Technical Instructions
Item 14.2. February, 1937.

DROITWICH TRANSMITTING STATION

This instruction describes the Power Supply Plant, Control Rooms and other equipment provided at the Droitwich Transmitting Station for the operation of the two transmitters installed there.
The transmitters themselves are not covered by this instruction. The **Medium-wave transmitter** *is dealt with in* **Item 15.1** *and the* **Long-wave transmitter** *will be covered in* **Item 15.2.**
The present instruction when complete will comprise the following parts which will be issued from time to time as they become available.

Part 1. General Description.
Part 2. Station Power Supplies.
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DROITWICH TRANSMITTING STATION

PART 1. GENERAL DESCRIPTION

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DROITWICH TRANSMITTING STATION

Part 1. GENERAL DESCRIPTION

Transmitters

The Droitwich transmitting station houses the long-wave National transmitter and the medium-wave Midland Regional transmitter.

The **long-wave transmitter** has an aerial carrier power of 150 kW and is designed to work at any frequency within the band 240-158 kc/s (1250-1900 metres). The transmitter is driven by a master oscillator which forms a separate rack-mounted unit. The components of the transmitter proper are contained in four units, namely ' A,' ' B ' and two ' C ' units. Series modulation in the penultimate stage is employed, the input to the stage being approximately 24 kW. The ' A ' unit contains the L.F. stages and the modulator half of the series modulator circuit. The ' B ' unit contains an H.F. amplifier and the modulated amplifier portion of the series modulator. The final stages of both units use water-cooled valves, C.A.M.3 valves in the modulator and C.A.T.6 in the modulated amplifier. Both types of valves require approximately 10,000 volts on their anodes, but the filaments of the valves in the modulated amplifier are at the same potential as the anodes of those in the modulator so that a common supply at approximately 20,000 volts is required. The ' C ' units contain the push-pull banks of the final H.F. amplifier and employ C.A.T.14 valves, working with approximately 20,000 volts on their anodes. In these valves both the anode and the pinch, where the filament leads enter the valve, are water cooled, while the seal between the copper anode and the glass body of the valve is cooled by means of an air blast.

A fifth unit known as the ' D ' unit, contains the H.F. output circuits of the final stage. A further unit situated immediately beneath the ' D ' unit, houses the various sections of a special network which is used for coupling the output of the ' D ' unit to the feeder line and is designed in conjunction with the aerial tuning circuits, to maintain the frequency response of the aerial system constant over the desired band of modulation frequencies.

The **medium-wave transmitter** is of the same type as those in use at other regional transmitting stations. It has an aerial carrier power of 70 kW and is designed to work at any frequency within the band 1500-600 kc/s (200-500 metres). It is driven by a separate master oscillator and comprises five units of similar appearance to the units of the long-wave transmitter. Unlike the long-wave transmitter, however, it employs the low-power choke modulation system. The ' A ' unit contains the L.F. and modulator stages and the H.F. and modulated amplifier stages. The ' B ' unit contains a push-pull high frequency amplifier, and the two ' C ' units the push-pull banks of the final high-frequency amplifier. The ' D ' unit contains the output circuits of the final stage and the coupling to the feeder line. The valves in the ' B ' and ' C ' units operate with 12,000 volts on their anodes and are water cooled.

Power Supplies

The main station supply is A.C. at 415 volts, 3 phase, 50 c/s and is generated by means of Diesel electric plant. The necessary D.C. supplies for the operation of the transmitters is obtained by conversion plant. The 20,000 volt supply for the long-wave transmitter is normally obtained by means of steel tank mercury arc rectifiers and the 12,000 volt supply for the medium-wave transmitter from motor generators. Facilities are, however, provided for operating two H.T. motor generators in series for supplying the long-wave transmitter in an emergency, a third machine being provided for running the medium-wave transmitter in such an event. Motor generators are also used for the H.T. supplies to the low-power stages of both transmitters and for all the filament and grid supplies. An auxiliary 220 volt D.C. supply is generated for providing the station lighting and various auxiliary services, and a 1200 ampere-hour battery is installed for maintaining the services when the main generating plant has been shut down.

Control Rooms, etc.

The front of the building faces approximately north-west. The office block (see Figure 2) is a two-storey structure with the Control rooms and associated power supply equipment, the Studio, Quality-Checking room and a room housing the master oscillator equipment on the first floor.

Transmitter Hall

The Transmitter Hall, which adjoins the office block, has a gallery extending all round it at the first floor level and the units of the two transmitters are installed facing one another on either side of it, the long-wave transmitter along the south-west side and the medium-wave transmitter along the north-east side. The units of the medium-wave transmitter are single-storey structures mounted in the gallery, but those of the long-wave transmitter are all two-storey structures extending from the ground floor up through the gallery. The valves, meters and the circuit components are contained in the upper parts of the units and the insulating hoses forming part of the valve cooling system, together with voltmeter multipliers and other auxiliary apparatus, in the lower parts.

On the ground floor of the Transmitter Hall are installed the filament and grid bias machines and the H.T. machines supplying the low-power stages. Except in the case of the ' B ' unit, the motor-driven field regulators for the filament machines are installed in the lower part of each associated unit. Those for the ' B ' unit are mounted directly on top of the generators. These regulators are remotely controlled from the control table in the gallery. The ' B ' unit ground-floor enclosure, is extended to accommodate the two insulated generators which supply the filaments of the series-modulated stage. The grid-bias and auxiliary H.T. machines, together with the filament machines for the medium-wave transmitter and for the low-power stages of the long-wave transmitter, are supplied in duplicate. In the case of the output stage of the long-wave transmitter there is a separate filament machine for each valve, including the spare valves.

The **Automatic Starting Switchboard** carries the remote-controlled switchgear associated with the starting of all the machines on the ground floor, and is installed along the south-east wall of the Transmitter Hall. The enclosure at the back of the switchboard also contains the smoothing condensers and resistances for the long-wave transmitter.

Transmitter Hall *(Contd.)*

The **Transmitter Hall Switchboard** is installed in the gallery immediately above the automatic starting switchboard and carries the switchgear for controlling all the D.C. supplies for the operation of both transmitters. All the operations connected with the selection of the main H.T. supplies are manually performed, but the operations of selecting one or other of the alternative auxiliary H.T. and grid-bias machines can be performed by means of remote control switches from the control table. The motor-operated field regulators of the main H.T. generators and also of the machines providing the grid bias and the H.T. supplies to the low-power stages, are mounted behind the Transmitter Hall switchboard. Their operation is remotely controlled from the control table. Direct-coupled hand-wheels are, however, provided on the switchboard for use in the event of failure of the remote control switchgear.

The enclosure at the back of the Transmitter Hall switchboard also contains the smoothing equipment for the medium-wave transmitter and a panel mounting a number of relays associated with the valve protective system.

The **Control Table** stands immediately in front of the Transmitter Hall switchboard and, in addition to the remote control switches for starting up both transmitters, carries a set of meters duplicating all the important readings.

Machine Room

The Machine room which adjoins the Transmitter Hall contains the conversion plant for providing the main H.T. supplies for both transmitters. There are two steel-tank mercury arc rectifier equipments, each capable of an output of 600 kW at any voltage between 15,000 and 20,000. Each of these is able to supply the whole of the H.T. power required by the long-wave transmitter. In an emergency either of these equipments can be employed to operate the medium-wave transmitter. In addition there are three motor generator sets, each having an output of 300 kW at 12,000 volts. Of these Nos. 2 and 3 are available for running the medium-wave transmitter while Nos. 1 and 2 can be connected in series to provide an output of 600 kW at 20,000 volts for running the long-wave transmitter should both the mercury arc rectifiers fail.

The A.C. supply to both rectifiers and to the driving motors of the H.T. motor generator sets, is controlled from the Machine room switchboard in the gallery along the north-west wall which communicates with the Transmitter Hall gallery. The necessary switching for selecting the desired H.T. supply is carried out on the Transmitter Hall switchboard by means of manually operated switchgear, but the operation of connecting the H.T. generators in series is achieved by means of manually operated switchgear mounted on the wall below the Machine room gallery within an enclosure.

The enclosure under the gallery also contains the main iron-cored smoothing chokes for both transmitters and a motor alternator set driven from the 220 volt D.C. supply and generating an A.C. output of 15 kVA at 415 volts, 3 phase, 50 c/s. This auxiliary supply is used during the night when the engines are shut down in order to maintain the vacuum pumps of the mercury arc rectifier chambers in continuous operation. The starting switchgear and that for substituting the generator output for the normal A.C. supply, are carried on the Machine room switchboard.

Water Cooling System

Each transmitter possesses a completely separate water cooling system of the enclosed type. Distilled water is used and the whole installation is carried out in copper piping. Spray-cooled radiators are used and these are situated at one end of the main 300,000 gallon reservoir external to the building on the north-east side. The cooling water is pumped up to a tank on the roof but, due to the fact that the transmitters are at first floor level, the head available is insufficient to provide an adequate flow through the water jackets. Booster pumps have, therefore, been installed in order to increase the pressure of the water at the point where it enters the insulating hoses feeding the valve jackets.

The valves are protected against damage due to failure of the water cooling system, by the provision of Electroflo water meters which control the operation of relays, the contacts of which are included in the protective interlock circuits. In the case of the medium-wave transmitter there is only one Electroflo water meter placed in the ~~common return from the valves~~ SUPPLY TO THE BOOSTER PUMPS. In the case of the long-wave transmitter there are eight Electroflo water meters, one each in the common return from the valves in the ' A ' and ' B ' units and one for each of the C.A.T. 14 valves, including the spare valves. No Electroflo water meter is included in the pinch water cooling system to the C.A.T.14 valves, but a sight-feed indicator is provided in the common return and is mounted on the edge of the Transmitter Hall gallery where it can be seen from the control desk.

The Electroflo meter bodies, together with the booster, spray-cooling and circulating water pumps, and the bottom tanks which form the lowest point in each system, are situated in a crypt under the Transmitter Hall along the north-east side. The air compressors which supply the air blast for cooling the seals of the C.A.T.14 valves, are also installed in the crypt, together with an air-extract fan for ventilating the Crypt. The following colour scheme is adopted in order to distinguish the various portions of the plant.

Yellow	—Medium-wave transmitter	circulating pumps.
Brown	— Do. do.	booster pumps.
Green	—Long-wave transmitter	circulating pumps.
Red	— Do. do.	booster pumps.
Purple	—Cooling spray pumps.	
Blue	—Air blast compressors.	

For the supply of water for domestic purposes two tanks are provided, one on the roof of the Engine room and the other on that of the Machine room. The tank on the roof of the Machine room supplies the cooling water for the mercury arc rectifiers which is allowed to drain away into the main reservoir. The roof tanks are filled directly from the main supply but in the event of failure water can be pumped up to them from the reservoir by means of a pump installed in a pit alongside it.

Interlock System

Certain necessary precautions have been taken to protect the personnel and also the main items of plant. An interlock system, controlled by the locking handles on the doors of the units and the gates of the H.T. enclosures, ensures that all dangerous voltages are cut-off and the supply leads earthed before access can be obtained to any of the units or enclosures. For the protection of the water-cooled valves the system ensures that the water flow to the anodes is correct and the filament voltages normal before any of the H.T. circuits

Interlock System (*Contd.*)

can be closed. In addition, in the event of the water falling to a dangerous level the filament supplies are automatically cut-off. This protective system is operated through a series of relays, mounted on a small panel behind the Transmitter Hall switchboard, which work in conjunction with the Electroflo meter bodies referred to above. Special provision is also made to give protection against overload of the H.T. generators and mercury arc rectifiers.

Engine Room

Engine Foundations. The Diesel electric plant for the generation of the main A.C. supply at 415 volts, 3 phase, 50 c/s, is installed in the Engine room which is at the far end of the building. The four engine sets are mounted on a foundation block 54′ long × 30′ wide × 9′ deep, weighing 800 tons. This is entirely separate from the remainder of the floor of the Engine room and, as a further precaution against the transmission of vibration, rests upon cork composition pads. Under the entire area of the Engine room there is a reinforced concrete raft to spread the load of the engine foundation block.

Engine Room Switchboard. The Engine room also contains two machines for the generation of the 220 volt D.C. supply and certain auxiliary plant. The Engine room switchboard is installed along the north-west wall, the meters and operating handles being mounted on the panels and the heavy duty circuit breakers and other associated apparatus in a series of sheet-steel cubicles located in a Crypt immediately below. The battery is installed in an adjoining room immediately behind the switchboard and is connected by copper bus bars to a tapping switch on the battery control panel. The switchboard carries the necessary switchgear for the manual control of the alternator outputs and for synchronising and paralleling them on to the bus bars, and a Tirrill regulator for automatically regulating the A.C. voltage under varying conditions of load. It also carries the switchgear for controlling the D.C. motor generator sets, battery charging and the distribution of the A.C. and D.C. power. A Brown-Boveri automatic voltage regulator is provided for automatically regulating the D.C. voltage under varying conditions of load and is mounted on a panel fixed to the wall behind the switchboard.

Power Supply Circuits. The A.C. power distribution from the Engine room bus bars is carried out (see Figure 3) by means of four three-phase feeders. Two main feeders supply two sets of bus bars on the Machine room switchboard and two auxiliary feeders supply two sets of bus bars on the automatic starting switchboard. Of the two sets of bus bars on each switchboard, one set normally supplies the long-wave transmitter and the other set the medium-wave transmitter. Switching facilities are, however, included so that both sets of bus bars can be simultaneously connected to the same feeder if required. Power is distributed to the H.T. motor generator sets and mercury arc rectifiers via the Machine room switchboard, and to the filament heating, grid-bias and low-power stage H.T. motor generator sets, to the valve cooling water pumps in the Crypt, and to the Control room D.C. generating plant, via the automatic starting switchboard.

The distribution of D.C. power is carried out in a similar manner. Six main feeders run from the Engine room switchboard and can be fed either directly from the D.C. generators or from the battery. Three of these feeders supply power to the engine auxiliaries, station lighting and mast lighting and lifts, respectively. A fourth is spare. Of the remaining two,

Engine Room *(Contd.)*

one supplies the auxiliary D.C. power for the long-wave transmitter and the other for the medium-wave transmitter. These feeders both run directly to the Transmitter Hall switchboard where they are each sub-divided into two auxiliary feeders, one supplying the generator field excitation and control circuits and the other the transmitter interlock circuits. A branch from the feeder supplying the long-wave transmitter is taken to the Machine room switchboard for driving the motor alternator set which furnishes the auxiliary A.C. supply required when the engines are shut down.

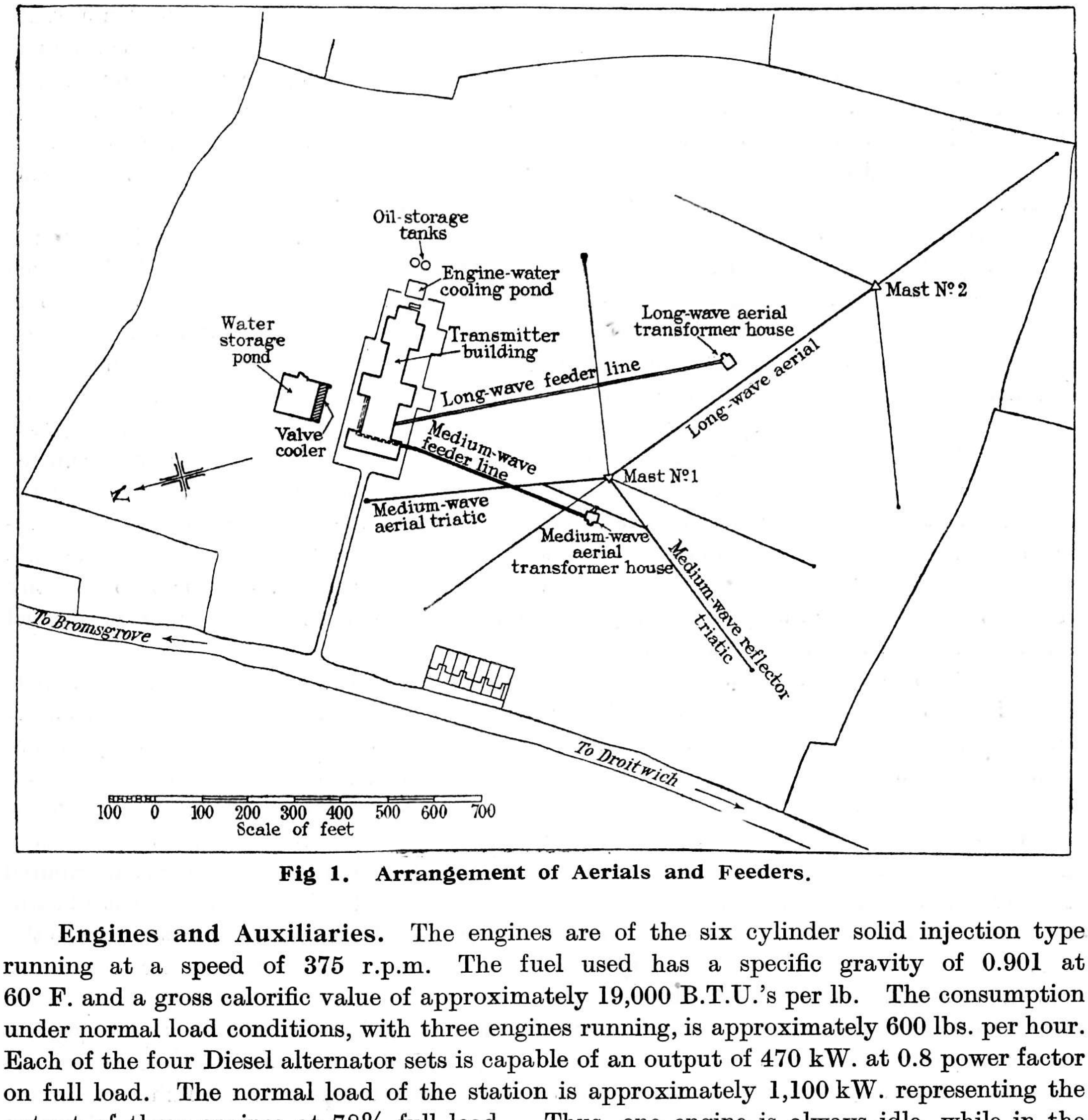


Fig 1. Arrangement of Aerials and Feeders.

Engines and Auxiliaries. The engines are of the six cylinder solid injection type running at a speed of 375 r.p.m. The fuel used has a specific gravity of 0.901 at 60° F. and a gross calorific value of approximately 19,000 B.T.U.'s per lb. The consumption under normal load conditions, with three engines running, is approximately 600 lbs. per hour. Each of the four Diesel alternator sets is capable of an output of 470 kW. at 0.8 power factor on full load. The normal load of the station is approximately 1,100 kW. representing the output of three engines at 78% full load. Thus, one engine is always idle, while in the

Engine Room. (*Contd.*)

event of a breakdown of an engine during the overhaul of the spare engine the whole of the station load can be carried by two engines with only a slight reduction in the power. The engine auxiliaries include hot and cold water circulating pumps, air compressors and lubricating oil purifying centrifuges. They are driven from the 220 volt D.C. supply since it is necessary for them to be started up when no engines are in operation. The air compressors, high pressure air tanks, cooling-water pumps and auxiliary oil tanks are installed in the Engine room. The fuel oil pumping and centrifuge plant is located in the annexe adjoining the Engine room. This also contains the exhaust-gas boiler for supplying the water radiators used for heating the building and an auxiliary oil-fired boiler to carry this service when the engines are not running. At the back of the building are the silencing pit for the engines, the water-cooling pond with the radiator and spray cooling plant for the engine circulating water, and two oil storage tanks each containing 150 tons, the combined capacity being sufficient to run the station on full load for a period of approximately three months.

Aerial System

Masts. Two stayed lattice steel masts 700′ high and 600′ apart are provided for the long and medium-wave aerials. Each mast is supported by means of three sets of three stays, the stay-block radius being 480′. The stays are broken up at 150′ intervals by egg-type insulators. The masts are insulated at the base by means of porcelain insulators capable of withstanding a working peak voltage of 70,000 volts R.M.S. at 200 kc/s. The weight of each mast is 100 tons but the load on the base insulators is increased by the stay tension to 150 tons. The size of the concrete base foundation is 14′ square at ground level and 7′ square at a height of 8′ 6″ from the ground ; its weight is 90 tons. The cross section of the masts is triangular and each is provided with an electrically operated lift within the structure. The hoisting gear is accommodated on a platform built out from the side of the mast.

At the base of each mast there is a framework carrying the isolator switches. These comprise a single-pole single-throw switch with horn-gap lightning arrestor for earthing the mast structure, a double-pole single-throw switch for isolating the D.C. power to the mast lifts, and a double-pole single-throw switch for isolating the telephone circuit to the top of the mast. The isolators are mechanically interlocked with the earthing switch so as to ensure that the mast must be earthed before the lift power and telephone circuits can be connected.

To conform with Air Ministry regulations, the top of each mast is lighted by means of a red light fitting of special design. There is a similar fitting on a bracket at a height of 350′. In addition a light is provided on a foot-pole 20′ high and 20′ distant from the base of each mast, ~~in the line joining the two masts~~. Power for the mast lights which have to be in operation under normal working conditions, is fed through a specially designed choke-circuit mounted in a cubicle at the foot of each mast.

Long-wave Aerial. The aerial for the long-wave transmitter is of the 'T' type. The top hamper consists of two wire cages each 20′ in diameter and 84′ in length with six equally spaced conductors connected in parallel. The down-lead consists of a single wire 608′ in length connected at the middle of the top hamper between the two cages. It is anchored at a height of 18′ from the ground through insulators to a steel structure incorporating a

Aerial System (*Contd.*).

spring-loaded tensioning device which ensures that the down-lead tension shall not reach a dangerous figure in high wind. ~~The halliards supporting the top hamper are similarly tensioned.~~

Medium-wave Aerial. The aerial for the medium-wave transmitter is of the half-wavelength type with a reflector at a distance of a quarter of a wavelength behind it in a south-westerly direction, designed to intensify the radiation in a north-easterly direction. The aerial and reflector each consists of a single vertical wire 450′ long slung from a triatic and anchored at the base through insulators to a compensator of the counter-weight type. The triatics, which are slung from the top of the more northerly mast are broken up with insulators every 75′ and are anchored at the base to concrete blocks via spring-loaded compensating devices.

Aerial Transformer Houses. Separate aerial transformer houses are provided for the two transmitters. That for the long-wave transmitter is situated at a point midway between the two masts and just clear of the line joining them, and that for the medium-wave transmitter is midway between the aerial and the reflector, slightly to the north-west of the more northerly mast from which these are slung.

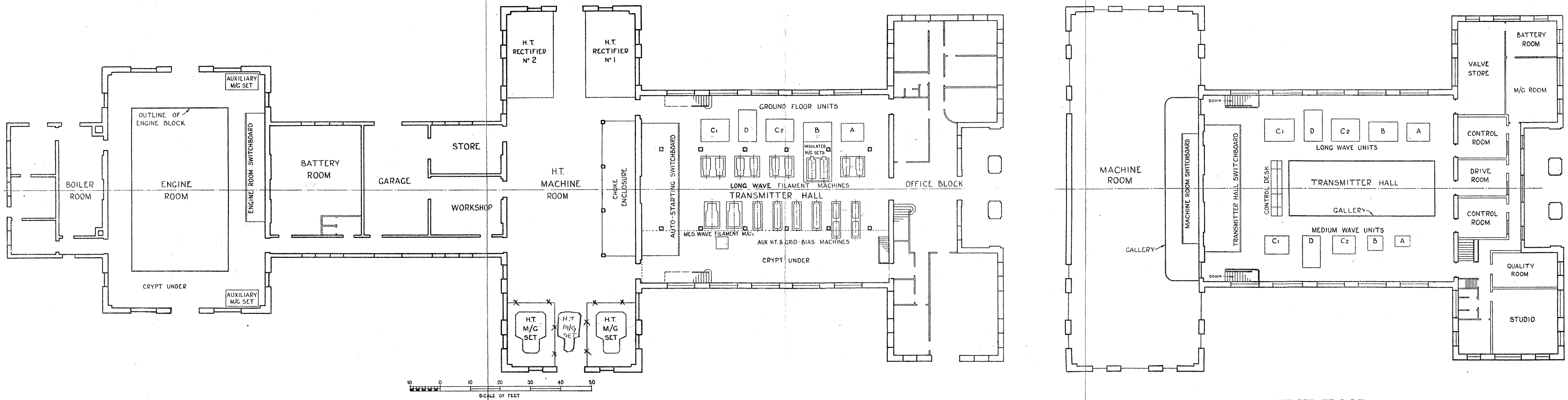
The high frequency output from the two transmitters is conveyed to the appropriate aerial transformer house in each case by means of a pair of open-wire feeders supported on steel poles.

The aerial down-lead of the long-wave transmitter is supported on a steel pylon, which also carries a lightning arrestor and earthing switch, and terminates on an insulator mounted on the transformer house. The aerial transformer house contains the coupling circuits between the feeder and the aerial and the whole of this equipment is supplied in duplicate, so that in the event of failure of any component the spare set can be brought into circuit without delay by means of isolator switches.

The horizontal lead-in conductors of the aerial and reflector for the medium-wave transmitter, are supported between steel pylons and opposite corners of the transformer house, and terminate on their respective lead-in insulators mounted on the wall of the transformer house, on the same wall of which are also mounted two sets of lightning arrestors and earthing switches. The aerial transformer house contains two similar sets of coupling circuits for the aerial and reflector, with the addition of a phasing unit for the reflector, but in this case no spare equipment is provided.

Aerial Earth System. The aerial earth system consists of No. 16 gauge copper wires about 700′ in length, buried in the ground at a depth of approximately 9″ and radiating from the long-wave aerial transformer house. Cross-connectors, bonding the radial members together, are provided at the aerial transformer house and at the foot of each mast. For the medium-wave transmitter the system of radial wires is extended over an area to the north-west of the more northerly mast and bonded to the main earthing system by means of copper strip connectors extending for a distance of about 300′ in either direction, approximately at right angles to the line of the masts.

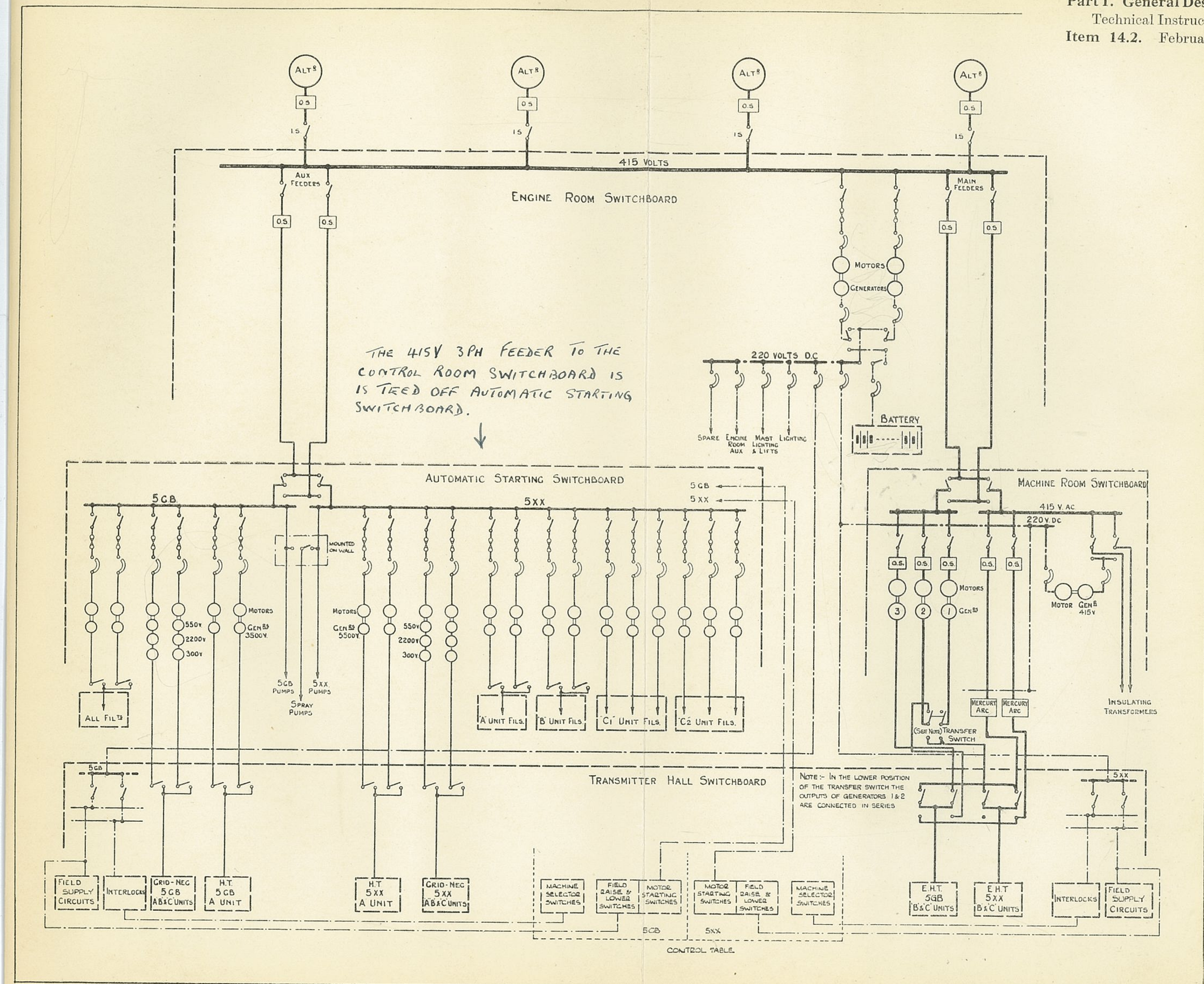
Fig. 2. Layout of Station



GROUND FLOOR

FIRST FLOOR

Fig. 3. Schematic of Power Circuits



Drawing MR/W/612R2

DROITWICH TRANSMITTING STATION

PART 2. STATION POWER SUPPLIES

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DROITWICH TRANSMITTING STATION

PART 2A. MAIN A.C. POWER SUPPLY (415 V. 3 ph. 50 c/s)

Description of Plant

The main station supply is 3 phase, 50 c/s, A.C. at 415 volts and is generated by means of Diesel electric plant. There are four identical units.

The engines are of the 6-cylinder solid-injection type each capable of developing 750 B.H.P. at 375 r.p.m. The engines are coupled to 3 phase, 50 c/s alternators.

The alternators are 3 phase delta connected, designed to give a maximum output of 588 kVA at 0.8 power factor, that is to say, an output of 470 kW. Each alternator is excited by a generator mounted on a shaft extension. A voltage range of 400 to 430 is obtained by adjustment of the exciter rheostat.

The H.T. rectifiers represent the major portion of the load and, as is well known, any form of rectifier produces heavy harmonics in the transformer primary circuit which, if not provided with a low impedance path, will produce serious distortion of the voltage waveform. It was, therefore, found necessary to adopt a special design of stator winding having a low impedance to harmonic frequencies. The problem normally does not arise in the commercial application of rectifiers since they are usually supplied from generating stations, the capacity of which is high compared with the capacity of the rectifier. The alternators as stated are Delta wound but the conductors of different phases are placed in the same slots instead of in adjacent slots as is more usual in commercial practice. The coils are therefore virtually non-inductive to certain harmonic frequencies.

Since the Delta connection of winding is used a neutral point is not available. In order therefore to provide an earth return for fault current and to anchor the system to earth in the event of accidental contact with H.T. D.C., a neutral earthing transformer is connected across the phases.

The switchgear associated with the generation and distribution of the A.C. supply is controlled on panels H—S of the Engine room switchboard. The switchgear itself is located in a series of sheet steel cubicles in the Crypt immediately below the switchboard and is operated from the switchboard by means of mechanical links. The letters I and Q have been omitted from the sequence used for designating the panels. Panels A—G of the Engine room switchboard are equipped for operating the switchgear associated with the generation and distribution of the 220 volt D.C. supply and are described in **Part 2B** of this Instruction.

Panel H carries the Tirrill regulator and the switchgear associated with the control of the main A.C. bus bar voltage.

Panels J-M each carry the switchgear controls and meters associated with the output of one of the alternator sets.

Panels N and O carry the switchgear associated with the main A.C. feeder circuits.

MAIN A.C. POWER SUPPLY

Description of Plant (*Contd.*)

Panels P and R carry the switchgear associated with the auxiliary A.C. feeder circuits. Panel S carries the switchgear associated with the artificial earthing transformer. It also carries a swivelling bracket supporting two voltmeters and a synchroscope.

Main Alternator Panels (*Figure 1—Panels J-M*)

There are four of these panels, one to control each alternator. The alternator output connection to the bus bars is completed via three single-pole isolating links and a triple-pole oil circuit breaker. Current transformers are provided for each of the phases for the operation of the meters. Overload coils for each phase, shunted by time-lag fuses, and a no-volt trip coil connected directly across ~~two~~ ONE phases of the alternator output, operate in conjunction with the tripping mechanism of the circuit breaker.

Each alternator is excited by means of its own exciter and each exciter possesses two regulators in series with its shunt field. One of these is the exciter field rheostat and the other the equaliser rheostat. The former is utilised to control the alternator excitation when on hand control and the latter is included in order that the excitation characteristics of all the alternator sets may be made identical when on automatic control.

A 0—200 ammeter is supplied to measure the field current. The other instruments are an indicating watt-hour meter, a three-wire integrating watt-meter and a 0—1,000 ammeter to measure the output of the alternator.

A synchronising socket is provided on each panel, wired directly across one of the phases of the alternator output to accommodate the plug which terminates the common voltmeter and synchroscope leads. The synchroscope and the associated 0/500 voltmeter, together with the 0/500 voltmeter permanently connected across one phase of the bus bars, are mounted upon a swivelling bracket projecting from panel S. The synchroscope is brought into circuit when running up the alternators for paralleling them to the bus bars, by inserting the plug into the socket on the panel associated with the alternator to be connected in parallel with those already connected to the bus bars, and by operating the synchroscope switches which are mounted on the bracket.

A triple-pole reverse power relay is fitted on each panel. It operates on the induction watt-meter principle, the energy being obtained from the current transformers. When the reverse current exceeds a predetermined amount, the relay operates and short-circuits the no-volt release coil of the oil circuit breaker, which is thereby tripped. A resistance is provided in series with the no-volt coil in order to avoid placing a short-circuit across the alternator output when the no-volt coil is shorted.

Red and green pilot lamps, operated by an auxiliary contact on the oil circuit breaker from the 220 volt D.C. supply, serve to show when the circuit breaker is closed or open, respectively.

Earthing Panel (*Figure 1—Panel S*)

The chief reasons for providing an earth on the systems are (a) for protecting the plant against breakdown to earth, (b) for providing a path to earth to safeguard apparatus in the

MAIN A.C. POWER SUPPLY

Earthing Panel *(Contd.)*

event of a breakdown between primaries and secondaries of the rectifier transformers, or accidental connection between the 20,000 volt D.C. circuits and the 415 volt A.C. system.

The panel mounts a four-pole single-throw switch and 0/100 ammeter connected in series with earth and the neutral point of the earthing transformer. The transformer which is located in the Crypt is three-phase interconnected star and provides for an artificial neutral for the mesh-connected system. The ammeter reads the total earth leakage current. Under normal conditions the continuous earth current of the system should be negligible.

The transformer reactance is sufficiently low to by-pass a current of 150/200 amperes (it is rated at 300 A. for 30 secs.) which will ensure that the overload trips on motors of 55 h.p. and less will function in the event of an earth on one or more phases. The larger items of plant, e.g. the 600 kW rectifier transformers and the 300 kW synchronous motors are protected by earth-leakage trip coils on the circuit breaker. The largest individual items take approximately a full load current of 1,000 amperes and the leakage current required to operate the direct acting trips is at least 25 per cent. of the full load current.

Feeder Panels *(Figure 1—Panels N-R)*

There are four of these panels. The two main feeder panels N and O, each control an output of 1,200 amperes per phase and supply power to the Machine room switchboard bus bars for running the mercury arc rectifiers and E.H.T. motor generator sets. The two auxiliary feeder panels, P and R, each control an output of 500 amperes per phase, and supply power to the automatic starting switchboard for running the filament, grid and H.T. machines installed on the ground floor of the Transmitter Hall, and also, via the bus bars of the automatic starting switchboard, supply power to the circulating water, booster and spray pump plant in the Crypt running under the north-east side of the Transmitter Hall, and to the Control rooms.

Except for the rating of the switches and meters, the equipment of each panel is similar. The connection to the bus bars is completed via a set of three-pole isolating links and a triple-pole oil circuit breaker. Current transformers are provided for operating the meters, which include ammeters in each phase and a watt-hour meter. Overload coils for each phase, shunted with time-lag fuses and no-volt and leakage trips are provided, operating in conjunction with the oil circuit breaker operating mechanism. The overload coils are connected in series with the meters in the secondary circuit of the current transformers and the leakage coil is connected in their common return lead. The no-volt coil is energised from ~~the 220 volt D.C. bus bars~~ ONE PHASE OF THE MAIN A.C. SUPPLY via the interlocking associated with the A.C. supply on the switchboard to which the particular feeder is connected.

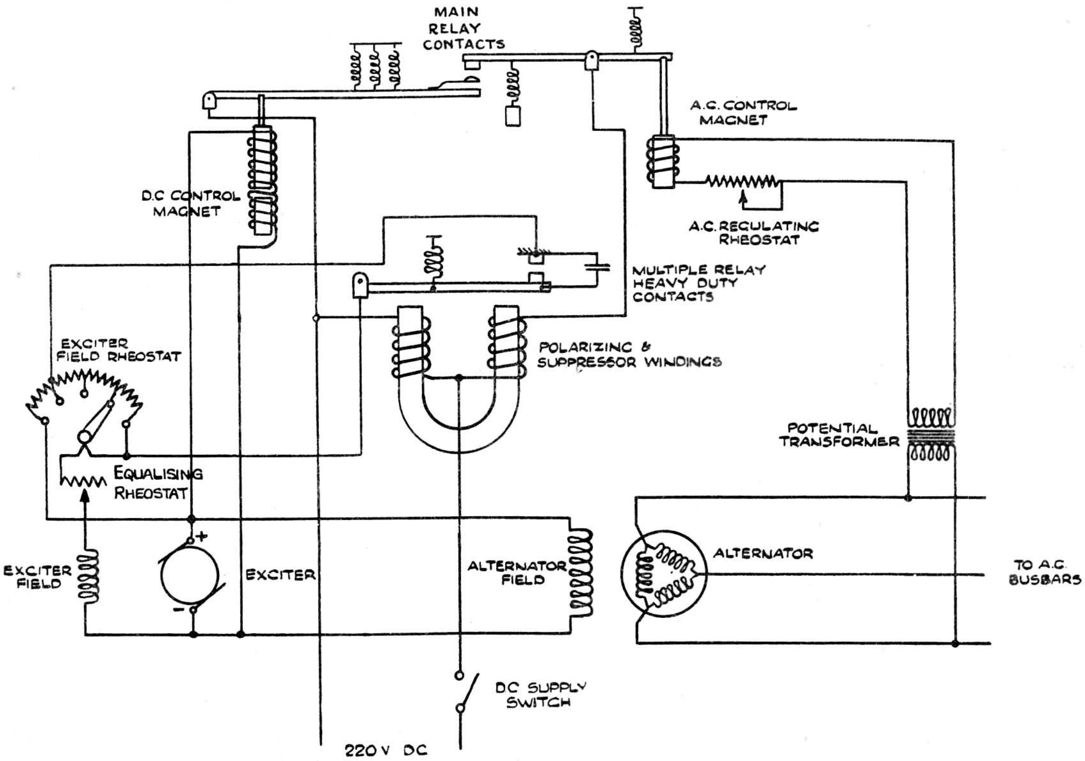
Automatic A.C. Voltage Regulator *(Figures 2, 3, 4 and 5)*

Principle of Operation. The Tirrill regulator is a vibrating relay system designed to maintain the alternator terminal volts sensibly constant under any condition of load within the range of the alternator.

MAIN A.C. POWER SUPPLY

Automatic A.C. Voltage Regulator *(Contd.)*

The operation of the regulator is based on the 'over-shooting the mark' principle. Thus, when the load of the alternator is increased causing the alternator voltage to fall, the regulator momentarily produces more excitation than is ultimately required; whilst, when



Drawing MR 767 Sheet 5

Figure 2. Tirrill Regulator—Theoretical Diagram.

the load on the alternator is decreased, the regulator momentarily reduces the excitation to a value below that which is ultimately required. This over-correction is necessary because, due to the time constant of the alternator field, if the excitation voltage were altered by the exact amount necessary to compensate for the change in output voltage, the flux would attain the desired value only very slowly. The vibrating relay system is, however, so arranged that before the alternator voltage has had time to reach the extreme value corresponding to the excitation applied, the regulator operates in the reverse direction. The alternator voltage, therefore, though apparently constant, is kept in a state of continuous fluctuation, within very narrow limits above and below the predetermined mean value.

MAIN A.C. POWER SUPPLY

Automatic A.C. Voltage Regulator (*Contd.*)

Referring to the simplified diagram, Figure 2, it will be seen that the regulator consists essentially of two relay arms each carrying a contact. The relay arm on the right is operated from an A.C. solenoid connected across the secondary of a potential transformer, the primary of which is connected across two phases of the A.C. bus bars. The relay arm on the left is operated by a D.C. solenoid connected across the exciter terminals of one alternator. The action of the two relays is, however, totally different.

The D.C. relay is provided with carefully graded spring loading so that the position taken up by its armature is directly proportional to the D.C. exciter output voltage. In other words, an extension of its contact lever, moving over an equally divided scale, would indicate the exciter voltage.

The A.C. relay, on the other hand, is so balanced by adjustment of its spring and gravity loading that at a predetermined applied voltage it is in a state of equilibrium. The armature will thus remain stationary in any position as long as the correct voltage is applied to the coil, but as soon as the voltage changes it will start to move, the direction of motion depending on the sense of the change. If the applied voltage is greater than the predetermined value for which the loading was adjusted, the armature will move into the coil, tending to open the contacts, while if the applied voltage is less than this value the armature will move out of the coil, tending to close the contacts. The movement in each direction will continue, either until the mechanical system reaches the end of its travel, or until the applied voltage is adjusted to the predetermined value when it will come to rest in the position it has assumed.

The polarised relay in the middle of the diagram is actually a multiple relay consisting of a closed iron ring provided with equal but opposite polarising and suppressor windings, and with a number of raised pole-pieces equally spaced around the circumference, each associated with a pair of spring-loaded heavy-duty contacts. Each pair of these contacts is connected across a portion of the field rheostat associated with the exciter of each alternator being controlled, so that when the contacts close that part of the resistance is short-circuited. In the case of large alternators, where the exciter field current is large, the volt-amperes to be carried by the contacts shorting the exciter field resistance will be high and it is, therefore, usual to split the portion of the rheostat to be short-circuited into two or more sections, each section being provided with its own pair of shorting contacts. Both windings on the core of the relay are connected either across the exciter output or across a separate D.C. supply, the polarising winding directly and the suppressor winding via the main relay contacts.

We will first consider the constant load condition. When the main relay contacts are open, the polarising winding only is energised and the multiple relay contacts are held open against the action of their spring loading. That part of the exciter field rheostat which they short out will, therefore, be in circuit and the excitation will be falling to a value less than that necessary to maintain the alternator output voltage. The energisation of the D.C. relay will also be falling and its armature will, therefore, move outwards and eventually cause the main relay contacts to close. The closing of these contacts completes the circuit of the suppressor coil of the multiple relay. The flux in the ring is thus neutralised and the multiple relay contacts close under the action of their spring loading, short-circuiting part of the exciter

MAIN A.C. POWER SUPPLY

Automatic A.C. Voltage Regulator (*Contd.*)

field resistance. The exciter voltage thereupon rises to a value greater than that necessary to maintain the bus bar voltage. The pull of the D.C. relay magnet accordingly increases causing its armature to move into the coil, withdrawing the contact arm and opening the main relay contacts. The suppressor winding circuit is thus interrupted. Since the polarising winding is now acting alone, the multiple relay contacts will be broken and the short-circuited portion of the exciter field resistance will again be inserted in circuit. The cycle of events outlined will now be repeated and the regulator will in fact vibrate continuously, causing the exciter voltage to fluctuate about a mean value which is the value required for maintaining the bus bar voltage at the proper value for the particular load condition.

It may at first glance appear that the A.C. relay contact arm should also go through a similar cycle of movement and so affect the opening and closing of the main relay contacts. It is true that the bus bar voltage will undergo a cyclic variation corresponding with that undergone by the excitation voltage, but whereas the latter variation is large, due to the alternate shorting and unshorting of a large part of the exciter field resistance, the variation in the bus bar voltage is extremely small, due to the relatively slow rate of change of flux in the alternator field and to the rapidity with which the cycle is completed. The motion of the A.C. relay contact arm is further damped by an oil dashpot. It will thus be seen that while the load remains constant the A.C. relay contact will remain practically stationary and the regulation will be performed by the beating of the D.C. contact arm alternately opening and closing the main relay contacts.

We will now consider what happens if the load conditions are changed.

Obviously, in order to maintain the bus bar voltage constant, the average level of excitation must be adjusted to correspond with the changed load condition, and until this is effected the bus bar voltage will depart from the correct value, going high if the load has been reduced and low if it has been increased. Such a change in the bus bar voltage, if sustained for a second or so, will result in movement of the A.C. relay arm. For example, if the voltage has fallen, due to an increase in the load, the armature will move away from the coil causing the main relay contacts to close, thereby shorting out part of the exciter field resistance and causing the excitation to rise. As previously explained, the A.C. relay arm will continue its movement, carrying the D.C. relay arm with it and maintaining the main relay contacts closed, until the bus bar voltage rises to the correct value. Conversely, if the bus bar voltage has risen, due to a decrease in the load, the A.C. relay armature will move into the coil and the contact arm will continue to move upwards until the correct bus bar voltage is restored, maintaining the main relay contacts open until the drop in the excitation has been sufficient to allow the D.C. relay contact arm to follow it and again close the main relay contacts. The regulation will then be carried out as has been described for the constant load condition, by the operation of the D.C. relay causing the exciter volts to fluctuate about the new mean value corresponding to the position assumed by the A.C. relay contact arm. Actually, due to the inherent instability of the system, a few cycles will elapse after any considerable change in the load condition has been made before the readjustment in the position of the A.C. relay arm, to accord with the changed conditions, will be completed. The position of the relay

MAIN A.C. POWER SUPPLY

Automatic A.C. Voltage Regulator (*Contd*)

arms will thus be seen to vary in space as the load on the system changes and the main contacts are, therefore, curved in order that the necessary rolling action can be accommodated.

The rate at which the regulator vibrates will be a function of the alternator load, the excitation voltage and the electrical and mechanical inertia of the system. Since the two latter factors are constant, the rate of vibration will depend only on the alternator load and the exciter voltage. These two factors are a function of one another and the speed of vibration must always be such as to produce the correct average excitation conditions required by any alternator load. Thus, on light loads the rate of vibration will be slow and the periods for which the relay contacts are open will exceed in length those for which they are closed, in order that the average level of excitation may be low. As the load on the alternator is increased the speed of vibration will also increase until a maximum is reached when the open and closed periods will be equal. If the load is still further increased the rate of vibration will become less, since it will then be necessary for the closed period to exceed the open period in order that the average level of excitation may be high. Progressing from the no-load to the full-load condition, the necessary excitation level is thus achieved by the automatic proportioning of the times during which the excitation field resistance is shorted and unshorted by the relay contacts. At the same time the position in space of the main relay contacts will progress from the extreme upper to the extreme lower position.

In order to set the voltage at which the Tirrill regulator will control the alternator, a variable regulating resistance is connected in series with the main A.C. relay solenoid. The effect of varying this resistance is to vary the ratio between the alternator terminal voltage and the voltage applied to the A.C. solenoid, which, it will be recalled, balances at one predetermined voltage only. To raise the alternator voltage it is thus merely necessary to insert resistance in the A.C. relay solenoid circuit. The Tirrill regulator will then build up the alternator voltage until the voltage on the A.C. relay solenoid is again sufficient to balance the relay. The regulator will then control the alternator at an increased value of output voltage. Similarly, a reduction in alternator voltage may be made by reducing the amount of resistance in series with the A.C. relay solenoid.

Description of the Equipment. At Droitwich the characteristics of the alternators are similar and if their exciter characteristics are properly equalised, by means of the equalising rheostats at the commencement of the run, the degree of excitation control required by one alternator will be exactly the same as that required by the others. Only one Tirrill regulator is, therefore, provided for controlling any number from one to four alternators connected in parallel to the common bus bars. One alternator is chosen as the master and the coil of the D.C. relay is fed by the exciter of this alternator, whilst the A.C. coil is energised by the common A.C. bus bar voltage.

Figures 3 and 4 show a schematic diagram of the connections as used at Droitwich. It will be observed that three **exciter voltage selector** switches are provided in order that any of the four exciters may be used as the master. The multiple relay system is provided with eight pairs of contacts, two pairs of which are associated with each alternator set. **Relay isolating** switches are provided to isolate any of the sets from the regulator control. The connections to the main regulator and relay contacts are made via double-pole switches designated **contact reversing switches** which enable the direction of the current through the contacts to be periodically reversed in order to equalise the wear on the two contacts of each pair.

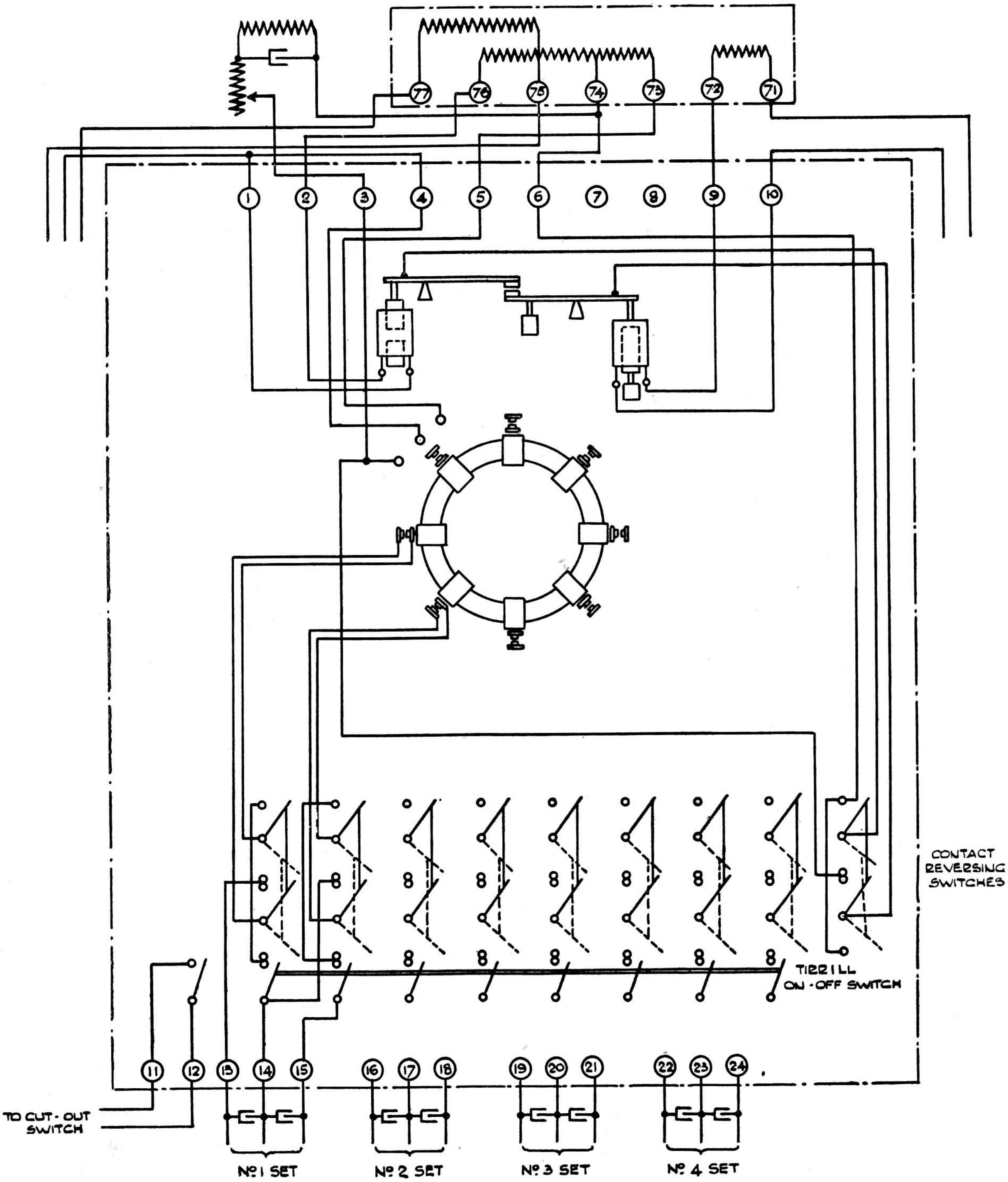


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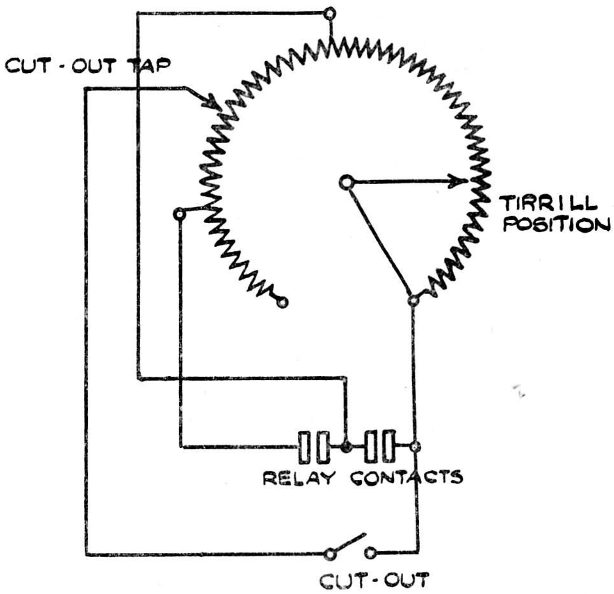
Figure 3. Tirrill Regulator—Schematic of Wiring.

MAIN A.C. POWER SUPPLY

Automatic A.C. Voltage Regulator (*Contd.*)

The section of the exciter field regulators to be shorted by the relay contacts is proportioned as follows. The alternator is run up to normal speed and the exciter field regulator arm moved to a position to give a specified percentage (usually 40 per cent.) of the alternator normal volts. This position (see Figure 5) is known as the **Tirrill** position and the rheostat arm should always be in this position when the alternator is on automatic control. It determines the minimum level of excitation which will be applied when the relay contacts open. It would also serve, in an emergency involving the failure of both the Tirrill regulator and the **High and Low voltage cut–out** switch, to ensure that the alternators are not left unexcited.



Drawing MR 767 Sheet 5.

Figure 4. Tirrill Regulator—Exciter Field Regulator Tappings.

The relay contacts are then connected to short-circuit a sufficient portion of the exciter rheostat to give an exciter voltage 15 per cent. in excess of that required for the alternator field when the alternator is on maximum load. This portion of resistance should be divided by the number of pairs of contacts available for shorting, i.e. two in the case of Droitwich.

A further tapping point, known as the **Cut-out Tap,** is also required on the rheostat since a **High and Low voltage cut-out** relay is provided which disconnects the Tirrill regulator, via a multi-pole cut-out switch, should the alternator voltage vary beyond predetermined limits.

High and Low Voltage Cut-Out. The cut-out relay consists of a pivoted horizontal lever operated by an A.C. solenoid, which is connected in series with the main A.C. relay solenoid and variable regulating resistance. The lever is spring-loaded and the loading is graded so that the position of the lever in space is proportional to the voltage applied to the solenoid. The lever will, therefore, take up definite positions corresponding to definite alternator voltages. The lever carries a vertical spring contact arm on each side of which is an adjustable stationary contact. The cut-out can, therefore, be set so that the contact arm makes contact on one side or the other at any desired value of high or low alternator voltage. An oil dashpot is fitted to give an adjustable time lag and prevents the cut-out from operating on a sudden change in voltage due to a transient surge or other reason.

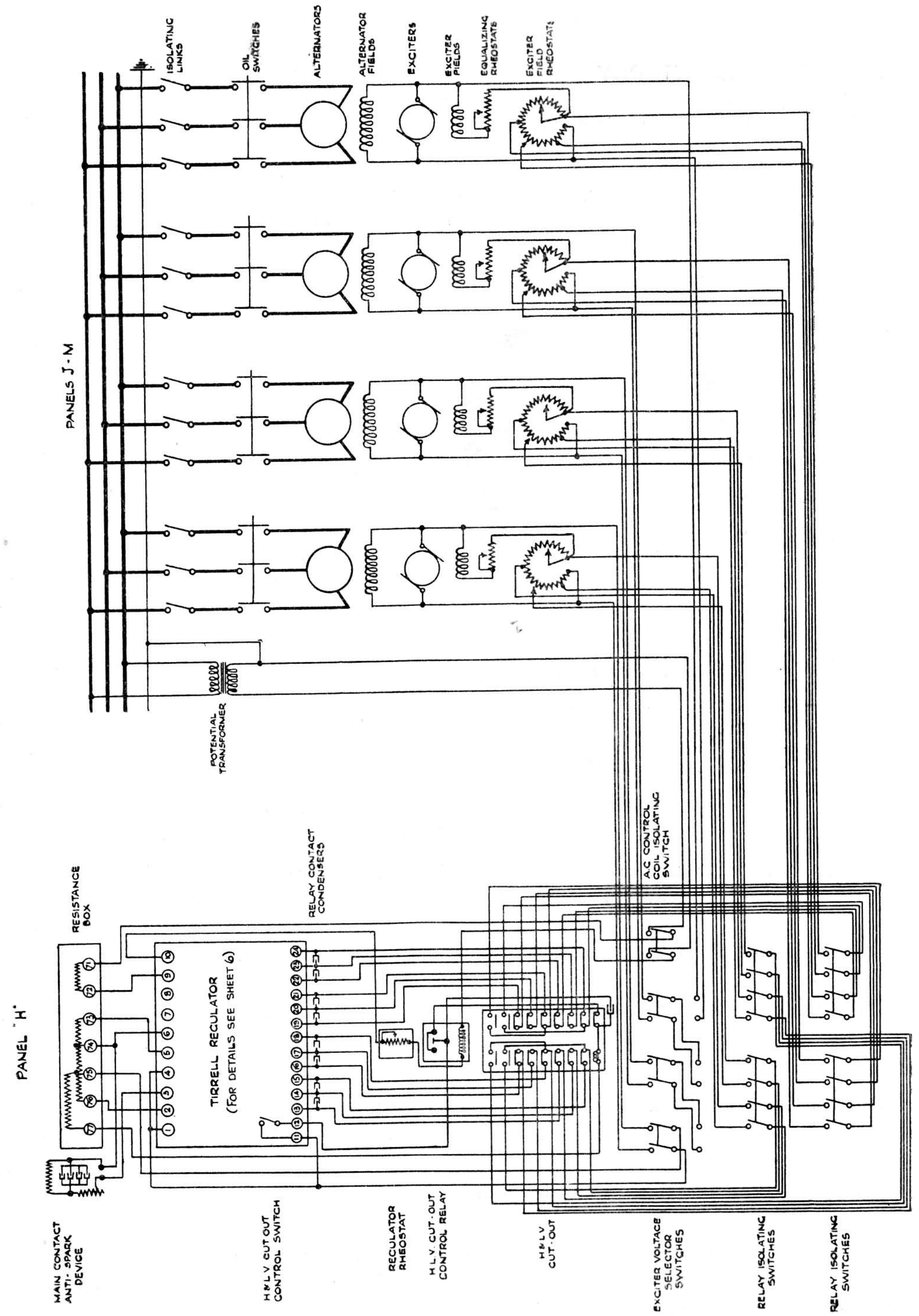


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Figure 5. Tirrill Regulator Panel.

MAIN A.C. POWER SUPPLY

Automatic A.C. Voltage Regulator *(Contd.)*

The cut-out is adjusted so that with normal alternator voltage, the lever balances in a horizontal position and the vertical contact arm is about midway between the two stationary contacts. The usual settings for the cut-out to make contact are 115 per cent. normal volts and 60 per cent. normal volts, the object of the rather low setting being to prevent the shutting down of synchronous machinery in the event of some such occurrences as a heavy short-circuit which may be cleared in a very short time. The stationary contact of the low voltage side is therefore usually adjusted to be a little more distant from the central contact arm than is the high voltage contact. When setting the cut-out care should be taken to ensure that the variable regulating resistance is in the position for normal alternator voltage, since the value of this resistance also determines the alternator voltage at which the cut-out lever will balance.

When the cut-out relay operates it trips the mechanism of a multi-pole cut-out switch which disconnects the Tirrill regulator from the exciter fields and from the A.C. bus bars. On disconnecting the regulator, however, the multi-pole switch establishes a circuit to the exciter field rheostat via the cut-out tap, so that the alternator is not left unexcited. The position of the cut-out tap is usually such that the excitation conditions obtained give normal alternator voltage at a half to two-thirds load. A small knob is provided on the multi-pole switch to reset the device when it is required to replace the Tirrill regulator in commission.

Operating Routine

Connecting One Alternator to the Bus Bars. Under normal conditions one alternator only is connected to the bus bars to carry the station load until the transmitter is ready for the main high tension power.

The operator should make sure that all switches on the Tirrill regulator are out and that the safety trip switch is in the **Set** position. The engine should then be run up to the correct speed, namely 375 r.p.m. and the voltmeter/synchroscope plug should be inserted in the sockets on the alternator panel. The alternator should be brought up to 415 volts by means of the exciter rheostat hand-wheel and when this voltage is reached the alternator oil-switch should be closed, thus connecting the machine to the bus bars. The alternator is now ready to take any load imposed upon it.

The next step is to put the machine on automatic voltage control. Let it be assumed that alternator No. 1 is the one under consideration, then the following switches must be operated.

(a) Close the Tirrill regulator, **A.C.** and **D.C. supply** switches (the D.C. switch is on the wall behind the switchboard at the left hand end).

(b) Close the Tirrill **relay isolating** switch for alternator No. 1.

(c) Set the **exciter selector** switches to the position for alternator No. 1 as master.

The Tirrill **On-Off** and the **Cut-Out** switches must still be left **Off.**

The regulator must first be balanced to the bus bar voltage. This is accomplished by turning the regulating rheostat hand-wheel on the Tirrill regulator panel until the relay contacts move in one sense ; the hand-wheel is then turned back until the contacts move

MAIN A.C. POWER SUPPLY

Operating Routine (*Contd.*)

in the opposite direction ; this action is repeated, with ever-decreasing movement of the hand-wheel, until the contacts are observed to 'float' or to 'chatter'. Due to the fact that the A.C. relay of the regulator is dashpot controlled, slow and deliberate turning will prevent the operator from 'over-shooting' the position in which the relay contacts change-over and will lead to quicker results.

The Tirrill **On-Off** switch is now closed and the exciter hand-wheel is turned back to the **Tirrill** position as marked on the board. The turning of the exciter hand-wheel must be done quite slowly so as to allow the regulator time to pick up. Voltage adjustment is effected by means of the variable regulating resistance on the Tirrill regulator panel.

If there is only one alternator to be connected to the bus bars the **Cut-Out** switch should now be closed. This switch must, however, always be open before any switching is done on the alternator and must be left open until all the switching is completed.

The operation of reverting to hand control and taking an alternator off the bus bars is as follows :—

(a) Open the **Cut-Out** switch.
(b) Slowly bring up the exciter hand-wheel from the **Tirrill** position until the regulator stops beating.
(c) Open the Tirrill **On-Off** switch and the four-pole Tirrill **relay isolating** switch.

The alternator is now on hand control, and as soon as the load has been taken off, provided it is the only alternator on the bus bars, it may be shut down by tripping it off the bus bars and turning its exciter rheostat hand-wheel back to minimum. The engine may then be stopped.

Paralleling Two or More Alternators. It is assumed that alternator No. 1 is already on the bus bars under automatic control, as described above, and that alternators Nos. 2 and 3 are to be paralleled.

Alternator No. 1 should be placed on hand control, as has already been described, and the 4-pole Tirrill **relay isolating** switches for alternators Nos. 2 and 3 should be thrown in readiness for subsequently placing them on automatic control. The setting of the Tirrill switches should, therefore, be as follows :—

On-Off switch	open.
Cut-Out switch	open.
Relay isolating switches for alternators Nos. 1, 2 and 3	closed.
Exciter selector switches	operated for whichever of the alternators is to be master.
High-volt and Low-volt cut-out trip switch..	set.
A.C. and D.C. supply switches ..	made.

The operations for paralleling No. 2 alternator on the bus bars will now be detailed.

Its engine is run up to approximately the correct speed and the voltmeter/synchroscope plug inserted in the socket on No. 2 alternator panel. The voltage of alternator No. 2 is brought up by means of its exciter rheostat hand-wheel to just over 415 volts, say to 417 volts. The synchroscope is switched on and the speed of No. 2 engine adjusted by the driver

MAIN A.C. POWER SUPPLY

Operating Routine (*Contd*)

until the synchroscope is rotating in the *fast* direction at a speed of approximately 1 revolution in 5 seconds. Then, judging the time, the alternator should be switched in at the moment when the synchroscope is at zero, i.e. with the needle vertical and pointing upwards, and when the lamp above is *dark*. The synchroscope must be switched off as soon as this operation has been completed as it is not intended for continuous operation.

The load must now be shared between the two alternators that are on the bus bars. This is done by adjusting the governor control of the engine whose alternator has just been connected on to the bus bars, and at the same time increasing the excitation of this alternator and reducing the excitation of the other alternator to counteract the tendency for the bus bar voltage to rise. The operation is carried out in a number of steps.

The exciter currents of the two alternators must be equalised to obtain the best power factor and this must be achieved before paralleling the next alternator. It should be borne in mind, however, that while the alternators are on hand control any change in the total exciter current will result in a corresponding change in the bus bar voltage. Therefore, in order to maintain the bus bar voltage constant it will be necessary, in the event of the two exciter currents being unequal, to adjust both, bringing the lower one up and the higher one down, step by step.

No. 3 engine should now be run up to approximately the correct speed and the third alternator paralleled on the bus bars in the same manner as has been described for the second machine. When this has been accomplished the exciter currents of all three alternators must be equalised, the bus bar voltage being maintained at 415.

The alternators may now be put on to automatic voltage control. Assuming the switches on the Tirrill regulator panel are in the positions detailed above, the regulator should be balanced to the bus bar voltage, in the manner described for connecting one alternator to the bus bars, and when the relays float the Tirrill **On-Off** switch should be closed. The exciter rheostat hand-wheels of all the alternators should be brought back to the **Tirrill** position. It will be noticed that when one exciter rheostat hand-wheel is turned back the exciter current of the associated alternator will fall and that of the other alternators will rise. In order, therefore, to keep the exciter currents of all the machines approximately equal while running down to the **Tirrill** position, the process must be carried out in stages, each being reduced slightly in turn. When all the exciter rheostat hand-wheels are in the **Tirrill** position the exciter currents must be finally equalised by means of the **Equaliser** rheostat hand-wheels. Operation of these hand-wheels has no effect on the bus bar voltage but merely corrects the power factor. When all the field currents are equal it will be found that the line amperes of each alternator will be the same. They will, therefore, all be operating at the optimum power factor with no circulating wattless currents flowing between the alternators.

If it should be found impossible to equalise the exciter currents by means of the **Equaliser** rheostat hand-wheels, it is permissible to use the **exciter** rheostat hand-wheels. The practice of moving the exciter rheostat hand-wheels away from the **Tirrill** position should be resorted to only when it is impossible to obtain the necessary adjustment on the **Equaliser** rheostat controls, and such adjustment as is necessary should always be made by moving the **exciter** field rheostat hand-wheels *above* the **Tirrill** position. Thus, to bring down the excitation

MAIN A.C. POWER SUPPLY

Operating Routine (*Contd*)

of one machine the exciter rheostat hand-wheels of the other alternators should be brought up above the **Tirrill** position. Conversely, if it is necessary to increase the exciter current on one machine then this must be done by slightly raising its excitation by means of its own exciter rheostat hand-wheel.

The alternators are now on automatic control and the **Cut-Out** switch should be closed. The voltage of the bus bars should be checked and regulated if necessary by means of the regulator rheostat hand-wheel on the Tirrill regulator panel. The speed of the engines should be checked and if necessary readjusted to bring it to exactly 375 r.p.m. If, in order to do this, it should be necessary to increase the speed, this should be done in small stages on each engine in turn, care being taken to see that the alternators are not overloaded. As the drive on one alternator is increased it will take more than its share of the load, and if this increase in the load is allowed to become excessive the particular alternator will be tripped off on overload.

If it should be necessary to shut down one engine, all the alternators should first be put on hand control. To do this the cut-out switch must be opened and the exciter rheostat hand-wheels of the alternators slowly brought up, each a little in turn so as to keep the alternator field currents equal, until the regulator stops beating. The Tirrill **On-Off** switch should finally be opened, placing the alternators on hand control.

If it is intended to replace the engine that is being shut down with another, the new alternator should be paralleled in the manner already described, but before reverting to automatic control, the engine that is to be shut down should have its alternator tripped.

Suppose that alternators 1, 2, 3 and 4 are now on the bus bars and that No. 3 is to be shut down, the governor control of No. 3 engine should be adjusted so as to reduce the kilowatts of alternator No. 3 and the excitation of the other three alternators increased, in order to compensate for the resulting drop in the bus bar voltage. The process must be continued until the kilowatts of alternator No. 3 have been reduced as far as is possible by means of the engine governor, and if necessary the speed of the other three engines should be increased in order to maintain the frequency constant. As the load on alternator No. 3 is reduced, its exciter current must also be reduced, otherwise its power factor will suffer. The line current of this alternator must, therefore, be ' tuned ' with the exciter rheostat hand-wheel to a minimum in order to bring the power factor to normal and thus reduce the current at ' break ' on the oil-switch. As soon as the kilowatts on the alternator that is to be tripped have been reduced as far as possible, and the line current generated by it reduced to a minimum, the alternator may be tripped off.

The remaining alternators carrying the load may now be put back on to automatic voltage control. The 4-pole Tirrill **Relay Isolating** switches of the alternators now on the bus bars should be closed and if the alternator that has been taken off was formerly the master another master must be selected and the exciter selector switches operated accordingly.

The procedure for placing the alternators on automatic control has already been detailed above for the case of three alternators paralleled on the bus bars.

It is possible in an emergency to change the master control from one alternator to another while on load and while operating with automatic voltage control. To do this the switches

MAIN A.C. POWER SUPPLY

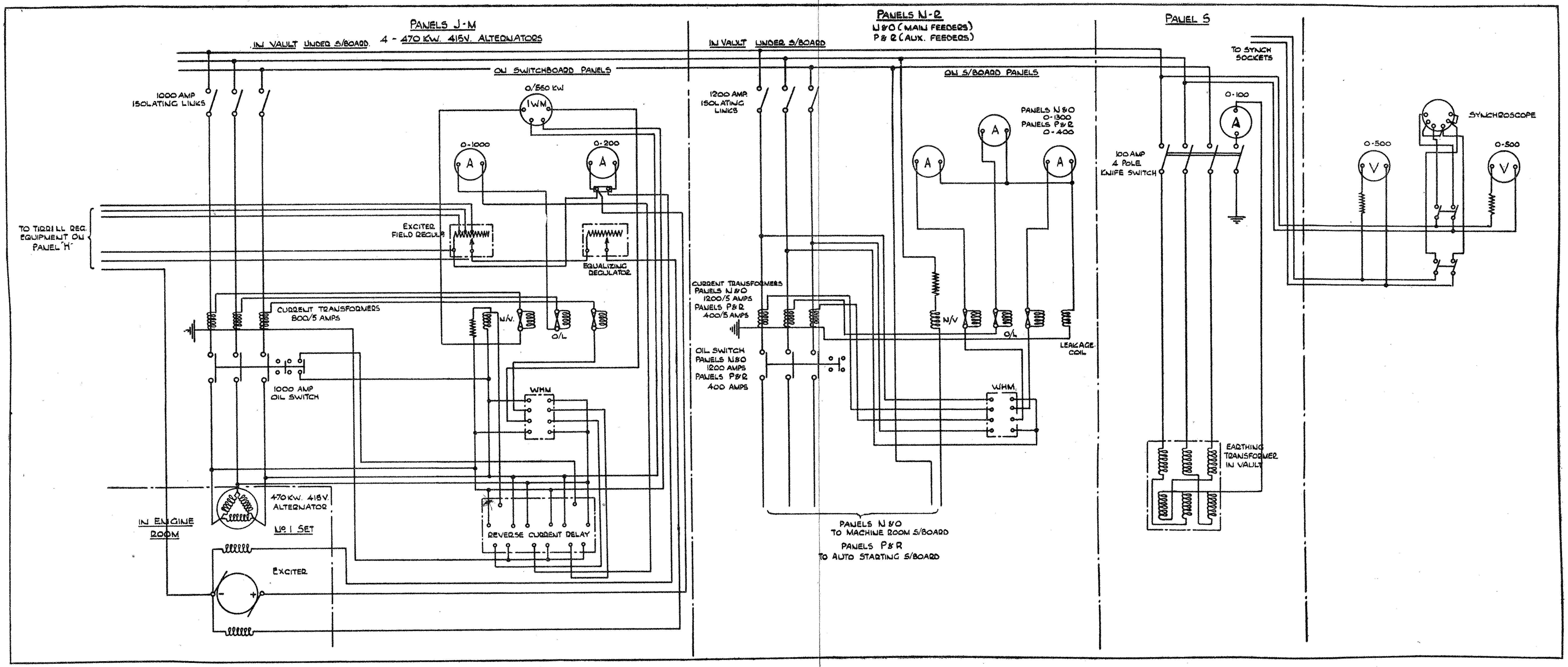
Operating Routine (*Contd.*)

must be moved as quickly as possible so that the total period of switching is not more than ½ second. A voltage surge, which is accentuated by any delay in changing-over the switches, is inevitable. This expedient should, therefore, never be resorted to except in an emergency such as that created by failure of the master engine, necessitating its being taken off before another could be put on the bus bars to replace it.

It is important to remember that the Tirrill regulator is provided not as an aid to paralleling but as a regulating device to keep the A.C. voltage constant under normal running conditions in the absence of a switchboard attendant. It should, therefore, be taken out of action for all alternator switching and the latter carried out on hand control.

The maintenance of the Tirrill regulator involves the regular inspection and adjustment of the relay contacts and renewal of the oil in the dashpot. In order to keep the main regulator and relay contacts in condition it is important for the direction of current through the contacts to be changed periodically, preferably each day, by suitable operation of the **contact reversing switches** provided on the Tirrill regulator panel.

Figure 1 *attached*



Drawing MR 767 Sheet 4

Figure 1. Alternator Control, A.C. Feeder and Earthing Panels.

PART 2B. AUXILIARY D.C. SUPPLY (220 V.)

Description of Plant

The two D.C. motor generator sets located in the Engine room are self-excited shunt-wound machines and have an output of 455 amperes at 220 volts. A Brown-Boveri automatic voltage regulator is fitted for controlling the generator output at this voltage. The generators also have an output of 230 amperes at 210/325 volts for battery charging, the voltage in the latter case being hand-controlled by varying the generator field rheostat. The generators are driven by 146 B.H.P. synchronous motors fitted with separate exciters. The starting of the synchronous motors is by auto-transformers in conjunction with automatic contactor-type starters.

The battery is used to carry the lighting and auxiliary D.C. loads during the non-transmitting periods and consists of a 1,200 ampere-hour lead accumulator battery of 122 cells. The D.C. bus bar voltage is only 220 so that when the battery is fully charged only 110 cells are required. The twelve additional cells are provided in place of booster plant for maintaining the bus bar voltage as the batteries become discharged, and provision is made for switching them into circuit as required. The normal battery charging current is 150 amperes and can be supplied by either D.C. motor generator set.

The switchgear associated with the generation and distribution of the 220 volt D.C. supply is carried on the Engine room switchboard.

Panels A, B and C carry the switchgear associated with the D.C. feeder circuits ;

Panel D carries the battery charging and voltage control switchgear ;

Panel E carries the switchgear for controlling the output circuits of the two auxiliary motor generator sets ;

Panels F and G carry the switchgear associated with the motor starting circuits of the two auxiliary motor generator sets.

The Brown-Boveri automatic voltage regulator is mounted on a framework fixed to the wall behind panel E of the Engine room switchboard.

Synchronous Motor Starting

Synchronous motors of the rotating salient-pole type have been used in preference to induction motors for all the heavier motor loads at this station. The reason for this choice is that an induction motor takes a heavy lagging current and so adversely affects the power factor of the installation, whereas with a synchronous motor the load current only lags behind the applied voltage at low values of excitation and the angle of lag becomes less and less as the excitation is increased until unity power factor is achieved, or even until the motor actually takes a leading current. An over-excited synchronous motor, therefore, has a beneficial effect upon the power factor of the installation as a whole.

A setting for the motor field rheostat, giving unity power factor with the generator on full load, was determined at the time of installation, and the plant is always operated with the motor field rheostat at this setting. The position of the controlling hand-wheel

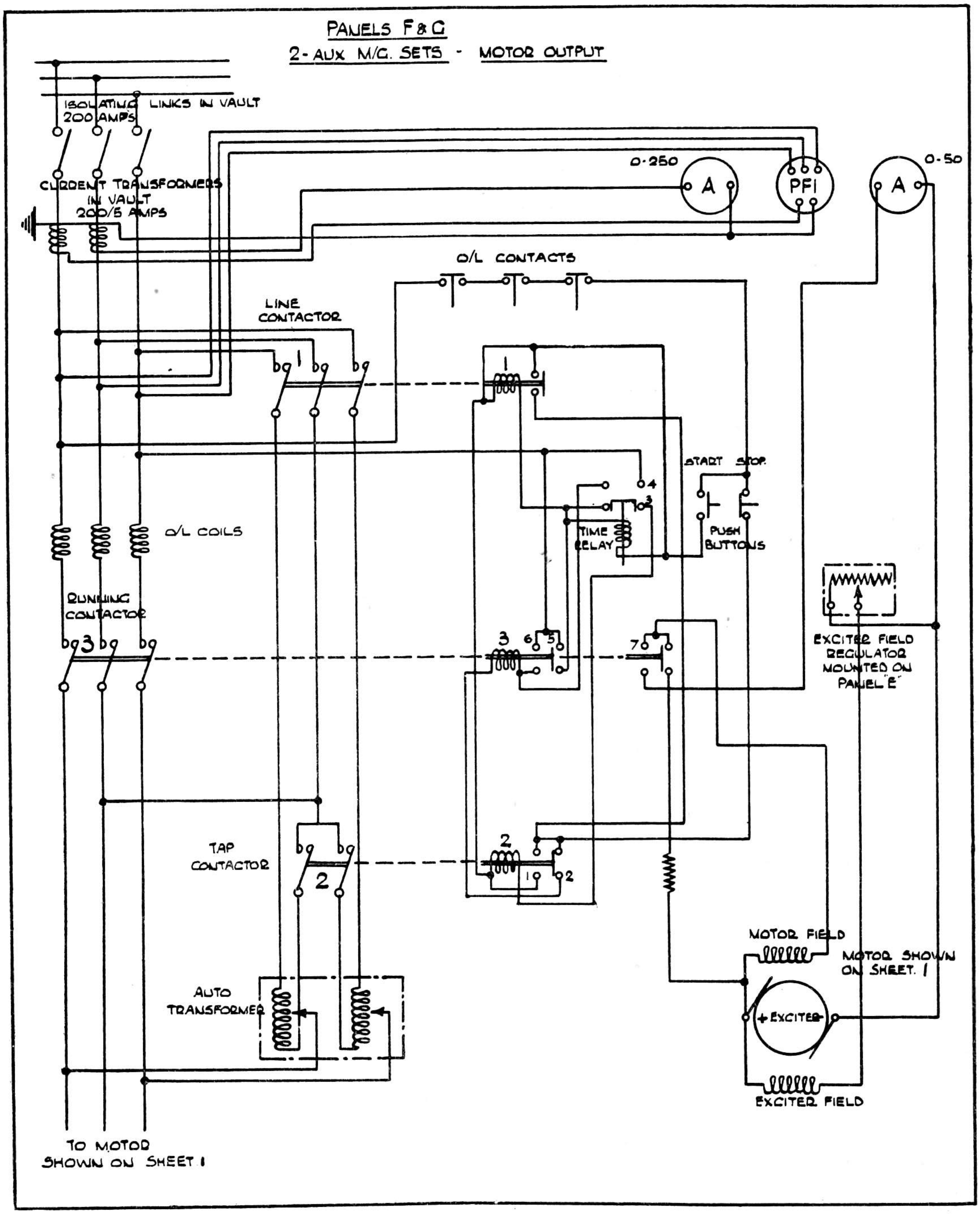


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Figure 6. Synchronous Motor Starting Circuit.

AUXILIARY D.C. SUPPLY

Synchronous Motor Starting (*Contd.*)

is marked so as to enable the setting to be checked and readily restored if at any time it should be changed.

The motors which have been installed are of the so-called ' self-starting ' type, although strictly speaking no synchronous motor is self-starting. The method of starting consists of employing the field winding on the rotor magnets as the rotor winding of a slip-ring induction motor during the starting period. The motor field is closed through a non-inductive resistance and no D.C. is allowed to flow in the windings until the machine has pulled into synchronism. The excitation current is then gradually increased to the value which will give the power factor required. An auto-transformer between the line and the stator enables a certain percentage of the normal voltage to be applied to the stator at the time of starting and thus reduces the current rush taken from the line. The transformer may be either double or triple phase but in either case the switching operations, whether manually or automatically performed, are similar.

Three switches or contactors are employed which operate in the following sequence :—

A. Line switch which energises the auto-transformer and connects the stator to the tappings.

B. Tapping or neutral switch—the closing of which causes the motor to start as an induction motor.

C. Running switch—which is closed when the motor reaches synchronous speed and converts it from an induction into a synchronous motor.

Mechanical or electrical interlocks are provided in order to prevent the running switch and the tapping switch from being closed simultaneously.

Motor Starting Circuit (*Figure 6—Panels F and G*)

There are two identical panels, one for each of the motor generator sets. In this case the auto-transformers are of the double-phase type and the starters are automatic. The motor exciter field regulator, shown in the drawing, actually appears on panel E.

The motor field is normally short-circuited through a resistance via auxiliary contact No. 7 on the running contactor. When the ' start ' button is closed the operating coils of the ' time ' relay, ' line ' contactor and ' tap ' contactor (the latter in series with the ' time ' relay contact) are energised in parallel from one phase of the main supply via the overload contacts and auxiliary contact No. 5 on the ' running ' contactor. The ' line ' and ' tap ' contactors operate immediately, locking themselves up over their own auxiliary contacts in series with the normally made ' stop ' button contact. The ' start ' button contacts open as soon as the pressure is withdrawn, but the coil of the slow operating ' time ' relay continues energised via the now made auxiliary contact of the ' line ' contactor in series with the ' stop ' button contact.

The ' line ' contactor connects the auto-transformer to the A.C. bus bars (via the triple-pole isolating links which must, of course, previously have been closed). The ' tap ' contactor completes the neutral point connection to the auto-transformer, the tappings on which are connected to the stator windings. The motor thereupon starts up as an induction motor.

AUXILIARY D.C. SUPPLY

Motor Starting Circuit (*Contd.*)

In operating, the 'tap' contactor interrupts the operating circuit of the 'running' contactor at auxiliary contact No. 2.

After an interval, during which the motor speed attains the required value for operation as a synchronous motor, the 'time' relay completes its operation. The breaking of contact No. 3 interrupts the holding circuit of the 'tap' contactor and causes it to trip. The 'tap' contactor on falling off makes auxiliary contact No. 2 so that when the 'time' relay makes contact No. 4 a circuit for the operation of the 'running' contactor is completed via the normally made 'stop' button contact.

The 'running' contactor connects the stator winding of the motor to the bus bars and, via the auxiliary change-over contact No. 7, completes the motor field and exciter circuits. In operating, it also breaks contact No. 5 thereby causing the 'line' contactor and the 'time' relay to trip, and closes contact No. 6, thereby locking itself up.

Operation of the 'stop' push-button momentarily interrupts the holding circuit of the 'running' contactor and so shuts the motor down. Overload coils are provided for each phase and in the event of an overload the 'running' contactor is tripped due to the interruption of the holding circuit of its operating coil.

Meters are equipped on each panel as follows:—

0/250 ammeter operating from a current transformer on one phase and indicating the current taken by the motor.

A power factor indicator operating from a current transformer on a second phase and used in conjunction with the motor exciter field regulator for adjusting the power factor of the motor load to the required value.

0/50 ammeter indicating the motor excitation current.

The normal full load current of the motors is 160 amperes per phase and the peak starting current from the auto-transformer tapping is 320 amperes corresponding to a current from the line of approximately 130 amperes per phase.

Generator Output and Battery Control Circuits (*Fig.* 7-*Panels D & E*)

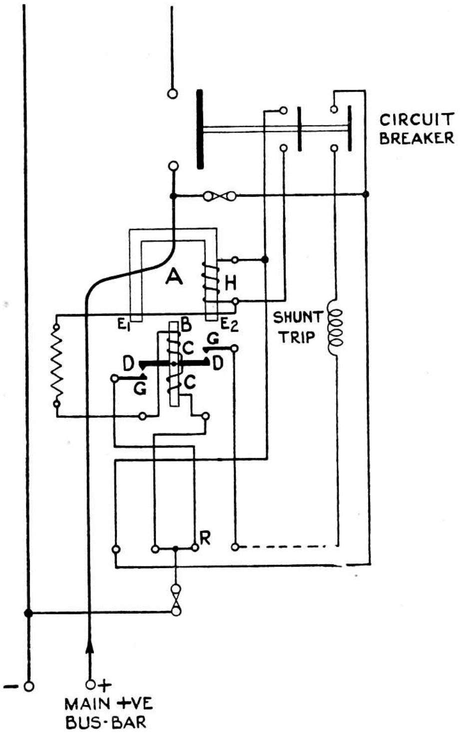
Panel E mounts the two motor exciter field regulators already described and one set of control equipment for each of the generators. The generator output control equipment consists of a single-pole isolating switch, double-pole change-over switch, single-pole air circuit breaker fitted with overload shunt trip and a polarised reverse current relay. A regulator, in series with the generator field, is provided for controlling the output of the generator and a 0/600 ammeter is provided for measuring the current. The double-pole double-throw switch enables the generator output to be connected either on to the main 220 volt D.C. bus bars or on to the auxiliary bus bars on the panel to which the battery is connected for charging purposes.

Figure 8 also shows the arrangement of the Brown-Boveri automatic voltage regulator which is described later.

AUXILIARY D.C. SUPPLY

Generator Output and Battery Control Circuits *(Contd.)*

The reverse current trip (see Figure 7) is a contact making device placed behind the breaker. The contacts are arranged in series with a shunt tripping coil which is de-energised by an auxiliary contact when the breaker opens. The device consists of an iron U-shaped magnet *A* embracing the main current stem. Below the magnet is pivotted a soft iron armature *B* which is polarized by two coils *C* mounted thereon and connected in series across the mains. It also carries a pair of tripping contacts *D*. With the current in the forward direction the armature is attracted toward the pole E_2 of the magnet and held against a stop. If the current reverses, the polarity of the magnet changes and the armature thereupon swings over towards the opposite pole E_1 until the contacts *D* complete the shunt trip circuit through the fixed contacts *G*. The breaker is, therefore, tripped. A small coil *H* is fitted on the magnet and connected in series with the armature coils *C*. When the breaker is closed the coil is short-circuited and rendered inoperative by means of an auxiliary switch incorporated in the breaker. After reverse operation the armature contacts would be held closed by reverse residual magnetism in the magnet *A*, but the coil *H*, becoming energised with the opening of the breaker overcomes the reverse residual magnetism and automatically resets the contacts to the normal forward current position.



Drawing SK 767 SH. Sheet 7.

Figure 7. Polarised Reverse Current Trip Relay.

Panel D carries the battery control circuit which consists of a double-pole double-throw change-over switch enabling the battery to be connected either to the station bus bars or to the charging bus bars, and a double-pole air circuit breaker fitted with over-load trips. A 15-way battery switch is provided for adjusting the output voltage. The switch is of the make-before-break type with a trailing flicker-blade and a resistance in series with the advance blade so as to avoid both interruption of the battery output connection and short-circuiting of the new cell during the switching operation. The resistance is momentarily included in the battery output circuit during the actual transit of the flicker-blade.

A 0/400 voltmeter is provided and in conjunction with a voltmeter switch can be used to read the voltage of either generator, the D.C. bus bar voltage or the voltage of the battery.

AUXILIARY D.C. SUPPLY

Generator Output and Battery Control Circuits *(Contd.)*

The other meters include a 400/0/500 discharge ammeter, a Watt-hour meter, and a recording volt-ammeter for the battery. THE WATT HOUR METER DOES NOT OPERATE DURING BATTERY CHARGING

The arrangement of the switching on these two panels provides for complete flexibility in the supply arrangements. Thus, either generator or the battery may be connected to the bus bars, while if desired the station load can be carried by one of the generators while at the same time the battery is connected across the output of the other generator for charging.

Automatic D.C. Voltage Regulator (*Figure* 8)

It is essential that the voltage of the D.C. bus bars should remain constant since the excitation for the filament motor generator sets and H.T. and grid bias machines is obtained from this source.

Owing to the variable demand on the D.C. bus bars, however, an appreciable variation in the D.C. voltage would normally occur by virtue of the inherent voltage regulation of the auxiliary D.C. generators. Further variation in voltage would occur due to fluctuations in the speed of the motor generator sets consequent upon changes in the frequency of the A.C. supply to the driving motor. Such departures of the A.C. supply frequency from its nominal value of 50 c/s are caused by small variations in engine speed which inevitably accompany the sudden application or removal of large portions of the total A.C. load on the engine-driven alternators due to switching operations in connection with the main H.T. conversion plant. As the result of these two causes the variation of the D.C. bus bar voltage and of the voltages of all machines obtaining their excitation from these bus bars, would be considerable during major switching operations, unless continuous adjustment of the excitation of the auxiliary D.C. generator was made in order to keep the D.C. bus bar voltage constant.

The Brown-Boveri automatic regulator maintains the D.C. bus bar voltage constant to within $\pm$ 1 per cent. of its nominal value of 220 volts. It performs the same function in respect to the D.C. bus bars that the Tirrill regulator performs in respect to the A.C. bus bars, but it operates in a different manner from the Tirrill regulator in as much as it is of the astatic or balanced type instead of the constantly vibrating type. It consists essentially of an electro-dynamic motive system that varies the value of a resistance connected in series with the generator field circuit. The motive system is such that it will remain balanced in any position within the limits of its travel, provided the voltage across it is of a predetermined value and is permanently connected to the D.C. bus bars. The bus bar voltage, that is to say, the voltage at which the regulator controls, is determined by means of a pre-set adjustable resistance in series with the operating coil of the motive system. If the load on the D.C. bus bars is increased the bus bar voltage will tend to fall, consequently the motive system becomes unbalanced and moves in such a manner as to remove resistance from the field circuit and continues to do so until a new value of excitation is obtained such that the D.C. bus bar voltage is returned to normal. On the other hand, if the load on the D.C. bus

AUXILIARY D.C. SUPPLY

Automatic D.C. Voltage Regulator (*Contd*)

bars is reduced the voltage will tend to rise and the regulator motive system will move in such a direction as to increase the value of the field resistance, thereby reducing the excitation to the new value required to obtain normal bus bar voltage for the reduced value of the load. In order that quick response may be obtained slight over-compensation of the generator excitation occurs. At the same time, in order that this over-regulation and the return movement that follows it shall not cause a continual oscillation of the contacts and consequently of the generator voltage, a momentary elastic control, which takes the form of a flexible spring coupling between the motive system and its damping, interrupts the regulation process and brings back the regulator before the voltage reaches its new normal value. It is the active over-regulation and the elastic control which are the characteristic features of this regulator.

The automatic regulator is intended to control the voltage of either of the two auxiliary D.C. motor generator sets and the machine it is to control can be selected by means of two change-over switches marked **Generator No. 1** and **Generator No. 2**, respectively, which are mounted on the front panel of the regulator. These switches are connected in the excitation circuit of the generator to be regulated and are of the make-before-break type in order to allow of change-over from automatic regulation to hand regulation, or *vice versa,* without interrupting the field circuit, while in order to prevent the regulator being connected by mistake to both machines at the same time, the switches are used with one common handle removable only when the switch is in the position for manual control. When the switch is in the **Automatic Control** position the variable resistance in the automatic regulator is connected in series with the hand-controlled generator field rheostat and when the switch is in the **Hand Control** position the extension leads are short-circuited leaving only the hand-controlled generator field rheostat in circuit.

D.C. Feeder Circuits (*Figure* 8—*Panels A, B and C*)

These three panels at the extreme left-hand end of the Engine room switchboard control the D.C. supplies to the whole station. Each panel controls two feeder circuits, the connection to the D.C. bus bars being made via single-pole link switches and single-pole circuit breakers fitted with overload release trips. Associated with each circuit there is a 0/200 ammeter and a Watt-hour meter. No interlocking devices are incorporated.

Panel A controls the feeder supplying the power station auxiliaries and a spare feeder circuit.

Panel B controls the feeder supplying the field and interlock circuits of the long-wave transmitter and the D.C. motor of the auxiliary A.C. generator in the Machine room, and the feeder supplying the field and interlock circuits of the medium-wave transmitter.

Panel C controls the feeder supplying power for lighting the building, and that supplying power for operating the mast lighting and lift, and for heating the aerial transformer houses.

AUXILIARY D.C. SUPPLY

D.C. Feeder Circuits (*Contd*)

The negative D.C. bus bar is connected to earth via a 0/20 ammeter and a 20 ohm resistance, the ammeter reading the earth leakage current of the battery when discharging to line.

Operating Routine

The normal condition when starting up the station in the morning will be with the battery connected to the main D.C. bus bars and both auxiliary D.C. machines shut down.

The engine-driven alternator sets should then be started up, the alternator outputs connected to the A.C. bus bars, and the voltage of these bus bars regulated in the manner described in **Part 2A.**

To Connect the Output of one of the Auxiliary D.C. Generators to the Station D.C. Bus Bars

Start up the machine chosen to carry the station D.C. load for the day by operating the motor '**start**' button, having first determined that its generator field change-over switch on the regulator panel is in the **hand-control** position. Check that the motor exciter field regulator has the normal setting indicated by the marked position.

Measure the battery voltage by suitable operation of the voltmeter switch and then connect the voltmeter for reading the particular generator output voltage. Adjust the generator field rheostat by hand to obtain an output voltage slightly in excess of that of the battery. Operate the associated change-over switch to connect the generator output to the D.C. bus bars and close the generator output circuit breaker.

The battery and the generator output are thus paralleled. The load should then be gradually transferred from the battery to the machine by further movement of the generator field rheostat in the direction to increase voltage. When all the load has been transferred the battery should be taken off the bus bars by tripping its circuit breaker and the generator field rheostat should be adjusted by hand to bring the station bus bar voltage to exactly 220 volts.

To Place the Generator carrying the Station D.C. Load on Automatic Control

In order that the voltage of the D.C. bus bars can be maintained constant at 220 volts during the running of the station the selected generator must be placed on automatic voltage control which, as previously described, is effected by means of the Brown Boveri regulator.

First ensure that the bus bar voltage is 220 and then check that the pointer on the motive system of the regulator is in the **Zero** position. This is important since before changing the generator from hand control to automatic control all the regulating resistance of the automatic regulator must be cut out of circuit. If the pointer is not at zero it should be brought to zero by reducing the bus bar voltage by a small amount, say by 2 or 3 volts, by careful adjustment of the generator field rheostat. The associated change-over switch on the regulator should then

AUXILIARY D.C. SUPPLY

Operating Routine *(Contd)*

be moved to the **automatic control** position, when if the pointer is at zero the value of the resistance included in the generator field circuit will not be altered and consequently no movement of the regulator motive system should occur. Next, gradually cut out the resistance of the generator field rheostat by turning the control in the direction to increase the voltage until the **full-raise** position is reached. During this operation the regulator will have been automatically inserting its own regulating resistance into the generator field circuit to replace the resistance being cut out by the field rheostat. When the **full-raise** position is reached the automatic regulator will have assumed complete control.

To Place the Battery on Charge

Operate the battery change-over switch so as to connect the battery to the charging bus bars and close the battery circuit breaker.

Start up the other motor-generator set by operating its motor '**start**' button and check that its motor exciter field regulator is at the normal setting indicated by the marked position.

By means of the voltmeter switch connect the voltmeter across the battery and measure the battery voltage. Then transfer the voltmeter to the generator output and adjust its field rheostat to bring the generator output voltage to a value slightly in excess of that of the battery.

Operate the generator output change-over switch to connect the generator output to the charging bus bars and close the circuit breaker. Finally adjust the generator field rheostat to give the correct value of charging current.

Thereafter regulate the generator output voltage by means of the field rheostat as required in order to maintain the correct charging rate.

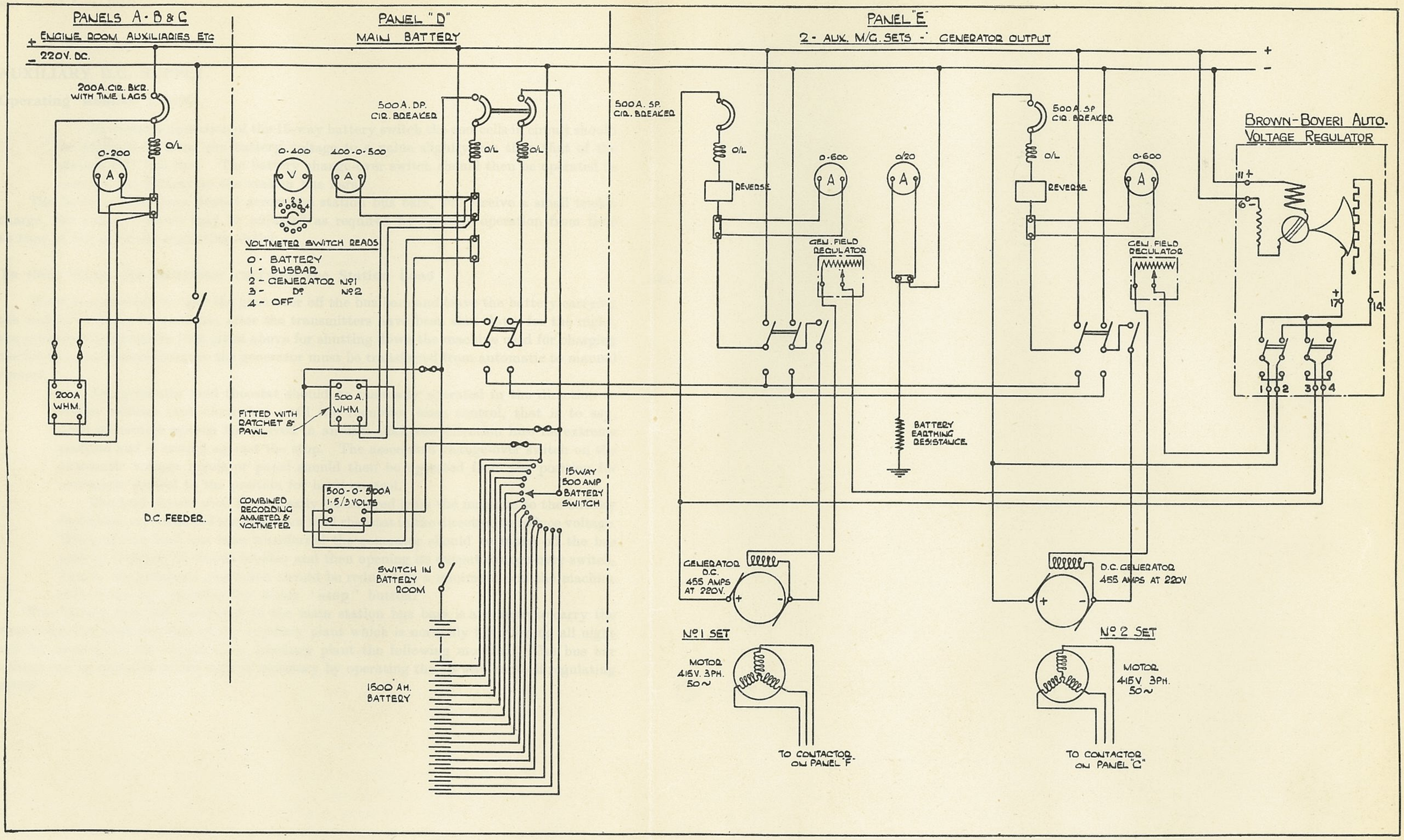
The battery charging should be carried out under the conditions specified by the makers and continued in the case of a normal charge, until the battery assumes the constant specified steady voltage. Provision should be made for periodical extended discharge and charging periods under the conditions specified by the makers. Whether or not the whole of the battery shall be placed on charge or only that part of it which has been on discharge, will depend upon the condition of the end-cells. In any case it is desirable from time to time that these should be included for a 'refresher' charge.

To Float the Batteries across the Station D.C. Bus Bars

When the battery has been fully charged it may again be connected to the main D.C. bus bar and remain permanently floating.

The excitation of the charging generator should be reduced until the charging current approximates to zero and the generator should then be tripped off the charging bus bars. Its excitation should then be further reduced by turning its field regulator clockwise into its extreme position and finally shut down by operating the motor stop button.

Figure 8 attached.
Text continued on page 26.



Drawing MR 767 Sheet 1.

Figure 8. Generator Output, Battery Charging and D.C. Feeder Circuits.

AUXILIARY D.C. SUPPLY

Operating Routine (*Contd*)

By suitable operation of the 15-way battery switch the end-cells in circuit should be adjusted to bring the battery voltage to a value slightly less than that of the station D.C. bus bars. The battery change-over switch should then be operated to connect the battery to the station bus bars.

The battery, when thus floated across the station bus bars, will receive a small trickle charge, the value of which may be adjusted as required by suitable operation from time to time of the end-cells regulating switch.

To Shut Down the Generator carrying the Station Load

When it is required to take the generator off the bus bars and leave the battery carrying the station load, as, for example, after the transmitters have been shut down for the night, the procedure is similar to that given above for shutting down the machine used for charging the battery, but before doing so the generator must be transferred from automatic to manual control.

The generator field rheostat should be manually operated in the direction to reduce voltage (anti-clockwise) until the regulator loses control, that is to say, until its motive system has moved in an anti-clockwise direction into its extreme position and is resting against the stop. The associated change-over switch on the automatic voltage regulator panel should then be operated from the position for automatic control to the position for hand control.

The load should then be gradually transferred from the machine to the battery by further movement of the generator field rheostat in the direction to reduce voltage. When all the load has been transferred the generator should be taken off the bus bars by tripping its circuit breaker and then opening its output change-over switch. Finally the generator excitation should be reduced to a minimum and the machine shut down by operating its motor '**stop**' button.

The battery thus left connected to the main station bus bars is available to carry the station lighting load and that of the auxiliary plant which is normally left running all night and for starting up the engine room auxiliary plant the following morning. The bus bar voltage can be adjusted to 220 volts if necessary by operating the 15-way end-cell regulating switch.

DROITWICH TRANSMITTING STATION

PART 6. CONTROL ROOM EQUIPMENT

CONTENTS

LIST OF ILLUSTRATIONS

DROITWICH TRANSMITTING STATION

PART 6. CONTROL ROOM EQUIPMENT

General Description

There are two Control rooms, No. 1 normally associated with the long-wave National transmitter, and No. 2 with the Midland Regional transmitter. The Control rooms are screened against H.F. with copper gauze built into the floors, ceilings and walls, bonded and earthed.

There are four unloaded and unrepeatered cable circuits communicating with M.R.O., suitable for programme transmission and two-way telephony. The lines are equipped with calling circuits for control purposes and with equalisers for programme purposes. A reserve calling equipment is also installed for use with an additional control line should this be found necessary.

The amplifiers associated with each Control room are mounted upon racks in that control room ; the line termination equipment, together with the line testing apparatus, is mounted in Control room No. 1 and the rebroadcasting receiver in Control room No. 2. The control desk provided in each Control room has two control positions, each equipped with control potentiometer and programme meter and a common equipment of programme switching and telephone keys with their associated lamps.

The emergency studio is provided with a gramophone equipment and carbon microphone.

For checking purposes either headphones or loudspeakers may be used in the Control rooms, and checkphone extensions to the transmitter control positions are also provided. The loudspeaker in the Quality Checking room can be used to reproduce either programme and may be connected either in the output of the 'B' amplifier or in that of the check receiver.

The supplies for the operation of the Control rooms are obtained from the 415 volt, 3 phase, 50 cycle station supply. The filament heating is obtained from a D.C. generator and the H.T. supply from a rectifier, via smoothing units individual to each amplifier. The relay operating current is provided by a 24 volt battery which also supplies power for lighting the indication lamps in the Control rooms and on the transmitter control table. This battery further provides supplies for the control room buzzer, the ringing dynamotor and for the microphone and control telephones. An additional load is provided by the 'Electroflo' meter circuits, of which there are eight in use on the National transmitter and one on the Regional transmitter. To cater for the continuous drain which has thus to be met, a battery having a capacity of 150 ampere-hours is used. The charging current is provided by a motor generator set.

The whole of the power supply equipment is provided in duplicate.

The two sets of duplicate machinery, namely, L.T. motor generator sets, battery charging motor generator sets and ringing dynamotor, together with the rack mounting the associated switchgear and the high tension rectifier, are contained in a motor generator room, which also accommodates racks carrying the L.T. and H.T. smoothing apparatus. The duplicate 24 volt batteries are housed in a separate Battery room.

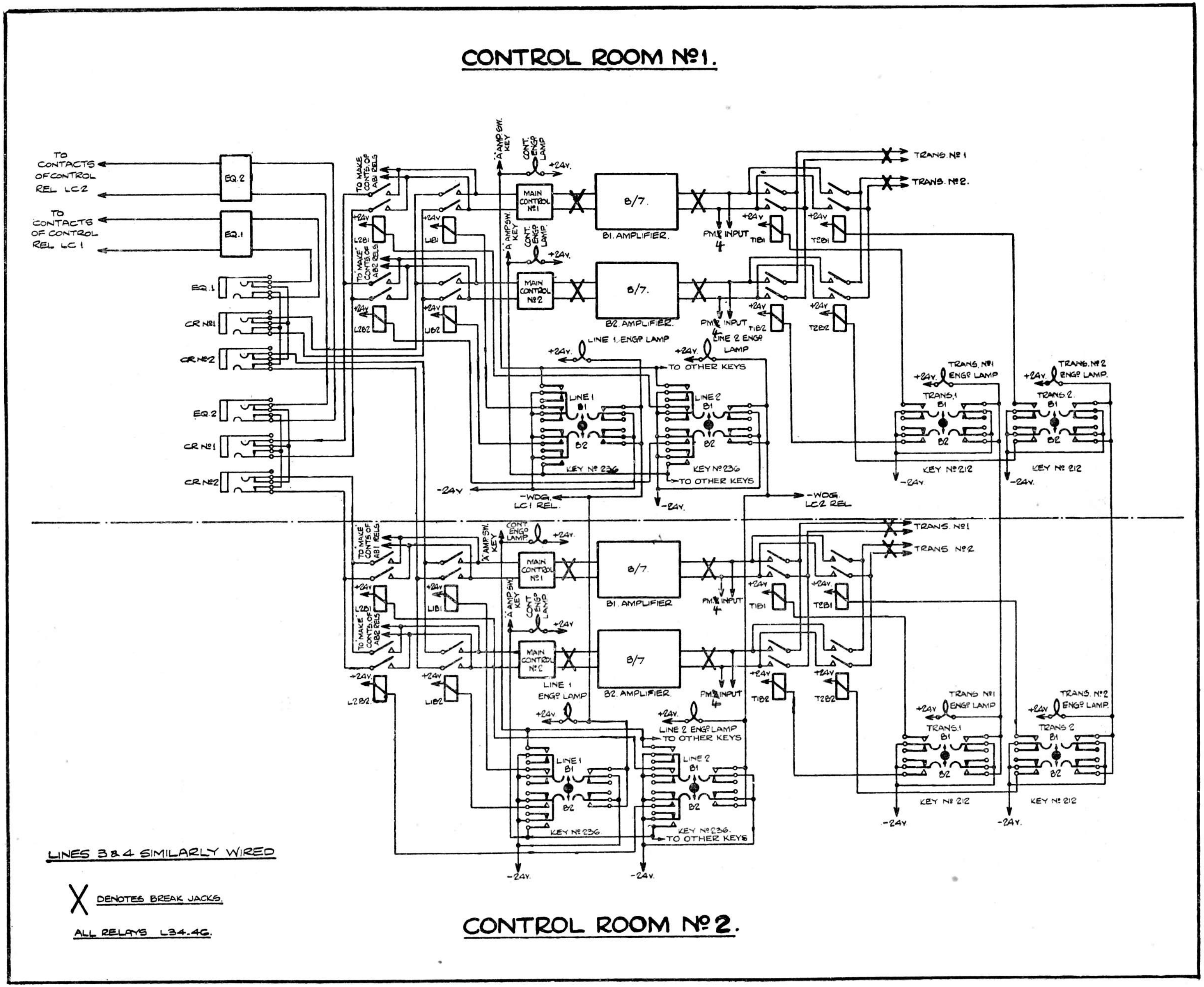


Figure 1. Relay Switching Circuits.

Drawing B 2596. Issue 1.

CONTROL ROOM EQUIPMENT

General Description (*Contd.*)

An auxiliary A.C. supply at 240 volts is obtained via a transformer from one phase of the main supply and is used for supplying the loudspeaker polarising of the LSM/1 units, for operating the gramophone motor, and for the remote control of the automatic switchgear controlling the L.T. and H.T. supplies.

Control Room Racks

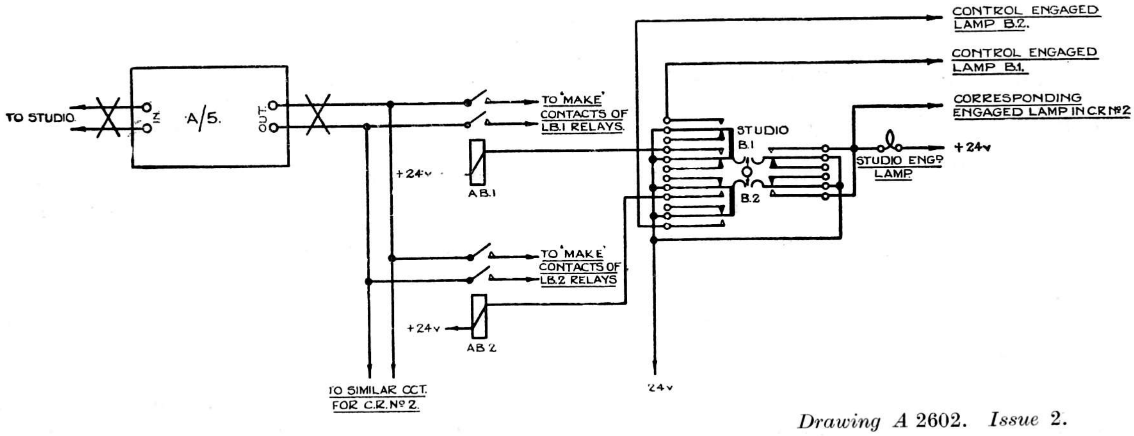
The rack in Control room No. 1 consists of four bays, Nos. 1-4, and that in Control room No. 2 of three bays, Nos. 5-7. Except that bay 5 carries the 'A' amplifier associated with the studio, the equipment of bays 5 and 6 is identical with that of bays 1 and 2.

Checking Bays (Nos. 1 and 5).
- Detector Unit, HRT/3.
- Checkphone and Loudspeaker Unit, CPL/2.
- Comprehensive Checking Amplifier, CCT/1.
- Meter Panel, M2/1A, for reading amplifier H.T. feeds and the rectified current of the detector unit.
- Meter Panel, M1/6A, for reading filament voltages.
- Key and Lamp Panel, KL/2, carrying the pilot lamps associated with the H.T., L.T. and 24 volt supplies, and the push keys for switching on the various amplifiers, with the associated amplifier engaged lamps.
- Checking Circuit Relays.
- Bay 5 also carries an 'A' amplifier, A/5.

Transmission Amplifier Bays (Nos. 2 and 6).
- Two Amplifiers, B/7.
- Two Programme Meter Amplifiers, PM/4.
- Meter Panel, M1/1A, or M2/1A, for reading amplifier H.T. feeds.
- Amplifier Jackfield, JF/3.
- Programme Switching Relays.

Line Termination and Testing Bay (No. 3).
- Thermocouple Panel, TC/1.
- Amplifier Detector, AD/3.
- Meter Panel, M1/1A, for reading AD/3 H.T. feed.
- Equaliser Panel, ET/2, carrying the fixed equalisers associated with the four programme lines.
- Jackfield, JF/4, carrying jacks associated with the A.C. testing apparatus and the lines.
- Two repeating coil mountings, RM/1.
- Line Fuse Mounting, FM/1.
- Relays associated with the control line calling equipment.

Tone Source Bay (No 4).
- Tone Source Oscillator and Amplifier, TS/5.
- Meter Panel, M3/2.



Drawing A 2602. Issue 2.

Figure 2. Relay Switching Circuits ('A' Amplifier).

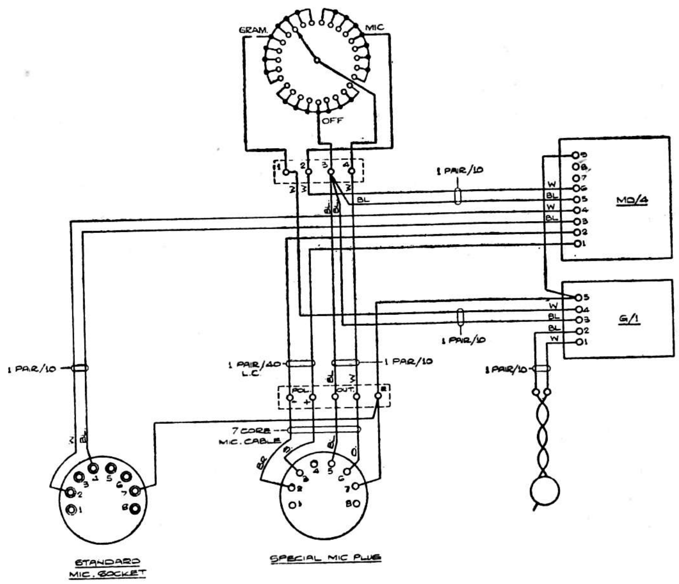


Figure 3. Wiring of Gramophone Recital Desk.

Drawing A 2568. Issue 2.

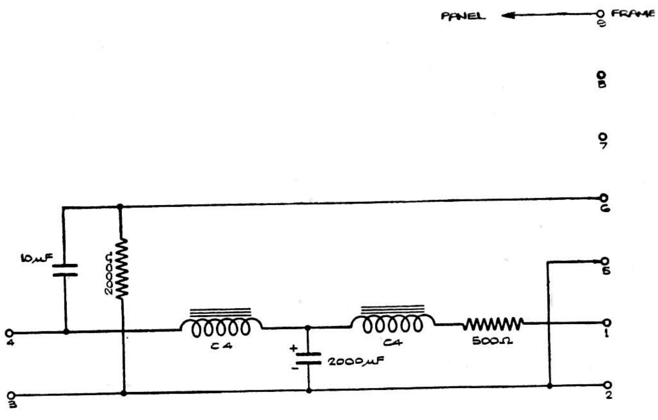


Figure 4. Microphone Decoupling Unit, MD/4.

Drawing A 2733. Issue 1.

CONTROL ROOM EQUIPMENT

Control Room Racks (*Contd.*)

Valve Testing Panel, VT/2.
Dynamotor Switch Panel, SG/5.
Panel carrying the switches associated with the duplicate main H.T.and L.T. supplies.

Rebroadcasting Receiver Bay (No. 7).

Rebroadcasting Receiver, RBR/1.
Meter Panel M2/2A.

For detailed descriptions of the various apparatus units and for the operation of the A.C. testing apparatus, reference should be made to the separate instructions dealing with them. (**Sections 3 & 9.**)

Programme Switching

The switching facilities in each Control room enable any of the lines or the ' A ' amplifier output to be connected to the input of either of the ' B ' amplifiers and also enable the output of the ' B ' amplifier in use to be connected either to transmitter No. 1 or to transmitter No. 2. The programme wiring is shown in Figure 6 and the switching arrangements in Figure **1.**

The control desk is equipped with four **Line** keys and one **Studio** key, controlling the ' B ' amplifier input switching, and two **Transmitter** keys controlling the ' B ' amplifier output switching. These keys are of the 3-position locking type and each has a normal **Off** position and two operated positions designated $\mathbf{B_1}$ and $\mathbf{B_2}$ respectively. Lamp indications are provided to show the connection which has been set up. Thus, when any particular connection has been set up the **Control** engaged lamp over the control potentiometer associated with the ' B ' amplifier in use is lighted, while the **Line** and **Trans** engaged lamps over the keys associated with the particular line and transmitter in use are lighted in both Control rooms.

Operation of a **Line** key in one of the Control rooms, (see Figure 1) e.g. operation in Control room No. 1 of the key designated **Line** 1 to the position designated $\mathbf{B_1}$,

(a) completes a circuit for the operation of relay **LC 1** (associated with Line 1, see Figure 14), which upon operation disconnects the calling circuit and connects the output of the line repeating coil to the input of the equaliser associated with Line 1.

(b) completes a circuit for the operation of relay $\mathbf{L_1B_1}$ in Control room No. 1, which upon operation extends Line 1 via the contacts of the relay and the main control potentiometer to the input of the B_1 amplifier.

(c) completes a circuit for the control engaged lamp over the B_1 control potentiometer in Control room No. 1.

(d) completes a circuit for the Line 1 engaged lamp in both Control rooms.

Operation of a transmitter key in one of the Control rooms (see Figure 1) e.g. operation in Control room No. 1 of the key designated **Trans. 1** to the position designated $\mathbf{B_1}$,

(a) completes a circuit for the operation of relay $\mathbf{T_1B_1}$. which upon operation establishes the connection between the output of amplifier B_1 and the input of No. 1 transmitter.

(b) completes a circuit for the **Trans. 1** engaged lamp in both Control rooms.

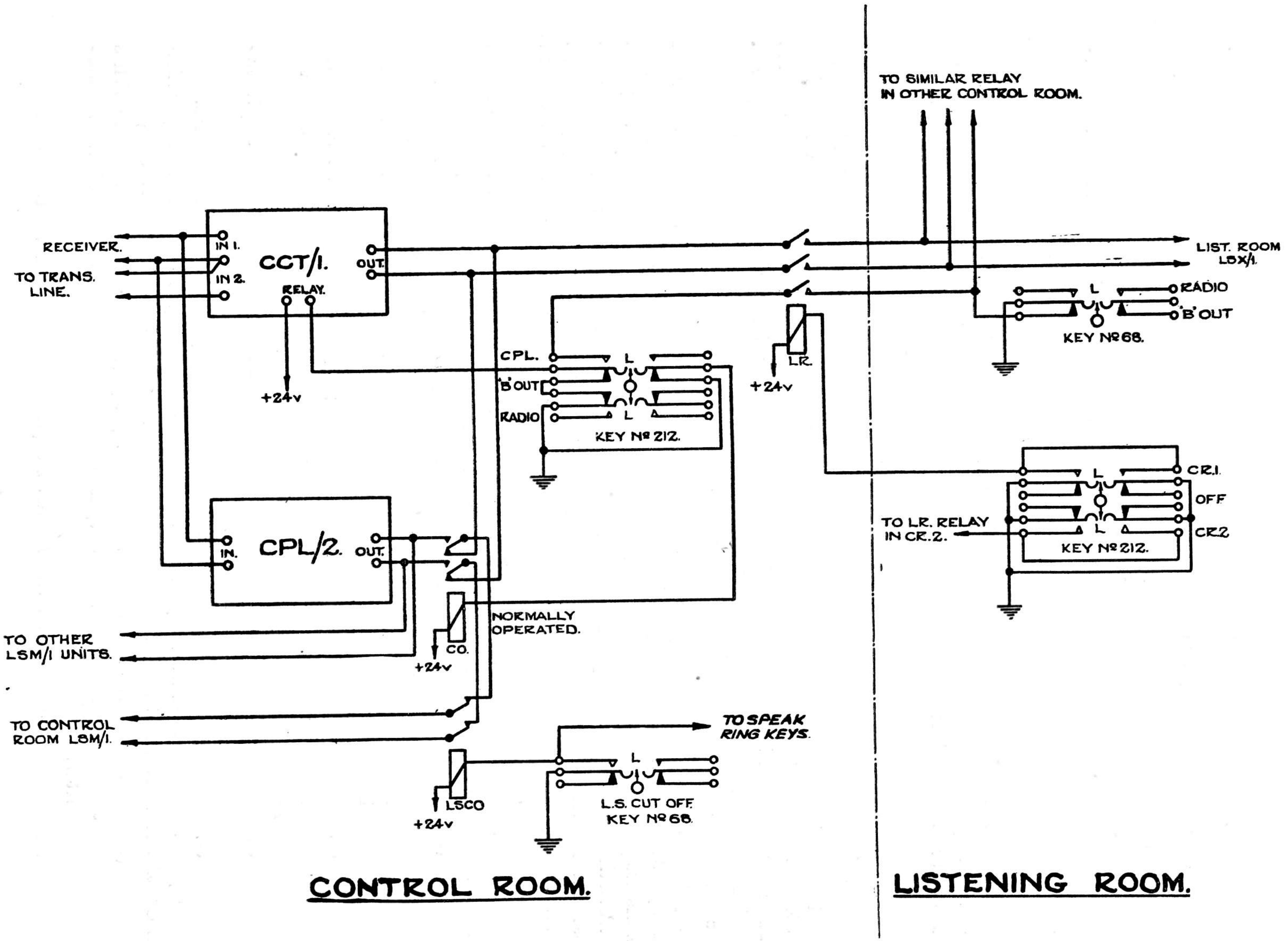


Figure 5. Comprehensive Checking Circuit.

Drawing A 2539. Issue 3.

CONTROL ROOM EQUIPMENT

Programme Switching (*Contd.*)

Operation of the **Studio** key in one of the Control rooms (see Figure 2) e.g. operation of the **Studio** key in Control room No. 1 to the position B_1,

(a) completes a circuit for the operation of relay AB_1 which establishes connection between the output of the ' A ' amplifier and the input of amplifier B_1 in Control room No. 1 via the associated main control potentiometer.

(b) completes circuits for the engaged lamp over the **Studio** key in both Control rooms, and of the control engaged lamp over the control potentiometer associated with amplifier B_1 in Control room No. 1.

Studio Signalling

Red lights are provided inside the studio and over the door of the studio on the outside. These are lighted from the station 220 V. D.C. supply and can be switched on from either control desk. A buzzer is provided in each Control room, operated from the 24 volt supply and controlled by a push switch in the studio.

Microphone and Gramophone Circuits

The studio contains a carbon microphone and a gramophone equipment. The gramophone cabinet contains a turntable driven by a single-phase A.C. motor from the auxiliary 240 volt A.C. supply, a gramophone unit, G/1, and a microphone decoupling unit, MD/4.

The microphone obtains its polarising current from the 24 volt battery, via one of the contacts of the ' A ' amplifier L.T. relay (see Figure 13b), terminals 2 and 3 of the special microphone plug (see Figure 3), the microphone decoupling unit, MD/4, and the microphone plug socket. The connection to the microphone is made by means of a standard two-conductor shielded cable, via a standard 8-pin microphone plug. The microphone output from terminals 5 and 6 of the MD/4 unit is connected via the microphone-gramophone switch to terminals 5 and 6 of the special microphone plug, and thence via the socket to the input of the ' A ' amplifier.

The gramophone output is connected via the gramophone unit, G/1, which incorporates the bass correction circuit and scratch filter and via the microphone-gramophone switch to terminals 5 and 6 of the special microphone plug, and thence to the input of the ' A ' amplifier.

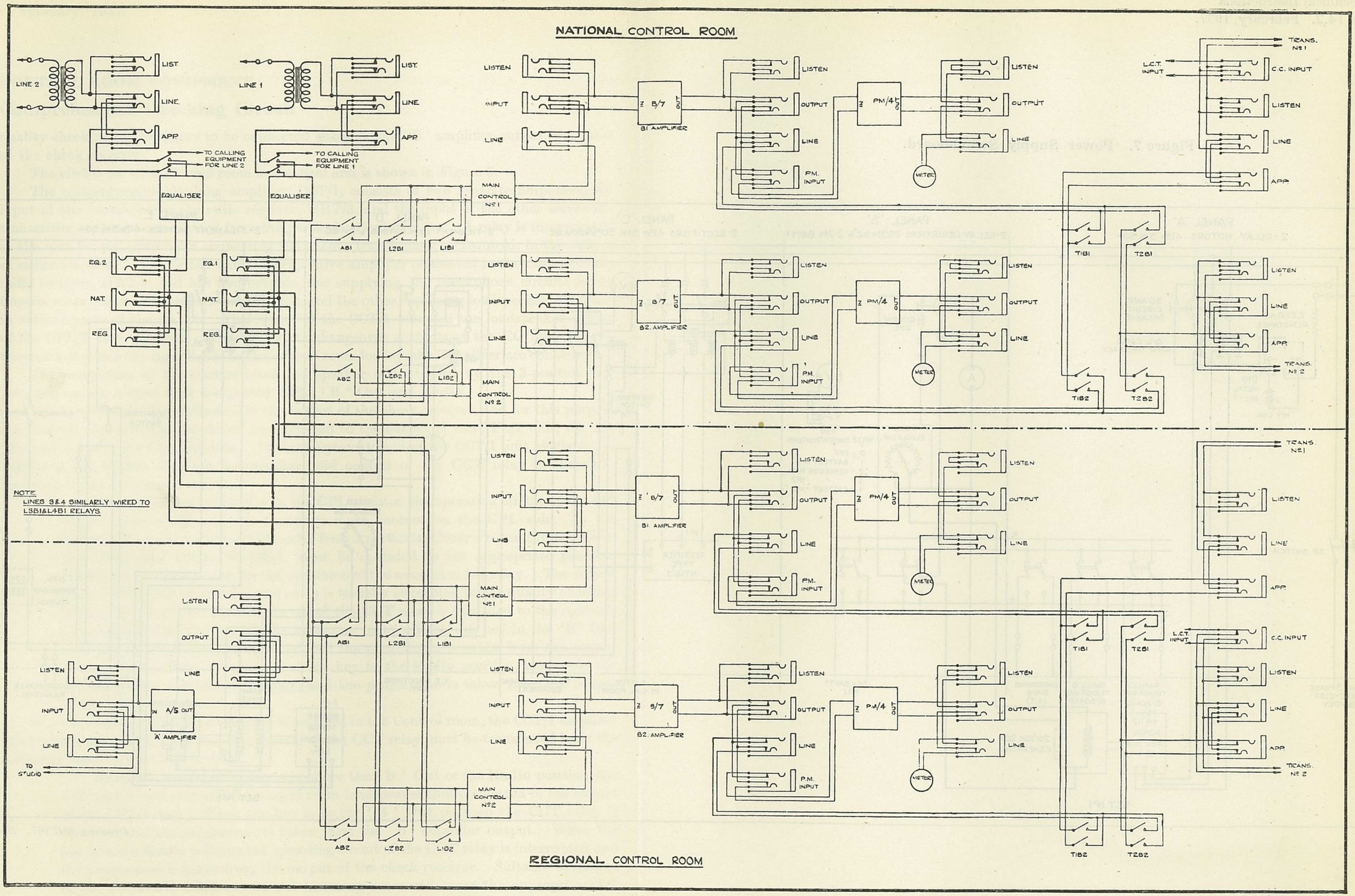
The switch is wired to provide a simple change-over from gramophone to microphone and vice versa, and an **Off** position.

The microphone decoupling unit, MD/4 (see Figure 4) incorporates a 500 ohm resistance to step-down the potential of the supply. The microphone is fed via the decoupling filter comprising a series choke and parallel condenser, and the microphone A.C. output is choke-capacity coupled to terminals 5 and 6. The 2,000 ohm resistance connected across the output is to prevent ' clicks ' when the output circuit is interrupted by maintaining a constant potential across the $10\mu F$ condenser.

The function of the comprehensive checking circuit is to enable the control room and

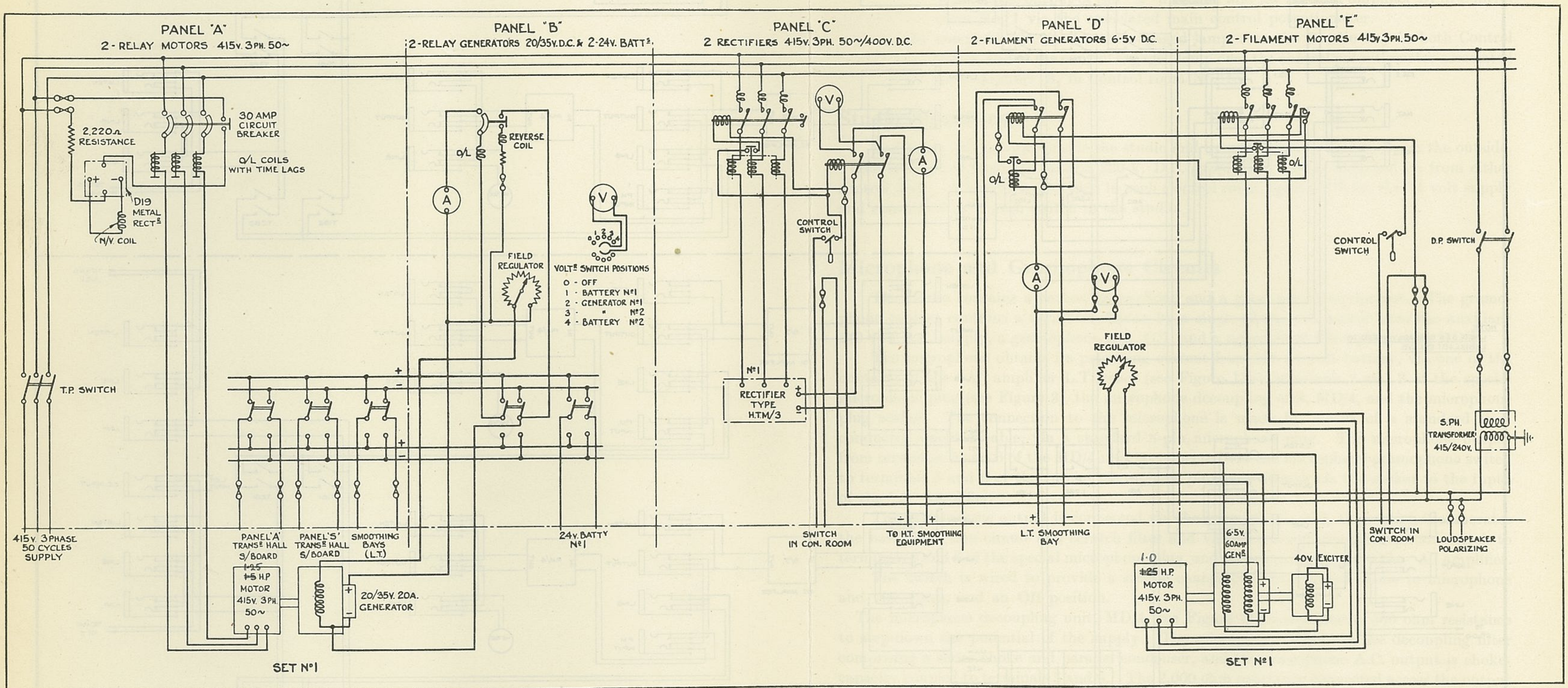
(*Figures 6 and 7 attached*)
(*Text continued on page 8*)

Fig. 6. Programme Wiring



Drawing C 3023. Issue 2.

Figure 7. Power Supply Switchboard.



Drawing MR 767. Sheet 100.

CONTROL ROOM EQUIPMENT

Comprehensive Checking Circuit

quality checking loudspeakers to be connected either in the ' B ' amplifier output or in that of the check receiver.

The circuit for each Control room is identical and is shown in Figure 5.

The comprehensive checking amplifier, CCT/1, consists of two separate amplifiers, the input of one connected to the radio receiver, HRT/3, and the input of the other across the transmitter tie lines normally fed from the particular Control room. A relay is incorporated in the unit for the purpose of connecting the output transformer, as required, in the output of either amplifier. The CPL/2 unit is a trap valve amplifier connected in the output of the radio receiver, HRT/3, and has two outputs, one supplying the checkphone circuits in the Control room, on the transmitter control desk, and the other supplying loudspeaker amplifiers in various parts of the station. The output of the CCT/1 unit and the loudspeaker output of the CPL/2 unit, are both connected to the changeover contacts of the **CO** relay, to the travellers of which the input leads to the control room loudspeaker amplifier are connected.

The connection of the control room loudspeaker is controlled by the 3-position key provided on the control desk designated **CPL, ' B ' Out** and **Radio.**

Checking is normally performed in the output of the check receiver, and for this purpose the control room loudspeaker should be connected to the output of the CPL/2 unit, the key being operated to the **CPL** position. This arrangement renders the CCT/1 unit available for supplying the quality checking loudspeaker, and control of the **CCT** relay is, therefore, extended to the Listening room.

With the control room key in the **CPL** position the operating circuit of the **CO** relay is interrupted and the travellers make contact on the **CPL** side. In the Listening room, to take the programme from a particular Control room, the 3-position key, designated **CR/1-Off-CR/2,** must be operated to the appropriate position, thereby providing a circuit for the operation of the associated **LR** relay. The output of the CCT/1 unit in that Control room is thereby connected to the quality checking loudspeaker, and the operating circuit of the **CCT** relay is extended to the contacts of the **Radio-'B' Out** key in the Listening room. With this key in the **'B' Out** position, the **CCT** relay is operated and the programme is taken from the output of the ' B ' amplifier. Operation of the key to the **Radio** position, interrupts the operating circuit of the **CCT** relay, and the programme is taken from the output of the check receiver.

If, however, comprehensive checking is required in the Control room, the CCT/1 amplifier will be necessary for this purpose and control of the **CCT** relay must be transferred from the Listening room to the Control room.

When the control room key is in either the **' B ' Out** or the **Radio** position, the **CO** relay is operated and the control room loudspeaker thus connected in the output of the CCT/1 unit. When the key is in the **' B ' Out** position the **CCT** relay is operated and the programme is taken from the ' B ' amplifier output. When the key is in the **Radio** position the operating circuit of the **CCT** relay is interrupted and the programme is taken from the output of the check receiver. Suitable operation of the **CR/1-Off-CR/2** key in the Listening room will cause the appropriate **LR**

CONTROL ROOM EQUIPMENT

Comprehensive Checking Circuit (*Contd.*)

relay to operate and connect the quality checking loudspeaker in the output of the CCT/1 unit. The **Radio-' B ' Out** key will, however, now be inoperative, the circuit being interrupted at the contacts of the key in the Control room.

When the Control room has finished with comprehensive checking, the control room key should be restored to the **CPL** position.

The keys in the Quality Checking room are mounted on the key switch unit, **KS/3**, the connections to which are made via a standard 7-conductor cable and 8-pin plug and socket.

A loudspeaker cut-off key is provided in each Control room and controls the operation of the **LSCO** relay, the contacts of which are included in the loudspeaker extension circuit. The winding of the **LSCO** relay is also connected to the **Speak-Ring** keys associated with the telephone calling circuits. The relay operates, cutting out the control room loudspeaker whenever the **LS Cut-Off** key is operated, or when any of the **Speak-Ring** keys in the particular Control room is thrown to the **Speak** position.

Power Supply Equipment

Machines. The 24 volt motor generator set consists of a squirrel-cage motor of 1.25 B.H.P. operating off 415 volts, 3 phase, 50 c/s supply and driving a shunt wound D.C. generator rated to give an output of 20 amps. at 20/35 volts D.C.

The filament motor generator set consists of a squirrel-cage motor of 1.05 B.H.P., operating from the 415 volts, 3 phase, 50 c/s supply and driving a level compound wound D.C. generator, rated to give an output of 60 amps. at 6.5 volts D.C., and a D.C. exciter generating an output at 40 volts D.C.

Switchboard. The switchgear associated with the various supplies is mounted upon a rack in the motor generator room. The rack is divided into five bays as follows :—

Bay ' A ' carries the mains isolating switch and the switchgear associated with the motors of the two 24 volt motor generator sets, together with the feeder switches, associated with the 24 volt supply.

Bay ' B ' carries the switchgear associated with the two 24 volt generators.

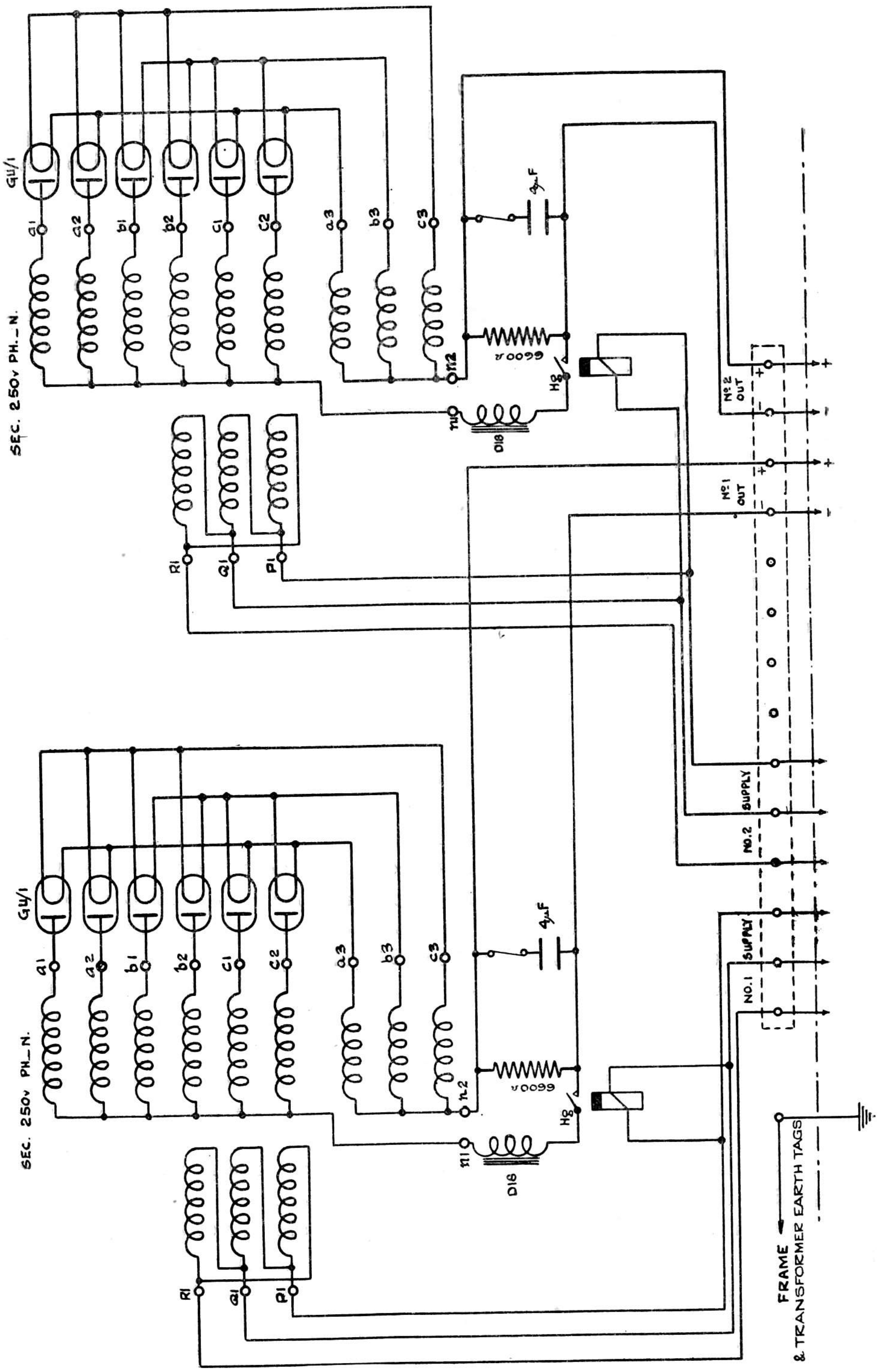
Bay ' C ' carries the H.T. rectifier, HTM/3, and the switchgear associated with the two circuits.

Bay ' D ' carries the switchgear associated with the two filament generators.

Bay ' E ' carries the switchgear associated with the motors of the two filament motor generator sets.

A simplified schematic of the control switchgear is given in Figure 7, from which, for the sake of simplicity, all the duplicate wiring has been omitted.

24 Volt Motor Generator Circuits. The station mains are connected to the 415 volts, 3 phase, 50 c/s bus bars via the main isolating switch on bay ' A.' The supply to the motor driving the 24 volt generator is applied by closing the circuit breaker which is fitted with no-volt and overload trips, the latter being equipped with air-vane delay action. The no-volt release is D.C. operated, the coil being supplied from a metal rectifier connected on its input side across one phase of the supply, through an auxiliary contact on the circuit breaker.



Drawing A 2905. *Issue* 1.

Figure 8. H.T. Rectifier Unit HTM/3.

CONTROL ROOM EQUIPMENT

Power Supply Equipment (*Contd*)

The generator output is connected via the single-pole circuit breaker on bay 'B,' and the double-pole double-throw knife switch to either of the duplicate 24 volt bus bars. The circuit breaker is fitted with overload and reverse coils and current limiting resistances in series with the latter. This bay also carries the generator field regulators and output ammeters, and a voltmeter provided with a rotary switch that enables the voltage to be measured across the output of either generator, or across either battery. Associated with each battery there is a double-pole double-throw knife switch which enables it to be connected across either of the 24 volt bus bars. The duplication of the bus bars and the arrangement of the change-over switching provides complete flexibility in the matter of the connections. For example, one battery can be floated across the output of one of the generators for supplying the load, whilst at the same time the spare battery can be on charge from the spare generator.

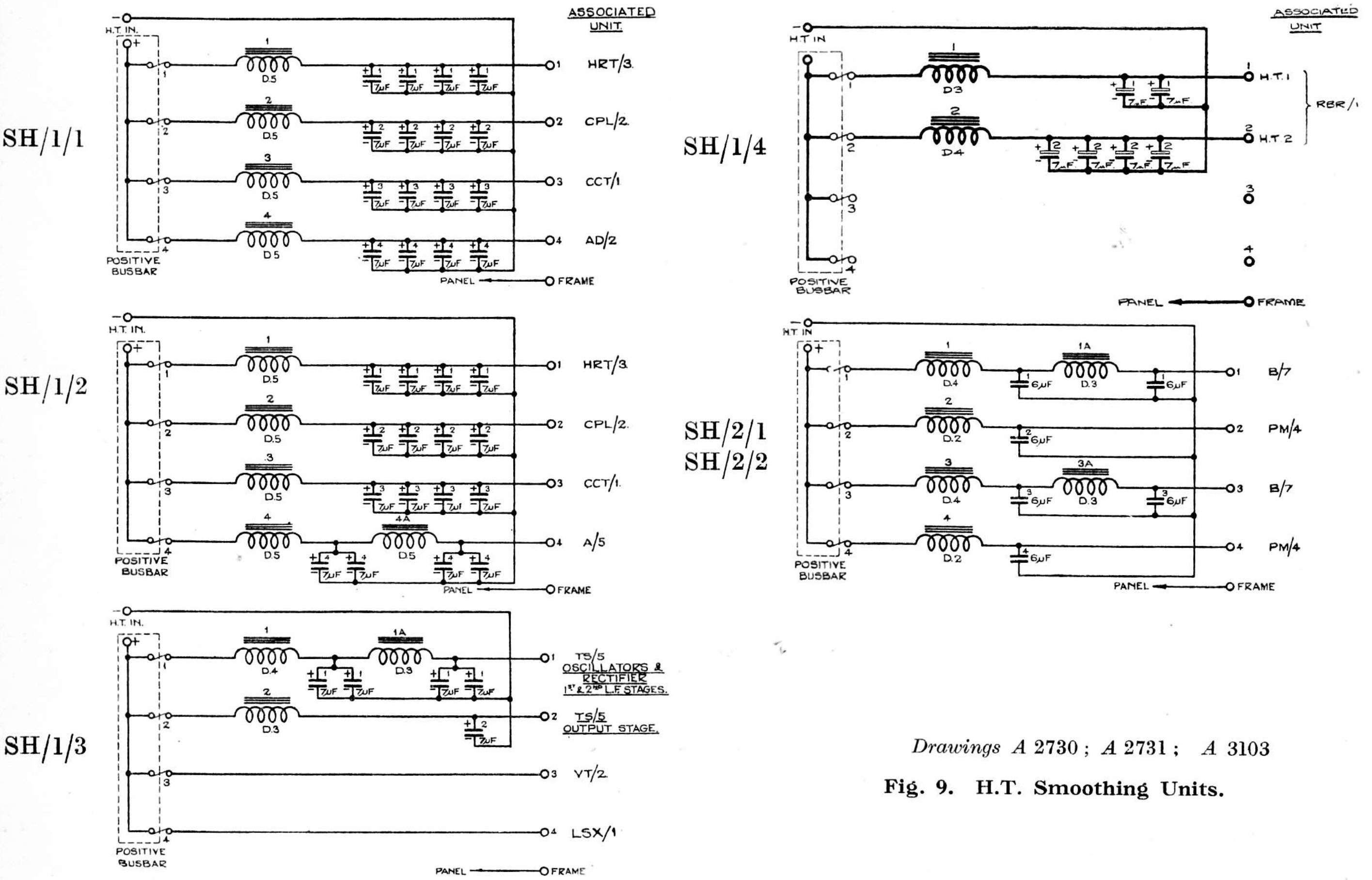
Double-pole double-throw knife switches are provided in the feeder circuits to enable them to be connected across either pair of bus bars. One of the feeder circuits provides the 24 volt supply via the smoothing bay to both Control rooms. The other feeder circuits, one for each transmitter, are connected to the D.C. control switchboard in the Transmitter Hall gallery and supply the 'Electroflo' meter circuits and the indicating lamps on the transmitter control table.

Filament Motor Generator Circuits. The starting contactor for the motor of the filament supply motor generator set is operated from a 240 volt A.C. supply, obtained from a transformer connected on its primary side, via an isolating switch, across one phase of the 415 volt, 3 phase, 50 c/s supply. The operating circuit is completed via the overload contact, and the control switch on bay 'E' and the main L.T. switch in No. 1 Control room, associated with the particular set in use.

The operating circuit of the generator output contactor is connected, in series with the overload contact and an auxiliary contact on the motor contactor, across the generator output. The contactor closes automatically as soon as the generator output voltage reaches its normal value. The outputs of the two generators are connected in parallel and the output ammeter and voltmeter are, therefore, common to both circuits. A field regulator is provided for controlling the generator output.

H.T. Rectifier Circuits. The operating coils of the supply and output contactors associated with the H.T. rectifier on bay 'C' are connected in parallel across the 240 volt transformer secondary, in series with the control switch on bay 'C' and the main H.T. switch in Control room No. 1, associated with the particular rectifier circuit to be used. Both contactors are thus closed at the same time. Each supply contactor applies 415 volts, 3 phase, 50 c/s to one of the rectifier units, HTM/3. The output circuits of both of the rectifier units are connected in parallel and the output ammeter and voltmeter are permanently connected in circuit.

H.T. Rectifier HTM/3. The H.T. rectifier, HTM/3, (see Figure 8) comprises two independent rectifier units for alternative use. The transformer is delta-connected on the primary side and has a diametric star-connected secondary, the common centre point providing the H.T. negative connection. The outer ends of the secondary windings are connected each to the anode of one of the six GU/1 mercury-vapour rectifier valves. The



Drawings A 2730 ; A 2731 ; A 3103

Fig. 9. H.T. Smoothing Units.

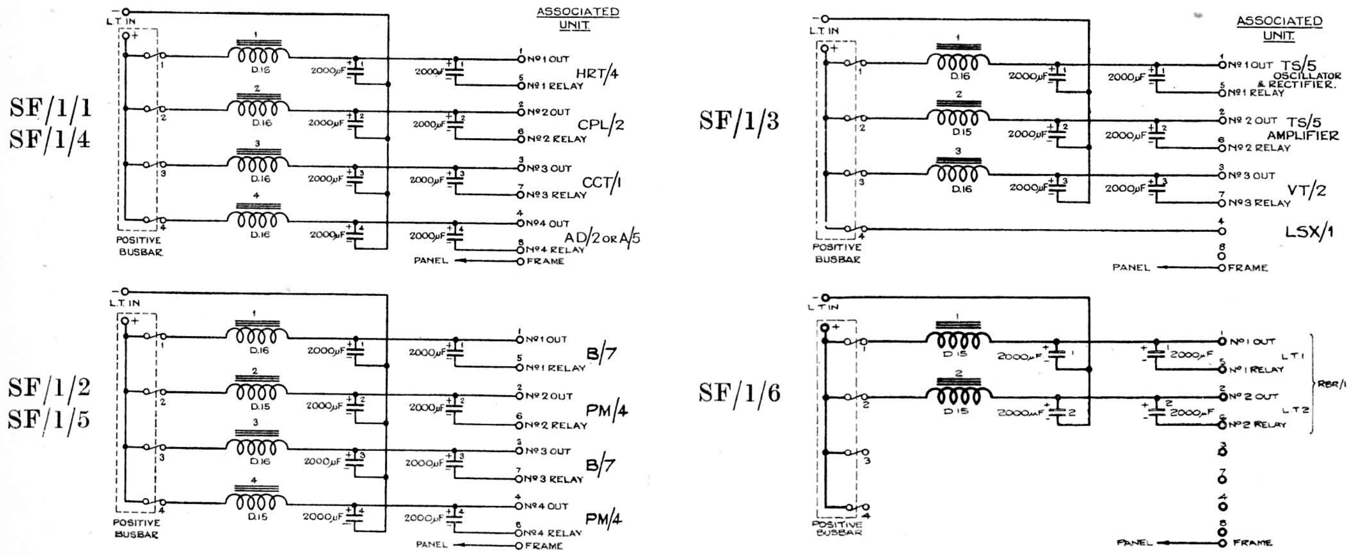


Fig. 10. L.T. Smoothing Units. *Drawings A 2732 ; A 3102.*

CONTROL ROOM EQUIPMENT

Power Supply Equipment (*Contd.*)

filament heating power is obtained from a separate three-phase star connected secondary winding with the individual filaments connected between phases, and the common centre point providing the H.T. positive connection. The 4μF condenser, connected in series with a 300 mA fuse across the rectifier output, serves as a reservoir, and the D.18 choke serves to protect the GU/1 valves when the rectifier is first switched on, by limiting the initial surge of current into the reservoir condenser. The 6,600 ohm resistance connected across the circuit, provides a permanent load which prevents the H.T. voltage from rising excessively when there is only a light load from the Control rooms.

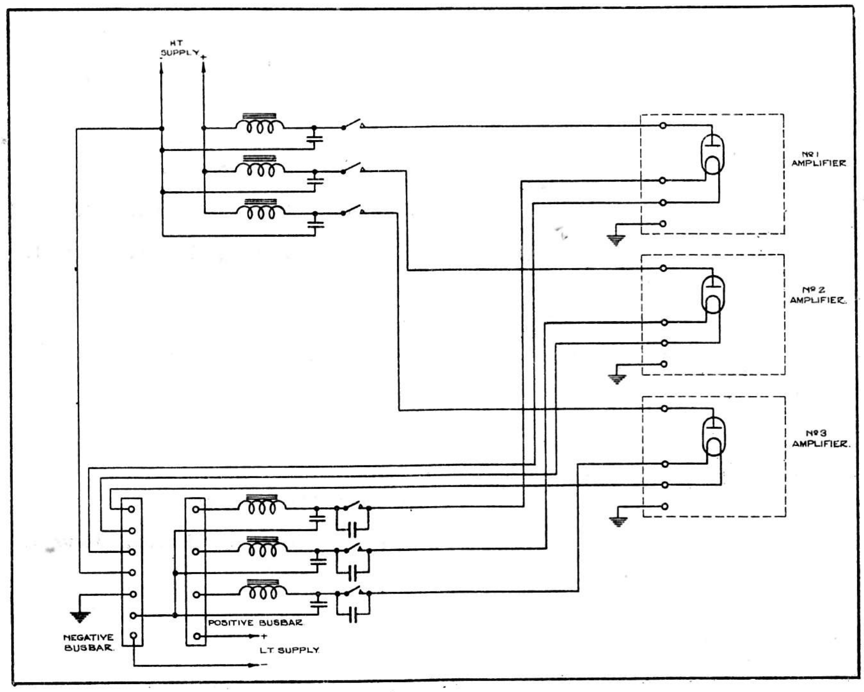


Figure 11. Supply Wiring and Earthing System.

Drawing A 2558. *Issue* 1.

The GU/1 valves must not be allowed to carry anode current until the filaments have heated up and the mercury has become vapourised. Provision is therefore made for delaying the completion of the anode circuits, and for this purpose a mercury contact delay switch with its operating coil energised from one phase of the main supply is used. The filament heating power is, however, applied as soon as the main contactor closes.

Smoothing System. The D.C. outputs of the rectifier and filament generator are connected, respectively, to the high tension and low tension smoothing bays, in the motor generator room. The supply system to the various amplifiers is shown in schematic form in Figure 11, individual smoothing circuits being provided in the H.T. and L.T. leads to each amplifier.

CONTROL ROOM EQUIPMENT

Power Supply Equipment (*Contd.*)

Details of the H.T. smoothing circuits, SH/1 and SH/2, are shown in Figure 9 and details of the L.T. smoothing units, SF/1, are shown in Figure 10. Each smoothing unit caters for four amplifier supply circuits, and each circuit is separately fused, the fuses being mounted at the back of the smoothing units. The L.T. smoothing units also include the 2,000 μF electrolytic condenser connected across the L.T. relay contacts for spark quenching purposes. The H.T. smoothing circuits are of conventional design, the degree of smoothing being adjusted to the requirements of the unit with which each circuit is associated. Thus a higher degree

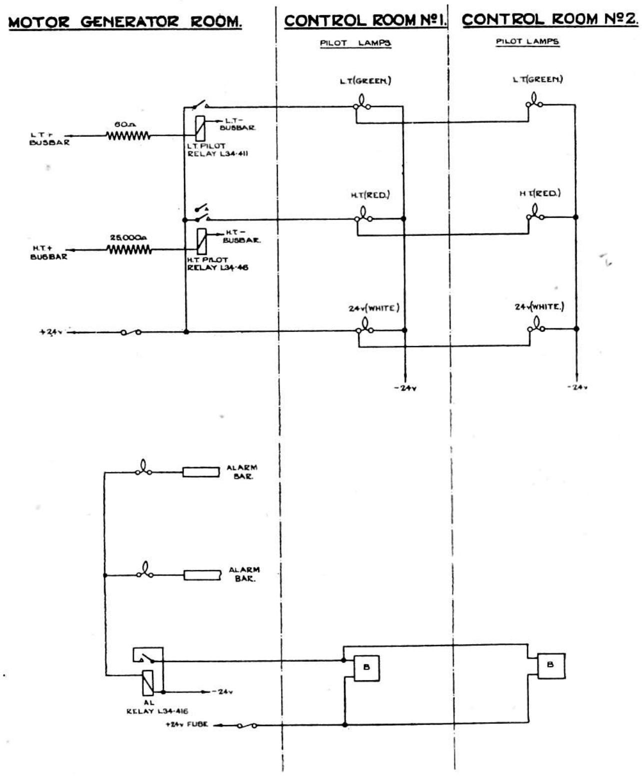


Figure 12.

(a) **Supply Pilot Lamp Circuit.**

Drawing A 2631. *Issue* 1.

(b) **Fuse Alarm Circuit.**

Drawing A 2632. *Issue* 1.

of smoothing is provided in the case of the 'A' amplifier than in that of the 'B,' since interference is relatively more serious in the former case, due to the lower programme level. In the smoothing units associated with the 'B' amplifiers, paper condensers are used in place of condensers of the electrolytic type used elsewhere.

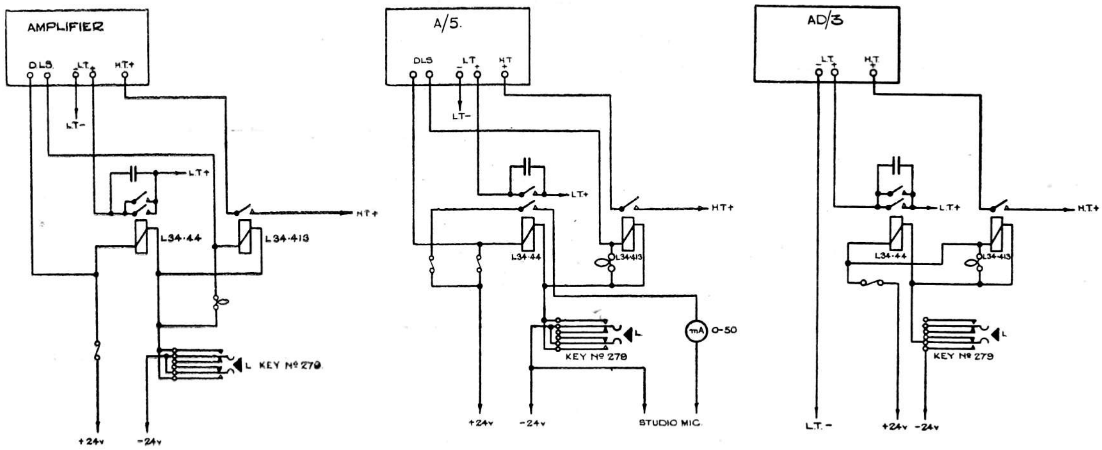
Supply Pilot Lamps. Pilot lamps are provided in each Control room (bays Nos. 1 and 5), to indicate when the main H.T., L.T. and 24 volt supplies are on the bus bars. The arrangement of the circuit is shown in Figure 12a. The lamps are lighted from the 24 volt battery, the circuits in the case of the L.T. and H.T. supplies being completed via the

CONTROL ROOM EQUIPMENT

Power Supply Equipment (*Contd.*)

contacts of the relays, the windings of which are connected, in series with suitable dropping resistances, across the respective supply circuits. Failure of any supply thus interrupts the pilot lamp circuit in both Control rooms.

The L.T. and H.T. pilot relays, together with the L.T. and H.T. relays associated with each amplifier, are mounted on panels at the bottom of the L.T. and H.T. smoothing bays, respectively.



(a) **Typical Circuit.**
Drawing A 2561. *Issue* 1.

(b) **'A' Amplifier Circuit.**
Drawing A 2597. *Issue* 1.

(c) **Amplifier Detector Circuit.**
Drawing A 2598. *Issue* 1.

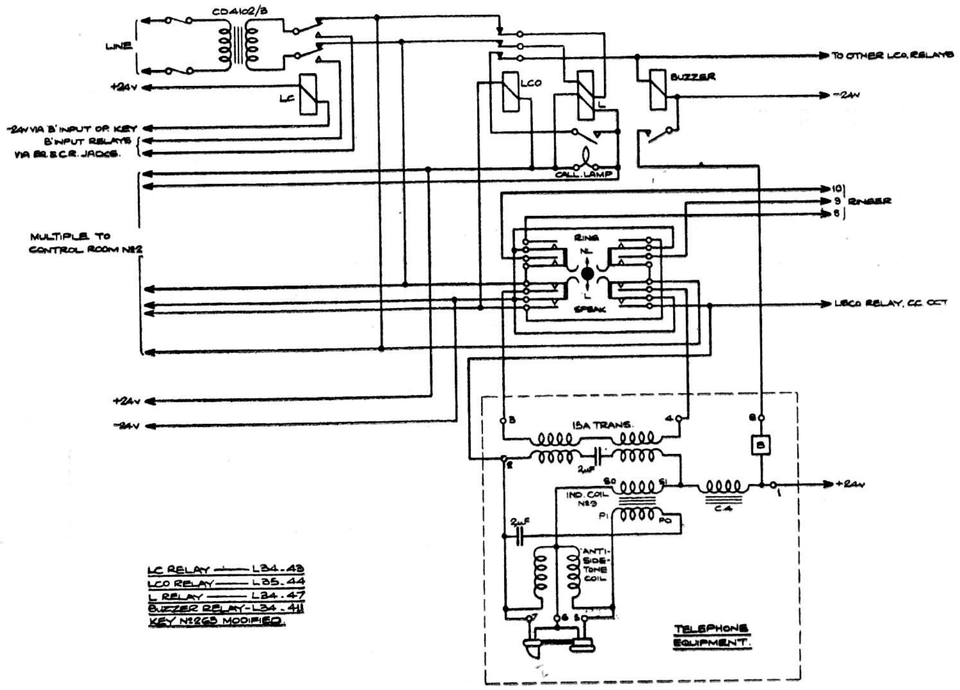
Figure 13. Amplifier Switching Circuits.

Fuse Alarms. The fuses associated with the 24 volt relay circuits are also mounted on the L.T. smoothing bays. These fuses are of the alarm type and when a fuse blows a circuit is completed for the alarm lamp associated with the particular row of fuses, and for the operation of the alarm relay (see Figure 12b). This relay, which is mounted on the L.T. smoothing bay, upon operation applies 24 volts to the alarm buzzers in both Control rooms.

Amplifier Switching

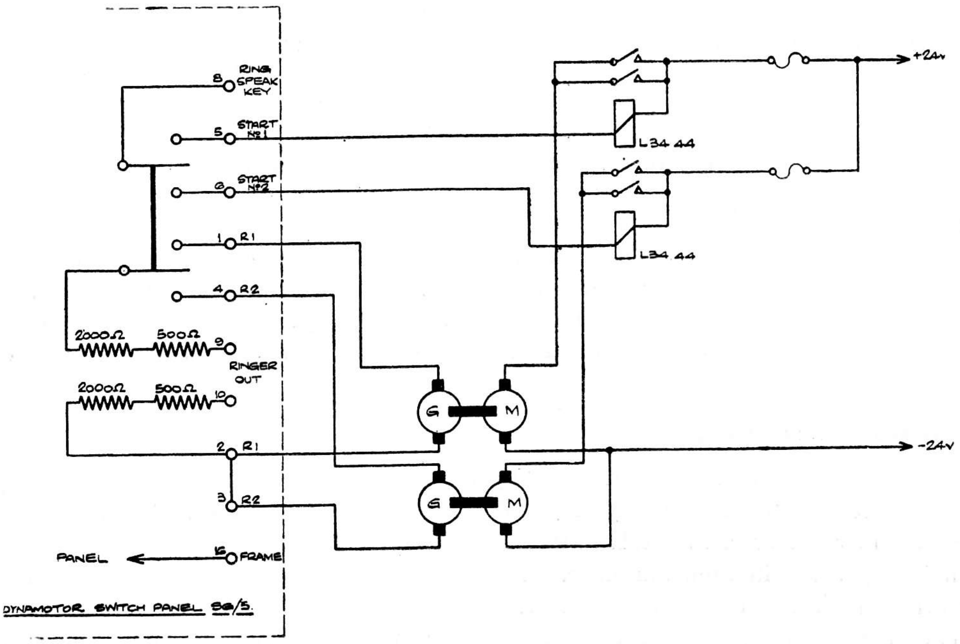
The amplifier switching is performed by the manual operation of keys on the key and lamp panel, KL/2, mounted on bays 1 and 5 of the control room racks. With the exception of the amplifier detector, the H.T. switching is delayed by the action of the thermal delay switch incorporated in each amplifier. The object of this arrangement is to prevent the application of H.T. to the valves before the emission has reached its full value.

The thermal delay switch, DLS/1, is constructed rather like a valve, the switching mechanism being enclosed in an evacuated bulb and the connections being made via a standard



Drawing A 2655. *Issue* 2.

Figure 14. Line Calling Equipment (Lines 1—3).



Drawing A 2599. *Issue* 1.

Figure 15. Ringing Circuits.

CONTROL ROOM EQUIPMENT

Amplifier Switching (*Contd.*)

4-pin base. The mechanism consists of a heater, connected across the filament supply to the amplifier, and a bi-metal strip. This is connected to one terminal of the switch and has at its upper end an extension wire projecting through a wire ring connected to the other terminal of the switch. This extension wire and the ring form the contacts of the switch. When the heater is cold the extension on the bi-metal strip assumes a position at the centre of the ring, but when the bi-metal strip becomes hot it bends away from the heater and contact is made between the extension wire and the ring. The switch terminals are connected in series with the winding of the H.T. relay across the 24 volt supply, consequently, the H.T. relay does not operate until the thermal delay switch is operated. The delay thus introduced is of the order of 30 seconds.

A typical amplifier switching circuit, using the thermal delay switch, is shown in Figure 13a. Operation of the manual key completes the circuit for the operation of the L.T. relay (L.34.44), which applies the filament heating supply to the amplifier. When in due course, the delay switch operates, a circuit is completed for the operation of the H.T. relay L.34.413 and for the amplifier engaged lamp in parallel.

The ' A ' amplifier switching circuit is shown in Figure 13b. The operation is similar to that of the typical amplifier switching circuit already described, except that in this case the second contact of the L.T. relay is used for switching on the microphone polarising current.

The amplifier detector, AD/3, is of standard design and does not incorporate a thermal delay switch. The switching circuit is shown in Figure 13c. Operation of the manual key completes circuits for the operation of the L.T. and H.T. relays, and for the lighting of the amplifier engaged lamp.

Line-Calling Equipment

The line-calling equipment associated with lines 1-3, is shown in schematic form in Figure 14. The line is connected via the fuse mounting, repeating coil, and break jacks, to the travellers of the associated **L.C.** relay. This relay when operated as the result of the operation of the associated **Line** key in either Control room, connects the line, via break jacks, to the ' B ' amplifier input switching in the particular Control room. In the normal unoperated condition of the **L.C.** relay, the line is connected via the contacts of the **LCO** relay across the calling winding of the **L** relay.

Ringing current incoming, causes the **L** relay to operate. This relay upon operation,

(a) provides a holding circuit for itself as follows :—
−24 volts, winding of buzzer relay, contact of **LCO** relay, operated contact of **L** relay, holding winding of **L** relay, +24 volts.

(b) completes a circuit for the lighting of the calling lamp (in parallel in both Control rooms).

(c) completes a circuit for the operation of the **buzzer** relay and thereby causes the calling buzzer to operate.

To answer a call the **Speak-Ring** key is operated to the **Speak** position. This operation connects the telephone across the line, via the contacts of the key, and also provides a circuit

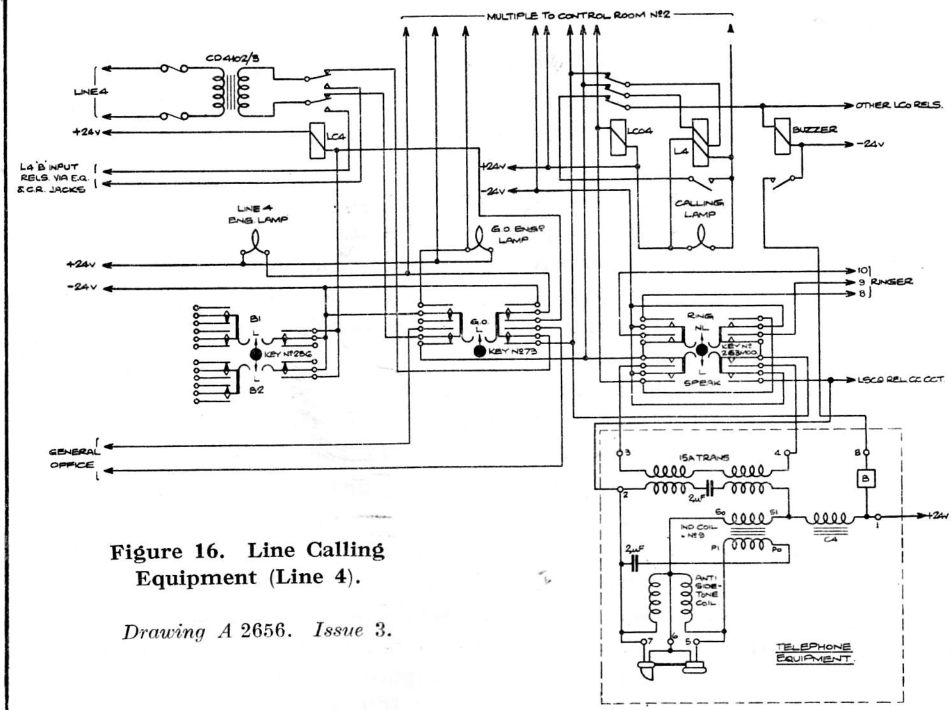


Figure 16. Line Calling Equipment (Line 4).

Drawing A 2656. Issue 3.

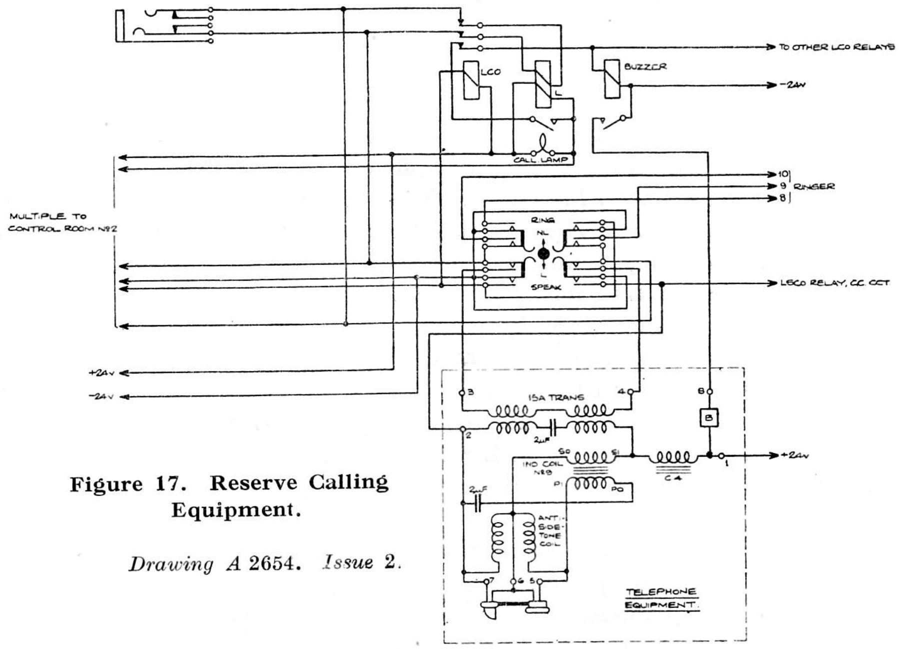


Figure 17. Reserve Calling Equipment.

Drawing A 2654. Issue 2.

CONTROL ROOM EQUIPMENT

Line-Calling Equipment (*Contd.*)

for the operation of the **LCO** relay, which cuts off the calling circuit and also interrupts the holding circuit of the **L** relay, thereby silencing the buzzer and extinguishing the calling lamp. It also provides a circuit for the operation of the loudspeaker cut-off relay (**LSCO**, Figure 5). The talking current is provided by the 24 volt relay battery, and is switched on by the operation of the key to the **Speak** position. On the completion of the conversation the **Speak-Ring** key is restored to its normal (mid) position ; the calling circuit is thereby re-connected and the circuit restored to the condition shown in the drawing.

To originate a call the **Speak-Ring** key is operated to the **Ring** position, and

(a) completes a circuit for the operation of the **LCO** relay, which cuts off the calling circuit, thereby preventing the out-going ring from operating the calling equipment.

(b) completes a circuit via the ringing change-over key on the dynamotor switch panel, SG/5 (Figure 15) for the operation of the dynamotor starting relay, whereupon the dynamotor starts up on the 24 volt battery supply.

(c) connects the line via the key contacts to the ringer output terminals.

The key is non-locking in the **Ring** position. On operation of the **Speak-Ring** key to the **Speak** position, the talking circuit is established as previously described.

The line-calling equipment for line 4 is shown in Figure 16. This line will normally be extended from the control position to the station general office for general communication purposes. Normally, therefore, the **G.O.** key will be operated, disconnecting the Control room calling equipment and extending the line to the PBX in the general office. The line 4 engaged lamp over the associated **Line** key and the G.O. engaged lamp over the **G.O.** key on the control desk in both Control rooms, are lighted when the **G.O.** key is in the operated position. If line 4 is required for control or programme purposes, the **G.O.** key is restored to normal. The line is now connected via the contacts of the key to the control room calling equipment and both lamps are extinguished. The operation of the circuit is now similar to that for lines 1-3 described above.

A reserve line-calling equipment is provided (Figure 17) similar in every respect to that of lines 1-3, with the exception that the LC relay is omitted and a jack is provided for plugging in the line when required.