



British Rail

TECHNICAL TRAINING NOTE EC/2

COACHING STOCK ELECTRICAL EQUIPMENT

ALTERNATORS

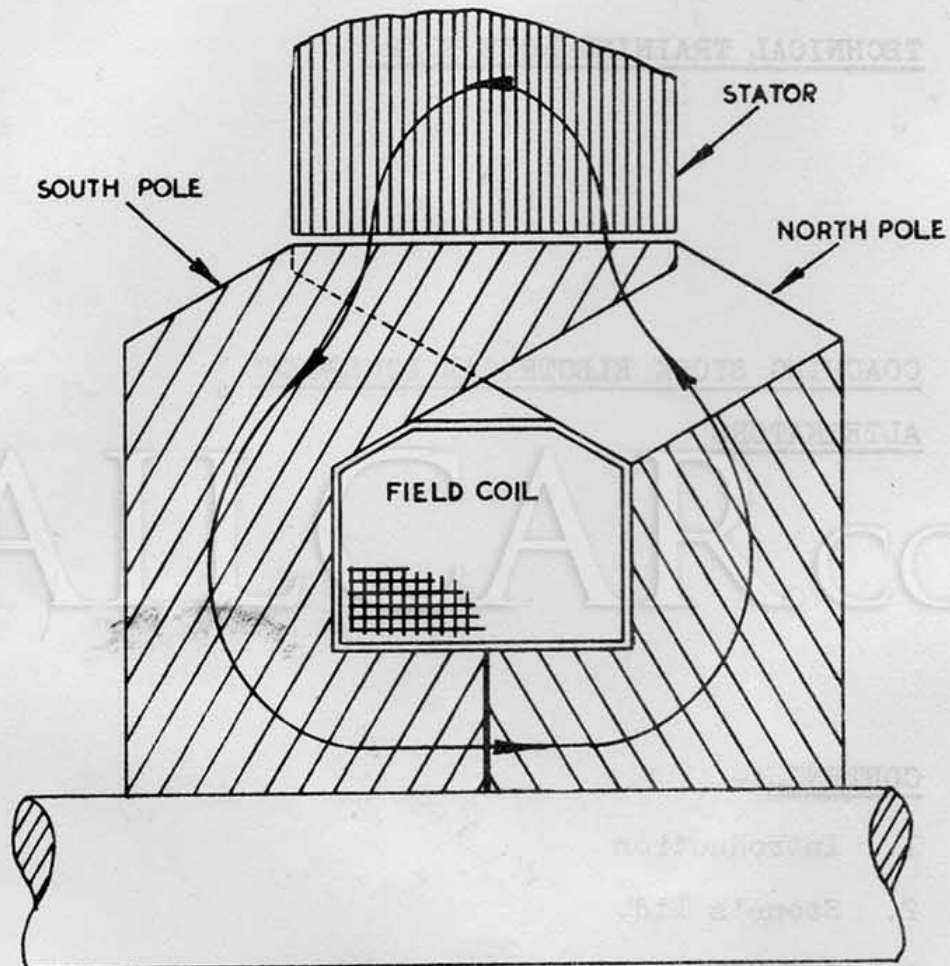
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2. Stone's Ltd.
3. C.A.V. Ltd.

RAILWAY ENGINEERING SCHOOL,
BRITISH RAILWAYS, DERBY.

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FIGURE 1



HALF SECTION THROUGH SOUTH POLE OF CLAW TYPE MAGNET

TECHNICAL TRAINING NOTE EC/2COACHING STOCK ELECTRICAL EQUIPMENT
ALTERNATORS1. INTRODUCTION

An axle driven alternator, together with a regulator operating in conjunction with the standard 28 volt d.c. battery provides a d.c. supply for fluorescent lighting, motor and associated control for pressure ventilating and heating together with battery charging.

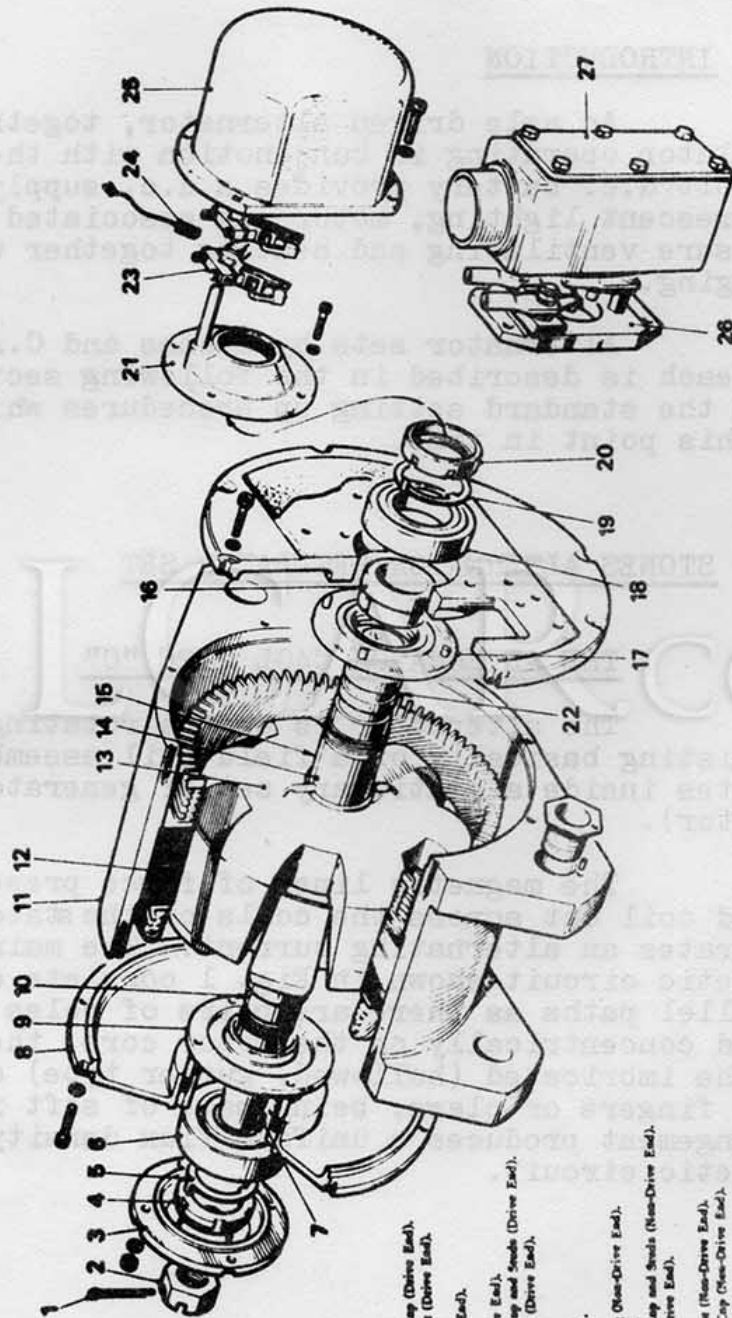
Alternator sets by Stones and C.A.V. are used and each is described in the following sections along with the standard setting up procedures which are correct at this point in time.

2. STONES ALTERNATOR REGULATOR SET2.1 THE ALTERNATOR C40L TYPE "C"

The alternator is of the rotating field type consisting basically of a field coil assembly (rotor) which rotates inside a stationary set of generator windings (stator).

The magnetic lines of force present around the field coil cut across the coils of the stator windings and generates an alternating current. The main feature of its magnetic circuit shown in Fig. 1 consists of as many parallel paths as there are pairs of poles (6) the core is wound concentrically on the rotor core, the pole pieces are of the imbricated (hollowed, gutter type) design and appear like fingers or claws, being made of soft iron, this arrangement produces a uniform flux density in the whole magnetic circuit.

FIGURE 2.



1. Split Pin.
2. Pulley Key.
3. Outer Bearing Cap (Drive End).
4. Bearing Lock (Drive End).
5. Tab Washer.
6. Pulley Key.
7. End Shield (Drive End).
8. Inner Bearing Cap and Seals (Drive End).
9. Bearing Sealing (Drive End).
10. Fan.
11. Vented Sinter.
12. Field Assembly.
13. Shield.
14. Bearing Sealing (Non-Drive End).
15. Bearing Sleeve.
16. Inner Bearing Cap and Seals (Non-Drive End).
17. Bearing (Non-Drive End).
18. Tab Washers.
19. Outer Bearing Cap (Non-Drive End).
20. Inner Bearing Cap (Non-Drive End).
21. Slip Ring Assembly.
22. Brushholder Assembly.
23. Brush.
24. Slip Ring Cover.
25. Terminal Assembly.
26. Terminal Cover.
27.

ALTONUM ALTERNATOR TYPE C40L

2.2 CONSTRUCTION (SEE FIG. 2)

The rotor assembly consists of the field coil, clip rings and two soft iron claws all mounted on a common shaft. The fingers of the claws are interposed and form the magnetic poles, the field coil system being positioned between them, each lead from the field coils is connected to its respective slip ring.

The complete rotor assembly is carried on two heavy ~~dirty~~ ball or roller bearings mounted in the slip ring and drive end shields, the end shields are secured one to each end of the stator, the whole assembly forming a very rigid structure.

The three phase stator windings (star-wound) are secured in the slotted stator laminations which are themselves contained within the aluminium alloy stator.

Terminal markings are A, B, C for the alternator 3-phase output. Z-Z main excitation supply Z-ZZ reverse or buck field supply (See Fig. 3).

2.3 OUTPUT

A constant output is maintained by means of a rectifier/regulator unit which controls the field coil assembly by carrying the field current on the "mark space ratio" principle. The regulated output is 24/28 volts d.c. at 180 amps, full output is obtained at 550 r/min and is maintained throughout the speed range up to a maximum of 4000 r/min.

An over voltage trip is provided and is set to operate at 36 volts, the current limit is set at 180 amps.

Initial build up of output from the alternator is due to residual magnetism in the imbricated pole system, the regulator allowing the field to be fully excited in the shortest possible time.

FIGURE 3

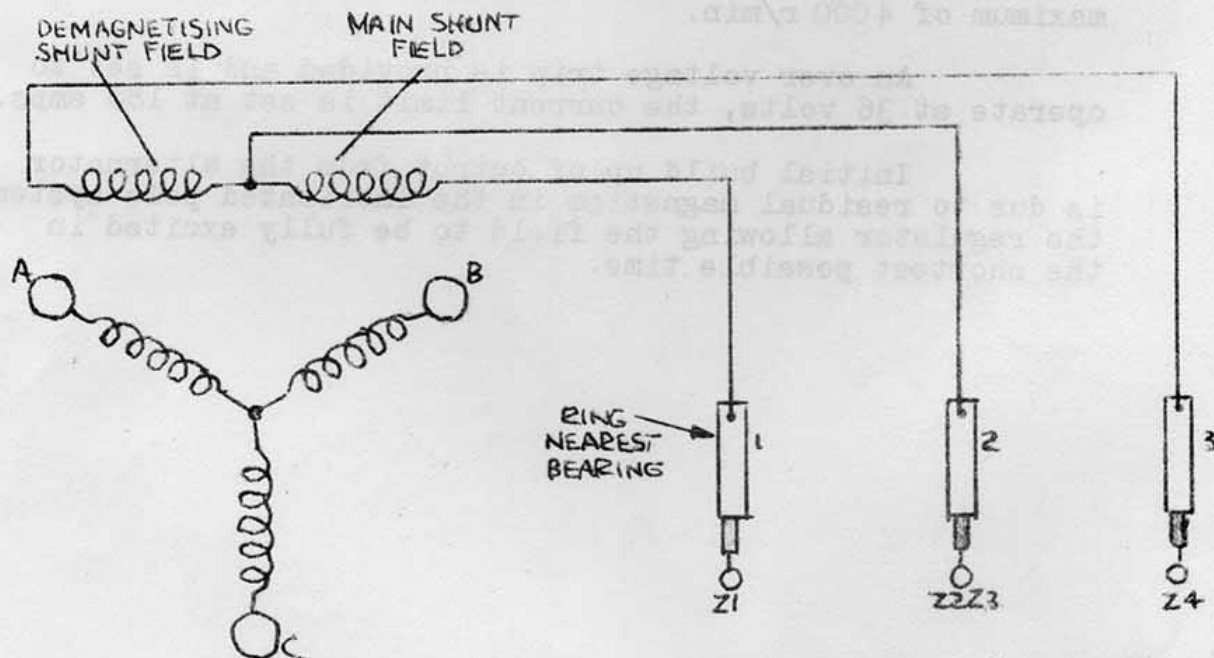
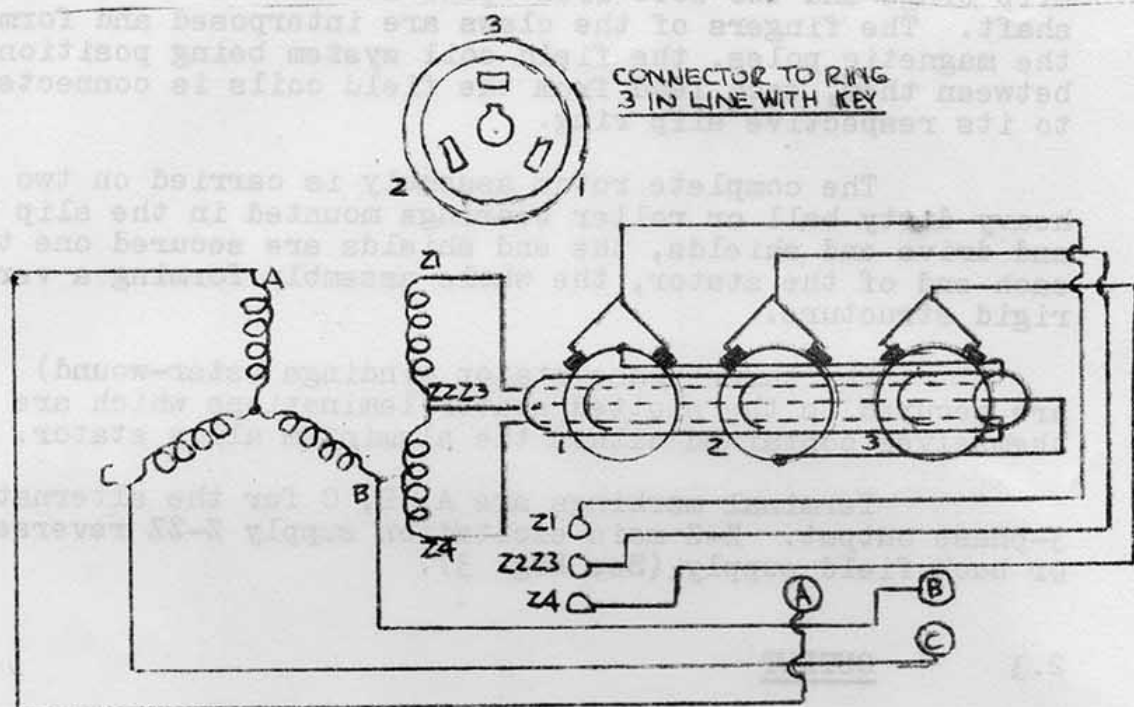


DIAGRAM OF CONNECTIONS FOR ALUMINIUM ROTATING FIELD ALTERNATOR
WITH DEMAGNETISING SHUNT FIELD.

2.4 STONES WDT6 RECTIFIER REGULATOR (SEE FIGURE 4)

The regulator is a transistorised unit operating on the "mark space ratio" principle and allows the main alternator field Z-Z supply to be interrupted and varied according to the output voltage of the machine, this control of the main alternator field together with the effect of the small reverse/buck field is capable of regulating the alternator output over the whole speed range. An over voltage protection unit is also included in the regulator, the main diode rectifier unit is housed along with the regulator.

2.5 OPERATION OF THE REGULATOR (SEE FIGURE 5)

A simplified layout diagram shows the general arrangement of the system, the function of the transistorised regulator is to control the alternator fields so that the alternator output in terms of voltage and current is held automatically to the requirement of the d.c. load.

The regulator comprises of three circuits:-

- (i) the alternator field,
- (ii) multivibrator oscillator,
- (iii) control chain.

The multivibrator and control chain circuits are so coupled that a pulsed voltage is delivered to the alternator field with a duration which is maintained constant while the pulse frequency is a controlled variable.

2.6 ALTERNATOR FIELD CIRCUIT (SEE CIRCUIT DIAGRAM)

This circuit is supplied from the full wave rectifier RCT2 and its smoothing capacitor C3, the supply being obtained from ONE of the secondary windings of the auxiliary transformer TFR2, whose primary winding is connected across two phases of the alternator (A & B) output. The main field Z1-Z2 is in circuit with a transistor bank, comprising transistors J1 and J2 which handle the pulsing voltage. A discharge path across capacitor C3 is provided by resistor R12, rectifier RCT8 serves as a main field discharge by providing an alternative path (free-wheel) for the field current when transistors J1 and J2 are in an OFF condition.

2.4 STONES WITH RECTIFIER REGULATOR (SEE FIGURE 4)

2.4

The regulator is a transistored unit operating on the "mark space ratio" principle and allows the main alternator field E-E supply to be interrupted and varied according to the output voltage of the machine, this control of the main alternator field together with the effect of the small reverse/boost field is capable of regulating the alternator output over the whole speed range. An over voltage protection unit is also included in the regulator, the main diode rectifier unit is housed along with the regulator.

2.5 OPERATION OF THE REGULATOR (SEE FIGURE 5)

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A simplified layout diagram shows the general arrangement of the system, the function of the transistored regulator is to control the alternator field so that the alternator output in terms of voltage and current is held automatically to the requirement of the d.c. load.

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- (ii) multivibrator oscillator,
- (iii) control chain.

The multivibrator and control chain circuits are so coupled that a pulsed voltage is applied to the alternator field with a duration which is maintained constant while the pulse frequency is a controlled variable.

2.6 ALTERNATOR FIELD CIRCUIT (SEE CIRCUIT DIAGRAM)

2.6

This circuit is supplied from the full wave rectifier RCT2 and its smoothing capacitor C3, the supply being obtained from ONE of the secondary windings of the auxiliary transformer TR2, whose primary winding is connected across two phases of the alternator (A & B) output. The main field E-E is in circuit with a transistor bank, comprising transistors J1 and J2 which handle the pulsing voltage. A discharge path across capacitor C3 is provided by resistor R12, rectifier RCT8 serves as a main field discharge by providing an alternative path (free-wheel) for the field current when transistors J1 and J2 are in an OFF condition.

2.7 THE MULTIVIBRATOR CIRCUIT (SEE CIRCUIT DIAGRAM)

This circuit is used to drive transistors J3 and J4, the power supply being derived from the other secondary winding of the auxiliary transformer TFR2, rectified by rectifier RCT7 and smoothed by capacitor C4. As there is a condition when either J3 or J4 is ON, a square wave output is available at the collectors of the oscillator transistors J3 and J4 which is used to control the alternator field transistors J1 and J2.

2.8 THE CONTROL CHAIN CIRCUIT (SEE FIG. 6 AND CIRCUIT DIAGRAM)

The circuit is connected across the rectified output of the alternator and consists of a voltage calibrating resistance bank, one resistor VCRL which can be adjusted to obtain the required regulated voltage, a further resistor VCR2 is provided which can be adjusted when the lights are "ON" but is not used in this application, also included is a voltage selecting resistor VSR which is used to trim calibrating resistor VCRL.

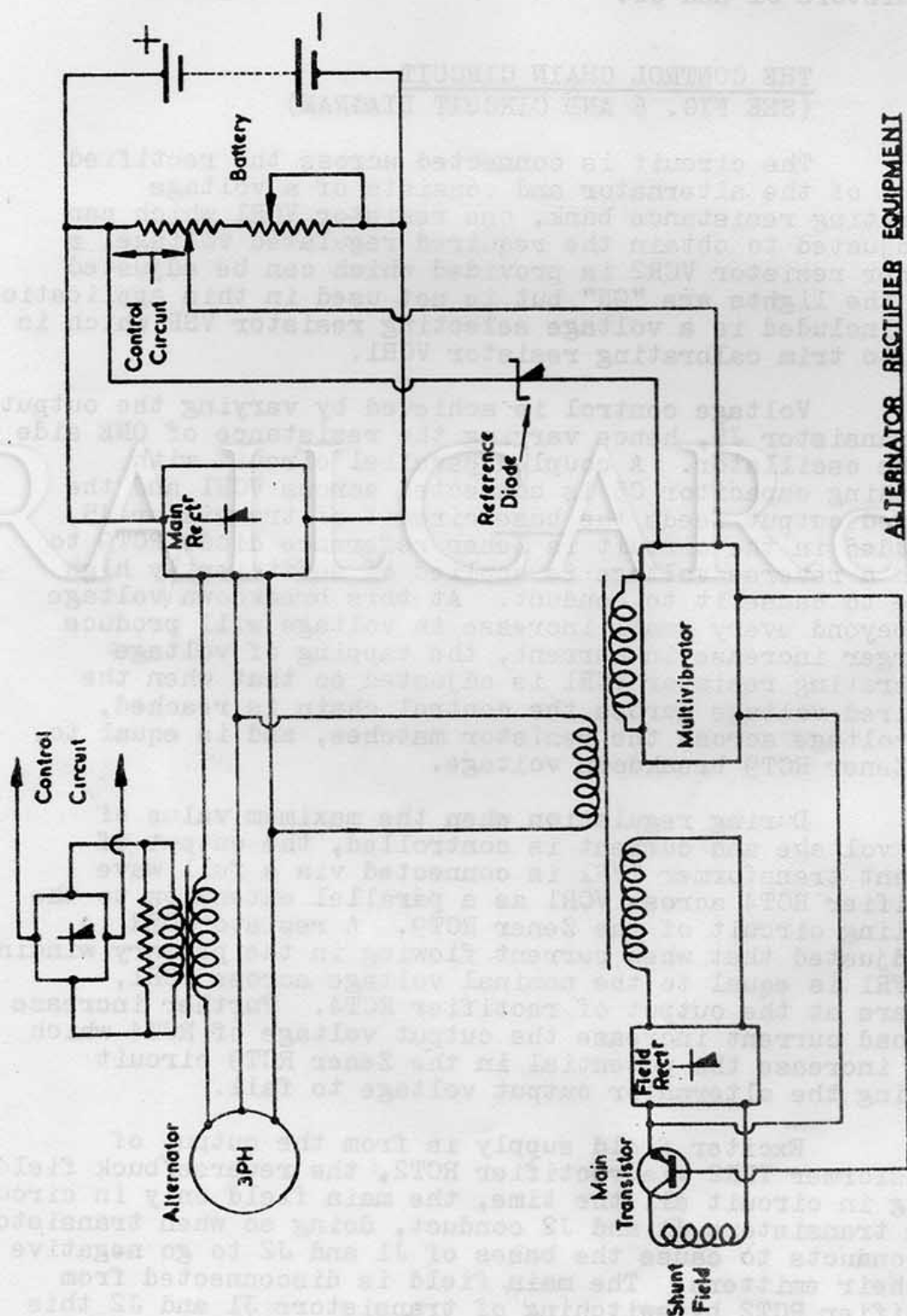
Voltage control is achieved by varying the output of transistor J5, hence varying the resistance of ONE side of the oscillator. A coupled parallel circuit with smoothing capacitor C5 is connected across VCRL and the derived output feeds the base circuit of transistor J5, included in the circuit is Zener reference diode RCT9 to which a reverse voltage is applied of sufficiently high value to cause it to conduct. At this breakdown voltage and beyond every small increase in voltage will produce a larger increase in current, the tapping of voltage calibrating resistor VCRL is adjusted so that when the required voltage across the control chain is reached, the voltage across the resistor matches, and is equal to, the Zener RCT9 breakdown voltage.

During regulation when the maximum value of both voltage and current is controlled, the output of current transformer TFR1 is connected via a full wave rectifier RCT4 across VCRL as a parallel extension to the coupling circuit of the Zener RCT9. A resistor OSR is so adjusted that when current flowing in the primary winding of TFR1 is equal to the nominal voltage across VCRL, appears at the output of rectifier RCT4. Further increase of load current increase the output voltage of RCT4 which will increase the potential in the Zener RCT9 circuit causing the alternator output voltage to fall.

Exciter field supply is from the output of transformer TFR2 via rectifier RCT2, the reverse/buck field being in circuit all the time, the main field only in circuit when transistors J1 and J2 conduct, doing so when transistor J4 conducts to cause the bases of J1 and J2 to go negative to their emitters. The main field is disconnected from rectifier RCT2 by switching of transistors J1 and J2 this being achieved when transistor J3 starts to conduct which causes the base voltage of J1 and J2 to go positive and switching off.

S.O.T.

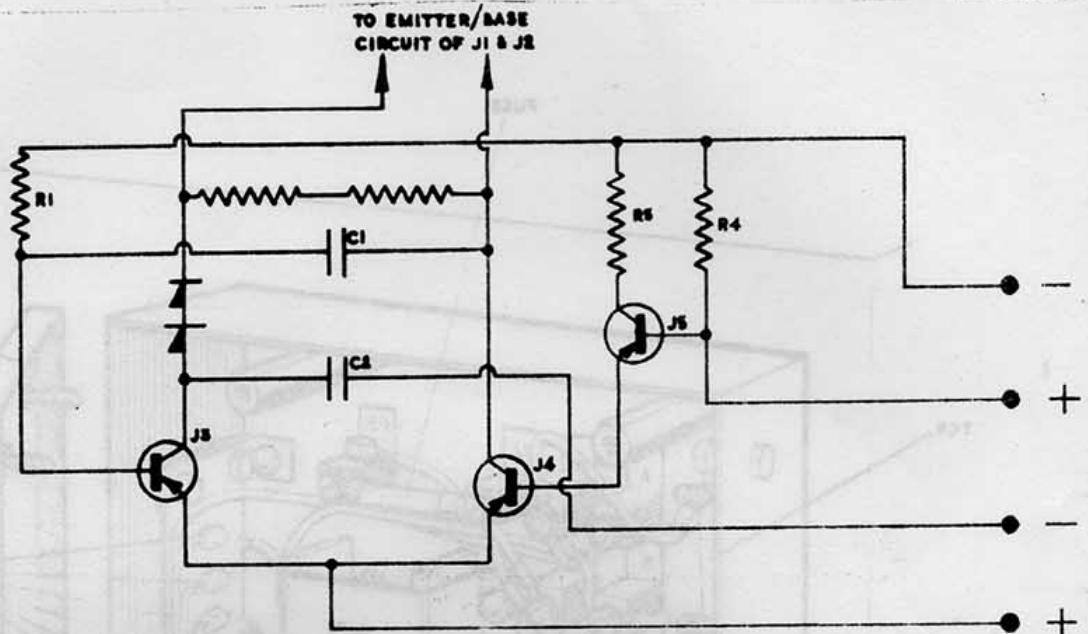
FIGURE 5



2.8

THE CONTROL CHAIN CIRCUIT
(SEE FIG. 6 AND CIRCUIT DIAGRAM)

FIGURE 6.

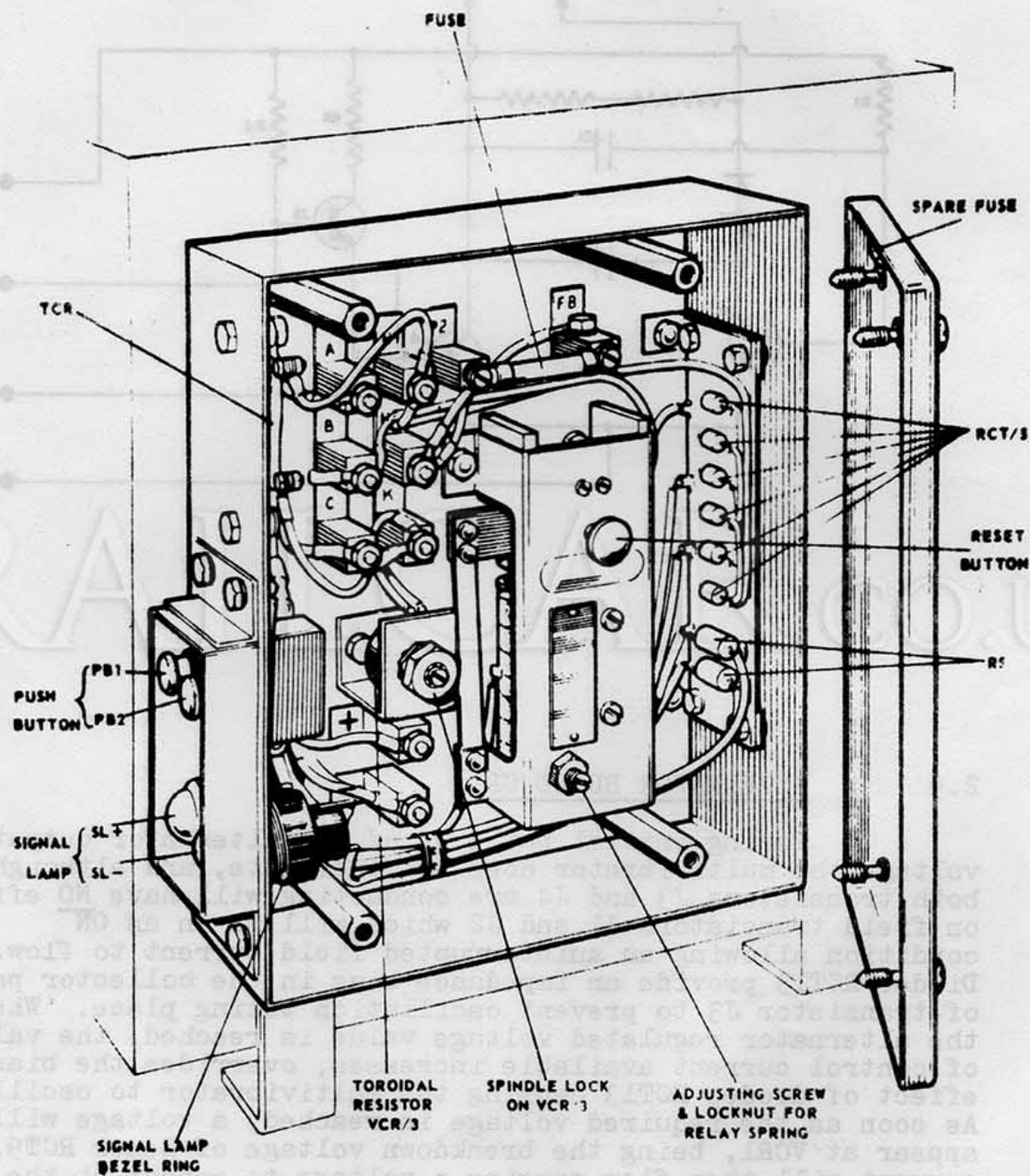


2.9

ALTERNATOR BUILD UP

During initial build up of the alternator output voltage the multivibrator does not oscillate, and although both transistors J3 and J4 are conducting will have NO effect on field transistors J1 and J2 which will be in an ON condition allowing an uninterrupted field current to flow. Diodes RCT13 provide an impedance bias in the collector path of transistor J3 to prevent oscillation taking place. When the alternator regulated voltage value is reached, the value of control current available increases, overrides the bias effect of diodes RCT13 causing the multivibrator to oscillate. As soon as the required voltage is reached, a voltage will appear at VCRL, being the breakdown voltage of Zener RCT9, current will then flow causing a voltage to appear at the base emitter terminals of control transistor J5, base of J4 and capacitor C2.

FIGURE 7

OVER-VOLTAGE PANEL

2.10 ALTERNATOR RUNNING

Voltage control, when the output is below the regulated datum, Zener RCT9 is NOT conducting hence control transistor J5 does not receive a signal to control, this will result in transistor J3 being ON for only short periods, allowing transistor J4 to conduct for long periods hence the alternator field current will be of a high value.

When the output voltage reaches the regulated datum, Zener RCT9 WILL conduct the cause the base of control transistor J5 to go more positive to its emitter, resulting in a fall of base current and hence collector current, this will increase the time transistor J3 is ON, resulting in a lower alternator field current to maintain the required datum.

When the output voltage exceeds the regulated datum, a large proportional current will flow in the Zener RCT9 circuit, making the base voltage of transistor J5 even more positive to its emitter, producing less current in its collector, causing transistor J3 to increase its ON time, lowering the alternator field current, returning the alternator output to its correct datum.

2.11 OVER-VOLTAGE PROTECTION UNIT (SEE FIG. 7)

The over-voltage relay is operated by coil OVR connected across the auxiliary rectifier RCT5 circuit, its normally closed contacts in the negative line Z2 of the alternator are in series with the field, when the relay operates it will break, open circuit the alternator field excitation circuit, the relay is of the latched type.

2.12 REGULATOR SETTINGS

- (a) The voltage is set to 28 volts d.c. with a charging current of 20 amps.
- (b) Current limit is set at 180 amps, 20 amps below the rating for the alternator.
- (c) The over-voltage relay is set to trip at 36 volts.

CIRCUIT DIAGRAM SYMBOLS

ALT	Alternator
C1, C2	Timing Capacitor
C3 - C5	Smoothing Capacitor
FUS	Fuse
J1, J2	Field Switching Transistor
J3, J4	Multivibrator Transistor
J5	Control Transistor
OVR	Over-Voltage Relay
OSR	Output Setting Resistor
PB1, PB2	Push Buttons
R1	Timing Resistor
R2, R3	Output Resistor
R4	Bias Resistor
R5	Stabilising Resistor
R12	Discharge Resistor
RB	Base Resistor
RCT/1	Power Rectifier
RCT/2	Field Rectifier
RCT/4	Dual Rectifier
RCT/5	Auxiliary Rectifier
RCT/7	Multivibrator Rectifier
RCT/8	Field Discharge Rectifier
RCT/9	Reference Diode
RCT/13	Starting Diode
RS	Series Limiting Resistance
SL+, SL-	Signal Light
SR	Suppression Resistance
TCR	Temp. Compensating Resistance
TFR/1	Current Transformer
TFR/2	Potential Transformer
VC1, 2&3	Voltage Calibrating Resistor
VSR	Voltage Selecting Resistor

STUDENT'S NOTES:- C.A.V. LTD. ALTERNATOR AND REG.

The equipment comprises of both 50 amp and 150 amp alternators, AC8 and AC1424 respectively, the 50 amp machines being fitted to D.M.U.s only, while the 150 amp machines are fitted to both D.M.U.s and loco-hauled coaching stock. A variety of regulators are used to accommodate both lead-acid and alkaline batteries, the regulators used are R.U.G.1 and 10 for alkaline cells, R.U.G. 2 and 11 for lead-acid cells and are used with AC8 alternators, regulators R.U.G.12, R.U.G.13 and R.U.C.8M for lead-acid cells and are used with the AC1424 alternators. The alternator set is capable of maintaining the batteries in a fully charged condition, and is designed to give full output irrespective of the direction in which it is driven and between machine speeds of 560 r/min to 4000 r/min approx.

3.1 THE ALTERNATOR (SEE FIG. 1)

The machine consists of a 12 pole cruciform rotor, with two field windings being wound one on the other, connections from the windings going to slip-rings mounted on the rotor shaft. Brushes which bear on the slip rings being connected to the alternator terminal box.

The stator contains a three phase star connected winding which produces a nominal 24 - 30 volts d.c. after rectification. During normal running conditions the alternator is self-excited since excitation current for the field windings is obtained from the d.c. regulated output of the charging unit, thus the alternator output is dependent upon the operating conditions and is automatically adjusted to suit instantaneous load demands.

Separate provision is required for excitation during the start up period, particularly at low alternator rotor speeds. This is achieved by having the field coils permanently connected to the battery supply through a high resistance, this ensures that sufficient flux is available for the alternator to produce an output at very low machine speeds. Once the alternator is producing an output, the machine becomes self-excited via the regulated output, the leakage current to supply the initial excitation is very small and is considered to be less than the normal wastage within the battery itself.

3. C.A.V. LTD. ALTERNATOR AND REGULATOR SETS

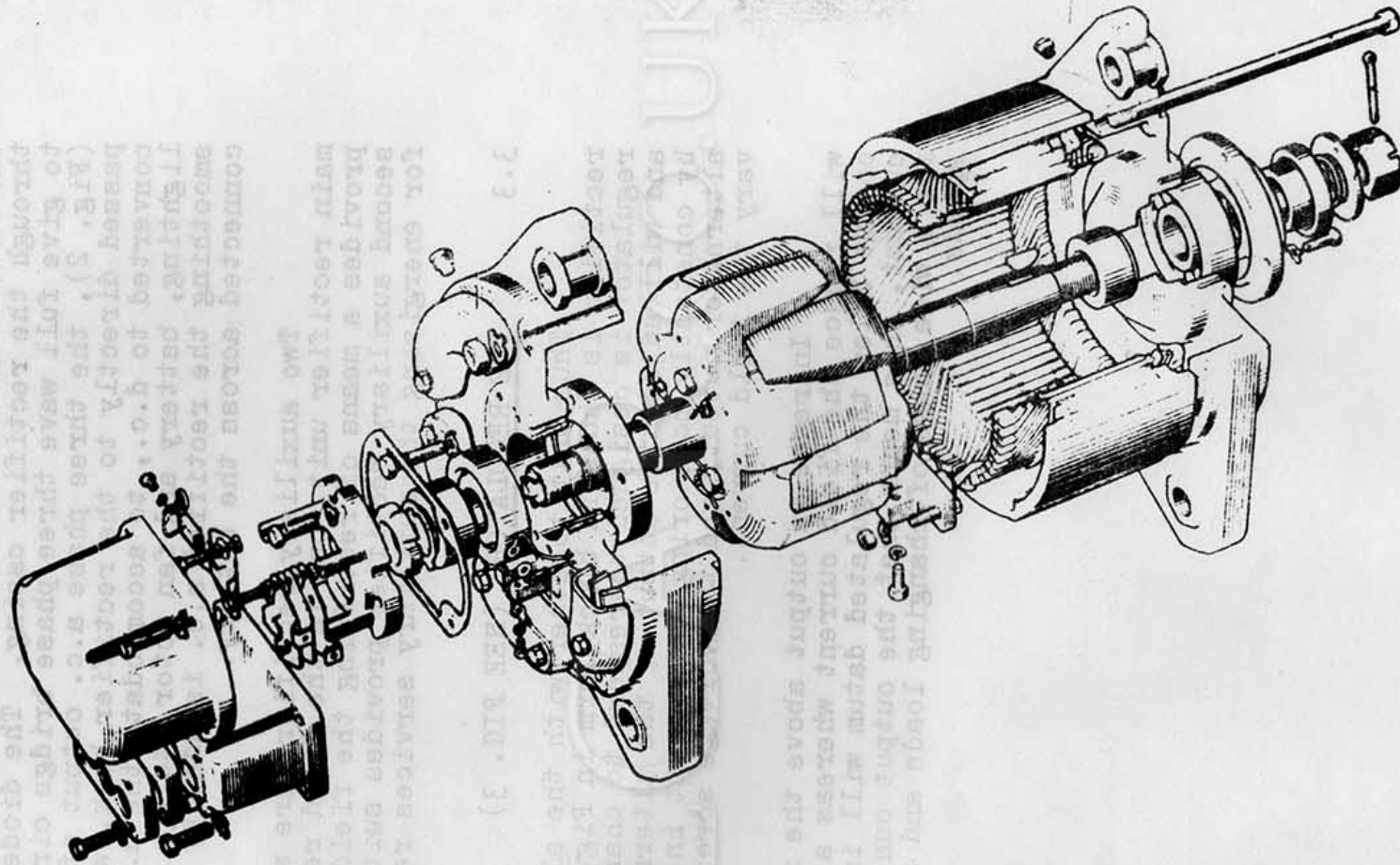
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EXPLODED VIEW OF ALTERNATOR

FIGURE 1

3.2 THE RECTIFIER (SEE FIG. 2)

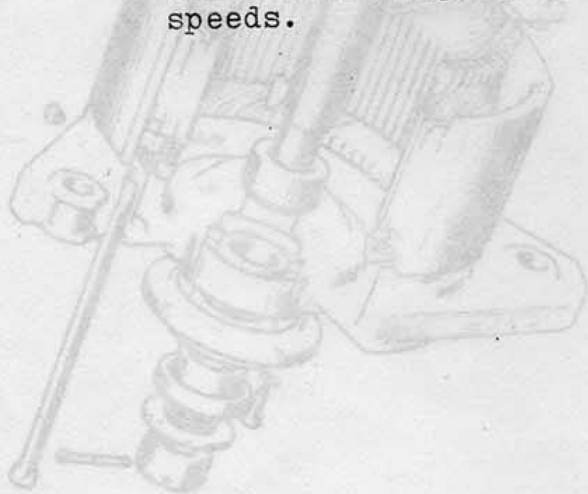
This unit comprises six diodes mounted on a suitable heat sink, heat that is generated during the operation of the rectifier unit is dissipated by a natural air flow through the rectifier casing. The diodes are connected to give full wave three phase bridge circuit configuration (Fig. 2), the three phase a.c. output of the alternator is passed directly to the rectifier bank, where it is converted to d.c., to accommodate the d.c. load of lighting, battery and fan motor etc., a degree of smoothing the rectified a.c. is done by a capacitor connected across the battery.

Two auxiliary rectifiers are associated with the main rectifier unit, one is the field rectifier which provides a means of rectifying the field current, the second auxiliary rectifier provides suitable d.c. power for energising the auxiliary services relay.

3.3 THE REGULATOR (SEE FIG. 3)

Thus unit together with the alternator and the rectifier is shown in block form in Fig. 3, the associated regulator is designed to respond to changing load conditions and will adjust the output of the alternator accordingly, by constantly monitoring the current in one phase of the alternator output, and the voltage across the battery to vary the field current.

Increase in output above the regulated datum will reduce the field current whereas a reduction in output below the regulated datum will increase the field current, this means that the output can remain constant for a wide range of changing loads and alternator rotor speeds.



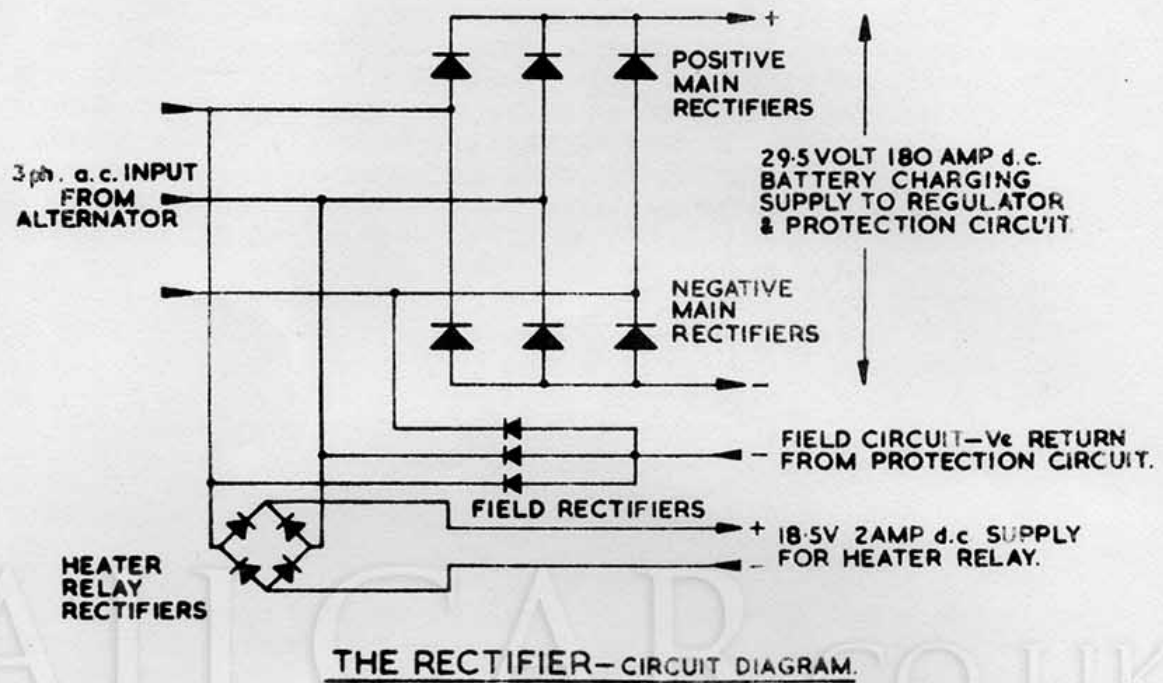


FIGURE 2

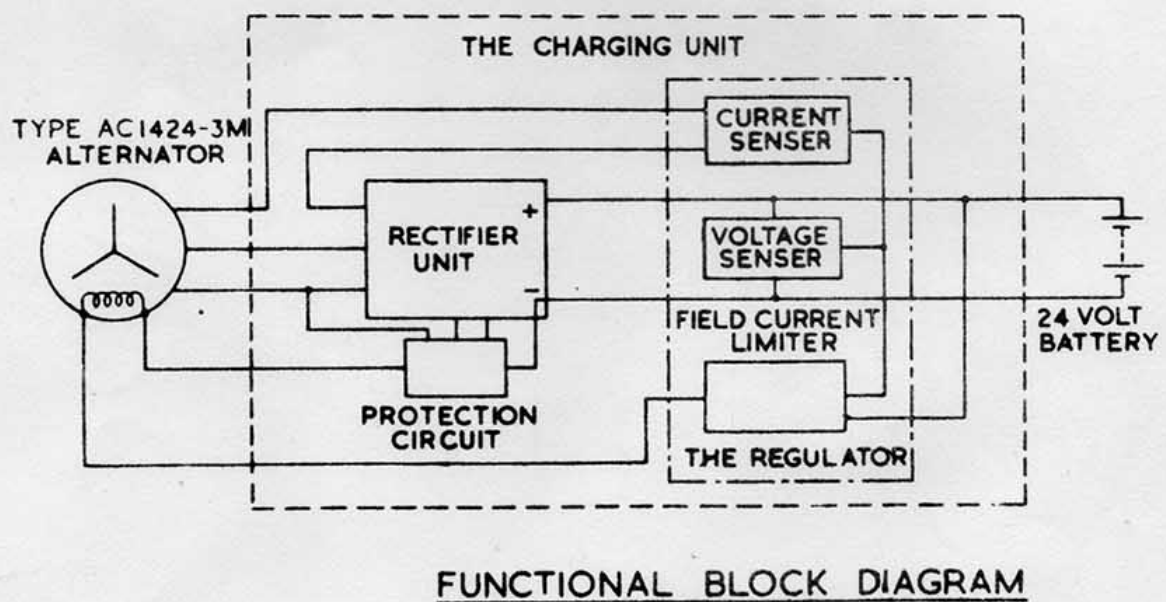


FIGURE 3

3.4

OPERATION OF THE REGULATOR AND ALTERNATOR (cont'd)

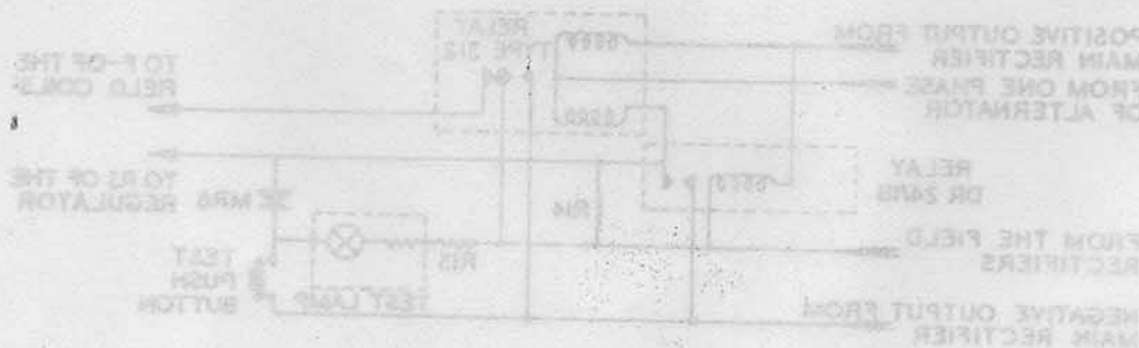
During normal operation of the regulator, this chain is connected across the battery via relay contacts DR24/18 (which are located in the protection unit), and as the voltage across the battery rises, the junction of R2 and R3 becomes more negative with reference to B+ line. This negative going aspect is in turn fed to the base of transistor VT1, causing it to conduct steeply, transistor VT1 forms a parallel circuit with transistor VT4, with VT1 conducting it has the same effect as an increase in current has on conduction of VT4.

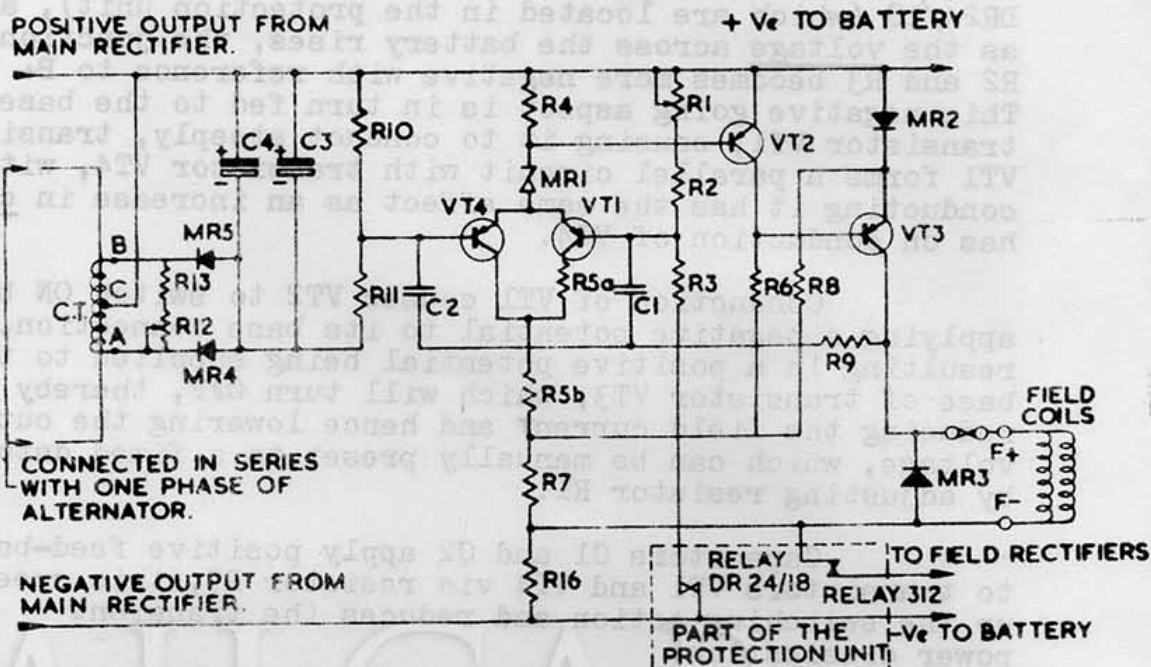
Conduction of VT1 causes VT2 to switch ON by applying a negative potential to its base connection, resulting in a positive potential being supplied to the base of transistor VT3, which will turn OFF, thereby reducing the field current and hence lowering the output voltage, which can be manually preset to a fixed datum by adjusting resistor R1.

Capacitors C1 and C2 apply positive feed-back to transistors VT1 and VT4 via resistor R9, this speeds up the switching action and reduces the transient power dissipation.

NOTE:-

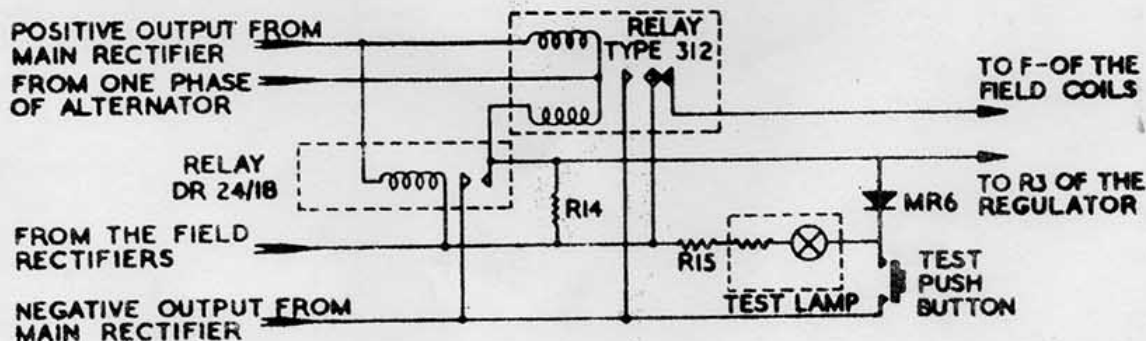
With the alternator at rest, all transistors are OFF with the exception of field transistor VT3 whose base is held negative by the series path formed by R6, R7 and R16, transistor VT3 allows current to flow via MR2, the field windings and R16, with R16 limiting the flow of current to a value sufficient to allow an immediate build up of alternator output on starting up.





THE REGULATOR—CIRCUIT DIAGRAM.

FIGURE 5



THE PROTECTION CIRCUIT

3.5 THE PROTECTION CIRCUIT (FIG.6)

The circuit is designed to detect alternator out of balance, between alternator phases, and a fault on the main rectifier diode bank should a fault occur then the alternator field is disconnected from its supply, to prevent the alternator from being overloaded.

Two relays 312 and DR24/18 which is energised when the alternator produces an output, as the contacts of DR24/18 complete the circuit to the coils of relay 312, both are connected across the output of the main rectifier diode bank.

Relay 312 consists of two series-connected coils wound in opposition to each other, and connected to one phase of the alternator at their junction. Provided that the magnitudes of the + and - d.c. outputs from the main rectifier bank are identical when referred to one phase of the alternator, then equal currents flow in both coils of relay 312, being in series opposition, the mean magnetic flux produced by the relay coils will be zero, hence under normal operation relay 312 remains de-energised.

In the event of a main diode failure the zero flux condition will be unbalanced and one coil will take more current than the other to energise relay 312 to break the field current.

TESTING

A test device which consists of a lamp and test button is included in the protection unit, with NO fault the green test lamp should light when the test button is pressed. If relay 312 is energised by the battery supply back-feeding through a faulty main rectifier bank diode, the test lamp is short-circuited.

C.A.V. REGULATORS/SETTING DATA

R.U.G. 1 & 10 - NIFE cells, set 30.5 volts d.c.
current limit 50 amps.

R.U.G. 2 & 11 - LEAD ACID cells set 29.5 volts
d.c. current limit 50 amps.

R.U.G. 12 - LEAD ACID cells set 29.5 volts d.c.
current limit 150 amps.

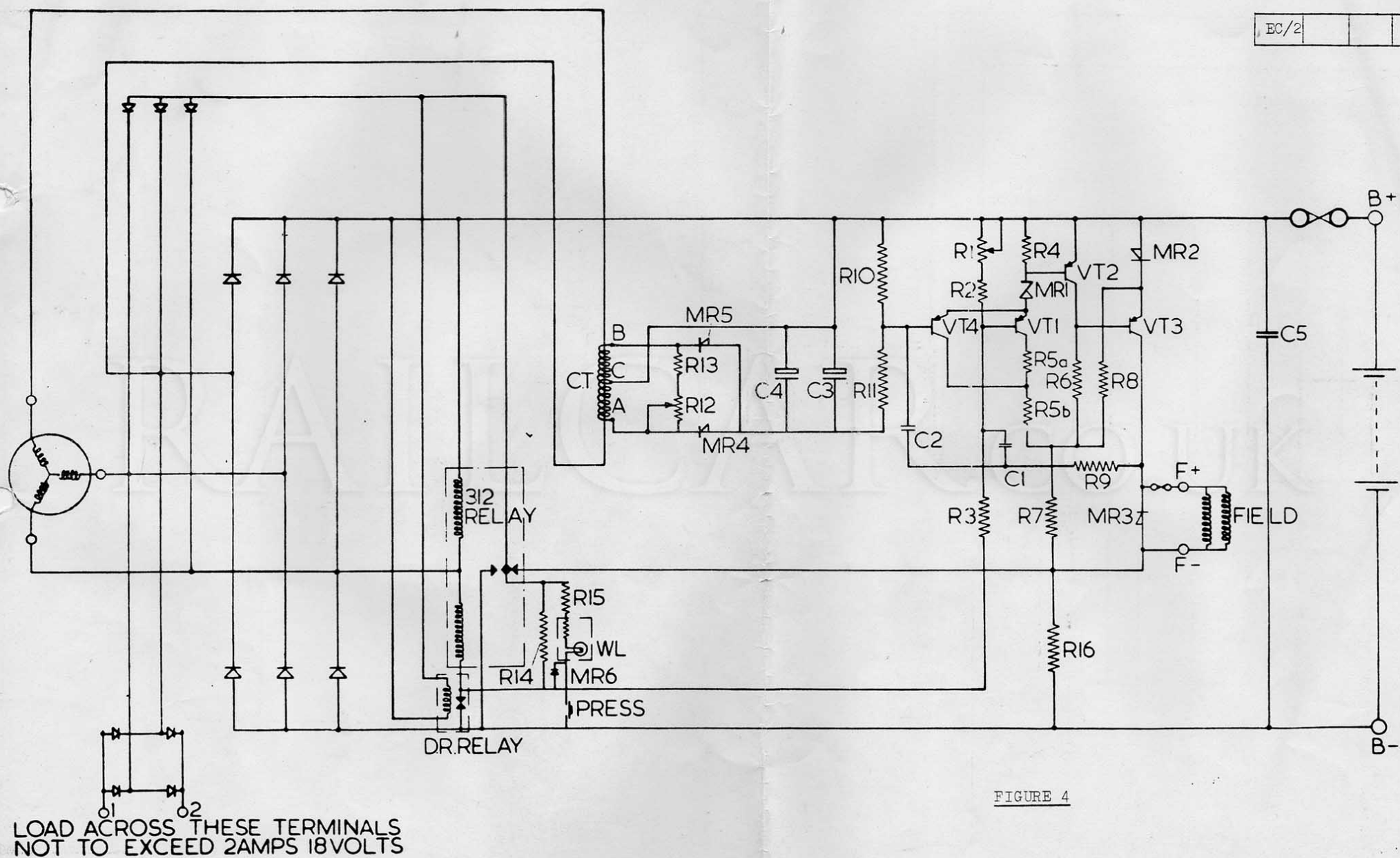


FIGURE 4

WIRING DIAGRAM-ALTERNATOR AND CHARGING CIRCUIT