GENERATOR OUTPUT CONTROL

LUCAS

JOSEPH LUCAS LTD · BIRMINGHAM · ENGLAND

GENERATOR OUTPUT CONTROL

INTRODUCTION

The Lucas Compensated Voltage Control Regulator was introduced and has been developed as a means of providing control of the generator so that its output is automatically adjusted to suit the state of charge of the battery. It also automatically varies the generator output according to the load or current which it is desired to draw from the battery, whatever its state of charge; it also protects the generator from overloading when the load applied to the circuit would tend to force the generator to give a greater output than it is in fact designed to give. A correctly adjusted regulator will thus enable the generator to put a greater charge into the battery when the battery is in a low state and will automatically taper off the charge as the battery becomes fully charged. If a heavy load is put on the battery (such as when the vehicle is running with headlamps on), the generator will endeavour to produce sufficient current to meet this load, so that whether the battery is in a low state of charge or not it will actually "float" in the charging system. The regulator also provides a boost charge when the equipment is cold, so that the heavy current withdrawn from the battery by the starting motor is rapidly replaced.

Present day equipment embodies, in the majority of cases, the LUCAS single contact regulator, but as the double contact unit finds some application on commercial vehicles, a full description is given in this publication. Similarly, as third brush generator regulation is still used to a limited degree, some notes on this method of control have been included.

In the explanation of the working of the Lucas Compensated Voltage Control system given in the following pages, certain abstruse technical considerations have been deliberately omitted, but these factors do, of course, have to be fully considered by Lucas Engineers when designing the equipment. It should be emphasised also that our recommendations in regard to regulator open circuit voltage settings should always be strictly adhered to if satisfactory working of the equipment is to be obtained.

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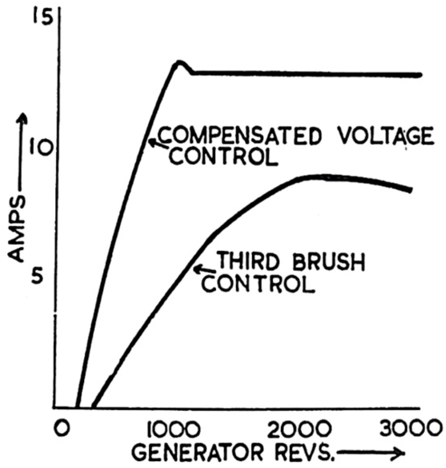
GENERATOR OUTPUT CONTROL

CONTENTS

WORKING PRINCIPLES OF THE LUCAS COMPENSATED VOLTAGE CONTROL SYSTEM

GENERATOR OUTPUT CONTROL

In considering the action of the regulator in the charging circuit, it should be realised that the voltage (and consequently the back E.M.F.) of the battery, varies very considerably according to its state of charge. Thus the back E.M.F. of the battery will be greater when the battery is fully charged than when it is in a low state of charge. The plain shunt wound generator has a rising output to speed characteristic and is by itself totally unsuitable for application to the motor vehicle. It should be borne in mind that the generator on the modern motor vehicle will be running at any speed between 600 and 6,000 revolutions per minute. In fact, with present day production model motor cycles, the generator may be driven at a speed as high as 9,000 r.p.m. The problems confronting the motor vehicle electrical equipment designer are partially solved by the third brush generator, but this type of machine does not completely cater for the requirements of the motor vehicle operator. With third brush regulation the voltage at the generator terminals will always vary according to the state of charge of the battery; in other words the voltage at the generator terminals will be the battery voltage plus the voltage or pressure necessary to overcome the resistance of the conductors in the charging circuit. Thus as the output of the third brush generator varies according to the generated voltage, it will be seen that with this type of regulation the generator output will be low when the battery is in a low state of charge, with a corresponding increase of output as the battery reaches its fully charged state.

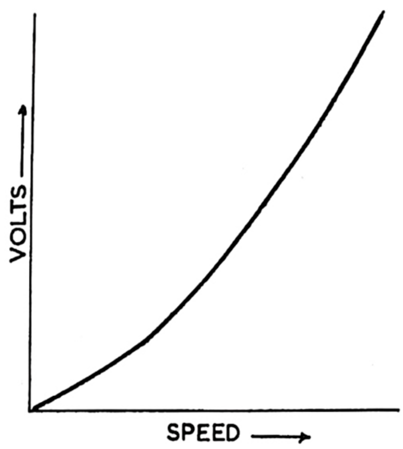


Graph I
Output to speed characteristics of (*a*) third brush generator and (*b*) voltage controlled generator

If, however, we are able to stabilise the voltage at the generator terminals at a pre-determined value and maintain this voltage no matter what the condition of charge of the battery, the difference between the battery terminal voltage and the generator terminal voltage will be considerable when the battery is in a low state of charge, the difference in voltage getting progressively less as the battery attains its fully charged state. If the pre-determined voltage at the generator terminals has been correctly set, we shall arrive at a state where the battery terminal voltage in its fully charged condition will exactly equal the generator terminal voltage. In this state no current will be allowed to flow through the charging circuit as the back E.M.F. of the battery will exactly equal the generating pressure or voltage of the generator.

CONSTANT VOLTAGE CONTROL

The plain shunt wound generator has a rising output to speed characteristic, but the output of such a machine can be controlled by inserting a resistance in the field circuit to limit the current flowing in the field windings, as, of course, the output will depend very largely on the ampere-turns of the field system. An electro-magnetic relay can be designed so that this resistance is inserted in the field circuit automatically to ensure that the generator voltage never rises above a certain pre-determined level. Under such circumstances the output of the generator would be controlled by the difference in the generator terminal voltage and the back E.M.F. of the battery. This difference would be great when the battery was in low state of charge and very little when it was fully charged. Thus we should obtain a high output from the generator when the battery most needed it.



Graph 2
Output to speed characteristics of a plain shunt wound generator

This, in effect, is a simple constant voltage control system and in practice could be arranged as follows: A resistance is connected in series with the field winding of the generator; the resistance is also shunted with a pair of movable contacts. The contacts are operated by an electro-magnet, the winding of which is connected across the main terminals of the generator. The contacts are normally kept together by an adjustable spring, the electro-magnet being assembled in such a way that when the current flows through its windings, the magnetic pull will tend to pull the contacts apart.

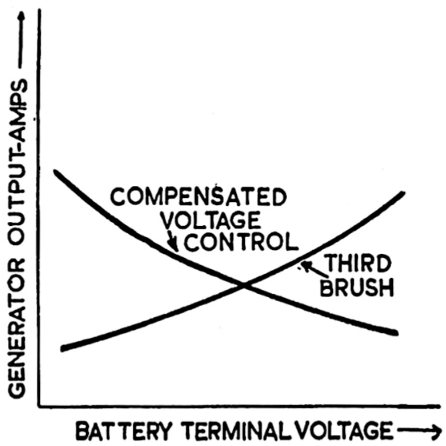
It should be explained that the resistance is of comparatively high value and its effect is such that when in the circuit practically no current will be allowed to flow in the field winding. The main duty of such a resistance is to protect the regulator points against the inductive surges which would occur when the contacts are opened at the instant when a comparatively heavy current is flowing in the field circuit.

It is now possible to examine the behaviour of the shunt wound generator and the voltage control regulator in practice. As the generator is driven and commences to charge (it will do so because of the residual magnetism in the poles of the field windings), the current will flow through the windings of the electro-magnet. However, immediately the strength of the magnet is sufficient to overcome the tension of the spring which holds the contacts together, the contacts will open. The current flowing through the field will then have to complete the circuit by way of the resistance instead of through the shorting contacts. As the resistance is of high value, very little current will then be flowing through the fields; this will weaken the magnetism of the field poles which in turn will cause the voltage at the generator main terminals to fall. The falling generator voltage will weaken the electro-magnet controlling the movable contacts and the spring will cause the contacts to close. This cycle of operations—the alternate opening and closing of the field controlling contacts—will be repeated very rapidly as long as the generator is being driven. As the speed of the generator rises, the voltage will rise and the increased voltage will exert a much bigger pull on the movable contact connected to the electro-magnet; this will cause the movable contact to travel further away from the fixed contact during each cycle. The periodicity of the cycle of operations will remain substantially constant whatever the speed and voltage of the machine; the speed of the moving armature of the electro-magnet will, however, increase with the rising output voltage because it will have further to travel during each cycle of operation. It will be apparent that whilst the periodicity of the cycle of operations remains constant, the contacts shorting out the field resistance will remain in the closed position for a much shorter period of time during each operation.

THE LUCAS COMPENSATED SYSTEM

Unfortunately, the simple constant voltage control system described above presupposes the use of a generator of very great generating capacity. If we consider the case of a battery in a low state of charge, its terminal voltage and back E.M.F. will also be low. If, in addition, we put a load across the battery (automobile headlamps), the terminal voltage will fall still lower. Under such conditions the generator will endeavour to maintain the pre-determined voltage at which the regulator is set, and an extremely heavy current will in consequence flow through the circuit. In practice, this current could be sufficient to burn out the armature of a standard automobile generator.

The LUCAS Compensated Voltage Control system overcomes these difficulties by arranging automatic variation in the *operational* voltage setting of the regulator so that the difference in the generator terminal voltage and the back E.M.F. is never great enough to cause such a heavy current to flow that the generator would be damaged. This variation in operating voltage is brought about by adding another winding to the regulator bobbin; this winding is in series with the main circuit and carries the main charging current. The regulator series winding is wound so that it assists the voltage coil of the regulator in pulling apart the moving contacts of the regulator. Thus the greater the current flowing in the main charging circuit, the greater will be the control effected by the regulator.

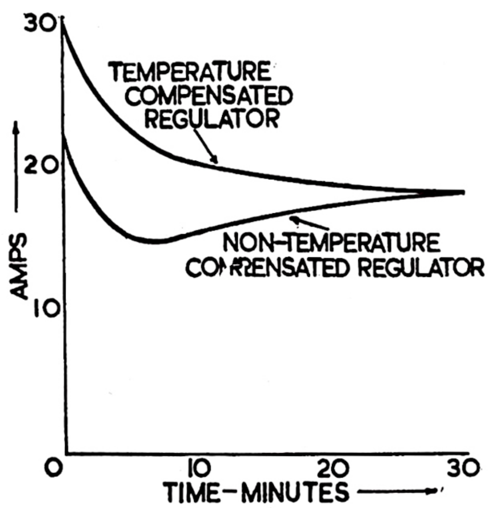


Graph 3
Effect of battery terminal voltage (back E.M.F.) on generator output for (*a*) compensated voltage control and (*b*) third brush control

Still another set of circumstances has to be considered in designing the regulator. If the battery is in a fully charged state, it is desirable that the load imposed by the lighting of the vehicle should be carried by the generator so as to maintain the battery in its fully charged state. Another winding of one or two turns only is therefore added to the compensating winding, the lighting and accessory load of the vehicle equipment being taken through this additional winding. In practice both these windings are made in one and the connection to the main charging circuit is tapped off at a carefully computed point. The result will now be that the generator is fully protected against overload when the lights are on and the battery is in a low state of charge; the battery will also "float" in the charging system when it is fully charged and the lights, etc., are switched on.

REGULATION OF GENERATOR OUTPUT WHEN COLD

When the generator is cold it is able to withstand a heavier output without fear of overloading than when it is hot. This condition coincides with our normal need for a high output as operation of the starting motor to crank a cold engine makes a considerable demand on the battery; in addition a slightly higher voltage is necessary for charging the battery when cold owing to the increased resistance of the electrolyte at a low temperature. If, therefore, we can make the spring tension of the regulator electro-magnetic armature automatically variable according to the temperature of the equipment, we can arrange for a heavier charge to be put into the battery when it most needs it at a time when the generator is able to produce a greater output without any fear of overload.



Graph 4
Effect of thermostatic control on generator output

Various metals have different co-efficients of expansion; that is, with a given temperature,

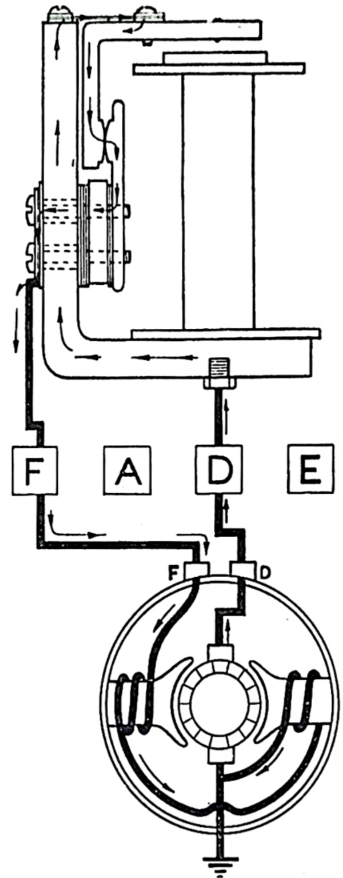


Figure 1 Generator field circuit

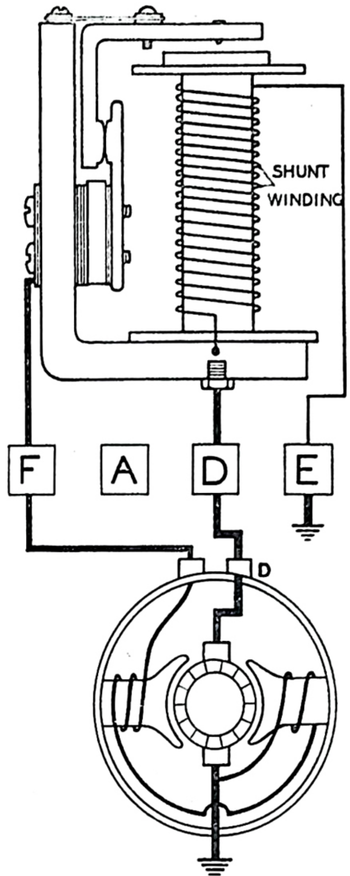


Figure 2 Regulator shunt coil

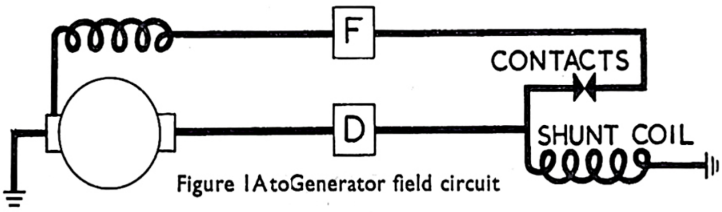


Figure 1AtoGenerator field circuit

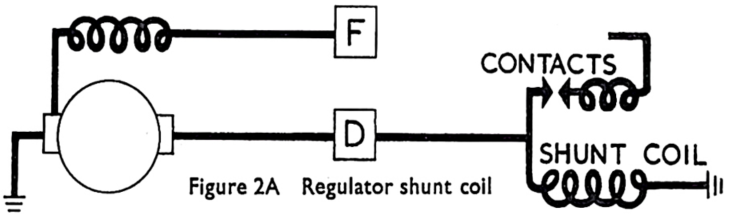


Figure 2A Regulator shunt coil

magnetic field around the regulator core. A point is reached when the magnetic pull of the core is strong enough to overcome the spring tension and separate the contacts. The field circuit is then completed by way of the regulator resistance (Figures 3 and 3A).

As the speed of the generator increases, its voltage will tend to increase also; the strength of the magnetic field in the regulator core will exert a greater pull on the movable contact and it will travel a greater distance in opposition to the tension spring. The mean result is that the cycle of operations—alternate opening and closing of the contacts—will maintain the same periodicity whatever the voltage output of the generator, but as the movable contact travels further each time with the increase of voltage, the contacts will be open for a greater average period. The net result will be that the generator output undergoes practically no change once the operating speed has been reached providing the load in the main circuit remains substantially constant. The alteration in output to meet varying loads is dealt with later. It will be obvious that the controlling voltage at which the regulator is set will depend on the amount of tension applied to the movable contact.

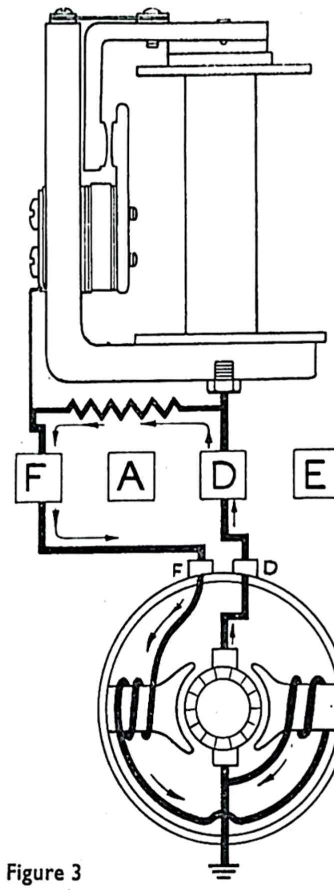


Figure 3
Generator field circuit via resistance

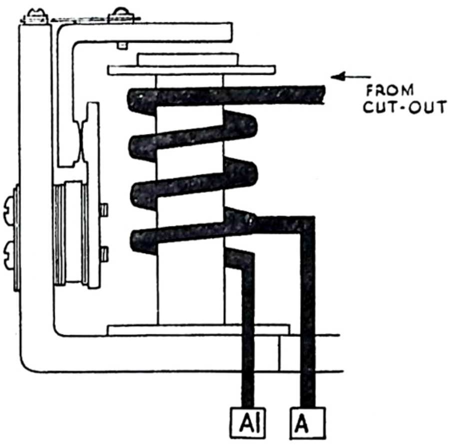


Figure 4
Regulator split series winding

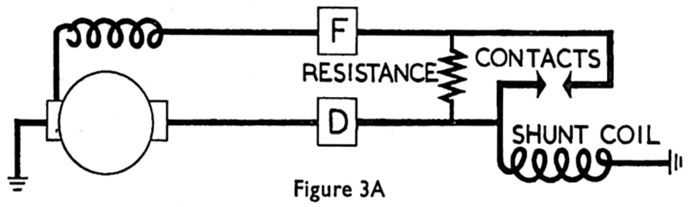


Figure 3A
Generator field circuit via resistance

Overloading of the generator when the battery is in a low state of charge is prevented by the compensating winding; this winding carries the main charging current and is wound on the regulator core so that the magnetic field already set up by the shunt winding is increased in strength. It will be seen from Figure 4 that the compensating winding consists of a few turns only of very heavy conducting wire as the main charging current may be of the order of some 20 amps. The overall effect will now be that when a heavy current over and above the rated output of the generator tends to flow through the circuit the regulator will operate at a reduced voltage and the output will be kept within safe limits. The load winding of the regulator described in the techincal section of this publication is seen as part of the compensating winding in Figure 4. Current to the headlamps, etc., of the vehicle passes through this part of the winding and enables a fully charged battery to "float" in the system when headlights, etc., are in use.

It is desirable for the generator to give a greater output when it is cold (when the ambient temperature is low) as explained in the technical section of this publication. A bi-metal strip is therefore fitted directly behind the contact spring. As the temperature rises the strip bends slightly and adjusts the operating characteristics of the regulator (Figure 5).

THE CUTOUT

The cutout is an automatic switch connected between the generator and the battery. It closes when the generator is running fast enough to charge the battery and opens when the speed is low or the engine is stationary, thus preventing current flowing from the battery through the generator windings (Figure 6).

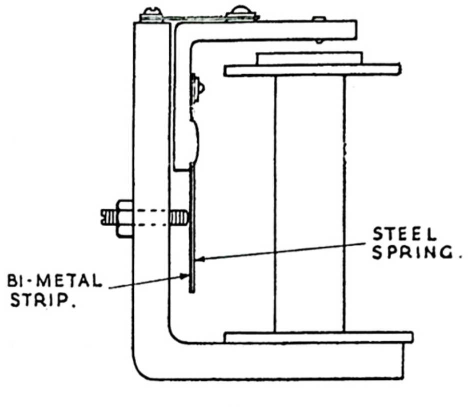


Figure 5
Bi-metal strip fitted behind contact tensioning spring

The switch consists of a pair of contacts which are held open by a spring and closed magnetically. When the engine is stationary or running slowly the contacts should be open.

There are two windings on the cutout core—a shunt winding of many turns of fine wire and a series winding of a comparatively few turns of thicker wire. Whenever current flows in either winding, the core becomes a magnet, the strength of which depends upon the amount of current flowing.

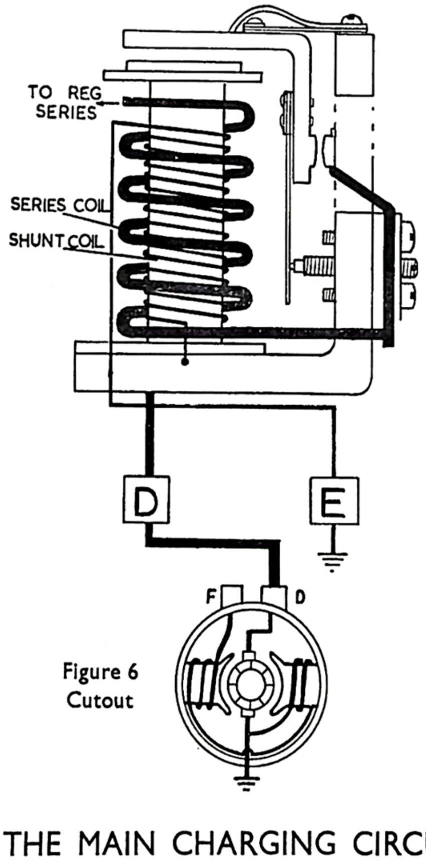


Figure 6
Cutout

The shunt coil is connected across the generator terminals. When the engine is started the generator voltage rises with the engine speed, until the electro-magnet is strong enough to overcome the spring tension and close the contacts. Current from the generator will now flow through the series coil to the battery. The series coil also sets up a magnetic pull which adds to that of the shunt coil, so that the contacts are firmly closed and cannot be separated by vibration.

When the engine slows down the generator voltage decreases until it is lower than that of the battery, i.e., below either 12 or 6 volts according to the voltage of the equipment. Current will now pass through the series winding in the reverse direction, i.e., from the battery to the generator. This will cause the partial demagnetisation of the cutout core, allowing the spring to separate the contacts and so open the charging circuit.

THE MAIN CHARGING CIRCUIT

The main charging circuit carries current from the generator to the battery. The circuit can be traced through Figure 7; the current flows from the generator armature to the "D" terminal on the generator. This terminal is connected to the "D" terminal at the control box, and a metal connecting strip joins the "D" terminal to the "L" shaped regulator frame, causing the frame to be at generator potential.

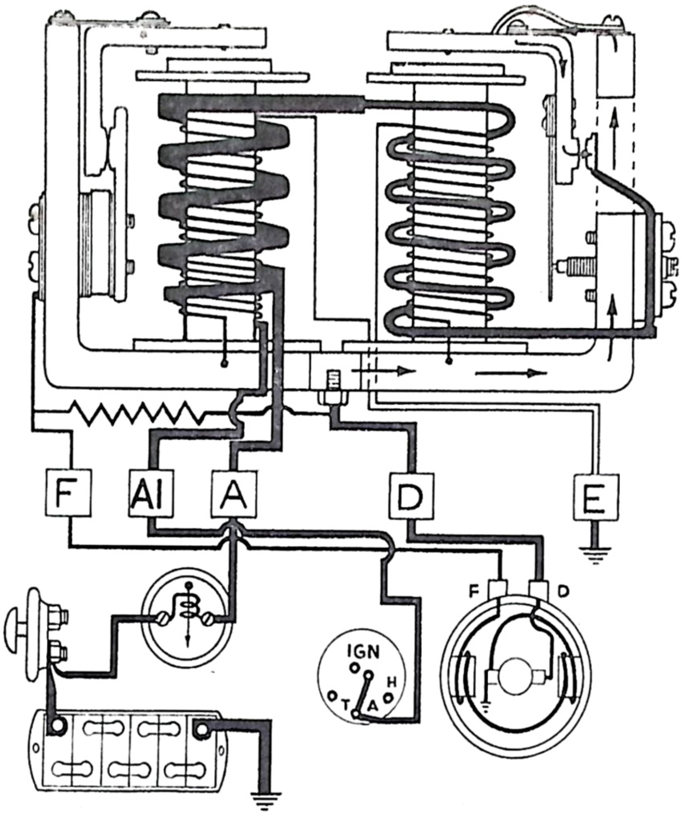


Figure 7 The main charging and load circuits (shown in heavy lines)

When the cutout points close, the current is able to flow through the series winding of the cutout and through the regulator series winding to the "A" terminal. The current then passes through the battery by way of the ammeter; the circuit is completed through the chassis frame of the vehicle and so to the earthed brush of the generator. It should be noted that the starter switch terminal shown in the circuit is used only as a convenient junction for the wiring.

LOAD CIRCUIT

The current for the load circuit is taken via a junction on the series turns to terminal "A1" and from there to the main lighting and ignition switch. The reason for splitting the series turns in this manner is explained on page 7.

AUXILIARY CIRCUITS

The "A2" terminal is connected to "A1" through a 35 amp. fuse marked "AUX". Any accessories connected to this terminal will be fed from the battery through the ammeter, and will have a fuse in the circuit (Figure 8).

Terminal marked "A3" is connected to the coil side of the ignition switch so that it will only be fed when the ignition is switched on. There is no fuse in this circuit.

Terminals marked "A4" are connected to "A3" by a 35 amp. fuse marked "AUX.IG". Accessories connected to "A4" will only operate when the ignition is switched on, and will have a fuse in the circuit (Figure 8).

ADJUSTMENT OF THE REGULATOR

The only adjustment normally needed to be made to the regulator is to the open circuit voltage setting. A high grade moving coil voltmeter (reading to 30 volts with half-volt divisions) must be used for this purpose and the regulator must be disconnected from the main circuit.

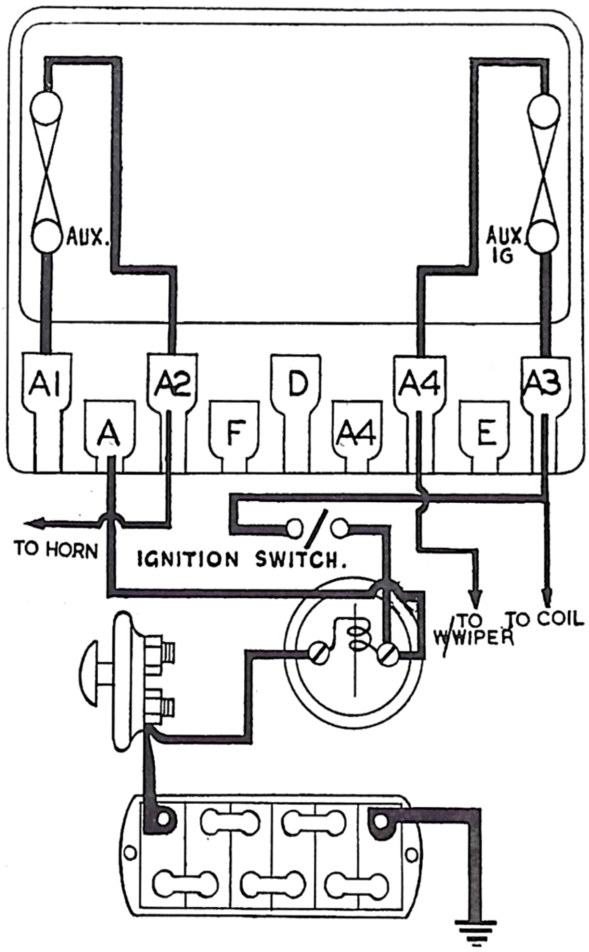


Figure 8 Auxiliary ignition and accessories circuits

The regulator can be isolated from the main circuit by inserting a piece of thin card between the cutout points. It is recommended, however, that the cables connected to the terminals marked "A" and "A1" be withdrawn and joined together for this purpose. Connect one lead of the voltmeter to the "D" terminal of the generator and the other lead to the generator-end bracket or other convenient point at chassis potential.

Slowly increase the speed of the engine until the voltmeter needle "flicks" and then steadies; this should occur at a voltage reading between the limits given in the appropriate section of this publication giving the open circuit voltage settings for all model regulators. When the generator is run at a high speed on open circuit, it builds up a high voltage, therefore, when adjusting the regulator, do not run the engine up to more than half-throttle or a high voltmeter reading will be obtained which will not be a true indication of the correct open circuit voltage setting.

If the voltage at which the reading becomes steady occurs outside these limits, the regulator must be adjusted. Release the locknut holding the adjusting screw, and turn the screw in a clockwise direction to raise the setting and anti-clockwise to lower the setting. For 12 volt sets, approximately one quarter turn of the screw will give a variation of one volt in the open circuit voltage setting. Tighten the locknut after adjustment is completed, and remake connections to terminals "A" and "A1".

MECHANICAL SETTING

The mechanical setting of the regulator is accurately adjusted before leaving the works and providing the armature carrying the moving contact is not removed, the regulator will not require mechanical adjustment. If, however, the armature has been removed from the regulator for any reason, the contacts will have to be reset (Figure 9). To do this proceed as follows:

Slacken the two armature fixing screws.

Insert a .018″ feeler gauge between the back of the armature and the regulator frame.

Press back the armature against the regulator frame and down on to the top of the bobbin core with the gauge in position; lock the armature by tightening the two fixing screws.

Check the gap between the underside arm and the top of the bobbin core. On earlier types of regulators, fitted with a stop rivet, this gap should be .020″—.028″ (not under the stop rivet). On later types a shim is fitted to the underside of the arm, and in these cases, the gap should be .010″—.018″. If the gap is outside these limits correct by adding or removing shims at the back of the fixed contact.

Remove the gauge and press the armature down, when the gap between the contacts should be .006″—.017″.

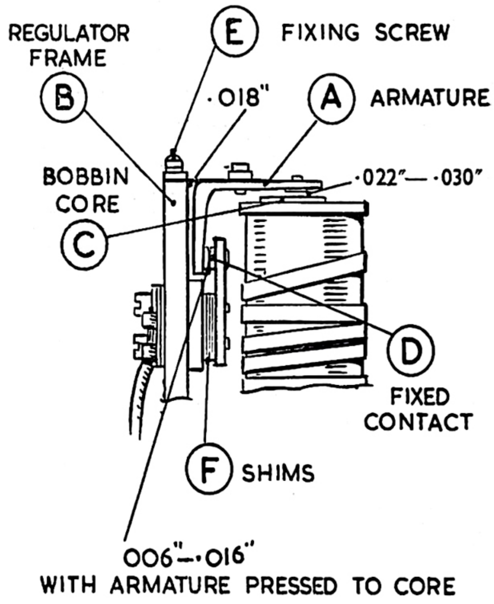


Figure 9
Regulator air gap settings

CLEANING CONTACTS

To render the regulator contacts accessible for cleaning, slacken the screws securing the plate carrying the fixed contact. It will be necessary to slacken the upper screw a little more than the lower so that the contact plate can be swung outwards. Clean the contacts by means of fine carborundum stone or fine emery cloth. Carefully wipe away all traces of dirt or other foreign matter. Finally tighten the securing screws (Figure 10).

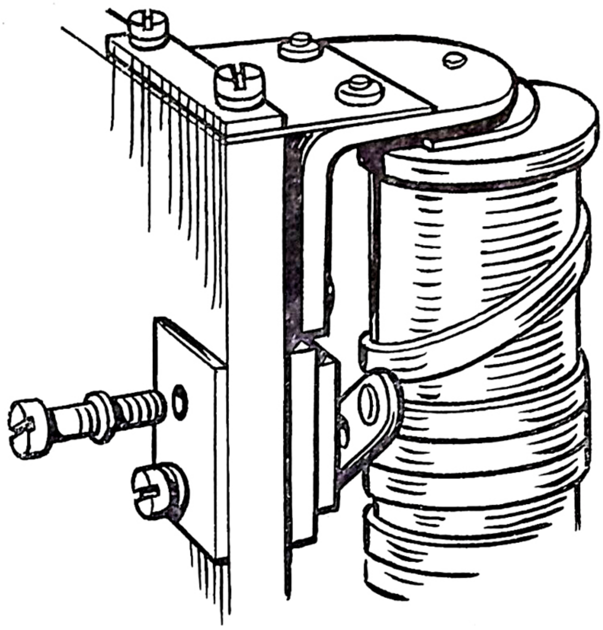


Figure 10
Position of contact for cleaning

REPLACEMENT OF CONTACTS

If the contacts are found to be badly worn, they must be replaced.

Remove the armature by withdrawing the two screws which secure the armature to the regulator frame, fit new armature in position, but do not tighten its securing screws. Insert a feeler (.018″ thick) between the regulator frame and the back of the armature. Press the armature firmly against the gauge so that the back of the armature is parallel with the frame. Tighten the screws securing the armature (Figure 11).

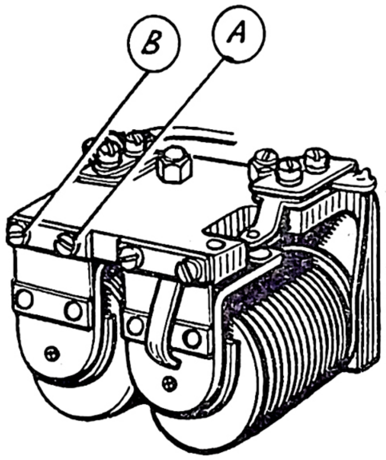


Figure 11
"A" and "B" — screws securing armature

To fit a new plate carrying the fixed contact, slacken the fixing screws (as described in "Cleaning Contacts") so that the old plate can be swung outward. The upper screw is now free and can be screwed into the corresponding tapped hole in the new plate.

Now slacken the lower screw until the old contact plate can be withdrawn, move the new plate into its vertical position and secure the plate by tightening both screws. (This procedure avoids displacing the insulation and distance pieces under the plate.)

The space between the armature and frame should be checked by inserting a feeler gauge between the armature and frame immediately behind the contacts. This gap should be .018″.

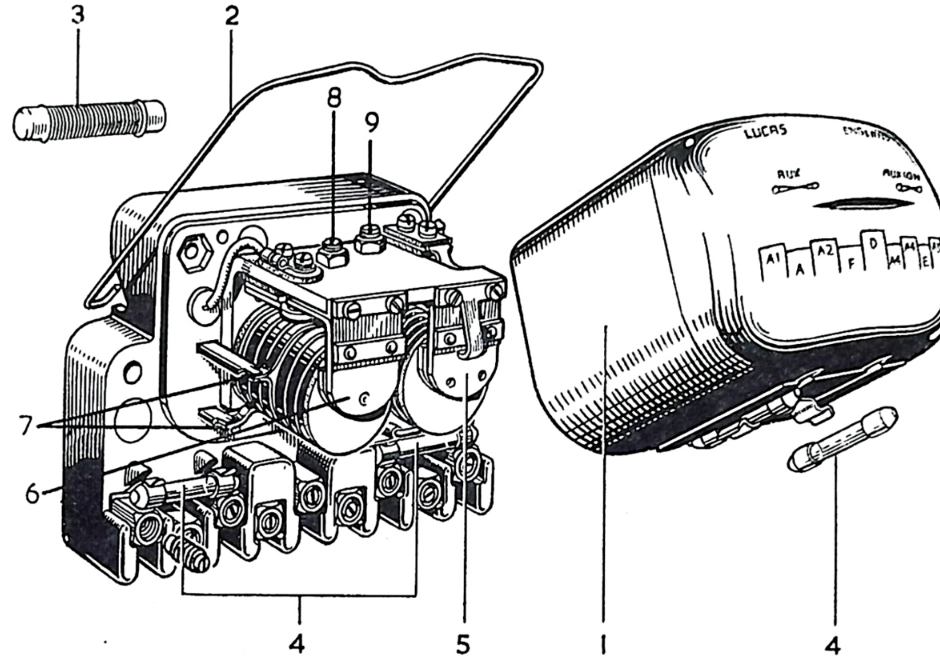
If necessary, adjust the position of the fixed contact by means of shims .005″ thick which must be fitted between the fixed contact plate and the packing plate. When the armature is pressed right down, the gap between the contacts must lie between .006″—.017″. Adjust the setting of the regulator as previously described.

ADJUSTMENT OF THE CUTOUT

If it is suspected that the cutting-in speed of the generator is too high, connect a suitable voltmeter between the terminals marked "D" and "E" on the cutout unit and slowly raise the engine speed. When the voltmeter reading rises to 12.7 volts—13.3 volts for 12 volt equipment and 6.3 volts—6.7 volts for 6 volt equipment the cutout contacts should close. If the cutout has become out of adjustment and operates at a voltage outside these limits it must be reset. To make the adjustment, slacken the locknut and turn the adjusting screw a fraction of a turn in a clockwise direction to raise the operating voltage and in an anti-clockwise direction to lower the voltage. Tighten the locknut after making the adjustment.

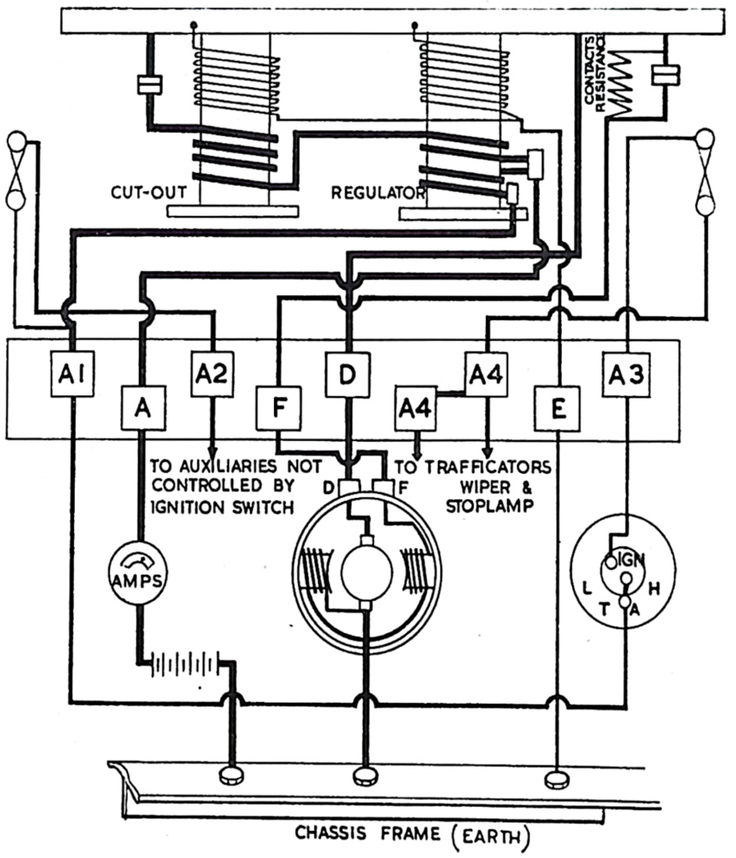
Continued on page 18

SINGLE CONTACT REGULATOR
COMPENSATED VOLTAGE CONTROL

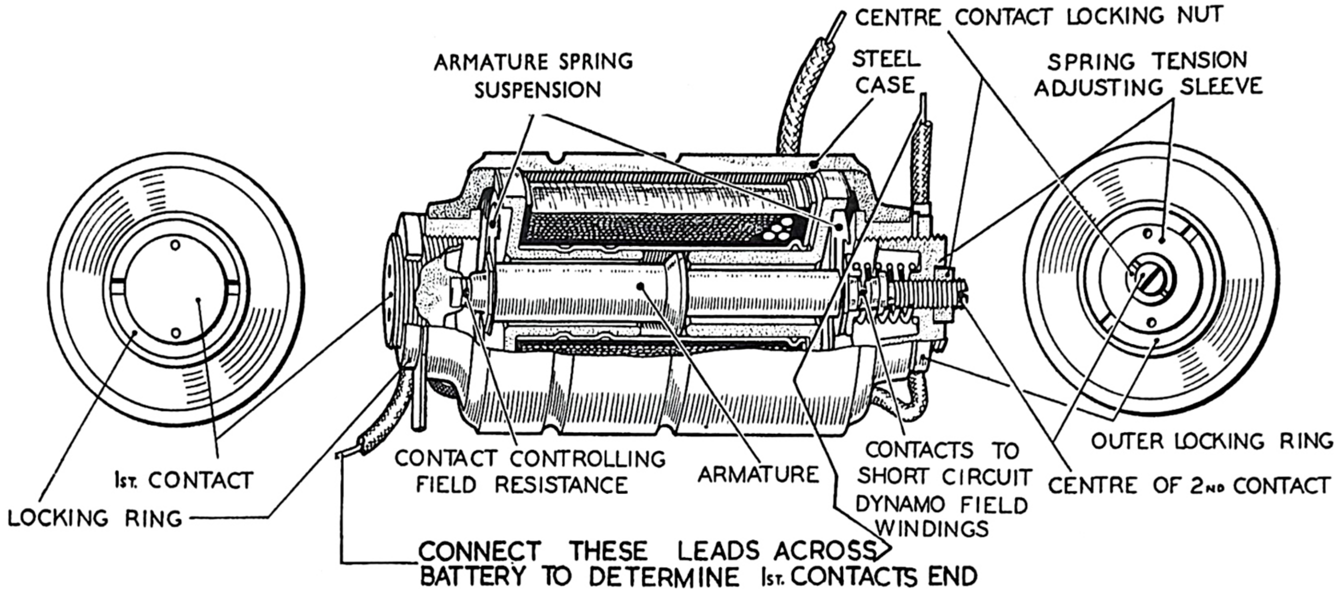


1. COVER.
2. COVER CLIP.
3. RESISTOR.
4. FUSES.
5. CUT OUT ARMATURE.
6. REGULATOR ARMATURE.
7. SPLIT SERIES WINDING.
8. REG. ADJUSTING SCREW.
9. CUT OUT ADJUSTING SCREW.

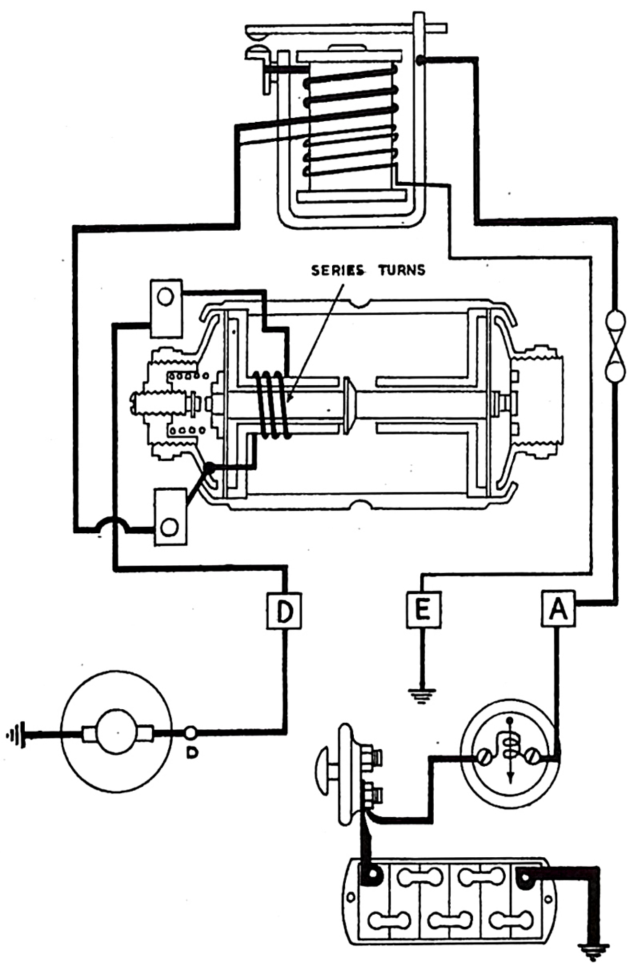
DIAGRAMMATIC LAYOUT
OF RF95 CONTROL BOX



DOUBLE CONTACT REGULATOR COMPENSATED VOLTAGE CONTROL



DIAGRAMMATIC LAYOUT OF DOUBLE CONTACT REGULATOR



MECHANICAL SETTING

As in the case of the regulator, adjustment of the mechanical setting of the cutout should not be necessary in normal service. Figure 12 illustrates the correct air gap settings which must be retained if for any reason it is found necessary to dismantle the cutout. On later types, a .005″ brass shim is fitted to the underside of the cutout armature, and the gap between the armature and core face in these instances must be .011″—.015″. (Figure 12 indicates the settings obtained when the brass shim is not fitted.) The contact gap of .002″—.006″ shown in Figure 12 is obtained with a feeler gauge .030″ between the cutout armature and bobbin face. This gap should not be confused with the operating gap of approximately .030″ which will be obtained with a correctly set cutout.

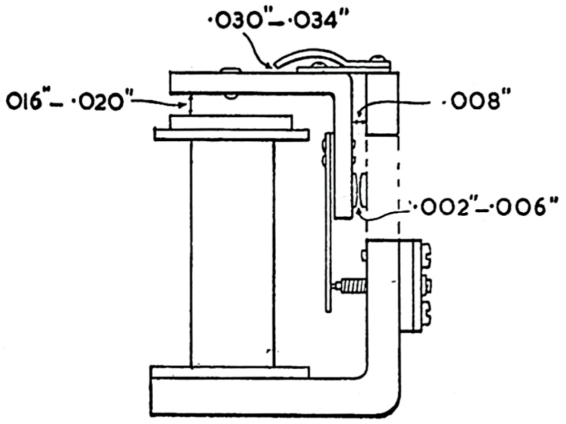


Figure 12
Cutout air gap setting

CLEANING CONTACTS

To clean the contacts, remove the cutout cover, place a strip of fine glass paper between the contacts and then, closing the contacts by hand, draw the paper through. This should be done two or three times, with the rough side towards each contact.

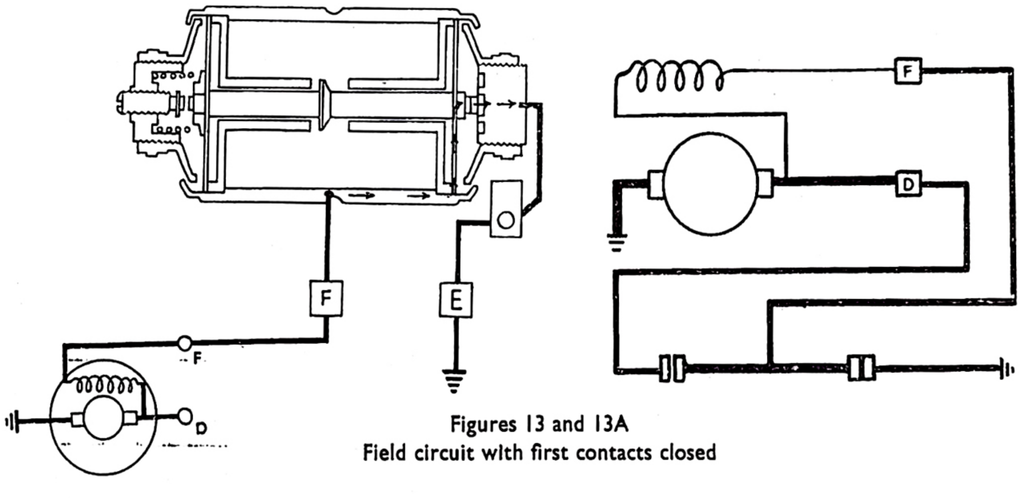
DOUBLE CONTACT REGULATOR

PRACTICAL CONSTRUCTION AND OPERATION

The Double Contact Regulator was used as standard equipment on many vehicles some years ago, but has now been superseded for all normal purposes by the single contact unit. Its use is now mainly restricted to commercial vehicles.

Its operating principles are similar to those of the single contact unit, but an additional pair of contacts are incorporated in order to obtain greater control of output at high speeds. The first set of contacts function in exactly the same way as those on the single contact pattern, but immediately the amplitude of vibration increases due to high voltage generated, the second set of contacts come into operation and completely short out the field system. In this way excessive output at higher speeds is fully controlled.

The regulator consists of a cylindrical steel shell housing two windings, while an armature carried on a pair of guide springs moves axially at its centre. This armature carries at its two extremities the moving elements of two pairs of contacts which control the field circuit, one pair serving to insert a resistance, while a second pair, on further movement of the armature, short circuits the field winding itself. The first pair of contacts are held closed by means of a spring when the regulator is inoperative (Figures 13 and 13A).



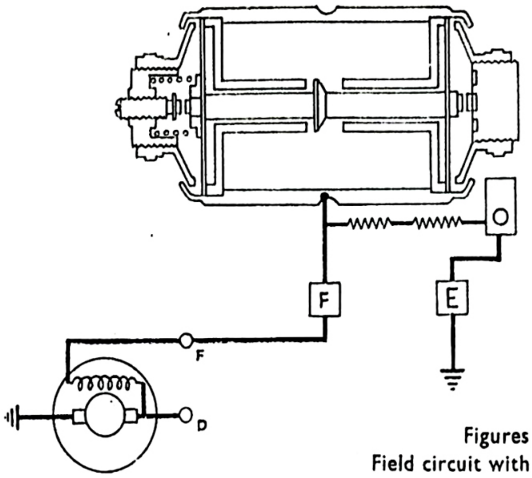
Figures 13 and 13A
Field circuit with first contacts closed

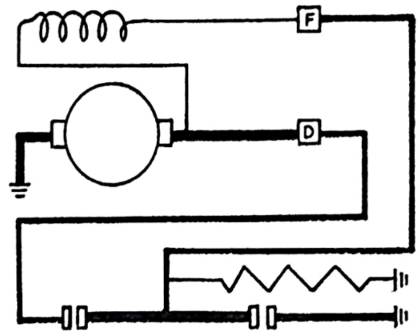
The windings consist of a voltage winding connected directly across the generator terminals and a current winding which carries the full current from the generator to the battery. These coils assist each other in energising the magnetic system and thus effecting movement of the armature.

When the generator voltage reaches a pre-determined figure, the magnetic field set up by the voltage winding becomes sufficiently strong to attract the armature. This causes the first set of contacts to open, thereby inserting the resistance in the field circuit (Figures 14 and 14A).

This reduction in the field current lowers the generator voltage, and so weakens the magnetic field, allowing the armature to return to its original position, thus closing the contacts. This cycle is then repeated, and the armature is set into vibration.

As the speed and generated voltage rise, the amplitude of vibration increases and the periods of interruption increase, with the result that the mean value of the voltage at the generator terminals undergoes practically no increase once the operating speed has been attained.

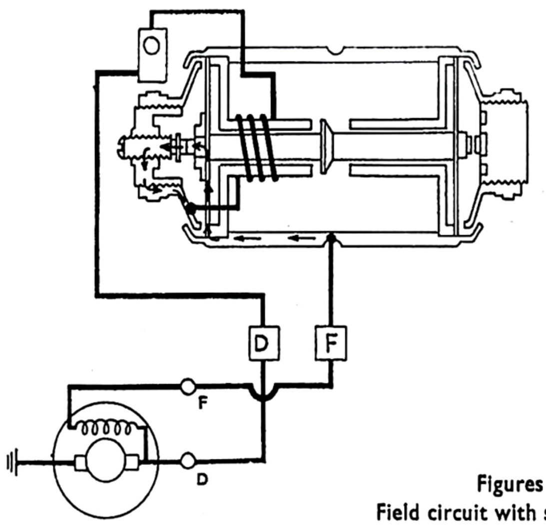


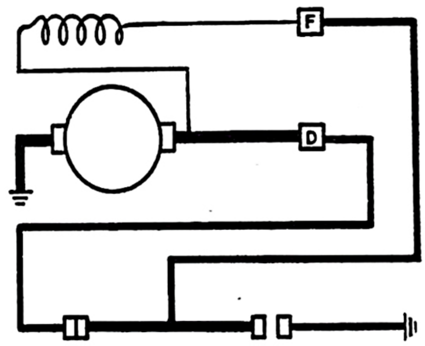


Figures 14 and 14A
Field circuit with first contacts opened

When the amplitude of vibration increases beyond a certain point, the second pair of contacts come into operation, short circuiting the field winding of the generator (Figures 15 and 15A). The initial movement of the armature, therefore, inserts resistance in the field, and additional movement short circuits the field winding entirely, so as to give a still more pronounced regulating effect.

The operational voltage of the double contact regulator is controlled by the compensating winding in exactly the same way as with the single contact regulator. It should be noted, however, that a load winding is not incorporated in the compensating winding.





Figures 15 and 15A
Field circuit with second contacts closed

TEMPERATURE CONTROL

On certain types of double contact regulators temperature control is incorporated. For this purpose a second shunt winding is used, wound so that its magnetic effect is in opposition to the main shunt winding. The main shunt itself is made up of a low resistance coil of copper wire and connected in series with this winding is another coil wound with Eureka wire, the resistance of which is practically unaffected by temperature change (Figure 16). As the copper turns form only about one quarter of the total resistance of these two windings, the effect of temperature change on the main shunt is negligible.

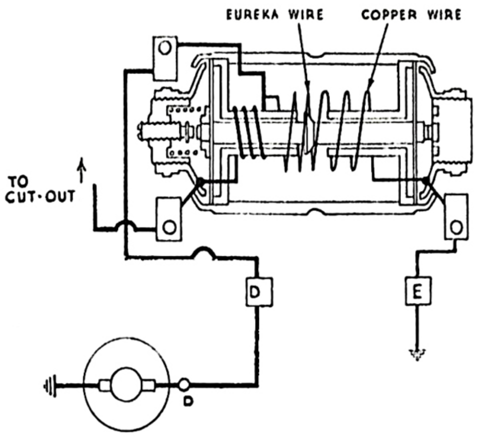


Figure 16 Main shunt coil

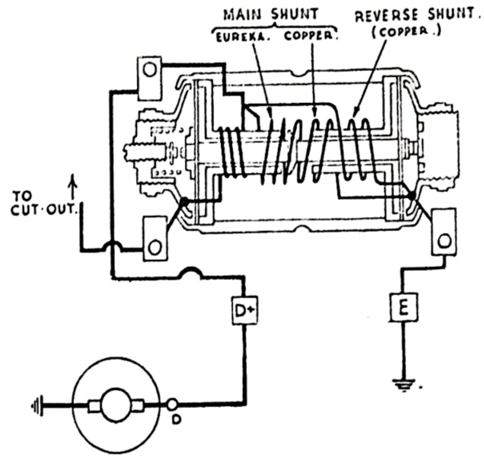
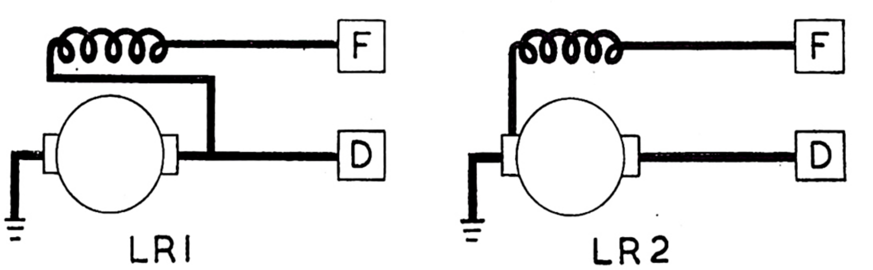


Figure 17 Reverse shunt coil

The reverse shunt is wound of fine gauge copper and is connected in parallel with the main shunt. This winding is of high resistance compared to the main shunt, and being of copper its resistance varies with temperature so that when hot it passes less current than when cold (Figure 17).

The magnetic pull set up by the reverse shunt opposes that of the main shunt, which means that the main shunt will require a higher voltage across it to overcome the spring tension and open the regulator contacts. When the regulator is cold, the reverse shunt carries more current so that its demagnetising effect on the main shunt is more pronounced; as the temperature of the regulator rises the resistance of the copper reverse shunt increases so that it takes less current and its demagnetising effect is reduced. The result is that the regulator will operate at a high voltage when cold, the voltage being reduced as the temperature rises.

Regulators incorporating the reverse shunt winding can be identified by a blue band painted round the one end of the barrel.



Figures 18 and 19 Methods of connecting field circuits

ADJUSTMENT OF OPEN CIRCUIT VOLTAGE

There are two methods of connecting the field circuits when a double contact regulator is used to control the generator output, and care must be taken to ascertain which method has been adopted before any adjustment is made to the regulator.

The method used will be either LR1 or LR2 according to the type of regulator fitted (Figures 18 and 19). The LR1 connections are made with one end of the field winding to the insulated brush of the generator, the other end of the field winding being connected to earth. The LR2 connections (the method used on present day vehicles) are made with one end of the field winding connected to the earth brush, the field circuit being completed when the other end of the field winding is connected to generator main terminal (insulated brush).

If it is only required to adjust the open circuit voltage setting of the regulator, this may be done without disturbing the first contact, providing that the regulator has not been interfered with. A high grade moving coil voltmeter, scale 0-30 volts in half-volt divisions, should be used to check the readings, proceeding as follows:

1. Place a piece of paper between the cutout points to isolate the regulator from the main charging circuit. (It is not convenient with this type of control box to remove the cables for this purpose.)
2. Connect voltmeter between the "D" terminal (to which the lead from the inside of the regulator is connected) and earth.
3. Mark position of the centre screw on the outer case.
4. Start the engine and increase the speed slowly until voltmeter needle flicks and steadies. This should occur at the correct voltage setting of the regulator, given in the appropriate section of this publication. If the voltage at which the reading becomes steady is outside these limits, then the regulator must be adjusted.
5. Adjust by turning the spring tensioning sleeve in to raise, or out to lower the setting, until voltage indicated by the meter is correct.
6. Turn the centre screw by an equivalent amount in the opposite direction from the tensioning sleeve.
7. Remove the paper from the cutout points.

SETTING OF CONTACTS

To determine which end to fit the first contact cap if the regulator has been dismantled, connect a battery across the extreme end of the regulator and the armature will be pulled away from the first contact end.

To set the contacts, proceed as follows:

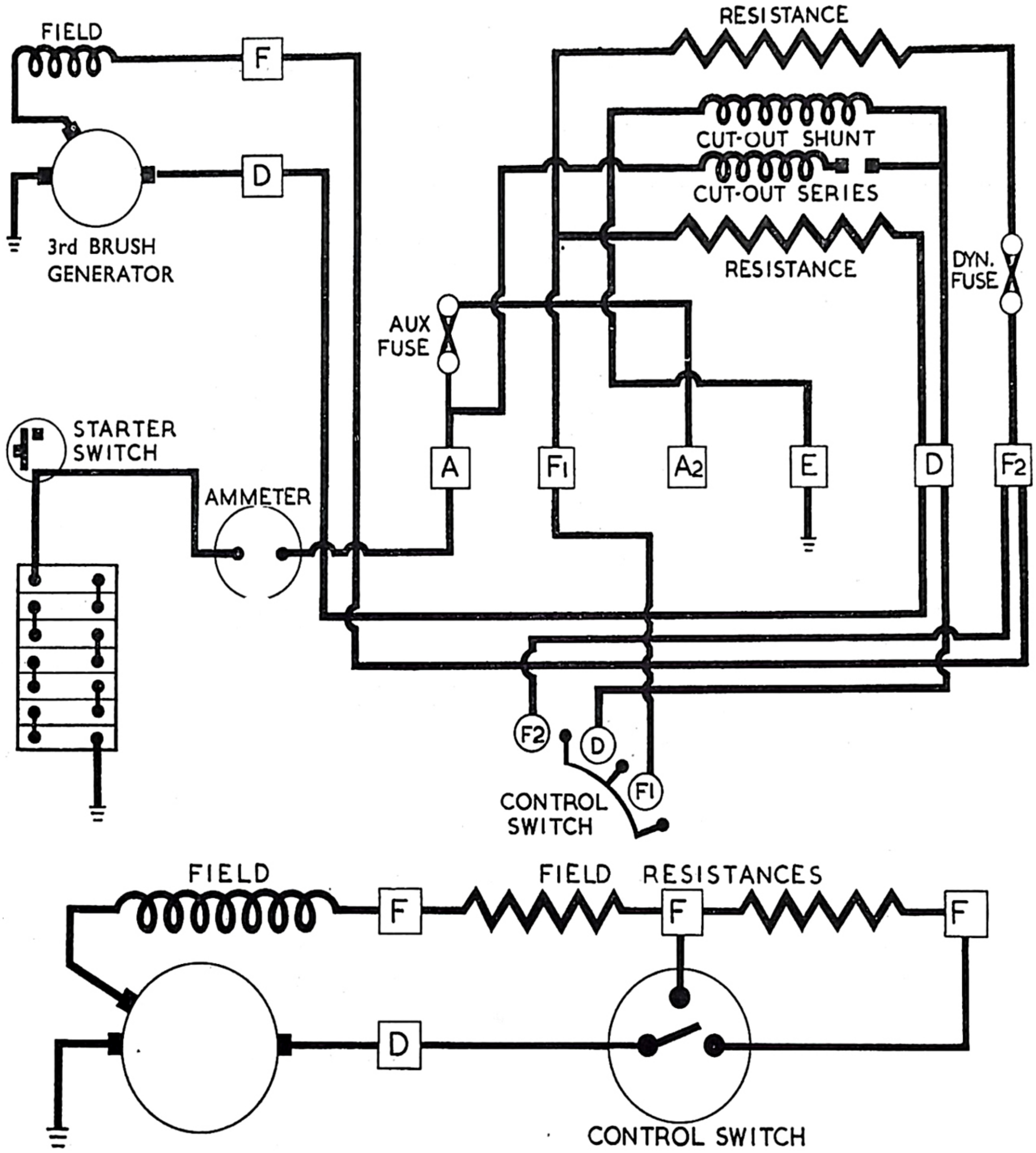
1. Screw the first contact of the regulator in gently until it locks. Turn back one-and-a-half turns and secure with the locking ring.
2. Isolate the generator from the battery by placing paper between the cutout contacts.
3. Connect the voltmeter between the "D" terminal and earth. Start the engine and screw the centre of the second contact right back. Screw in the spring tension adjusting sleeve until the voltmeter flicks and steadies between 15.7 volts to 16.7 volts (as given in Test Data Section of this publication). Tighten the outer locking ring.

   The remaining adjustment is to the second contact and **it is important that the engine is stationary while this is being done.**
4. Screw in the centre of the second contact gently until it locks, and then unscrew one complete turn. Tighten centre contact locking nut.
5. Start engine, and raise the speed slowly until the voltmeter flicks (as the first contacts come into operation) and remains steady at between 15.7 volts—16.7 volts (see note in paragraph 3 above). Slowly increase the engine speed until voltmeter flicks again (as the second contacts come into operation). This should occur at approximately half-volt above the first reading.

   If the second contacts do not operate at half-volt higher than the first contacts, the adjustments should be re-checked, and the two turns at the first contact end varied slightly, the contacts being screwed in to increase, or out to decrease the setting.
6. Remove the paper from the cutout contacts.

THIRD BRUSH REGULATION

The normal characteristics of the shunt wound generator are modified by adding a further brush with this method of output control. One end of the field winding is connected to the third brush whilst the other end is brought out to the field terminal on the carcase of the generator. The field circuit is completed externally as explained later. Inherent control of the generator is obtained by armature re-action which reduces the current for excitation of the field system.



Figures 20 and 21
Typical wiring layout using third brush control

By increasing the angular displacement between the main brush and the auxiliary brush, the voltage across the field winding can be increased and the maximum output of the generator raised; likewise, by moving these two brushes nearer together, the maximum output can be reduced. Adjustment of the third brush, therefore, provides means of varying the maximum output to suit the working conditions of the equipment. The maximum output obtainable is, of course, governed by the design of the generator. By moving the third brush in the direction of armature rotation, the output can be increased; conversely, the output can be decreased by moving the brush in the reverse direction.

Control of the output of the generator to meet varying running conditions is obtained by inserting a resistance or resistances of different values in the external field circuit. This is usually done by means of a manually operated switch incorporated with the main lighting switch so that full charge is only obtained when lights are in use.

The cutout used in conjunction with a third brush generator operates in the same manner as the cutout already described in the Regulator Section.

HANDY FAULT LOCATION GUIDE (C.V.C.)

Symptoms	*Possible causes*	*Remedy*
Battery in low state of charge, shown by lack of power when starting. (Hydrometer readings less than 1.200)	Generator not charging indicated by ammeter not showing charge reading when running at about 20 m.p.h. with no lights in use. Due to:	
	Broken or loose connection in generator circuit, or regulator not functioning correctly.	Examine charging and field circuit wiring. Tighten loose connection or replace broken lead. Particularly examine battery connections. Proceed with Systematic Fault Location Test.
	Commutator greasy or dirty.	Clean with soft rag moistened with petrol.
	Generator giving low or intermittent output indicated by ammeter giving low or intermittent reading when car is running steadily in top gear. Due to:	
	Loose or broken connections in generator circuit.	Examine charging and field circuits wiring. Tighten loose connections or replace broken lead. Particularly examine battery connections.
	Brushes greasy or dirty.	Clean with soft rag moistened with petrol.
	Brushes worn or not fitted correctly.	Have worn brushes replaced. See that brushes "bed" correctly.
	Regulator not functioning correctly.	Proceed with Systematic Fault Location Test.
Battery over-charged, shown by burnt-out bulbs and very frequent need for "topping-up". (Hydrometer readings high).	Generator giving high output, indicated by ammeter giving high charge reading. Due to:	
	Regulator not functioning correctly.	Proceed with Systematic Fault Location Test.

SYSTEMATIC FAULT LOCATION GUIDE FOR THE CHARGING CIRCUIT

Before any attempt is made to alter the regulator settings, it should be established that the fault does not lie in the circuits associated with it. Standard regulator settings are given in each case. See page 29 for special settings.

Important points which can give a false indication of a regulator fault are:

1. Slipping generator belt.
   Check belt and make sure it is not slipping.
   Adjust till fan can only just be turned by hand.

2. Crossed over generator connections.
   These may be crossed either at the regulator or generator.
   Examine these leads.
   If they are crossed over, the regulator points will have burnt the moment the engine was started.

3. Faulty battery.
   Check battery.
   Test with hydrometer and "drop" tester.
   Top-up if required.
   Clean any sulphation off lugs.
   Make sure top of battery is clean and dry.

4. Bad earth connections.
   Check earth connections from battery to chassis frame and from regulator to chassis frame.

The tests detailed should be carried out with a moving coil voltmeter, scale 0-30 volts, which should be large enough to permit accurate readings to within half a volt. The tests should be made strictly in the order given.

TEST 1

Voltmeter connections	*Reading on voltmeter*	*Action to be taken*
Disconnect wires from generator. Connect meter; one lead to terminal "D" on generator, the other to a good earth. Start up engine and raise speed slowly. (See Figure 22A.)	1. 2-4 volts as engine is speeded up. ($\frac{1}{2}$-$1\frac{1}{2}$ volts for motor cycle generators.)	Proceed to Test 2.
	2. Zero reading.	Examine brushes and make sure they are free in their boxes. If still no reading fault is in generator armature. Remove generator for repair or replacement.

TEST 2

Voltmeter connections	*Reading on voltmeter*	*Action to be taken*
Connect voltmeter as for Test 1. Connect ammeter across "D" and "F" terminals on the generator. Raise engine speed very slowly. (See Figure 22A.)	1. Voltage rising with speed and a full scale reading at a fast tick over. Adjust voltmeter reading by variation of engine speed to give rated voltage of generator, i.e., 6 volt or 12 volt. At this voltage, ammeter must not read higher than 2 amps.	Proceed to Test 3.
	2. 2-4 volts and zero ammeter reading. ($\frac{1}{2}$-$1\frac{1}{2}$ volts for motor cycle generators.)	Remove generator and locate break or earth in field coils.
	3. Rising voltage, but ammeter reading greater than 2 amps.	Locate earth on field coils, probably on coil interconnections.

TEST 3

Reconnect generator cables. Yellow or heavy cable to "D" terminal, green or lighter cable to "F" terminal. Disconnect "D" and "F" wires from terminals "D" and "F" at the control box. Connect voltmeter from end of "D" cable to a good earth. Raise engine speed slowly. (See Figure 22B.)	1. 2-4 volts. ($\frac{1}{2}$-$1\frac{1}{2}$ volts for motor cycle generators.)	Proceed to Test 4.
	2. Zero reading.	Renew yellow cable from generator to control box.
	3. Rising volts. Rising speed.	Locate short between "D" and "F" cables, somewhere between generator and control box.

TEST 4

Leave voltmeter connected as in Test 3. Join wire from terminal "F" (green) to wire from terminal "D" (yellow). Raise engine speed slowly. (See Figure 22C.)	1. Rising volts with rising speed.	Proceed to Test 5.
	2. 2-4 volts. ($\frac{1}{2}$-$1\frac{1}{2}$ volts for motor cycle generators.)	Replace broken field wire between generator and control box.

TEST 5

Do not reconnect "D" and "F" leads. Connect voltmeter — one lead to terminal "A", the other to terminal "E" on control box. (See Figure 22D.)	1. Battery voltage.	Proceed to Test 6.
	2. Less than battery voltage, or zero reading.	Rectify bad earth contact or broken earth lead between terminal "E" and chassis frame.

TEST 6

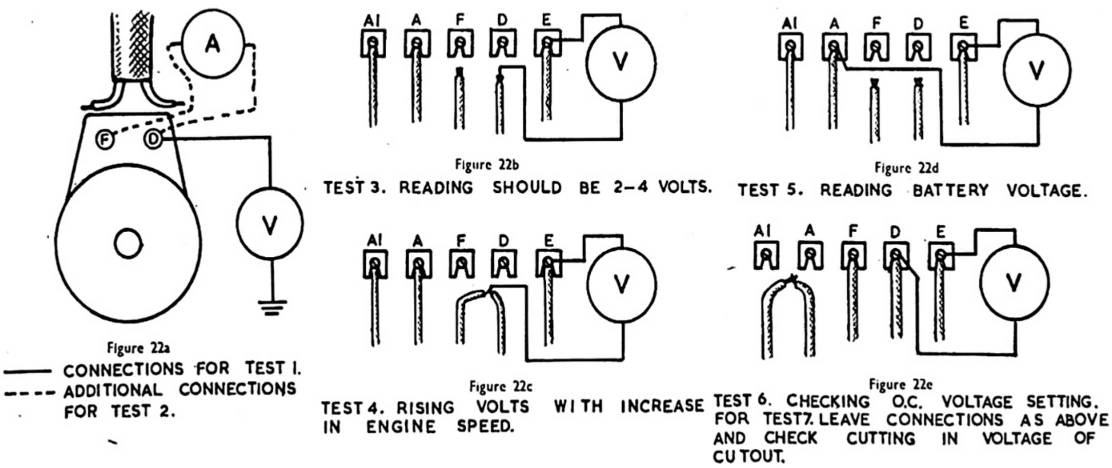
Voltmeter connections	*Reading on voltmeter*	*Action to be taken*
Reconnect "D" and "F" leads into control box terminals "D" and "F". Connect voltmeter from terminal "D" to terminal "E" on control box. Remove cables from terminals "A" and "A1" on control box and join together. Start engine and raise speed slowly. (See Figure 22E.)	1. Voltage rises steadily with speed and at a fast tick-over speed, remains constant within the following limits. *Atmospheric Temperature* — *6v. Type* — *12v. Type* 10°C. 50°F. 7.9–8.3 16.1–16.7 20°C. 68°F. 7.8–8.2 15.8–16.4 30°C. 86°F. 7.7–8.1 15.6–16.2 40°C. 104°F. 7.6–8.0 15.3–15.9	Proceed to Test 7.
	2. Voltage remains constant outside the given limits.	Adjust regulator by turning adjusting screw in to raise the setting or out to lower the setting.
	3. Voltage does not rise with speed or is erratic.	Remove control box for repair or replacement.

TEST 7 — TO CHECK CUTOUT

Connect voltmeter — one lead to terminal "D", the other to terminal "E". Leave "A" and "A1" wire as in Test 6. Raise engine speed slowly. Observe movement of cutout points. (See Figure 22E.)	1. Cutout points close when voltage is within the following limits. *6v.:* 6.3–6.7 *12v.:* 12.7–13.3	Proceed to Test 7A.
	2. Cutout points close outside voltage limits.	Adjust setting by screwing the adjustment screw in to raise or out to lower the setting.
	3. Cutout points do not close.	Remove control box for repair or replacement.

TEST 7A

Connect voltmeter to terminals "A" and "E". Raise engine speed slowly.	1. Voltmeter records a reading as the cutout points close, which rises to regulator setting as given in Test 6.	Cutout is in order. Reconnect "A" and "A1" leads.
	2. No voltage or a very low voltage is recorded when cutout points close.	Clean or adjust cutout contacts so that they meet correctly. Reconnect "A" and "A1" leads.



Figures 22A, B, C, D, and E Ammeter and voltmeter connections for fault location

TEST DATA

C.V.C. UNITS (REGULATORS) AND CUTOUTS

This section includes all test data necessary for the correct setting of the above units.

The type model of combined cutouts and regulators is given on the back of the regulator frame. As some units may be difficult of access when testing in place on the vehicle, we give on page 29 an application list showing the type of regulator and/or cutout fitted to each type of control box. The type model of barrel type (double contact) regulators is stamped on the body of the regulator, whilst the type model of cutouts and relays will be found on the top hinged frame of the unit.

The majority of Lucas voltage control regulators conform to standard open circuit voltage settings. Some vehicles and units, however, owing to special equipment being fitted or to operation under unusual conditions, require special regulator settings. These are listed individually under the appropriate heading.

Special regulators are listed for fitting to motor cycles equipped with Ni-Fe batteries; it should be noted, however, that these special regulators conform to standard open circuit voltage settings.

Later pattern LRT regulators and cutouts are fitted with a magnetic-gap retaining brass shim which extends over the whole of the underneath surface of the cutout or regulator armature. It is thus impossible to take a direct gap reading between the armature and core faces; in such cases it will be necessary to make the following allowances for the shim thickness when setting the appropriate air gap:

Regulator	Reduce air gap by .010″
Cutout	Reduce air gap by .005″

REGULATOR AND CUTOUT APPLICATION LIST

Control Box	Cutout	Regulator
RF	SB5	LR1
RF2	„	LR2
RF10	„	LR1 or LR22
RF30	Combined with Reg.	LR3 or LR4
RF35	„	LR5
RF50	„	„
RF51	„	„
RF70	„	LR7
RF71	„	LRT7
RF90	„	LRT9
RF91	„	„
RF91S	„	„
RF91X	„	„
RF92	„	„
RF92X	„	„
RF95	„	„
RF95S	„	„
RF96	„	„
RF96S	„	„
RF97	„	„

Control Box	Cutout	Regulator
RJF	SB5	LR1 or LR2
RJF20	„	LR2
RJF50	Combined with Reg.	LR5
RJF70	„	LR7
RJF71	„	LRT7
RJF90	„	LR9
RJF91	„	LRT9
RJF91X	„	„
RJF92	„	„
RJF92X	„	„

Motor Cycle Types

MCR	Combined with Reg.	LR6
MCR1	„	LRT8
MCR2	„	LRT9

C.V.C. REGULATORS—SPECIAL SETTINGS

Control Box Service	Ref.	Type	Vehicle or Engine	Open Circuit Voltage Setting
37035	RF96	L	Ford Industrial Engine	7.4 — 7.8
37045	RF96	L2	Fordson Tractor (P6 Engine)	15.0 — 15.6
37052	RF96S	L4	Rolls Royce and Bentley (C45PV Generator) ...	16.8 — 17.0
37061	RF97	L1	Nuffield, Turner, Massey Harris Tractors ...	15.0 — 15.6
37064	RF96	L7	Ford Industrial Engine, Ford Pilot	7.4 — 7.8
37089	RF96S	L10	Rolls Royce and Bentley (RA5 Generator) ...	15.7 — 16.3
37093	RF95	L11	Dodge	7.4 — 7.8
37102	RF96	L14	Ford 'Prefect'	7.6 — 8.0
37116	RF96S	L16	Rolls Royce (RA5 Generator)	15.7 — 16.3
37118	RF96	L15	Ford (ET7) Diesel Trucks	15.6 — 16.0
37149	RF97		Massey Harris Combine	17.0 — 17.4

All the above settings are given for an atmospheric temperature of 20°C. (68°F.). For different atmospheric temperatures the following allowances should be made to the open circuit voltage settings:

For every 10° Centigrade (18° Farenheit) increase in atmospheric temperature, decrease the settings given above by .1 volts for 6 volt equipment and by .3 volts for 12 volt equipment. For a lower temperature a corresponding increase to the open circuit voltage should be made.

STANDARD OPEN CIRCUIT VOLTAGE SETTINGS FOR LUCAS VOLTAGE CONTROL REGULATORS

Thermostatically Controlled Regulators

Regulator Model	Atmospheric Temperature		6v.	12v.
LR1, LR2, LR22. (Lucas Barrel Type Regulators were made in 12v. only. Temperature Controlled Regulators of these types have a blue band round the body of the Regulators.)	10°C.	50°F.	—	16.0 — 16.6
	20°C.	68°F.	—	15.9 — 16.5
	30°C.	86°F.	—	15.8 — 16.4
	40°C.	104°F.	—	15.7 — 16.3
LRT7, LRT8, LRT9. (LRT8 is a Motor Cycle pattern, manufactured in 6v. only.)	10°C.	50°F.	7.9 — 8.3	16.1 — 16.7
	20°C.	68°F.	7.8 — 8.2	15.8 — 16.4
	30°C.	86°F.	7.7 — 8.1	15.6 — 16.2
	40°C.	104°F.	7.6 — 8.0	15.3 — 15.9

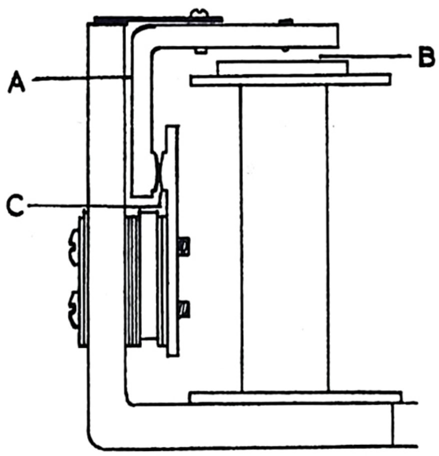
Non-Thermostatic Type Regulators

LR1	—	15.7 — 16.7
LR2	—	15.7 — 16.7
LR22	—	15.9 — 16.5
LR3	7.5 — 8.0	16.2 — 16.5
LR4	—	15.9 — 16.0
LR5	7.5 — 8.0	16.2 — 16.5
LR6	7.5 — 7.8	—
LR7	—	16.3 — 16.7
LR8	7.5 — 7.8	—
LR9	—	16.2 — 16.7

AIR GAP SETTINGS FOR SINGLE CONTACT REGULATORS

A — Gap between Armature and Frame.

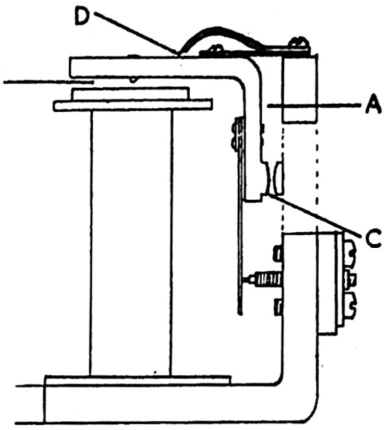
C — Gap between points.



B — Gap between Core Face and Armature.

Model		Gap Setting A	B	C
LR3, LR4, LR5, LR6	... ...	.015″	.020″ — .025″	.012″ — .016″
LR7, LRT7, LR9, LRT9	... ...	.018″	.022″ — .030″	.006″ — .016″
LR8, LRT8	... ...	.015″	.020″ — .025″	.002″ — .008″

AIR GAP SETTINGS FOR CUTOUTS—COMBINED CUTOUT AND REGULATOR TYPES



Model	A	B	C	D
		Gap Setting		
LR3, LR4, LR5, LR6, LR7, LRT7, LRT9...	.008″	.016″ — .020″	.002″ — .006″	.030″ — .034″
LR8, LRT8	.008″	.016″ — .020″	.002″ — .006″	.023″ — .026″

	Cutting-in Voltage	Drop-off Voltage
12v. All Models	12.7 — 13.3	9 — 10
6v. All Models	6.3 — 6.7	4.5 — 5.0

Model	Reverse Current in Amps.
LR6, LR8, LRT8 (6v. Models)	1.0 — 2.5
LR3, LR4, LR5, LR7, LRT7, LR9, LRT9 {6v. and 12v. Models} ...	3.0 — 5.0