VICTORIAN RAILWAYS

Instructions to Electric Train Drivers and Other Employees Engaged in the Operation of ELECTRIC LOCOMOTIVES Nos. 1100 to 1111

MAY, 1950

By Authority—Victorian Railways Print. 2100—48

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Electric Train Drivers and Other Employees Engaged in the Operation

OF

ELECTRIC LOCOMOTIVES Nos. 1100 to 1111.

MAY, 1950.

The instructions contained in this book are supplementary to those in the book of instructions to electric train drivers, guards, shunters, and other employees engaged in the operation of electric trains.

Most of the electrical equipment of the locomotives is the same as that of the multiple unit stock, but there are certain important differences in the electrical and mechanical control arrangements. The instructions relating to that equipment which is common to both types of stock is not contained in this book and must be obtained from the book of instructions referred to above.

These instructions deal with the equipment peculiar to electric locomotives Nos. 1100 to 1111 inclusive, and should be read in conjunction with other relative instructions issued by the Department.

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PART 1—DEFINITIONS.

100. GENERAL NOTE.

The definitions that follow apply to various technical terms used in this instruction book and elsewhere, and are included so that a clearer understanding may be obtained of the various instructions issued to electric train drivers who will be operating electric locomotives.

101. ADHESION PERCENTAGE.

The ratio—expressed as a percentage—of the starting tractive effort to that portion of the weight of the locomotive concentrated on the driving wheels. In the case of the V.R. electric locomotives, the adhesion percentage is equal to:—

$$\frac{\text{Starting tractive effort}}{\text{Total weight of locomotive}} \times 100$$

102. BALANCING SPEED.

The speed of a locomotive or train at which the total tractive effort is exactly balanced by the forces which resist the motion.

103. BRIDGE TRANSITION.

A method of changing the main motor circuits, from series to series parallel without breaking the circuit and whilst maintaining the same current in all the motors.

104. JUMPER (COUPLER) PLUGS AND SOCKETS.

Devices for readily connecting and disconnecting the electric circuits between locomotives or between coaches of a multiple unit train. Each set consists of a pair of plugs connected by a flexible cable and arranged to engage with suitable sockets attached to the vehicles.

105. PILOT OR DEAD-MAN'S VALVE.

Unlike the master controller on the electric motor cars, no pilot or dead man's valve is provided on the controller of the electric locomotives.

106. **HIGH SPEED (OR HIGH RUPTURING CAPACITY) FUSES.**

A special type of fuse having silver wire embedded in sand as the fusible element. It has the quality of more quickly and more efficiently rupturing the electrical circuit in case of a fault, than the ordinary type of main fuse fitted to the base of the pantograph.

107. **NOSE SUSPENSION.**

A method of mounting a traction motor on a bogie truck by supporting one side of the motor on the axle by special suspension bearings and the other side on the framework of the bogie truck by a lug or nose projecting from the motor case.

108. **NO. 1 END AND NO. 2 END.**

Each end of the locomotive is known by the numbers 1 and 2 respectively. No. 1 end is that end of the locomotive adjacent to the main switchboard.

109. **REVERSER.**

A combination switch for changing the connections of traction motor field windings in order to reverse the direction of rotation.

110. **STRAIGHT AIR BRAKE.**

An auxiliary air brake system whereby the compressed air for applying the brakes is admitted direct from the main reservoir to the brake cylinders via a pressure reducing valve and a drive's straight air brake valve in each driving compartment. (See also book of instructions for air brake equipment as fitted to electric trains.)

111. **TRACTIVE EFFORT.**

The total propelling force measured at the tread of the locomotive wheels.

112. **TRACTIVE RESISTANCE.**

The sum of the frictional and atmospheric forces which resist locomotive or train movement.

113. **WATTHOUR METER.**

An electrical instrument which records the quantity of energy used by the locomotive for traction purposes. The kilowatt-hours of energy recorded by the meter is equal to:

$$\frac{\text{Traction motor Amperes x Volts x Time in Hours}}{1000}$$

Part 2.

ELECTRIC LOCOMOTIVES
Nos. 1102-1111.

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DESCRIPTION OF ELECTRIC LOCOMOTIVES, Nos. 1102-1111.

200. EQUIPMENT DISSIMILAR TO THAT ON MOTOR CARS.

As referred to in the introductory note at the commencement of this instruction book, the equipment installed on the electric locomotives is very similar to that on the electric motor cars.

There are, however, important differences in certain of the major electrical and mechanical parts, and a description of these is given hereunder:—

(a) **Electrical.**

(i) The locomotives are equipped with two pantographs as compared with one on a motor car. The pantograph isolating switch is hence of the 2-way type and a special 2-way air cock is also provided in the magnet valve connections.

(ii) The locomotives are equipped with high rupturing capacity **high speed** fuses in a 'dition to the normal type of main fuse m. unted on the base of each pantograph.

(iii) Heavier type resistance grids are provided.

(iv) Eight contactors are used for reversing the traction motor fields, and the corresponding direction of movement of the locomotive, instead of the **reverser** used on the electric motor cars.

(v) Two line breakers are used for supplying current to the locomotive motor circuits in place of one on each motor car.

(vi) The master controller is of a different type to that used on the electric motor cars and provides for manual control of the locomotive acceleration instead of control by an accelerating relay.

(vii) Sixteen point couplers are used for coupling up the control circuits between adjacent locomotives (for enabling 2 locomotives to be controlled by one driver) instead of the standard 9 point coupler used on electric motor cars.

(viii) A kilowatt-hour meter is provided in each locomotive for measuring the energy consumption of the motor circuits.

(ix) Two air compressors are provided in each locomotive.

(x) The locomotives are equipped with electrolytic type lightning arresters.

(b) **Mechanical.**

(i) The electric motors are geared to the locomotive axles through a pinion and gear wheel of a different gear ratio to that used on the electric motor cars.

(ii) The locomotive is equipped with the straight air brake in addition to the automatic air brake.

(iii) A tripping handle lever is provided in the control compartment of each locomotive for raising the tripping handle in the same way as by the operation of the safety apparatus isolating cock.

(c) **General.**

With the exception of a few minor items of equipment, all the electrical and mechanical control equipment is installed in the cab of the locomotive instead of being suspended from the underframe—as on an electric motor car.

GENERAL DESCRIPTION OF LAYOUT OF EQUIPMENT IN BODY OF LOCOMOTIVE.

201. GENERAL NOTE.

The body of the locomotive, which is carried on two bogie trucks, has a driving compartment or cab at each end partitioned off from a central equipment compartment.

As the controllers, brake valves, and sanders are in duplicate, the locomotive can be driven effectively from either end.

The central equipment compartment contains most of the apparatus, which on a motor car is carried on the underframe. It is divided into two sections by a narrow aisle running the full length of the compartment. Access to the electrical equipment contained in the central compartment is obtained by means of a door in each partition.

202. EQUIPMENT IN CAB AT NO. 1 END.

In the cab at No. 1 End of the locomotive, the equipment is located as follows:—

(a) **On a frame above the main switchboard behind the driver's seat (reading from left to right when facing the frame).**

No. 1 air compressor and protective relay switch.
Dynamotor switch.

(b) **On the main switchboard, top row, left to right.**

No. 1 compressor cut-out switch.
Bus line switch.
Main control switch.
Main lighting switch.

(c) **On the main switchboard, second row, left to right.**

No. 1 end radiator snap switch.
Headlights snap switch.

Signal and gauge lights snap switch.
Locomotive lighting snap switch.

(d) **On the bottom of the main switchboard.**
Pantograph and control cut-out switches and fuses.

Note.—The circuits and fuses, as shown on diagrams Nos. 8 to 21, reading from left to right, are as follows:—Nos. 15 and 14 pantograph operating circuits, No. 13 circuit—not fused—Nos. 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2 and 1 control circuits.

(e) **Underneath the main switchboard.**
Emergency jumper.

(f) **In front of the controller and above window.**
No. 1 control and line breaker resetting switch.
No. 1 end pantograph operating switch.

(g) **Above the secondary switchboard on the right or assistant's side of the cab.**
No. 2 air compressor and no volt relay switch.

(h) **On the secondary switchboard.**
Kilowatt-hour meter.
No. 2 compressor cut-out switch.
Traction motor cut-out switches with control switches attached—at bottom of switchboard.
Shunts for kWh. meter and ammeter (behind switchboard).

(i) **Above the outside door.**
No. 1 control governor—on the side nearest to the controller.
No. 1 control governor switch—on the side furthest from the controller.

(j) **On instrument board above the controller.**
Ammeter—top instrument.
Brake cylinder pressure gauge for straight air operation—to the left of centre.
Pantograph pressure gauge—to the right of centre.
Duplex gauge for registering main reservoir and brake pipe pressures.

(k) **On side wall of locomotive to the left rear of driver's seat.**

Train cable connection box.

(l) **On side wall of locomotive to the left front of driver's seat.**

No. 1 headlight snap switch.
No. 1 headlight **dim** and **bright** snap switch.
Brake cylinder hand release valve.

(m) **Between controller and outside door.**

Magnet valve.

(n) **Between driver's seat and front window.**

Master controller.
Driver's equalizing automatic brake valve.
Driver's straight air brake valve.
Air sanding lever.

203. **EQUIPMENT IN CAB AT NO. 2 END.**

(a) **On the switchboard in front of the controller and above the window**—left to right.

No. 2 control and line breaker resetting switch.
Main control switch.
No. 2 end pantograph operating switch.
No. 2 end radiator snap switch.

(b) **Above the outside door.**

No. 2 control governor (on the side nearest to the controller).
No. 2 control governor switch (on the side furthest from the controller).

(c) **On instrument board above the controller.**

Ammeter—top instrument.
Brake cylinder pressure gauge for straight air brake operation—to the left of centre.
Duplex gauge for registering main reservoir and brake pipe pressures.

Note.—There is no pantograph pressure gauge at No. 2 end.

(d) **On side wall of locomotive to the left rear of driver's seat.**

Train cable connection box.
Brake cylinder hand release valve.

(e) **On side wall of locomotive to the left front of driver's seat.**

No. 2 end headlight snap switch.

No. 2 end headlight **dim** and **bright** snap switch.

(f) **In front of the assistant's seat.**

Hot plate switch.

(g) **Behind the assistant's seat.**

Hot plate.

Hand brake.

(h) **Between driver's seat and front window.**

Master controller.

Driver's equalizing automatic brake valve.

Driver's straight air brake valve.

Air sanding lever.

204. **EQUIPMENT IN CENTRAL COMPARTMENT ON THE SAME SIDE AS NO. 1 CONTROLLER.**

(a) **On the partition dividing No. 1 cab from the central compartment.**

Electrolytic lightning arrester.

(b) **On the ceiling.**

Choke coil.

(c) **On the side wall.**

Dynamotor resistance.

Kilowatt-hour meter resistance.

(d) **On the top of the equipment frame.**

No. 1 section of resistance grids.

(e) **Suspended from the equipment frame**—commencing from No. 1 end.

No. 1 line breaker.

No. 1 contactor box—contains Nos. 1 to 12 contactors. At No. 1 end of the box is a terminal board and at No. 2 end are control resistance tubes Nos. 1 to 13. (See table hereunder).

No. 1 governor equipment.

One main reservoir.

(f) **On the floor**—commencing from No. 1 end.

Commencing from No. 1 end.

Auxiliary reservoir—underneath No. 1 line breaker.

Dynamotor—underneath No. 1 contactor box.

No. 1 air compressor.

(g) **On the partition dividing No. 2 cab from the central compartment.**

Hot plate series resistance.

205. **EQUIPMENT IN CENTRAL COMPARTMENT ON THE OPPOSITE SIDE TO NO. 1 CONTROLLER.**

(a) **On the top of the equipment frame**—commencing from No. 1 end.

One main reservoir.

No. 2 section of resistance grids.

(b) **Suspended from the equipment frame**—commencing from No. 1 end.

Two pantograph storage reservoirs.

No. 2 governor equipment.

No. 2 contactor box—containing Nos. 13 to 24 contactors. At No. 1 end of the box is a terminal board and at No. 2 end are control resistance tubes Nos. 14, 15 and 16. (See table hereunder).

No. 2 line breaker.

(c) **On the floor**—commencing from No. 1 end.

No. 2 air compressor.

Whistle and pantograph reservoir, with duplex check valve.

(d) **On the partition dividing No. 2 cab from the central compartment.**

Headlight resistances.

206. **EQUIPMENT IN CENTRAL COMPARTMENT IN OR OVER THE CENTRAL AISLE.**

Traction motor main switch—over the door at No. 1 end.

High speed fuse.

Pantograph isolator and interlocking air cock—on the ceiling near No. 2 section of grid resistances.

207. **NOTE RE CONTACTOR INTERLOCKS.** The contactors are fitted with interlocks as follows:—

Number of interlocks fitted.	Contactors in box No. 1.	Contactors in box No. 2.
No interlocks ..	Nos. 7, 8, 9, 10 & 11	Nos. 18, 19, 20, 21 & 22
One interlock ..	Nos. 2, 3, 4, 5 & 12	Nos. 14, 15, 16, 17 & 24
Two interlocks ..	No. 6	No. 23
Three interlocks ..	No. 1	—
Four interlocks ..	—	No. 13

DESCRIPTION OF SPECIAL ITEMS OF APPARATUS.

210. THE PANTOGRAPHS.

The pantographs and their connections, also the method of raising and lowering, are the same as on each electric motor car, except for the addition of the pantograph isolator with its safety air cock and a two-way cock situated above the magnet valve and used for controlling the passage of air to either pantograph. A general description of the pantographs and their attendant valves and cocks is given in the book of instruction to electric train drivers and other employees engaged in the operation of electric trains. The control circuits and fuses used when raising or lowering the pantographs electrically are Nos. 14 and 15 respectively.

211. THE PANTOGRAPH ISOLATOR.

The pantograph isolator is a two-way switch, the knife blade of which must be placed in the contact fingers nearest to the pantograph which is to be raised. Care must be taken after operating the isolator to close the cover of the isolator box.

A safety air cock is provided which must be moved to a position which interrupts the air supply and exhausts the air from the pantograph cylinders—thus lowering the pantograph if raised—before the cover of the pantograph isolator box can be opened and the isolator operated. The cover in turn must be closed before the safety air cock can be returned to the **on** position.

Note.—Electric train drivers and others concerned are warned that they must not assume that any pantograph is lowered until they satisfy themselves by observation that the pantograph is down.

212. TWO-WAY COCK ABOVE MAGNET VALVE.

This cock must be set to the correct position of the pantograph which is to be operated, i.e.,

(a) For the operation of No. 1 pantograph the cock handle is moved to a position approximately 45 degrees to the right of the central vertical position, the air supply to the pantograph cylinders then passes through the right-hand side pipe.

(b) For No. 2 pantograph the cock handle is moved to a position approximately 45 degrees to the left of the central vertical position, the air supply in this case passing to the pantograph cylinders via the left-hand side pipe.

213. **LINE BREAKERS.**

The two line breakers of the locomotive are the same type as those on the motor cars and are designated by numbers 1 and 2 respectively. No. 1 line breaker is in operation in both series and series-parallel connections of the motors, whilst No. 2 line breaker does not come into operation till the series-parallel control circuit No. 9 is energised on the 8th step.—See Diagram No. 17.

Each line breaker has two interlocks, one being the **reset** interlock; the other, which is referred to as the **line breaker** interlock, works in conjunction with the line breaker contact carrying lever arm.—See Diagram No. 4. This latter interlock is part of the interlocking arrangements of the circuit which ensures that the line breaker is the last switch to close in the main motor circuit. When the line breaker closes, this interlock is opened. The **reset** interlock of the line breaker operates in a similar manner to that on each electric motor car line breaker, i.e., when excess current flows to the motors through the overload coil of a line breaker, the pull of the coil overcomes the resistance of a spring and causes a trigger attachment to operate and open the **reset** interlock. If this happens it is necessary to reset this interlock—by either of the control and line breaker reset switches—before the line breaker can be brought into operation again.—See instruction No. 223, description of **No. 1 compressor and protective relay circuit and No. 12 control and line breaker resetting circuit.**

When the motors are working in series-parallel, there is a line breaker in the circuit of each pair of motors; this arrangement permits each line breaker to be set to open at a lower value of current than if there were a single line breaker on each vehicle. If when working in series-parallel motors 3 and 4 take excessive current and open the reset interlock of No. 2 line breaker, No. 9 control circuit will be interrupted and both line breakers will open and cut power off from the motors. When, however, the controller is returned to No. 7 step —full series—Nos. 3 and 11 control circuits will become energised and all motors will work in the full series connection. Series-parallel operation cannot, however, be reverted to until No. 2 line breaker is reset.—

See Instruction No. 223.

214. **GRID RESISTANCES.**

The grid resistances are used to limit the amount of current through the motors during the period of initial acceleration. They are divided into 9 sections. Cables connect these sections to the various contactors which short circuit them out of the motor circuits, the contactors being operated by the control circuits which become energised as the controller is stepped up. The grid resistances are all shorted out of circuit when the controller is in the **full series** and **full series-parallel** positions respectively. If the ammeter reading is low, and slow train movements are required, the controller handle may, if necessary, be held much longer on a resistance step without ill-effects to the equipment than if the ammeter reading were of a high value.

When a high ammeter reading is present, the controller must be stepped up to the **full series** or the full **series-parallel** positions as soon as practicable, because the amount of heat generated in the grid resistances increases very rapidly with the current strength. The controller should, therefore, not be held on resistance steps longer than is absolutely necessary.

215. MAIN MOTORS.

Each of the two four-wheel bogie trucks of the locomotive is fitted with two axle hung, nose suspended traction motors, i.e., one motor is used to drive each axle. These motors are of the same type as those used on the electric motor cars, but the locomotive motors have gearing of a different ratio—See diagram No. 2—more suitable for the class of work for which the locomotive is designed. The motor field tapping arrangements, which are used on the electric motor cars to give greater train speed, are not used on the electric locomotives as they are not required, the maximum speed of the locomotives being limited to 40 M.P.H.

216. MOTOR CUT-OUT SWITCHES.

The two motor cut-out switches are each of the three pole double throw knife type, the two large blades of each switch being connected in the traction motor circuit and the small blade being part—under normal conditions—of No. 9 control circuit. The function of the motor cut-out switches is to cut out of action either pair of motors in the event of a pair becoming defective, and at the same time complete the circuit, with the good pair of motors and provide for control in any position of the controller handle. When a pair of motors is cut out by either of the motor cut-out switches, the **series-parallel** control circuit No. 9 is opened and the **full series** control circuit No. 11 is connected via the small blade of the M.C.O. switch to No. 9 wire, thus providing for the retaining of No. 11 circuit when the controller handle is moved to any of the series-parallel positions. If it is necessary to cut out a pair of motors, stepping up should be done cautiously to control the higher current peaks which will be produced owing to the lowered electrical resistance of the traction motor circuit.

217. DYNAMOTOR.

The dynamotor on each locomotive is identical with that on each electric motor car. It provides the 750

volt supply for the control, lighting and heating circuits and is electrically coupled to these circuits via the usual emergency jumper.

218. **CONTROLLER.**

As the locomotive controllers are of a different type from those fitted to the electric motor cars, the main features of the locomotive controllers are given hereunder:—

(a) Each controller has two cylinders, i.e., a main cylinder and a reversing cylinder.

(b) On the main cylinder are mounted the groups of insulated segments which make the required connection with the stationary fingers when the controller is operated.

(c) The reversing cylinder carries a contact segment which—according to the position of the handle from the central or off position—will connect the control voltage to No. 1 circuit for a **forward** movement or to No. 2 circuit for a **reverse** movement.

(d) The shaft of the reversing cylinder projects above the cover plate of the controller and is operated by a special removable reversing handle. This reversing handle can only be removed when it is in the central position. The shaft of the reversing cylinder is so interlocked with the shaft of the main cylinder that—

(i) the position of the reversing cylinder cannot be altered while the controller is in any other than the **off** position, and

(ii) the main cylinder cannot be moved when the reversing cylinder is in the central position.

(e) The controller handle is attached to the shaft of the controller main cylinder. It is moved in the same direction of rotation for either **forward** or **reverse** movement of the locomotive.

(f) There is no spring to return the controller to the **off** position.

(g) An auxiliary cylinder on the lower end of the main cylinder shaft has a contact piece, which, when the controller is in the **off** position, connects two fingers which are part of No. 12 circuit. This circuit is open at these fingers while the controller handle is in the **on** position.

(See description of line breaker and protective relay resetting circuit No. 12, Instruction No. 223.)

(h) The 750 volt supply to the controller is fed to the various circuits via a **feed switch** consisting of the two upper fingers of the controller and a bridging contact. When the controller is in the **off** position, the supply is disconnected from the controller circuits, but when the first and subsequent steps are made the two fingers are connected by the bridging contact and the 750 volt supply is fed to the controller circuits via No. 3 wire—See diagrams Nos. 8-21 inclusive. The feed switch also makes the 750 volt supply available to the reverser via a connection from **B** finger of the feed switch.

(i) The controller has twelve steps which are indicated on the cover plate, the seventh being the **full series** and the twelfth the **full series-parallel** running position. A star wheel with a spring actuated pawl gives a definite indication of each step. It must be understood that the driver is responsible for the acceleration of the locomotive, the controller must therefore be stepped up step by step at a rate governed by the reading on the ammeter, and the controller must not be held on a resistance step longer than necessary.

(See notes in operating instructions section of this book re stepping-up on the controller—Instruction No. 261.)

219. CONTROL RESISTANCE TUBES.

There are 16 control resistance tubes and their function is to limit the current flowing through the operating coils of the contactors. Each tube is stamped with its ohmic resistance, i.e., Nos. 1, 2, 3, 4, 9, 10, 11 and 12 resistance tubes are 150 ohms each, and Nos. 5, 6, 7, 8, 13, 14, 15 and 16 tubes are 200 ohms each.

When replacing a resistance tube care must be taken to see that a 150 ohm tube is not put in place of a 200 ohm tube as the lower resistance of the 150 ohm tube will allow more current to flow than is necessary and as a result the control fuse which protects the circuit may blow.

The control resistance tubes are employed in the control circuits as follows:—

No. 1 tube is in No. 1 circuit.
No. 2 tube is in No. 2 circuit.
Nos. 3 and 4 tubes are in No. 6 circuit.
Nos. 5, 6, 7 and 8 tubes are in No. 8 circuit.
Nos. 6, 7 and 8 tubes are in No. 4 circuit on the 6th step.
Nos. 9, 10, 11 and 12 tubes are in No. 7 circuit.
No. 13 tube is in Nos. 3, 10 and 11 circuits during series operation.
Nos. 14, 15 and 16 tubes are in No. 4 circuit on the 12th step.

220. TRAIN CABLE AND JUMPER.

The train cable, 16 core—Nos. 1 to 15 circuits plus a spare—terminates at each end of the locomotive in the respective connection boxes. One box is located in each driving cab. The 16 terminals of the connection box are connected by 16 core cables to the right and left hand coupler sockets respectively, and by lesser core cables to the adjacent controllers and to the pantograph operating switches. No. 1 connection box is also connected to the pantograph and control cut-out switches and fuses.

A 16 core train cable jumper is part of the equipment of each locomotive. This jumper may be plugged in to the coupler socket of an adjacent locomotive to enable the locomotives to be operated from any of the controllers in a similar manner to the **multiple unit control** of the electric motor cars. [Instructions 219-220.

221. BUS LINE.

The bus line terminates in a connection box at each end of the locomotive. At No. 1 end the terminal of the connection box is connected to the 750 volt supply —via the bus line switch—and to a right and left hand coupler socket. At No. 2 end the terminal of that connection box is connected to a right and left hand coupler socket and to the main control and heating circuit switches in the driving cab.

Under normal conditions, therefore, the function of the bus line is to supply power to No. 2 end for the operation of the locomotive from that end, and to supply power for the heating circuits at that end.

Under abnormal conditions the bus line is used to carry the 750 volt supply through an **emergency jumper** to or from an attached locomotive or motor car.

222. LIGHTING AND HEATING CIRCUITS.

(a) The lighting circuits of the locomotive are supplied through the main lighting switch and 5 ampere fuse—the latter is in the switch box. The switch is mounted on the main switchboard at No. 1 end. After passing through the main switch the supply divides into several minor circuits each controlled by a snap switch and protected by a 3 ampere fuse contained in that switch body. These snap switches are also located on the main switchboard and arranged as detailed in instruction No. 202 of this instruction book.

(b) The heating circuits of the locomotive are supplied as follows:—

No. 1 end radiator. Supplied through the main lighting switch and controlled and protected by a combined snap switch and 3 ampere fuse mounted on the main switchboard at No. 1 end adjacent to the lighting snap switches.—See instruction No. 202.

No. 2 end radiator. Supplied from the bus line and controlled and protected by a combined snap switch and 3 ampere fuse located in No. 2 end cab in front of the controller and above the window.—See instruction No. 203.

No. 2 end hot plate. Supplied from the bus line and controlled and protected by a combined switch and 5 ampere fuse, located in No. 2 end cab in front of the assistant's seat.

223. NO. 1 COMPRESSOR AND PROTECTIVE RELAY CIRCUIT AND NO. 12 CONTROL AND LINE BREAKER RESETTING CIRCUIT.

In connection with these circuits, reference to diagrams Nos. 8 to 21 will show that the closing of No. 1 compressor and protective relay switch does not energise and reset No. 1 protective relay. To reset the relay it is necessary to momentarily energise the line breaker reset coils and with them No. 1 compressor and protective relay coil via No. 12 circuit. This is done by moving the handle of the control and line breaker resetting switch momentarily to the left hand side. When this is done the path of No. 12 circuit from the right hand contact of the control and line breaker reset switch is across the two fingers at the base of the controller—see note below—to the control cut-out switch, and thence via No. 12 fuse to No. 12 terminal on No. 1 contactor box terminal board where the circuit divides into three paths. Two of these paths are through the two line breaker reset coils to rail, and the remaining path is through the top (No. 1) contact of the interlock and the coil of No. 1 compressor and protective relay and thence through two 600 ohm resistance tubes to rail. It should be noted that the drawing of an arc when the control and line breaker reset switch is operated to the reset position does not necessarily indicate that **each** of the three circuits from terminal No. 12 at No. 1 contactor box terminal board is complete to rail, because with any one of the circuits complete an arc will be obtained.

The protective relay has five interlocks which are used as follows:—

(a) No. 1—Top—contact of the interlock is part of No. 12 circuit and is used in resetting the protective relay as referred to above. When the relay resets it opens No. 1 contact of the interlock and closes Nos. 2, 3, 4 and 5 contacts of the interlock.

(b) No. 2 contact of the interlock being closed retains the circuit for the relay coil when No. 12 circuit is de-energised by the replacement of the handle of the control and line breaker resetting switch to the normal right hand position. The 1500 volt supply then passes through No. 1 compressor and protective relay switch, 10 No. 500 ohm resistance tubes, No. 2 contact of the interlock, the relay coil, and the two 600 ohm resistance tubes to rail and thus retains the relay in the reset position.

(c) No. 3 contact of the interlock is in the circuit of No. 1 compressor relay. The closing of this contact of the interlock when the protective relay resets prepares a circuit to rail in parallel with the circuit from the protective relay coil through the two 600 ohm resistance tubes. This parallel circuit, however, is not complete until a compressor governor closes. When this happens, the current through the protective relay coil to rail takes the following paths:—

(i) **First parallel circuit.** Through the two 600 ohm resistances tubes to rail.

(ii) **Second parallel circuit.** Through protective relay interlock contact No. 3, No. 1 compressor relay coil, No. 1 compressor cut-out switch, the common compressor governor wire, and the closed compressor governor contacts to rail.

When No. 1 compressor relay coil is energised, the relay contacts close and feed

the 1500 volt supply to the motor of No. 1 air compressor.

(d) No. 4 contact of the interlock is in No. 3 control circuit and if it does not close the locomotive will be inoperative.

(e) No. 5 contact of the interlock is in No. 11 control circuit and if it does not close the locomotive will be inoperative in No. 7 step, i.e., the full series running position.

It is necessary to reset No. 1 compressor and protective relay on any occasion when power has been restored after being temporarily cut off. For example, this must be done after a power failure, or the lowering of the pantograph, or after a main or a high speed fuse has blown, or after No. 1 compressor and protective relay switch has been opened for any reason.

It should be noted that if a defect prevents No. 1 compressor and protective relay from closing, the locomotive will fail as well as No. 1 air compressor.

Should a line breaker reset coil be burnt out, or open circuited, and the line breaker then be opened by an overload, it will be impossible to reset the line breaker electrically. It can, however, be reset by hand.

Note.—When the controller handle is in the **off** position, the two fingers at the base of the controller are bridged by a contact segment carried on an auxiliary cylinder mounted on the main cylinder shaft. This feature prevents the possibility of the line breakers or protective relay being reset while the controller is in any other than the **off** position.

224. NO. 2 COMPRESSOR NO-VOLT RELAY CIRCUIT.

The no-volt relay of No. 2 compressor has one set of interlock contacts only. When No. 2 compressor and no-volt relay switch is closed, current passes through the ten resistance tubes, the coil of the no-volt relay and two 600 ohm resistance tubes to rail. When the

relay coil becomes energised, the interlock contacts are closed. This prepares a circuit to rail in parallel with the circuit from the no-volt relay coil through the two 600 ohm resistance tubes. This potential circuit, however, is not complete until a compressor governor closes. When this happens, the current passing through the no-volt relay coil to rail follows the parallel paths shown hereunder:—

(a) **First parallel circuit.** Through the two 600 ohm resistance tubes to rail.

(b) **Second parallel circuit.** Through the interlock of No. 2 compressor no-volt relay, No. 2 compressor relay coil, No. 2 compressor cut-out switch, the common compressor governor wire, and the closed compressor governor contacts to rail. When No. 2 compressor relay coil is energised, the relay contacts close and feed the 1500 volt supply to the motor of No. 2 air compressor.

It should be noted that a defect in No. 2 compressor no-volt relay does not affect the operation of the locomotive electrically, although No. 2 compressor will not operate.

225. AIR BRAKE EQUIPMENT.

(a) DESCRIPTION.

Electric locomotives are provided with the combined automatic and straight air brake equipment. This equipment comprises the standard automatic arrangement with the addition of a straight air brake feature which provides for independent control of the locomotive brakes without interfering with their automatic operation when the driver's automatic brake valve is used, or should any discharge of air from the brake pipe be caused, either purposely or accidentally.

The brake equipment, which is shown diagrammatically in diagram No. 7, is so arranged

that it can be manipulated from either driving compartment of the locomotive.

The locomotive is provided with standard trip gear at each end with the addition of a tripping handle lever in each driving compartment, which, when pulled downwards as far as possible, causes the tripping handle to be raised clear of the train stop arm in the same manner as that caused by the operation of the safety apparatus isolating cock. When the tripping handle lever in the driving compartment is released the tripping handle returns to the normal operating position. The purpose of the tripping handle levers in the driving compartments is to avoid the train being tripped to a stop when the locomotive is passing an automatic signal at the stop position. For further instructions regarding the use of this device see General Appendix on "Working of goods trains hauled by electric locomotives."

(b) **PARTS OF THE EQUIPMENT.**

Two electrically driven **air compressors** which furnish the compressed air for use in the air brake system and other air operated devices.

Two **air compressor governors** which automatically control the operation of the air compressors so as to maintain the main reservoir pressure between 87 and 100 lbs.

Two **main reservoirs** into which the compressed air is delivered and where it is cooled and stored for use as required. Each main reservoir is provided with a drain cock to enable the reservoirs to be frequently drained.

A **main reservoir safety valve** which is adjusted to open at 110 lbs. and thereby prevent the accumulation of excessive main reservoir pressure.

A **duplex check valve** which delivers compressed air to the whistle and pantograph reservoir only

when there is a pressure of 80 lbs. or more in the main reservoir.

A **duplex air pressure gauge** in each driving compartment, fitted with a red and a black pointer. The red pointer indicates main reservoir pressure and the black pointer brake pipe pressure.

A **single pointer pressure gauge** in each driving compartment which indicates brake cylinder pressure when a straight air brake application is made.

A **brake valve isolating cock** in each driving compartment to enable the main reservoir pressure to be isolated from the driver's equalizing brake valve.

A **driver's equalizing automatic brake valve** in each driving compartment which controls the flow of compressed air from the main reservoir to the brake pipe to charge and release the automatic brake, and from the brake pipe to atmosphere to apply the automatic brake. This brake valve handle has five operating positions, viz., I. *Charging and releasing,* II. *Running,* III. *Lap,* IV. *Service application,* V. *Emergency application.*

An **automatic feed valve** which regulates the air pressure in the brake pipe at 70 lbs. whilst the handle of the driver's equalizing brake valve is in running position. It also provides for excess pressure being carried in the main reservoir for the efficient release of the automatic brakes and operation of the straight air brake.

A **brake valve equalizing reservoir** in each compartment to assist the driver to more efficiently manipulate the automatic brakes.

A **pressure reducing valve** located on the pipe connecting the main reservoir pipe to the driver's straight air brake valve in each driving compartment. It is adjusted to provide a maximum straight air brake pressure of 45 lbs. in the brake cylinder when the straight air brake is fully applied.

A **driver's straight air brake valve** in each driving compartment which controls the application and release of the straight air brake.

An **improved triple valve** which operates automatically to control the flow of air from the brake pipe to charge the auxiliary reservoir; from the auxiliary reservoir to the brake cylinder to apply the brake; and from the brake cylinder to atmosphere to release the brake.

A **triple valve bracket** embodying a double check valve which separates the two air brake systems so that the operation of either system may be achieved as desired.

An **auxiliary reservoir** in which is stored the compressed air for the application of the automatic brake on the locomotive.

A **brake cylinder** with piston, rods and levers so connected that when the piston is forced outwards by compressed air the brake blocks are forced on to the wheels.

A **hand release valve** in each driving compartment which is connected to the brake cylinder and serves to hand release the air brake when required.

An **automatic brake slack adjuster** which automatically maintains a constant brake piston travel provided the brake rigging is properly adjusted.

A **brake cylinder safety valve** adjusted to open at 50 lbs. pressure is fitted on the brake cylinder pipe to avoid wheel sliding due to the development of excessive brake cylinder pressure in the event of the pressure reducing valve overfeeding, or when a full automatic brake application is superimposed on a heavy straight air brake application.

A **safety apparatus isolating cock** at each end of the locomotive which controls the cutting in or out of the trip gear and the control governor.

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Various cut-out cocks, brake pipe cocks, hose coupling pipes and other fittings, incidental to the air piping are included in the equipment, the location and purpose of which will be understood from their position on diagram No. 7. Illustrated descriptions of various parts of the air brake equipment and their operation are also contained in the "Book of instructions governing the Westinghouse air brake as fitted to electric trains."

226. **THE HAND BRAKE.**

The hand brake is located in the No. 2 driving compartment between the assistant's seat and the dividing partition.

227. **COMPRESSED AIR OPERATED SANDING EQUIPMENT.**

There are eight sand boxes and sand ejectors on the locomotive, one to each wheel. With the standard arrangement the compressed air for their operation is supplied from the main reservoir pipe direct and is controlled by a hand valve in each driving compartment so arranged that, when the valve is opened, sand is applied in advance of the leading wheels of each bogie in the direction of running.

228. **TRAIN DISC BOX.**

The train disc box is situated in the cab at No. 2 end on the side wall above No. 2 train cable connection box.

CONTROL CIRCUITS FOR ACCELERATING STEPS.

(See Diagrams Nos. 8 to 21 inclusive.)

231. **STEP NO. 1 FOR FORWARD RUNNING**—(See diagrams Nos. 8 and 9).

From finger **A** of the controller through the feed

switch to finger **B** and thence to No. 3 finger and the reverser segment for Nos. 3 and 1 circuits respectively.

No. 1 circuit. From controller reversing cylinder to the following points in succession :—

(a) No. 1 train cable connection box—No. 1 terminal.
(b) No. 1 control cut-out switch and fuse.
(c) No. 1 terminal of No. 1 contactor box.
(d) Coil of No. 2 contactor.
(e) No. 1 (Top) contact of the interlock of No. 3 contactor.
(f) Coil of No. 4 contactor.
(g) No. 1 contact of the interlock of No. 5 contactor.
(h) No. 1 resistance tube (150 ohms).
(i) No. 1E terminal of No. 1 contactor box terminal board.
(j) No. 1E terminal of No. 2 contactor box terminal board.
(k) No. 1 contact of the interlock of No. 17 contactor.
(l) Coil of No. 16 contactor.
(m) No. 1 contact of the interlock of No. 15 contactor.
(n) Coil of No. 14 contactor.
(o) Rail.

No. 3 circuit. From finger 3 on controller to the following points in succession :—

(a) No. 1 train cable connection box—No. 3 terminal.
(b) No. 3 control cut-out switch and fuse.
(c) No. 4 contact of the interlock of No. 1 compressor and protective relay.
(d) Reset interlock of No. 1 line breaker.
(e) No. 1 contact of the interlock of No. 1 line breaker.
(f) No. 3 contact of the interlock of No. 1 contactor.
(g) Coil of No. 1 contactor.
(h) No. 13 resistance tube—200 ohms.
(i) No. 1 contact of the interlock of No. 12 contactor.

(j) No. 3G terminal of No. 1 contactor box terminal board.
(k) No. 3G terminal of No. 2 contactor box terminal board.
(l) No. 1 contact of the interlock of No. 13 contactor.
(m) Coil of No. 23 contactor.
(n) Coil of No. 24 contactor.
(o) No. 10 terminal of No. 2 contactor box terminal board.
(p) No. 10 terminal of No. 1 contactor box terminal board.
(q) No. 10 fuse and control cut-out switch.
(r) No. 10 finger on controller.
(s) Controller drum contact segments.
(t) **D** finger on controller.
(u) Rail.

It will be observed that when No. 1 contactor is energised the positions of its interlock contacts are reversed, i.e., No. 3 contact of the interlock opens and No. 4 contact closes. The circuit current then passes from the reset interlock to No. 1 line breaker—in lieu of **e** and **f** above— as follows:—

e1 No. 1 contact of the interlock of No. 1 line breaker in parallel with No. 4 contact of the interlock of No. 1 contactor, to
f1 Coil of No 1 line breaker,
and thence in accordance with **g** to **u** above.

When No. 1 line breaker closes, its No. 1 contact of the interlock opens, and No. 3 circuit is maintained via No. 4 contact of the interlock of contactor No. 1, the coil of No. 1 line breaker, and thence in accordance with **g** to **u** above.

This interlocking arrangement ensures that the line breaker is the last switch to close in the traction motor circuit. It should be noted that circuit No. 3 remains energised in the above form during steps 1 to 6 inclusive.

[Instruction 231.

232. **STEP NO. 1 FOR REVERSE RUNNING.**

From controller finger **A** through the feed switch to finger **B** and thence to No. 3 finger and the reverser segments for Nos. 3 and 2 circuits respectively.

No. 3 circuit. Same as that for step No. 1 for forward running.

No. 2 circuit. From controller reversing cylinder to the following points in succession:—

(a) No. 1 train cable connection box—No. 2 terminal.
(b) No. 2 control cut-out switch and fuse.
(c) No. 2 terminal of No. 1 contactor box.
(d) No. 1—top—contact of interlock of No. 2 contactor.
(e) Coil of No. 3 contactor.
(f) No. 1 contact of interlock of contactor No. 4.
(g) Coil of No. 5 contactor.
(h) No. **2** resistance tube—150 ohms.
(i) No. **2E** terminal of No. 1 contactor box terminal board.
(j) No. **2E** terminal of No. 2 contactor box terminal board.
(k) Coil of No. 17 contactor.
(l) No. 1 contact of the interlock of No. 16 contactor.
(m) Coil of No. 15 contactor.
(n) No. 1 contact of the interlock of No. 14 contactor.
(o) Rail.

NOTES:

(a) Having fully described Nos. 1, 2 and 3 circuits, no reference will be made in steps Nos. 2 to 12 to the connection boxes and/or terminal boards.

(b) It should be noted that at No. 2 connection box each train cable wire, except Nos. 1 and 2, is connected to the terminal bearing its distinguishing number. In order that the control circuits may be correctly energised for the **forward** or **reverse** operation of the locomotive from

either end, Nos. 1 and 2 wires (Nos. 1 and 2 control circuits) are cross-connected at No. 2 end, i.e., at No. 2 train cable connection box No. 1 wire is connected to No. 2 terminal and vice-versa.

Note.—These wires are similar to wires Nos. 4 and 5 on the electric train stock.

(c) Either circuit No. 1 or circuit No. 2 remains energised during steps Nos. 1 to 12 inclusive.

233. **STEP NO. 2** (Diagram No. 10).

No. 8 circuit energised as follows: From No. 3 controller finger through controller drum contact segments to No. 8 finger and thence to following points in succession:

(a) No. 8 control cut-out switch and fuse.
(b) Nos. 5, 6, 7 and 8 resistance tubes—200 ohms.
(c) Coil of No. 7 contactor.
(d) Rail.

234. **STEP No. 3** (Diagram No. 11).

No. 7 circuit energised as follows: From No. 3 controller finger through controller drum contact segments to No. 7 finger and thence to:

(a) No. 7 control cut-out switch and fuse.
(b) Nos. 9, 10, 11 and 12 resistance tubes—150 ohms.
(c) Coil of No. 8 contactor.
(d) Coil of No. 19 contactor.
(e) Rail.

235. **STEP NO. 4** (Diagram No. 12).

No. 6 circuit energised as follows: From No. 3 controller finger through controller drum contact segments to No. 6 finger and thence to:

(a) No. 6 control cut-out switch and fuse.
(b) Nos. 3 and 4 resistance tubes—150 ohms.
(c) Coil of No. 9 contactor.
(d) Coil of No. 20 contactor.
(e) Coil of No. 8 contactor.

(f) Coil of No. 19 contactor.
(g) Rail.

236. **STEP NO. 5** (Diagram No. 13).

No. 5 circuit energised as follows: From No. 3 controller finger through controller drum contact segments to No. 5 finger and thence to:

(a) No. 5 control cut-out switch and fuse.
(b) No. 3 contact of interlock No. 6 contactor.
(c) Coil of No. 10 contactor.
(d) Coil of No. 21 contactor.
(e) Coil of No. 9 contactor.
(f) Coil of No. 20 contactor.
(g) Coil of No. 8 contactor.
(h) Coil of No. 19 contactor.
(i) Rail.

237. **STEP NO. 6** (Diagram No. 14).

No. 4 circuit energised as follows: From No. 3 controller finger through controller drum contact segments to No. 4 finger and thence to:

(a) No. 4 contact cut-out switch and fuse.
(b) No. 1 contact of interlock of No. 6 contactor.
(c) Coil of No. 11 contactor.
(d) No. 2 contact of interlock of No. 23 contactor.
(e) Nos. 6, 7 and 8 resistance tubes—200 ohm.
(f) Coil of No. 7 contactor.
(g) Rail.

238. **STEP NO. 7** (Diagrams Nos. 15 and 16.)

No. 3 circuit. Same as described for Step No. 1 for **forward** running as far as No. 1 contact of the interlock of No. 13 contactor—a to 1 inclusive—then, as No. 10 controller finger opens circuit, No. 11 closes, and the circuit is made as follows:—

(a) to (l) as for Step No. 1, then—
(m) Coil of No. 18 contactor.
(n) Coil of No. 6 contactor.

(o) No. 5 contact of interlock of No. 1 compressor and protective relay.
(p) No. 11 fuse and control cut-out switch.
(q) No. 11 finger on controller.
(r) Controller drum contact segments.
(s) **D** finger on controller.
(t) Rail.

It will be noted that as a result of the de-energising of No. 10 circuit and the energising of No. 11 circuit, Nos. 6 and 18 contactors close and Nos. 23 and 24 contactors open.

239. **STEP NO. 8** (Diagrams Nos. 16 and 17).

No. 3 circuit remains made—as far as and including the coil of No. 1 contactor—the same as steps Nos. 1 to 7, **a** to **g** inclusive. From this point the circuit on step No. 8 is as follows:—

(h) No. 2 contact of interlock of No. 1 contactor.
(i) Reset interlock of No. 2 line breaker
(j) No. 1 contact of interlock of No. 2 line breaker.
(k) No. 3 contact of interlock of No. 13 contactor.
(l) Coil of No. 13 contactor.
(m) No. 1 contact of interlock of No. 23 contactor.
(n) No. 1 contact of interlock of No. 24 contactor.
(o) Coil of No. 12 contactor.
(p) Motor cut-out auxiliary switches.
(q) No. 9 fuse and control cut-out switch.
(r) No. 9 finger on controller.
(s) Controller drum contact segments.
(t) **C** finger on controller.
(u) Rail.

It will be noted that when No. 13 contactor is energised the positions of its interlock contacts are reversed, i.e., No. 3 contact of the interlock opens, and No. 4 contact closes. The circuit then passes from the reset interlock of No. 2 line breaker as follows:—

j No. 1 contact of the interlock of No. 2 line breaker in parallel with No. 4 contact of the interlock of No. 13 contactor to

k Coil of No. 2 line breaker,
and thence to rail in accordance with **1** to **u** above.

When No. 2 line breaker closes, its No. 1 contact of the interlock opens and No. 3 circuit is maintained via No. 4 contact of the interlock of No. 13 contactor and thence to rail as explained above.

This circuit remains energised during steps 8 to 12.

240. **STEPS NOS. 9, 10, 11 and 12.** (Diagrams Nos. 18, 19, 20 and 21).

The control circuits of these steps are the same as those described for steps Nos. 3, 4, 5 and 6 respectively, i.e.,

For Step No. 9 see Step No. 3—circuit No. 7,
For Step No. 10 see Step No. 4—circuit No. 6,
For Step No. 11 see Step No. 5—circuit No. 5,
For Step No. 12 see Step No. 6—circuit No. 4,

except that on Nos. 11 and 12 steps, No. 7 contactor is de-energised by the open-circuiting of No. 8 control circuit and by the opening of No. 2 interlock of No. 23 contactor. Also on step No. 12, No. 4 circuit passes from the coil of No. 11 contactor to rail as follows:—

(d) Nos. 14, 15 and 16 resistance tubes.
(e) Coil of No. 22 contactor.
(f) No. 2 contact of interlock of No. 13 contactor.
(g) Rail.

241. **FUSES IN PANTOGRAPH AND CONTROL CUT-OUT SWITCH BOX** (LEFT TO RIGHT).

No. 15 Pantograph lowering circuit.
No. 14 Pantograph raising circuit.
No. 12 Line breaker reset and No. 1 compressor and protective relay reset.
No. 11 Return wire for No. 3 circuit. In use on No. 7 step only—**Full Series.**
No. 10 Return wire for No. 3 circuit. In use on Nos. 1 to 6 steps only.
No. 9 Return circuit—in conjunction with No. 3 circuit—used on Nos. 8 to 12 **series-parallel** steps.

No. 8 In use of steps 2-5 and 8-10 inclusive.
No. 7 In use on Nos. 3 and 9 steps.
No. 6 In use on Nos. 4 and 10 steps.
No. 5 In use on Nos. 5 and 6 and 11 and 12 steps.
No. 4 In use on Nos. 6 and 12 steps.
No. 3 Retaining circuit, steps 1 to 12.
No. 2 Reverse circuit.
No. 1 Forward circuit.

Notes:

(a) The above fuses, except No. 12, are all of 3 ampere capacity. No. 12 fuse is of 5 ampere capacity and to distinguish it from the others is painted green.

(b) No. 13 circuit is not fused but is connected to a terminal in the box containing the pantograph and control cut-out switches and fuses.

TRACTION MOTOR CIRCUITS FOR ACCELERATING STEPS.

244. **STEP NO. 1** (First Series, Diagram No. 9).

Through line breaker No. 1 to the following points in succession:—

(a) Contactor No. 1.
(b) Motor cut-out switch—Nos. 1 and 2 motors.
(c) **AA1** terminal of No. 1 motor.
(d) No. 1 motor armature and commutating field of No. 1 motor to **A1** terminal.
(e) **AA2** terminal of No. 2 motor.
(f) No. 2 motor armature and commutating field of No. 2 motor to **A2** terminal.
(g) Contactor No. 4.
(h) Main field coils of Nos. 1 and 2 motors, via **FF1** to **F1**, to **F2** and to **FF2**.
(i) Contactor No. 2.
(j) Motor cut-out switch—Nos. 1 and 2 motors.
(k) Resistance sections between **R1** and **R6**.
(l) Contactor No. 24.

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(m) Contactor No. 23.
(n) Resistance sections between **R11** and **R7**.
(o) Motor cut-out switch—Nos. 3 and 4 motors.
(p) **AA4** terminal of No. 4 motor.
(q) No. 4 motor armature and commutating field of No. 4 motor to **A4** terminal.
(r) **AA3** terminal of No. 3 motor.
(s) No. 3 motor armature and commutating field of No. 3 motor to **A3** terminal.
(t) Contactor No. 14.
(u) Main field coils of Nos. 3 and 4 motors, via **FF3** to **F3**, to **F4** and to **FF4**.
(v) Contactor No. 16.
(x) Motor cut-out switch—Nos. 3 and 4 motors.
(y) Ammeter shunt and **kWh.** meter shunt.
(z) Rail.

245. **STEP NO. 2** (Diagram No. 10).

Same as step No. 1 except that the energising of No. 7 contactor short circuits resistance sections **R1** to **R2.**

246. **STEP NO. 3** (Diagram No. 11).

Additional contactors energised are Nos. 8 and 19. When these contactors close, resistance section **R2** to **R3** and **R7** to **R8** are short circuited.

247. **STEP NO. 4** (Diagram No. 12).

Additional contactors energised are Nos. 9 and 20. When these contactors close resistance sections **R3** to **R4** and **R8** to **R9** are short circuited.

248. **STEP NO. 5** (Diagram No. 13).

Additional contactors energised are Nos. 10 and 21. When these contactors close, resistance sections **R4** to **R5** and **R9** to **R10** are short circuited.

249. **STEP NO. 6** (Diagram No. 14).

The additional contactor energised on this step is No. 11. When this contactor closes, resistance section **R5** to **R6** is short circuited.

250. **STEP NO. 7** (**Full Series**—Diagram No. 15).

Through No. 1 line breaker and thence as detailed for Step No. 1 as far as contactor No. 2 and the motor cut-out switch for Nos. 1 and 2 motors. Then through contactors Nos. 6 and 18 and motor cut-out switch for Nos. 3 and 4 motors and thence via Nos. 3 and 4 motors to rail as detailed for Step No. 1.

It will be noted that contactors Nos. 6 and 18 have bridged all resistances and that contactors Nos. 7, 8, 9, 10, 11, 19, 20, 21, 23 and 24 have all been opened. The four traction motors are now in **full series.**

251. **STEPS 7-8 (TRANSITION**—Diagram No. 16.)

The transition of the motor circuits from the **full series** connection to the first **series parallel** connection is brought about as follows:—

It will be noticed from diagram No. 16 that those controller drum contact segments which make contact with No. 11 and **D** fingers overlap the contact segments which make contact with Nos. 3, 8, 9 and **C** fingers so that in passing from No. 7 step to No. 8 step, Nos. 11 and 9 control circuits are momentarily energised at the same time. The result of this is that contactors Nos. 6 and 18—**full series** contactors—do not open until after line breaker No. 2 and contactors Nos. 12, 13 and 7 have closed. The resulting traction motor connections are shown on diagram No. 22, and it will be seen that the transition circuit employed—which enables the motors to be changed from the series to the **series-parallel** connection without opening off the current through the motors—resembles the well-known Wheatstone bridge circuit used for electrical measurements. The transition circuit is therefore known as **bridge transition.**

252. **STEP NO. 8** (**First Series Parallel**—Diagram No. 17).

On this step as explained above, contactors Nos. 6 and 18 are opened and No. 2 line breaker and contactors Nos. 7, 12 and 13 are closed. A separate circuit to

rail through each pair of motors is thus provided as follows:—

Nos. 1 and 2 motors. Through No. 1 line breaker and as for Step No. 2 to contactor No. 7, thence through the resistance sections between **R2** and **R6** to contactor No. 12 and the **kWh.** meter shunt to rail.

Nos. 3 and 4 motors. Through No. 2 line breaker, contactor No. 13, resistance sections between **R11** and **R7** to motor cut-out switch for Nos. 3 and 4 motors. Thence via armatures and fields of Nos. 3 and 4 motors to rail as described in Step No. 1.

253. **STEP NO. 9** (Diagram No. 18).

Additional contactors energised are Nos. 8 and 19. When these contactors close, resistance sections **R2** to **R3** and **R7** to **R8** are short circuited.

254. **STEP NO. 10** (Diagram No. 19).

Additional contactors energised are Nos. 9 and 20. When these contactors close, resistance sections **R3** to **R4** and **R8** to **R9** are short circuited.

255. **STEP NO. 11** (Diagram No. 20).

On this step No. 7 contactor opens and Nos. 10 and 21 contactors close. This results in short circuiting resistance sections **R4** to **R5** and **R9** to **R10.**

256. **STEP NO. 12** (Diagram No. 21).

Additional contactors energised are Nos. 11 and 22. When these contactors close all resistance sections are short-circuited and thereby in effect cut out of circuit. The motors are now in full **series-parallel.**

257. **GENERAL NOTE.**

Contactors Nos. 2, 3, 4, 5, 14, 15, 16 and 17 are field reversing contactors and thereby motor reversing contactors. For **forward** running—i.e., No. 1 end lead-

ing—Nos. 2, 4, 14 and 16 are closed, and for reverse running—i.e., No. 2 end leading—Nos. 3, 5, 15 and 17 are closed.

OPERATION OF ELECTRIC LOCOMOTIVES Nos. 1102-1111.

260. PREPARATION OF LOCOMOTIVE FOR SERVICE.

SINGLE UNIT

The employee preparing the locomotive for service should enter the locomotive at the No. 1 end and proceed as follows.

1. See that the pantograph two-way cock and the pantograph isolating switch are in the required positions and that the pantograph safety air cock is closed.
2. Raise the leading pantograph by one of the following means,
   (a) If the main reservoir gauge shows 80 or more lb. per square inch, place the three-way service cock in the No. 1 position and raise by the magnet valve, or,
   (b) If there is not sufficient main reservoir air to raise the pantograph, place the three-way service cock in the No. 2 position and open the storage reservoir (s) or,
   (c) If there is not sufficient air in the storage reservoirs to raise the pantograph, close the storage reservoirs and operate the hand pump.
3. When the pantograph is in contact with the overhead wire, close the dynamotor switch, and then all other switches on the main switch boards. Operate the control and line-breaker reset switch to start No. 1 compressor.
4. Whilst the main reservoir system is being charged, check the following:—

   Lights, (a) car lights.
   (b) marker lights at both ends.
   (c) head lights at both ends for dim and full operation.

Check that the racks for spare fuses and resistance tubes are filled.

See that the locomotive is equipped with:—

Three high speed fuses,
One drag chain,
One 16-core cable,
One kit of tools,
One electric hand lamp,
Three oil lamps trimmed and filled ready for use,
One broom.

5. At No. 2 end, see that the brake valve isolating cock is closed, that the automatic brake valve handle is in the charging or release position, and that the straight air brake valve handle is in the lap position.
   See that the reverser is in the neutral position and the controller off.
   Return to the No. 1 end.
6. When the main reservoir pressure reaches 80 lb. per square inch, secure the pantograph by raising with the magnet valve and placing the three-way service cock in the No. 1 position.
   Recharge the storage reservoirs by placing the three-way service cock in the No. 3 position, and wait until the compressors stop. Close the storage reservoirs valves and return the three-way service cock to the No. 1 position.
7. Drain both main reservoirs.
8. Open the brake valve isolating cock at the leading end of the locomotive and charge the brake pipe.
   Then test both brake valves at the leading end in all five positions.
9. Instruct the fireman to release the hand brake.
   Move the locomotive forward and stop with the automatic brake.
   Move the locomotive back and stop with the straight air brake.
10. Lower the pantograph by opening the pantograph safety cock, place the pantograph isolating switch in the trailing position, open the dynamotor switch, reverse the pantograph two-way cock and raise the pantograph by the magnet valve.
    Close the dynamotor switch, then lower the pantograph electrically.

Open the dynamotor switch and raise the pantograph by the magnet valve.
Close the dynamotor switch and operate the control and line-breaker switch.

11. Apply the automatic brake and instruct the fireman to operate both sand valves.
12. Check that the brake piston travel is within the working limits of from 3 to 5 inches.
Check that the sand valves are working and that the sand is being directed to the rails.
Check that the main reservoir and brake pipe hose connections are coupled to the dummy couplings.
The locomotive is now ready for service.

MULTIPLE-UNITS

The staff at South Dynon are to ensure that the units are correctly coupled, that the 16 core jumper cable is in its correct position and that the main reservoir and brake pipehose connections are coupled and that the main reservoir and brake pipe cocks between the units are open.

The employee preparing the locomotives for service should enter the trailing locomotive and proceed as follows:

1. See that the pantograph two-way cock and the pantograph isolating switch are in the required positions, and that the pantograph safety air cock is closed.
2. Raise the leading pantograph, start the dynamotor and both compressors as per the previous instructions for one unit.
3. Check that both brake isolating cocks are closed and then proceed to the leading locomotive.
4. See that the pantograph two-way cock and the pantograph isolating switch are in the required positions and that the pantograph safety air cock is closed.
5. Raise the leading pantograph, start the dynamotor and both compressors as per the previous instructions for one unit.
6. Whilst the main reservoir system is being charged, proceed as per previous instructions for one unit, recharge the storage reservoirs and place the pantograph three-way service cock in the No. 1 position. Drain both main reservoirs.

7. Lower the pantograph by opening the pantograph safety air cock, place the pantograph isolating switch in the trailing position, and reverse the pantograph two-way cock.
8. Open the dynamotor switch, raise the trailing pantograph by the magnet valve, close the dynamotor switch.
9. Return to the trailing locomotive, recharge the storage reservoirs and place the three-way service cock in the No. 1 position.
10. Lower the pantograph by opening the pantograph safety air cock, place the pantograph isolating switch in the trailing position, reverse the pantograph two-way cock' open the dynamotor switch, raise the trailing pantograph by the magnet valve and close the dynamotor switch.
11. Check the interior of the locomotive as per instructions for one unit, see that all brake valves are in the release position, and that both controllers are in the "off" position, and the reverser key is removed from the controller.
12. Drain both main reservoirs and if lights are not required, open the dynamotor switch. Return to the leading locomotive.
13. On the leading locomotive, open the leading brake valve isolating cock, charge the brake pipe, then test both brake valves at the leading end in all five positions.
14. Instruct the fireman to release the hand brakes.
    Move the locomotives forward and stop with the automatic brake.
    Move the locomotives back and stop with the straight air brake.
15. Open the control cut-out switch on the leading locomotive, and operate the controller forward and back on the first step, to check the operation of the trailing locomotive.
    Close the control cut-out switch on the leading locomotive.
16. Lower both pantographs electrically, open the dynamotor switch on the leading locomotive, raise the pantograph on the leading locomotive by means of the magnet valve. Close the dynamotor switch, then

returned to the **Full Series** or to the **off** positions and not to a resistance step.

When two locomotives are operating in parallel, and a pair of motors become defective, stepping up on the controller should be carried out in accordance with one of the following alternatives:—

(a) If one locomotive will haul the load, all the traction motor circuits on the defective locomotives should be cut out by opening the control cut-out switch and operating the sound locomotive by means of the controller at either end of the block comprising the two locomotives. It should be noted that when driving from the defective locomotive, there will be no reading on the ammeter and the driver should be guided by experience when stepping up on the controller.

(b) If one locomotive will not haul the load, the defective motors should be cut out by the motor cut-out switch and the sixteen core jumper should be removed from between the locomotives. The driver should then instruct his assistant to drive the rear locomotive. The driver of the defective locomotive should advance his controller from each notch at 200 amperes instead of the normal figure of 250 amperes while the driver of the sound locomotive operates at the normal figure (250 amperes).

Note.—It should be noted that when a pair of motors is cut out of circuit on a defective locomotive, the interlock contacts of the motor cut-out switch prevent any alteration in the traction motor circuits from the **full series** connection when the controller is advanced beyond that point. There is, therefore, no necessity to advance the controller beyond the **full** series position although no harm to the locomotive equipment will result if this is done.

[Instruction 261.

262. OPERATION OF LOCOMOTIVES IN PARALLEL.

As referred to in the section of this instruction book dealing with the train cable and jumper, electric locomotives may be coupled together and their operation controlled from any of the driving cabs.

In this respect, attention is drawn to the provision of the General Appendix on "Working of goods trains hauled by electric locomotives."

263. ARRANGEMENT OF AIR BRAKE EQUIPMENT IN SERVICE.

(a) When an electric locomotive is in service the air brake equipment in each driving compartment must be arranged as follows whilst the air brakes are released:—

Driving Compartment.

Drivers straight air brake valve—*Release* position.

Driver's equalizing automatic brake valve—*Running* position.

Brake valve isolating cock—Open.

Non-driving Compartment.

Drivers straight air brake valve—*Lap* position.

Driver's equalizing automatic brake valve—*Release* position.

Brake valve isolating cock—Closed.

(b) When two or more electric locomotives are coupled to run together, the air brake equipment in the leading or controlling locomotive must be arranged as shown in Clause (a) hereof, whilst that in each driving compartment of the other locomotives must be arranged as follows:—

Drivers straight air brake valve—*Release* position.

Driver's equalizing automatic brake valve—*Release* position.

Brake valve isolating cock—Closed.

264. TRAIN HANDLING AND BRAKE MANIPULATING.

To apply the automatic brakes with moderate force the driver's brake valve must be moved to *service* position until a brake pipe reduction of 6 to 8 lbs. has been made when it should be returned to *lap* position. This minimum brake pipe reduction is necessary to ensure that the brake cylinder pistons are forced beyond the leakage grooves in the wall of the cylinders.

When the brakes have thus been applied, further graduated reductions of brake pipe pressure will correspondingly increase the brake power as desired. The brakes, however, become fully applied when a brake pipe pressure reduction of 25 lbs. has been made as this results in the pressures in the auxiliary reservoir and the brake cylinder equalizing, and any further reduction of brake pipe pressure would merely be a waste of compressed air.

Should, however, an emergency application of the air brakes be required, the driver's brake valve must be immediately placed, and left in *emergency* position until the train comes to a stop.

If the brakes are applied from any point of the train other than by the driver's brake valve, such as by the guard, or by a hose coupling pipe bursting, the driver must, unless he considers it dangerous to do so, assist to stop the train as quickly as possible.

Every driver must be particularly careful in the use and management of the air brakes when descending long and steep gradients. Before commencing the descent he must be satisfied that the brakes are operating properly throughout the train and that sufficient air pressures can be maintained. In making the descent careful manipulation of the brakes is required to prevent waste of compressed air by too frequent applications without providing release periods of sufficient length to ensure the recharging of the auxiliary reservoirs.

Should a driver have any doubt, particularly during darkness, as to whether his train may have accidentally

divided in running, he must place the brake valve in *lap* position and the brake pipe pointer of the duplex pressure gauge will then immediately indicate an open brake pipe if the train has divided.

When making ordinary air brake applications to stop a locomotive or train, the driver's brake valve must be used in *service* position. *Emergency* position must not be used except in cases of emergency, otherwise dirt and grit from the brake pipe will be deposited between the rotary valve and its seat in the driver's brake valve. This will cause the brake valve to become difficult to operate and will increase the wear of the valve faces.

When two or more electric locomotives are coupled together to run light or are attached to a train the driver of the leading locomotive must take charge of the air brake and manipulate it as he would on a single headed train. He must see that the hose coupling pipes are properly connected between the locomotives with their corresponding brake pipe cocks fully open and must satisfy himself that all brake valve isolating cocks except that in the leading driving compartment are closed.

Whilst a train is in running, the driver's equalizing automatic brake valve, except when it is being used to apply or release the brakes, must be kept in *running* position for the following reasons:—

(a) To maintain an excess pressure of about 25 lbs. in the main reservoirs, which will enable the driver to release the train or locomotive brakes more efficiently when desired.

(b) To ensure an automatic application of the train brakes in any of the following circumstances:—

I. The application of the brakes by the guard or shunter.

II. The train accidentally dividing.

III. The bursting of a hose coupling pipe.

IV. The fracture or uncoupling of any air pipe, or the failure of any compressed air joint between the air compressor and any triple valve on the locomotive or train.

Should the driver become aware that the train brakes have been applied from some point other than at the driver's brake valve, he must exercise great care to ascertain that none of the conditions detailed in clause (b) hereof are present, before releasing the brakes with his brake valve. In any case of doubt the train must be stopped and the cause of the irregular application ascertained.

When a driver takes charge of any train in circumstances such as when effecting relief of another driver, or changing over, he must, on receipt of the guard's starting hand signal and before starting the train, make an equalizing brake application and then release in the prescribed manner.

Should a driver find that his train is being retarded by the irregular application of the brakes on any vehicle or vehicles, he must stop his train under the protection of fixed Signals, if practicable, and make an examination of the vehicles concerned.

At stations and sidings where shunting operations are performed with the air brake in operation on the vehicles attached to the locomotive, the driver must keep the equalizing brake valve in *running* position when the brakes are not applied in order to prevent the brake pipe and auxiliary reservoirs being charged above standard pressure. This will avoid any subsequent release difficulties that may develop as a result of the fact that when vehicles having different air pressures are coupled together the brake will automatically apply on those having the highest pressure.

At locations where shunting movements of rakes of vehicles are made with the air brake in operation on the locomotive only, the driver must exercise great care in applying the locomotive brake in order to reduce the harsh effects of coupling slack action. If controlling the movements with the straight air brake, the driver's equalizing automatic brake valve must be kept in *running* position.

Every driver should adopt the habit of observing the strength and duration of the brake pipe exhaust when

making a brake application. This will enable him to determine if the exhaust is proportionate to the length of the train and in this way any obstruction such as would be presented by a closed or partially closed brake pipe cock or other brake pipe obstruction at or near the head of the train can be readily detected. Should any such obstruction be present, the equalizing piston will promptly open the discharge valve, but instead of the air discharge being of normal duration it will quickly weaken or cease altogether according to the location or extent of the obstruction. The closer the obstruction is to the locomotive the earlier the exhaust will weaken or cease.

In the event of any defect developing in the air brake equipment of a train whilst in running, such as the air compressors stopping, an undue loss of air pressure, or any other brake failure that would interfere with the safe control of the train, the driver must bring the train to a stop with as little delay as safely practicable. If the defect cannot be immediately rectified he must notify the guard and confer with him regarding the working of the train through the section, or to its destination, in accordance with the instructions contained in page 602 of the General Appendix.

The automatic air brakes must not be used to hold a train stationary for more than a few moments whilst it is on a falling gradient, as it is essential to release the brakes and recharge the auxiliary reservoirs as soon as possible after stopping. If the straight air brake will not hold the train—which ordinarily it will do, provided the train coupling slack is controlled—hand brakes must be applied on as many vehicles of the train as required.

Delays may arise from connecting portions of trains carrying different air pressures as the air brakes automatically apply on those vehicles having the higher pressure when the brake pipe cocks are opened. To avoid detentions from this cause, the driver should avoid leaving more than 50 lbs. pressure in the brake pipe of the train when the locomotive with or without

any part of the train is to be detached for shunting or any other purpose.

The driver must call the attention of the train examiner, at the first examining station at which his train arrives, to any irregularity in the operation of the air brake equipment on any vehicle in the train. He must also, before leaving duty, or as soon as practicable thereafter, report the matter on Form R.S.12A to the Electric Running Superintendent, giving the number and class of the vehicle or vehicles concerned.

Where there is no train examiner on duty, the driver is responsible for the safe working condition of the air brake equipment on his train and must carry out the Rules and Regulations, and any other instructions issued for the guidance of train examiners when examining and testing the brakes of departure trains.

265. GOODS TRAIN HANDLING.

(a) Coupling slack action.

Damage to the draw and buffer gear of rolling stock on moving trains and to the loading contained therein is caused by coupling slack action, that is, the amount of slack movement that may occur between adjoining vehicles when coupled together. The total length of the coupling slack depends on the number of vehicles in the train.

There are two kinds of coupling slack, namely, loose slack and spring slack. Loose slack is that which exists between adjoining vehicles without any compression of the draw springs or the buffer springs, as the case may be, whilst spring slack is the additional movement permitted between the vehicles when these springs are compressed. Spring slack also reacts and helps to drive the slack in the opposite direction, thereby increasing the train shocks.

It is obvious also that with no coupling slack, starting and stopping shocks could not occur, neither could it occur if the draw gear was all held in tension or the buffer gear held in compression. The shocks and damage result from its sudden change from one con-

dition to the other and this can occur when starting a stationary train, whilst it is in running, or when it is being stopped. When coupling slack is run in or out rapidly one part of the train attains a higher speed than the other and the resultant shock is caused by the stresses set up in the draw or buffer gear in suddenly making the speed of both parts uniform. The extent of the shock will depend partly on the difference in speed of the vehicles in the train and partly to the weight that must be suddenly altered in speed.

Coupling slack action cannot be prevented, but it can be effectively controlled and its harsh effect reduced by the driver acquiring a knowledge of its various causes as a result of practical observation and by then anticipating and countering it by proper train handling and brake manipulation. Smooth train handling therefore depends entirely on the ability of the driver to control the coupling slack and prevent it being changed suddenly.

Coupling slack cannot be changed both gently and quickly, and the driver must realize this fact when power, grade, or brake action is about to change the slack when the train is being started, stopped, or is in running. When the coupling slack is in process of changing under any of these conditions, ample time must be allowed by the driver for the run of slack to be completed before taking any action that would tend to hasten the change or reverse its direction, otherwise severe shocks must be produced. No attempt must be made to place the controller in the **on** position following the release of the brake until the driver has satisfied himself by observation of the pressure gauge that sufficient brake pipe pressure has been restored to insure that the brakes are properly released on the rear vehicles in the train.

A further condition that has a material effect on coupling slack action is the group marshalling of empty and loaded vehicles in a goods train. The braking power of empty vehicles is approximately three times greater than that of loaded vehicles and the location

in the train of groups of loaded and empty vehicles will cause severe coupling slack action in adverse circumstances.

A train which is marshalled with grouped empty vehicles at the head end and grouped loaded vehicles at the rear will provide the best conditions for eliminating severe coupling slack action during normal service brake applications in running, and when releasing the brakes after reducing speed, but should an emergency or even a heavy service brake application be made at a moment when the draw gear is in tension, whilst running, particularly at low speed, severe buffing compression must eventuate which will probably cause damage to rolling stock and loading.

Existing instructions provide for goods trains being marshalled as far as practicable with the loaded vehicles at the locomotive or head of the train, and under these conditions the driver must exercise extreme care in train handling to avoid the possible results of severe coupling slack action during brake operations, particularly at low speeds.

Whilst a train is in running and the controller has been returned to the **off** position for the purpose of applying the brakes under normal conditions to reduce speed, ample time must be allowed for the coupling slack to be run in gradually before the brake application is commenced and even then the brakes must be applied in graduations.

If the coupling slack, due to grade conditions, is either all in or all out prior to the brakes being applied, any brake action that would tend to run it in the same direction could not cause any severe shock. As a general rule, whilst the train is running forward, a condition where all slack has run in is the most favourable for an application of the brakes, and where the slack has run out, for the release of the brakes.

(b) **Starting.**

When starting a goods train, the locomotive must be started slowly and kept at a uniform low speed for about a locomotive length to enable the coupling slack

to be stretched gradually and uniformly, and this practice must be adopted as a general rule regardless of the length of the train. It has to be remembered that when a train is being started, each vehicle in succession must be brought from a stationary condition to the speed of the locomotive at the moment, and if the locomotive acceleration is increased whilst the coupling slack is being stretched, very severe slack action must occur, particularly on long trains.

Should it be necessary to reverse the locomotive to obtain coupling slack for starting, it must be eased up slowly and must not be again reversed until the entire train has stopped. If a brake application should be necessary when easing up, the locomotive brakes must be prevented from applying by means of the hand release valves, whilst the train brake application is being made.

When a train has been stopped by an application of the air brakes, sufficient time must be allowed for the brakes on the entire train to release before any attempt is made to restart it.

In order to insure the prompt release of the train brakes when a locomotive is recoupled to its train after being cut off for any purpose, or when a fresh locomotive is attached to the train, the driver must place the automatic brake valve in *lap* position after reaching the train in order to obtain maximum main reservoir pressure before he attempts to release the train brakes.

(c) **Running.**

The driver must frequently observe the air pressure gauges and be prepared to act promptly if any improper condition is indicated. He should observe the pressure gauges as far as possible during brake applications and releases in order to enable him to more efficiently manipulate the air brake equipment.

Uniform and correct regulation of the brake pipe and main reservoir pressures have an important bearing on good brake operation, therefore the driver must determine from the air pressure gauges that the feed

valve and air compressor governors are functioning correctly. The uniform regulation of brake pipe pressure is particularly important as any pressure variation permitted by the feed valve of three pounds or more is almost certain to cause sticking brakes.

If the standard brake pipe pressure cannot be maintained with the automatic brake valve in *running* position, it must not be placed and left in *release* position except in the case of a feed valve failure. In any such case, however, the driver must take particular care to insure that the brake pipe pressure is not being reduced from some irregular cause, and in any case of doubt, the train must be stopped within the protection of fixed signals if practicable, and the cause of the irregularity ascertained.

Train running safety down long heavy falling gradients, in so far as air brake control is concerned, depends on the ability of the brake equipment to not only provide the usual retardation necessary to stop the train on level track, but to also overcome the gravitational pull down the grade. Efficient manipulation of the air brake equipment by the driver, therefore, is necessary to enable him to safely control the speed of the train as well as to maintain sufficient reserve braking power to stop it on the grade if required.

Although standing brake tests may indicate that the air brake equipment of a train is in good order, its braking efficiency can only be determined by the retarding effect of the first running brake application made at the top of the grade. This application, therefore, must be made whilst the speed is still low in order to determine the subsequent action necessary to safely control the train down the grade.

The retarding effect of the air brakes during serial braking on long grades is chiefly dependent on the prompt recharging of the auxiliary reservoirs during the release and charging periods and this is determined largely by the condition of the triple valve feed grooves. All feed grooves cannot be depended upon to be perfectly clear and the extent to which they are

capable of providing a quick recharge of the auxiliary reservoirs can only be determined by actual experience when controlling the train down the grade.

It is impossible to maintain a uniform speed down a long grade and yet retain safe control of the train, for the reason that the speed must be so reduced during a brake application that ample time will be provided for the auxiliary reservoirs to be fully recharged before the train accelerates to a speed that necessitates the next serial brake application being commenced. Further, in order to reduce the consumption of compressed air to a minimum, the air admitted to the brake cylinders should not be discharged to atmosphere until it has performed sufficient work in retarding the train.

Speed and air pressures must be frequently and carefully observed during the descent of the grade. *Speed down and pressures up mean safety, whilst the reverse means danger.*

(d) **Reducing Speed and Stopping.**

When applying the brakes on a goods train either to reduce speed or stop the train, one graduated brake application should be made as a general rule. The initial brake pipe reduction must be from 6 to 8 lb. and additional reductions then made as required, allowing sufficient time between successive reductions for the coupling slack to become adjusted. If the train is to be stopped, the final *service* reduction should be commenced when the locomotive is about a length from the stopping point to ensure that the air will be still discharging from the equalizing exhaust port of the driver's brake valve when the train comes to a stop.

When circumstances necessitate the locomotive being powered during the immediate approach to a stopping point the controller must be returned to the **off** position in ample time to allow the coupling slack to run in gradually before the brake application is commenced.

If power is required right up to the stopping point, it should be gradually eased off until the speed is reduced to a walking pace when the brake application

may then be made. The object of this is to keep the coupling slack stretched as much as possible.

If a train is rolling slowly backwards towards a stopping point, after the controller has been placed in the **off** position the coupling slack will tend to run out and the train brakes must then be applied with a light application and held until the driver is satisfied that the coupling slack has all run out when the brake application can be increased as required.

Spot stops with long trains must not be attempted, that means that the train must not be run up to stop accurately at a definite point such as for van goods. It must be stopped smoothly a few yards short of the required spot and then moved ahead very slowly to the stopping point. Spot stops cannot be regularly made without setting up severe coupling slack action.

The best method of stopping a long goods train depends generally on local conditions and these being known to the driver he can employ the most suitable of the foregoing methods in order to efficiently control the speed of his train and stop it smoothly where required.

When a brake application is required to reduce the train speed to conform with a speed restriction or other slow down, the initial service brake application must be between 6 and 8 lb. and after the coupling slack has become adjusted, further service reductions must then be made as required. The running release must not be attempted unless the brake pipe pressure has been reduced by 15 lb. and the speed is sufficiently high to enable the release to be satisfactorily achieved without setting up severe coupling slack action, otherwise the brakes must be left applied until the train comes to a stop when the release can then be satisfactorily accomplished.

The severity of coupling slack action during an application or release of the brakes depends on the speed of the train and the value of the brake application. This is due to the fact that brake block friction, which

is the actual retarding power, is directly greater with the same brake application as the speed is lower, and because the harder the brakes are applied, the more rapidly those on the rear vehicles, which commence to release last, will run out the coupling slack. This explains why the slower releasing rear brakes, particularly following a heavy brake application, are liable to cause a break away when the train brakes are released at low speed, yet will not cause any severe coupling slack action when they are released at higher speeds. It follows, therefore, that the lighter the brake application at any particular speed, the less will be the coupling slack shock produced during the release.

(e) **Releasing brakes.**

In order to properly release the brakes after an application has been made, particularly on long trains, it is essential that as much pressure as possible built up in the brake pipe above that remaining in the auxiliary reservoirs. For this purpose, it is necessary that a large volume of compressed air be maintained in the main reservoirs. To then provide the maximum excess pressure on the brake pipe sides of the triple valve pistons, to insure their movements to release position, it is also necessary to reduce the pressure in the auxiliary reservoirs to their lowest value whilst the brakes are applied. The nearer the brakes are applied to a full *service* application the more prompt and certain will be the release, and it is very undesirable, therefore, to attempt the release following a light brake application from standard brake pipe pressure. Should circumstances necessitate a light application being made to stop a train, the brake pipe reduction should be continued to 25 lbs. after stopping before the release is attempted.

Whilst it may be necessary under certain circumstances in running to make a light brake application for slowing down purposes without it being practicable to increase the brake pipe reduction before releasing, such conditions should be avoided as far as possible.

The coupling slack shock produced by releasing the automatic brakes whilst the train is running at low speeds can be materially reduced by proper use of the straight air brake on the locomotive, particularly if the head of the train is on a straight track and the rear end on a curve, as the retarding power of the locomotive brake will assist to prevent the harsh running out of the coupling slack. As a general rule, however, no attempt should be made to release the brakes on long trains after a light brake application has been made, and in no circumstances when the train is running at low speed.

The minimum speed at which the brakes of a goods train can be released without causing severe coupling slack action and possible break aways depends on how heavily they have been applied, the length of the train, whether the coupling slack is then bunched or stretched, and on whether the track conditions such as humps and curves do, or do not, favour releasing. These conditions must be determined by the driver and where adverse releasing conditions are presented he must, if necessary, allow the train to come to a stop before releasing.

The proper length of time to leave the automatic brake valve in *release* position when releasing the brakes depends chiefly on the length of the train and whether a full *service* or *emergency* brake application has been made. After a full equalizing *service* brake application has been made on a standing or running train, the brake valve must be placed in *release* position for a period of one second for each five vehicles in the train and then returned to *running* position. For example, with a train of 30 vehicles, the brake valve must be placed in *release* position for 6 seconds, with 40 vehicles, 8 seconds, with 50 vehicles, 10 seconds, and so on. After the brake valve has been placed in *running* position following the above periods, it must be left in that position until the brake pipe pressure has equalized and has commenced to rise, when it must

be again placed in *release* position for two seconds to make a kick off and then returned to *running* position. The object of the kick off is to release any brakes on the leading vehicles of the train that may have re-applied as a result of a slight overcharge.

To release the brakes promptly after the brake pipe pressure has been exhausted or reduced to a low pressure, such as may occur when the locomotive has been detached for some time, when a hose coupling pipe has burst or the air pressure has been discharged from any other cause, the brake pipe has first to be recharged from the main reservoir to a pressure of approximately 50 lbs. to equal that in the auxiliary reservoir. A further substantial increase in brake pipe pressure will then be necessary to insure the release movement of the triple valves. The brake valve, therefore, must be left in *release* position for reasonably longer periods before it is returned to *running* position than that stipulated for releasing after equalizing *service* applications. One or two kick offs must then be made to release any brakes that may have re-applied as a result of slight overcharge.

It follows therefore from the above that the most favourable condition for releasing brakes on a long train is presented when the train is stationary, with maximum reservoir pressure and the brakes almost fully applied, and that the most adverse release position is presented when the brake pipe pressure is very low, or when it has been completely exhausted by improper brake manipulation, or by an *emergency* application resulting from the train accidentally dividing, or other such irregularity.

After releasing the brakes whilst the train is in running the controller must not be placed in the **on** position until the driver is satisfied that the coupling slack has had time to run out and even then it should be opened gradually to avoid the possibility of severe coupling slack action.

The most common causes of triple valves failing to move to release position when the train brakes are being released is improper brake manipulation by the driver whereby the brake pipe pressure is not quickly and substantially increased above that remaining in the auxiliary reservoirs. This is caused either by the release being attempted after too light an application has been made which results in the auxiliary reservoir pressures not being sufficiently reduced, or by the brake valve not being left in *release* position long enough to provide a rapid increase of brake pipe pressure on the vehicles at the rear of the train. The handle of the brake valve therefore must not be moved alternately between *release* and *running* positions whilst the initial release is being effected as this destroys the continuous flow of main reservoir pressure to the brake pipe that is so essential for the rapid increase of brake pipe pressure necessary to insure a prompt release of the brakes on the rear vehicles of the train.

Triple valves may also irregularly re-apply on vehicles at the head of the train as a result of an auxiliary reservoir overcharge caused by the driver moving the handle of the brake valve alternately and unnecessarily between *release* and *running* positions after the train brakes have been fully released and recharged, particularly when the train is approaching a heavy ascending grade, the object being to insure that all brakes are released. It generally produces the opposite effect, however, to that desired and is therefore very bad practice.

By studying the effect of the air brake operation on the smooth handling of long goods trains, and by analysing his daily experience in practice, a driver can become proficient in anticipating the possibility of severe coupling slack action or brake releasing difficulties and by then exercising the necessary care in his train handling and brake manipulating he can avoid any adverse operating results.

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266. LOCOMOTIVE RATING.

The maximum load that can be hauled by each locomotive depends on the grade up which the load is to be hauled, and a table of allowable loads for various grades is set out hereunder.

Grade	Trailing load
1 in 30 (3.33%)	210 tons
1 in 40 (2.5%)	280 „
1 in 50 (2.0%)	340 „
1 in 100 (1.0%)	570 „
1 in 150 (0.66%)	700 „
1 in 200 (0.5%)	780 „
Level	1200 „

For grades intermediate between these values, see Diagram No. 6.

267. STABLING THE LOCOMOTIVE.

Instructions regarding stabling of trains as laid down in the book of instructions for drivers of electric trains will similarly apply, except that both pantograph storage reservoirs must be left fully charged with compressed air.

OPERATION WITH DEFECTIVE APPARATUS.

Under this heading the following parts will be dealt with:—Pantographs, motors and motor circuit apparatus, dynamotor, compressor and protective relay circuits, control circuits.

270. WITH DEFECTIVE PANTOGRAPH.

Should either pantograph become defective, it must be lowered and the other pantograph used. If, however, a main or high speed fuse blows when a panto-

graph is raised to make contact with the overhead wire, the pantograph must be lowered and assistance obtained—unless the locomotive is coupled to another electric locomotive.

If two locomotives are coupled together, and both pantographs on the leading locomotive become defective, the emergency jumper must be used when it is necessary to operate from the locomotive with the defective pantographs.

271. WITH DEFECTIVE MOTORS AND MOTOR CIRCUITS.

If the main fuse or the high speed fuse should blow twice when the controller is being operated, or if the line breaker keeps opening, it will be necessary to operate the motor cut-out switches to cut out the defective pair of motors—see instructions in electric train instruction book regarding similar trouble on a single unit motor car. When a pair of motors is cut out it will be necessary to step up cautiously.

If a locomotive fails in both directions and Nos. 3 and 10 control circuits are tested and found in order, the fault is in the traction motor circuit. The main switch may be open, a resistance grid broken or an open circuit may exist in the circuit of one pair of motors. When it is definitely ascertained that failure is due to an open circuit in the traction motor circuit, it can be determined whether the defect is a broken resistance grid, or an open circuit involving a pair of motors by stepping up on the controller to the 7th step. If the defect is a broken grid, the locomotive would tend to start when the controller reaches the step on which the defective grid section is cut out. The result of the locomotive starting on other than the first two or three steps would result in the opening of No. 1 line breaker owing to the excessive current flowing in the motor circuit. If such is the case obtain assistance. If, however, the controller can be stepped up to the 7th step—where all resistances would be cut out—and the locomotive does not start, the failure is not due to a

broken grid. In this case care should be taken not to advance the controller beyond the 7th step, because if the defect is an open circuit on a pair of motors, the good pair would start to work on the 8th step, and in doing so would take excessive current and open the appropriate line breaker. The action to be taken in this case is to operate the motor cut-out switches to cut out the defective pair, and the good pair would then operate when the controller is opened to the 1st step.

If two locomotives are coupled together and a traction motor circuit becomes defective in either locomotive, proceed as follows:—

(a) If one locomotive will haul the load, do not delay train by testing for the defect.

(b) If one locomotive will not haul the load, the driver must operate the motor cut-out switches and test for the defective pair of motors. When the defective pair is found, leave the motors cut out, remove the sixteen-core cable jumper from between the locomotives and proceed on journey with the assistant operating the controller of the second locomotive.

See Instruction No. 261 of this instruction book, also special instructions in the General Appendix (Working of Goods Trains Hauled by Electric Locomotives) dealing with a defect in one of two coupled electric locomotives which necessitate the division of the train owing to the inability of a single locomotive to take the load.

272. WITH DEFECTIVE DYNAMOTOR.

If two electric locomotives are coupled and the dynamotor of the leading locomotive becomes defective, the emergency jumper must be placed between the locomotives, thus enabling power to be obtained from the dynamotor of the second locomotive for the operation of the controller, etc., on the leading locomotive. The instructions and safety precautions pertaining to the use of the emergency jumper on the motor cars also apply to the locomotives. If the dynamotor fails on a single locomotive, assistance must be obtained.

273. WITH DEFECT IN NO. 1 COMPRESSOR AND PROTECTIVE RELAY CIRCUIT.

If No. 1 compressor fuse blows twice, open the compressor relay switch and No. 1 compressor cut-out switch. Renew the fuse, close No. 1 compressor and protective relay switch and leave No. 1 compressor cut-out switch open. If, on attempting to set No. 1 protective relay, the fuse blows again, the relay is defective and the locomotive cannot be driven. In this case obtain assistance. If, however, the fuse does not blow the fault is in No. 1 compressor.

If No. 1 compressor and protective relay is open circuited owing to the fuse being blown or owing to any one of the ten 500 ohm resistance tubes being defective, the interlocks of the relay will rattle when an attempt is made to reset it. When this indication is given change the fuse, if the fuse does not then blow the fault may be in one of the 500 ohm resistance tubes or the second contact of the interlock of the relay.

If the locomotive fails, and No. 1 compressor will not work, and after opening and closing No. 1 compressor and protective relay switch and operating the control and line breaker reset switch for an arc, the protective relay is not heard to reset, the defect may be in one of the 600 ohm resistance tubes.

In either of the above cases the services of a troubleman must be obtained—if possible—to deal with the defect. Should, however, the defect occur where the services of a troubleman cannot be obtained, and where serious delay to traffic would occur, the driver is authorised to deal with the fault as follows:

(a) Lower and isolate the pantograph (see note below).

(b) Remove the defective resistance tube and replace it with a new one from the rack.

If the defect is in one of the ten 500 ohm tubes, and the defective tube cannot be detected by inspection, remove all the tubes and replace them with 10 good tubes from the circuit of No. 2 compressor no-volt relay. Test the removed tubes when convenient.

Note.—Any apparatus not protected by a switch must not be handled until the pantograph is lowered and isolated. It should, therefore, be distinctly understood that as these resistance tubes are directly on the 1500 volt circuit, any neglect to take the necessary precautions would have serious consequences.

274. WITH MAIN CONTROL FUSE BLOWING.

General Note.

Before changing or testing any of the control fuses, the controller must be in the **off** position and the key centred or removed.

If the main control fuse blows twice when the controller is in the **off** position, drive from the other controller.

If the main control fuse blows twice when the controller is being operated, put in a third fuse and test it, then try to drive from the opposite end controller.

If the main control and bus line fuses do not then blow, instruct the assistant to drive under the driver's instruction or if either of these fuses blow, obtain assistance.

If, when the two locomotives are coupled, the main control fuse blows twice when the controller is operated, try the opposite end controller.

If the fuse does not blow, proceed with the assistant driving under the driver's instructions. If the fuse then blows at the rear end, or if the bus line fuse blows, open the control cut-out switch, replace the fuse at the leading end, test it and try to operate the controller. If the fuse does not blow, operate the second locomotive —if it will take the load—by driving from the leading locomotive. If the second locomotive will not take the load, divide the train or obtain assistance, whichever is the more expedient.

If, however, the third fuse should blow on the leading locomotive at the leading end, remove the 16 core jumper from between the locomotives—take it right out—close the control cut-out switch, renew and test the

fuse and try to drive from the leading locomotive again —that is if the locomotive is in order and can take the load. Should one locomotive be unable to haul the load, test the other locomotive, and if in order put in the other 16 core jumper and test both locomotives from the leading end. If the control fuse does not again blow, proceed.

If, after the jumper has been removed, the leading locomotive is still defective, the driver must instruct his assistant to drive the second locomotive—providing one locomotive will take the load. The driver must signal to his assistant—by flag or lamp and by a succession of short whistles—when to apply or shut off power, and he shall brake the train from the leading locomotive. If, however, one locomotive cannot haul the load, obtain assistance or divide the train, whichever is the more expedient.

275. **WITH DEFECT IN NO. 3 CONTROL CIRCUIT.**

No. 3 circuit is not a complete circuit in itself. It is completed to rail via either Nos. 10, 11 or 9 circuits for different positions of the controller handle. Two of the controller fingers **C** and **D** are bonded together and connected to rail, and the contact segments on the controller drum are so arranged that connections are made with the rail fingers when the controller drum is rotated.

These connections provide for No. 3 circuit to be completed to rail as follows:—

(a) Via No. 10 circuit on steps Nos. 1 to 6.
(b) Via No. 11 circuit on full series step No. 7.
(c) Via No. 9 circuit on series-parallel steps Nos. 8 to 12.

Should any one of these circuits (Nos. 10, 11 or 9) become defective, the locomotive would fail only on the steps where the defective circuit is required to complete No. 3 circuit. If No. 3 fuse is blown, it follows that circuits Nos. 10, 11 and 9 will be inoperative until No. 3 fuse is replaced. The first contacts of the interlock of either Nos. 12 or 13 contactors, if defective,

would fail the locomotive on any of steps Nos. 1 to 7, whilst the 2nd contact of the interlock of No. 1 contactor or the 1st contact of the interlocks of either Nos. 23 and 24 contactors would fail the locomotive on steps 8 to 12.

276. **WITH DEFECT IN NO. 10 CONTROL CIRCUIT.**

If No. 10 fuse is blown or the circuit otherwise defective, No. 3 circuit will not operate and the motors will not work while the controller handle is on steps 1 to 6. Should, however, it be rotated to the 7th step where No. 3 circuit is completed to rail via No. 11 circuit, the motors would start working in full series, that is, without any grid resistances in circuit and in doing so would take excessive current and open No. 1 line breaker. For this reason, when the locomotive fails and the contactor knocks are heard, the controller handle should not be rotated past the 6th step unless the circuits have been tested and it has been ascertained that the failure is not due to a fault on No. 10 circuit.

277. **WITH DEFECT IN NO. 11 CONTROL CIRCUIT.**

If No. 11 fuse or circuit is defective, the result is that when the controller handle is rotated to the 7th step, No. 3 circuit would then become open-circuited and No. 1 line breaker would open the motor circuit and cut current off from the motors while the controller remains on that step. If the fault occurred while the locomotive was moving at a reasonably high speed with a corresponding low ammeter reading, and it was not convenient to renew the fuse at once, the controller could be moved on to the 8th step—**first series-parallel.** If the ammeter reading was too high the controller could be returned from the 7th to the 6th step and held there for a short time. It must be understood, however, that should circumstances, such as low speed with a high ammeter reading, not permit of the controller being advanced to No. 8 step, then the handle must not be held too long on any of the series steps

owing to the danger of overheating the grid resistances, but must be returned to the **off** position and the fuse renewed or the defect remedied.

The 5th contact of the interlock of No. 1 compressor and protective relay is on this circuit, so that if on testing No. 11 fuse no fault is found in it, look for the trouble at one of the following places:

(a) The 5th contact of the interlock of No. 1 compressor and protective relay.
(b) No. 11 finger of the controller.
(c) The 1st contact of the interlock of either No. 12 or No. 13 contactor.

278. WITH DEFECT IN NO. 9 CONTROL CIRCUIT.

If No. 9 fuse or circuit is defective, No. 3 circuit would be open-circuited when the controller handle is rotated to the 8th step. This would open No. 1 line breaker and cut off current from the motors, but on returning the controller to the 7th step, the motors would again operate in full series.

Change and test No. 9 fuse, and if the fuse does not blow, reset the set interlocks of the line breakers as the fault may be due to the reset interlock of No. 2 line breaker being open. If this does not effect a remedy, look for the trouble on any of the following:

(a) The 4th contact of the interlock of No. 13 contactor.
(b) The 1st contact of the interlock of No. 23 contactor.
(c) The 1st contact of the interlock of No. 24 contactor.
(d) The 2nd contact of the interlock of No. 1 contactor.
(e) The reset interlock of No. 2 line breaker.
(f) The control circuit switches linked with the motor cut-out switches.
(g) No. 9 finger of the controller.
(h) "C" finger of the controller.

If the 4th contact of the interlock of No. 13 contactor was defective, it would be indicated by the rapid

continuous opening and closing of both line breakers when the controller handle was rotated to the 8th or succeeding steps.

279. **WITH DEFECT IN NO. 8 CONTROL CIRCUIT (STEPS NOS. 2 AND 8).**

If No. 8 circuit is defective, No. 7 contactor will not close on the 2nd and 8th steps to cut out resistance section **R1** to **R2**, but the closing of No. 8 contactor on the succeeding step will cut out this section as well as section **R2** to **R3**. The fault may be easily detected by there being—

(a) no variation of speed;
(b) no increase in the ammeter reading; or
(c) no contactor knocks heard when the controller handle is rotated from the 1st to the 2nd step.

The effect of No. 8 circuit being defective should not be very noticeable when the controller is moved from the 7th to the 8th steps as this movement brings into operation the **series-parallel** connection of the motors. The failure of No. 8 control circuit would cause Nos. 1 and 2 motors to have an extra section of resistance in circuit on the 1st series parallel step. The effect on the ammeter reading would be more marked when the controller is moved from the 8th to the 9th step, as No. 8 contactor then closing would cut out two grid resistance sections instead of one.

The action to be taken is to change No. 8 fuse. If the fuse is found to be sound, examine control resistance tubes Nos. 5, 6, 7 and 8.

See note hereunder at the end of No. 5 circuit in respect to the operation of the controller when a control circuit affecting a motor circuit resistance is faulty.

280. **WITH DEFECT IN NO. 7 CONTROL CIRCUIT (STEPS NOS. 3 AND 9).**

If No. 7 circuit control fuse or the circuit itself is defective, Nos. 8 and 19 contactors would fail to close on the 3rd and 9th steps, with the result that grid re-

sistance sections **R2** to **R3** and **R7** to **R8** would not be cut out on these steps, but on succeeding steps, after which normal working of the locomotive would ensue.

See note on page 78.

To remedy the defect, change No. 7 fuse. If the fuse is sound look for the fault in control resistance tubes Nos. 9, 10, 11 or 12.

281. **WITH DEFECT IN NO. 6 CONTROL CIRCUIT (STEPS NOS. 4 AND 10).**

If No. 6 circuit is defective Nos. 9 and 20 contactors will not close and grid resistance sections **R3** to **R4** and **R8** to **R9** will not be cut out when the controller handle is advanced to either the 4th or the 10th step.

With No. 6 circuit defective, a distinct falling off in power and a drop in the ammeter reading will be noticed when the controller handle is moved from the 3rd to the 4th step due to No. 6 circuit failing to provide a retaining circuit for the contactors which were energised on No. 3 step—Nos. 8 and 19. The opening of these two contactors re-inserts grid resistance sections **R2** to **R3** and **R7** to **R8** in the motor circuit.

When the controller is advanced further to the 5th step, Nos. 8, 9, 10, 19, 20 and 21 contactors will be closed and grid resistance sections **R2-R3-R4-R5** and **R7-R8-R9-R10** will be cut out of the motor circuit and a marked increase in power and a rise in ammeter reading will be noticed.

In series-parallel operation the indications will be similar to those given above. When the controller handle is moved from the 9th to the 10th step, a drop in power and in the ammeter reading will result, but when the controller handle is further advanced to No. 11 step, a distinct increase in power and a rise in the ammeter reading will be noticed and normal operation of the locomotive will ensue.

See note on page 78.

When these indications occur change No. 6 fuse. If the fuse is sound, examine Nos. 3 and 4 control resistance tubes.

282. WITH DEFECT IN NO. 5 CONTROL CIRCUIT (STEPS NOS. 5 AND 11).

If No. 5 circuit fails, Nos. 10 and 21 contactors will not close and grid resistance sections **R4** to **R5** and **R9** to **R10** will not be cut out of the motor circuit on the 5th and 11th steps.

If this circuit fails a marked decrease of power and a fall in ammeter reading will be noticed when the controller handle is moved from the 4th to the 5th step. This is caused by No. 5 circuit failing to provide a retaining circuit for the contactors which were energised on the 3rd and 4th steps—Nos. 8, 9, 19 and 20. The opening of these four contactors re-inserts grid resistance sections **R2-R3-R4** and **R7-R8-R9** in the motor circuit.

When the controller is advanced further to the 6th step, an increase in power and a rise in the ammeter reading will be noticed owing to No. 11 contactor closing and cutting out grid resistance sections **R2-R3-R4-R5-R6.** A further advance of the controller to No. 7 step will give an additional increase in power and in ammeter reading, as the closing of Nos. 6 and 18 contactors—No. 11 circuit—will cut out of the motor circuit all remaining grid resistances.

The indications on No. 11 step will be similar, but more pronounced, as No. 7 contactor on No. 8 circuit also opens on No. 11 step, and the whole of the grid resistances would be re-inserted in the motor circuit.

On advancing the controller of No. 12 step, contactors Nos. 11 and 22 close on No. 4 circuit thereby cutting all grid resistance sections out of the motor circuits, and a very pronounced increase in power and in ammeter reading would result.

It would not be advisable, however, to advance the controller to the 12th step unless the locomotive was moving at considerable speed with a low ammeter reading.

When these indications are given, change No. 5 fuse. If this does not effect a remedy, look for the fault at the 3rd contact of the interlock of No. 6 contactor.

Note.—*When a resistance short circuiting circuit fails to operate, and the situation is not favourable to at once remedy the fault, the driver must carefully note the ammeter reading. If he considers that the reading will not rise to an excessive figure, then the controller can be advanced to the succeeding steps to obtain normal operation. If, however, the ammeter reading is too high when this is done, the controller should be returned at once to the previous step and kept there long enough to allow the ammeter reading to fall to a value that would permit the controller to be advanced two steps at once. It must be understood, however, that the controller must not be held too long on a resistance step as the grids may become overheated.*

283. **WITH DEFECT IN NO. 4 CONTROL CIRCUIT (STEPS NOS. 6 AND 12).**

If No. 4 circuit is defective, No. 11 contactor will not close and grid resistance section **R5-R6** will not be cut out on the 6th step, and Nos. 11 and 22 contactors will not close to cut out grid resistance sections **R5-R6** and **R10-R11** on the 12th step.

The fault is easily detected as there will be no variation of speed and no higher ammeter reading, when the controller handle is moved from the 5th to the 6th or from the 11th to the 12th steps. When No. 4 circuit is defective there will be one section of grid resistance left in each motor circuit when the controller is advanced to the 12th step **full series-parallel.** Care must therefore be taken not to run with the controller too long in that position as these grid resistances may become overheated.

Look for the fault either in No. 4 fuse or in the 1st contact of the interlock of No. 6 contactor. If it is not convenient to do this, operate the locomotive with the controller handle in the 7th step **full series** where all

grid resistance is cut out from the traction motor circuit. Should it happen that No. 4 circuit operates on the 6th step but fails on the 12th step, examine Nos. 14, 15 and 16 control resistance tubes, and the 2nd contact of the interlock of No. 13 contactor. If it operates on the 12th step but fails on the 6th step, examine Nos. 6, 7 and 8 control resistance tubes and the 2nd contact of the interlock of No. 23 contactor.

DIAGNOSIS OF FAILURES AND APPROPRIATE TESTS.

286. **GENERAL NOTE.**

All failures of the locomotive to respond when the controller is operated can be grouped under three headings, viz.:

(i) Failure due to no power on the controller.
(ii) Failure due to defective control circuit.
(iii) Failure due to defective traction motor circuit.

The defects or conditions responsible for the failures coming under each heading are numerous.

The following instructions are made out for the guidance of the driver in locating and dealing with the various faults that may occur. By making the tests in the proper sequence the driver cannot fail to locate —and where possible remedy—the fault.

The tests that follow are made out on the assumption that all necessary cocks and switches are in the correct driving position, so that should the locomotive fail at any time, the driver must not attribute the failure to a defect until he has seen that everything is correctly set and that the brakes are released.

As the contactors are located in the central equipment compartment, they can be distinctly heard when operating, and the **knocks** made by them when closing and opening are a valuable aid to the driver in determining the nature and location of a fault.

287. APPARATUS IN USE ON THE VARIOUS STEPS OF ACCELERATION.

As a guide to the driver, the following table is given to indicate the various pieces of apparatus involved on each accelerating step:

FORWARD OPERATION.

Step No.	Circuit and fuse Nos.	Control resistance tube Nos.	Contactors Nos.	Section of grid resistance cut out of motor circuit on step.
1	1, 3, 10	1, 13	1, 2, 4, 14, 16, 23, 24	All grids in
2	1, 3, 8, 10	1, 5, 6, 7, 8, 13	1, 2, 4, 7, 14, 16, 23, 24	R1-R2
3	1, 3, 7, 8, 10	1, 5, 6, 7, 8, 9, 10, 11, 12, 13	1, 2, 4, 7, 8, 14, 16, 19, 23, 24	R2-R3 and R7-R8
4	1, 3, 6, 8, 10	1, 3, 4, 5, 6, 7, 8, 13	1, 2, 4, 7, 8, 9, 14, 16, 19, 20, 23, 24	R3-R4 and R8-R9
5	1, 3, 5, 8, 10	1, 5, 6, 7, 8, 13	1, 2, 4, 7, 8, 9, 10, 14, 16, 19, 20, 21, 23, 24	R4-R5 and R9-R10
6	1, 3, 4, 5, 10	1, 6, 7, 8, 13	1, 2, 4, 7, 8, 9, 10, 11, 14, 16, 19, 20, 21, 23, 24	R5-R6

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FORWARD OPERATION—continued.

7	1, 3, 11	1, 13	1, 2, 4, 6, 14, 16, 18	All grids cut out
8	1, 3, 8, 9	1, 5, 6, 7, 8	1, 2, 4, 7, 12, 13, 14, 16	**R1-R2**
9	1, 3, 7, 8, 9	1, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 4, 7, 8, 12, 13, 14, 16, 19	**R2-R3** and **R7-R8**
10	1, 3, 6, 8, 9	1, 3, 4, 5, 6, 7, 8	1, 2, 4, 7, 8, 9, 12, 13, 14, 16, 19, 20	**R3-R4** and **R8-R9**
11	1, 3, 5, 9	1	1, 2, 4, 8, 9, 10, 12, 13, 14, 16, 19, 20, 21	**R4-R5** and **R9-R10**
12	1, 3, 4, 5, 9	1, 14, 15, 16	1, 2, 4, 8, 9, 10, 11, 12, 13, 14, 16, 19, 20, 21, 22	All grids cut out

REVERSE OPERATION.

1	2, 3, 10	2, 13	1, 3, 5, 15, 17, 23, 24	All grids in
2-12	As shown for forward operation except that No. 2 circuit is energised instead of No. 1			

288. INSTRUCTIONS FOR LOCATING AND DEALING WITH FAULTS.

If a locomotive fails to move, one of four sets of indications will be present which will direct the driver where to start testing in order to locate the fault. The indications and the tests to be made are as follows:

(a) **Indications "A." The locomotive fails and the dynamotor is not working.**

Tests.—Open and close No. 2 compressor no-volt relay switch, if power is available, the relay will be heard to operate, or if the compressors are working, change the dynamotor fuse. If the relay does not operate see if the pantograph is in contact with the overhead wire; if so, lower pantograph and change over the pantograph isolator and two-way cocks and raise the other pantograph. If no result, lower the pantograph again and change the high speed fuse. If still no result, change the dynamotor fuse and Nos. 1 and 2 compressor fuses. If these steps are not effective, power is off.

(b) **Indications "B." The locomotive fails and the dynamotor is working but no knocks are heard.**

Tests.—Test for lights, click of magnet valve and arc of control and line breaker reset switch if none are obtained, open the dynamotor switch and when the dynamotor stops running, examine the emergency jumper. If lights appear but no click and arc, change the main control fuse. If, however, lights, click and arc are obtained, try the controller again and if there are no results, reduce the brake pipe pressure and test the control governor. If no results, instruct the assistant to hold over the control governor switch, and if the locomotive still fails with the control governor switch held over, try to drive from the other controller.

(c) **Indications "C." The locomotive fails in one direction only.**

Tests.—If the locomotive fails in the forward direction, but moves in reverse, change No. 1 fuse. If still no result, try the other controller in the desired direction. If the locomotive still fails from the 2nd controller, change or test No. 1 control resistance tube. Examine interlocks on Nos. 3, 5, 15 and 17 contactors.

If the locomotive fails in reverse but moves forward, apply the above test to No. 2 fuse and No. 2 control resistance tube. Examine interlocks on Nos. 2, 4, 14 and 16 contactors.

(d) **Indications "D." The locomotive fails in both directions and knocks are heard.**

Tests.—Operate the control and line breaker reset switch for an arc. If no arc is obtained, change No. 12 control fuse and reset the line breaker and No. 1 compressor and protective relay. Test locomotive and if all is correct, proceed.

If, when operating the control and line breaker reset switch, an arc is obtained and the relay is not heard to set, the fault would be in the 1st contact of the interlock of the protective relay or in one of the 600 ohm resistance tubes.

If the 1st contact of the interlock of No. 1 compressor and protective relay, or one of the 600 ohm resistance tubes, became defective whilst the relay was closed, the locomotive would not fail. However, both compressors would work continuously until either compressor cut-out switch was opened when both compressors would stop and the locomotive would fail.

The services of an equipment fitter must be obtained to remedy this defect, but should the trouble occur at a locality where an equipment fitter cannot be readily obtained and serious delay to traffic would result, the driver must first lower the pantograph and isolate it

and see that it is clear of the contact wire, then remove the defective resistance tube and replace it with a new one from the rack.

If, when testing for an arc, a rattling noise heard in No. 1 compressor and protective relay indicates that No. 1 compressor and protective relay fuse is blown or that one of the ten 500 ohms resistance tubes or the 2nd contact of the interlock of the relay is defective. (See instruction No. 273 in respect to defective resistance tubes in No. 1 compressor and protective relay circuit.)

If no rattle, try again after getting the arc, and if the locomotive moves the line breaker or No. 1 compressor and protective relay had required resetting.

If the locomotive still fails, test Nos. 1, 3 and 10 control circuits separately. Test No. 1 circuit by taking out No. 3 fuse and operating the controller to the 1st step only in the **forward** direction. If knocks are heard, No. 1 circuit is O.K. Next replace No. 3 fuse and remove No. 1 fuse; if knocks are heard Nos. 3 and 10 circuits are sound and the fault may be in the traction motor circuits, i.e., main switch open, a broken grid resistance, or an open circuit on one of the motors. But if when testing Nos. 3 and 10 control circuits no knocks are heard, the control circuits are defective.

Test Nos. 3 and 10 fuses and renew them if blown. If no result, try to drive from opposite end controller. If still no result, test No. 13 control resistance tube—it may be tested by changing it with No. 8 resistance tube.

If Nos. 3 and 10 control circuits are still defective, the fault may be found in any of the following:—

(i) The 4th contact of the interlock of No. 1 compressor and protective relay.
(ii) The interlock contacts of No. 1 line breaker.
(iii) The 3th contact of the interlock of No. 1 contactor.
(iv) The 1st contact of the interlock of No. 12 contactor.
(v) The 1st contact of the interlock of No. 13 contactor.

Part 4.

DIAGRAMS.

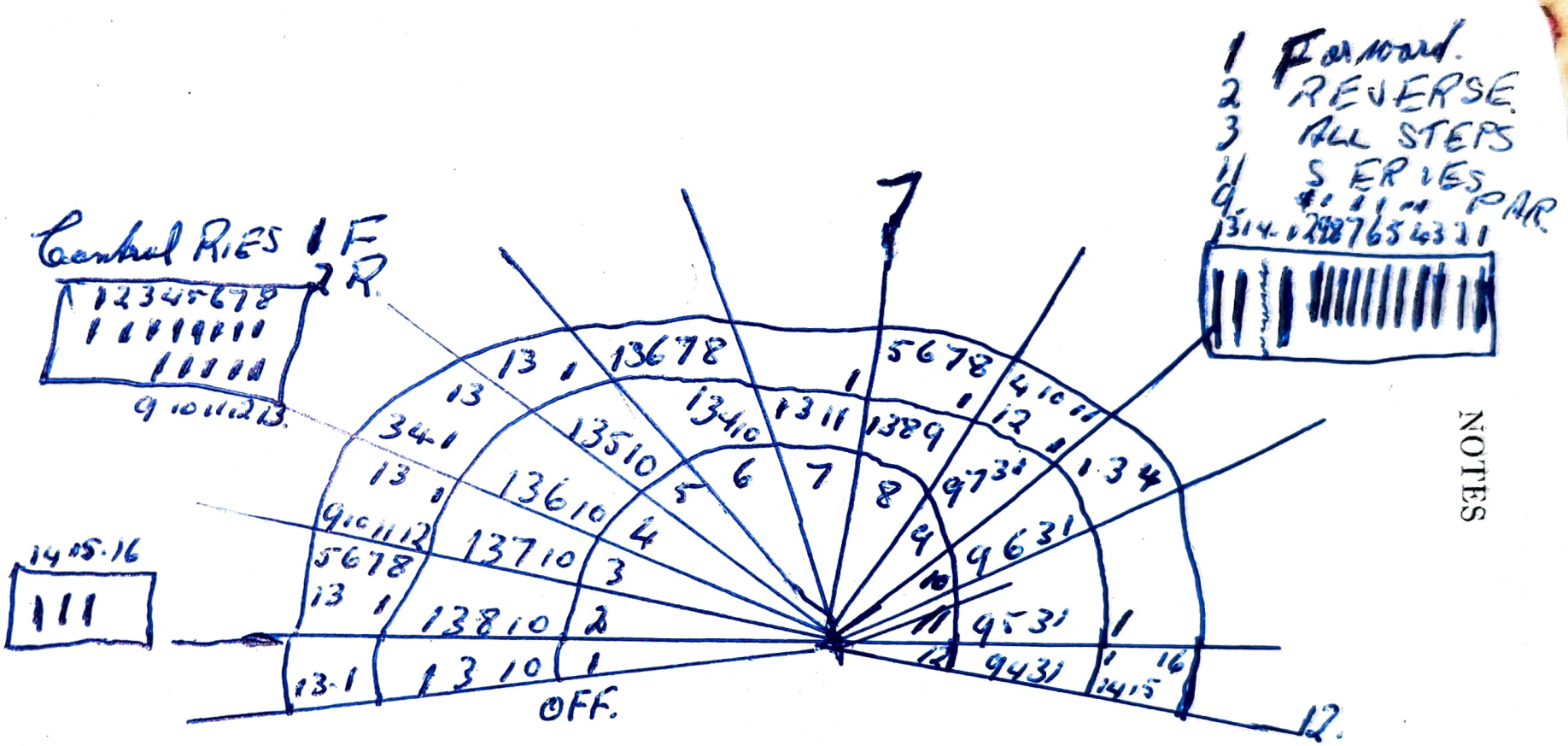
DIAGRAMS.

400. **GENERAL NOTE.**

The diagrams which follow hereafter are included to give the electric locomotive driver a clearer understanding where necessary of the instructions contained in this book.

LIST OF DIAGRAMS.

Diagram No.	Title.
1	Electric locomotives Nos. 1100 and 1101 outline drawing.
2	Electric locomotives Nos. 1102 to 1111 outline drawing.
3	Electric locomotives Nos. 1100 and 1101 detail wiring diagram.
4	Electric locomotives Nos. 1102 to 1111 detail wiring diagram.
5	Electric locomotives Nos. 1100 and 1101 schematic wiring diagram.
6	Maximum loads allowable on various grades.
7	Westinghouse brake diagram.
8-21	Acceleration diagrams, step by step.
22	Motor transition circuits.


1 Forward.
2 REVERSE.
3 ALL STEPS
4 SERIES PAR.
Central RIES 1F 2R.
1 2 3 4 5 6 7 8
9 10 11 12 13.
14 15 16
OFF.
12.
NOTES

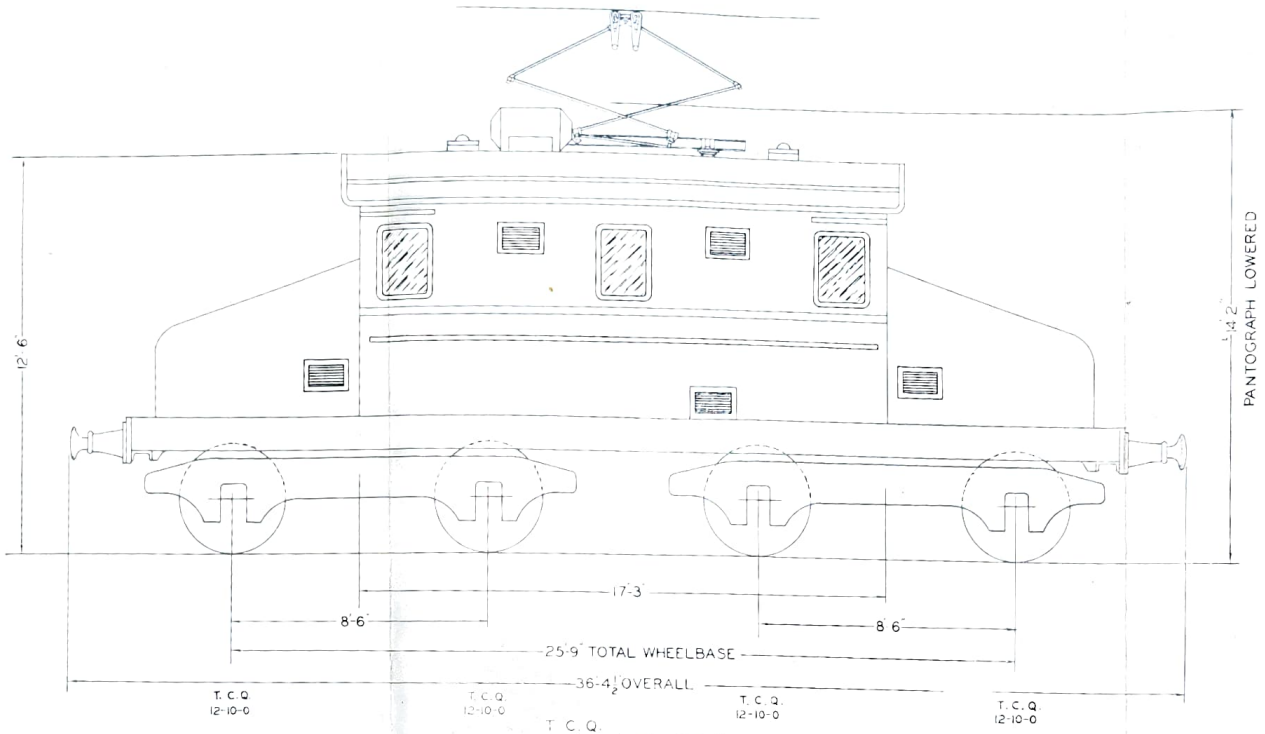
NOTES

NOTES

NOTES

ELECTRIC LOCOMOTIVES Nº 1100 & 1101

Nº 1



T. C. Q.
50-0-0 TOTAL WEIGHT

LEADING PARTICULARS

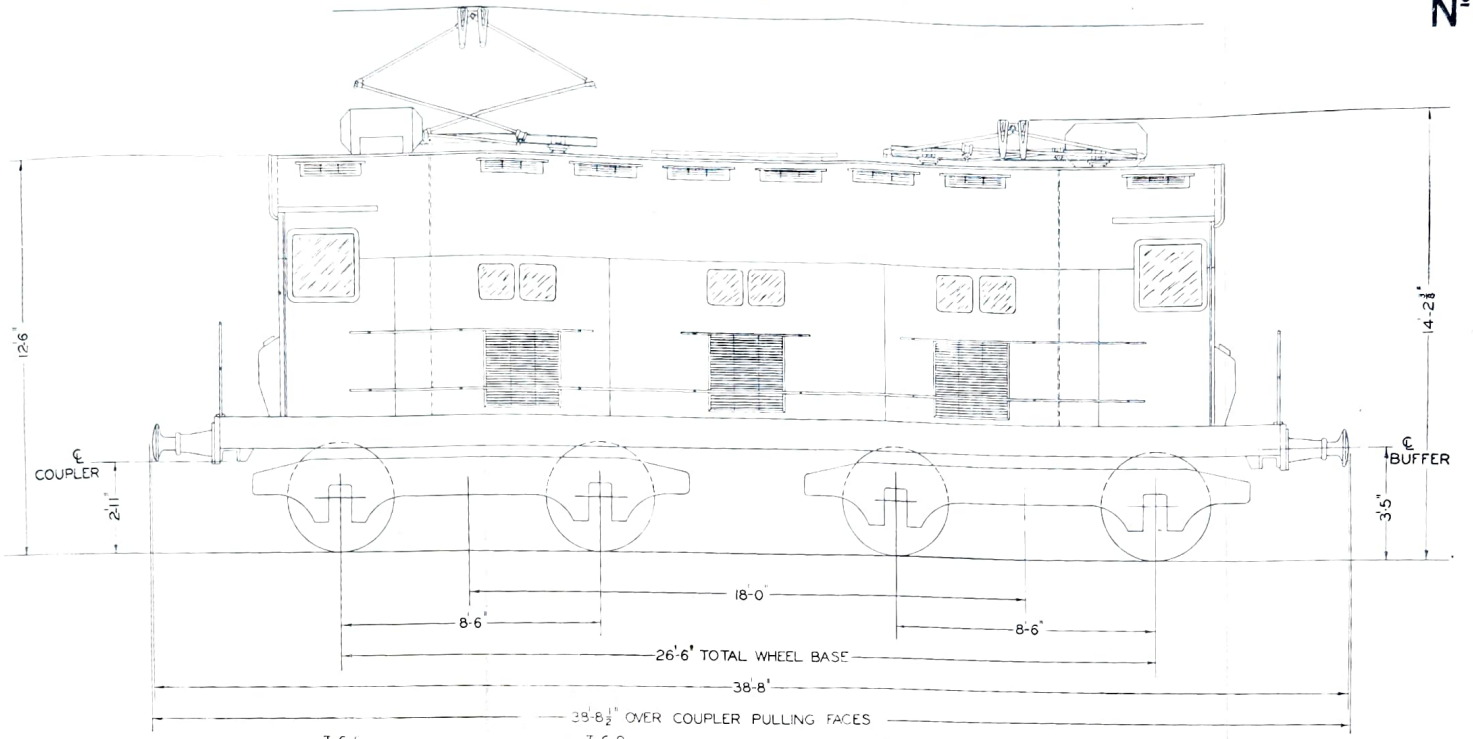
Width Overall-9'6"
Driving Wheel Diam-42"
Traction Motors-4 Nº GE 237
Gear Ratio-79/18 = 4.38/1
Max. Permiss. Speed-40 M.P.H.

Starting Tractive Effort-24,400 lbs
" Adhesion Percentage-21.8%
Hourly Rating, Tractive Effort-14160 lbs
" " , Amperes-368
" " , Speed-10 M.P.H.
" " , Horsepower-620

Q.2940

ELECTRIC LOCOMOTIVES Nos 1102 – 1111

Nº2



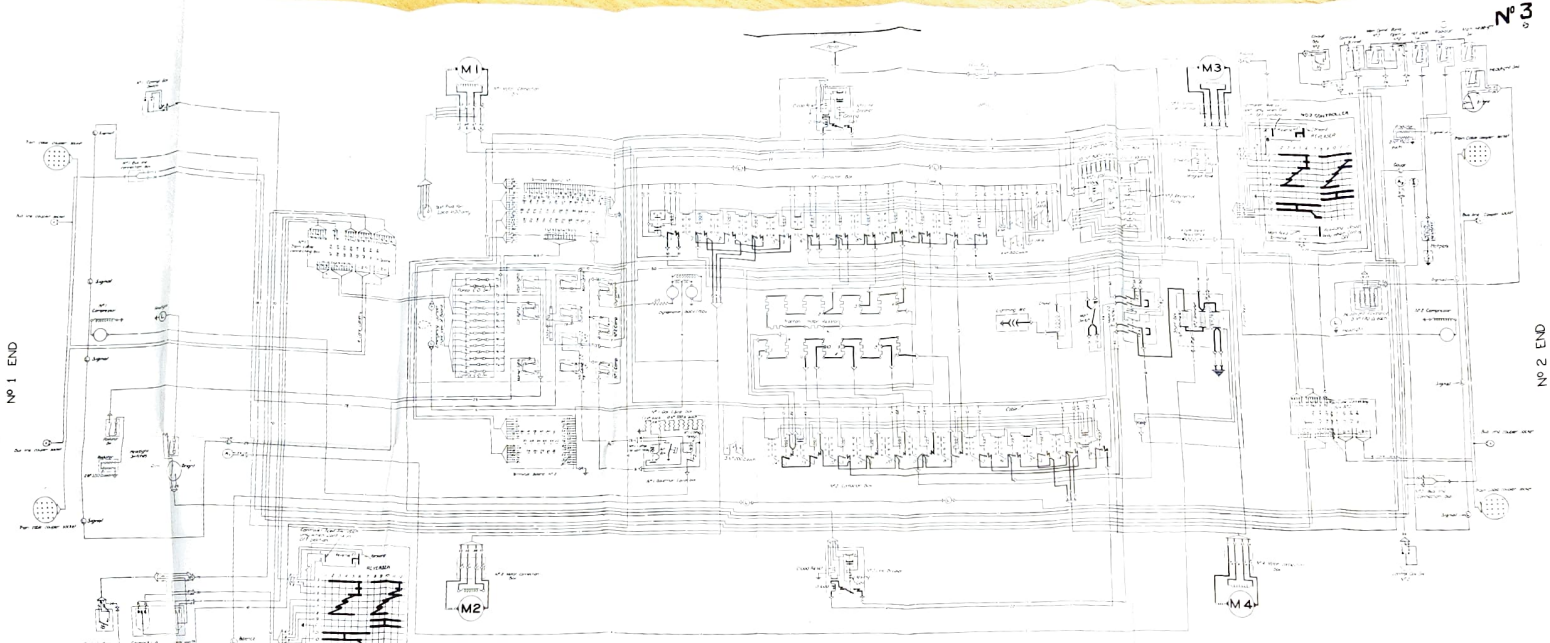
T. C. Q.
55-2-0 TOTAL WEIGHT.

LEADING PARTICULARS

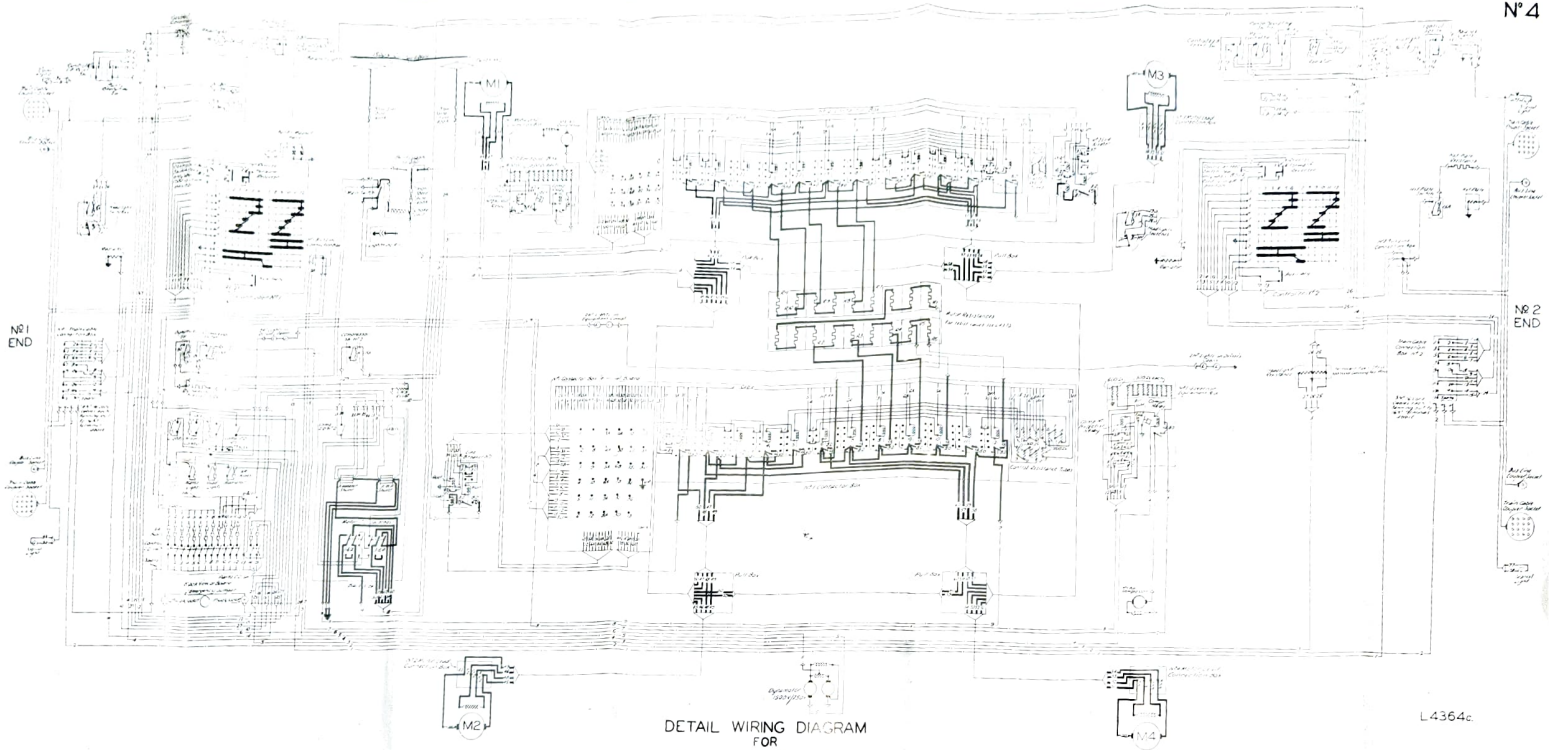
Width Overall 9'-5½"
Driving Wheel Diam 42"
Traction Motors 4 No GE 237
Gear Ratio 79/18 = 4.38/1
Max Permiss. Speed 40 MPH

Starting Tractive Effort 24400 lbs.
Adhesion Percentage 19.8%
Hourly Rating, Tractive Effort 14160 lbs.
Amperes 368.
Speed 16 M.P.H.
Horsepower 820

Q2941

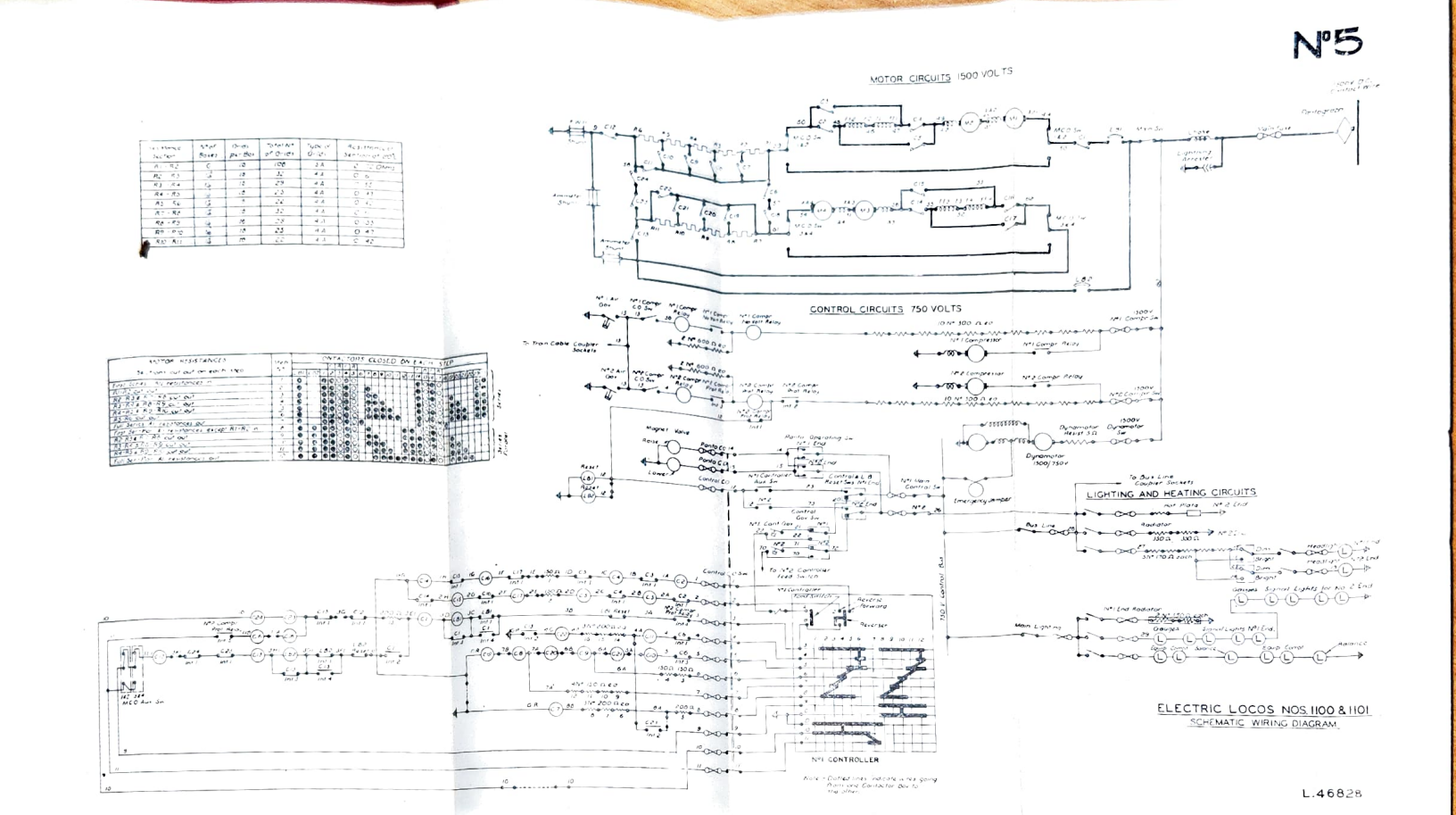


DETAIL WIRING DIAGRAM
FOR
ELEC LOCOS Nºs 1100 & 1101

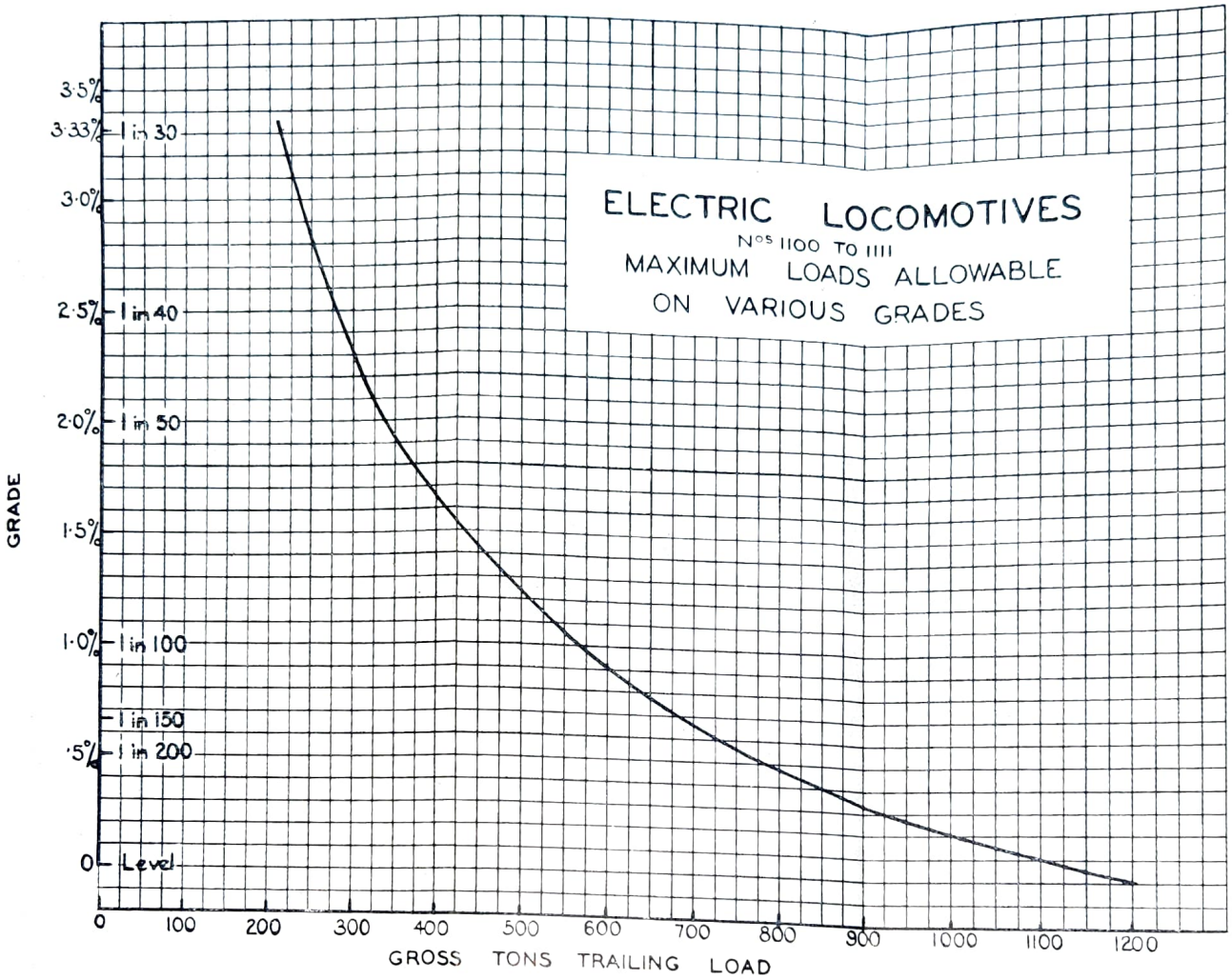


DETAIL WIRING DIAGRAM
FOR
ELEC LOCOS Nos 1102 & 1111

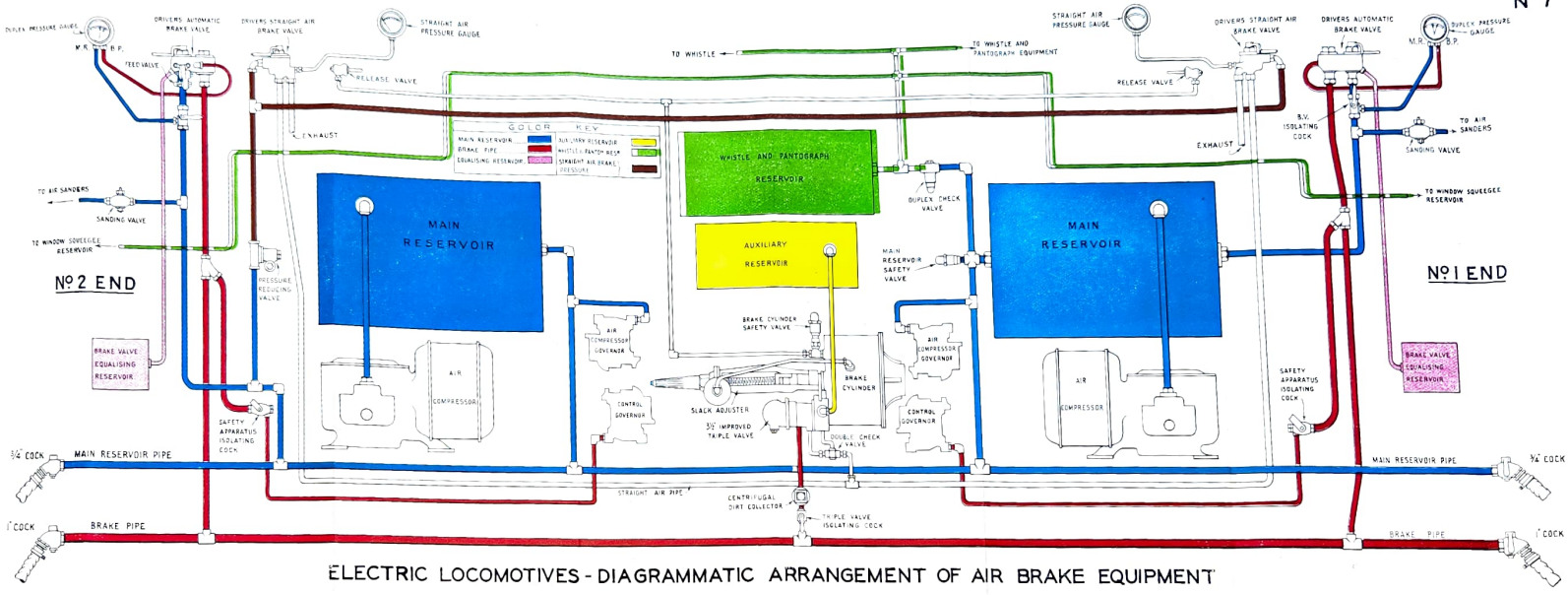
L4364c


MOTOR CIRCUITS 1500 VOLTS
CONTROL CIRCUITS 750 VOLTS
LIGHTING AND HEATING CIRCUITS
N°1 CONTROLLER
ELECTRIC LOCOS NOS. 1100 & 1101
SCHEMATIC WIRING DIAGRAM.
L.46828

N°6


ELECTRIC LOCOMOTIVES
Nos 1100 TO 1111
MAXIMUM LOADS ALLOWABLE
ON VARIOUS GRADES
GRADE
3·5%
3·33% 1 in 30
3·0%
2·5% 1 in 40
2·0% 1 in 50
1·5%
1·0% 1 in 100
1 in 150
·5% 1 in 200
0 Level
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
GROSS TONS TRAILING LOAD

F 4897



ELECTRIC LOCOMOTIVES - DIAGRAMMATIC ARRANGEMENT OF AIR BRAKE EQUIPMENT

FIRST STEP (PRELIM)

Nº 8

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 75°C
R1 - R2	6	18	108	5A	1.240 Ohms
R2 - R3	3	18	54	4A	743 "
R3 - R4	3	18	54	4A	662 "
R4 - R5	3	18	54	4A	580 "
R5 - R6	3	18	54	4A	497 "
R6 - R7	3	18	54	4A	745 "
R7 - R8	3	18	54	4A	662 "
R8 - R9	3	18	54	4A	580 "
R9 - R10	3	18	54	4A	497 "

MOTOR RESISTANCES

CONTACTORS CLOSED ON EACH STEP

MOTOR CIRCUITS

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

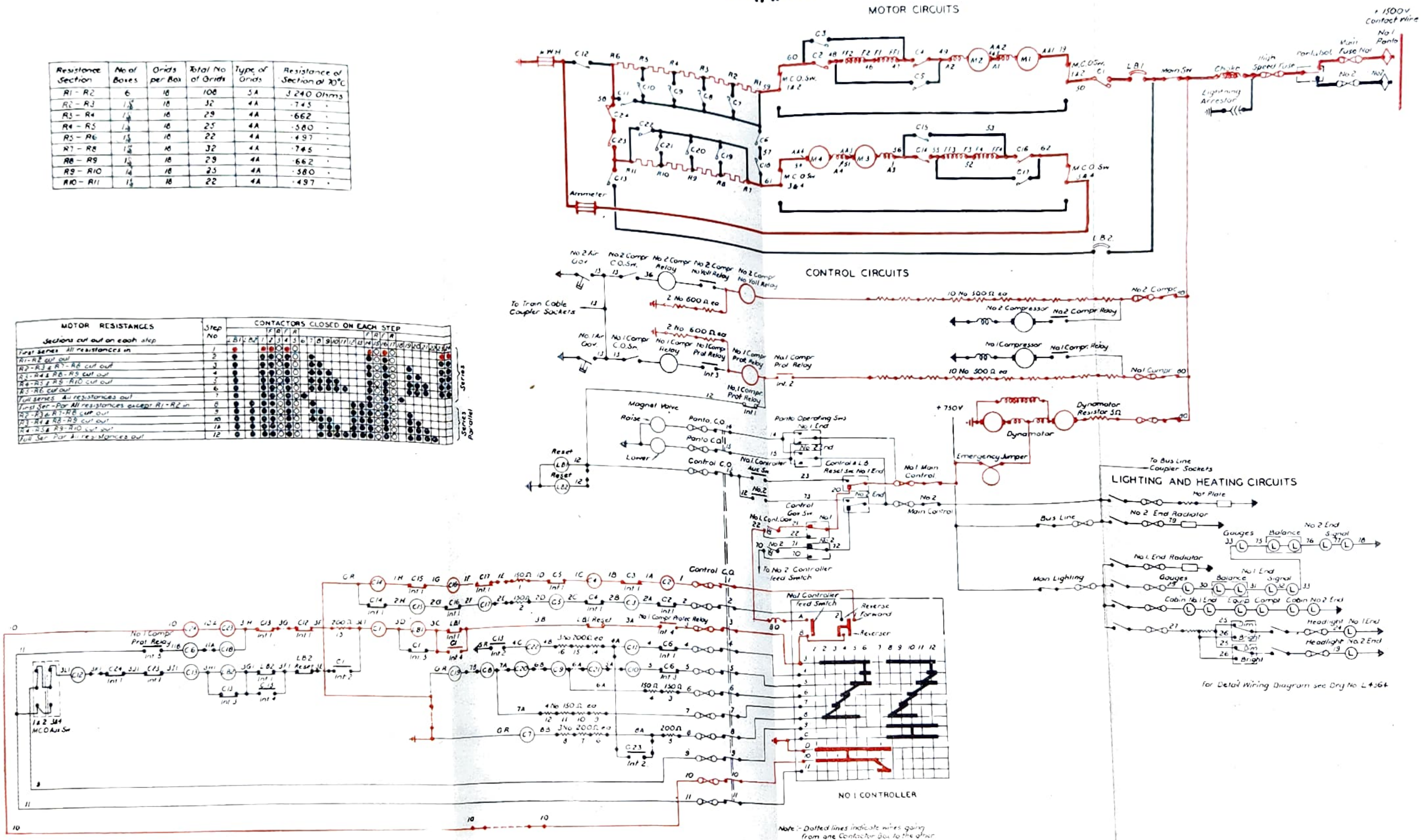
Note :- Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Drg No. L 4364

FIRST STEP (FINAL)

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 70°C
R1 - R2	6	18	108	5A	3 240 Ohms
R2 - R3	1⅞	18	32	4A	·745 "
R3 - R4	1⅝	18	29	4A	·662 "
R4 - R5	1⅜	18	25	4A	·580 "
R5 - R6	1⅛	18	22	4A	·497 "
R7 - R8	1⅞	18	32	4A	·745 "
R8 - R9	1⅝	18	29	4A	·662 "
R9 - R10	1⅜	18	25	4A	·580 "
R10 - R11	1⅛	18	22	4A	·497 "

MOTOR RESISTANCES Sections cut out on each step	Step No	CONTACTORS CLOSED ON EACH STEP																										
					F	R	F	R									F	R	F	R								
		LB1	LB2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
First Series All resistances in	1	●		●	●	○	●	○									●	○	●	○						●	●	Series
R1-R2 cut out	2	●		●	●	○	●	○		●							●	○	●	○						●	●	Series
R2-R3 & R7-R8 cut out	3	●		●	●	○	●	○		●	●						●	○	●	○		●				●	●	Series
R3-R4 & R8-R9 cut out	4	●		●	●	○	●	○		●	●	●					●	○	●	○		●	●			●	●	Series
R4-R5 & R9-R10 cut out	5	●		●	●	○	●	○		●	●	●	●				●	○	●	○		●	●	●		●	●	Series
R5-R6 cut out	6	●		●	●	○	●	○		●	●	●	●	●			●	○	●	○		●	●	●		●	●	Series
Full series All resistances out	7	●		●	●	○	●	○	●								●	○	●	○	●							Series
First Ser-Par All resistances except R1-R2 in	8	●	●	●	●	○	●	○		●					●	●	●	○	●	○								Series Parallel
R2-R3 & R7-R8 cut out	9	●	●	●	●	○	●	○		●	●				●	●	●	○	●	○		●						Series Parallel
R3-R4 & R8-R9 cut out	10	●	●	●	●	○	●	○		●	●	●			●	●	●	○	●	○		●	●					Series Parallel
R4-R5 & R9-R10 cut out	11	●	●	●	●	○	●	○			●	●	●		●	●	●	○	●	○		●	●	●				Series Parallel
Full Ser Par All resistances out	12	●	●	●	●	○	●	○			●	●	●	●	●	●	●	○	●	○		●	●	●	●			Series Parallel



SECOND STEP

Nº 10

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 70°C
R1 – R2	6	18	108	5A	3·240 Ohms
R2 – R3	1½	18	32	4A	745 "
R3 – R4	1½	18	29	4A	662 "
R4 – R5	1½	18	25	4A	580 "
R5 – R6	1½	18	22	4A	497 "
R7 – R8	1½	18	32	4A	745 "
R8 – R9	1½	18	29	4A	662 "
R9 – R10	1½	18	25	4A	580 "
R10 – R11	1½	18	22	4A	497 "

MOTOR RESISTANCES

Step No	CONTACTORS CLOSED ON EACH STEP
Sections cut out on each step	1R 2R 3R 4R 5R M1 M2 M3 M4 C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17
First Series All resistances in	1
R1–R2 cut out	2
R2–R3 & R7–R8 cut out	3
R3–R4 & R8–R9 cut out	4
R4–R5 & R9–R10 cut out	5
R5–R6 cut out	6
Full series All resistances out	7
First Sec – Par All resistances except R1–R2 in	8
R1–R2 & R7–R8 cut out	9
R3–R4 & R8–R9 cut out	10
R4–R5 & R9–R10 cut out	11
Full Sec – Par All resistances out	12

Series
Series Parallel

MOTOR CIRCUITS

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

Note:- Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Drg No L 364

THIRD STEP

No 11

MOTOR CIRCUITS

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 30°C
R1 - R2	6	18	108	5A	1.240 Ohms
R2 - R3	1½	18	32	4A	745 "
R3 - R4	1½	18	29	4A	662 "
R4 - R5	1½	18	23	4A	580 "
R5 - R6	1½	18	20	4A	497 "
R7 - R8	1½	18	16	4A	345 "
R8 - R9	1½	18	29	4A	662 "
R9 - R10	1½	18	23	4A	580 "
R10 - R11	1½	18	20	4A	497 "

MOTOR RESISTANCES	Steps No	CONTACTORS CLOSED ON EACH STEP
Sections cut out on each step		1 2 3 4 5 6 7 8 9 10 11 12
Trial Series All resistances in	1	
R1-R2 cut out	2	
R2-R3 & R1-R2 cut out	3	
R3-R4 & R2-R3 cut out	4	
R4-R5 & R3-R4 cut out	5	
R5-R6 cut out	6	
Full series All resistances in	7	
1st Step For All resistances except R9 - R11 in	8	
R9-R10 & R8-R9 cut out	9	
R8-R9 & R7-R8 cut out	10	
R7-R8 & R5-R6 cut out	11	
Full Step For All resistances out	12	

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

Note - Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Dwg No L 4364

FOURTH STEP

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 30°C
R1 - R2	6	18	108	5A	3.240 Ohms
R2 - R3	1/3	18	32	4A	145 "
R3 - R4	1/9	18	29	4A	662 "
R4 - R5	1/9	18	25	4A	580 "
R5 - R6	1/9	18	22	4A	497 "
R7 - R8	1/9	18	32	4A	745 "
R8 - R9	1/9	18	29	4A	662 "
R9 - R10	1/9	18	25	4A	580 "
R10 - R11	1/9	18	22	4A	497 "

MOTOR RESISTANCES

Sections cut out on each step

CONTACTORS CLOSED ON EACH STEP

Step No	Sections cut out on each step	1	2	3	4	5	6	7	8	9	10	11	12
	First Series All resistances in												
1	R1 - R2 cut out												
2	R2 - R3 & R7 - R8 cut out												
3	R3 - R4 & R8 - R9 cut out												
4	R4 - R5 & R9 - R10 cut out												
5	R5 - R6 cut out												
6	Full Series All resistances out												
7	Short Circuiting All resistances except R - R11 in												
8	R6 - R7 & R7 - R8 cut out												
9	R7 - R8 & R8 - R9 cut out												
10	R8 - R9 & R9 - R10 cut out												
11	R9 - R10 & R10 cut out												
12	Full Series For All resistances out												

Series

Parallel

MOTOR CIRCUITS

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

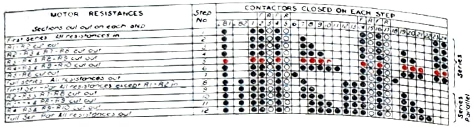
NO 1 CONTROLLER

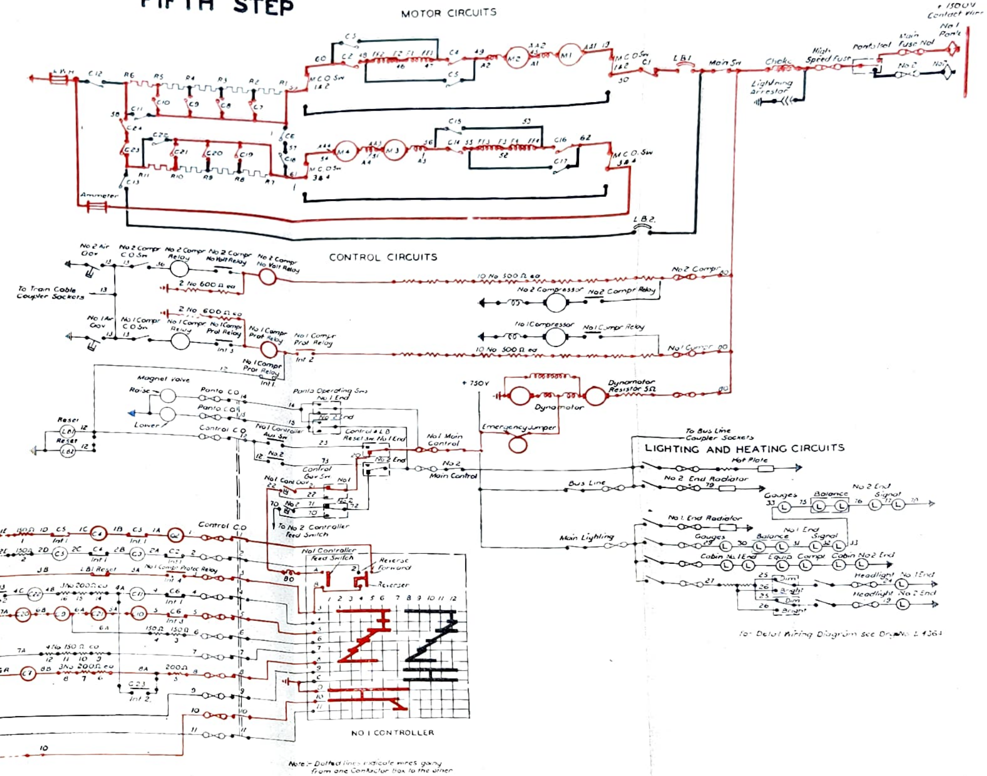
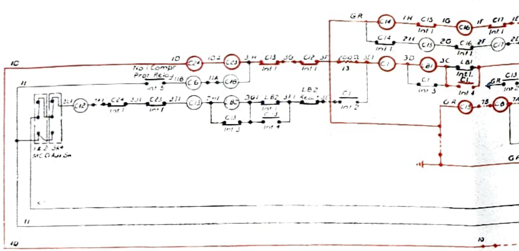
For Detail Wiring Diagram see Drg No. L 4364

Note:- Dotted lines indicate wires going from one Contactor Box to the other

FIFTH STEP

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 70°C
R1 – R2	6	18	108	5A	3·240 Ohms
R2 – R3	1 16/18	18	32	4A	·745 "
R3 – R4	1 11/18	18	29	4A	·662 "
R4 – R5	1 5/18	18	23	4A	·580 "
R5 – R6	1 4/18	18	22	4A	·497 "
R7 – R8	1 14/18	18	32	4A	·745 "
R8 – R9	1 11/18	18	29	4A	·662 "
R9 – R10	1 7/18	18	25	4A	·580 "
R10 – R11	1 4/18	18	22	4A	·497 "



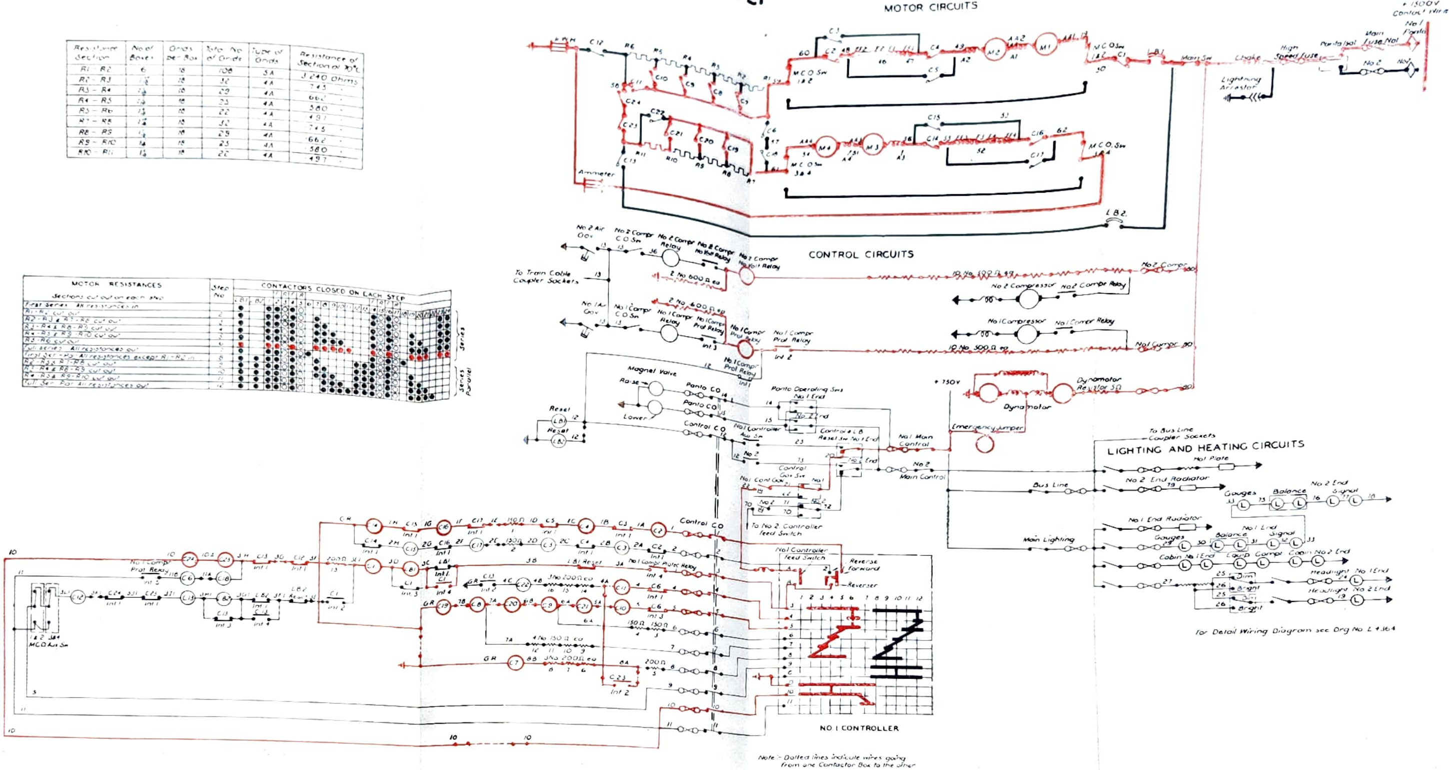
SIXTH STEP

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 70°C
R1 – R2	6	18	108	5A	3 240 Ohms
R2 – R3	1¾	18	32	4A	745 "
R3 – R4	1⅝	18	29	4A	662 "
R4 – R5	1⅜	18	25	4A	580 "
R5 – R6	1¼	18	22	4A	497 "
R7 – R8	1¾	18	32	4A	745 "
R8 – R9	1⅝	18	29	4A	662 "
R9 – R10	1⅜	18	25	4A	580 "
R10 – R11	1¼	18	22	4A	497 "

MOTOR RESISTANCES — Sections cut out on each step	Step No
First Series. All resistances in	
R1 – R2 cut out	2
R2 – R3 & R7 – R8 cut out	3
R3 – R4 & R8 – R9 cut out	4
R4 – R5 & R9 – R10 cut out	5
R5 – R6 cut out	6
Full Series. All resistances out	7
First Ser – Par. All resistances except R1 – R2 in	8
R2 – R3 & R7 – R8 cut out	9
R3 – R4 & R8 – R9 cut out	10
R4 – R5 & R9 – R10 cut out	11
Full Ser – Par. All resistances out	12

CONTACTORS CLOSED ON EACH STEP

Series
Series Parallel



SEVENTH STEP

Resistance Sections	No of Rods	Grids per Rod	Total No of Grids	Type of Grids	Resistance of Section at 30°C
R1 - R2	6	9	108	5A	3.240 Ohms
R2 - R3	3	9	54	4A	1.62
R3 - R4	3	9	54	4A	1.62
R4 - R5	3	9	54	4A	1.62
R5 - R6	3	9	54	4A	1.62
R7 - R8	3	9	54	4A	1.62
R8 - R9	3	9	54	4A	1.62
R9 - R10	3	9	54	4A	1.62
R10 - R11	3	9	54	4A	1.62

MOTOR RESISTANCES

Sections cut out on each step

CONTACTORS CLOSED ON EACH STEP

Step No.

Series

Series Parallel

MOTOR CIRCUITS

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

Note - Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagrams see Dwg No E 4356

SEVENTH - EIGHTH STEPS (TRANSITION)

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 70°C
R1 - R2	6	18	108	5A	3·240 Ohms
R2 - R3	1½	18	32	4A	7·45 "
R3 - R4	1½	18	29	4A	6·62 "
R4 - R5	1½	18	25	4A	5·80 "
R5 - R6	1½	18	22	4A	4·97 "
R7 - R8	1½	18	32	4A	7·45 "
R8 - R9	1½	18	29	4A	6·62 "
R9 - R10	1½	18	25	4A	5·80 "
R10 - R11	1½	18	22	4A	4·97 "

MOTOR CIRCUITS

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

MOTOR RESISTANCES	Step No	CONTACTORS CLOSED ON EACH STEP
Sections cut out on each step		1' 2' 3' 4' 5' R 7 8 9 10 11 12 A 1 2 3 4 5 6 7 8 9 10 11 12 A
First Series All resistances in	1	●
R1-R2 cut out	2	●
R2-R3 & R7-R8 cut out	3	●
R3-R4 & R8-R9 cut out	4	●
R4-R5 & R9-R10 cut out	5	●
R5-R6 cut out	6	●
Full series All resistances out	7	●
First Ser - Par All resistances except R1-R2 in	8	●
R2-R3 & R7-R8 cut out	9	●
R3-R4 & R8-R9 cut out	10	●
R4-R5 & R9-R10 cut out	11	●
Full Ser - Par All resistances out	12	●

Note:- Dotted lines indicate wires going from one Contactor box to the other

for Detail Wiring Diagram see Drg No L 4 Je 4

EIGHTH STEP

Nº17

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 70°C
R1 - R2	6	18	108	5A	3.240 Ohms
R2 - R3	1⅔	18	32	4A	745 "
R3 - R4	1⅔	18	29	4A	662 "
R4 - R5	1⅔	18	25	4A	580 "
R5 - R6	1⅔	18	22	4A	497 "
R7 - R8	1⅔	18	32	4A	745 "
R8 - R9	1⅔	18	29	4A	662 "
R9 - R10	1⅔	18	25	4A	580 "
R10 - R11	1⅔	18	22	4A	497 "

MOTOR RESISTANCES

Sections cut out on each step

Step No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1																		
2	●																	
3	●	●																
4	●	●	●															
5	●	●	●	●														
6	●	●	●	●	●													
7	●	●	●	●	●	●												
8	●	●	●	●	●	●	●											
9	●	●	●	●	●	●	●	●										
10	●	●	●	●	●	●	●	●	●									
11	●	●	●	●	●	●	●	●	●	●								
12	●	●	●	●	●	●	●	●	●	●	●							
13	●	●	●	●	●	●	●	●	●	●	●	●						
14	●	●	●	●	●	●	●	●	●	●	●	●	●					
15	●	●	●	●	●	●	●	●	●	●	●	●	●	●				
16	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			
17	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
18	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	

CONTACTORS CLOSED ON EACH STEP

Series

Parallel

MOTOR CIRCUITS

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

Note - Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Drg No L4364

NINTH STEP

Nº18

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 30°C
R1 - R2	6	18	108	5A	2.240 Ohms
R2 - R3	1/2	18	36	4A	2.43
R3 - R4	1/2	18	36	4A	662
R4 - R5	1/2	18	36	4A	580
R5 - R6	1/2	18	36	4A	497
R7 - R8	1/2	18	36	4A	745
R8 - R9	1/2	18	36	4A	662
R9 - R10	1/2	18	36	4A	580
R10 - R11	1/2	18	36	4A	497

MOTOR CIRCUITS

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

MOTOR RESISTANCES	Step No	CONTACTORS CLOSED ON EACH STEP
Sections cut out on each step		
First Series All resistances in	1	
R1 - R2 cut out	2	
R2 - R3 & R7 - R8 cut out	3	
R3 - R4 & R8 - R9 cut out	4	
R4 - R5 & R9 - R10 cut out	5	
R5 - R6 cut out	6	
Full series All resistances out	7	
First Shunt Note All resistances except R1 - R2 in	8	
R2 - R3 & R7 - R8 cut out	9	
R3 - R4 & R8 - R9 cut out	10	
R4 - R5 & R9 - R10 cut out	11	
Full Shunt For All resistances out	12	

NO 1 CONTROLLER

Note :- Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Dwg No L 4364

TENTH STEP

MOTOR CIRCUITS

Resistance Section	No. of Boxes	Grids per Box	Total No. of Grids	Type of Grids	Resistance of Section in Ω's
R1 - R2	6	18	108	5A	3240 Ohms
R2 - R3	4	18	72	4A	720
R3 - R4	6	18	108	4A	662
R4 - R5	6	18	108	4A	580
R5 - R6	4	18	72	4A	497
R7 - R8	4	18	72	4A	745
R8 - R9	4	18	72	4A	662
R9 - R10	4	18	72	4A	580
*R10 - R11	13	18	72	4A	497

MOTOR RESISTANCES — Sections cut out on each step	Step No.	CONTACTORS CLOSED ON EACH STEP — R1 R2	1	2	3A	3B	4	5	6	7	8	9	10	11	
Full Series. All resistances in	1														Series
R2 - R3 & R8 - R9 cut out	2														
R1 - R4 & R8 - R9 cut out	3														
R1 - R4 & R8 - R10 cut out	3A														
R1 - R6 cut out	3B														
1st Series. All resistances out	4														
1st Par. - 2nd Ser. All resistances except R1 - R4 in	5														
1st Par. - 2nd Par. R2 cut out	6														
1st Par. - 2nd Par. R3 cut out	7														
1st Par. R2 - R3 cut out	8														
1st Par. R2 - R3 - R4 cut out	9														
1st Par. R1 - R4 cut out	10														
1st Par. All resistances out	11														Parallel

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

Note - Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Drg No L 4164

ELEVENTH STEP

MOTOR CIRCUITS

Resistance Section	No of Boxes	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section or Box
R1 - R2	6	18	108	3A	3.240 Ohms
R2 - R3	1/2	18	31	4A	744
R3 - R4	1/2	18	23	4A	552
R4 - R5	1/4	18	23	4A	380
R5 - R6	1/2	18	22	4A	491
R7 - R8	1/2	18	31	4A	744
R8 - R9	1/4	18	29	4A	662
R9 - R10	1/4	18	23	4A	380
R10 - R11	1/4	18	22	4A	491

MOTOR RESISTANCES

CONTACTORS CLOSED ON EACH STEP

CONTROL CIRCUITS

LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

Note - Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Dwg No L-7364

TWELFTH STEP

MOTOR CIRCUITS

Resistance Section	No of Bases	Grids per Box	Total No of Grids	Type of Grids	Resistance of Section at 30° C
R1 - R2	6	18	108	5A	3240 Ohms
R2 - R3	½	18	32	4A	745 "
R3 - R4	½	18	29	4A	662 "
R4 - R5	½	18	24	4A	560 "
R5 - R6	½	18	22	4A	497 "
R7 - R8	½	18	32	4A	745 "
R8 - R9	½	18	29	4A	662 "
R9 - R10	½	18	23	4A	500 "
R10 - R11	½	18	22	4A	457 "

MOTOR RESISTANCES

Sections cut out on each step

Step No	Sections cut out on each step
	First Series All resistances in
1	R1 - R2 cut out
2	R2 - R3 & R8 - R9 cut out
3	R3 - R4 & R9 - R10 cut out
4	R4 - R5 & R10 - R11 cut out
5	R7 - R8 cut out
	Full Series All resistances out
6	First Series in All resistances except R1 - R2
7	R2 - R3 & R8 - R9 cut out
8	R3 - R4 & R9 - R10 cut out
9	R4 - R5 & R10 - R11 cut out
10	Full Tap All resistances out

CONTACTORS CLOSED ON EACH STEP

Step No	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										

CONTROL CIRCUITS

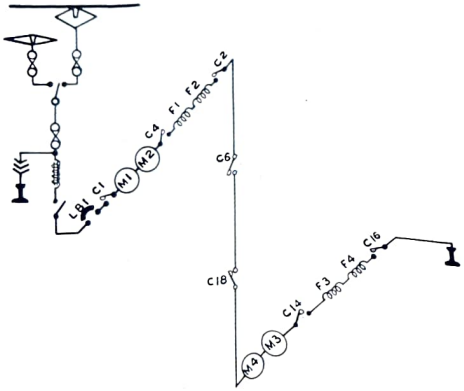
LIGHTING AND HEATING CIRCUITS

NO 1 CONTROLLER

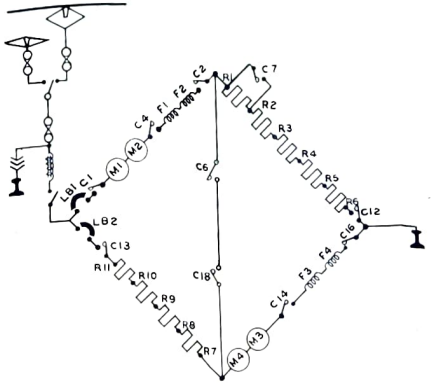
Note:- Dotted lines indicate wires going from one Contactor Box to the other

For Detail Wiring Diagram see Dwg No L 4364

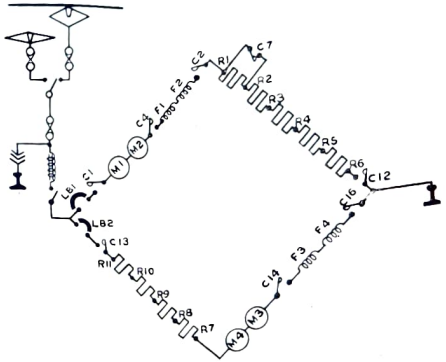
MOTOR TRANSITION CIRCUITS



STEP 7 FULL "SERIES"



STEPS 7-8 "BRIDGE TRANSITION"



STEP 8 FIRST "SERIES-PARALLEL"

NOTE - MOTOR CUT-OUT & FIELD REVERSING CIRCUITS ARE NOT SHOWN

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