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"Modern Telephone Repeater Station Power Plant"

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Modern Telephone Repeater Station Power Plant

Introduction.

During the past few years, considerable changes have taken place in the design of Power Plant for Telephone Repeater Stations. Prior to 1934 it was the practice to provide duplicate batteries for charge-discharge working with duplicate charging plant. In those days there were very few stations having an adequate public electricity supply. In most cases a supply was either not available or of doubtful reliability and the battery charging plant provided had to be one of the following types :—

(*a*) Duplicate motor-generators where public supplies were available from entirely independent power stations.

(*b*) A motor-generator and standby engine set where a public supply of fair reliability was available.

(*c*) Duplicate engine sets where no public supply was available or, if available, was too small and not sufficiently reliable to carry the repeater station load.

The plant installed had necessarily to be of ample size, and to eliminate the expense of week-end charging, batteries having an ultimate capacity for 48 hours discharge were usually provided. The engines were of the slow speed horizontal semi-Diesel type varying in size from 22 to 124 H.P.

Since the introduction of the Grid scheme it has been possible to obtain a power supply in most parts of the country, and the need for duplicate engines no longer arises. Motor-generators or rectifiers can be used and the batteries worked on a continuously floating basis.

At the repeater stations having motor generators a high speed Diesel Engine is provided and arranged to drive the motor generators in the event of a mains failure, whilst at the stations using rectifiers a standby battery with sufficient capacity for 24 hours' discharge is installed. With both schemes several automatic features have been introduced and contribute considerably toward the efficiency and economies that are apparent with the modern power plant. As the power plant arrangements for a telephone exchange are probably better known than those required for a repeater station, it is thought that a brief comparison should be included here as a matter of interest :— For normal working continuous floating is adopted wherever possible. The emergency condition of power mains failure is covered in the exchange case by the provision of batteries having sufficient capacity to cater for the busiest twelve hours traffic. The exchange load varies considerably from hour to hour, and the permissible voltage variation is of the order of $\pm 6\%$. In the repeater station case, the continuity of supply is of the first importance as a failure of any one station on a cable route obviously affects the whole of the circuits working between the two terminal ends. The provision of an oil-engine wherever possible, as mentioned above, is, therefore, desirable. The repeater station load is reasonably constant over considerable periods, the only variations being those due to the occasional use of testing equipment. The permissible voltage variations of the battery supplies, however, are more rigorous than for an exchange, as they have to be kept within approximately $\pm 1\%$.

Battery Supplies.

The various supplies necessary for the equipment have changed very little since the inception of the telephone repeater, except in the case of the Department's carrier system No. 4, which is about to be introduced. This equipment requires a 200 volt anode potential in place of the 130 volts required by standard main-line repeaters. Details of the supplies required are as follows :—

TABLE I.

Departmental Designation.	Voltage.	Purpose.	Remarks.
'A' Battery	24—	Filament heating and relay circuits	Regulated to 21 ± 0.25 volts for filament heating
'B' Battery	130+	Anode potential	Regulated to 130 ± 2.0 volts
,, ,,	200+	,, ,,	Regulated to 200 ± 2.5 volts
'C' Battery	10—	Grid priming	

The regulation limits quoted in the last column of Table I are obtained by using automatic voltage regulators in either the floating or main discharge circuit, and ensure that any variation in repeater amplification, due to change in 'A' and 'B' voltages, will be within the limits recommended by the C.C.I.F. The average amplification variations, per repeater, for the four types of valves in use, are as follows :—

Filament Current.	0.15 amp.	0.25 amp.	0.82 amp.	0.97 amp.
Amplification change due to max. 'A' voltage variation	0.05 db.	0.07 db.	0.15 db.	0.05 db.
Amplification change due to max. 'B' voltage variation	0.18 ,,	0.2 ,,	0.1 ,,	0.2 ,,

The functions of the 'A' and 'B' batteries are, of course, well known. The 'C' battery supply is only required at stations in which 2-wire or 4-wire single stage repeaters are installed, as with these types of equipment auto-grid priming from resistors in the filament circuit is not possible for all the valves and a separate 10 volt supply is necessary. 2-10volt 16Ah batteries are provided and used alternately to furnish a current of 10 mA through a potentiometer from which 4 and 8 volt tappings are taken to the grid circuit of the repeaters. A variable resistor is connected in series with the potentiometer to maintain the current of 10 mA, and an alarm contact type of milliammeter is provided to indicate any variation in current. As the batteries are of small capacity they are charged from the working 'A' battery and no special equipment is required other than the necessary change over switches, resistors and indicating instruments.

Types of Power Plant.

Three different types of power plant have been standardized for repeater stations built since 1934; the type adopted at any particular station being determined chiefly by the staffing arrangements at that station, as scheduled in Table II.

TABLE II.

Staffing Arrangements.	Power Plant Installed. For normal working.	Power Plant Installed. For emergency, *i.e.*, during power mains failure.
Continuously attended	Duplicate motor-generator sets and floating batteries	Hand-started Diesel engine, arranged to drive the motor-generator set on floating duty
Unattended at night and week-ends	As above.	As above, but engine arranged to start automatically
Unattended except for periodical maintenance visits	Rectifiers and floating batteries	Automatic change-over to separate batteries having sufficient capacity to maintain service for 24 hours.

Before dealing with each of the above schemes in detail, it is proposed to consider the common features *i.e.*, floating 'A' and 'B' batteries, generators or rectifiers and automatic voltage regulators.

Floating Batteries.

It is now generally recognized that the system of floating batteries is more economical than the charge-discharge scheme and this is especially so where an automatically started engine is installed to operate in the emergency conditions of mains failure. The batteries only carry the repeater station load for a few seconds and are of much smaller capacity than in the charge-discharge scheme. The capacity of the charging plant is also considerably reduced.

In the charge-discharge method of working, the size of the plant depends upon the repeater station load and the number of hours it is proposed to work each battery whereas in the floating scheme it is dependent upon the load only.

Assuming a load of 100 amperes and, in the case of the charge-discharge scheme, 48 hours' capacity in each battery and a 9-hour charging rate from the generator (to avoid overtime and week-end attendance) the relative sizes of the plant would be as follows :—

TABLE III.

Scheme.	Battery Capacity Ah. (9-hour rate)	Generator output. amps.
Charge — Discharge	4,800	640
Floating (Engine standby)	400	100

In the automatically-started engine type of plant, it would be possible to reduce the floating battery capacity to a value considerably less than that given above, but this battery is an important factor in the reduction of generator 'ripple'—referred to later—and the use of very small cells is undesirable.

The battery sizes for the hand-started engine plant are based upon the estimated time required to enable the staff to make the necessary arrangements for starting the engine, and are dependent to a certain extent upon local conditions.

At the unattended stations, the floating 'A' and 'B' battery sizes have been standardized at 200 Ah and 16 Ah respectively. The standby batteries have sufficient capacity to maintain the ultimate load for 24 hours, and are kept in good condition by trickle chargers.

Continuous floating, and trickle-charged standby batteries were first brought into use in a repeater station in 1931 and the latest reports on these batteries indicate they are still in excellent condition. From theoretical considerations, it is reasonable to expect longer life from floating and trickle-charged batteries than is obtained from those worked on a charge-discharge basis and, although the Department's experience is limited in this respect, there is a case quoted in the Spring 1935 issue of the *Chloride Chronicle* of a 3,300 Ah battery being on trickle-charge since 1927. Tests were made in July, 1934, from which it was evident that the full rated capacity of the battery was still available. There was an entire absence of distortion in the plates and the amount of sediment was too little to be measured.

Generator 'Ripple'.

The system of floating has created one difficulty that is not present with the charge-discharge method of working, *i.e.*, the introduction of audio-frequency fluctuations ('ripple') from the generators or rectifiers on to the equipment busbars. This condition is a serious one, especially in the case of the 'A' supply, part of which is used for auto-grid priming. Any ripple superimposed on the supply to the repeaters will, of course, be amplified and result in noisy circuits. The elimination of ripple, therefore, forms an important part of the specification for floating type generators. A smoothing circuit is necessary, consisting of choke coils and electrolytic condensers. The permissible limits of ripple from the generators are specified as follows :—

> Noise measured across the generator terminals, without smoothing equipment, must not exceed that equivalent to 2 millivolts R.M.S. at 800 c.p.s. noise, per D.C. volt generated, at full load current.

The above values are specified in order to ensure that generators having reasonably small noise-content are obtained. Further values covering the limits of noise that must not be exceeded at the bus-bars in the repeater room are :—

'A' generators.

When floating across the station 'A' battery via the smoothing circuit, the noise measured at the bus-bars in the repeater room must not exceed that equivalent to 0.5 millivolts R.M.S. at 800 c.p.s., at any value of current from quarter to full load.

'B' generators.

The test to be similar to the above, except that the noise measured must not exceed that equivalent to 7 millivolts R.M.S. at 800 c.p.s.

It will be appreciated that the ripple superimposed upon the load at the equipment bus-bars is that developed across the battery—assuming the drop in leads to be negligible between the power board and load. The equivalent circuit is shown in Fig. **1.** The impedance of the battery circuit must, therefore,

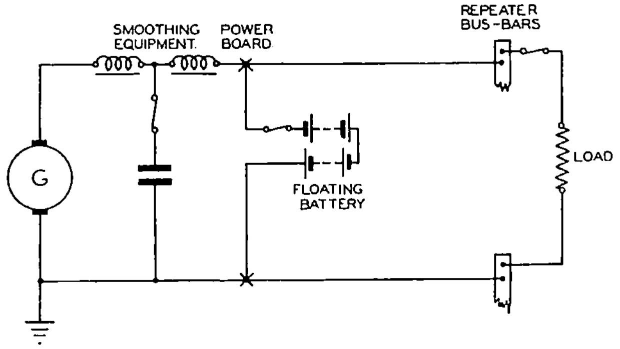


Fig. 1.

be kept as small as possible, and in view of this the layout of the plant is such that the shortest possible route is obtained for the cables between the power board and battery. A further precaution is taken by arranging each battery in two halves, thereby forming a "loop," which results in the battery circuit inductance being reduced to a minimum. The reduction of inductance is important since it has been found in the majority of cases that the A.C. impedance of a secondary cell battery circuit has an inductive reactance which at 800 c.p.s. is comparable to its effective resistance. In view of this, generators having a low frequency ripple are most likely to fulfil the required noise conditions.

A low frequency ripple is also preferable to high frequency due to the fact that the ear is considerably less sensitive to low frequency notes than to those of the order of 1000 c.p.s. of equal amplitude. This fact can be seen from the curve in Fig. **2** which has been reproduced from a report issued by the Comité Consultatif International. The 'weighted' values indicate the amount of disturbance caused at different frequencies relative to that at 800 c.p.s. for equal values of disturbing voltage, *e.g.*, the disturbance at a frequency of 200 c.p.s. would be only 0.1 of that at 800 c.p.s.

As the disturbance effect is a function of frequency as well as of amplitude, an instrument capable of measuring only the latter is not alone sufficient. The measuring set actually used for the noise tests is one designed in the Department's Research Branch and consists essentially of a valve-voltmeter having

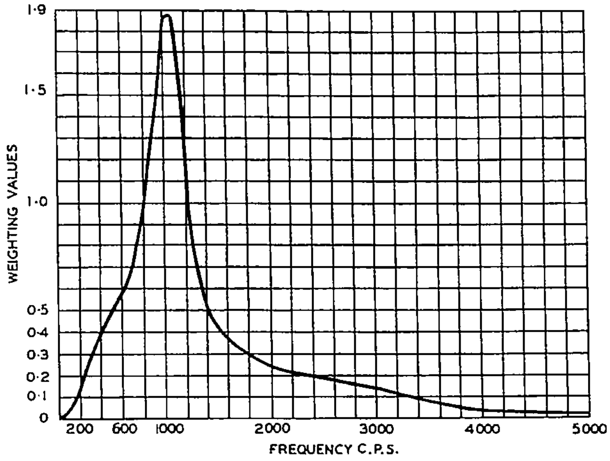


Fig. 2.

a 'weighting' network in the input which gives an overall frequency response similar to the curve shown in Fig. **2.** In this way, an allowance for frequency is made and a result obtained which is a measure of the disturbing *effect* as distinct from actual disturbing voltage.

Automatic Voltage Regulation.

The most important requirement to ensure the complete success of the continuously floating battery scheme is constant voltage from the floating generator or rectifier. This will enable the battery to be kept in a satisfactory condition and, at the same time, provide a steady voltage for the discharge circuit, this latter condition being especially necessary when the load comprises the filament and anode circuits of telephone repeaters. The usual hand regulation is inadequate as it cannot immediately cope with the output current and speed variations that normally occur under working conditions. Some automatic device must, therefore, be adopted and two types of automatic voltage regulators are being used, vibrating contact pattern for generators and carbon pile pattern for the rectifier schemes.

The vibrating contact type is illustrated in Fig. **3.** The Contacts K and H are vibrated by the eccentrics G which are belt driven from the generator shaft. The contacts alternately short circuit and insert the resistance W in the field circuit of the generator and produce an average value of field current which will maintain the correct voltage. The relative position of the short-circuit contacts H and the resulting value of field current is controlled by a movable core of the solenoid S which is connected across the generator terminals. In the event of the generator voltage tending to rise, the core lifts the contacts H and causes a longer "break" period, which results

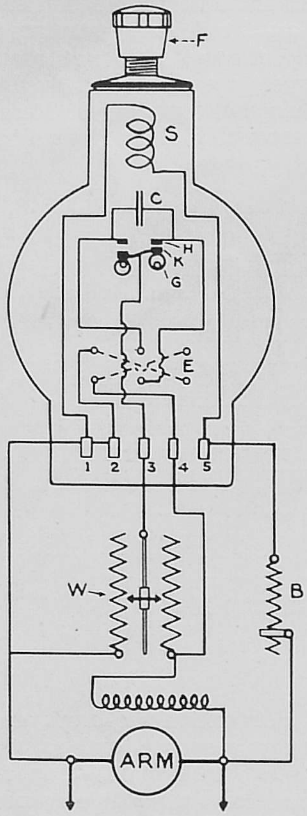


Fig. 3.

in a reduction of field current and corresponding restoration of voltage. The reverse operation occurs should the generator voltage tend to decrease. The screw-cap F is provided for initial adjustment of the solenoid core and the condenser C absorbs contact sparking. The change-over switch E is operated by a handle passing through the front case of the regulator and provides a means of disconnecting the regulator and also of reversing the polarity of the contacts. This latter operation is carried out daily and reduces the wear on the contacts. By means of these regulators the 'A' generator voltage is held within ± 0.5 volts and the 'B' generator within ± 2.0 volts of the nominal floating voltage, from no load to full load.

The carbon pile type of automatic voltage regulator is shown in Fig. **4** with a schematic diagram in Fig. **5.** The operation of this type of regulator depends upon the well-known property of carbon to change in resistance with varying degrees of compression. The main regulator consists of a pile of carbon rings, the mechanical compression of which is controlled by the position of an armature rotating between the poles of an electromagnet. The initial compression is obtained by a spring which has a torque opposing that exerted by the armature when the latter is being influenced by the field of the electromagnet. The electromagnet is connected across that part of the circuit where a constant voltage is required. If due to a variation in applied volts or change in load current, the voltage at this point alters, the correct field strength will no longer

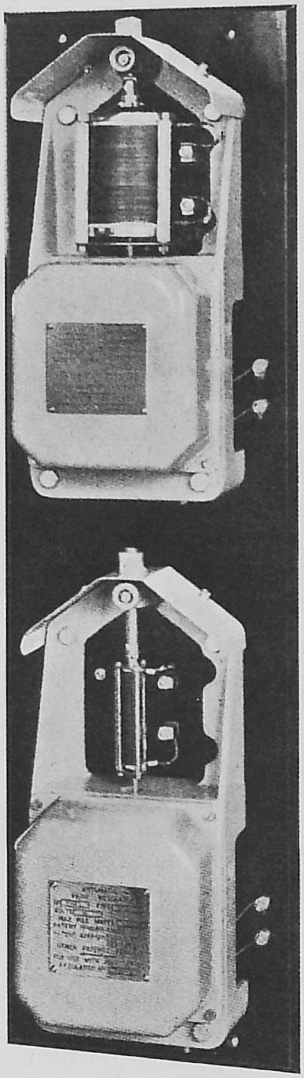
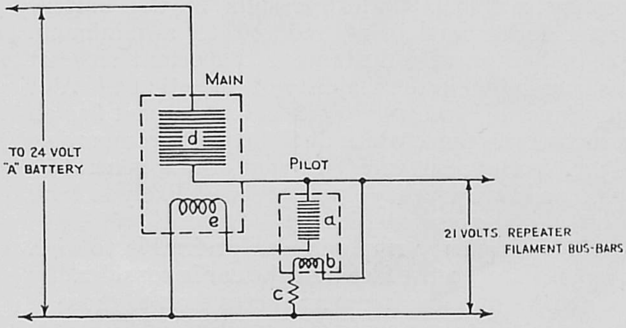


Fig. 4.



a CARBON PILE OF PILOT REGULATOR
b EXCITING COIL OF PILOT REGULATOR.
c TEMPERATURE COMPENSATING COIL FOR ITEM b
d MAIN SERIES CARBON PILE(S).
e EXCITING COIL OF MAIN SERIES REGULATOR.

NOTE: IN THE CASE OF THE PILOT REGULATOR, AN INCREASE OF CURRENT THROUGH ITS EXCITING COIL, b, WILL CAUSE A DECOMPRESSION OF ITS CARBON PILE, WITH A RESULTING INCREASE OF RESISTANCE. THE REVERSE IS THE CASE IN THE MAIN REGULATOR

Fig. 5.

be obtained and the armature will rotate with a resulting change in carbon pile resistance until once again the desired voltage is obtained across the electromagnet. The armature will now come to rest on account of the state of equilibrium existing between the forces exerted upon it by the electromagnet and the spring.

As seen from Figs. **4** and **5**, two regulators are actually employed, the larger which carries the main current being actuated by a smaller "pilot." This arrangement is necessary when close limits of regulation are required as the pilot regulator with its light construction is a much more sensitive component than the main regulator. The pile of the main regulator will carry 25 amps. and the regulator can be constructed with three of these piles connected in parallel, giving a maximum current carrying capacity of 75 amps. The overall regulation obtained for the combined pilot and main regulators is within $\pm$ 0.25 volts for the 'A' supply and $\pm$ 1.3 volts for the 'B' supply, of the normal floating voltage.

Automatic Starting Engine Plant.

The arrangement of the automatic starting plant provided at those repeater stations unattended at night is shown in Fig. **6**. Each set consists of an induction type motor coupled to shunt wound 'A' and 'B' generators, each of which has a vibrating contact type voltage regulator associated with its field circuit. Mounted on the end of the shaft of each set is a solid steel fly-wheel and half of a magnetic clutch. The other half of the clutch is carried on a short shaft in line with the generator shaft. This short shaft also carries a pulley with two vee belts coupling up to the standby engine which is mounted centrally between the two sets. The engine is of the twin-cylinder Diesel type running on light Diesel oil and is water cooled via a radiator whose fan is belt driven from the engine shafting. Mounted on the bed-plate of each set is a centrifugal switch, belt driven from the generator coupling. A high and low speed centrifugal switch belt driven from the engine and controlling the operation of a decompressor and fuel injection solenoid mechanism is also provided. A schematic diagram of the automatic starting engine equipment is given in Fig. **7**. Assuming that set No. 1 is running on floating duty and that the power supply fails, the sequence of operations is as follows:—

The set will begin to slow down and when 5% reduction in speed occurs, the contacts VS1 of the centrifugal switch driven from the generator shaft will "make" providing 24 volts from the floating 'A' battery via SW1 to the coil of contactor R1 which operates. This contactor has two pairs of contacts, one pair completing the locking circuit for the contactor and the other pair providing 24 volts via switches SW3 and SW4 to

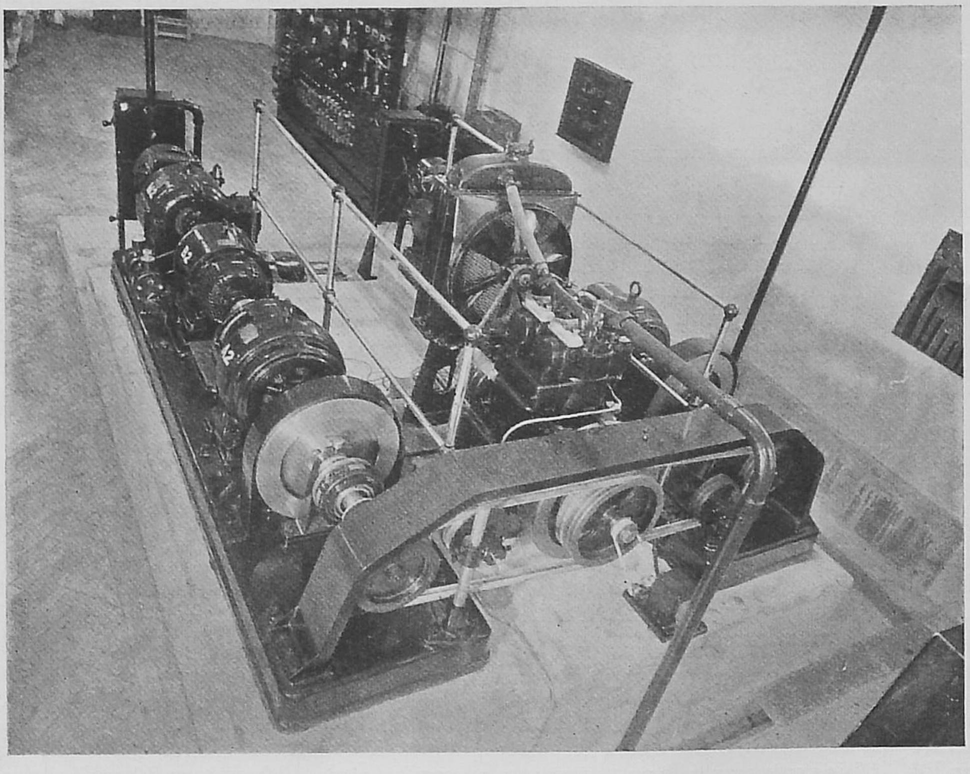


Fig. **6**.

(*a*) the coil of contactor R2 via the normally closed contacts of R5.

(*b*) the clutch starter solenoid CS1.

(*c*) the magnetic clutch CL1 associated with set No. 1.

Contactor R2 operates and disconnects the A1 and

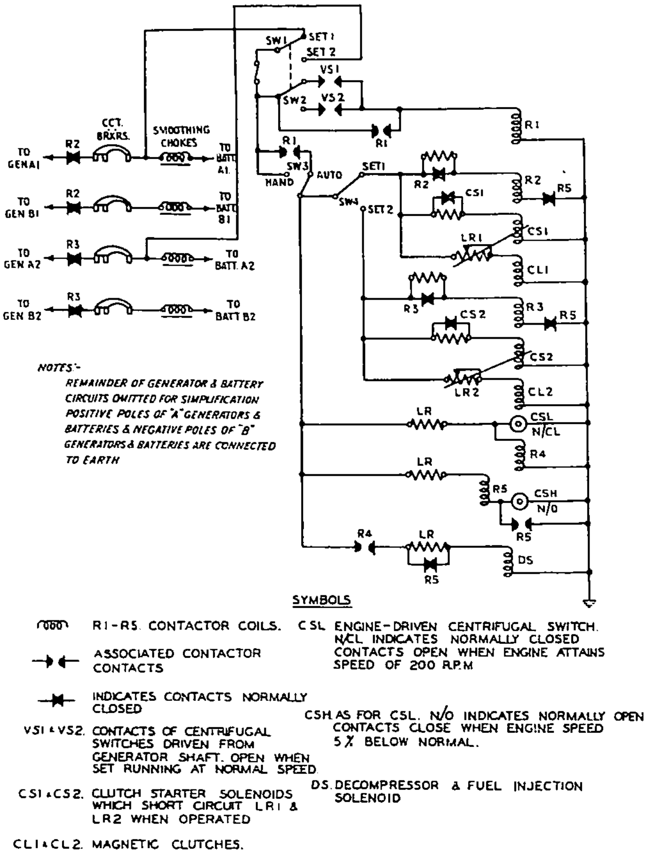


FIG. 7.—CIRCUIT OF AUTOMATIC ENGINE STARTING EQUIPMENT.

B1 generators from their batteries in order to prevent the circuit breakers tripping on the reverse current which would flow due to the reduction in speed of the set. The clutch starter CS1 also operates. This component is a solenoid, the plunger of which carries a contact which slides over 4 studs and during its operating time of approximately 4 seconds, short circuits in steps the resistance LR1 in series with the magnetic clutch CL1. The clutch starter thus supplies an increasing current to the clutch which is thereby "eased-in" in a manner equivalent to that adopted in a car and ensures that the drive applied to the engine is a comparatively gradual one. Both halves of the clutch are "solid" when the resistance LR1 is completely cut out and the momentum of the fly-wheel is sufficient to turn the engine shaft via the vee belt drive. The engine is normally decompressed and will remain so until it has attained a speed of 200 R.P.M. when the low speed contacts of the centrifugal switch CSL—which is belt driven from the engine—will open and remove the short circuit from contactor R4. This contactor will now operate and its contacts provide 24 volts to energise the decompressor solenoid DS, the plunger of which is arranged to give the engine full compression and also to turn on the fuel. The engine will now fire and run up to the speed which is sufficient to close the high speed contacts of the centrifugal switch CSH. These contacts complete the circuit for contactor R5 which operates and

(a) provides a locking circuit for itself;
(b) removes a short circuit from "economy" resistance in series with the decompressor solenoid DS;
(c) opens the circuit of contactor R2.

Contactor R2 in releasing, restores the 'A' and 'B' floating generator circuits and normal conditions now obtain except that the engine instead of the motor is driving the generators. The whole of the operations described, from the instant of mains failure to that of the restoration of contactor R2, occupy no more than 12 seconds, during which time the repeaters are being served by the batteries only.

The operation of contactor R2 removes the load from the 'A' and 'B' generators and permits the use of a fly-wheel considerably smaller than would be required if the engine was to be started with these generators on load.

Contactor R3, clutch starter CS2 and magnetic clutch CL2 are associated with set No. 2 and operate if this set is running instead of set No. 1. The resistors in series with the contactors adjust the various currents to the required value.

Referring to Fig. 7, it will be seen that by means of switches SW1, SW2 and SW4, the set which will continue to run from the engine in the event of a mains failure can be selected. This facility is necessary when both sets are running, one of them charging one set of batteries and the other floating the remaining batteries across the repeaters. Under this condition the switches are put to the position that will ensure the floating set being driven from the engine should the mains fail.

Switch SW3 is normally in the auto position, but by operating to the hand position it will be seen that 24 volts are applied to the automatic starting equipment and the sequence of operations previously described—less the energising of contactor R1—will take place resulting in the starting of the engine. By this means the equipment can be routine tested as required.

A view of the power board used for this type of equipment is shown in Fig. 8. The contactors, etc., are mounted on the right-hand panel.

The batteries and associated change over switches have been omitted from Fig. 7 for the sake of clearness. The switching has been arranged to enable either of the 'A' batteries to be floated or charged from either of their respective generators. The two 'A' batteries can be paralleled if necessary, as can also the two 'A' generators, and the combination floated across the repeaters. Similar facilities are provided for the 'B' batteries and generators. A two-position switch is included in the field circuit of each generator whereby the automatic regulator can be replaced by normal hand controlled rheostats when the generators are required for battery charging.

The 'A' and 'B' batteries are provided in duplicate and floated alternately at weekly intervals, each 'A' battery consisting of 12 cells and each 'B' battery of 63 cells. In view of the fact that the batteries are in duplicate and that the idle set can be reconditioned at any time from the m/g set not on floating duty, the batteries are floated at their open-circuit voltage, *i.e.*, approx. 2.07 volts per cell. If only one 'A' and one 'B' battery were provided, they would have to be floated at 2.15 volts per cell to maintain them in good condition, but this would lead to a continuous power wastage, as the 'A' and 'B' voltages would amount to 25.7 and 140 respectively.

The 'A' supply of approximately 24 volts is reduced to 21 $\pm$ 0.25 volts for the valve filament circuits by carbon-pile regulators installed in the repeater room. Prior to the introduction of this type of regulator the filament supply was regulated to 21 $\pm$ 0.5 volts by hand-operated rheostats that were mounted upon

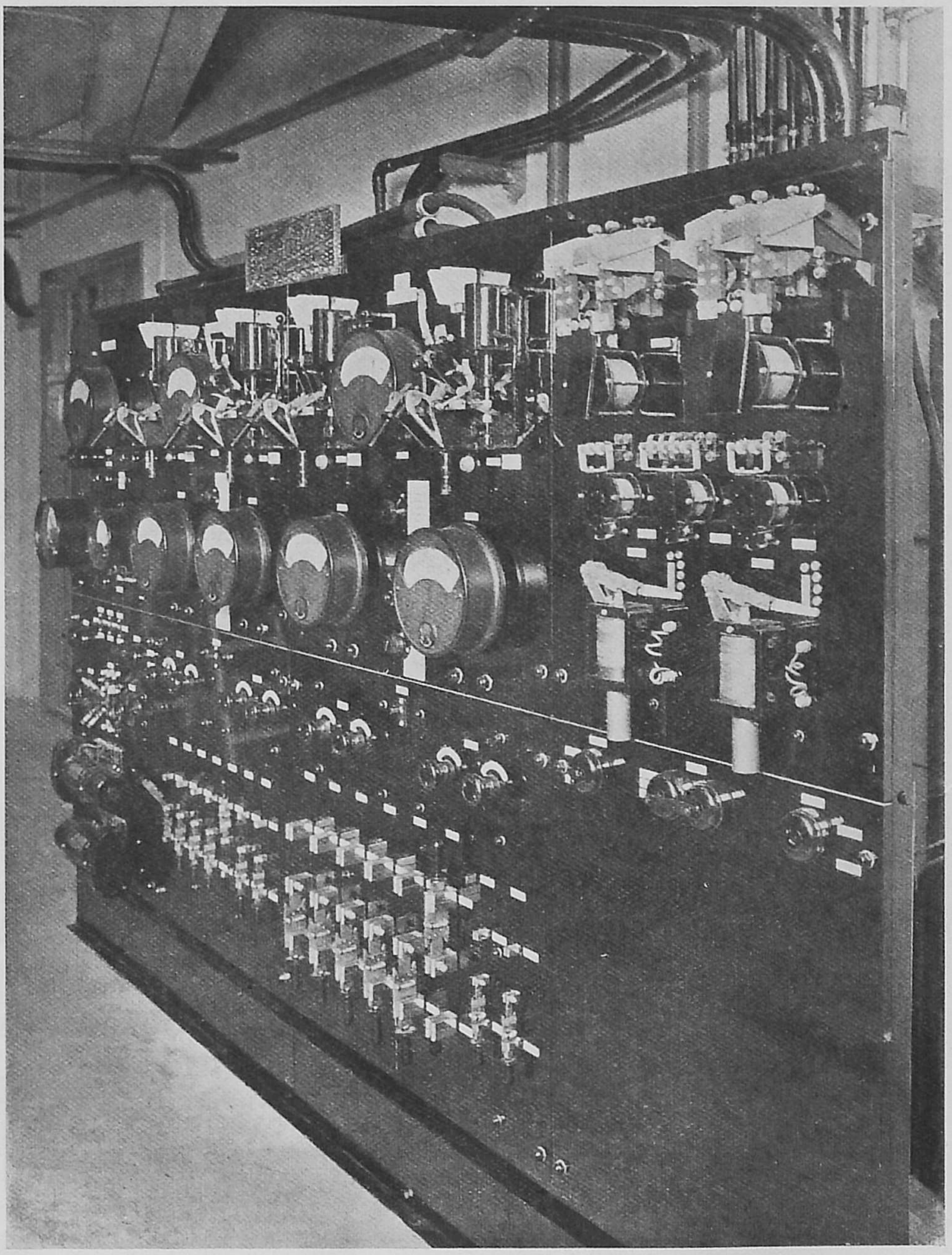


FIG. 8.

Consideration is being given to the provision of trickle-chargers for the restoration of the batteries during the idle period at a slow rate of charge. Charging at a low rate, to avoid gassing, from the duplicate generator set is, of course, possible but would be inefficient.

a Voltage Control Board, situated centrally in the repeater room. This board is now dispensed with, the new pattern regulators and associated fuses being mounted at the end of the repeater racks, an arrangement that has resulted in a considerable saving in floor space. In addition, the regulation is automatic, within finer limits than in the old scheme, and a more flexible power distribution to the individual racks is made possible.

Eight of the automatic-starting engine plants are at present installed and have been working for periods varying between 3 months and 2 years. A total of 12 power mains failures have occurred to date, resulting in the automatic starting of the engine. A number of the stations are in remote districts, and some of the failures occurred at night during the absence of the engineering attendant. It will be appreciated that, in these circumstances, an automatically-started engine has decided advantages over the alternative hand-started arrangement, as, with the latter, the batteries would have to be considerably larger to cover the time taken for an emergency man to be called out and arrive on site. The time required for this purpose would obviously depend upon local conditions and the batteries would have to be large enough to provide an adequate margin of safety under all possible contingencies. The cost would exceed that of the equipment required for the automatic starting facilities, and at the same time, the scheme as a whole would be less reliable, as conditions could possibly occur that would prevent the emergency man arriving in time to start the engine.

Non-Automatic Starting Engine Plant.

At repeater stations that are permanently staffed, and at the stations situated in exchange buildings that have continuous engineering attendance, the provision of automatic starting facilities for the engine is not usually necessary. In the event of a mains failure, the 'A' and 'B' floating motor generator set stops, and the batteries carry the load until the engine is started.

As only the largest stations come under the above category, the power plant installed therein is naturally of more ample proportions than that provided at the unattended stations, and on account of its size, the engine is provided with a starting motor to simplify the starting operation. This simplification is also desirable in view of the fact that the engine may have to be started by an officer not normally associated with the plant. The motor is direct-coupled to the engine and is energised, via a push-button control, from the idle 'A' battery. Magnetic clutches are provided on each motor generator set to effect the coupling to the engine in the manner already described for the auto-starting engine scheme.

A view of the plant is shown in Fig. **9** and a schematic diagram of the starting-motor and magnetic clutch circuit in Fig. **10**. Referring to the latter, it will be seen that by the operation of the " Start " push button PB1, 24 volts is applied to the coil of Contactor R1 via the normally closed Contacts of the thermal Relay TR1, which will be referred to later. Contactor R1 will operate and

(*a*) complete a locking circuit for itself ;
(*b*) complete the circuit for the starting motor S.M.

The motor will now drive the engine, which should fire within 4-6 seconds. If, however, for any reason it fails to do so the thermal relay TR1 will operate and disconnect contactor R1, which, in turn, will

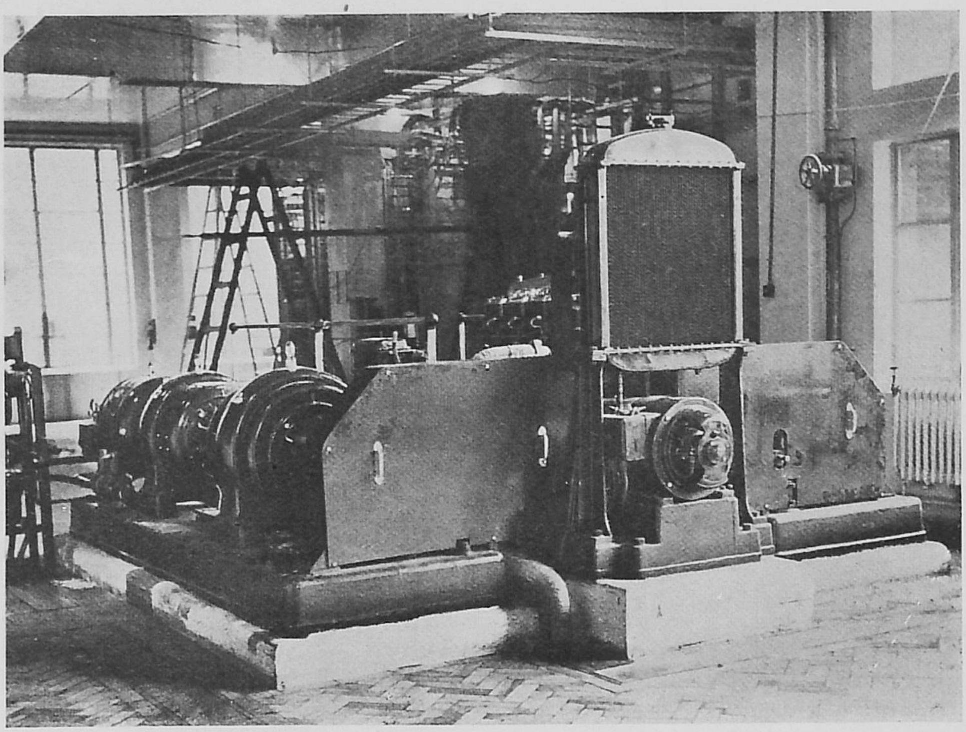


FIG. 9.

disconnect the starting-motor circuit. This arrangement guards against the possibility of a prolonged running of the starting-motor in an endeavour to start an engine which is obviously faulty. Immediately the engine has attained full speed, the push-button PB2 is operated, which results in the release of contactor R1 and the disconnection of the starting-motor circuit.

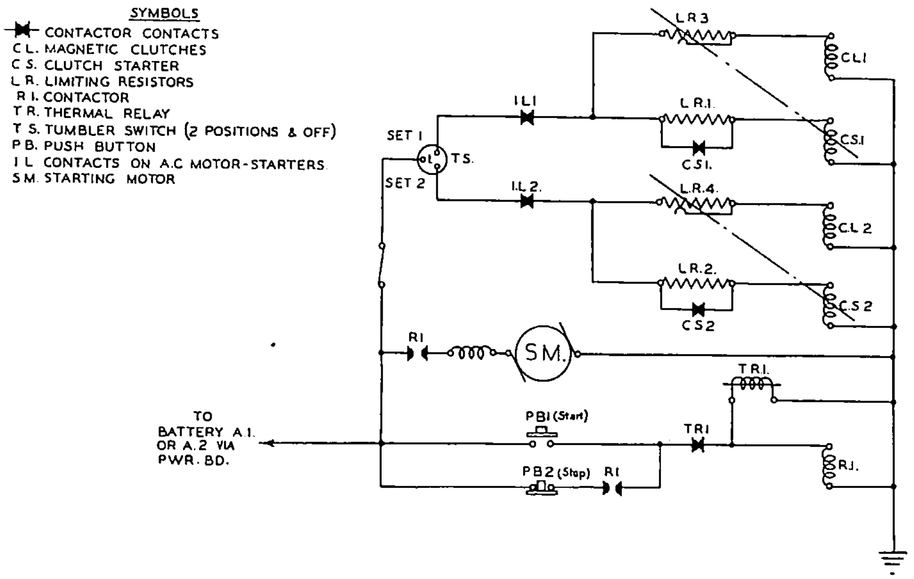


Fig. 10.—Engine Starting-Motor and Magnetic Clutch Control Circuit.

If, say, motor generator set No. 1 is to be brought into use, the tumbler switch TS is operated to the appropriate position completing a circuit for the relative magnetic clutch CL1 and associated clutch starter Solenoid CS1, via the contacts IL1, which will be referred to later.

The clutch starter will now function and short-circuit the resistor LR3 in series with the clutch which will then be fully actuated and provide the coupling between the engine and motor generator set. Contacts CS1 open at the end of the operating period of the clutch starter CS1 and remove the short-circuit from the economy resistor LR1. The current through the clutch starter is thereby reduced from the operating value to a lower one sufficient to retain its armature in the actuated position.

Contacts IL1 and IL2 are provided to prevent the possibility of using the motor generator sets to start-up the engine. In the fully automatic type of plant this is, of course, possible by virtue of the fact that each set is provided with a flywheel. In the plant at present being described, however, flywheels are not included, and undue strain would be put upon the couplings if one of the clutches were energised whilst the associated motor generator set was running.

The condition whereby this could be attempted—by the operation of Switch TS to the appropriate position for one of the motor generator sets whilst the set is in operation from the mains—must, therefore, be guarded against. To this end, the starting switches associated with the AC motors are each provided with a pair of contacts IL1 and IL2, for motors 1 and 2 respectively, which are closed only when the switches are in the " Off " position. With either set running from the mains, therefore, the 24 volt circuit to the relative magnetic clutch is broken and the mis-operation of switch TS can do no harm.

The switching arrangements for the generators and associated batteries are identical to those already described for the auto-started engine scheme.

Rectifier Plant at Unattended Repeater Stations.

The adoption by the Department of multi-channel U.G. carrier systems has necessitated the construction of a number of small repeater stations along cable routes at intervals of approximately 20 miles, to accommodate the carrier amplifiers. The permanent staffing of these stations is not justified, as once the circuits are lined up, no further attention should be required apart from occasional valve replacements. The stations are often at remote villages with no permanent engineering attendance. The provision of static power plant requiring the minimum of maintenance was therefore indicated, and a floating scheme employing rectifiers has been provided, together with automatic change-over to standby batteries of 24 hours' capacity to cater for the emergency condition of mains failure. An 'A' supply of 21 $\pm$ 0.25 volts and a 'B' supply of 130 $\pm$ 1.3 volts is required and the plant includes carbon-pile type regulators to automatically maintain these values across the floating batteries. As the stations are normally unattended, the floating batteries must be worked at a voltage that will maintain them in good condition without the necessity for periodical reconditioning that could be given at an attended station. The batteries are therefore floated at approximately 2.15 volts per cell, 10 200 Ah cells constituting the 'A' battery and 60 16 Ah cells the

'B' battery. The 'A' and 'B' supplies of 21 volts and 130 volts are thus made available at the power board, and the equipment bus-bars are fed direct from this point with no intervening regulator. The carbon-pile regulator already referred to is in circuit between the rectifier and battery, its control solenoid being connected to the equipment bus-bars.

In the event of a mains failure, the following conditions are automatically effected, with no perceptible time lag, by means of contactors :—

(*a*) Floating batteries disconnected and replaced by standby batteries.

(*b*) Automatic regulators transferred to discharge circuit between standby batteries and equipment bus-bars.

(*c*) Alarm circuit actuated at the nearest attended repeater station.

The standby 'A' and 'B' batteries have 12 and 75 cells respectively and are normally kept in good condition by trickle-chargers. Each battery has sufficient capacity for a 24 hours' discharge and during this period, the automatic regulators maintain the equipment bus-bars at the normal working voltage of 21 and 130 volts. The previous floating conditions are automatically restored immediately the power mains become live again.

Separate rectifiers are provided for recharging the standby batteries after a mains failure, but these rectifiers have an output identical to those used for floating and can be hand-switched to floating duty in the event of a fault developing on the rectifier normally used for this purpose. As these duplicate rectifiers have outputs identical to the floating ones, it will be appreciated that the standby batteries can only be recharged at approximately the 24 hour rate. This, perhaps, is a disadvantage, but it is considered that the provision of special rectifiers for battery recharging at the 9 hour rate would not be justified. For the initial charging of the batteries, the outputs from the duplicate rectifiers of each type can be paralleled. Westinghouse type rectifiers are used, 3-phase, full wave for the 'A,' and single phase, full wave for the 'B' supplies. The two 'A' rectifiers are contained in separate cubicles and both the 'B' rectifiers are housed in a common cubicle. Each cubicle is 6ft. in height, 2ft. 6ins. wide and 3ft. deep and they are lined up with the power board with a space of approximately 12 ins. between them for adequate ventilation.

A view of the power board and rectifier cubicles is shown in Fig. **11**.

A schematic diagram of the circuit is shown in Fig. **12** for the 'A' supply. That for the 'B' is similar except that 3 chokes each of 500 mH are used, and 2 electrolytic condensers each of 100 mF. 60 16 Ah. cells are provided for the floating battery and 75 120 Ah cells for the standby.

In addition to a mains failure, there are several other fault conditions that will effect the automatic changeover to the standby batteries and these are scheduled in Table IV together with the operation of the relative relays shown in Fig. **12**.

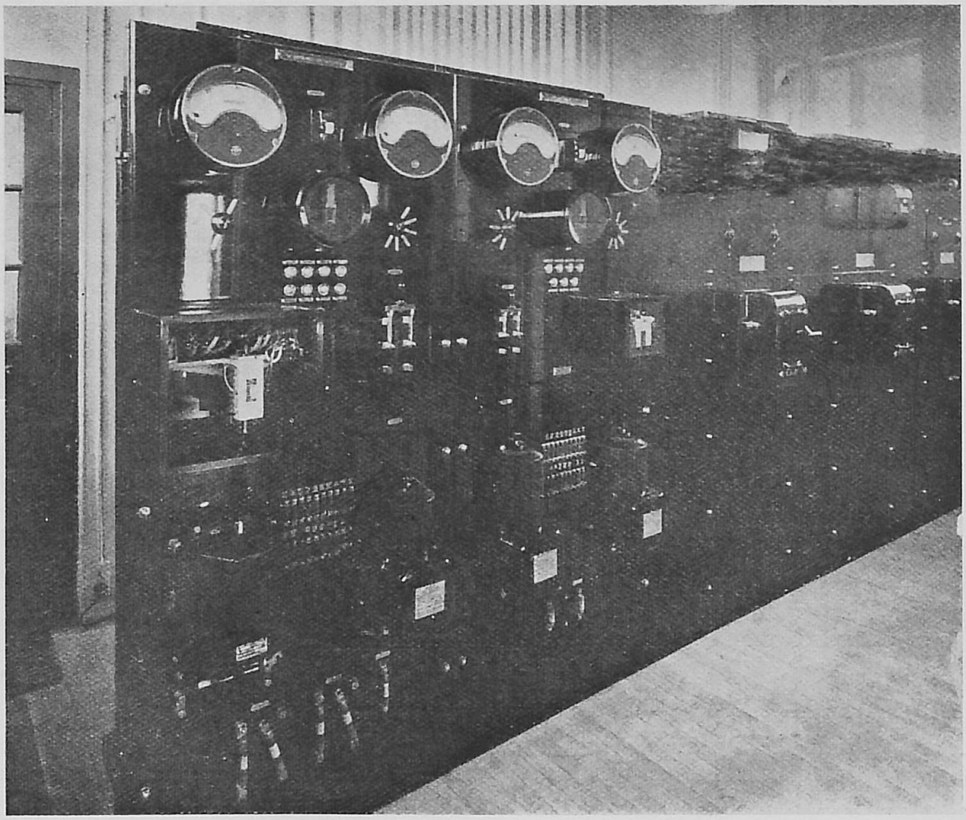
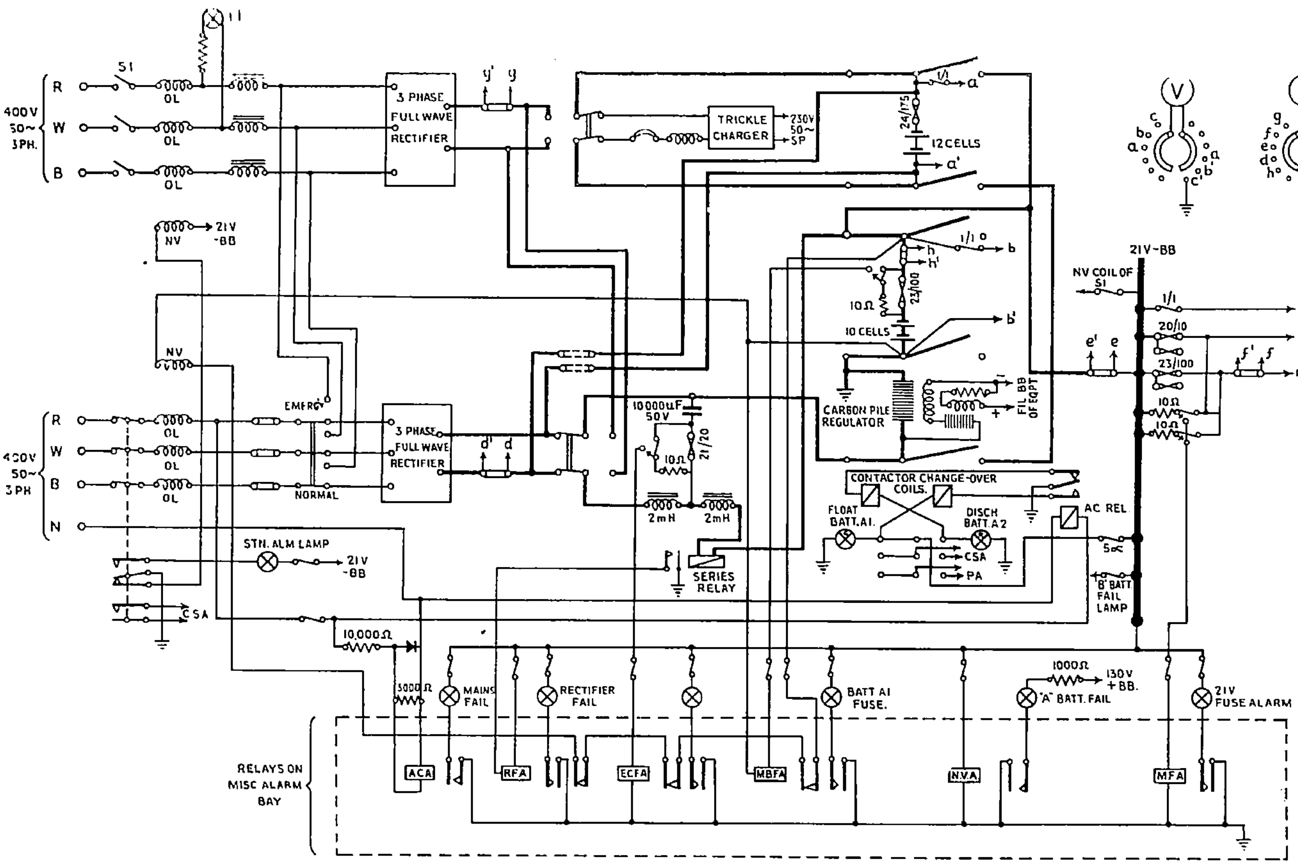


Fig. 11.



C S A INDICATES CONTROL STATION ALARM

FIG. 12.—POWER PLANT FOR 12 CHANNEL CARRIER EQUIPMENT 21 *v*. SUPPLY SCHEMATIC.

TABLE IV.

Item.	Fault Condition.	Relay Operation, etc.
1	Mains Failure	AC relay releases and provides circuit for contactor coil S which energises and changes-over contactor. Lamp R lights indicating standby battery in use. Lamp G disconnected. Relay ACA releases and lights lamp indicating mains failure. Pilot alarm in station and alarm at nearest attended station actuated.
2	Rectifier output failure (Independent of mains failure)	Relay in series with rectifier output releases and actuates only RFA which lights lamp indicating rectifier failure and breaks circuit of 'no volt' coil on main circuit breaker. Main circuit breaker trips, disconnects A.C. input to rectifier and releases AC relay. Operation now as for Item 1.
3	Overload on rectifier	Main circuit breaker trips due to actuation of overload trip coils. Operation now as for Item 1.
4	Electrolytic condenser short circuit	Main fuse in series with condenser blows together with small alarm type fuse in parallel. Spring contact on latter completes circuit for relay ECFA which actuates, lights lamp indicating failure of condenser and breaks circuit of 'no volt' coil on main circuit breaker. Operation now as for Item 1.
5	Blown fuse in series with floating battery	Small alarm type fuse in parallel with main fuse also blows and the spring contact completes circuit for relay MBFA which actuates, lights lamp indicating failure of floating battery fuse and breaks circuit of 'no volt' coil on main circuit breaker. Operation now as for Item 1.

In addition to the above, relays NVA and MFA are provided to indicate respectively a failure of the battery supply at the mains bus-bars and a failure of the main fuse serving the equipment. These two conditions do not operate the contactor, as they obviously could not be rectified by a change-over to standby battery. Immediate attention would be required, and for this reason the alarms for these two conditions are commoned and actuate an 'urgent' alarm at the nearest attended repeater station. The fault conditions scheduled in Table IV each effect a changeover to the standby battery and prompt attention is not so important. Their associated alarms are therefore arranged to actuate a 'non-urgent' alarm at the attended station. Although immediate attention is not necessary in these cases, it should, of course, be given in a reasonably short period, well within the 24-hour period that can be catered for by the standby battery. The alarms are extended to the nearest repeater station over spare cable pairs which are at present available. It will be necessary in the near future, however, to arrange for their extension over carrier channels.

The economics of providing an engine-set to start automatically on the failure of the supply, as an alternative to the standby rectifier and battery is at present under consideration.

Fully Automatic Duplicate Engine-driven Plant.

An isolated case has recently had to be considered involving the provision of power plant at an unattended repeater station where a power supply is not available. The normal 'A' and 'B' supplies of 24 and 130 volts were required and the following arrangement is proposed.

Duplicate 'A' and 'B' batteries will be provided, each having sufficient capacity for 48 hours' discharge at the maximum load. Duplicate engine sets will be installed, each set consisting of a Diesel engine direct coupled to an 'A' and 'B' generator. The batteries will be worked on the charge-discharge basis and at the end of the discharge period of say batteries A1 and B1 the following conditions will be automatically effected :—

(*a*) Starting of No. 1 Engine set.
(*b*) The instantaneous changeover to batteries A2 and B2.
(*c*) Switching of batteries A1 and B1 to the relative charging generators associated with No. 1 Engine set.

The engine will drive the generators until both batteries are fully charged, this condition being detected by a thermal type contact volt meter associated with each generator. Should one of the batteries reach the fully charged condition before the other, the associated generator output will be automatically reduced to a ' trickle ' rate until the remaining battery has attained the required condition. The engine will then shut down. The generators will have output capable of charging the batteries in approximately 10 hours. At the end of the discharge period of batteries A2 and B2, the operation (*a*)—(*c*) above will again take place except that engine set No. 2 will now come into use to charge batteries A2 and B2 and the discharge load will be taken over by batteries A1 and B1. It will be seen, therefore, that the engines will run alternately, No. 1 set being normally associated with A1 and B1 batteries and No. 2 set with A2 and B2 batteries. In the event of either engine failing to start the other will automatically be brought into commission in its place.

The starting of the engines is controlled by a time switch which will be arranged to complete the circuit of the associated 'A' generator. The 'A' generators are arranged with series starting turns and serve as motors for engine starting purposes. The energy required for these generators working as motors is taken from the 'A' battery which is standing idle in a fully charged condition. This arrangement will ensure that the discharge load will not be affected as would be the case if the extra load imposed by the motor was taken by the working battery.

When the engine has attained full speed the 'A' generators are automatically converted to normal shunt-wound charging machines. The time switches can be adjusted to complete the circuit of the 'A' generators for engine starting duty at any predetermined time, dependent upon the discharge rate of the batteries with the maximum load connected, the switches will be set to ensure that the engines are started alternatively at 48 hour intervals.

The fuel oil, lubricating oil, and cooling-water service tanks for the engines will be of sufficient size to ensure that the plant will run unattended for at least 14 days. Water thermostats will be included in the cooling system of each engine to ensure that should the cooling water reach a predetermined maximum temperature the engine will stop and the other be brought into commission automatically to carry on the duty. Oil pressure relays will be provided for the lubricating system on each engine to detect failure of lubrication and in this case also the engine will shut down and the other be brought into commission.

Alarms will be transmitted to the nearest attended repeater station in a similar manner to that already described for the unattended stations.

Arrangement of Plant to provide an Emergency A.C. Supply.

Co-axial carrier equipment requires an A.C. supply which is normally obtained from the supply mains. At main line repeater stations where this type of equipment is included, it is necessary to arrange for a standby A.C. supply in addition to those required by the main line repeaters. It will be appreciated that the problem is somewhat complicated by the fact that the use of batteries to cover the interval between mains failure and engine running is of course impossible so far as the A.C. load is concerned, and that continuity of supply to the co-axial equipment must nevertheless be maintained.

The arrangement adopted resembles very closely that already described for the auto-started engine scheme, except that synchronous motors are used. Upon the failure of the supply mains the engine is automatically started and continues to drive the motor and 'A' and 'B' generators, via the belt drive and clutch thus maintaining the 24 volts and 130 volts floating conditions for the main line repeaters. In addition the synchronous motor now functions as an alternator and supplies the co-axial equipment, the A.C. voltage from the machine being regulated to within $\pm$ 3% by a vibrating contact type of regulator which is included in the field circuit of a separate excitor. A drop in frequency will occur until the engine has attained full speed, but this is immaterial. The flywheels are somewhat heavier than those provided on the sets already described as, in addition to supplying the necessary energy to start the engine, they have also to provide that required to drive the motors as alternators prior to the engine attaining full speed.

The motors are of the auto synchronous type, starting up as squirrel cage, and provided with separate excitors which are coupled to the main shafting. Automatic synchronization is effected and obviates to a large extent the need for skilled attendance usually associated with the synchronous type motor.

Voltage, frequency and engine acceleration conditions immediately following a mains failure are indicated in Fig. **13**.

Conversion of Existing Plants.

The conversion from charge-discharge to floating has recently been made at a number of continuously attended stations that were brought into service 1924—1928. At these stations the batteries were

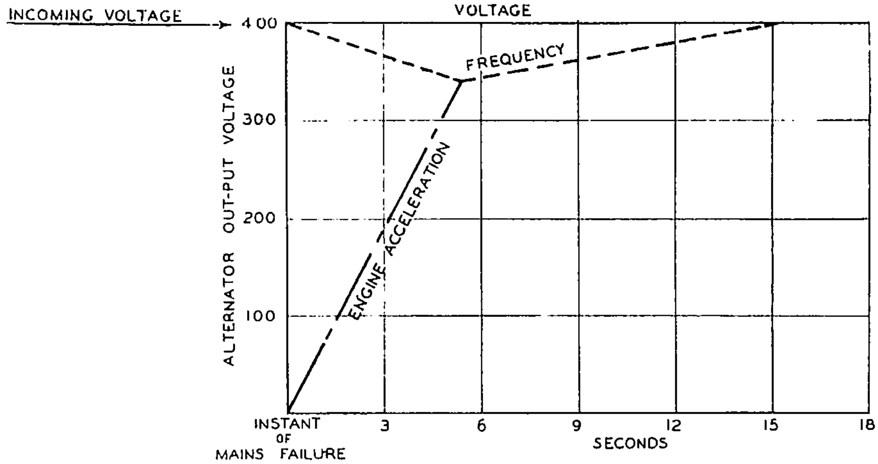


FIG. 13.

due for replating and/or enlarging, and the opportunity was taken to bring the plant into line as far as possible with latest standard practice.

One each of the 'A' and 'B' batteries has been brought up to 24-hour capacity where necessary for the standby supply, and are kept in good condition by trickle chargers. The remaining 'A' and 'B' batteries have been replaced by smaller ones and are continuously floated from motor generator sets. In most cases, the existing motor generator sets are used, and have been provided with automatic voltage regulators and smoothing equipment.

Automatic carbon-pile regulators have been installed in the repeater room for the filament circuits and the voltage control boards have been recovered. Apart from standardization, this procedure was necessitated by the fact that most of the hand-regulators were practically fully loaded.

200 volt Anode Supplies.

It is proposed to provide the 200 volt anode potential required by the Department's carrier system No. 4 by means of duplicate machines, driven from the normal 'A' or 'B' supplies to ensure continuity. It is anticipated that adequate smoothing will be possible without floating, and in fact, the provision of 200 volt batteries in addition to those already existing would, in a number of cases, give rise to serious accommodation difficulties.

Summary.

The use of floating batteries, automatically started engines and automatic voltage regulators, has made possible the introduction of power plant of new design at main line repeater stations and has resulted in very considerable saving in the capital expenditure on plant and buildings and in maintenance costs.

The closer limits in voltage regulation permit constancy of repeater amplification to a degree not hitherto possible with hand regulators. It is anticipated that the use of either of the methods described, at the repeater stations on a long communication system, will contribute considerably to the stability of the circuits without the necessity for night and week-end attendance.

In conclusion, the author wishes to thank Messrs. Austinlite Ltd., and Standard Telephones and Cables for the supply of photographs and details included in this paper.

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