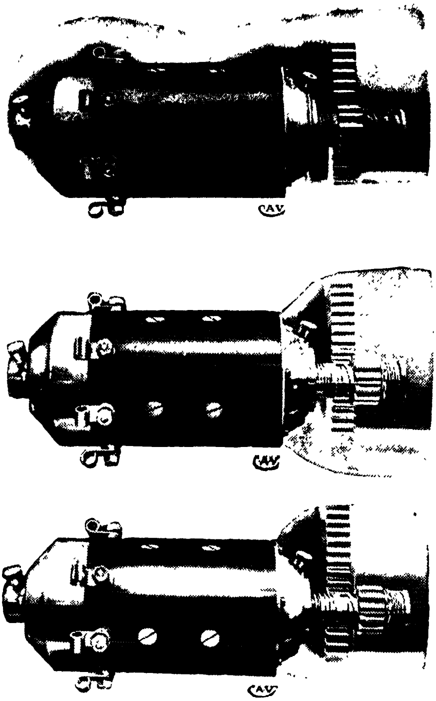


FIG. 165.—Positions of Starter Pinion corresponding to Fig. 164 connections.

the other in which the pinion goes outwards from the motor (see Fig. 167). These are known by the names "in-board" and "out-board" respectively; Figs. 166 and 167 illustrate the two species. The motor shown in Fig. 166 is an "in-board" one, as the pinion comes towards the motor in order to mesh with the fly-wheel; most of the installations are of this type. It is in exceptional circumstances only where the fitting of the in-board action is impossible that the alterative is used.

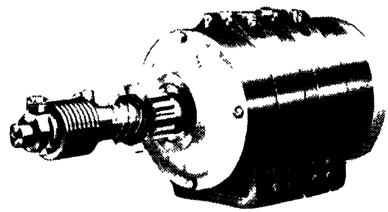


FIG. 166.—The "In-board" type of Starter.

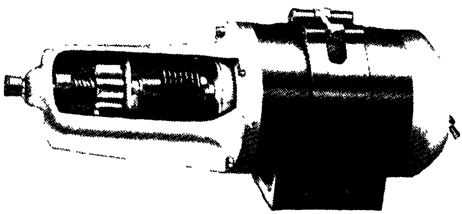


Fig. 167.—The "Out-board" arrangement of Pinion.

The Care of the Bendix Drive.

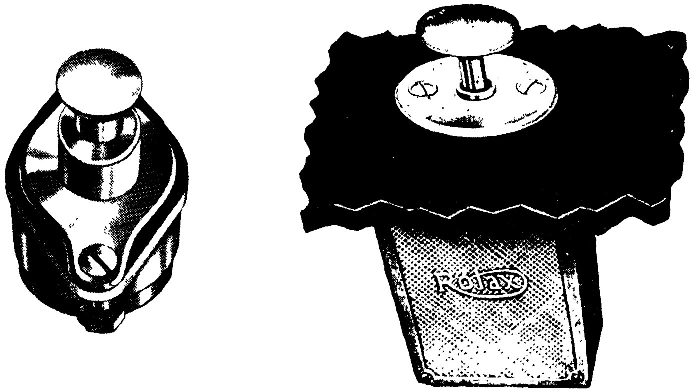
(*a*) The screw shaft must be kept clean and free from dirt and all grease, otherwise it will "gum up," and the pinion will not travel as it should.

(*b*) See that the spring that is fastened between the screw shaft sleeve and the extension of the armature shaft of the motor is unbroken and lightly bolted in place.

(*c*) The small pinion should be clean and its teeth should not be rough, in addition it must be possible to rotate the pinion freely on the screw shaft by turning it with the hand.

(*d*) The teeth cut on the fly-wheel should be clean and smooth; if, owing to wear, they are burred, they should be filed with a medium file until all roughness is removed.

(*e*) A little grease should occasionally be applied to the pinion, fly-wheel gear, screw of shaft extension and springs, the grease cups of the motor periodically charged, and at the same time the bearings of the dynamo given a few drops of oil.



Smith Switch. Rotax Switch.

FIG. 168.—One Position Starter Switches.

Chapter XII gives some hints and tips for the care of other forms of starters, in addition to those with Bendix drive.

Starter Switchgear and its Operation.

In Fig. 168 is given the external impression of the usual form of one-position starter switches, sometimes called the single-contact switch, to distinguish it from the two-position or double-contact switch. The single-position switch is usually free from all complications, whereas, with the other type, we have resistances, short-circuiting devices, etc. In operation these devices are usually foot operated, and are fitted to some convenient part of the footboard; however, they must not be attached to a loose board or any part that has to be removed. It must be fitted in easy reach of the driver. On some cars the hand position is used, and the switch is fitted to the dashboard in easy reach of driver's hand. This position has one serious disadvantage in that it requires rather more heavy section cable to connect it up, and, as we have seen, it is of first importance to secure short wire runs with starters. There is another type of switch which is partly automatic in action, such as with the Lucas switch, for instance, where we have the initial closure sending the current round an electro-magnet, which then performs the rest of the work itself on the motor. The Delco, with its magnetic latch device, is a further example of a semi-automatic switch; or, again, the Rolls-Royce, with its dash-board relay switch. Referring to the one-position switches more particularly, we find that the heavy copper contacts are usually protected by additional carbon ones, that is the first and last contacts are made by carbon blocks, and thus all possible damage to the copper contacts is eliminated should the switch be operated in too great a hurry. The switch of this type needs to be used definitely and decisively the plunger being pressed right down and *released smartly immediately the engine fires.* If the plunger shows any tendency to stick or jam, the cover should at once be removed and the contacts examined, when the trouble will most probably be due to burnt contacts caused by careless operating, in which case the main cables should first be disconnected at the battery and the switch contacts then filed up clean, care being taken to see that none of the switch parts are loose or bent before replacing the cover and reconnecting the batteries.

In the two-contact switches, such as is used in the C.A.V. outfit, one does not press the switch right home in one go, one has to make the first contact and wait for a second before passing on to the second one. There are two distinct movements. The first part of the travel connects the battery, as in Fig. 164, second position, and allows the motor to thoroughly enmesh with the gearing of the fly-wheel also. This point of travel can be distinctly felt, as at this point a ball, backed by a spring, enters a recess in the spindle of the switch. This effects a momentary pause, after which the switch is pressed right home.

Failure to comply with the above directions does not necessarily entail damage to any part, but when trouble has been taken in the design to ensure that silent engagement of gears which is pleasing both to driver and passengers, it is as well to take advantage of the possibilities provided.

Always be careful that the **gear lever** is in **neutral position** before attempting to start the engine, also when leaving the car standing.

Before starting from cold, don't neglect all the little preliminary precautions that would be observed if starting by hand, such as flooding the carburettor, injecting petrol, etc. Remember that, although the starter will turn the engine over, however stiff it is, a little help is worth a deal of pity for the battery and tends to lengthen its life.

Don't turn the engine round for five minutes before ascertaining whether the switch is on, or the petrol turned on or pumped up to pressure, or the air shutters closed. When starting does not involve hard work at the starting handle, it is astonishing how easily these little details are forgotten.

Don't use the starter for pumping up the petrol tank in a pressure system, or use the starter for manœuvring the car in the garage.

The function of the starter is to swing the engine, but no engine will start unless carburation and ignition are in proper order. If the engine does not fire in the first dozen revolutions, don't blame the starter, but find the cause, and do not uselessly exhaust the battery.

It is a pretty poor electric motor that will not drive the car, indeed, the Gray and Davis starter used on a Peerless motor car was able to propel a load (including passengers) of some 5,100 lb. for $\frac{1}{8}$th mile up a 7 per cent. grade on second speed in 12 minutes. However, *do not try this, because it will damage the battery.*

Selection of the Starter.

The size of the starter, also its type, will have to be chosen from the particulars given in the manufacturer's catalogue, if the reader's car has no starter fitted by the maker. Many quite old cars have a complete lighting plant, and if the battery of this outfit is fairly robust it can be employed to operate a fairly large starter, although, unless specially designed, it will not survive the strain for more than twelve months. However, by that time the owner will have learnt all that there is to know about his starter and will use this knowledge to advantage when his new battery arrives. Should the reader have no lighting plant aboard his car, he may have sufficient space "to let" to fit a dynamotor; if so, the following data will interest him :—

(*a*) In **operation** the single-unit (dynamotor) has a slight advantage.

(*b*) In **weight** for the same cranking speed and the same generator output the two unit (separate dynamo) is 20 per cent. lighter, as there is a considerable amount of loss in the gearing necessary with the dynamotor (see Fig. 149).

(*c*) In **electrical efficiency** working as a generator the dynamotor is 5 per cent. lower than the dynamo, while as a motor it is from 2 per cent. to 3 per cent. lower.

The would-be installer is often exercised in his mind as to what voltage he should work at, 6 or 12 ? Here again, there is some information to impart. The 12-volt battery is about 30 per cent. heavier than the 6-volt for the same **watts** (i.e. volts × amps — the energy used). In cost there is also a big difference in favour of the lower voltage. The trouble and cost of repairs are 100 per cent. more in the 12-volt battery.

With whatever type of plant is adjudged suitable, it is important to have a correct gear ratio. The choice of pinion sizes offered on modern sets will enable this to be accomplished on any standard car. The maximum gear ratio should not exceed 13 to 1, and the minimum should be 10 to 1. In certain cases these ratios can be extended, but it is necessary to gain expert advice upon this point. In the Liberty motor, which is fitted as Standard Ford equipment, the motor turns at 12 times the speed of the engine, as there are 10 teeth on the Bendix pinion and 120 gear teeth on the fly-wheel, to make the ratio of 12 to 1 suitable for the fast engine of the Ford.

The Position of the Starter.

The starter must, of course, be fitted in a position suitable for the pinion to mesh properly with the gear ring, which has to be fitted to the fly-wheel. When this gear ring is fitted on the edge of the fly-wheel nearest to the engine, the pinion will face the rear of the car, and the commutator end of the motor will project beyond the dash towards the radiator, the starter being on the near or off side, depending on where the necessary space is available, and the convenience of fixing. The direction of the starter will be clock-wise, looking at the pinion end. Another favourite location for the motor is to the rear of the fly-wheel ; in that case the cogged rim is attached to the clutch side of the fly-wheel, while the starter pinion faces the radiator, and the direction of rotation viewed from the pinion end is counter-clockwise.

Although only two positions have been mentioned, it is obviously possible and indeed practicable to fit the starter in any intermediate position, and one frequently adopted is to place it directly over the centre of the fly-wheel, building the footboard round it, should it project through.

The position finally chosen will be determined by the best location for the gear ring on the fly-wheel,

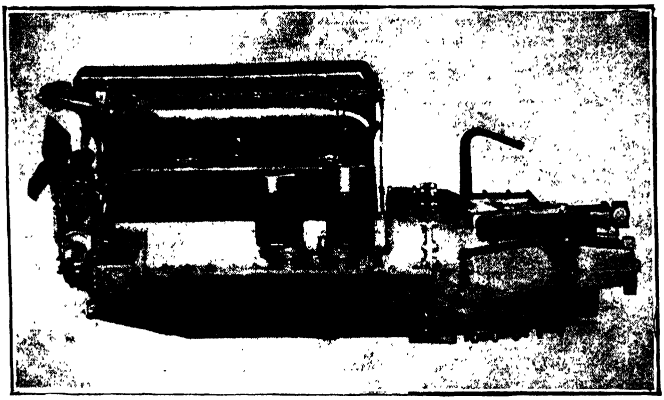


FIG. 169.—Lucas Plant, shaft driven by worm gear. Left-hand machine is the starter, the one on right is the dynamo.

and the bracket for the starter. The most usual position, when accommodation has not been provided by the car manufacturer, is below the clutch pedals.

The disposition of the electric machines is a matter which offers a wide field for the designer's discretion. Fig. 169 shows a most original planting of the electrical gear on a large car. On some cars manufacturers have not done their best, as quite a few chassis have an electrical machine so placed that the commutator end comes between the foot of the steering column and the crank case, rendering it most difficult to inspect the brushes or to clean the commutator. It is much better to turn the starter round so that the terminal end comes under the front floor boards, where it can be easily reached when required. Similar awkward positions are allotted to the dynamo, so that to give attendance to the terminals or brush gear one has to be double-jointed or better!

Fitting the Starter.

First of all it is necessary to fit a gear ring on to the fly-wheel: before doing this the main points to determine are, (1) that there is sufficient metal in the fly-wheel rim; (2) the clearance between the fly-wheel and frame of chassis, or any other obstruction.

Owing to the fact that the conditions in no two cars are alike, it is impossible for makers to stock complete gear rings ready to slip on the fly-wheel.

Further, the gear ring should always be fitted to the fly-wheel, and finally turned to size in place, in order to ensure true running and balance. The teeth should also be cut with the gear ring in position on the fly-wheel. These remarks do not apply when a gear ring is supplied by car manufacturers who have standardized same. It is important to see that the ends of the teeth on the bevelled side of the gear are properly rounded off.

The bracket carrying the starter must be rigid in design, and attached to a part of the chassis frame or engine which is not liable to spring. (The majority of lighting dynamo brackets would not be strong enough for a starter.) A cast-iron or heavy aluminium bracket usually makes the best job.

In the matter of adjustment it is necessary, in order to promote sweet running, to have the centre line of the starter pinion exactly parallel with the engine crank-shaft. This point is liable to be overlooked when the engine is set at an angle in the frame with the centre line sloping down from the fan to the rear. The teeth should be set the correct distance into mesh, so that the clearance between the top of the pinion teeth and the bottom of the gear teeth is 0·01 inch. There will then be the merest fraction of a back-lash if the pinion is rocked backward and forward with the fingers. The clearance distance when the pinion is in its extreme out-of-gear position should be $\frac{1}{10}$th inch.

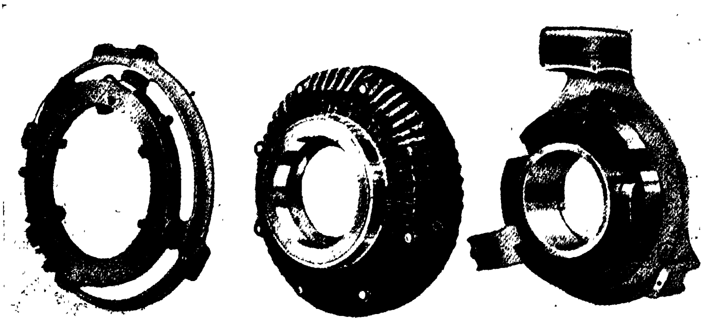


FIG. 170.—The Fly-wheel Type of Dynamotor (U.S.L.).

If the pinion is worked by hand into the in-gear position it will be noticed that it does not make contact with the fly-wheel teeth, for the whole width of face. However, the cushion spring takes care of this when the starter is in actual use, and the teeth are by that means brought into proper alinement.

There are, of course, other possible drives for the motor than on to the fly-wheel; for instance, in the Rolls-Royce car, which has a starting system of its own, the starter-motor is arranged to start the engine through the lay shaft of the gear box, and is controlled by a relay switch operated from a push button fitted on the dash.

In the dynamotor type we find considerable variety in positions allotted to that apparatus.

We have now to consider the third type of starter—the fly-wheel equipment. The successful example of this type is shown in Fig. 170: the first picture on the right shows the field, which remains stationary, as is usually the case with fields; the second shows the armature, which follows the usual practice and revolves; whilst in the third picture we have what is called the brush rig. Contrary to custom the armature revolves *outside* the fields. The brush gear is quite accessible and can be adjusted easily upon removal of a simple cover plate.

The U.S.L. fly-wheel dynamotor is used as formerly on the Sheffield-Simplex cars, and it is difficult to understand why this efficient system is not more generally to be found, at any rate on the larger cars. By this means the surplus dead weight of the fly-wheel is to a large extent done away with, the armature of the dynamotor taking its place.

Not only is the weight where it is wanted and of advantage, with this integral dynamotor, but the total extra weight to the car is from 30 to 40 lb. only, for the whole outfit, including battery. The whole thing is built up with the chassis forming an integral part of the design; all questions of gearing and drives for dynamo and motor are done away with, and a most powerful and effective starter is provided. It works at considerably higher speed than most starters of the ordinary type and operates silently. Twenty-four volts are used for starting and 12 volts for lighting, the arrangement being on the three-wire system.

The starting switch used with this set is another example of the magnetically operated type. The switch is automatically closed when the electrical circuit containing the solenoid coil is energized by pressing in the starting button. When the starting button is released, the switch opens automatically by the force of spring pressure. The switch operates with a quick "make and break" action, even though the starting button be operated slowly. The switch is also provided with auxiliary carbon contacts, which take the arc when the starting circuit, carrying the heavy current, is opened; in this way the pitting of the copper contacts is prevented. The switch is very small and simple, being not over 5 inches long and about 3 inches in diameter, and requires little or no attention.

The U.S.L. starter and lighter can be applied to the crank-shaft at either the front or rear of the engine and is applicable with any type of clutch. The following table will interest designers:—

TABLE OF STARTER-LIGHTER SIZES REQUIRED FOR VARIOUS ENGINE SIZES.

Armature Diameter.	Torque in Lb. at 1 Foot.	Approximate Cubic Inch Displacement of Engine.
12 inch	35	0 to 100
14¾ inch	50 to 75	100 to 200
17 inch	75 to 125	200 to 350
18 inch	125 up	350 up

Electric Gear Shifts

A word or two about the electrical devices for gear changing may be of interest to readers, before we pass on to the important matter of "Shooting trouble."

The motorist will in all probability be well aware that several cars are equipped with some of their speeds under electric control. These devices are calculated to give the necessary finishing touches to the electrically lighted, started and ignited car.

The points for the adoption of electric gear shifts, as they are termed, may be briefly summed up as follows :—

(1) The provision for changing gear, without removing the hands from the car, whilst driving.
(2) The clutch will be always fully disengaged, and the gears always draw to neutral mechanically, before a shift is made, thus rendering it impossible to strip a gear.
(3) The increased speed with which the gears may be changed in traffic makes such devices useful in large cities.
(4) The driver may always anticipate his speed change, before he throws out the clutch pedal.

A communication received from an American correspondent sets out the claims of the electric gear shifter rather graphically. " The troublesome gear shift lever," he says, " dates back to the birth of the automobile industry itself, and is the last relic of primitive automobile design.

" The motor has been wonderfully improved.
The axles—the wheels—the tyres—have been made increasingly better and better.
The electric self-starter has displaced the crude hand-operated starting crank.
Electric lighting has taken the place of acetylene gas.
Everything about the car has been improved upon except the method of shifting gears. You still have to do that—as you did twenty years ago—by taking one hand off the steering wheel, leaning forward, grasping a lever and moving it backwards, forwards and sideways every time you want to shift gears.

"How much longer do you think the automobile-buying public is going to tolerate this clumsy method of gear shifting? It didn't take the public very long to make up its mind about the relative merits of the starting crank and the electric self-starter. How long do you think manufacturers can continue to sell cars with hand-lever gear shifts after the automobile-buying public learns that there is a magnetic gear-shifting device that operates merely by pressing a button?

"The starting operation you are called upon to perform only occasionally, but gear-shifting is a frequent operation—always a troublesome operation—and occasionally a dangerous one.

"Imagine your car half-way up a steep hill with a ditch on your right and a car descending the hill trying to pass you on the left just at the moment when you must drop back to second speed to keep your engine from stalling. That's a nice position to be in with a hand lever gear shift, isn't it? You must steer between the ditch and the descending car with your left hand alone, while with your right hand you try to slip the gears into second speed. A stone in the road, or a rut, may overcome the resistance of your one hand, throwing you off your course, and causing you to collide with the other car, or over-turning you into the ditch.

"Not so if your car is equipped with a magnetic gear shift. At the foot of the hill you pressed button number 2 (the second speed button) with the idea that you *might* have to drop back to second speed before reaching the top of the hill. Nothing happened when you pressed this button except that you selected *in advance* the speed into which you intend to go *if necessary*. Perhaps you reach the top of the hill on high gear; if so, well and good, you continue on your way without shifting gears at all. But if you *are* obliged to drop back to second speed while going up the hill, you can do so by merely pushing your clutch pedal to its extreme position. You do not have to take one hand off the steering wheel, nor your eyes from the road ahead, at the very moment when you need both hands and both eyes to enable you to steer between the descending car and the ditch.

"Get this advance selection feature of the magnetic gear shift firmly fixed in your mind—it is one of its big advantages. With a hand-lever gear shift you must take your right hand off the steering wheel at the instant you are obliged to shift gears, although this may be the very time when you need both hands on the wheel. You can't operate the hand-lever shift in advance of the occasion that necessitates shifting the gears. But with the magnetic gear shift you can do this very thing—select in advance the next shift and not actually shift the gears until occasion necessitates it. When the time *does* come to shift, you shift not with your hand, but with the foot that operates the clutch pedal.

"Another very important advantage is that the magnetic gear shift makes it *impossible to strip the transmission gears*, as the operation is such that the clutch is disengaged and the gears are automatically thrown to neutral before the shift takes place. In shifting gears by hand, the gears are frequently stripped or damaged.

* * * * *

"Five years ago you cranked your car by hand. To-day you push a button and the engine starts.

"But you still shift gears with a hand lever that obstructs the floor-board of your car and is almost as clumsy a device as the old starting crank.

"How long do you think it will be before the automobile-buying public will insist that the shifting of gears shall be made as easy as starting the engine? There is no reason why it should be any harder. The same power that cranks the engine—electricity—can be made to shift the gears. The same simple method of operation can be employed—a push button ! "

There are at least two brands of electric or, better, magnetic gear shifts in use in the United States. One of the most widely used is the "Cutler Hammer" magnetic gear shift. Another, even older, was the Vulcan electric gear shift. Essentially, the automatic gear shift consists of two parts, a selector switch situated on the steering post just below the wheel, or sometimes on the wheel itself, fitted with a series of push buttons, one for each forward speed, one for reverse, and one for neutral. The switch is fitted with a mechanical inter-lock, so that one button only may remain in position at one time. The buttons are numbered 1, 2, 3, R, and N, for a three-speed forward and reverse transmission, with an extra button for a fourth-speed when used. The second unit consists of "the shifting assembly" or group of magnets of solenoidal construction, attached to the transmission housing. This set of solenoids is provided instead of the ordinary hand lever—one solenoid* being required for each speed forward and reverse. To the clutch pedal is connected a mechanical neutral device and a small mechanical switch, which completes the circuit to the battery for energizing the solenoid required.

When the driver has selected the desired speed through the medium of his push-button switch on the steering

* To illustrate the action of a solenoid, let us take the bobbin from off an old electric bell magnet. If we join this up to a dry cell, like that shown in Fig. 10, on page 50, we shall now have a solenoid. Upon bringing a rod of iron of such a diameter that it will just pass through the bobbin—a short length of about two inches will answer best—the solenoid will at once exert a magnetic pull upon it, so much so, that if the rod is brought into line with the aperture of the coil it will be sucked into the interior of the solenoid. This particular sort of magnetic attraction is, of course, only possible with hollow electro-magnets ; such an effect is precisely what is wanted for gear selectors.

wheel, the clutch pedal is pushed all the way down. This fully releases the clutch, drawing the gears from their previous position to neutral, and engages the mechanical switch, which closes the circuit to the battery and operates the solenoid selected by the push button and drawing the gear to position instantly. The clutch is then engaged in the usual way with the pedal. When another speed is desired, another button is pushed down, the clutch pedal thrown all the way out; the shift is made instantly and the clutch is re-engaged, as in the customary practice. The driver may slip his clutch or fully disengage it, by a partial throw of his pedal, without changing his speed until he is ready, as the actual shift is made only at the extreme throw of the pedal. This, as we have said, allows an advance selection of gear to be made. The energy consumed in a gear shift is about 17 amperes, and the pull exerted by the solenoid is from 40 to 100 lb. This energy consumption is of momentary duration only; in fact, a recent experiment upon the Cutler Hammer gear shifter showed that it was possible to change gear over 300,000 times with a full charge of an 80 ampere-hour 12-volt battery. This is enough to provide for 400 shifts daily, for a period of three years.

An electrically operated gear shift, though quite dissimilar in both design and function, was at one time embodied on the Cadillac car. It was based upon the use of two pairs of bevel gears, either pair working alternately, and thus providing the car with two different gear ratios. The rear axle was equipped with two bevelled gears, in place of the usual single gear. To inter-mesh with these gears there were, of course, two bevel pinions instead of the one necessary on ordinary cars. Each drive was accomplished direct to the axle, no intermediate gearing whatsoever being interposed. The selecting was accomplished by the action of two solenoids upon two pawls, which was so arranged that either of the pawls could be attracted, in accordance with the ratio desired, and so to engage it with the arm that was connected with the clutch pedal.

The Cadillac device did not provide for the actual shifting of the gears themselves—this was done by hand—but merely altered their ratio. The obvious advantage of such an arrangement lies in the fact that it doubles the number of speeds possible to a car not so equipped. The controlling switch was fitted on the inside of the right-hand front door. The ratio change was accomplished without noise or shock.

In addition to the devices mentioned, there appear periodical efforts to dispense with the ordinary clutch altogether and replace it with some form of electrical transmission.* Their performances do not come up to their promises, as the low efficiency in transmission, both at high and low car speeds, is against their survival. Among the few types that can claim a commercial existence we might cite the Tilling-Stevens system, in which there is no mechanical connection at all between the "engine" and the "drive," this latter taking the form of an electric motor driven from a petrol-electric installation situated on the chassis. Speed change is provided for by the addition and subtraction of field resistance in the dynamo's field. The Owen magnetic system is another type of the dynamo-motor idea that has some striking points of difference from the last example, principally in the fact that the dynamo and

* One of the most recent of these possesses more than the usual amount of ingenuity in the fact that it is a gearless lighting and starting set in addition to a magnetic clutch brake for the facilitation of gear changing. A "Gramme" ring armature, combined with the outer member of the clutch, surrounds and overhangs a four-pole stationary field magnet system. The free clutch member can thus be set spinning with the gear in neutral and the clutch out, and the engine started up gently by letting the clutch in. Normally, the arrangement gives current as a lighting dynamo, and when the clutch is taken out with the car in motion, the torque between field and armature tends to slow down the spinning clutch member.

electric motor are mechanically connected. The petrol engine in this case rotates the field magnets of the dynamo. These tend to drag round the armature of the dynamo, but the inertia of the car restrains this and the device at this stage operates as a slipping clutch generating not heat, but electricity, which is passed to the motor unit to assist in propelling the car. The consideration of these electro-magnetic transmissions is, of course, outside the scope of this volume, so we must perforce pass on to more pertinent subjects.

CHAPTER XII

THE FAULT CHASER'S FRIEND

Notes and Diagrams of Typical Installations

[*This section is complete in itself; all the needed information has been included, even at the risk of repetition, to save the busy consulter having to hunt through the rest of the book.*]

All electrical circuits must comprise a source of current, wires to carry it, a switch to interrupt it, and apparatus to be actuated by it; this sounds simple, but when something goes amiss with the electric system of the modern car, it is not usually an easy matter to put it right. Not that there is anything occult or recondite about the electrical mechanism of a motor car—merely that, taking the world over, there are at least two hundred distinct makes of car electric systems. Some of these appear so complicated to the uninitiated that when an "under-bonnet" view, like that in Fig. 171, is thrust upon the motorist, he feels somewhat tangled up in the wiring. Fortunately, the two hundred can be reduced to about half a dozen primal types, and these, again, naturally fall into two categories, according to their method of output control, viz. the mechanical and the electrical system. For our purpose we find it convenient to group existing apparatus under the heading of "one-wire" or "two-wire" installations. As we have seen, these names are given to systems employing an "earth" or "ground" return, and a "wire" return respectively. Fig. 172

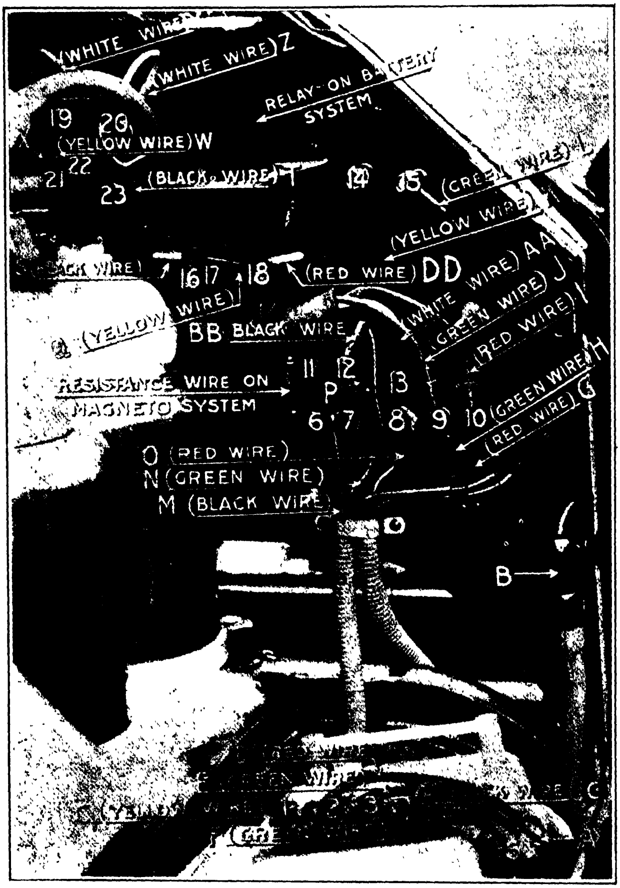


FIG. 171.—Electric Wiring simplified !

depicts the "earthed" system used upon the most widely-known motor car.

(1) Earthed (One-wire) Systems Explained.

Attention is drawn to the following signal points :—

(*a*) A single wire conductor alone is used, the return of the current taking place through the frame of the car, and finally up the wire marked " return " back to the battery (see left of Fig. 172). Each lamp or other apparatus is " fed " by the wire conductor and the circuit " completed " through the chassis by a short cable attached to a convenient bolt.

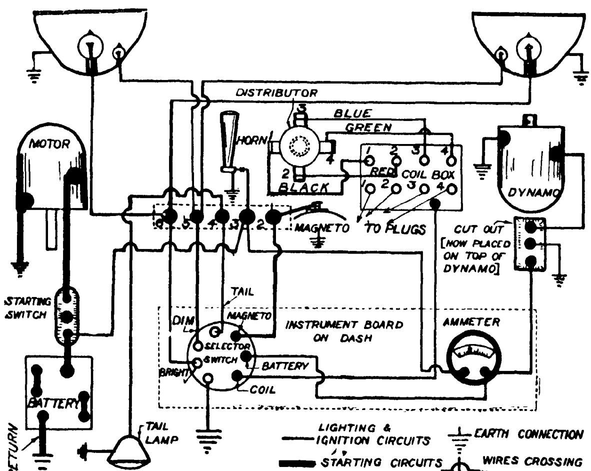


FIG. 172.—Diagram of Ford Starting and Lighting Circuits. Head lamps have double-bulbs.

(*b*) Providing the " earthing " is consistent throughout, it matters not which pole or terminal of the battery is put to the frame. Convention has it, however, that it should be the " negative " one, doubtless because, in the early battery-ignition days, we came to the erroneous conclusion that the negative wire was more immune from those effects which are associated with the undesirable phenomena of electric supply. If one does much motoring in swamps, fords, and other damp places, it is better to earth the positive pole, because if electrolysis sets up, the conductors will tend to thicken through the metals of the car plating upon *them*, instead of their copper electrolyzing into the insulation. The author does not suggest that all the missing parts of a customer's car will be found encircling the conductors, although where the negative has been earthed he has found all the copper, in places subject to electrolysis, resolved into a powdery material resembling verdigris—a non-conductor when dry.

(*c*) If the wiring is not a first-class job, look out for trouble, as upon this system a short circuit is easily developed. When making "earth" connections to the chassis use a bolt and white lead over contact areas. It is obvious that with the double-wire system one has two chances of avoiding a "short," although the advocates of the "earthed" system tell us that in most two-wire lay-outs we *have* to earth the battery in order to run the ignition! As representative of the grounded systems, we might mention the various Delco outfits; a diagram of this machine, applied to the latest Cadillac car, will be found in Fig. 173, and an earlier schema is shown in Fig. 174, whilst in Fig. 175 we have a general arrangement of a typical Delco plant.

Taking into consideration the total number of installations, the earthed systems are at least numerically superior. There are no *special* faults inherent to these; so we will defer the consideration of fault-finding.

(2) Non-earthed (Two-wire) Systems Explained.

Apart from the reservation just made, the non-earthed system is cable all the way from "positive" of battery to "negative" battery. Fig. 176 shows the

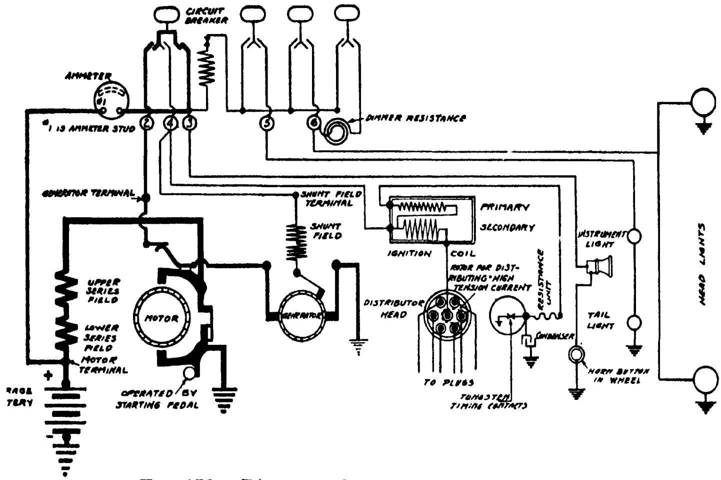


FIG. 173.—Diagram of Circuits—Delco System.

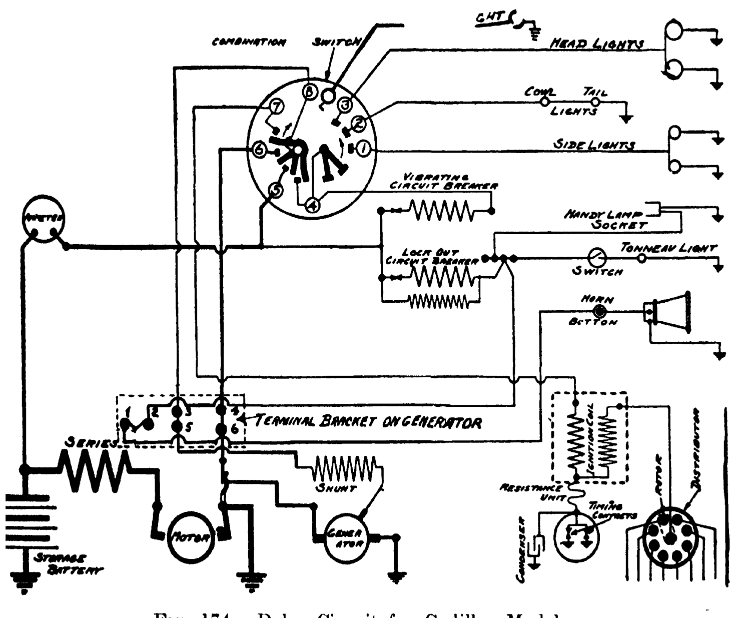


FIG. 174.—Delco Circuit for Cadillac Model.

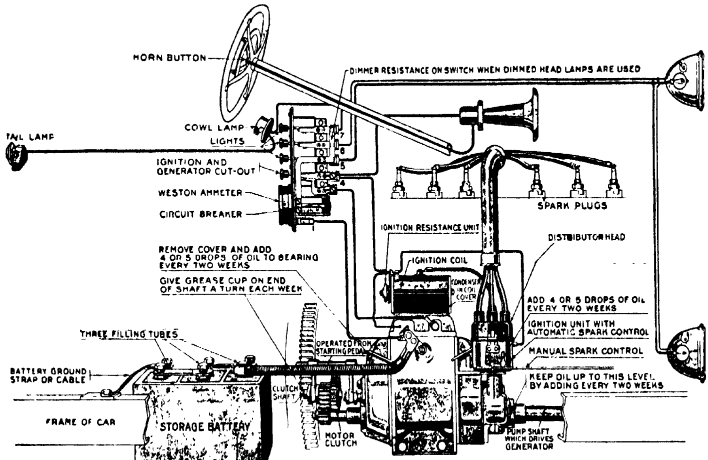


FIG 175.—General Lay-out of the Present Delco Generator and Starter System.

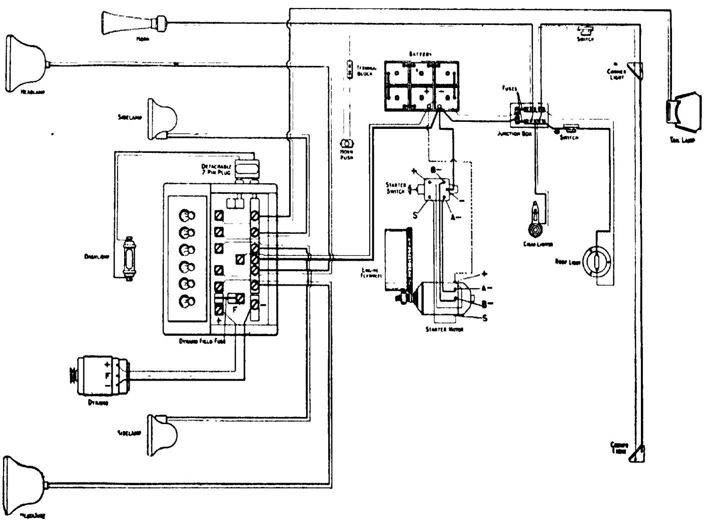


FIG. 176.—Diagram of C.A.V. Starting and Lighting System.
With switchboard connections used for Types 1, 2, 2A, and 3.
Diagram of switchboard connections used for Types 10A and 12 is given in Fig. 177.

lay-out of the C.A.V. set. It is curious to observe that in this diagram it is the negative wire which is given prominence. Several other two-wire sets are illustrated in the diagrams 178 to 184.

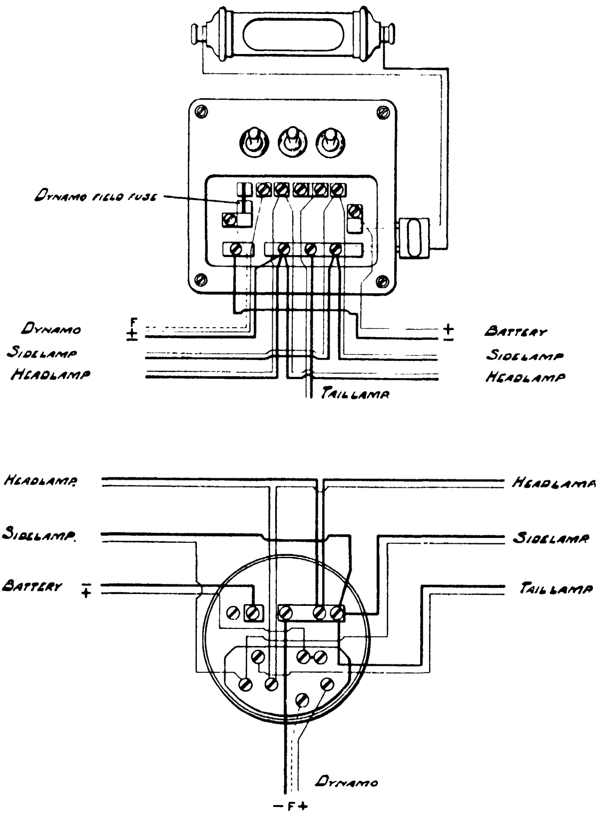


Fig. 177.—Wiring for other types of C.A.V. Switchboards.

Before we proceed with the actual trouble-hunting we may give our attention, with advantage, to the method used for locating two very common forms of wiring fault, "the *earth*" and the "*short.*" We have

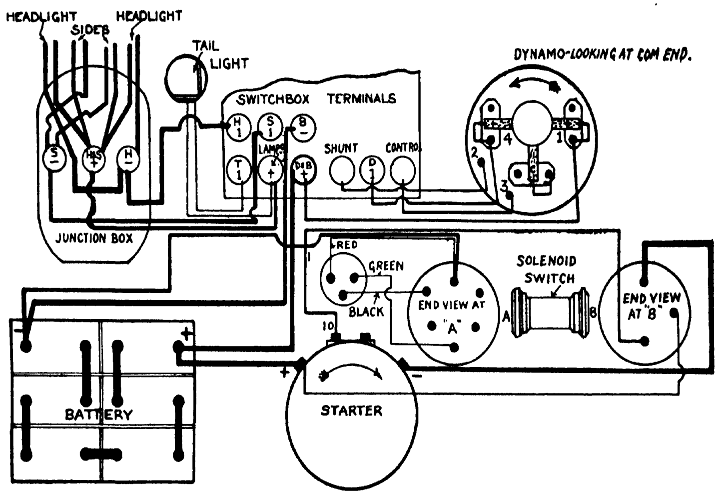


FIG. 178.—Diagram of Lucas Two-unit Lighting and Starting Lay-out.

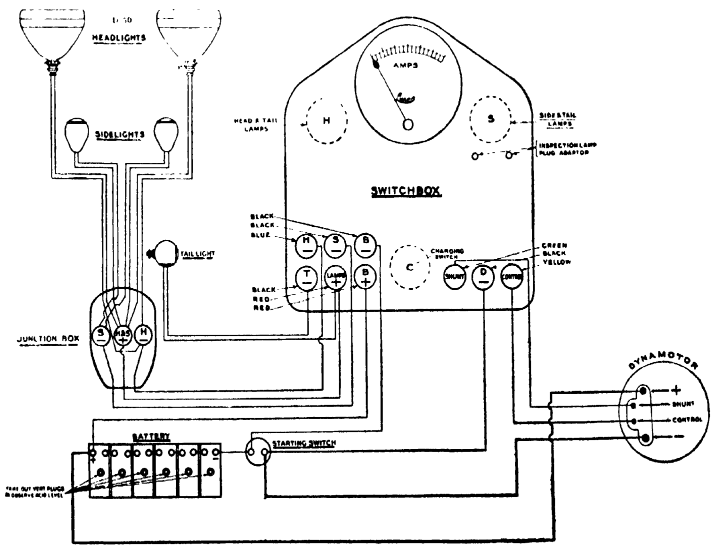


FIG. 179.—Diagram of Lucas Combined (two-in-one) Generator and Starter Set. A special terminal and nut are used for the head lamp socket connectors (shown in detail on page 192).

already, in Chapter I, explained what these are, so it will be assumed that the reader is *au fait* with these terms.

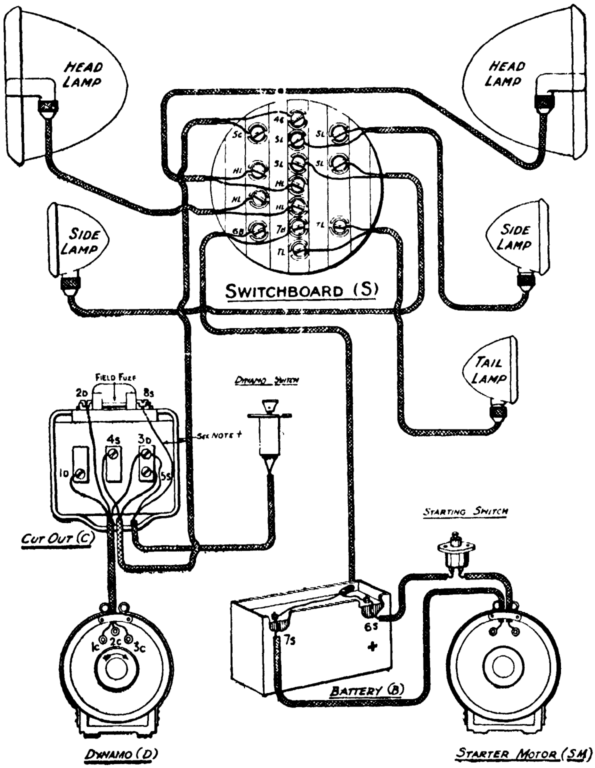
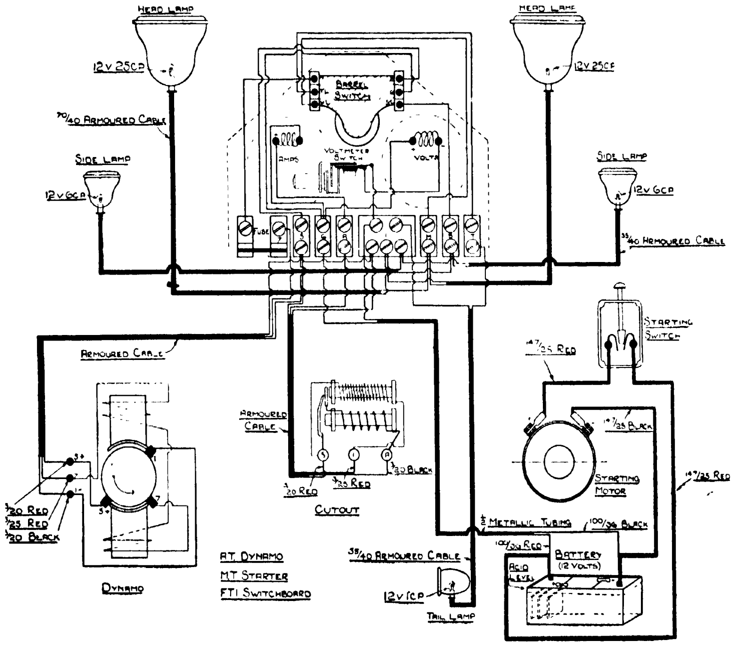


FIG. 180. Diagram of Smith Starting and Lighting Lay-out.

Dynamo circuit from D to C ; Cut-out circuit to switchboard C to S ; Switchboard circuit to battery S to B.
Terminal connections :—Dynamo to cut-out 1C to 1D, 2C to 2D, and 3C to 3D.
Cut-out to switchboard 4S to 4C and 5S to 5C.
Switchboard to battery 6B to 6S and 7B to 7S.

To test for an earth in the wiring simply disconnect the cables from one of the terminals of the accumulator, say the positive, and connect a voltmeter, or a test lamp of the same voltage as car supply between this terminal and the frame of the car, at any convenient spot. If a reading is shown on the meter or the test lamp lights, there is an *earth* on the negative side of the wiring. If no result is obtained, repeat the test



'IG. 181.—Diagram of Rotax-Leitner Generator and Starter.—Two Unit Lay-out.

on the other terminal of the battery after replacing the cables on the terminal previously disconnected. If an indication is obtained it must be "cleared" by examining all the cables in their most likely places, such as bends, sockets, under cleats, etc.

To test for a short-circuit in the wiring. A short may be suspected when the bulbs are dull red. To locate

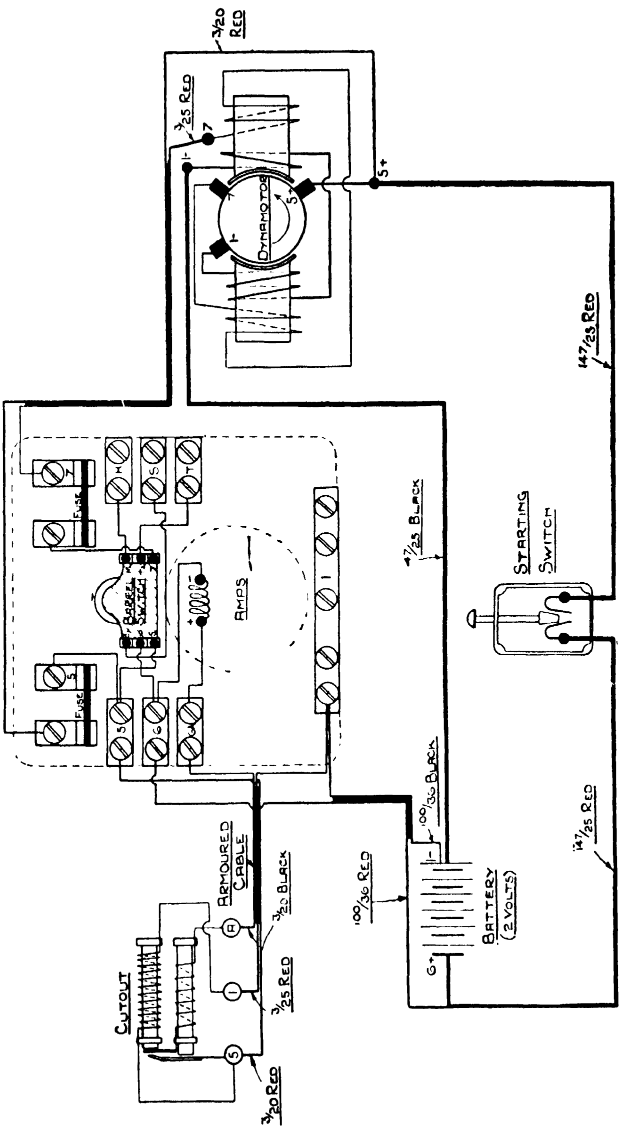


FIG. 182.—Lay-out of Rotax-Leitner Combined (Two-in-one) Generator and Starter System. Wiring to Lamps not shown. The Wires should be carried to the same Numbered Terminals as above.

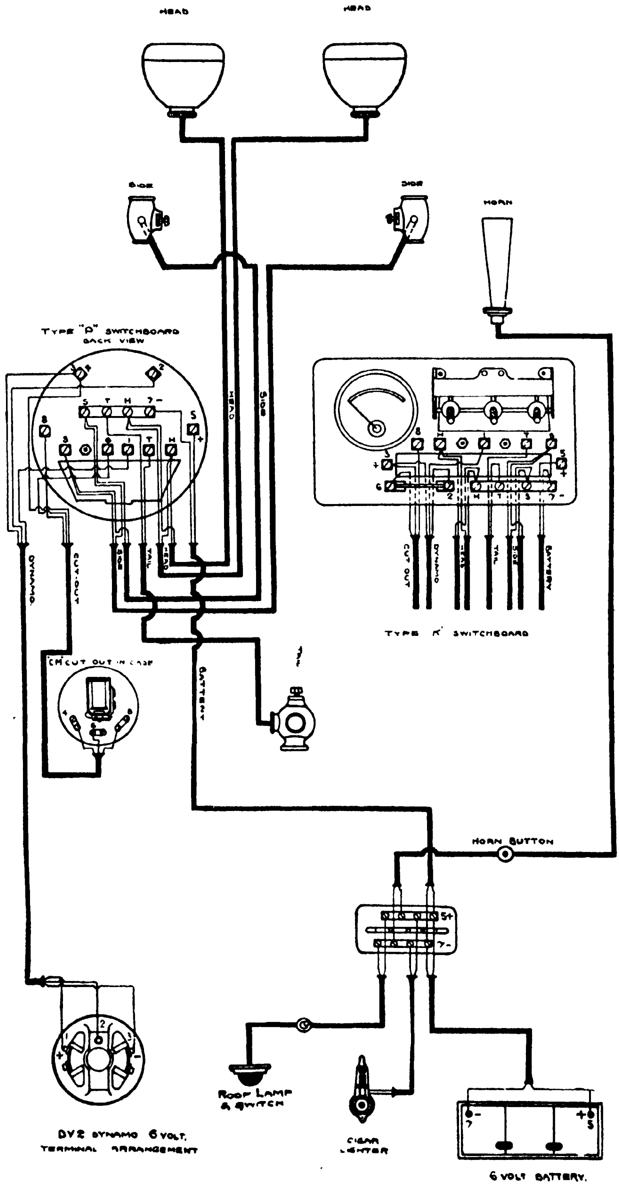


FIG. 183.—Wiring for Brolt 6-volt Set.

the trouble disconnect each lamp cable on the switch-board in turn, when the remaining lights glow brightly

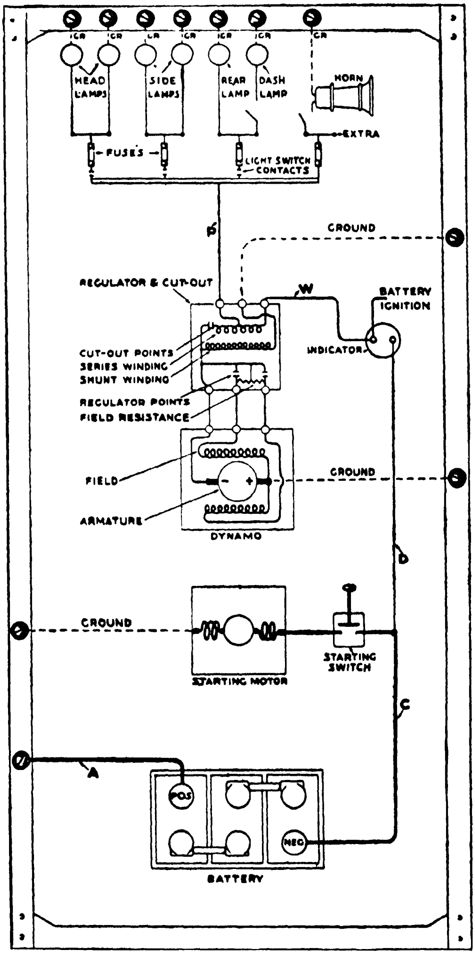


FIG. 184.—Diagram of Connections for the Gray and Davis Plant.

the faulty cable has been found. Be sure to switch the lights off when disconnecting the cables, and switch on only when ready to test, or the excessive current may injure the battery and switchboard. If one of the wires from the battery is disconnected and touched on to the terminal again, a characteristic snappy spark will be noticed if the wiring is shorted anywhere. It is not unlike the noise of a wax vesta being rubbed on the pavement. The spark from a normal load makes a different kind of splutter and is not so pronounced in volume. We have assumed in the above that the battery itself is O.K.

Tracing Circuit Troubles.

When a customer brings in his car and complains that his lights burn "red" and his starter cranks his engine backwards, he may have mechanical, mental, or electrical trouble. To ascertain which, it is necessary to do a series of systematic tests. Upon an average, very little time will be saved by guessing or having a "hunch" where the trouble is. True, one might, as a result of long experience, locate the trouble right off, but one will miss several other secondary and potential troubles which would be revealed by systematic inspection and testing. For example, the battery may have chronic constipation, and need a set of new plates or at least half a dozen separators! A separator in time saves nine—*plates*! Too much stress cannot be laid upon a thorough inspection of the battery, as this unit is the most ill-used of any, and complains the least, and always dies game right on the job!

A Few Battery Pointers.

(*a*) Have acid level ¼ inch above plates.

(*b*) See that its specific gravity is 1·225.

(*c*) Take out a sample with a syringe, and note its colour; if dirty, empty battery and re-fill with fresh 1·225 s.g. acid, taking care that it is supplied by an accredited manufacturer of *accumulator* acid and added *only at the conclusion of a charge.* It is a mistake to add charged gravity acid to a discharged battery. American batteries call for a higher specific gravity than ours, and this of course should be heeded. The commercial acid contains traces of ammonia compounds, which in time dissolve out the antimony in the grids which support the paste, thereby allowing the lead to become active material like the paste. The presence of antimony in the lead deters this action.

(*d*) The temperature of the battery (a most important point) must not exceed 110 deg. Fah., and is best at 80–90 deg. Fah. If higher than 110 deg. Fah., reduce the dynamo output.

(*e*) The amount of charge in a battery is proportional to the specific gravity differences; thus from the charged s.g. of 1·225 to the discharged s.g. of 1·175 we have 1·225 — 1·175 = 50 points (of difference) for full usage. Now, therefore, if upon hydrometering the cells we get an average s.g. of 1·200, we subtract this from the full s.g. value, and we obtain 25 points discharged, or 25 over 50 = $\frac{1}{2}$ discharged. In adjudication of the differences of s.g. readings in the same battery do not bother about any slight discrepancy which may exist between the component cells. However, if the between-cell variation is over 15 points, it indicates something wrong.

(*f*) Always return test acid to the cell it is taken out of.

(*g*) Discharged plates tend to crystallize, and the paste hardens, and hardened plates have poor energy-storing capacity.

(*h*) Do not over-discharge and charge at advertised rates.

(*j*) Tag or mark the wires and battery leads or binding posts before removing the battery for charging, so that the wires can be again connected exactly as they were. When replacing the battery, be certain that the proper wires are connected to the positive and negative terminals of the battery, but before connecting the second wire see that the switches are "*off*."

(*k*) For corroded terminals try soaking them with bicarbonate of soda ($NaHCO_3$) for 15 minutes.

General Inspection Service of the Installation.

It is well to encourage customers to have their car-lighting and starting systems regularly inspected, so that impending trouble may be caught early, and, if possible, forestalled. The following is a typical circular for sending out to customers, with a view to encouraging satisfactory electrical relations :—

ELECTRICAL SERVICE

Upon receiving notice from the Owner that he wishes to avail himself of the Service, his name and address is noted on our records, together with full particulars of the electrical equipment.

An approximate date is then given to him upon which to bring the car to our Depot for Service. When the inspection is made, a record is kept as to the condition of the equipment, and any existing or potential defect which should be dealt with is notified to the Owner. (See below.)

Later, at a suitable period, a postcard is sent to the Owner advising the due date for the next inspection. This is then made, recorded, and the service then carries on automatically.

TERMS

Inspection of accumulators, filling up with distilled water or acid as required, and general survey of equipment, 2s. per time per vehicle.

This price includes the removal of any small obvious and easily dealt with "fault," but does not include anything in the nature of a repair, or removing an obscure or difficult "fault." Such are notified to the Owner (unless we are given an open order to deal with them), and the Owner decides in what manner these shall be dealt with.

The Service Contract can be entered into for three, six, or twelve inspections, and, to keep the cost as low as possible, we must ask for the fees to be paid in advance. If a series is entered into and for some reason the full number is not completed a proportional rebate will be allowed.

MILNE AND RUSSELL, LTD.

CROYDON.

Apart from the battery inspection just set forth, it is desirable to give the wiring the "once over," paying attention to the following points :—

Hints *re* Armoured Cables and Connections.

(*a*) Frayed armouring—particularly frequent where cables go into switchboard. The remedy is to draw it up tight, and secure by a dab of solder, and cut off the frayed portion.

(*b*) See that there are no armoured cables with the ends pointing upwards and which are unprotected from the weather, as these will form convenient traps for rain.

(*c*) Pay special attention to the condition of the wiring that passes through the metal valances, as at the point where the battery cables pass through the sheet metal valance behind the running board on their way from the battery box to the dynamo or switch-box. Usually a suitable insulation is provided for the armour to pass through, but after a time it is apt to fracture and come adrift. The insulation should be pushed back into place and retained there with a piece of insulating or friction tape, wrapped tightly up against the insulation upon each side of the valance.

(*d*) Any wires which are in close proximity to a moving part should be pulled back out of danger ; they sometimes come unfastened from their moorings.

(*e*) Note the condition of the cable entrance at the plug ends of the cables. If a pin system is used, see that these pins make positive contact. If of the split variety, spread them a little if loose. In the case of bayonet equipment sometimes the fit into the female portion of the holder has become poor, owing to the weakening of the lamp socket stud springs. In such a case, drop a bead of solder on the adaptor contacts, and file flat, but let the contact surface stand a little "proud."

(*f*) All wires must be installed so that there is no danger of interference with operating rods, levers, etc., which will in time wear through the insulation and cause grounds, or short circuits.

(*g*) All connections to switches, ammeter, etc., must be made by special terminal connections, or the wire may be looped and dipped in solder. All frayed strands of wire must be carefully clipped off to prevent bridging across terminals and causing a short circuit or earth.

(*h*) All connections to lamp terminals and connectors must be made by first twisting the strands of wire tightly together and then dipping in solder. Before making the connections, all loose strands of wire must be carefully removed.

(*j*) All screw terminals and connectors must be made up tight. Make certain that the wire is securely clamped when the screw is tightened down.

(*k*) Every wire, connector, adaptor, and socket must be absolutely insulated from the car, and must not be in metallic contact at any point, except where the connections are made at the terminals of the apparatus.

(*l*) All wires must be insulated from each other at points where permanent connections are made. Such connections must be soldered and taped.

(*m*) Wires must be held in position by cleats or clips so that there is no possibility of sharp metal corners or edges wearing through the insulation.

(*n*) Do not forget that grease, oil, and water have a rotting action on insulation; so keep them off the wires as much as possible.

(*o*) All screw connections should be examined occasionally, to make certain that none have worked loose from car vibration.

(*p*) All connections, where possible, must be thoroughly wrapped with tape. In the case of connector terminals the tape should be drawn between terminals to make certain that no frayed strands of wire are bridging across to form a short circuit.

(*q*) Very careful attention should be paid to every detail of the wiring, especially keeping in mind the possibility of loose strands bridging across from one wire to another, or to the metal parts of the car, lamps, connectors, switches, and other fittings. Also the possibility of breaking of wires and other parts from car vibration.

(*r*) Any switches, connectors, lamp sockets, bulbs, or other fittings found earthed, short circuited, worn out, or defective, must be replaced.

(*s*) Particular attention should be given to the loose wires in the lamps and other connections to the lamp sockets. Use plenty of tape to prevent the possibility of earth or short circuits caused by sharp edges.

(*t*) If the engine back-fires when being shut down and makes one or more reverse revolutions, the ammeter needle may be found pointing to extreme left-hand side of scale owing to the fact that the cut-out contacts are held closed, and thus a dead short of the dynamo and battery is taking place. This defect concerns permanent magnet machines only. Remedy by disconnecting momentarily one of the wires at the dynamo (A or B on Fig. 185) or by cranking the engine.

(*u*) Bear in mind that the wires at the dynamo are marked (+) and (—) [see Fig. 185]; and if the wires to the generator are disconnected for any purpose, make certain that these are not reversed, or the ammeter will show a "dead short" when the engine is started, and if allowed to remain so will "drain" the battery.

(*v*) Slackness of the belt will cause fluctuation of output. If machine is not capable of adjustment it will be necessary to take out a full link and insert a half-link in its place. Slack dynamo belts are apt to be left on the road! To take up a slight over-play it is permissible to "draw" (make slots of) the dynamo bolt holes.

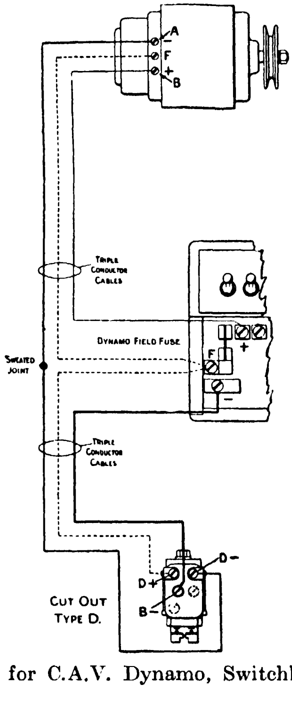


FIG. 185.—Wiring for C.A.V. Dynamo, Switchboard, and Cut-out.

Snap-shot Diagnoses

"Do not attempt to cure, gentlemen, until you have made your diagnosis."—SIR WILLIAM OSTLER.

STARTER WILL NOT START

Starting Troubles.

(1) Battery discharged. (2) Disconnections—poor brush contact at holders; faulty springs (tension should

give one-pound pressure at commutator); brushes worn too short or stuck in holders; faulty "earth" on battery chassis attachment; loose connections in motor; commutator very dirty; starting switch blades do not make contact; connections off at motor terminals, battery terminals or connectors, switch terminals. (3) Short circuits and earths—armature or field windings burned out or earthed; rotted from other causes; insulation worn off cable; metal cleats or screws cutting through insulation; starting switch shorted or earthed; defective insulation or water-soaked.

Starter Turns too Slowly

(1) Battery partly discharged, low battery efficiency, gravity of acid too low. (2) Starting switch—poor contact of switch blades. (3) High resistance in starting circuit—brushes badly fitted, part surface only in contact with commutator, no brush tension, poor brushes (high resistance), pig tails (brush leads) not making good connection. (4) Dirty commutator, loose connections in wiring.

Starter Rotates but does not Rotate Engine

Bendix Drive Type.

(1) Screwed sleeve, of Bendix drive, dirty or gummed with oil, etc. (2) Pinion not properly enmeshed with fly-wheel. To remedy, clean with rag dipped in petrol or benzine and see that pionion is quite free.

Mechanical Machines.

Overrunning clutch is at fault—(1) spring slipped out; (2) spring broken.

Metal Friction Roller Machines.

(1) Pedal not pressing friction roller in contact with fly-wheel grooves; (2) A metallic "sing" denotes bad

adjustment of roller, probably roller is touching fly-wheel, even when pedal is released ; (3) Epicyclic gear needs cleaning and oil ; give half-teaspoonful once a month. Lubricators on friction roller require a few drops of oil occasionally.

Rubber Friction Roller Machines.

(1) *The rubber drive* is fitted only to cars which are known to be exceptionally free from the presence of oil on the fly-wheel. As with the metal drive, the friction roller is first operated, followed by the switch, and should any slipping occur, this may denote the presence of oil or other foreign matter. Sometimes, after a very long run, the crank case breather ejects an oil vapour which deposits a film of oil on the fly-wheel, which cools and settles into a consistency of " tacky " rubber solution, which is most damaging to the friction roller surface. This should be removed, when improved results will be obtained.

Sets of rubber discs are supplied for replacements, and can be readily fitted to the roller by parting the aluminium housing and removing the lock nut on the spindle.

The correct adjustment is important ; when not in use the rubber roller surface should be $\frac{1}{16}$th distant from the fly-wheel face. Springs are always fitted to bring the friction roller away from the fly-wheel, and therefore the space need only be quite small.

Assuming that the fly-wheel is dry, and still the pulley does not seem to get a grip, it may be that, owing to wear or vibration, some of the bolts holding the brackets or pedal gear have worked loose, allowing so much play that the pedal is home before the pulley is making proper contact, or that the pressure is not being applied in the best position. The pulley is fixed so that it makes contact at a definite position on the fly-wheel relatively to the centre line, to take advantage of the "building up" action of the two revolving surfaces drawing in together. Obviously, if owing to a loose bracket, spring, or play in joints, this position is lost and the friction pulley can, when pressure is applied, be moved away from its correct position, no amount of pressure on the pedal will enable it to get a grip. The drawing on page 37 shows the pulley in its correct position. The above remarks apply more particularly to the rubber friction drive. The metal "V" pulley, working in a groove in the fly-wheel, will grip under much more adverse circumstances, and when fitted in the correct position no amount of oil can make it slip. Care should be taken that the pedal lever does not foul the footboard.

(2) *Shaft and Couplings.*—Considerable strain is placed on the shaft when in use, and it is therefore wise to make periodical examination to see all nuts, pins, and keys are firm and tight. The condition of the leathers should also be noted, and slackness checked to eliminate chance of noisy drive or fracture. Replacement leathers and metal disc forming a universal joint are supplied.

Lights out or Dim—Engine Stopped

Lighting Troubles.

Battery discharged, fuse blown, "short" in wiring, lamps and fittings.—(1) Connections at lamps, bare wires touching, loose strands bridging lamp terminals, sockets earthed to metal reflector, sockets short-circuited within themselves, "short" in lamp filament support. (2) Lighting and starting switches—connections at switch, bare wires touching each other or switch parts, loose strands bridging across terminals—defective switch gear—shorted in working parts, earthed. (3) Connectors and junction boxes—(*see above*)—"earthed" to car body. (4) Wire—short circuits—insulation rotted by grease and water, cut by sharp corners or metal edges;

bare wires in contact at joints through tape coming off. "Earthed"—(*see above*).

Trouble in battery.—(1) Internal leakage of current—cells worn out—buckled plates—sediment—plates disintegrating. (2) External leakage of current—acid on top of cells—insulation of wires wet with acid—corroded terminals or contact with metal box. (3) Low acid—cells broken—not filled up periodically. (4) Plates injured through jarring of loose battery fit. (5) Battery not kept charged while car is laid up.

Short in Cut-out.—(1) Earthed. (2) Contacts held closed—connections of wire to generator or battery reversed. (3) Back-firing [*see* Par. "*t*" and read up Cut-out section, on page 185]. (4) Dirty or worn-out contacts.

System overloaded.—(1) Leakage through "earths" and "shorts." (2) Unnecessary use of lights. (3) Not using standard bulbs or replacing by lamps of poor efficiency. (4) Connection of additional apparatus. (5) Faulty operation of starting motor.

Open circuits.—(Hunt for open circuits—i.e. breaks—by feeling wires at tags, terminals, etc.)—(1) Wires not making contact at terminals of battery—loose connections—wires off or poor contact—corroded terminals. (2) Connections to lighting switch terminals off or loose. (3) Wires off or loose in connector terminals. (4) Wires off or loose in lamp sockets. (5) Bulbs burnt out. (6) Halves of connectors do not make good contact [*see* Pars. "*e*," "*h*," and "*j*"]. (7) Bulb bases do not make contact in lamp socket. (8) Defective switch—contacts do not close. (9) Broken wire—search joints and "taps," back of reflectors, etc. [*see* Par. "*s*"].

Generator Trouble.

Charging rate appears low.—See that the needle of the ammeter is not bent, as this may cause it to stick.

Field magnets weak.—(A) Permanent magnet type.—

(1) Magnets want re-magnetizing. (2) No keeper used when removing magnets from machine. (3) Magnets reversed when re-assembling on generator. (B) Wound type.—(1) Shunt coil or coils earthed. (2) Short-circuited *—burnt out through disconnection of battery—coils wet. (3) Series coil disconnected.

Armature winding.—(1) Burned out—current overload through improper regulator adjustment—wet—reverse current from battery—cut-out contacts do not open. (2) Earthed.

Commutator.—(1) Defective—earthed—short between segments—loose segments. (2) Blackened or roughened—sparking from short brushes—high micas—over-lubrication—stuck brushes—no spring pressure.

Brushes and holders.—(1) Earthed—insulation faulty—deposit of metallic and carbon dust. (2) No tension on brushes—brushes worn too short—tension lost from heat—springs broken. (3) Brushes stuck in holder—binding—dirt and grease. (4) Improper fitting. (5) Overheated holders—poor brushes—sparking—no pig-tail connections.

Mechanical governor.—(1) Broken. (2) No spring tension. (3) Excessive lubrication between shoes and drum. Poor governor causes low charge current from dynamo.

Cut-out.—(1) Broken. (2) Coils burnt out or earthed. (3) Faulty adjustment—does not put dynamo into circuit with battery. (4) Platinum points sticking—excessive current—points worn out—dirty or corroded—reversed wires at dynamo terminals—back-fire of engine.

Open circuits.—(1) Dynamo terminal connection loose

* Bear in mind that with a shunt dynamo the lowering of the resistance of the external circuit takes current from the field and therefore lessens the output, through acting adversely on its E.M.F. Short-circuiting the field, although producing no heating effect, prevents the generator from working, as there is then no field to build up the E.M.F. of the armature.

or not making contact. (2) Connections to lighting switch loose or off. (3) Wires out of terminal sockets or loose. See also paragraph on Open Circuits above [page 311].

Dynamo gets very hot.—Some heat is naturally generated when dynamo is working, but excessive heating is due (1) to the gear being too high, or (2) dynamo too close to the engine, exhaust pipe, etc., (3) the design office !

Other Trouble.

All lights out or dim when engine is running.—(1) Battery partly discharged. (2) Cut-out or dynamo not working. (3) Pulley slipping. (4) Belt slipping. (5) Dynamo not generating—field broken which in mechanical and certain other types of cut-outs causes the armature to be shorted across battery at *cutting-in speed*, and at this period lamps grow dimmer in consequence. (6) Battery reversed.

One or more lights flicker.—(1) Cut-out not operating properly. (2) Broken lamp filament. (3) Bad contact in wiring, switch, connectors, or lamp holders. (4) Look at junction box connections and also fuses if used.

Some lamps bright, others dim.—(1) Partial short in wiring, switch, or lamp holder and connector. (2) Earthed. (3) Poor bulb, or made for higher voltage. (4) Blackened or nearly burnt-out bulb.

Lamps will not light from battery.—If light from dynamo brightly. (1) Broken wire from battery to switchboard. (2) Battery fuse blown. (3) Lug or connection broken at battery itself. (4) One or more cells empty of acid.

We have now completed a survey of all the most likely faults that may be met with. Troubles in the dynamo itself had best be referred to the manufacturers. The same remark applies to the starting motor.

ALPHABETICAL LIST OF CAR LIGHTING DYNAMOS DESCRIBED OR ALLUDED TO IN THE TEXT.

NAME.	PARTICULARS OF CONTROL.	PAGE.
Bijur	Electrical field regulator	107
Bleriot Phi	Reversed Compound and Rheostatic Vibrating Regulator	140*
Bosch	Electrical field regulator	106
Bottone	Reversed series winding, special distortion flaps	108*
B.R.C. Dynauto	Electric field regulator	106
Brolt	Inter-brush (four brushes)	124*
C.A.V. (Old type)	Extra poles to distort flux (Rosenberg principle)	111*
C.A.V. (New)	Inter-brush (four brushes)	117*
C.A.V. (combined ignition and lighting)	Four brush type, with ignition coil and distributor	120
Deaco	Permanent magnets and autocontroller for field	79*
Ducellier	Permanent magnets and 3rd brush with backing coil	77*
Dufty	Wheatstone Bridge scheme with lamps and pilot coil	100*
Facile	Electrical field regulator	105
Ford	Third brush control	138
Ford (unauthorised)	No battery, lights from ignition magneto	142*
Gray & Davis (mech.)	Mechanical slipping clutch	88*
Gray & Davis (elect)	Electrical field regulator (thermostatic)	299*
Klersite (G. E. Co.)	Series wound dynamo (no battery)	142
Lithanode	Hot wire and ballast coil	98
Lodge	Permanent magnet field	69*
Lucas	Third brush control	136*
Mira magnetolite	Permanent magnet field	73*
Peto Radford (P. & R.)	Mechanically governed pulley	86*
Polkey Jarrott	Mechanical, centrifugal governor and reversed series connected to third brush	85*
Powell & Hanmer	Mechanical, slipping clutch	90*
Remy	Third brush, and electrical field regulator (thermostatic)	101*
Rotax	Third brush control	132*
Rotax ignition dynamo	Third brush control and coil unit added	135*
Rushmore	Hot-wire ballast coil	96*
Smith	Inter-brush type (four brushes)	126*
Tredelect	Armature reaction and design of field	93

Denotes illustration.

ALPHABETICAL LIST OF ELECTRIC ENGINE STARTERS REFERRED TO IN THE TEXT.

NAME.	PARTICULARS.	PAGE.
Blériot-Scott ..	Dynamotor (Single unit)	255*
Brolt	Series motor (Two unit)	260* 264*
C.A.V.	Friction drive type (metal or rubber roller)	37* 307
C.A.V.	Series motor (Two unit) reinforced field, special switchgear ..	264*
Delco	Dynamotor (Single unit)	246*
Ford	Series Motor (Two unit)	36
Lucas	Dynamotor (Single unit)	250*
Lucas	Series motor (Two unit), magnetic damping device	262* 274*
Powell & Hanmer ..	Dynamotor (Single unit), mechanical machine	252*
Rolls-Royce	Series motor (Two unit)	276
Rotax	Series motor (Two unit)	245*
Rushmore	Series motor (Two unit), sliding armature	257*
Smith	Series motor (Two unit)	258* 268*
U.S.L.	Dynamotor (Single unit), flywheel type	277*

Denotes illustration.

THE REPAIRMAN'S GUIDE TO WINDINGS, ETC.

(*Kindly supplied by the* AERO ELECTRIC COMPANY, *Sydney, N.S.W.*)

N.B.—As it is frequently impracticable to procure the original type of conductor in every case, the size of an equivalent sectional area of flexible copper-stranded conductor are given. This conductor requires insulating with silk tape before use. To effect this, the flexible is first of all cut to required coil lengths, and attached by one end to a swivel situated at a convenient height. The silk tape can then be readily wrapped round the flexible.

NAME AND TYPE.	VOLTS AND AMPS.	WINDING PARTICULARS, ETC.
Apple. Start.-Gen.	6 volt (gen.) 12 volt (start.)	Two turns per coil of 3 mm. flexible.
Autolite	6 volt 14 amps.	Six turns per coil of 19 S.W.G., two coils per slot.
Autolite, G. ..	6 volt 14 amps.	Eleven turns per coil of 19 S.W.G.
Autolite, G.G. ..	6 volt	Eleven turns per coil of 19 S.W.G., two coils per slot.
Autolite	6 volt 8 amps.	Twenty-one turns per coil of 21 S.W.G.
Autolite, starter ..	6 volt	One turn per coil of 3 mm. flexible.
Bijur, S. 9 ..	6 volt	One turn per coil of 3 mm. flexible.
Bijur	6 volt	Four turns per coil of 20 S.W.G., three coils per slot.
Brolt, type C. 5 ..	12 volt	Ten turns per coil of 2/23 S.W.G. in parallel, two coils per form.
C.A.V., type E ..	12 volt	Ten turns per coil of 22 S.W.G., two coils per form.
C.A.V., M.E. ..	12 volt	Seven turns per coil of 19 S.W.G., two coils per form.
Ducellier (permanent magnet type)	12 volt	Seven turns per coil of 20 S.W.G., two coils per slot.
Genemotor ..	12 volt (2 pole)	Three turns per coil of 2/15 S.W.G. in parallel.
Genemotor ..	12 volt (4 pole)	Four turns per coil of 3 mm. flexible.

NAME AND TYPE.	VOLTS AND AMPS.	WINDING PARTICULARS, ETC.
Gray & Davis, type C.I.	6 volt 10 amps.	Nine turns per coil of 21 S.W.G.
Heinze-Springfield	6 volt	Nine turns per coil of 17 S.W.G.
Henderson (motor cycle), type S.D.A.	6 volt	Twenty turns per coil of 24 S.W.G.
Henderson (motor cycle)	6 volt	Thirteen turns per coil of 23 S.W.G.
Mira (permanent magnet type) ..	8 volt	Sixteen turns per coil of 20 S.W.G.
North-East S-Gen.	12 volt	Four turns per coil of 3 mm. flexible.
Remy	6 volt	Seven turns per coil of 18 S.W.G., two coils per slot.
Rotax ..	12 volt	Twelve turns per coil of 19 S.W.G., two coils per slot.
Simms-Huff ..	12 volt	One turn per coil of 14 S.W.G., two coils per slot.
Wagner E.M. 107 (1914)	6 volt 15 amps.	Two turns per coil of 2/18 S.W.G. in parallel, four coils per form.
Wagner E.M. 107 (1915)	6 volt 15 amps.	Three turns per coil of 16 S.W.G., two coils per form.
Wagner E.M. 107 (1916)	6 volt 15 amps.	Six turns per coil of 18 S.W.G., two coils per form.
Wagner E.M. 214 (1919)	6 volt 15 amps.	Seven turns per coil of 18 S.W.G., two coils per form.
Wagner E.M. 174 .	6 volt 10 amps.	Seven turns per coil of 19 S.W.G., three coils per form.
Wagner starter (1915)	6 volt	Two turns per coil of 2/15 S.W.G. in parallel, two coils per slot.
Wagner starter (1920)	6 volt	One turn per coil of 3 mm. flexible.
Ward Leonard ..	6 volt	Seven turns per coil of 19 S.W.G.
Westinghouse ..	6 volt 15 amps.	Five turns per coil of 19 S.W.G., two coils per slot.

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