INSTRUCTIONS

for

INSTALLATION and MAINTENANCE

of

HEWITTIC RECTIFIERS

SMALL SINGLE BULB CUBICLES

(Types 40/100, 100/200 & 100/200 E.T.)

CONTENTS

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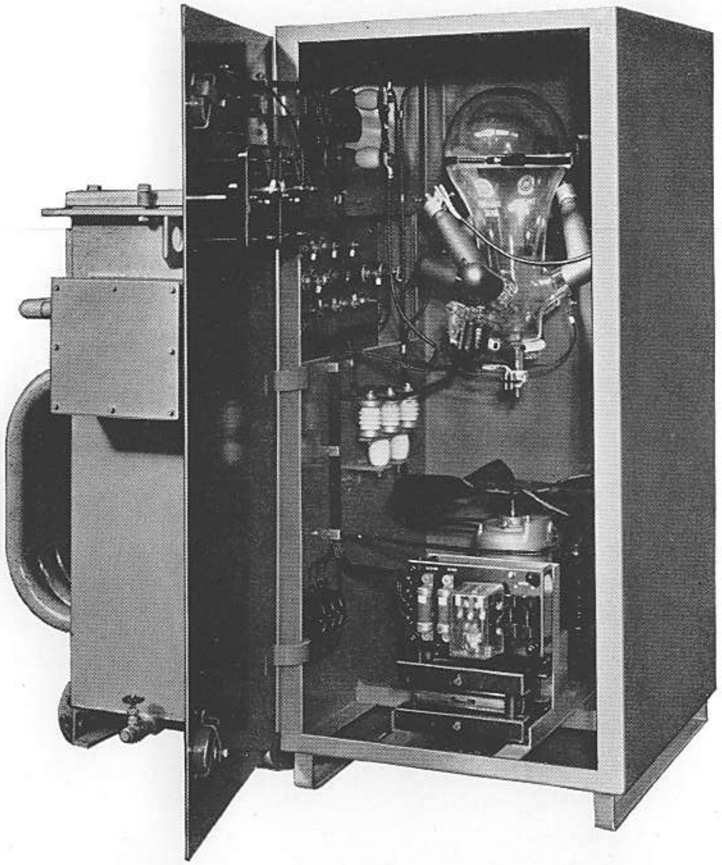

Fig. 1. A typical 3-phase 15 kW Hewittic rectifier using an oil-cooled external transformer.

EXAMINATION ON DELIVERY

Rectifier units for Great Britain are, in general, delivered to site on the Company's own vehicles: equipments for overseas are suitably crated for shipping. The bulbs are despatched in individual cases, as described later.

Immediately upon receipt, the complete equipment should be examined and any transit damage reported at once.

INSTALLATION

Positioning. The rectifiers require a moderate degree of ventilation and should have a space of about 6 in. at sides and rear. If there is plenty of room however, it is an advantage from a maintenance point of view to increase this to 2 ft. As the rectifier is static in operation, foundation fixings are not essential.

Before being placed in position the rectifier should be thoroughly examined and any connections or sheeting screws that may have worked loose in transit, tightened.

Cabling. In small equipments the internal wiring is usually complete, just as it leaves the test department and all that needs to be done is to connect the A.C. supply to the transformer, and attach the outgoing D.C. cables.

Where the transformer is not built into the cubicle however, the interconnecting cables also have to be attached at the transformer end.

For 3-phase equipments with grid control or a 3-phase cooling fan motor, it is important that the equipment be connected to the supply with correct phase rotation. If there is a 3-phase cooling fan the phase rotation may be checked by observing the direction of the fan which is correct when blowing air upwards. If this is not so, any two of the main A.C. supply leads should be interchanged. If the phase rotation of a grid controlled equipment is incorrect, the required voltage control will not be obtained.

Supply Voltage Tappings. The transformer is usually provided with tappings for A.C. supply voltage variation. The links controlling these tappings should be set to suit the average supply voltage actually obtained. The output voltage also may be varied a little by the use of these tappings but, in general, tappings provided to allow for low supply voltages should not be used to boost the output voltage.

Installing the Bulb. The rectifier bulb is transported upside down, with the mercury in the condensing chamber, in a specially sprung case. *When moving the case it must not be jolted violently and it is essential that the case be kept the right way up.*

Do not unpack the bulb until the rectifier has been installed and all necessary work carried out, so that the bulb can be transferred straight from the case to the cradle in the rectifier. Before unpacking the bulb, undo the top band of the cradle in the rectifier, ready to receive the bulb.

To unpack the bulb, *unscrew and remove the lid* (do not attempt to dismantle the case) and unfasten the spring straps. Lift the bulb from the harness, holding it under the main arms close to the condensing chamber, as shown in Fig. 2. Then put one hand under the condensing chamber (see Fig. 3) and turn the bulb *slowly* into the upright position, i.e. with the cathode stem pointing downwards, allowing the mercury to flow gently down the side of the condensing chamber (between the arms as far as possible) into the cathode pool.

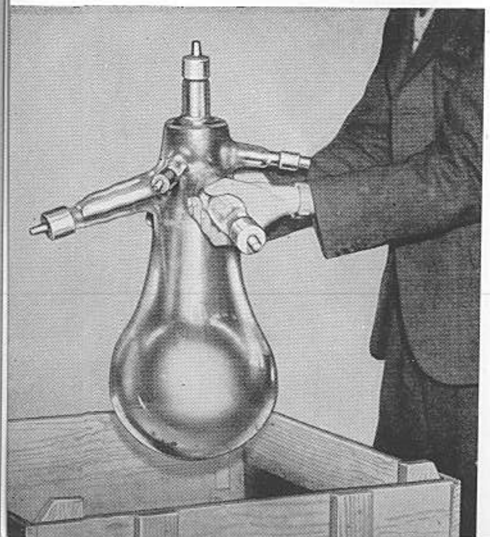

Fig. 2. Lifting the bulb from the case.

Mind the Seal-off! The seal-off, covered by a small black cap, is situated towards the end of the lower part of one main anode arm. Care should be taken not to strain this point and, particularly when turning the bulb, mercury should not be allowed to enter this arm violently. By keeping this arm uppermost while inverting the bulb all risk of damaging the seal will be avoided.

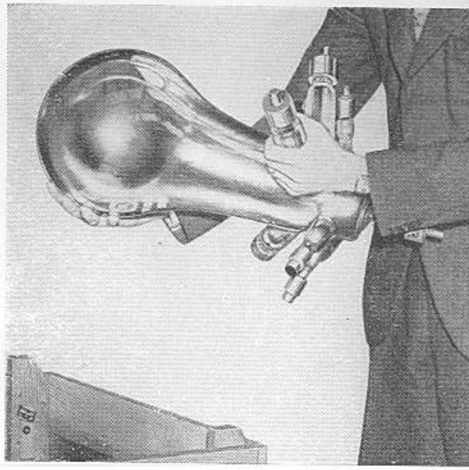

Fig. 3. Turning the bulb into the upright position.

Having inverted the bulb, it should be placed in the cradle in the rectifier cubicle, the lower end being seated in position first (Fig. 4). The top band should then be fastened round the bulb, remembering to insert the asbestos strip between the band and the glass.

Fig. 5 shows the correct position of the starting coil on the starting electrode arm. The diameter of the electrode arm is increased near the cap, and the fixing clip of the starting coil is clamped round this enlarged section.

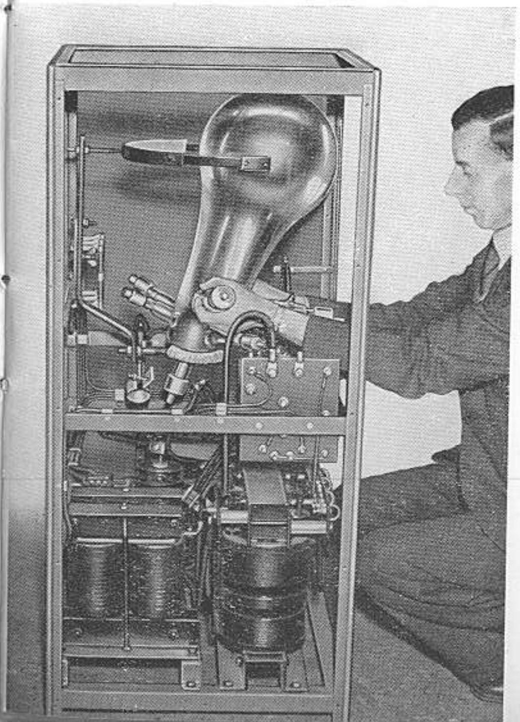

Fig. 4. Seating the bulb in the cradle.

Removal of grease from bulb terminals. Before fitting the clip connections (see Fig. 6), the grease should be removed from each bulb cap by wiping with a clean rag, rubbing gently down towards the arm. On no account should the cap be twisted during this operation, since this may damage the anode seal.

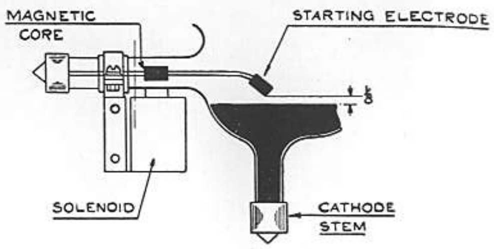

Fig. 5. Adjustment of the starting electrode.

Fitting the bulb clips. Each clip connection should be loosened before it is slid on the cap, after which the ears of the clip should be pinched together and the knurled nut tightened reasonably by hand. The lock-nut should then be tightened against it, also by hand: under no circumstances should pliers or a spanner be used.

The tip of the starting electrode (or dipper) should be about $\frac{1}{8}$ to $\frac{1}{4}$ in. above the surface of the mercury. To adjust this gap, loosen the wing nut securing the bulb cradle and alter the angle of the cradle as necessary, after which the wing nut should be retightened.

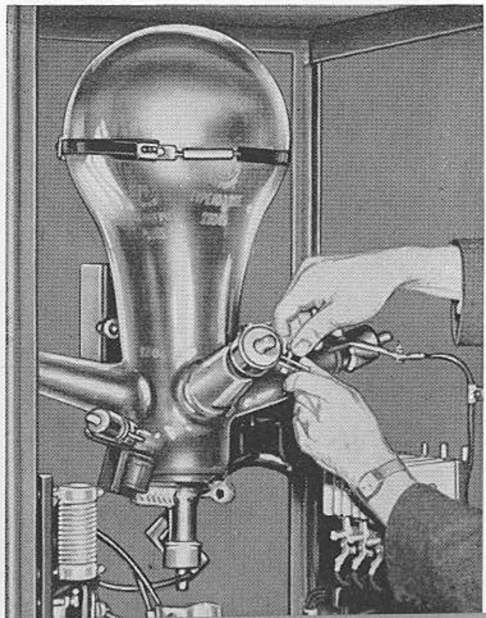

Fig. 6. Fitting the clip connections.

THE GENERAL PRINCIPLE OF THE HEWITTIC RECTIFIER

The mercury arc rectifier consists essentially of a highly evacuated vessel containing a mercury pool known as the cathode, and a number of electrodes known as anodes which are sealed into the arms forming part of this vessel. These anodes are usually made of graphite.

Its principle of operation depends upon the fact that, under suitable conditions, a stream of electrons can be drawn from the surface of the mercury towards the anodes, whereas under the same conditions there is no such flow from the anodes to the mercury pool.

The conditions referred to are that the rectifier must be evacuated to a very high degree of vacuum, that a "hot-spot" must be created and maintained on the mercury pool, and that the rectifier must be maintained within certain limits of temperature. (See "Operating Temperature".)

The "hot-spot" is initiated by drawing a small arc between a starting electrode and the surface of the mercury. This is just a momentary arc because immediately this "hot-spot" is created, there is a source of free electrons which enables the exciter anodes to strike up. These anodes may be fed from a winding on the main transformer or alternatively from a separate auxiliary transformer, and the voltage from either end of the winding to its mid-point is 60 volts.

It will be seen that the exciter anodes are alternately at a positive potential to this mid-point, and therefore to the mercury pool which is connected thereto. As each anode becomes positive, a stream of electrons is drawn to it and passes round the circuit external to the bulb. This constitutes an electric current identical with the current generated by a machine or circulated by a battery. The exciter circuit is, in effect, a small rectifier, as the current from the cathode to the mid-point of the transformer is unidirectional.

The early conception of an electric circuit, viz., that the current flowed from the positive pole of a battery or

generator, through the external circuit to the negative pole, clashes with the modern electron theory. Within the rectifier the electron stream is necessarily described as flowing from the cathode to the anodes. Externally, however, the current is spoken of as flowing from the cathode, via the load circuit to the mid-point of the transformer secondary winding, which is always the negative terminal of a rectifier using this type of connection.

If an alternating potential is applied to the main anodes, and there is a complete external circuit, then there will be a similar electron stream to those anodes. Each anode conducts until the potential on the one in the succeeding phase reaches and exceeds its own falling potential, and thus the stream, or arc, transfers from anode to anode in synchronism with the alternations of the source of supply; but, in consequence of the retentivity of vision, all of the arms of a glass bulb type of rectifier appear to be conducting simultaneously, when operating on a 50 to 60 cycle supply.

Starting and Maintaining Circuits

Fig. 9 gives the starting and excitation circuits for the type "W" starting relay now in general use. Its principle of operation, however, may be more readily understood from the following description with simplified diagrams.

Stage 1. The transformer gives an open-circuit voltage of 60 volts from either 1 or 3 to the mid-point 2. When the transformer is energised, current flows from 3, via a contact on the starting relay and the current limiting resistor to the starting coil 5-7, returning via the other contact of the relay to the mid-point 2 (Fig. 7).

The starting electrode or dipper, is immediately pulled into contact with

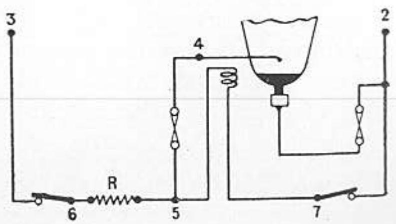

Fig. 7. Energising the starting coil.

the cathode pool, and it will be seen that this provides a short circuit to the starting coil. The springy electrode is thereupon released and when it leaves the surface of the mercury it draws a small arc.

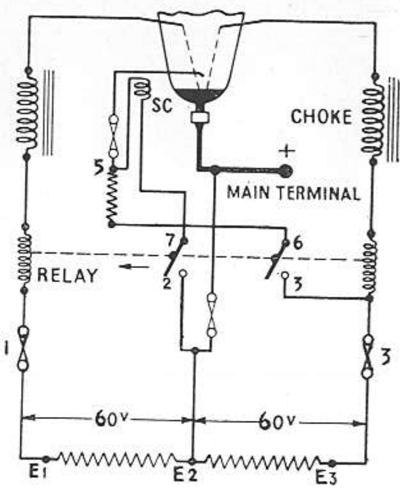

Fig. 8. Bulb running on exciters.

Stage 2. The free electrons resulting from this arc enable the exciter electrodes to strike up and remain energised (Fig. 8). The diagram shows that the circuits to the exciter anodes pass through the coils of the starting relay as well as the exciter reactor (or choke). As soon as the bulb is running on the exciters, the relay operates, isolating the starting coil and the starting electrode. This usually happens too quickly to be observed, and is the normal running condition the whole time that the rectifier is in service.

On the full wiring diagram (Fig. 9), will be seen a set of surge diverters connected across the exciter reactor and transformer. These protect the highly inductive windings against damage from voltage surges.

Many equipments already in service have a different type of starting relay (known as type "I") and in this case the circuit is as in Fig. 10. Actually, the only difference is that instead of the relay being operated by twin coils, one in each exciter reactor lead, there is a single coil which is connected in the circuit between the cathode and the mid-point of the transformer.

For some types of service the exciter anodes can be dispensed with, their place being taken by the main anodes. In such cases the starting relay is operated by the load current from the cathode of the bulb.

It is necessary, in these cases, for the load circuit to be closed before starting up or there will not be a flow of current to maintain the cathode spot. Where, as is more usual, a separate exciter circuit is provided, the value of the excitation current is determined by the amount of packing in the exciter reactor. The normal exciter currents for the smaller bulbs are tabulated on page 18. As this load is mainly inductive, the energy consumption for excitation purposes is only about 100 to 150 watts.

It was stated earlier that a high degree of vacuum must be maintained in the rectifier. The Hewittic air-cooled glass bulb is a permanently evacuated vessel and does not need a pump and gauge for maintaining and checking the vacuum once the bulb is made and sealed. Moreover, since there is no consumption of either the mercury or the electrodes, it follows that the bulb will operate for an indefinite period without replacement or maintenance. It can be left out of service for any period yet will always be ready to carry load immediately the A.C. supply is switched on.

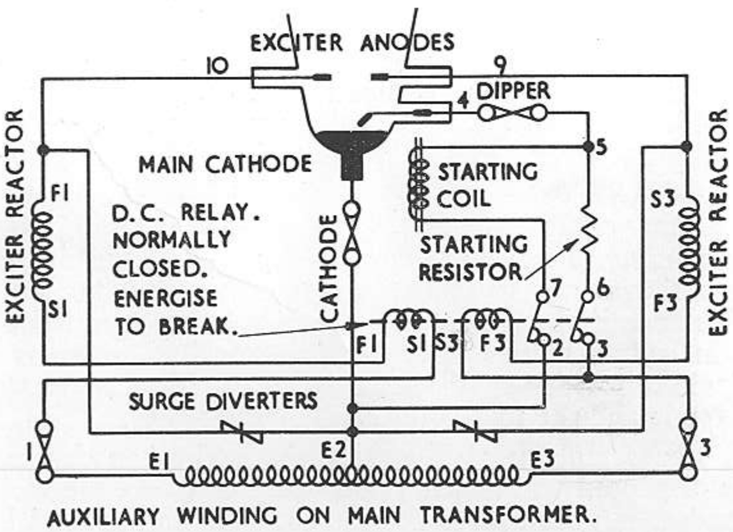

Fig. 9. Complete starting and excitation circuits for type W relay.

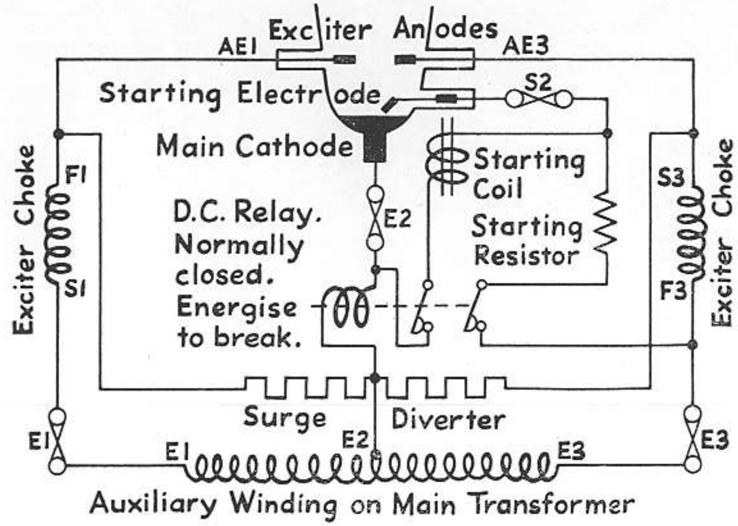

Fig. 10. Starting and excitation circuits using type I relay (now superseded by type W).

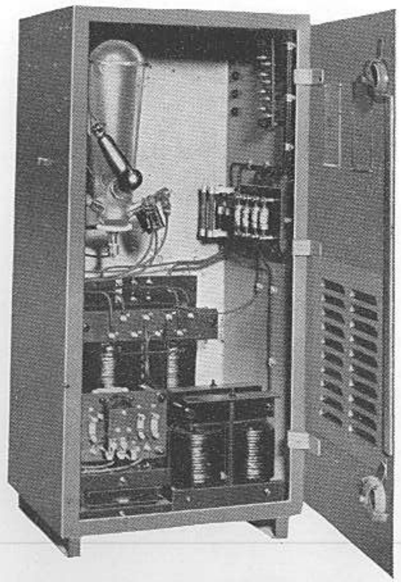

Fig. 11. A typical small equipment with self-contained air-cooled transformer.

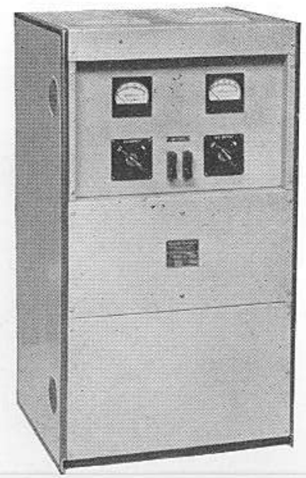

Fig. 12. A small self-contained equipment as developed for supplying tabulating machines.

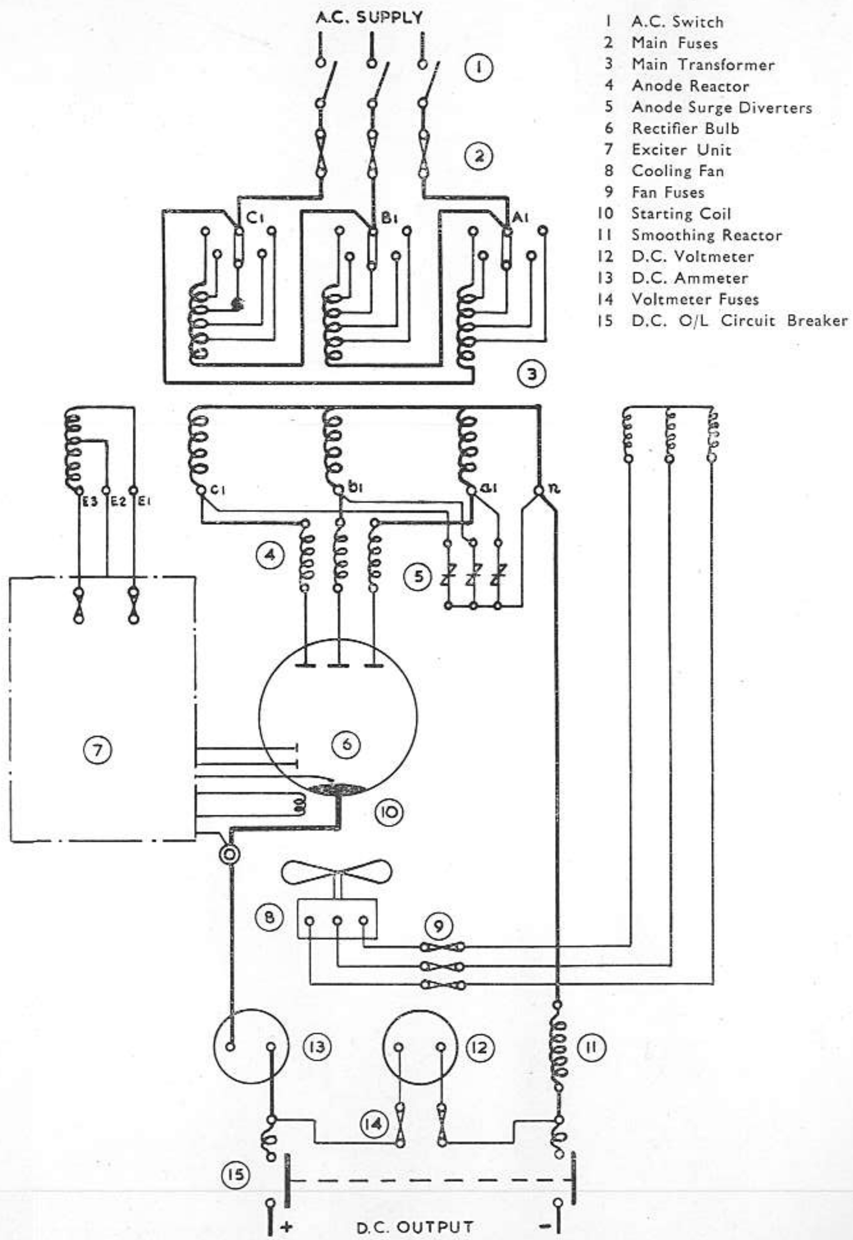

Fig. 13. Diagram of connections for a 3-phase rectifier.

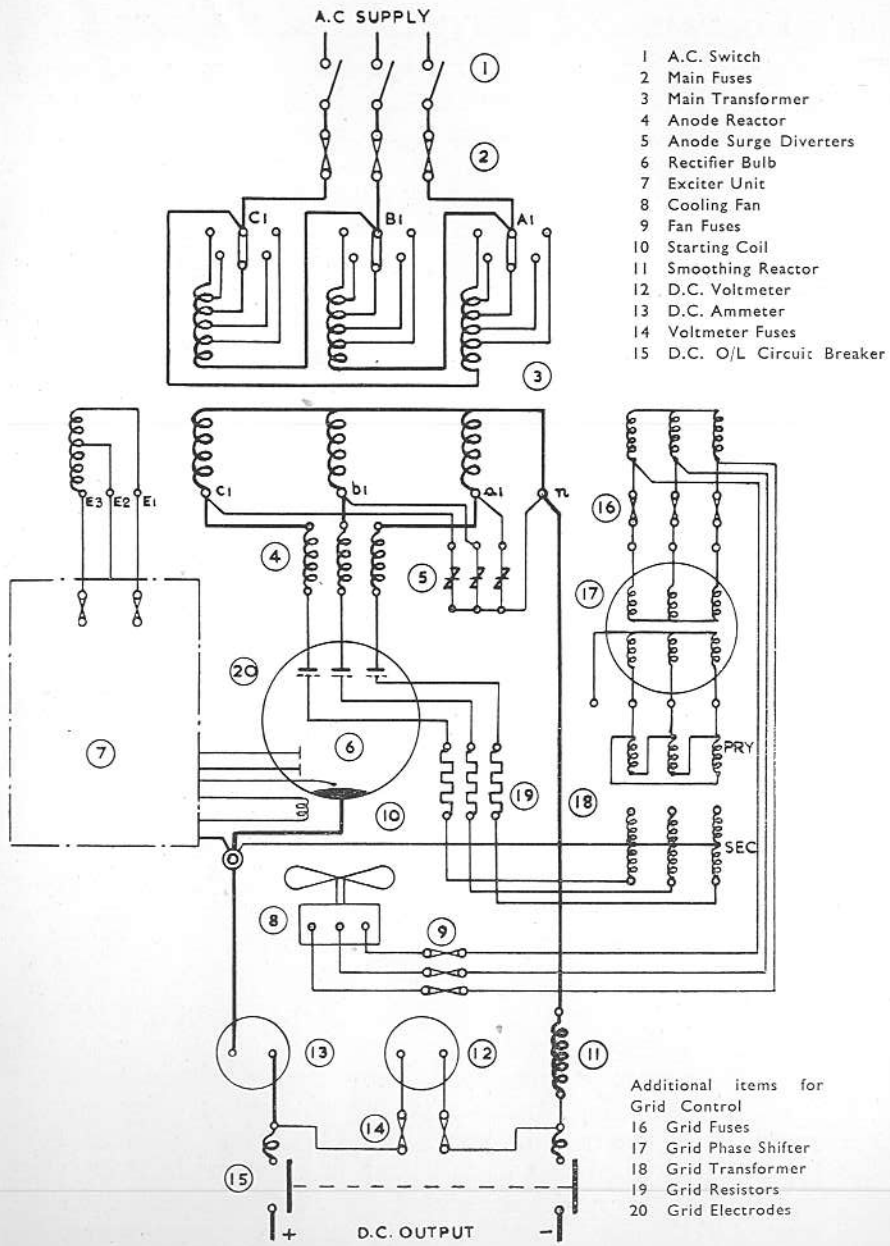

Fig. 14. Diagram of a grid controlled 3-phase rectifier.

DETAILS OF A TYPICAL EQUIPMENT

Fig. 13 is a diagram of a standard 3-phase rectifier, whilst Fig. 14 shows the additional items necessary for a grid controlled equipment as used for battery charging and other applications.

The A.C. control switch gives a supply to the transformer via a set of fuses. The primary winding normally has taps to compensate for sustained departures of the supply voltage from the nominal declared pressure, and these are altered by means of separate radial links in each phase. In addition to the main secondary there are shown two auxiliary windings. On the left is the one for starting and exciting the bulb, and on the right is a 3-phase winding for supplying the grid control equipment (if required) and also the cooling fan.

The secondary phases connect to the bulb anodes, but between the transformer and the bulb there is, in this case, an anode reactor (Item 4). This comprises a laminated core with an adjustable air gap and a single coil on each limb, and its purpose is to give an increased regulation to the rectifier. A flat regulation characteristic is generally desirable with resistance loads because the D.C. voltage then remains substantially constant with changes in D.C. load. The anode reactors therefore are often omitted from standard rectifier equipments. With battery chargers, where the back e.m.f. of the load is a high proportion of the D.C. voltage, the regulation is deliberately increased so that small changes in A.C. supply voltage will not cause large changes in charging current. The advantage of this characteristic is that frequent adjustment of voltage is not required as the battery e.m.f. increases.

Anode reactors (or chokes) are used also to enforce good load sharing when a number of rectifier bulbs are required to operate in parallel. The rectified current from the three phases is collected at the cathode (which constitutes the positive pole of the rectifier), and conducted to the double pole circuit breaker via the ammeter. The negative pole of the rectifier comes from the star-

point of the transformer secondary winding and in this lead is often inserted an iron cored smoothing reactor (Item 11), which evens out the ripple which results from the rectification of an alternating current.

Item 5 is a set of surge diverters. These are connected one across each secondary phase of the transformer from outer end to mid-point. These provide a by-pass for the stored magnetic energy in the core should the D.C. circuit be interrupted suddenly.

GRID CONTROL EQUIPMENT

While it is by no means essential for the operator of a grid-controlled rectifier to understand the principle upon which it works, the majority would prefer to know something about the apparatus under their care.

Under the heading " The General Principle of the Hewittic Rectifier " it was explained that the rectified current comprises a rapid succession of pulses (all in the same direction) from the anodes in turn. These pulses are normally the peaks of the rectified A.C. waves of the supply. Fig. 15(a) shows the wave of rectified voltage (unsmoothed) for a normal 3-phase rectifier. If now a means be adopted of delaying the transfer of the arc from one anode to the next, the effect is as shown in Fig. 15(b). The average voltage is appreciably less, since one is no longer rectifying the maximum portion of the A.C. voltage wave.

The method of delaying the anode firing is by placing an additional electrode known as a " grid " in the arc path and close to each anode. This has impressed upon it a voltage that is variable in phase to that of its associated anode and, for the inhibited portion of the cycle, must be negative to the cathode. This overpowers the attraction of the anode for the electrons at the cathode spot, and consequently the arc in this arm is delayed. The arc to the preceding anode however does not necessarily extinguish but is prolonged until its voltage is no higher than the back e.m.f. (if any) of the D.C. load circuit or has dropped to zero, when of course the current flow ceases. Once the arc is struck the grid cannot regain

control of that anode until the arc extinguishes. The grid control equipment can be regarded as a separate rectifying unit which passes a very small and strictly limited current. Its anodes act as pilots to the main anodes and it is during its blocking half cycle that it prevents the latter from striking up.

If required, the delay can be increased to the point where the anodes do not fire at all. Fig. 15(c) shows what happens when firing occurs for only the last few degrees of each half cycle—the D.C. voltage is now reduced to almost vanishing point.

To vary the delay, a phase shifter (Item 17) is introduced. This is similar physically to a 3-phase induction motor with a wound rotor, except that usually the rotor can be moved through only about 150 electrical degrees. The latter, therefore, is not provided with sliprings and brushes but only flexible leads from the rotor windings. It functions as a transformer with a variable phase angle. The rotor, or secondary winding connects with grid transformers (Item 18) which step up the voltage to the value required for the particular equipment and also provides phase splitting when required for 6-phase rectifiers. The mid-point of the hexaphase winding connects with the cathode, and in each grid lead is a resistor of several

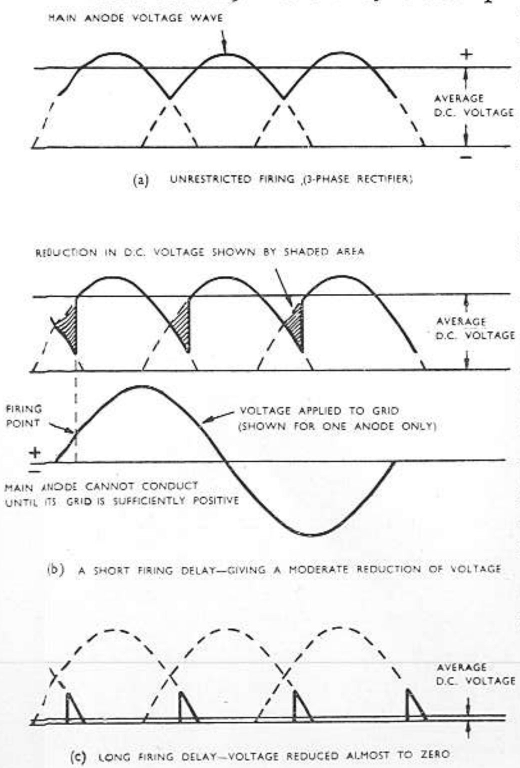

Fig. 15. Diagram showing how D.C. voltage is reduced by delaying the firing of the anodes (grid control).

thousand ohms, to limit the grid current to that required for ionisation of the main arc path.

The phase shifter in small rectifiers is usually manually operated by means of a handwheel. On some equipments it may be driven by an electric motor through a worm gear. Operation may then be by local push buttons or by push buttons located at a remote control point. This type of equipment lends itself readily to an automatic control scheme under which it would maintain say a constant voltage, or constant current output, or vary the voltage or current in any desired manner.

Voltage control by means of grids is thus very convenient and gives stepless variation. Where the rectifier is likely to be run for long periods at low voltages transformer tappings may be used to reduce the necessary degree of firing delay and so improve the wave form.

Alternatively, a voltage regulating transformer of the stepless type may be used. The anodes are then allowed to fire freely but are fed at an externally controlled voltage.

The use of an iron-cored reactor (Item 11) in the D.C. circuit smooths the output current and this device is always included where the circumstances call for it.

SWITCHING ON FOR THE FIRST TIME

All rectifiers are tested for insulation and correct operation before leaving the works, after which nothing is disturbed apart from detaching the external cables and removing the bulb for separate transport. Therefore, after the cubicle has been installed on a level floor, the supply and D.C. load cables connected, and the bulb placed in its cradle with the leads attached, the rectifier should strike up immediately and be ready for load. Should the equipment have been left under damp conditions for some time since delivery from the works an insulation test would be advisable, and if necessary, it should be dried out—particularly the transformer if this is not oil immersed.

It is not possible to quote a standard figure for insulation resistance, as so many factors are involved, but

if a figure of about 2 megohms is obtained it would be safe to put the rectifier into commission. The heat evolved in operation would soon restore the insulation to the original high level.

Should drying out be considered advisable this is readily done by means of one or more electric radiators. The use of a fan to increase the circulation of air would hasten this drying out process.

Adjustments. (a) *Level of the mercury pool*

If the bulb will not strike up, examine the level of the mercury relative to the starting electrode ; there should be a gap of $\frac{1}{8}$ in. to $\frac{1}{4}$ in. so that the electrode can immerse in the cathode pool when drawn down by the starting coil, and definitely leave the mercury when released (see Fig. 5).

The level is adjusted by altering the angle of the bulb cradle by the means provided.

(b) *Exciter current*

Should the bulb persistently restrike, after having been allowed a minute or two to warm up, the exciter current should be checked. Remove exciter fuse E_2 and insert a moving coil ammeter reading up to 10 amps. The correct current is as follows :—

	without fan	with fan
For bulb type 40	4.6 to 5.0 amps	5.0 to 5.4
„ „ 100	5.0 to 5.4 amps	5.4 to 5.8
„ „ 150	5.4 to 5.8 amps	5.8 to 6.2
„ „ 200	5.8 to 6.2 amps	6.2 to 6.6

The above current applies after the bulb has been running for 2 or 3 minutes with the ambient temperature between 10 and 30 deg. C.

To increase the current, the gap in the exciter reactor must be increased. Loosen the tie bolts and add about $\frac{1}{16}$ in. of presspahn or similar material to the packing already there. After adjustment the choke head should be bolted down hard and the locknuts tightened, otherwise the choke may be noisy. The exciter current should then be rechecked.

OPERATION AND MAINTENANCE

General. The Hewittic mercury arc rectifier is such a simple piece of apparatus that " operation " means little more than switching on when required for service and switching off when its duty is finished.

Upon switching on the A.C. supply to the transformer, the bulb strikes up and remains running on its exciters. As soon as the D.C. switch or circuit breaker is closed the rectifier will pick up any connected load.

Sometimes, in cold weather, the bulb may restrike several times before settling down to run steadily on the exciters. This does not necessarily indicate that something is wrong or that the bulb is deteriorating. If some load can be applied the bulb will soon warm up and run steadily. Should restriking be persistent an investigation should be made—see " Fault Location."

Having put the rectifier on load it remains only to adjust the voltage to suit requirements (where provision is made for on-load voltage or load control) and to see that the equipment is not overloaded beyond its proper rating.

Cleaning. Dusting or cleaning the interior of the cubicle should not be regarded as a routine operation, under normally clean conditions, as a reasonable accumulation of dust will not impair operation. If it is desired at any time to give the plant a clean, no attempt should be made to clean the bulb. There is the risk of a rag catching one of the bulb clips and the sudden wrench may fracture the seal. It is advisable therefore to confine the cleaning to terminal boards and the components in the lower part of the cubicle.

The Starting Relay. This is unlikely to give any trouble for many years. The contacts are in use only momentarily at the striking up of the bulb, and the whole relay is protected by a dust-proof cover. This is transparent, so that the condition of the contacts can be observed without admitting dust from the atmosphere. No provision is made for adjustment—in fact the screws are sealed, it being considered preferable to replace a

defective relay with a new one and return the original one for investigation (on plants overseas this, of course, may not be practicable).

Fan Motors. The cooling fan, where provided, is driven by a totally enclosed low voltage induction motor. This runs in ball bearings which are filled with grease when the rectifier leaves the factory, and this first filling should suffice for about 3,000 hours of operation. After this period the dust should be removed from around the grease caps and feed pipes, and the caps then removed and filled with grease and screwed back again on the feed pipes. This will force a replenishment down to the ball races and will suffice for a further period of about 3,000 hours running.

The recommended lubricant is Power Petroleum RBB.3.

It is recommended that the motors be taken down after about 10,000 running hours and the bearings cleaned out. The old grease can be run out by warming the bearing, followed by swilling in clean paraffin or petrol and draining. The bearing is then repacked with grease and the motor reassembled. The utmost cleanliness is essential until the overhaul is completed, as any gritty dust finding its way into the grease would cause rapid wear and necessitate early replacement of these precision ground bearings.

OPERATING TEMPERATURE

The optimum ambient temperature for mercury arc rectifiers is between 10° and 30°C (50° and 86°F). Higher temperatures are permissible when allowance is made for this in the original design of the plant.

Glass bulb rectifiers are less susceptible to low temperatures than are other types and, if not fitted with grids, may be operated down to 5°C (41°F). When grids are fitted for voltage control, however, the rectifier must be maintained at a temperature above 10°C if erratic operation and possible damage to the plant are to be avoided : THIS IS MOST IMPORTANT.

Therefore, whenever a grid controlled rectifier is installed in a location which may be subject to low temperatures, artificial means should be used to maintain a temperature of not less than 10°C, both prior to starting and during operation. Where considered necessary, a heater can be built into the cubicle during manufacture in the works. This dispels any anxiety on this point and also is far more economical than keeping the whole of an unattended substation or plant room warm throughout the winter months.

Mention has been made of the need for ventilation. All but the very smallest equipments have a ventilating fan fitted to increase the air flow over the surface of the bulb. For the larger bulbs, and especially when they carry approximately full load continuously, it is necessary to ensure that an adequate replacement of air enters the substation or rectifier room. The mere recirculation of the same air may not suffice to prevent an undue temperature rise of the bulb and transformer, particularly in hot weather.

TRACING FAULTS

In spite of the simplicity and reliability of the Hewittic rectifier, there may come a time when, for some reason or other, a bulb fails to strike up or operate satisfactorily. The attendant will then require to know the quickest way to locate the trouble and restore the rectifier to service.

Warning. Although the exciter circuits operate at only 60 volts to the mid-point of the transformer winding, it should be remembered that being connected to the cathode of the bulb they are always at cathode potential to earth.

In the case of battery charging equipments or other installations where there can be a back feed from the D.C. circuits, the D.C. switchgear should be opened to prevent an accident.

First of all make a visual examination of the equipment, looking for signs of excessive heating or damage

to insulation at any point. Also check for loose connections or a fuse not properly located in its holder. If no such evidence is discovered, proceed on the following lines.

Assuming that all of the phases of the A.C. power supply are alive, and at normal voltage (it may be found necessary to check this), the trouble should be investigated in the following manner :—

(1) Starter circuit.
(2) Exciter circuit.
(3) Main circuit.
(4) Grid control equipment.
(5) The bulb itself.

(1) Starter Circuit. Upon switching on the supply to the main transformer there should be a voltage across the starting coil (see diagram on page 8).

If the dipper, or starting electrode pulls into the mercury and remains there, it indicates that fuse S2 or E2 has blown, otherwise the electrode would short-circuit the starting coil and cause its own release.

Observe that when the electrode is pulled down it actually makes contact with the mercury. After some hours of operation the condensing chamber of the bulb becomes coated with condensed mercury (which eventually trickles back to the pool) and the constant suspension of this small quantity naturally results in a slight lowering of the pool level. If the original gap had been set rather wide it could be that after a period of operation the starting electrode could no longer touch the mercury when pulled down by the starting coil. A slight adjustment to the bulb cradle would remedy this difficulty.

Should there be no pull on the starting electrode and the appropriate fuse is sound, check with a voltmeter the volts across the starting coil. If the full 60 volts is indicated, then the coil would appear to be open-circuited. If no reading is obtained do the same to the starting resistor : the same remarks apply. Finally

examine the starting relay : its contacts are in series with the starting coil and therefore should be closed until the bulb has struck up.

(2) Exciter Circuit. If the starting electrode repeatedly makes and breaks with the mercury pool, producing a bluish spark at each break, check the remaining auxiliary fuses. Should the ambient temperature be very low, introduce some heat to the cubicle, say from an electric radiator and allow a little time for the bulb to warm up. If necessary test the circuit for continuity, after first checking the voltage across the exciter anode caps : it should be approximately 120V A.C. on open circuit (i.e. with the exciters not striking up). The contacts of the exciter relay are not involved in the exciter circuit, but its operating coil is, and an open circuit in this would account for the trouble. However, as this coil is wound to carry at least 10 amps continuously, it is unlikely that a fracture would occur in such substantial wire.

If the above mentioned examination does not reveal any defect and the spark at the starting electrode is noticed to be white instead of the usual blue, the bulb vacuum may be suspected (see paragraph 5).

(3) Main Circuit. There will be no need to suspect the bulb if it is running normally on its exciters : if the D.C. voltage of a three- or six-phase equipment is abnormally low observe the bulb and it may be discovered that a main anode is not firing at all. This could be due to the blowing of a primary fuse or to a fault on the transformer or the circuit between the transformer and the bulb. The latter may include a coil on an anode reactor.

The following points should be borne in mind :—

(a) There can be no glow in the main anode arms until an external load is being carried.

(b) Those bulbs that do not have an exciter circuit will not strike up until an external load is connected.

(c) Current will not feed back into the rectifier from a battery or other source whether or not the rectifier be running on its exciters, or even if isolated on the A.C. side.

Should A.C. fuses blow with no external load on the rectifier a short circuit in the transformer may be indicated. Alternatively, if the rectifier equipment cannot be made to ignite, run on its exciters or take load this may be due to an open circuit in the transformer, which can be checked by measuring the voltages on the secondary side.

(4) Grid Control Equipment. Any rectifier bulb that is fitted with control grids requires the starting potential to be applied to each grid at every positive half cycle. A discontinuity in the circuit to any grid will cause that arm to fail to fire, and the average D.C. voltage of the rectifier will fall appreciably.

Inspect the grid equipment fuses (Item 16) and if intact measure the voltage between each grid cap on the bulb and the cathode terminal. This should be about 390 volts A.C. in each case. Move the rotor of the phase shifter to and fro whilst observing the voltmeter: any violent fluctuations in the reading would suggest a fracture in one of the flexible leads. If the above has failed to locate the trouble test the continuity of the resistors, and failing this the circuit must be checked from point to point.

(5) The Bulb. This is not likely to give trouble except as a result of gross overloading, overheating, or mechanical damage to a seal.

TESTING FOR LOSS OF VACUUM

If a full investigation finally throws suspicion on the bulb it may be removed from its cradle and manipulated so that mercury pours into an exciter pocket at a moderate speed. If the vacuum is unimpaired this will produce a sharp metallic click, whereas if there is appreciable air in the bulb it will produce only a dull

leaden sound. Further, it may then be possible to trap small bubbles of air in one of these pockets, and if any are seen there can be no further doubt as to the condition of the bulb.

OBTAINING A REPLACEMENT AT SHORT NOTICE

All types of bulbs and most spares are normally available from stock, and can be despatched promptly by the most suitable method of transport.

To obtain a replacement of any item, or if unable to correct a fault, the works should be informed, quoting all the particulars given on the equipment rating plate which will be found on the inside of the door of each rectifier.

CARE OF DAMAGED BULBS

Return the defective bulb to its cradle until a replacement is received. When the new bulb has been installed in the cubicle, place the defective one in the bulb case and strap securely for return to the works. Even though an arm may be broken off it may be possible to repair it at appreciably lower cost than that of a new bulb. For transport purposes all of the mercury must be in the inverted condensing chamber. If any appreciable quantity is left in an arm further damage could result in the event of rough travelling.

EMPTY BULB CASES

Where equipments are supplied for overseas service, the bulb cases need not be returned, but one should be retained in case it is necessary to return a bulb for repair.

With equipments for installation in Great Britain the bulb cases are supplied on loan and should be returned.