The Pennsylvania Railroad

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DATED NOVEMBER 1, 1917

Alternating Current
Multiple-Unit Car Equipment

Electrical Equipment, Air Brake
and Train Signal Instructions

Altoona, Pennsylvania
November 21, 1928
# INDEX

**TEXT**

ELECTRICAL EQUIPMENT INSTRUCTIONS

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GENERAL NOTICE

Every employe whose duties are in any way connected with the operation and maintenance of the Electrical Equipment and Air Brake and Train Signal Apparatus used on Electric Multiple-Unit Cars operated by alternating current is required to have a knowledge of the apparatus he is called upon to operate and repair in the performance of his duties.

Trainmen are required to familiarize themselves with the name, location and purpose of all apparatus in order that they may carry out the instructions given them by the enginemen or conductor.

Enginemen are required in addition to the above to know in general the principle of operation of the various pieces of apparatus, the manner in which they should be operated and the method of procedure in case of failure.

Inspectors are required in addition to the above to familiarize themselves with the construction and details of the apparatus and methods of making repairs.

J. F. PATTERSON,
General Manager, New York Zone.

R. K. ROCHESTER,
General Manager, Eastern Region.

F. W. HANKINS,
Chief of Motive Power.
Electrical Equipment Instructions

GENERAL

2. The Motors Cars for operation on the electrified portion of the railroad terminating at Broad Street Station, Philadelphia, are equipped with two 225 horse power motors, both of which are mounted on one truck known as the Motor Truck. The other truck is known as the Trailer Truck. The Westinghouse Type “AB” electro-pneumatic unit switch control is used, which permits multiple unit operation.

2. By Multiple Unit Operation is meant the operation of a train of two or more motor cars, from any master controller in the train; that is, a train of several cars, each propelled independently by its own motors, is controlled as one car.

3. There are two separate and distinct systems of wiring and electrical apparatus on the car which are known as the Motor Control System and the Master Control System. The Motor Control System includes all apparatus connected in the alternating current circuits through which power is transmitted to the main motors. The Master Control System includes all the apparatus connected in the low voltage direct current circuits through which the various switches, etc., of the motor control system are caused to operate.

The motor control circuits are divided into the Primary Circuit and the Secondary Circuit. The Primary Circuit or high potential alternating current circuit includes the pantograph, a small series transformer, the
primary winding of the main transformer, and the sections of cable which connect these parts in the order given and connect the primary winding to the car frame through which the primary current returns to the track rails. The Secondary Circuit or low potential alternating current circuit includes the secondary winding of the main transformer, the main motors, switches, reverser, the preventive and reactance coils, and the cables connecting these parts. The secondary circuit is supplied with current at various reduced voltages from the secondary winding of the main transformer which also supplies current for the operation of auxiliaries such as the air compressors, heaters, etc.

The master control circuit is a direct current circuit of from 24 to 30 volts which receives current from a motor-generator and battery. It operates the magnet valves governing the motor control apparatus through the master controller and supplies current to other devices described later.

4. The wires of the master control circuit are called the Control Wires. They extend the length of each car in two Train Cables which are connected between cars by the Control Jumpers. Taps from the wires of the train cables on each car branch off to the various pieces of apparatus on the car. When any master controller in the train is operated, various wires of the master control circuit are energized, not only on the car containing the controller operated, but on all cars of the train, actuating Magnet Valves connected to them, which admit compressed air from the Control Reservoir to the operating cylinders of the motor control switches and reverser in proper sequence. This causes the motors on all cars to operate simultaneously, each car taking current for its own motors from the secondary winding of its main transformer.
DESCRIPTION AND OPERATION OF APPARATUS

MOTOR CONTROL APPARATUS

PRIMARY CIRCUIT

5. The Motor Control Primary Circuit receives single phase, 25 cycle, alternating current from the trolley wire, the normal voltage between pantograph and track rails being 11,000 volts. The motor control apparatus consists of the following:

6. Pantograph — One (Plate No. 1.) The Pantograph collects current from the trolley wire by means of a sliding Contact Shoe and conducts it to a cable which connects with the next piece of apparatus. It is mounted on the roof of the car above the motor truck and is insulated therefrom by means of porcelain Pantograph Insulators.

The operation of the pantograph is controlled by two push buttons on the master controller which actuate two magnet valves controlling the admission of compressed air to the operating cylinders of the pantograph. These magnet valves, which form the Magnet Valve Set (Plate No. 2), are located in a steel box under the car, and operate in a manner similar to the unit switch magnet valves which are fully described in Paragraph No. 18.

The pantograph is raised by pushing the Pantograph-Up Button, which is the left hand button on the bottom face of the master controller in the engineman's compartment. This closes one of the master control circuits and energizes the right hand unit of the magnet valve set, or Pantograph-Up Magnet Valve on all cars of the train which will operate to admit compressed air from the control reservoir on each car to the Pantograph Release
Cylinder causing the Locking Device, holding the pantograph down, to disengage, permitting the Operating Springs to raise the pantograph and hold it against the trolley wire. When the pantograph-up button is released, a spring pushes it out and the circuit to the magnet valve is broken.

The pantograph is lowered by pushing the Pantograph-Down Button, the right hand button on the bottom face of the master controller. This closes another master control circuit and energizes the left hand unit of the magnet valve set, or Pantograph-Down Magnet Valve on all cars, which will operate to admit compressed air to each of the two Pantograph Operating Cylinders, thus turning the shafts and forcing the pantograph down where it is engaged and held by the locking device. This magnet valve will be energized until the button is pulled down since no spring is provided on this button.

When it is desired to raise the pantographs, the pantograph-down button should be pushed momentarily before pushing the pantograph-up button. This charges the operating cylinders with air, insure a steady rise and preventing the bouncing action with attendant arcing at the contact shoe which would otherwise obtain. This should be done also when testing the pantograph in shops where there is no trolley wire.

The pantograph-up circuit is interlocked in such a way that the pantograph cannot be raised when the master controller is in any running position, and unless the control cut-out plug is inserted in the control cut-out receptacle on the master controller.

The pantograph-down master control circuit is not inter-locked and the pantograph can, therefore, be lowered at any time, whether the control cut-out plug is in-
serted in its receptacle or not. However, to prevent excessive arcing at the contact shoe, the pantograph should never be lowered when the main motors are operating, except in case of emergency.

Each car is equipped with a Pantograph Lowering Relay described in paragraph No. 26, so that in case excessive current flows through the primary circuit of the main transformer, as would be caused by a short circuit or ground, the pantograph on the car affected will automatically be lowered after the power has been removed from the line by the opening of the sub-station breakers.

In case of failure of any pantograph to lower when the pantograph-down button is pushed, it may be lowered by the use of a wood Pantograph Pole carried on each car under the car body and located at the trailer truck end of the car on the left hand side when facing the car from the trailer truck end. The pole is fitted with a hook at one end which engages in the opening of the pantograph contact shoe end horns. The pantograph may be pulled down all the way when it will engage and be held by the locking device. Rubber gloves must be worn while using these poles, with hands not less than six feet from the hook.

If the car has no compressed air and the pantograph is down, it cannot be released in the usual manner, and to meet this condition, a Hand Pump is located in front of the preventive coils, under the car, with a connection to the pipe leading to the pantograph release cylinder. A few strokes of this pump will compress enough air to charge the release cylinder, thus unlocking the pantograph and allowing the springs to raise it. Near the hand pump are two air cocks, the Hand Pump Cock in the pump branch pipe, and the Pantograph Main Cock between the
branch pipe and the pantograph-up magnet valve. Normally the former cock is closed and the latter open, in which case the handles of both cocks point toward the ground. When it is necessary to use the hand pump, the main cock should be closed and the hand pump cock opened, in which case the handles of both cocks will be turned lengthwise of the car. After the pantograph has been raised, both cocks should be turned back to their normal position. On some cars the hand pump cock has been replaced by a check valve, leaving only the pantograph main cock to manipulate.

A pantograph Grounding Device, mounted on the roof of the car, is provided to insure safety to any one working on the apparatus of the car. It consists of a switch that is normally open, which, when closed, connects the pantograph frame to the car roof, thus grounding the pantograph and at the same time locking it down. Care should be taken to see that the pantograph is down far enough at the time this device is operated for the locking shoulder on the grounding switch to engage the locking arm on the pantograph shaft.

The switch is operated by a long rod and handle, the handle being directly over the vestibule door at the motor end of the car, from which point it must be closed immediately upon ascending to the roof. When in use, this device should be fastened by removing the Locking Pin from the pantograph frame and inserting it in the locking shoulder of the switch.

The switch blade is connected by a copper cable to the car roof, thus providing a reliable ground connection for the switch.

7. Series Transformer—One (Plate No. 3). The
series transformer is located under the car body near the main transformer on the saloon side of the car.

It is connected in the circuit between the pantograph and the main transformer. When excessive current flows from the pantograph to the main transformer, the current from the secondary of the series transformer also increases and causes the pantograph lowering relay to operate.

8. Main Transformer—One (Plate No. 3). The main transformer serves to change the voltage from that of the trolley, 11,000, to lower voltages for operating the motors and auxiliary apparatus at the voltages for which they are designed. It is hung from the center sill of the car near the motor truck.

It consists of a laminated iron core on which are two separate windings, each consisting of a series of coils. One winding, connected between the pantograph and track rails, is called the high voltage or Primary winding and induces in the other winding, called the Secondary winding, current of low voltage.

The transformer is cooled by a flow of air from the blower, which should be running when the pantograph is up.

SECONDARY CIRCUIT

9. The Motor Control Secondary Circuit receives alternating current from the transformer secondary winding from a number of cables connected to various points in the winding called taps. These provide various voltages up to about 900 volts.

10. Unit Switch Group—(Plates Nos. 4, 5 and 6). The unit switch group consists of a number of unit switches assembled in a steel box and hung from the car body near the main transformer opposite the saloon side of the car.
The group is made up of nine unit switches on some cars and seven on others. These switches make connections in the main motor circuit for accelerating the car. The connections are shown on Plates Nos. 33 and 34 for the seven and nine unit switch groups respectively.

Each switch consists of three main parts: (1) the switch proper which has a fixed jaw or contact and a movable jaw which is connected in some part of the motor circuit; (2) an air cylinder with a piston which closes the switch by forcing the movable jaw against the fixed jaw when air is admitted to the cylinder; (3) a magnet valve which is fully described in Par. 18. The switch proper is provided with a Blowout Coil which acts magnetically to blow out the arc formed between the jaws of the switch as the switch opens. The switch jaws are mounted in an arc chute of arc resisting insulating material.

11. Reverser—One (Plates Nos. 8 and 9). The reverser governs the direction of flow of electric current through the main field windings of the motors, thus governing the direction of armature rotation and consequent forward or reverse movement of car or train. It is mounted on the steel frame of the switch group at the end toward the motor truck.

The reverser consists of three main parts: (1) an insulated Drum upon which are mounted two metal segments, or a metal drum in two separate insulated parts, and four sets of contact fingers which bear upon the drum; (2) two air cylinders and a piston which rotate the drum to its “Forward” and “Reverse” positions; (3) two magnet valves which control the flow of air to and from the two air cylinders. When a master controller is operated for movement in one direction, battery current is supplied through one of the control wires to the proper
magnet valve which admits air to one of the cylinders and moves the drum so that the proper fingers are connected through the drum to send current through the main fields to produce movement in the intended direction. When the master controller is operated for movement in the reverse direction, the other magnet valve is energized and the drum is rotated to its other position, reversing the direction of current through the main fields and the direction of rotation of the main motors.

12. Preventive and Reactance Coils—(Plate No. 10). Two preventive coils are used with the nine-unit switch group and one preventive and one reactance coil with the seven-unit switch group.

These coils are located under the car body near the main transformer.

Preventive and reactance coils are alike in that they consist of a coil wound on a laminated iron core with taps brought out for connection in the main motor circuit.

In general, the preventive coil is used so that the main motor connections to the transformer taps can be changed smoothly without interrupting the circuit. The reactance coil is used to improve commutation of the motors.

These coils are cooled by air from the blower.

13. Motors—Two (Plate No. 11). The motors for propelling the car are located on the motor truck as previously outlined. Each motor consists electrically of two separate parts, the Armature, which rotates, and the Field, which is stationary.

The armature consists of a drum built up of laminated iron having slots in the face into which is placed the winding of copper conductors called the Armature Coils. The coils connect to a commutator consisting of a number
of copper segments, arranged around the armature shaft and insulated therefrom and from each other by means of mica. Against the fact of this commutator the carbon Brushes carrying the current to the armature, bear and rub as the armature revolves. There are six sets, each set consisting of four brushes. The field consists of a laminated iron frame surrounding the armature, slotted in the same manner as the armature. In these slots are placed coils so connected that they form two distinct field windings, each of which produces six magnetic poles around the circumference of the armature. In any electric motor the armature is caused to revolve by the reaction of two magnetic forces, one set up by the winding of the movable armature and one by the stationary field winding. In starting this motor, current from the transformer passes through the field and armature windings establishing two magnetic fields thereby, which react on each other to produce rotation. To increase the motor speed the voltage impressed upon it is increased gradually by closing certain unit switches, thus changing the transformer connections to supply higher voltage to the motor. The direction of rotation of the motor armature is changed by reversing the connections to the main field by means of the reverser. To prevent the motors on the car from overheating and damaging the insulation of the windings, they are cooled by an air blast from the blower.

**MASTER CONTROL APPARATUS**

14. The unit switches controlling the motor circuit and the devices operating the pantograph, sequence switch, and reverser are all actuated through the Master Control Circuit, the apparatus of which consists of the following:

15. **Motor-Generator**—(Plate No. 12). The motor-generator is supported under the car body either exposed
or protected in a steel box. On some cars the exposed type of motor-generator is located on the saloon side of the car, and on others both the exposed and enclosed types are on the opposite side of the car near the brake cylinder.

The purpose of the motor-generator is to supply direct current for the master control circuit, for lights on cars that have direct current lighting and for charging the battery.

There are several types in use which differ principally in output capacity. They consist of an alternating current motor and a direct current generator with their rotating parts on the same shaft.

The Motor-generator Switch, mounted on the switchboard, is a two-circuit switch, one side completing the A. C. circuit to the motor and the other side the D. C. circuit from the generator.

16. Battery—(Plate No. 13). The battery is carried in the battery box under the car body near the main transformer.

The battery is made up of cells of the Edison type, and is provided to supply direct current in case of failure of the motor-generator from any cause.

The battery is connected to the master control circuit by the Battery Switch mounted on the switchboard. To charge the battery, both the battery switch and the motor-generator switch must be closed.

In case of failure of the alternating current supply to the motor-generator, an Automatic Switch opens the circuit from the battery to the generator to keep the battery current from feeding back through it.

17. Master Controller—Two, one in each engineman's compartment (Plates No. 14 and 15). The master
controller, operated by the engineman, serves to complete the connections from the motor-generator and battery to the magnet valves, actuating the unit switches, reverser and sequence switch in proper sequence as the controller handle is turned for either forward or reverse movement of car.

It consists of a movable metal Controller Drum, rotated by the movement of the Controller Handle, and eight stationary spring Contact Fingers arranged in two rows of four fingers, each finger being insulated from the others. The drum is so shaped that, as it is turned from one position to another, certain fingers are brought to bear upon the metal drum and are thus connected together electrically. To each finger is connected a control wire which leads through the train cable. One wire is connected to the battery and supplies battery current to the controller drum. Other wires connected to the other fingers carry the battery current to one or more magnet valve coils, thus actuating the various switches, etc., of the motor control circuit.

On the face of the controller are a number of notches which engage the spring pawl of the controller handle as the latter is moved to its different Positions. Unless the handle when turned, is held, a spring returns it to its vertical or Emergency Position. The other positions, to the right or left, are called the Off Position, the Switching Position, the First and the Second Running Positions, respectively. To progress from one position to the next, the button in the controller handle must be pressed, thus releasing the pawl. Moving the controller handle to the right of the emergency position results in the forward movement of the car, and moving it to the left, in the reverse movement of the car, as indicated on the face of the controller. The controller drum rotates against spring pressure so that if the handle is released, it will automatically return to the emergency position, where the
power is cut off the train and the emergency brakes are applied.

The master control circuit from the battery switch leads to two receptacles located directly below the handle on the face of the master controller, one marked “Cut-out” and the other “Re-set.”

The “Cut-out” receptacle serves as a combined cut-out for the control and brakes. A Control Plug, attached to the controller handle by a chain, must be inserted all the way to connect the battery circuit to the controller, brakes and other master control apparatus.

In order to cut out the electric features of the brake as controlled by the engineman’s brake valve, this plug should be pulled out about one inch. With the plug inserted and the controller handle in emergency position, two contact fingers connected together through the drum complete a circuit to the Emergency Magnet Valve of the Universal Valve (see Figure No. 26 in air brake instructions), causing an emergency application of the brakes.

To prevent an emergency application of the brake when the controller is not in use, the control plug must be removed from the receptacle before the controller handle is allowed to take its vertical or emergency position. Similarly in starting, the controller handle must be moved to one of the “off” positions before the control plug is inserted in the receptacle.

When in “off” position, all fingers are disconnected from the drum, hence all unit switches are open, current is not supplied to the motors and the emergency brake magnet valve is not energized. Placing controller handle in switching position completes the master control circuit closing those unit switches resulting in lowest speed of
car. Placing the controller handle in first running position gives medium speed. The highest speed is obtained in second running position. The closing of the various switches during the acceleration is governed on each car by the current limit relay (Par. 23), i.e., each step in the sequence is delayed by the relay until the current in the main motors has fallen below a certain value.

When the overload relays, explained in Paragraph No. 27, operate from excessive current, they may be reset by inserting the control plug in the re-set receptacle, after which the insertion of the plug in the cut-out receptacle will permit of normal operation of the car.

On the bottom of the controller are the two push buttons for raising and lowering the pantograph as explained in Par. No. 6.

For the use of inspectors, a special Control Plug is provided. This plug will make contact to energize the brake circuits when inserted in the cut-out receptacle of the master controller but will not energize the control circuits to any of the contact fingers.

By referring to control wiring diagrams, Plates No. 29 and 30, it will be seen that the wires within the controller are numbered, some being connected to wires in the train cable having corresponding numbers. These wires to the master controller are used as follows:

- **B+** is the positive generator and battery wire connection.
- **Operating Through Controller Fingers.**
- **AB+** is the positive generator and battery wire connection leading to the controller drum after passing through the control plug and receptacle.
- **B5** for operating emergency magnet valve of
Universal valve when controller is in emergency position.

F for operating the reverser for forward movement.

R for operating the reverser for reverse movement.

Nos. 3, 4 and 8 for operating the unit switches governing the current to the motor and control circuits.

Not Operating Through Controller Fingers.

No. 5 for operating pantograph-up magnet valve through “up” button.

No. 6 for re-setting over-load relays through reset receptacle after automatic opening of Overload Relays.

BB+ is the positive generator and battery wire connection leading to pantograph-up button button contact finger, after passing through the control plug and receptacle.

No. 12 for lowering pantograph through “down” button.

B2 is the positive generator and battery wire connection, leading to the electric portion of the engineman’s brake valve after passing through the control plug and receptacle.

18. Magnet Valve. The standard magnet valve, shown in Plate No. 16, consists of an electro-magnet, energized by the master control circuit, whose movable Armature pushes down a rod running through the core, called the upper valve stem, the lower end of which forms the Exhaust Valve. The bottom of the upper valve stem acts upon the lower valve stem which carries the Inlet Valve. One of these valves is open when the other is
closed and vice versa. A spring below the inlet valve normally holds the armature up with the inlet valve closed and the exhaust valve open. Air connections lead from the control reservoir to the magnet valve and thence to either an operating cylinder or other device. The magnet valves of the magnet valve set, switch group, reverser, and the "On" magnet valve of the sequence switch are of this type.

The "Off" magnet valve of the sequence switch, shown in Plate No. 17, is of the Inverted type, i.e., a spring below the exhaust valve normally holds the armature up, inlet valve open, and exhaust valve closed. Its particular functions will be explained in Paragraph No. 20.

The unit switch Operating Cylinder is an air cylinder having a piston and rod, the movement of which operates the switch mechanism. The piston is normally held down by a coiled spring and is raised when air pressure is applied under it.

The operation of a unit switch and its magnet valve is then as follows: When the unit switch is open, the air piston operating it is held down by its spring, and the inlet valve of the magnet valve is held closed and its armature up by a spring bearing upward on the valve stem. When the magnet coil is energized through a master control circuit its armature is pulled down, thus lowering the valve stem which opens the inlet valve and closes the exhaust valve. Compressed air from the control reservoir then enters the operating cylinder, forcing the piston upward and closing the switch contacts. As soon as the master control circuit through the magnet coil is broken, the armature is released and the magnet valve spring forces the valve stem upward, closing the inlet valve and opening the exhaust valve, which cuts off the air pressure from the operating cylinder and exhausts.
the air already in the cylinder. The operating cylinder spring then forces the piston down, separating the unit switch contacts.

19. **Interlocks**—(Plates Nos. 4 and 6). Each unit switch has one or more **Unit Switch Interlocks** which make or break certain connections of the master control circuits whenever the unit switch is operated. They are not electrically connected to any part of the motor control circuit. Their purpose is to provide for the proper sequence of switches and other apparatus, and to prevent any conflicting switches from being closed at the same time. They consist of several stationary contact **Fingers**, the number varying with each switch, which bear upon **Contact Plates** attached on an insulating block which moves with the unit switch piston. The contact plates are arranged in two rows across the fact of the block so that certain fingers are connected together when the switch is in one position but not when it is in its other position. The fingers are connected in the master control circuits to the magnet valves of other switches, etc.

The reverser also has interlocks so arranged, that when the master controller is thrown for either forward or reverse movement, the motor control circuit through the unit switches to the motors is not established until the proper reverser magnet valve has operated and the reverser has thrown to such position that proper field connections are made for the desired movement. These interlocks consist of contact plates mounted on an extension of the reverser drum on which bear stationary fingers held by an insulating block and connected to wires of the master control circuit.

20. **Sequence Switch**—One (Plate No. 18). In order to reduce the number of interlocks on the unit
switches and to provide for interlocks for which there would otherwise not be room, an interlocking or **Sequence Switch** is provided, which is mounted on the end frame of the switch group opposite the end on which the reverser is mounted.

The sequence switch consists of three parts: (1) A **Drum** or cylinder of insulating material upon which are mounted metal segments, and two rows of stationary contact fingers which bear upon the metal segments; (2) two air cylinders with a piston, part of which forms a rack meshing with a pinion on the drum shaft; (3) two magnet valves controlling the flow of air to and from the air cylinders.

The drum is rotated from one position to another in each step of the sequence, as the car accelerates, by a movement of the rack. Between steps, the rack is held stationary by the balanced pressures in the two cylinders. The “On” magnet valve is a standard magnet valve. During the acceleration of the car, it is energized all the time, keeping one cylinder charged with air. The “Off” magnet valve is of the inverted type. It keeps the other cylinder charged with air except when energized. When advancing from one step of the sequence to another, the “Off” magnet valve is momentarily energized and vents air from its cylinder, unbalancing the pressures and causing a movement of the sequence switch. If the master control circuits are opened, as by moving the controller handle to “off” position, both magnet valves are de-energized and the inverted “Off” magnet valve returns the sequence drum to its “off” position.

21. **Control Cut-out Switch**—One. This is a single pole knife switch mounted on the switchboard. It is connected in the master control circuits controlling the
motors so that it can be opened when, for any reason, it is desired to keep the main motors from operating on that car.

22. **Automatic Switch**—One (Plates Nos. 19 and 20). The automatic switch is mounted on the switchboard either on the board itself or in the relay box. There are two different types used.

The one shown on Plate No. 19 has a magnet coil, energized from the main transformer. This coil holds the armature up and the upper disc makes contact to complete the battery circuit to the motor-generator, while the lower disc is held off its contacts. When the main transformer is not energized, the relay armature drops and the upper disc opens the circuit between the battery and motor-generator while the lower disc makes contact to complete the circuit between the battery and emergency lights. This type is used on cars with alternating current lights.

The type shown on Plate No. 20 has two operating coils which are connected in parallel with the motor of the motor-generator. The hinged armatures carry a wooden block with contact plates, one at the top and one at the bottom. When the motor-generator is running, the operating coils are energized and the armatures move the block so that the top contact plate makes contact with the spring contact fingers at the top, completing the circuit between the battery and the motor-generator. When the motor-generator is not running, the armature is released and the block moves so that the bottom contact plate makes contact with the spring contact fingers at the bottom, shortcircuiting the resistances (Paragraph No. 41) in the light circuits. (See Plate No. 30.)

23. **Current Limit Relay**—One (Plate Nos. 8 and 9). The purpose of the current limit relay is to control the
acceleration of the car so that the motors will not receive excessive current. In each step of the sequence during the acceleration of the car, the current limit relay opens the master control circuit to the “Off” magnet of the sequence switch until the current in the main motors has fallen to a predetermined value according to the setting of the relay.

The type shown in Plate No. 8 is applied to the older cars equipped with the nine-unit switch group. It consists of a few turns of heavy copper strap called the Current Coil which is connected in the main motor circuit, and an iron core carrying a contact disc that makes contact in the master control circuit.

When the current in the main motor circuit exceeds a certain value, the current coil lifts the core and disc, breaking the master control circuit to the “Off” magnet valve of the sequence switch.

There is another coil on this relay called the Potential Coil, which is energized by current from the master control circuit during all steps of the sequence except that corresponding to position No. 6 of the sequence switch. The action of the potential coil is to change the setting of the current limit relay so that the movement of the sequence switch is delayed until the motors have attained the proper speed.

The type shown in Plate No. 9 is applied to the newer cars equipped with the seven-unit switch group. It has a current coil like the one described above and an Auxiliary Coil energized from the master control circuit. The auxiliary coil operates a hinged armature that breaks the circuit to the upper contacts when the coil is energized. This coil regulates the operation of the unit switches by delaying the sequence in each step, thereby
preventing over-running of the sequence switch on each step. The operation of the auxiliary coil is adjusted by the resistance shunted around it.

24. Current Limit Relay Cut-Out Switch. This switch is a single pole knife switch mounted on the switchboard. Normally, it is blocked and sealed in the open position.

The purpose of this switch is to prevent the operation of the current limit relay from becoming effective until after the first running position. This is provided so that maximum starting power can be obtained when it is necessary due to the main motors being cut out on one or more cars in the train.

25. Slip Cut-Out Relay—One (Plate No. 20). On some cars this relay is mounted at the switchboard, either on the board itself or in the relay box. On some other cars, it is mounted beside the sequence switch. The purpose of this relay is to prevent damage to the main motors due to excessive spinning of the wheels.

When both pairs of wheels on a truck spinn together, the speed is not so great as when one pair of wheels spins alone, the other pair adhering to the rails. The slip cut-out relay operates when the two motors on the truck operate at widely different speeds as under the latter condition. It therefore does not prevent the wheels from spinning but does stop spinning when the condition of a dangerous speed is reached. It is used in connection with a reactor mounted in the switch group. (Plate No. 6).

The reactor is connected in parallel with the main motor armatures. The operating coil of the relay is connected between the middle point of the reactor and a point between the two main motor armatures. (Plate No. 30).
When the main motors operate at widely different speeds, the unbalancing of the voltage across the armatures causes a current to flow in the relay coil, actuating the armature of the relay and opening the contacts at the bottom. This opens the master control circuit to the magnet valves of the unit switch group and the sequence switch, cutting off the current from the main motors and allowing the wheels to stop spinning. The re-application of power then proceeds as normally without attention of the engineman.

26. Pantograph Lowering Relay—One (Plates Nos. 20 and 21). The pantograph lowering relay is mounted in the relay box either under the car body or at the switchboard.

The purpose of the pantograph lowering relay is to lower the pantograph when a short circuit or heavy overload occurs in the high voltage winding of the main transformer. It operates to lower the pantograph as soon as the substation breakers open and remove the power from the trolley wire or when the overload has cleared. The object of this feature is to avoid excessive arcing that would result if the pantograph were lowered while drawing a heavy current from the trolley.

Two different types are used, both accomplishing the same thing with slightly different mechanism.

The current coil is connected to the secondary winding of the series transformer. On one type the core of the current coil carries two contact discs, one at the top and one at the bottom. When the core is lifted, the bottom disc breaks contact between the bottom contacts which are connected in the circuit to the pantograph-down magnet. At the same time the top disc lifts the two top contacts to a position where they are latched by two vertical flat springs. The two top contacts are con-
nected to battery and the pantograph-down magnet. The top disc does not make connection between these contacts until the power is removed from the line or the overload has cleared and allowed the core to drop.

On the other type the current coil acts upon a hinged armature that makes contact on a pivoted block, completing the normal circuit to the pantograph-down magnet. When the armature is lifted, this circuit is broken and the block rotates, bringing another contact under the armature. As soon as the power is removed from the trolley wire or the overload has cleared, the armature drops and completes the circuit between the battery and the pantograph-down magnet valve.

With either type, the pantograph cannot be raised again until the relay is re-set by hand. Before re-setting the relay, the car should be taken out of service and inspected.

**27. Overload Relay**—(Plates No. 18 and 21). Two overload relays are mounted in the relay box under the car body or one overload relay combining the functions of two is mounted beside the sequence switch.

The purpose of the overload relay is to open the unit switches when a short circuit or overload occurs in the main motor circuit.

This relay has a current coil, connected in the main motor circuit. The current coil acts upon a hinged armature that controls a plunger with two contact discs. Normally, the lower disc completes the master control circuit to the unit switches and the upper disc is off its contacts. When the overload relay operates, it raises the lower disc from its contacts, opening the unit switches, and holds the top disc against its contacts, which are
connected in the master control circuit to the re-set coil at the bottom of the relay.

The re-set coil has an armature that latches the plunger in its upper position when the relay has operated. The unit switches cannot then be closed until the control plug is inserted in the re-set receptacle of the master controller, energizing the re-set coil, tripping the armature, and allowing the plunger to drop to its normal position.

When only one overload relay is used, it consists of two current coils, mounted one above the other, with their respective armatures connected by a link. The plunger and re-set coil operate the same as above. The lower current coil is connected in the auxiliary field circuit and the upper one in the armature circuit.

When two separate overload relays are used, one current coil is connected in the auxiliary field circuit and one in the circuit between the main field and the preventive coil.

28. Relay Box—One. When the relay box is located under the car body between the battery box and the hand pump it contains the pantograph lowering relay and two overload relays. When it is located at the switchboard, it contains the automatic switch, pantograph lowering relay, and the slip cut-out relay when used. (Plate No. 20.)

29. Train Cables—Two. There are two train cables, one containing seven wires and called the Seven Point Train Cable, the other containing nine wires and called the Nine Point Train Cable.

They are contained in iron conduit under the car and serve to carry the master control circuits necessary for train operation to each end of the car where provision is made for carrying the circuits to adjacent cars. The nine point cable contains the wires governing the motor
control, viz., F, R, 3, 4, 5, 6, 8, 12 and B—while the seven point cable contains the positive motor-generator or battery wire and also the wires for controlling the electro-pneumatic air brake system, viz., B+, B1, B2, B3, B4, B5 and B8.

30. **Train Cable Receptacles**—(Plates Nos. 22 and 23). The master control wires are connected between cars by means of train cable receptables and Control Jumpers. There are two receptables and two jumpers at each end of the car so that the jumpers of one fit into the receptables of the next one in a train. Dummy Receptables are provided beside the jumpers to hold them when not in use.

31. **Switchboard**—One (Plates Nos. 24 and 25.) The switchboard is located in the vestibule at the motor end of the car.

All the knife switches and fuses used on the car except the cab heater fuses are mounted on the switchboard. The name of each switch and fuse is stenciled on the switchboard.

The following apparatus is mounted on the switchboard:

- Motor-Generator Switch
- Battery Switch
- Control Cut-out Switch
- Current Limit Relay Cut-out Switch
- Air Compressor Governor Switch
- Compressor-Blower Switch or Separate Switches for Compressor Motor and Blower Motor
- Car Heater Switches (3)
- Fuses Protecting the Various Circuits
- Automatic Switch

If the relay box is mounted at the switchboard, it will contain the automatic switch, pantograph lowering relay and the slip cut-out relay when used.
On cars equipped with direct current lighting, there are resistance units mounted on the switchboard. These resistance units may be mounted on the back or front of the board.

**AUXILIARY APPARATUS**

32. **Air Blower**—One (Plate No. 27). The blower consists of a rotor having a series of horizontal blades equally spaced around its circumference. The air supply is taken through the Air Intake to the interior of the rotor where the blades collect and force it into the air ducts leading to all apparatus cooled by forced ventilation, viz., transformer, main motors, preventive coils and blower motor. The blower is direct connected to the motor shaft and always operates with the motor.

33. **Compressor-Blower Motor**—One (Plate No. 26). On some cars the air compressor supplying the main reservoirs, and the blower supplying the cooling air to the transformers, motors and preventive coils are both operated by the same motor, called the Compressor-Blower Motor. It is an alternating current motor of the doubly-fed type, supplied with current at 150 volts from taps on the transformer, controlled by a three pole Compressor-Blower Motor Switch on the switchboard and suitable fuses. The compressor-blower apparatus is supported on the bottom of the car near the transverse center line.

34. **Blower Motor**—(Plate No. 27). The blower on cars which have a separately driven air compressor is operated by a single phase, alternating current motor of the doubly-fed type, supplied with current at 110 volts from taps on the transformer, controlled by a two pole Blower Motor Switch on the switchboard and suitable
fuses. It is supported on the bottom of the car near the transverse center line.

35. Compressor Motor. The motor used to drive the air compressor is of the same general design as the blower motor, and drives the compressor directly through a worm gear. It is supported on the bottom of the car near the trailer truck.

It is supplied with current at 90 volts from taps on the transformer and is controlled by a two pole Compressor Motor Switch and suitable fuses on the switchboard and by a pneumatically operated Compressor Switch located under the car near the air compressor.

36. Compressor Switch—One (Plate No. 28.) A compressor switch operated by air from the main reservoirs and controlled by a compressor governor is connected in the compressor motor circuit.

A coil spring in the operating cylinder holds the piston down and the contacts closed. When the magnet valve is not energized, it admits air to the operating cylinder, raising the piston and opening the switch. When the magnet valve is energized, it connects the operating cylinder to atmosphere, allowing the spring to lower the piston and close the switch.

On cars equipped with compressor-blower motor, the compressor is driven through a clutch which is controlled by the clutch magnet valve. (See Air Brake Instructions).

37. Control Reservoir—One. The air pressure for actuating the master control apparatus is not taken directly from the main reservoir but from the control reservoir which is connected to the main reservoir through a check valve and a pressure-reducing (feed)
valve which supplies air at 70 pounds per square inch. The valve requires no attention by the engineman, as its action is automatic.

On some cars the control reservoir is supplied from the feed valve pipe through a reducing check valve.

38. Car Heaters. The cars are heated by electric heaters located along the sides of the cars near the floor. Each heater unit is connected to one or the other of two separate circuits, one-third of the total number of units being connected to No. 1 Heater Circuit and two-thirds to No. 2 Heater Circuit.

The heater circuits are controlled by three single pole knife switches on the switchboard marked, "Main Switch," "No. 1" and "No. 2." The main switch must be closed before the current can be passed through any of the heaters, but it of itself will not complete any heater circuit. With the main switch closed, closing No. 1 switch will complete No. 1 Heater Circuit giving the first or lowest degree of heat; closing No. 2 switch will complete No. 2 Heater Circuit giving, with No. 1 Switch open, second or intermediate degree of heat; closing both No. 1 and No. 2 switches will give the third or highest degree of heat. (See Plate No. 36).

39. Cab Heaters. In each engineman's compartment there is a Cab Heater which is controlled by the Cab Heater Switch independently of circuits No. 1 and No. 2, although the main switch on the switchboard must be closed to complete this circuit also. The cab heater switch is located near the floor to the right of the controller. (See Plates Nos. 15 and 36). The switch contacts are enclosed in an iron box and the switch is operated by foot push buttons. Depressing the button on top of box closes the switch and pushing in the button on front of box opens the switch. On the bottom of the vestibule end door is an attachment which when the door
is swung around to enclose the control apparatus when not in use, bears upon the lower button and insures the opening of this switch in all vestibules except the one from which the train is operated. Directly above the switch is a cast iron box with hinged cover containing the Cab Heater Fuse.

40. Car Lights and Head Light—All main car light and head light lamps are supplied with current at 32 volts through various circuits, each protected by fuses mounted at the top of the switchboard. The current used is either direct current obtained from the motor-generator set or storage battery, or alternating current brought from special taps on the transformer to the switchboard. If a car is arranged to use direct current only for lighting, it will be wired as shown in Plate No. 35. If alternating current is used for lights, provision is made for obtaining direct current lighting when the main car lighting lamps receive no current due to power failure. This is done by two emergency lamps located inside the car, one at each end. They receive current from a storage battery through two fuses on the switchboard marked “B+” and “B-,” and through the lower contact disc of the automatic switch, as described in Paragraph No. 22, and are controlled by a snap switch mounted above the switchboard and marked “E.” This switch is connected in the circuit between the automatic switch contacts and the lamps so that this switch must be closed to complete the circuit when the automatic switch is de-energized.

The lamps in the passenger portion of the car are distributed between two separate circuits, each having two fuses marked “P” and controlled by two snap switches marked “P,” located in the vestibule directly above the switchboard. In passenger-baggage cars the lamps in the baggage compartment are controlled by a snap switch in that compartment.
The lamps in both vestibule and saloon are on one circuit taken from the switchboard through two fuses marked "V" and are controlled by a main snap switch above the switchboard marked "V." The lamps of each vestibule are further controlled by a snap switch located overhead in the engineman's compartment and marked "Vestibule." This switch is for the use of the engineman only in controlling the lamps in the compartment from which he is operating.

A Headlight is mounted on each end of a car and contains two lamps, the Headlight Main Lamp and the Headlight Emergency Lamp. The main lamps are on one circuit coming through two fuses marked "HL" on the switchboard, each being controlled by a snap switch marked "Headlight," located overhead in the engineman's compartment.

On cars using alternating current for lights the emergency headlight lamps are supplied with current from the storage battery through the same fuses as the emergency car lights but are controlled independently of that circuit by a snap switch for each headlight located beside the headlight snap switch and marked "Emergency." It should be used whenever the headlight main lamp burns out while in service or when it is necessary to run with pantograph down on the head car.

On cars provided with direct current lighting both main and emergency lamps are on the same circuit but controlled by separate snap switches, marked "Headlight" and "Emergency," respectively. The emergency lamp should be used whenever a headlight main lamp burns out while in service.

In series with the headlight main lamp is the Gauge Lamp located in the hood over the air gauge for illum-
nation of the latter. In the base casting on which the air gauge is mounted, is a push button switch which when closed, short-circuits the gauge lamp. If a gauge lamp burns out while in service this switch should be closed so that the headlight lamp will receive current.

41. Resistance Units. Since the voltage of the battery is higher when the motor-generator is running, resistance units are provided to be cut in the various light circuits by the automatic switch. These resistance units are mounted on the switchboard, either on the back or front of the board.

CIRCUITS COMPLETED THROUGH THE MASTER CONTROLLER

42. By moving controller handle to the operating positions, connections as indicated in either of the following tables are made to operate the motors:

NINE UNIT SWITCH CONTROL
(See Plate No. 29)

<table>
<thead>
<tr>
<th>Controller Position</th>
<th>Seq. Switch No.</th>
<th>Controller Fingers Connected</th>
<th>Wires Connected</th>
<th>Unit Switches Closed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AB+, F, 8</td>
<td>AB+, F, 14; M, 15, seq. switch AB-, control cutout switch, 11, overload relay, 13, overload relay B-. Also 'on' magnet coil, 15, seq. switch, AB-.</td>
<td>M</td>
<td>If reverser is in reverse position at start its F coil is energized before unit switch M closes (AB+, F, F coil, F1, B-) thus throwing reverser in forward position.</td>
<td></td>
</tr>
</tbody>
</table>

40
### NINE UNIT SWITCH CONTROL (Continued)

(See Plate No. 29)

<table>
<thead>
<tr>
<th>Controller Position</th>
<th>Controller Fingers Connected</th>
<th>Wires Connected</th>
<th>Unit Switches Closed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FORWARD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switching 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>1</td>
<td>AB+, F, 8, 3.</td>
<td>Sequence No. 1 raises current limit relay. After it drops it connects AB+, 3, 51, 52 and 54, 56, seq. switch, 60, &quot;off&quot; magnet coil, 15 and AB-, moving sequence switch to its No. 2 position.*</td>
<td></td>
</tr>
<tr>
<td>Switching 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>2</td>
<td>AB+, F, 8, 3.</td>
<td>Sequence No. 2 raises current limit relay. After it drops it connects AB+, 3, 51, 52 and 54, 57, seq. switch, 60, &quot;off&quot; magnet coil, 15 and AB-, moving sequence switch to its No. 3 position.*</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>3</td>
<td>AB+, F, 8, 3.</td>
<td>M, A-1, A-2, S, D-2</td>
<td>When D-1 comes in S drops out because 38 and AB- are broken at D-1. D-2 does not come in until S drops out because 36 connects to AB- at S.</td>
</tr>
<tr>
<td>No.</td>
<td>3</td>
<td>AB+, F, 8, 3, 4.</td>
<td>M, A-1, A-2, S, D-1</td>
<td>Sequence No. 3 raises current limit relay. After it drops it connects AB+, 4, 51, 52 and 54, 58, seq. switch, 60, &quot;off&quot; magnet coil, 15 and AB-, moving sequence switch to its No. 4 position.*</td>
</tr>
</tbody>
</table>

**NOTE 1**—Following connection made: AB+, 8, 30, 16, current limit relay potential coil, AB-, Control cut-out switch, 11, overload relay, 13, overload relay, B-.

*Each time the sequence switch moves it momentarily connects 30 to 60 directly on sequence switch drum.

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## NINE UNIT SWITCH CONTROL (Continued)

(See Plate No. 29)

<table>
<thead>
<tr>
<th>Controller Position</th>
<th>Seq. Switch Position No.</th>
<th>Controller Fingers Connected</th>
<th>Wires Connected</th>
<th>Unit Switches Closed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>4</td>
<td>AB⁺, F, 8, 3.</td>
<td>AB⁺, 8, 30, seq. switch, 24, P, 34, 44, AB⁻</td>
<td>M₈</td>
<td>A-2, D-1, D-2; P</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P does not come in until A-1 drops out as 34 connects to 44 at A-1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>4</td>
<td>AB⁺, F, 8, 3, 4.</td>
<td>Sequence No. 4 raises current limit relay. After it drops it connects AB⁺, 4, 51, 52 and 54, 56, seq. switch, 60, “off” magnet coil, 15 and AB⁻, moving seq. switch to its No. 5 position.*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td>5</td>
<td>AB⁺, F, 8, 3.</td>
<td>AB⁺, 8, 30, seq. switch, 23, A-3, 33, AB⁻</td>
<td>M₈</td>
<td>A-2, D-1, D-2; A-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A-3 comes in after P drops out as 33 and AB⁻ are connected at F.</td>
</tr>
<tr>
<td>No. 2</td>
<td>5</td>
<td>AB⁺, F, 8, 3, 4.</td>
<td>Sequence No. 5 raises current limit relay. After it drops it connects AB⁺, 4, 51, 52 and 54, 59, seq. switch, 60, “off” magnet coil, 15 and AB⁻, moving seq. switch to its No. 6 position.*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td>6</td>
<td>AB⁺, F, 8, 3.</td>
<td>AB⁺, 8, 30, seq. switch, 24, P, 34, AB⁻</td>
<td>M₈</td>
<td>D-1, P, D-2; A-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P comes in after A-2 drops out as 34 and AB⁻ are connected at A-2.</td>
</tr>
<tr>
<td>No. 2</td>
<td>6</td>
<td>AB⁺, F, 8, 3, 4.</td>
<td>Sequence No. 6 raises current limit relay. After it drops it connects AB⁺, 4, 51, 52 and 54, 56, seq. switch, 60, “off” magnet coil, 15 and AB⁻, moving seq. switch to its No. 7 position.*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NOTE 1

Following connection made: AB⁺, 8, 30, 16, current limit relay potential coil, AB⁻, control cut-out switch, 11, overload relay, 13, overload relay, B-

*Each time the sequence switch moves it momentarily connects 30 to 60 directly on sequence switch drum.
## NINE UNIT SWITCH CONTROL (Continued)
(See Plate No. 29)

<table>
<thead>
<tr>
<th>Controller Position</th>
<th>Seq. Switch Position No.</th>
<th>Controller Fingers Connected</th>
<th>Wires Connected</th>
<th>Unit Switches Closed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FORWARD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>7</td>
<td>(AB^+, F, 8, 3, 4)</td>
<td>Sequence No. 7 raises current limit relay. After it drops it connects (AB^+, 4, 51, 52) and (54, 57), seq. switch, 60, &quot;off&quot; magnet coil, 15 and (AB^-), moving seq. switch to its No. 7a position.*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td>7a</td>
<td>(AB^+, F, 3, 3)</td>
<td>(M. A-3. P, D-S)</td>
<td>Contact at 26 wire broken at seq. switch, dropping out D-2.</td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>7a</td>
<td>(AB^+, F, 3, 4)</td>
<td>Sequence No. 7a raises current limit relay. After it drops it connects (AB^+, 4, 51, 52) and (54, 53), seq. switch, 60, &quot;off&quot; magnet coil, 15 and (AB^-), moving seq. switch to its No. 7b position.*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td>7b</td>
<td>(AB^+, F, 8, 3)</td>
<td>(M, D-3, A-3, A-2)</td>
<td>A-2 comes in after (P) drops out as 32 and (AB^-) are connected at (P)</td>
<td></td>
</tr>
</tbody>
</table>

| **REVERSE**         |                          |                             |                |                     |         |
| Switching           | 1                        | \(AB^+, R, 8\)              | \(AB^+, R\), reverse coil, R1, B-. Then after reverser operates, \(AB^+, R, 14, \) etc., as in forward movement. | \(M\) | After reverse connections are made, same sequence follows as for forward movement. |

**NOTE 1**—Following connection made: \(AB^+, 8, 30, 16\), current limit relay potential coil, \(AB^-\), control cut-out switch, 11, overload relay, 13, overload relay, B-.

*Each time the sequence switch moves it momentarily connects 30 to 60 directly on sequence switch drum.
## SEVEN UNIT SWITCH CONTROL

(See Plate No. 30)

<table>
<thead>
<tr>
<th>Controller Position</th>
<th>Seq. Switch Position No.</th>
<th>Controller Fingers Connected</th>
<th>Wires Connected</th>
<th>Unit Switches Closed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FORWARD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switching</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off</td>
<td>AB+, F, 8</td>
<td></td>
<td>AB+, F, “For” magnet coil, F1, seq. switch, B–.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AB+, F, 14, slip cutout relay, O, control cut-out switch, 15, overload relay, 16, M, 17, seq. switch, B–.</td>
<td></td>
<td></td>
<td></td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>AB+, 8, 30, “on” magnet coil, 61, B–.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AB+, 8, 30, 25, seq. switch, 21, A–1, 31, B–.</td>
<td></td>
<td></td>
<td></td>
<td>A–1</td>
</tr>
<tr>
<td></td>
<td>AB+, 8, 30, 25, seq. switch, 24, P, 31, 44, B–.</td>
<td></td>
<td></td>
<td></td>
<td>P</td>
</tr>
<tr>
<td>Off</td>
<td>AB+, F, 8</td>
<td>When P closes, it connects AB+, 8, 30 and 40, seq. switch, 60, “off” magnet coil, 61, B–, moving seq. switch to No. 1 position.*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>AB+, F, 8</td>
<td>AB+, 8, 30, 25, seq. switch, 26, 36, 8, B–.</td>
<td></td>
<td></td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A–1</td>
<td></td>
<td></td>
<td>P</td>
</tr>
</tbody>
</table>

Sequence No. 1 raises current limit relay. After it drops, it connects AB+, 3, seq. switch, 55 and 56, seq. switch, 60, “off” magnet coil, 61, B–, moving seq. switch to No. 2 position.*

*Each time the sequence switch moves it momentarily connects 30 to 60 directly on the sequence switch drum. At the same time it connects 30 to 50, energizing the auxiliary coil on the current limit relay which assists the raising of the relay and also prevents the sequence from progressing too rapidly by holding the lower contact open for a short interval.
**SEVEN UNIT SWITCH CONTROL (Continued)**

(See Plate No. 30)

<table>
<thead>
<tr>
<th>Controller Position</th>
<th>Seq. Switch Position No.</th>
<th>Controller Fingers Connected</th>
<th>Wires Connected</th>
<th>Unit Switches Closed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FORWARD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sw. 2</td>
<td>AB–, F, 8, 3.</td>
<td>AB–, 8, 30, 25, seq. switch, 22, A–, 32, B–.</td>
<td>M A–1 S A–2</td>
<td>A–2 comes in after P drops out because 32 goes through P interlock to B–.</td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td>AB–, F, 8, 3.</td>
<td>Sequence No. 2 raises current limit relay. After it drops, it connects AB–, 3, seq. switch, 55 and 56, seq. switch, 60, “off” magnet coil, 61, B–, moving seq. switch to No. 3 position.*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>AB–, F, 8, 3, 4.</td>
<td>Sequence No. 3 raises current limit relay. After it drops, it connects AB–, 4, seq. switch, 55 and 56, seq. switch, 60, “off” magnet coil, 61, B–, moving seq. switch to No. 4 position.*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 1</td>
<td>AB–, F, 8, 3.</td>
<td>AB–, 8, 30, 25, seq. switch, 24, P, 34, 54, B–.</td>
<td>M A–2 D–2 P</td>
<td>P comes in after A–1 drops out because 34 goes through A–1 interlock to 54.</td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>AB–, F, 8, 3, 4.</td>
<td>Sequence No. 4 raises current limit relay. After it drops, it connects AB–, 4, seq. switch, 55 and 56, seq switch, 60, “off” magnet coil, 61, B–, moving seq switch to No. 5 position.*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Each time the sequence switch moves, it momentarily connects 30 to 60 directly on the sequence switch drum. At the same time it connects 30 to 50, energizing the auxiliary coil on the current limit relay which assists the raising of the relay and also prevents the sequence from progressing too rapidly by holding the lower contact open for a short interval.*

45
# SEVEN UNIT SWITCH CONTROL (Continued)

(See Plate No. 30)

<table>
<thead>
<tr>
<th>Controller Position</th>
<th>Seq. Switch Position No.</th>
<th>Controller Fingers Connected</th>
<th>Wires Connected</th>
<th>Unit Sw. Closed</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>REVERSE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sw.</td>
<td>Off</td>
<td>AB−, B, 8, AB+, B, &quot;Rev&quot;</td>
<td>magnet coil, R1, seq. switch, B−</td>
<td>Reverser moves to reverse position and is held through AB−, B, &quot;REV&quot; magnet coil, R1, B−</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Connections are the same in reverse as in forward movement, except F is replaced by R.</td>
</tr>
</tbody>
</table>

## RE-APPLICATION OF POWER ABOVE THIRTY MILES PER HOUR

Normally, the current limit relay lifts when M, A−1, and P close. When power is reapplied at a speed of thirty miles per hour or over, the motor current will be insufficient to operate the current limit relay and 27 and 57 will be momentarily connected together at the sequence switch between ‘‘off’’ and No. 1 positions of the sequence switch. This connects AB−, 8, 30, sequence switch, 56, 57 and 27, 37, D−2, 48, B−, closing D−2. S cannot close then because 26 must go through D−2 interlock to 36. D−2 is then held in through 26, 37, 48, B−, until its normal circuit is established. The sequence of switches is the same as above schedule except that S is replaced by D−2.
INSTRUCTIONS

PREPARING A TRAIN FOR SERVICE

43. When cars are prepared for service after a long lay-over, the following procedure should be followed:

FIRST: See that one set of control jumpers between cars are properly inserted in the receptacles and the other set between cars and those at the ends of the train are inserted in the dummy receptacles; that the air hose between cars are coupled and the cocks in the main reservoir pipe opened and that the air hose at the ends of the train are attached to the dummy couplers and the cocks in the main reservoir pipes at the ends of the train are closed; that all drain cocks are closed; that the safety chains between cars are hooked up and those at the ends of the train are hooked across the end doorway; that the end door in the front end is closed and securely fastened by the devices provided for that purpose and that all other end doors are swung against the master controller and latched in place. While carrying out the above procedure, observe that no one is working on or about any car.

SECOND: Close the compressor-blower switch or the compressor motor and blower motor switches, battery, control cut-out, motor-generator, and governor switches on all cars.

THIRD: If there is not sufficient air pressure to unlock the pantograph, raise the pantograph on one or two cars with the hand pump. This will
start the compressor on those cars and allow them to charge the whole train. When about 55 pounds has accumulated, the pantographs on the rest of the cars can be raised.

FOURTH: Attach the controller handle to the master controller and move it to “off” position. Insert the control plug in the cut-out receptacle, raise the pantograph-down button momentarily and pull it down, then push the pantograph-up button. Remove the control plug. All pantographs should then be up.

FIFTH: Pass along the train and see that all blowers are operating properly.

The train is now ready for the air brake test as prescribed in the Air Brake Instructions.

44. Pantograph Test. When a train is made up or when its composition has been changed, a test of the pantographs must be made in the following manner:

Lower the pantographs by raising the pantograph-down button on the operating master controller for a sufficient length of time to lower the pantographs, then pull this button down. Inspect the pantographs from the ground if necessary, to see that all are down and latched. Then insert the control plug in the cut-out receptacle, press the pantograph-down button momentarily to charge the lowering cylinders with air, and press the pantograph-up button. Inspect each pantograph to make sure that all are up.

Trainmen must know that the pantograph on each car is up unless the car or pantograph is out of order and the pantograph locked down.
45. **To Start.** Attach the controller handle, move it to "off" position and insert the control plug in the cut-out receptacle. Inasmuch as this plug, when inserted in the cut-out receptacle, controls the electric features of the brake and the emergency brake features of the master control system, it should never be removed from the cut-out receptacle while a train is in motion except when necessary to re-set the overload trips. After re-setting the overload trips, the plug should be returned to the cut-out receptacle immediately. When it becomes necessary to cut out the electric features of the automatic brake, the control plug should be withdrawn about one inch.

When signalled to start, if the rails are in proper condition for maximum acceleration, the controller handle may be turned immediately from "off" to No. 2 running position, and the current limit relay will govern the acceleration so that the motors will not receive excessive current.

When accelerating a train in the above manner on slippery rails, if the wheels on any car start to spin, the current limit relay allows the sequence to progress up to the highest speed on that car, resulting in damage to the motors and wheels. For this reason, acceleration on slippery rails should be controlled by "stepping up" as follows:

Place the controller handle in switching position, holding it there until the train reaches the normal speed for that position. Move the handle to first running position for an instant and back to switching position to get the next step in the sequence. The third step is obtained by again moving the controller handle to first running
position. Additional steps are obtained by moving the handle to second running position for an instant and back to first running position. The rate of acceleration can be held as low as desired by this method and the tendency of the wheels to slip is thus held to a minimum. The number of steps in the acceleration between first and second running positions is one on some cars and four on others, but since both types of cars are operated in the same trains, it should be considered as the latter figure.

The action of the slip cut-out relay should not be relied upon when wheels slip, but the controller handle should be turned to “off” position immediately when this occurs and acceleration controlled by “stepping up.”

The switching position should be used only when accelerating the train or when making yard movements and should not be used as a running position.

46. To Reverse. To move in reverse direction, the controller handle should be moved to the left. To move the handle from forward to reverse, the handle must pass through emergency position. If the control plug is in the cut-out receptacle, this movement must be made quickly to prevent an emergency application of the brakes.

Trains should not be reversed while moving.

47. To Stop. Place the master controller handle in the “off” position and apply the brakes as instructed in the Air Brake Instructions.

If the controller handle is released, it will return to the emergency position, cutting off power and energizing the emergency magnet valve coil in the universal valve,
thus exhausting the air from brake pipe to atmosphere and causing an emergency application of the brakes.

48. Coasting. To allow a train to run free after acceleration has taken place, shut off the power by moving the controller handle to “off” position and holding it there.

It is desirable to coast as much as possible, consistent with the schedule, as it results in a saving of power. Use excess time in coasting rather than in standing at stations. Coast, when possible, before applying brakes to make a service stop or in slowing down on account of a speed restriction.

If power is shut off the motors while moving about 30 miles per hour, power must not be re-applied until the speed has been reduced to less than 30 miles per hour. This is necessary to prevent the motors from flashing over.

49. To Cut Off Car from Train. After the engineer has depleted the brake pipe, the control jumpers must be hung in the dummy receptacles, the main reservoir pipe cocks closed, the air hose attached to the dummy couplers, and the safety chains unhooked between cars.

50. To Prevent Tampering with Apparatus. To prevent tampering with apparatus, the end doors should be swung into place against the master controller and latched in place, except where the engineman is operating. Switchboard doors should be closed and latched. Enginemen should not leave the operating compartment without taking the control plug and controller handle with them.

51. Blocking Controller Handle. Under no circumstances must the controller handle be blocked so that the spring cannot return it to the “emergency” position.
52. **Assisting Steam Trains.** Electric cars must never be used to assist steam trains.

53. **Pantograph Drop Orders.** When observing "Pantograph Drop" orders, the pantograph-down button should not be pulled out until ready to raise the pantographs again. This prevents damage that might be caused by any pantograph rising too soon due to failure of the locking device to engage.

**TRAIN FAILURE**

54. The failure of a train of one or more cars to move or to attain full speed when the directions for train operation have been followed, may be due to one or more of the following causes:

**FIRST:** Failure of Power.

**SECOND:** Defect in Motor Control Circuits.
- (a) Pantograph in down position.
- (b) Operation of overload relays.
- (c) Failure of unit switches to close.

**THIRD:** Defect in Master Control Circuits.
- (a) Poor contact in master controller.
- (b) Loose or defective control jumper.

The engineman should be informed immediately if any car is not operating so that the defect may be located and proper steps taken.

55. **By Failure of Power** is meant that current has been cut off the trolley wire at the power station or substation. It will then be impossible to operate the blower motor or any other auxiliary apparatus on the car or to get a flash by opening and closing the heater switches. After being sure that the pantograph is up and after
repeating these tests on another car with the same results, it may be assumed that the power is off. The controller handle must not be moved to any operating position until the power is restored.

56. **Pantograph in Down Position.** The pantograph will fail to rise when it is held down by the grounding device, when the locking device fails to receive air to release it, when the pantograph-down magnet valve is energized or when the master control circuit to the pantograph-up magnet valve is not completed.

When it is held down by the grounding device, the reason for it should be ascertained before releasing it.

The locking device may fail to receive air to release it either on account of a broken control air pipe, or a closed pantograph main cock. If due to the former, it will be impossible to raise the pantograph. If due to the latter, open this cock after making sure that no person is working under the car and that the car and pantograph are in proper condition for service.

The pantograph-down magnet valve may be energized, either on account of a pantograph-down button in a master controller on some car in the train being raised, by a defect in the control cable or jumper, or by the operation of the pantograph lowering relay. If on account of the latter, it will be possible to raise the pantographs on all cars in the train other than that on which the relay has operated. If caused by a raised pantograph-down button, each controller will have to be inspected and the button causing the trouble pulled down.

The master control circuit to the pantograph-up magnet valve may not be completed due to poor contact
at the control cut-out receptacle in the master controller, or to poor contact at the pantograph-up button. In this case, raise the pantographs from another master controller on the train.

57. **Pantograph Fails to Lower.** If it is desired to lower the pantograph and this cannot be done in the usual way, the pantograph pole carried under the cars should be used. Insert the hook on end of pole in the opening on either end of pantograph contact shoe and pull down pantograph until it engages the latch. **Rubber gloves must be worn while using these poles, with hands not less than six feet from the hook.**

58. The **Operation of Overload Relays** indicates trouble in the motors themselves or in the motor control circuits between motors and unit switches. The operation of an overload relay in a train is usually indicated by slow and uneven acceleration. Remove the control plug from the cut-out receptacle and insert in the re-set receptacle, performing this operation several times, if necessary.

If the trouble does not clear itself, proceed to terminal, unless the motor or preventive coil insulation is on fire, in which case the blower motor and control cut-out switches should be opened in order to cut off the air and minimize burning of the insulation and at the same time prevent possibility of the overload trip re-setting and throwing the motor load on the unventilated main transformer.

If any of the apparatus, including cables, has caught fire and is burning, apply fire extinguisher or, if not available, water or sand.

59. **Failure of Unit Switches to Close** on any car may be due to insufficient control air pressure caused by a broken control air pipe on that car. In this event, the control reservoir should be cut out and the control cut-
out switch opened. Failure of the unit switches to close may also be caused by operation of an overload relay or by a defect in the master control circuit.

60. Poor Contact in the Master Controller. Poor contact of the fingers on the drum or in the control cut-out receptacle may cause a failure of the train to start or attain full speed. The control plug should be removed and inserted in the cut-out receptacle several times and if the defect cannot be corrected, the train should be operated from the controller of the next car. An inspection of the contacts should be made at the terminal to see whether all fingers make contact.

61. Loose or Defective Control Jumpers. If all the cars behind a certain set of jumpers fail to operate properly, that set of control jumpers should be examined to see whether they are properly inserted in the receptacles. If properly inserted, they should be hung in the dummy receptacles and the jumpers on the other side inserted.

62. Blower Failure. If a blower fails from any cause, the control cut-out switch on that car must be opened to prevent over-heating of the main motors, transformer and preventive or reactance coils, and when the train reaches its terminal, the pantograph must be lowered.

Particular attention should be given by members of the train crews to discover blower failures and cut out the control as described above.

63. Motor-Generator Failures. If the motor-generator fails, the fuse should be renewed. If this does not remedy the trouble, the motor-generator switch should be opened and report made upon arrival at the terminal.
64. Use of Current Limit Relay Cut-out Switch. When difficulty is experienced in starting a train due to inoperative cars in the train, the current limit relay cut-out switch on all the operative cars should be closed.

When it becomes necessary to close the current limit relay cut-out switches, report should be made on the proper form with full explanation upon arrival at the terminal.

These switches should always be opened as soon as conditions permit.
GENERAL DIRECTIONS

65. Warning. All employes are warned that no portion of the 11,000 volt high tension circuit, including pantograph, main and series transformer and pantograph lowering relay, on a car must be touched unless the pantograph of that car is lowered and the grounding switch closed. The grounding switch must be closed by the person intending to do the work and must be opened after the work is completed by the same person, after warning all others around the car to clear, and making sure that all are safely away from live parts.

Overhead Wires Must Never Be Touched.

66. If It Becomes Necessary to work on broken pantographs in order to clear same, great care should be exercised to avoid injury when handling broken parts.

67.—The 30 Volt Alternating Current Lighting Circuits must at all times be considered as high voltage circuits. Under certain conditions there may be a difference of potential of 930 volts between a lighting wire and ground.

68. Work Must Not Be Done on any circuit on a car unless the switch controlling that circuit is opened. Fuses in lighting, motor-generator and heater circuits must not be replaced, nor switches in these circuits be repaired without lowering the pantograph. Furthermore, neither the switch group, nor metal parts of the control wiring should be touched unless the pantograph is lowered.

69. In Manipulating the Quick-Break Knife Switches on switchboard, care should be taken. These switches should be opened with a single quick movement. In closing single pole knife switches, switch blade should
be moved up close to the switch jaws, but not touching
same, and if it is seen that it will fit in the jaws, it should
be pushed firmly into place.

_Umbrellas, Clothing and Other Material_ must not
be placed where they may come in contact with switches
or other portions of the electric circuits.

70. **If Short Circuit, Arcing or Smoking Occurs**
throw controller handle to off position, if running. If
the disturbance continues, immediately push pantograph-
down button, leaving same raised until all pantographs
are lowered and latched. If, for any reason, pantograph
on defective car does not lower, it must be pulled down
by means of wooden pantograph pole until engaged by
the latch.

71. **If Any Car Heater Smokes or Arcs**, all heater
switches on that car should be opened immediately, open-
ing No. 1 and 2 switches first and then the main switch.

72. **All pantographs in a Train** can be lowered by
pushing the pantograph-down button on any controller
in the train, whether the control plug is inserted in the
cut-out receptacle or not, and all trainmen should be
familiar with this fact so that in an emergency they can
lower pantographs without waiting to advise the engine-
man of the trouble.

73. **Unusual Noises** in train movements should be
located at once. To avoid delay the conductor or brake-
man should stand beside the train while it is moved
slowly.

74. **Working on Car Roof.** Employes must not go
on the roof of electric car equipment except in the dis-
charge of their duty. They must first lower pantograph
and ground same with handle provided for that purpose.
They must exercise great caution to avoid coming close to trolley wire or allowing material or tools to do so.

75. **Detention Reports.** In filling in Form M. P. 390-F entitled “Motorman’s Report of Defects and Train Detentions,” the cause of any detention should be noted as accurately as possible and such information given as will aid the inspector to readily locate the trouble. In each case an attempt should be made to ascertain exactly what apparatus has caused the failure. A list of equipment is given herewith as a guide to the engineman in ascribing causes.

76. **Use the Names** given the various apparatus in this book when referring to any of this equipment.
LIST OF EQUIPMENT FOR USE IN REPORTING TRAIN DETentions

MASTER CONTROLLER
- Control-Cut-out Receptacle.
- Re-set Receptacle.
- Control Jumper.
- Current Limit Relay.
- Overload Relay.
- Pantograph Lowering Relay.
- Automatic Switch.
- Controller.
- Sequence Switch.
- Motor-Generator.
- Battery.

MOTOR CONTROL
- Pantograph.
- Pantograph Shoe.
- Pantograph-up Device.
- Pantograph-down Device.
- Grounding Device.
- Reverser.
- Unit Switch.
- Reactance Coil.
- Preventive Coil.
- Main Transformer.

MOTORS
- Motor Inoperative.
- Motor on Fire.
- Leads Defective.
- Gears.

AIR SUPPLY SYSTEM
- Compressor-Blower Motor.
- Compressor Motor.
- Blower Motor.
- Compressor.
- Blower.
- Governor Defective.
- Compressor Switch Defective.

AIR BRAKES
- Sticking.
- Rigging.
- Fixtures.
- Pipes.
- Hose.
- Emergency Attachment.

TRAIN SIGNAL
- Pipes.
- Hose.
- Fixtures.

HOT BEARINGS
- Journal.
- Roller Bearings.
- Armature.
- Motor Axle.

MISCELLANEOUS
- Electric Heaters.
- Headlight.
- Car Lights.
- Alarm Whistle.
- Train Parting.
- Draft Rigging Defects.
- Spring Rigging.
- Truck.
- Wheels.
- Various Details of Car Body.
PLATE No. 1

PANTOGRAPH.
Par. No. 6.
PLATE No. 2

MAGNET VALVE SET.
Par. No. 6.
PLATE No. 3

SECONDARY TAPS

SERIES AND MAIN TRANSFORMERS.

Pars. Nos. 7 and 8.

PANTOGRAPH LEAD

SERIES TRANSFORMER

AIR INTAKE

SECONDARY TAPS
PLATE No. 4

NINE-UNIT SWITCH GROUP—FRONT.

Pars. Nos. 10 and 19.
PLATE No. 5

NINE-UNIT SWITCH GROUP—REAR.
Par. No. 10.
PLATE No. 6

SEVEN-UNIT SWITCH GROUP—FRONT
Pars. Nos. 10, 19 and 25.
PLATE No. 7

UNIT SWITCH—CROSS-SECTION SHOWING INTERLOCK, AND MAGNET VALVE.

Pars. Nos. 19 and 19.
REVERSER AND CURRENT LIMIT RELAY—USED WITH NINE-UNIT SWITCH GROUP.

Para. Nos. 11 and 23.
REVERSER AND CURRENT LIMIT RELAY—USED WITH SEVEN-UNIT SWITCH GROUP.

Pars. Nos. 11 and 23.
PREVENTIVE COILS—REACTANCE COILS ARE SIMILAR.

Par. No. 12.
MOTOR GENERATOR ON CAR.
Par. No. 15.
PLATE No. 14

MASTER CONTROLLER—COVER REMOVED.
Par. No. 17.
ENGINEMAN'S COMPARTMENT.

Pars. Nos. 17 and 39.
MAGNET VALVE (Standard) CROSS SECTION.
Par. No. 18.
MAGNET VALVE (Inverted) CROSS SECTION
Pars. Nos. 18 and 20.
SEQUENCE SWITCH AND OVERLOAD RELAY.

Pars. Nos. 20 and 27.
PLATE No. 19

AUTOMATIC SWITCH.
Par. No. 22.
RELAY BOX—SWITCHBOARD.
RELAY BOX—REAR COMPARTMENT—UNDER CAR BODY.

Parts Nos. 26, 27 and 28.
CONTROL JUMPERS AND DUMMY RECEPTACLES.

Par. No. 30.
TRAIN CABLE RECEPTACLES.
Par. No. 30.
SWITCHBOARD.
Par. No. 31.
SWITCHBOARD—NEW TYPE.
Par. No. 31.
PLATE No. 27

BLOWER MOTOR AND ROTOR
Par. No. 34.
SEQUENCE OF SEVEN-UNIT SWITCH GROUP

Pars. Nos. 10 and 42
HEATER CIRCUITS

Parts Nos. 38 and 39
Air Brake and Train Signal Instructions

GENERAL

77. The Multiple-Unit Cars now in electric service are equipped with the Westinghouse Air Brake Co.'s electro-pneumatic brake, designated the AMUE equipment. This equipment is so designed that it may be used in either steam or electric service.

78. This brake differs from the ordinary pneumatic brake in that the brake pipe reduction is made on each car by means of the electric control, instead of being made entirely with the engineman's brake valve. Thus the addition of the electric control to the pneumatic brake does not add in any way to its power, but shortens the time required to get the brakes applied on all cars.

79. While it has many additional features, it operates in essentially the same manner as the older automatic equipment. By that is meant that the principles of operation remain the same. A reduction in brake pipe pressure applies the brakes, and an increase in brake pipe pressure releases them.

80. The brake equipment on each car consists of the following: (See Fig. 1 or Fig. 2.)

One air compressor which supplies the compressed air (Par. No. 81).

One compressor governor which causes the air compressor to start and to stop automatically and maintain the air pressure in the main reservoir within predetermined limits (Par. No. 99).

One clutch magnet (Fig. 1) (Par. 110), or one compressor switch (Fig. 2) (Par. 36), either of
which actuated by the compressor governor, starts and stops the compressor.

**Radiating pipe** which is inserted between the compressor and the two main reservoirs so that the air, after being compressed, may be cooled, in order that all moisture will be deposited in the main reservoirs and not be carried over into the brake system.

**Two main reservoirs** which store the compressed air.

**One safety valve** which prevents excessive pressure accumulating in the main reservoirs in case of a governor failure. (Par. No. 97.)

**One main reservoir pipe** which serves to connect the main reservoirs of different cars together and to conduct the main reservoir air, either to the operating brake valves (Fig. 1), or to the brake feed valve (Fig. 2).

**Two engineman’s brake valves with or without feed and reduction limiting valves** attached, the brake valve operating the brakes, and the reduction limiting valve, when used, limiting the brake pipe reduction during service applications (Pars. Nos. 112 and 115).

**Two feed valves**, one attached to each brake valve (Fig. 1), which reduce the main reservoir pressure before admission to the brake pipe; or, **one feed valve**, located inside the car (Fig. 2), which reduces the main reservoir pressure before admission to the **feed valve pipe**, leading to the operating brake valves (Par. No. 125).

**Two combined equalizing and reduction limiting reservoirs** which are required for the operation of both the equalizing piston of the brake valve and the reduction limiting valve, one at each end of car,
or two equalizing reservoirs for the operation of the equalizing piston, one at each end.

One brake pipe which conducts the compressed air from the brake valve to the universal valve on each car.

One universal valve which controls (1) the charging of the reservoirs; (2) the application of the brakes; (3) the release of the brakes (Par. No. 133).

One emergency or quick recharge reservoir which stores compressed air used for quickly recharging the service and auxiliary reservoirs.

One auxiliary and one service reservoir which store compressed air used in both service and emergency applications.

One brake cylinder which, by means of its piston and the attached levers and rods of the foundation brake rigging, forces the brake shoes against the car wheels.

One slack adjuster which automatically maintains a uniform piston travel. (Par. No. 149.)

Two duplex air gauges which indicate the pressure in the brake pipe and main reservoir, one located at each end of car.

One cable containing seven wires which extends the length of the car and is connected to the adjoining cars by jumpers.

One conductor's valve which makes possible an emergency application of the brakes from within the car.

Accessories which include cut-out cocks, air strainers, hose, dirt collectors, switches, etc.
THE AIR COMPRESSOR.

81. There are two types of air compressors used to supply the compressed air, one type being a duplex, single-acting compressor driven by a motor through a herringbone gear and pinion, and the other a four cylinder, single-acting compressor driven by a motor through a worm gear.

82. The Duplex Compressor (Figs. 3 and 4) consists of an air compressor and motor, the frames of which are bolted together and suspended from the car body by four wrought iron hangers. The pinion through which the compressor is driven is normally coupled to the motor shaft by a multiple disc clutch. When the air pressure in the main reservoir has reached the maximum carried, the governor cuts out, the clutch is disengaged and the compressor stops. It is necessary that the motor runs constantly, because to its shaft is attached a blower, which provides for the forced ventilation of various electrical devices. By means of the clutch, one motor is able to drive the blower and the air compressor.

The motor is described in Par. No. 33.

The commutator end bearing is of the waste-packed type, and the pinion end is oiled by the splash system from the pinion. The oil should be replenished when its level falls below normal in the gauging wells. The multiple disc clutch, which is mounted upon the motor shaft at the opposite end from the blower, receives sufficient oil from the gear and pinion and should require no other lubrication.

83. The Duplex Air Compressor is made up of the following principal parts: a crank case and two horizontal cylinders cast in one piece, a casting forming the two cylinder heads and containing the inlet and discharge valves, a top crank case cover, a crank shaft, two pistons, two piston rods and the necessary crank shaft bearings.
The inlet and discharge valves are made of cold rolled steel, and are alike but should not be moved from one seat to another without regrinding.

84. The Operation of the Duplex Air Compressor is as follows: when the crank shaft is rotated by the motor pinion, the pistons are moved backward and forward horizontally. On the stroke toward the crank shaft, air is drawn into the compressor cylinder through the inlet valve, passing through a strainer to prevent the entrance of dust or dirt. On the return stroke, the inlet valve is closed and the air compressed until it opens the discharge valve and passes from the compressor into the main reservoir. The crank shaft must always rotate in the same direction; when facing the gear case side of the compressor, this direction is counter-clockwise.

85. To Remove the Armature of the Duplex Air Compressor, take the blower from the shaft, detach the housing at the commutator end, and draw the armature out. The pinion end of the shaft fits into a square socket in the clutch, so this end housing does not have to be disturbed. When the armature is withdrawn, care should be taken that it does not rub against the laminations.

86. To Remove a Piston of the Duplex Air Compressor unbolt the cylinder head casting and top crank case cover. Uncouple the hinged bearing of the connecting rod of the piston to be removed. The piston and connecting rod can then be drawn out through the cylinder.

87. The Four-Cylinder Air Compressor consists of an air compressor and motor, the frames of which are bolted together and suspended from the car body by three wrought iron hangers. As cars which are equipped with this type of compressor have a separately driven blower, it will not be necessary for the motor to run constantly.
88. The motor of the four-cylinder air compressor is similar to the one described in Par. No. 33 of electrical equipment instructions. The bearings are of the ball-bearing type, the commutator end bearing being lubricated by a grease cup and the worm end bearing by the splash system from the pinion. The oil should be replenished when its level falls below normal in gauging wells.

89. This compressor is made up of the following principal parts: A crank and gear case and four cylinders, two horizontal and two vertical, in one piece; four cylinder heads each containing an inlet and a discharge valve; two crank case covers and one gear case cover; four piston rods and the necessary crank shaft bearings. The inlet and discharge valves should not be moved from one seat to another without regrinding.

90. The Operation of the Four-Cylinder Air Compressor is as follows: When the crank shaft is rotated by the motor worm, two pistons are moved backward and forward horizontally and two up and down vertically. When any piston is moving toward the crank shaft, air is drawn into the compressor cylinder through the inlet valve, passing through a strainer to prevent the entrance of dust and dirt. On the return stroke, the inlet valve is closed and the air compressed until it opens the discharge valve and passes from the compressor into the main reservoir.

91. To Remove the Armature of the Four-Cylinder Air Compressor, detach the commutator end housing, remove the cap from the worm end housing and the nut from the armature shaft and draw out the armature. The armature shaft is slotted so that it will engage a key in the worm gear through which it passes.

92. To Remove a Piston of the Four-Cylinder Air Compressor, unbolt the cylinder head casting and crank
case cover, uncouple the connecting rod bearings of the piston to be removed, and draw the piston and rod out through the cylinder.

93. **The crank shaft bearings** of both compressors are lubricated by the splash system; that is, the crank case is filled with oil to such a height that when the crank shaft rotates, the connecting rod heads strike the oil, splashing it over the inside of the crank case and such parts of the cylinder as are exposed, thus lubricating the crank shaft bearings, wrist pins, and cylinders. The gear and pinion are lubricated by oil from the crank shaft bearing and consequently require no separate oiling. The oil in the crank case should be replenished when required, as indicated by the gauge.

94. **In the event of compressor pounding**, examine for defective cylinder head gasket, broken valves or loose connecting rod bearing; if the latter, remove the top crank case cover and take out one of the liners between the halves of the connecting rod bearings, tightening up the bolt so that there will be no play between the crank and the connecting rod bearing. Care should be taken not to make the bearing too tight.

95. **Undue friction** in the air compressor is frequently the cause of the compressor-blower or compressor motor fuses blowing. To locate the trouble, examine the discharge valves and see that they are not sticking; examine the pistons and the shaft bearings for undue friction to see if they are running hot.

96. **To clean the suction strainer**, remove the four screws at the bottom, take out frame containing curled hair and clean thoroughly.
THE SAFETY VALVE.

97. The safety valve is of the E-7 type and is shown in section in Fig. 7. When the air pressure below valve 4 (which is open directly to the main reservoir) is greater than the spring pressure, the valve raises, and as a larger area is then exposed, it moves upward very quickly, being guided by the brass bush in body 2. Ports are drilled in this bush upward to the chamber and outward through the body to atmosphere. As the valve moves upward, its lift is determined by the stem 5 striking cap nut 3. It closes the vertical ports in the bush connecting the valve and spring chambers and opens the lower ports to the atmosphere. As the air pressure below valve 4 decreases, and the compression of the spring forces the stem and valve downward, the valve gradually closes the lower ports to the atmosphere and opens those between the valve and spring chambers. The discharge air pressure then has access to the spring chamber. This chamber is always connected to the atmosphere by small holes through the body 2. The air from the valve chamber enters more rapidly than it can escape through these holes, causing pressure to accumulate above the valve and to assist the spring to close it with a "pop" action.

98. The valve is adjusted by removing cap nut 3 and screwing up or down the adjusting nut 7. The closing is adjusted by adjusting nut 8 which restricts ports f. Lock nut 9 holds the adjusting nuts from turning. After the proper adjustment is made, cap nut 3 must be replaced and securely tightened, and the valve operated a few times. Particular attention must be given to see that the holes in the valve body are always open and that no dirt collects on the valve seat. The valve should be adjusted to lift at 130 pounds.
THE COMPRESSOR GOVERNOR.

99. The Governor, used to stop and start the compressor automatically, is of either the “J” or the “S” type and is illustrated by Figs. Nos. 8 and 10. This governor opens the circuit to the magnet valve which controls the compressor switch or compressor clutch, depending on whether the car has a separately driven air compressor or not. Both the “cutting-in” and “cutting-out” points of this governor are adjustable. The governor consists of two parts, an electric switch to open and close the compressor switch magnet circuit, or clutch magnet circuit, as the case may be, and a pneumatic regulating mechanism to cause movement of this switch.

100. The electric switch, of the “J” type is shown in Fig. No. 9. Its principal parts, as shown in Fig. No. 9, are: The switch spider 43, the switch piston and rod 16, and the finger contacts 5. The circuit is made or broken by the falling and rising of the switch piston. The electric switch portion is insulated from the regulating portion and is protected by a metallic cover, which may be readily removed for inspection.

101. The pneumatic regulating mechanism of the “J” type is shown in Fig. No. 9; this is not an actual section but a diagrammatic drawing. The piston 25, movement of which is caused by the “cutting-in” and the “cutting-out” mechanism, admits main reservoir air to the piston chamber or exhausts it therefrom, thus causing the switch spider to rise or fall, opening or closing the electric switch. Main reservoir air is always present in chamber B of the double piston on account of the permanent connection a. When the pressure in the main reservoir falls below the “cutting-in” point, the cutting-in regulating spring 70 is able to force inward
diaphragm 71 against main reservoir pressure, which acts on the diaphragm by flowing through passages a, q and p. When the regulating diaphragm moves inward, the consequent movement of diaphragm spindle 67 permits the regulating valve 65 to open. The air in chamber D, which is present due to leaking past the ring, is thereby vented to atmosphere through passage n. Since the pressure on the larger of the double pistons is balanced, the unbalanced pressure on the smaller piston causes the double piston to move to the right into its "cut-in" position, as shown in Fig. 9. The air below switch piston 20 is then vented to the atmosphere through passages g, h and f, which permits the compressed spring 17 to move the switch piston downward. The clutch magnet, or compressor switch magnet circuit, is thereby closed and remains closed so long as the regulating mechanism remains in "cut-in" position.

102. When main reservoir pressure has reached the "cutting-out" point, it is able to move outward diaphragm 59, since main reservoir pressure acts upon this diaphragm through passages a and e. The consequent movement of the spindle opens regulating valve 28, which vents air from chamber C back of the larger of the double pistons, to atmosphere through passage l. The unbalanced pressure then acting upon the double piston causes it to move to the left into "cut-out" position. With the slide valve in this position, air at main reservoir pressure is admitted to the switch piston chamber through passages b and g. This insures a quick and positive upward movement of the switch piston, which opens the electric switch and breaks the circuit. The upward movement of the piston compresses the air within the piston chamber, and it is expelled through exhaust port z to the atmosphere. The governor remains in this position until the main reservoir pressure has fallen sufficiently to allow it to "cut in."

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103. **To adjust** the "cutting-in" and "cutting-out" points of the "J" type governor, proceed as follows: Slack off completely both regulating nuts 63 and 68 (Fig. No. 9), until neither regulating spring exerts any pressure. The cutting in regulating valve 65 is then open and the cutting out regulating valve 28 closed, so that the double piston is in "cut-in" position. As soon as the compressor starts and builds up pressure in the main reservoir, as previously explained, the cut-in regulating valve will close and the cut-out regulating valve open. The compressor consequently stops. Then tighten up the cutting-out regulating nut 63 until the regulating spring 62 is under considerable compression. Start the compressor by slowly screwing in the cutting-in regulating nut 68. After the compressor starts, observe the cutting-out point. If it is too low, screw in the cutting-out regulating nut 63; if too high, screw out this nut. Start the compressor by again tightening the cutting-in regulating nut 68, but first make certain that the main reservoir pressure is less than that intended for the normal "cutting-in" point. If the "cutting-out" point is then too low, adjust the cutting-out regulating nut 63 accordingly. After the "cutting-out" point has been adjusted at 120 lbs., slowly bleed the main reservoir and observe when the governor "cuts in." If too low, screw in the cutting-in regulating nut 68; if too high, screw out this nut. Then, after attaining sufficient main reservoir pressure, test the "cutting-in" point and make adjustment until the governor "cuts in" at 105 lbs. After both "cutting-in" and "cutting-out" points have been adjusted, tighten the regulating check nuts 64 and 69, which lock the regulating nuts 63 and 68. Then test the adjustment again to make certain that no change occurred when tightening up the lock nuts.

104. The governor should be cleaned and oiled at least once a year. The slide valve and its seat and the
pistons should be thoroughly cleaned with turpentine substitute and after being wiped dry, lubricated with standard oil for this purpose. The hole through the larger of the double pistons should be free from dirt and gum. The switch piston cylinder should be cleaned at the same time. To remove the piston, break the joint below the cylinder; then remove the top cover and cotter pin and nut, which will allow the spring 17 to force out the piston. In replacing the piston, be certain that the groove in the rod engages the "T" shaped guide pin as otherwise the rod may turn, so that the contacts do not register with the fingers. Care should be taken that diaphragms are not buckled or distorted; each diaphragm should work freely when operated by hand. The gaskets under the end covers of the regulating mechanism must be perfectly tight to insure satisfactory operation. So long as the governor "cuts in" and "out" satisfactorily, the regulating mechanism should not be disturbed. If the governor cuts in and out very rapidly it indicates that the "cutting-in" point is higher than the "cutting-out" point.

105. The electric switch of the "S" type compressor governor is similar to that of the "J" type and is illustrated in Fig. No. 10. Its principal parts, as shown in Fig. No. 11 are: The switch spider 53, the switch piston and rod 24, and the finger contacts 7. The circuit is made or broken by the falling and rising of the switch piston. The electric switch portion is insulated from the regulating portion and is protected by a metallic cover which may be removed for inspection.

106. The pneumatic regulating mechanism of the "S" type is shown in Fig. No. 11. The main reservoir pressure building up against the face of cut-out valve 38 eventually becomes sufficiently high to overcome the tension of the cut-out valve regulating spring 35, causing
valve 38 to lift from its seat and due to the construction of this valve, the slight lifting from its seat exposes an increased area, causing the valve to lift quickly, at the same instant delivering pressure via port e to the face of the cut-in valve 39. The main reservoir pressure now acting upon the full area of valve 39 will overcome the tension of its regulating spring 35', causing the valve to lift with a snap, forming a seal at its upper seat j which will close communication from the face of the switch piston 24 to the atmosphere (through port g and d) and, at the same time connect main reservoir pressure to the face of piston 24 through port g and chamber w.

The main reservoir pressure acting upon the face of the switch piston 24 will cause it with the attached switch spider 53 to move quickly to a position for breaking the circuit which is made through the switch piston spider 53 and the finger contacts 7.

As the switch piston completes its full travel towards the cut-out position, main reservoir pressure will be connected to the cut-out regulating spring chamber F through port f, resulting in equalizing the air pressure on each side of cut-out valve 38, whereupon the tension of the regulating spring 35 will then move the cut-out valve to its seat.

After cut-out valve 38 has been returned to its seat, the main reservoir pressure will continue to be supplied to the face of the switch piston through passages a, q and c, past tail valve 43, and through port g to chamber W. The switch piston remains in the cut-out position, as described above, until the main reservoir pressure is reduced to a point where the force exerted by it against the face of the cut-in valve 39 is equal to a fraction below the tension of the regulating spring 35'.

107. When the force of the main reservoir pressure, which is acting upon the full face area of the cut-in valve
39, is reduced to a fraction below the tension of the regulating spring 35', cut-in valve 39 will be moved to its normal cut-in position, causing the tail valve 43 to be seated by its spring 45, closing communication between the main reservoir and the face of the switch piston and, in turn, opening communication between chamber W on the face of the switch piston and the atmosphere, through passage g, port j, through passage d to EX.

This action permits the switch piston spring 29 to return the switch piston to its normal cut-in position, at the same time, opening communication between the cut-out regulating spring chamber F and the atmosphere, through f and n, port j, cut-in regulating spring chamber D, and passage d to Ex, thereby freeing spring chamber F of main reservoir pressure. The cut-out valve 38 which is now held to its seat only by the tension of the regulating spring 35, will immediately rise from its seat upon a slight increase of main reservoir pressure above the setting of the regulating spring.

108. To adjust the "cutting-in" and "cutting-out" points of the "S" type governor, proceed as follows: Loosen check nuts 37 and 37' and screw cut-out regulating stem 32 down until the desired cutting-out point is reached. At the same time, screw down cut-in regulating stem 32' to as nearly the same tension as can be judged under ordinary observation. If when the "cutting-out" point is reached the range is not as desired, screw the cut-in regulating stem down to raise the "cutting-in" point and back it off to lower the "cutting-in" point.

109. The "S" type governor should be cleaned and oiled once a year. The parts should be cleaned with turpentine substitute and a few drops of the standard oil for the purpose should be placed on the surfaces passed over by the cut-in and cut-out valves. Piston 24 may be
removed by removing the pipe bracket, top cover and the cotter pin nut at the extreme end of the piston rod, which will allow the piston rod to slip through the insulating bushing and washer; spring 29 will then force the piston and rod out of the cylinder. In replacing this piston, the groove in the rod should embrace the end of the T-shaped guide pin 21. This pin keeps the rods from turning. Pin 21 should not be turned as its end is flattened to fit the groove and the piston cannot be inserted unless the flattened sides of the pin are parallel with the sides of the groove.

**THE CLUTCH MAGNET.**

110. As the motor of the combined compressor-blower motor outfit must operate the blower continually, the air compressor is started or stopped by the throwing in or out of the multiple disc clutch on the motor pinion. The separately driven compressor with which certain cars are equipped is started and stopped by a compressor switch (see Par. No. 36, Electrical Equipment Instruction).

The movement of the clutch, caused by main reservoir air pressure, is controlled by a clutch magnet, which is of the inverted type (see Par. No. 18, Electrical Equipment Instructions). As shown in Fig. 12, the clutch magnet consists of a magnet operating a valve 515. When the compressor governor has “Cut in” a circuit is completed from the battery through the clutch magnet (Fig. 40). When the magnet is energized, valve 515 is held closed but valve 514 is held open. Chamber b is in direct communication with the air cylinder “A” of the multiple disc clutch, as illustrated, so that the pressure in this chamber is reduced to atmospheric. The coiled spring of the clutch then forces the discs together so that the clutch is thrown “In”, which starts the air compres-
This method of operating the clutch is necessary because the clutch must be “In” when there is no air pressure. When the main reservoir pressure has increased to the “Cutting out” point, the governor opens the magnet circuit, de-energizing the magnet. Valve 514 then closes and valve 515 opens. Main reservoir air, which is present in chamber a, can then flow to the air cylinder “A” of the clutch by passage b, forcing the disc apart and thus throwing “Out” the clutch. The clutch magnet is, therefore provided to operate the pneumatic disc clutch of the motor, so as to start and stop the air compressor as determined by the governor.

THE GOVERNOR SYNCHRONIZING SYSTEM.

111. This system has been devised to insure that all compressors will start and stop at precisely the same time, thus dividing the burden of compressing air equally between them. For this purpose a synchronizing wire, known as B1 (Fig. 40), is extended throughout the train. All governor terminals are connected between this wire and one of the battery wires, through a switch on switchboard known as the Governor Switch. All clutch magnet or compressor switch magnet terminals are between this wire and the other battery wire. The first governor to “Cut in”, therefore, connects the synchronizing wire to one side of the battery. Current from the battery can then flow throughout the train along the synchronizing wire through all the clutch magnets, or compressor switch magnets, and back to the battery. Since all the clutch magnets or compressor switch magnets are thus energized, all clutches are thrown in, or compressor switches closed, as the case may be, and all compressors start. The compressors stop when the governor “Cuts out”, as the synchronizing wire is not then connected to the battery. The clutch magnets, or compressor switch magnets
are then de-energized and, either, clutch thrown out, or compressor switch opened.

If the governor on any car is defective, or cut-out cock in governor pipe closed, the governor switch on that car should be opened, so that the defective governor will not interfere with the control of compressors. In order to locate a defective governor in a train of several cars, pass through the train and open the governor switches, allowing a sufficient interval of time to elapse between this operation on each car to see if the opening of the governor switch has removed the cause of the improper operation of the compressors.

THE ENGINEMAN’S BRAKE VALVE

112. The engineman’s brake valve, type ME-23, is shown in Fig. 13. This brake valve contains both electric and pneumatic parts, Fig. 13. The handle positions are, from left to right, (1) Release-and-Running, (2) Electric holding, (3) Handle off, (4) Lap, (5) Service, (6) Emergency. These positions cause the following operations:

Release-and-Running—All brakes throughout the train are released and the system recharged.

Electric Holding—in pneumatic operation, the same as release-and-running position; in electric operation, holds all brakes throughout the train and recharges the system.

Handle Off—Provides for removing the brake valve handle. All ports are closed.

Lap—All ports are closed, except that one from the chamber below the equalizing discharge valve.

Service—All brakes are applied throughout the train.
Emergency—All brakes are quickly and fully applied throughout the train.

113. **The pneumatic** portion of this brake valve closely resembles the ordinary equalizing piston brake valve. The equalizing piston of the ME-23 brake valve is made collapsible (See Fig. 14) to insure that there will be no difference of pressure between the equalizing reservoir and the brake pipe in order that the brakes may be applied with the least possible delay. If the equalizing reservoir should charge faster than the brake pipe, the piston will be forced downward on its stem and the grooves in the piston bush uncovered, thus permitting the equalization of the equalizing reservoir and brake pipe pressures.

114. **The electric portion** consists of four contact fingers mounted upon the brake valve, with suitable contacts mounted upon an insulated cylinder through which the rotary valve key passes. The contact fingers from the top down are respectively connected to (1) B2, the supply wire, (2) B4, the service magnet wire, (3) B3, the release magnet wire, and (4) B5, the emergency magnet wire. (Fig. 40.)

**Electric brake cut-out receptacle and plug** is combined with the master control cut-out receptacle and plug, the two contacts through which the brake circuits are completed by the control plug being located inside the master controller directly back of the three contacts for the master control circuit. In order to operate the pneumatic devices of the brakes electrically, the plug should be inserted all the way in the receptacle of the master controller from which the car or train is being operated. In order to cut-out the electric features of the brake withdraw the control plug about one inch.

115. **The reduction limiting valve**, which is a part of some brake valves, limits the possible brake pipe reduc-
tion to that necessary to cause a full service application. That is, although the brake valve handle may remain in service position, the brake pipe reduction will automatically cease after the brake pipe pressure has been reduced the proper amount.

PNEUMATIC OPERATION

CHARGING

116. To charge the brake system, the engineman's brake valve should be placed in Release-and-Running Position. Direct communication is then obtained from the main reservoir, through the feed valve to the brake pipe through passage a, chamber A above the rotary valve 5, port r of the rotary valve, and passage g, Fig. 15, thus quickly charging the brake pipe to the pressure for which the feed valve is adjusted, and, through the brake pipe, and universal valve to the reservoirs, as will be explained in Par. No. 135. At the same time the chamber under the equalizing discharge valve piston is charged through these passages and passage g', to the same pressure as the brake pipe to which it is always connected. Also, the equalizing reservoir, chamber D above the equalizing discharge valve piston, and chamber B above the limiting valve piston and charged to brake pipe pressure; the equalizing reservoir through passage a, chamber A, and passages p and n; chamber D through these ports and port s; and chamber B through these ports and port n'. The brake system is thus charged and ready for use.

SERVICE APPLICATION

117. To apply the brakes in a service application, the handle of the engineman's brake valve should be moved to Service Position until the desired reduction has been made. When the brake valve handle is placed in Service Position, a connection is made from the equalizing reservoir to the atmosphere through passages n,
t, q, o, u and l, Fig. 19, and from the chamber above the rotary valve, in which is feed valve pressure, to the reduction limiting reservoir through passages r, w, v and j, and to chamber C below the limiting valve piston through these passages and j'. Thus, while the equalizing reservoir pressure is being reduced, the reduction limiting reservoir pressure is being increased. One side (Chamber B) of the limiting valve piston 81 is connected to the equalizing reservoir through passages n' and n, and the other side (Chamber C) to the reduction limiting reservoir through passages j' and j. Consequently, the piston 81 will move from its lower to its upper position, Fig. 20, as soon as the pressure in chamber C (Reduction limiting reservoir) becomes sufficiently greater than that in chamber B (Equalizing reservoir) or as soon as a full service reduction has been made. The piston carries with it slide valve 83, and this upward movement cuts off communication from the equalizing reservoir to the atmosphere by blanking passages q and u, thus preventing any further reduction of brake pipe pressure.

118. As the pressure in the equalizing reservoir, and hence in chamber D, decreases, the brake pipe pressure under the equalizing discharge valve piston 51 raises it, and the brake pipe air is then exhausted to the atmosphere through passages e, c, b and l. In order to make the reduction start even more promptly than with the old style of pneumatic brake valve, an additional direct brake pipe exhaust is provided through passage g, x, k, m, l' and l. Both the exhaust from chamber D and equalizing reservoir and from the brake pipe direct lead through slide valve 83 of the reduction limiting valve, and the upward movement of this valve cuts them off. In this way, even if the brake handle were left in Service position, the reduction cannot be greater than that required to obtain a full service application.
119. If it is not desired to make a full service application, the brake valve handle should be moved to Lap Position as soon as the desired reduction has been made. In this position, the rotary valve "Laps," or closes communication between all ports, except that the chamber below the equalizing discharge valve 53 is open to the atmosphere through passages e, c, b and l, (Fig. 18). Thus, no further brake pipe reduction can take place.

120. If, however, it is desired to apply the brake with more force, the brake valve handle should again be moved to Service Position until the desired reduction has been made, when the brake valve handle should again be returned to Lap Position. In this way the brake may be applied in steps, or as it is called, "Graduated on."

The effect of a brake pipe reduction made at the brake valve, on the universal valves will be explained in Par. No. 137.

RELEASE

121. When it is desired to release the brakes, the engineman's brake valve handle should be moved to Release-and-Running Position. This will increase the brake pipe pressure to the desired maximum, as explained under "Charging," thus moving the universal valves to release position, as will be explained in Par. No. 140 and releasing the brakes. At the same time the reduction limiting reservoir is connected to the atmosphere through passages j, c, b and l, and chamber C through passages j', c, b and l. As chamber B above the reduction limiting valve piston 81 is charging to brake pipe pressure, piston 81 is moved to its lower position, and the brake system is again ready for use.

122. Electro-Pneumatic Graduated Release Operation. The brake valve handle should be moved to Re-
lease-and-Running Position and then returned to Holding Position, Fig. 16, instead of Lap Position, in order to partially release the brakes. In this position (Holding) the brake system is charged, as in Release-and-Running Position, but due to the release magnet of the universal valve, the brake cylinder pressure is not released. The brakes may then be released in steps, or, as it is called, “Graduated Off,” by successive movements of the brake valve handle between Holding and Release-and-Running Positions.

**EMERGENCY APPLICATION**

123. If it is desired to apply the brakes with their maximum force, the brake valve handle should be moved to Emergency Position (Fig. 21), and left there until the train has stopped. In this position the brake pipe, and chamber below equalizing discharge valve piston 51, the chamber below equalizing discharge valve 53, chamber C below reduction limiting valve piston 81 and the reduction limiting reservoir are connected to the atmosphere, thus applying the brakes in emergency (the operation of the universal valves will be explained in Par. No. 141); the brake pipe through passages g, c, b and l; the chamber below equalizing discharge valve piston 51 through passage g' and the above passages; the chamber below equalizing discharge valve 53 through passages e, c, b and l; chamber C through passages j', j, Y, b and l, and the reduction limiting reservoir through passages j, Y, b and l.

**HANDLE OFF**

124. All the engineman’s brake valves, except that from which the brakes are to be operated, should be left in Handle Off Position (Fig. 17) and the cut-out cock in the brake pipe closed. Feed valve pressure air is still present above rotary valve 5 to keep it to its seat, but the brake pipe passages g and g’ are blanked by the cut-out
cock. All other ports are also blanked, so that there is no chance of this brake valve interfering with the operation of the brakes as long as the cut-out cock in the brake pipe is closed and the brake valve handle is in the Handle-Off Position.

When the cut-out cock in the brake pipe under the brake valve is closed, there will be an exhaust of equalizing reservoir air pressure through the vent in the side of cut-out cock, until this pressure has been depleted.

**THE FEED VALVE**

125. There are two types of feed valves in use, the C-6 and the M-3-A. These are shown in Figs. No. 22 and 24.

126. The C-6 feed valve. Referring to Fig. 23, its principal parts are: The supply valve 7, the supply valve piston 6, the supply valve piston spring 9, the regulating valve 12, the diaphragm 17 and the regulating spring 19.

127. With no pressure in the brake system, spring 9 holds supply valve piston 6 and supply valve 7 in their inmost position, and regulating spring 19 holds diaphragm 17 over against valve 12; this unseats valve 12 and opens passage h to passage e. When main reservoir pressure has built up sufficiently during charging operation, the supply valve piston is moved to the left by main reservoir pressure acting upon its inner face, thereby opening supply valve 7. Main reservoir air then flows through the supply valve until the pressure in passage e becomes sufficient to move diaphragm 17 to the right and close regulating valve 12. After this valve has closed, the pressure on the supply valve piston 6 rapidly equalizes, which permits the compressed spring 9 to force it to the right, preventing further flow of main reservoir air to passage e.

128. Whenever the pressure in passage e falls sufficiently below its normal value the compressed spring 19
causes the diaphragm 17 to move to the left again and open regulating valve 12. The pressure in chamber G back of the supply valve piston reduces to that in passage e, which permits main reservoir pressure acting upon the other side of the piston to move it to the left and open the supply valve, as described in Par. No. 127. Recharging then takes place exactly as explained in the preceding paragraph.

129. To adjust the C-6 feed valve, it is necessary to tighten or loosen the regulating nut 20, Fig. 23. The feed valve should be cleaned at least every six months. All parts should be thoroughly blown out and a little dry graphite placed upon the slide valve and its seat. No lubricant should be used upon the regulating valve or supply valve piston.

130. The M-3-A Feed Valve. Referring to Fig. No. 25, its principal parts are: The supply valve 22, the supply valve piston 20 which has a sealing ring, the supply valve piston springs 28 and 31, the regulating valve 7, the diaphragm 11, the regulating spring 15, venturi tube z and the choke fitting 25.

131. With no pressure in the brake system, the springs 28 and 31 hold the supply valve piston 20 and the supply valve 22 in their inmost position, and regulating spring 15 holds the diaphragm 11 against the regulating valve 7. This unseats valve 7 and opens passage n to o. When main reservoir pressure has built up sufficiently during charging operation, the supply valve piston is moved against the springs by main reservoir pressure acting upon its inner face, thereby opening supply valve 22. Main reservoir air then flows through the supply valve until the pressure in passage o becomes sufficient to move diaphragm 11 against the regulating spring pressure, allowing regulating valve to close. With valve 7

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closed, the pressure on the supply valve piston 20 rapidly equalizes through passage P and choke fitting 25, permitting the springs 28 and 31 to move the supply valve piston and supply valve to their inmost positions and preventing the flow of main reservoir air to the feed valve pipe.

132. Whenever the pressure in the feed valve pipe falls below its normal value, the pressure in passage o is insufficient to hold the diaphragm against the regulating spring pressure and the diaphragm moves against the regulating valve 7 and opens it. The pressure in chamber m is then reduced to that in the feed valve pipe through passage n, regulating valve 7 and passage o. Recharging then takes place as explained in the preceding paragraph.

The function of the venturi tube z is to obtained a sustained air delivery flow from the main reservoir to the feed valve pipe up to the point of pressure for which it is adjusted. Its operation is on the same principle as a steam injector. The main reservoir air in flowing through the venturi tube causes a reduction in pressure in passage o and under the diaphragm which permits the regulating spring to open the regulating valve 7 more fully, allowing a greater flow of air with consequently greater reduction in pressure on the face of piston 20. As the feed valve pipe pressure approaches the pressure for which the regulating spring is adjusted, the velocity of air through the venturi tube diminishes. The effect of reduction in pressure in the diaphragm chamber then becomes proportionately less, permitting the accumulation of pressure in the diaphragm chamber which tends to close the regulating valve at its true setting.

There are two adjustable stops, 18, which permit of two settings of the feed valve, either one of which may be had by turning the adjusting nut until the pin strikes the stop.
THE UNIVERSAL VALVE
(For List of Parts See Appendix)

133. The universal valve, Figs. 26 and 27, consists of the following portions:
   a. The pipe bracket (Fig. 28) is the portion to which the other portions and the various pipes are attached. It contains two chambers.
   b. The equalizing portion (Fig. 29) contains the moving parts employed in service and emergency operations.
   c. The quick action portion (Fig. 30) contains the moving parts employed in producing quick action.
   d. The high pressure cap contains the parts employed in securing a high cylinder pressure in an emergency application.
   e. The magnet bracket portion (Fig. 31) contains the magnets employed in electrical control of brake operations, emergency switch and piston, and cut-out cap.

134. These different portions contain parts which are as follows (see Fig. 32):
   a. The pipe bracket contains:
      The quick action and quick-action closing chambers, which supply pressure to control the emergency piston, open the quick action exhaust, and close the emergency switch. The quick-action closing chamber also supplies the pressure to keep the quick-action exhaust open and the emergency switch closed for a pre-determined time.
   b. The equalizing portion contains:
      The equalizing piston which moves the equalizing and graduating slide valves when the brake
pipe pressure is varied. The equalizing graduating valve which controls the flow of air,

(1) From the auxiliary reservoir to the resistance increasing cavity, or resistance increasing cavity through the equalizing slide valve to atmosphere;

(2) From the auxiliary reservoir through the equalizing and release slide valves to atmosphere;

(3) From the end chambers of the release piston through the equalizing slide valve to atmosphere;

(4) From the auxiliary reservoir through the equalizing slide valve to the brake cylinder;

The equalizing slide valve which controls the flow of air,

(1) From the auxiliary reservoir, through the equalizing graduating valve and release slide valve to atmosphere;

(2) From the end chambers of the release piston through the equalizing graduating valve to atmosphere;

(3) From the auxiliary reservoir by the equalizing graduating valve to the brake cylinder;

The graduating stop and spring which forces the equalizing piston slightly away from the cylinder cap gasket following a service application and thereby causes the graduating valve to lap. Without this stop and spring, the seating of the equalizing piston against the gasket, especially when soft and flexible, might result in exposing a considerably larger piston area to
the action of brake pipe pressure when the piston moves back to lap position than is exposed to brake pipe pressure when the movement away from application position first commenced. The consequence of this is that the differential is suddenly allowed to act on the full area of the equalizing piston which may be enough greater (depending upon the amount of contact between the piston and the gasket) to result in the total pressure on the piston being slightly more than the resistance of the piston and slide valve, in which case the parts might move back to release position. In other words, this stop and spring is for the same purpose as has always been that of the graduating stop and spring.

The service port check valve, which prevents the flow of high pressure air from the brake cylinder to the equalizing piston chamber (auxiliary reservoir) during an emergency application.

The emergency reservoir charging check valve, which prevents the flow of air from the emergency reservoir to the brake pipe or the equalizing piston chamber during a service or emergency application.

The service reservoir check valve, which prevents the flow of air from the auxiliary reservoir to the service reservoir.

The graduated release piston, which holds the equalizing slide valve in graduated release position when making a graduated release with the cap set in graduated release position.

The charging valve, which provides for the recharging of the service reservoir, practically without drawing any air from the brake pipe until all the brakes have been released.
The release piston, which is a differential piston causing movement of the release slide valve.

The release slide valve which controls the flow of air,

(1) From the emergency reservoir, through the charging valve, to the service reservoir;

(2) From the emergency reservoir to the auxiliary reservoir (only with graduated release cap in graduated release position);

(3) From the emergency reservoir to the back of the high pressure valve;

(4) From the back of the high pressure valve through the emergency slide valve to atmosphere;

(5) From the auxiliary reservoir through the equalizing graduating and slide valves to atmosphere;

(6) From the brake cylinder through the release magnet valve to atmosphere (in electro-pneumatic operation).

C. The quick action portion contains:

The quick action chamber charging check valve, the ball check farthest from the pipe bracket, which prevents the flow of quick action chamber and quick action closing chamber air to the brake pipe during a service application.

The quick service port check valve, the ball check next to the pipe bracket, which prevents backflow from the brake cylinder to the brake pipe whenever cylinder pressure is higher than that of the brake pipe or quick action chamber (slide valve chamber).
The emergency piston, which moves the emergency graduating and slide valve when the brake pipe pressure is suitably varied.

The emergency graduating valve, which controls the flow of quick action chamber and quick-action closing chamber air through the emergency slide valve to atmosphere in service and controls the flow of air from these two chambers to the quick-action piston and emergency switch piston in emergency.

The emergency slide valve, which controls the flow of air,

1. From the quick action chamber, through the emergency graduating valve to atmosphere;

2. From the quick action and quick action closing chambers to the quick action piston and switch piston;

3. From the back of the high pressure valve through the release slide valve to atmosphere;

4. From the top of the high pressure valve and bottom of cut-off valve to atmosphere;

5. From the brake cylinder to the quick action chamber (in emergency application).

The quick action piston and valve which vent brake pipe air to atmosphere during an emergency application.

The ball charging choke, located in the emergency graduating valve, which, by means of the clearance between it and the walls of its cavity, governs the rate of charge for the quick action and quick action closing chambers. It also serves
to prevent the graduating valve from blowing off its seat during charging.

d. **The high pressure cap contains:**

The protection valve, which vents brake pipe air to atmosphere, causing an emergency application, when the brake pipe pressure has fallen to approximately 35 lbs.

The emergency check valve, which prevents the sudden admission of air from the brake pipe to the emergency piston chamber, but permits unrestricted flow of air from this chamber during emergency applications.

The emergency piston chamber charging choke which restricts the flow of brake pipe pressure to the face of the emergency piston thus avoiding a sudden build-up of pressure in this chamber which might slam the piston to its release position.

The emergency piston stop, which increases the differential required to move the emergency piston from service to emergency position.

The intercepting valve, which, during an emergency application, causes the service reservoir to equalize with the brake cylinder, and then cuts off the service reservoir and permits emergency reservoir air to equalize with the brake cylinder.

The high pressure valve, which separates the emergency reservoir from the brake cylinder, except in an emergency application.

The safety valve, which limits the service brake cylinder pressure.

The cut-off valve, which cuts off the safety valve from the brake cylinder during an emergency application.
e. The magnet bracket portion contains:

The release magnet which controls the electrical release of air from the brake cylinder.

The service magnet, which vents brake pipe air to the brake cylinder to produce a service application.

The emergency magnet, which vents brake pipe air through the quick action piston to atmosphere to cause an emergency application.

The magnet cut-out cap, which provides for cutting out defective service or emergency magnets (no cut out is required for the release magnet).

The electric service port check valve, which prevents the flow of brake cylinder air through the service magnet to the brake pipe.

The emergency switch piston and switch, which so operates that when a pneumatic emergency application originates on any car, the application is transmitted electrically throughout the train.

PNEUMATIC OPERATION

CHARGING

135. To charge the brake system, the engineman’s brake valve is placed in Release-and-Running position. Air at feed valve pressure flows through the brake valve into the brake pipe and thus throughout the train, passing through each branch pipe and to the universal valve on that car. The brake pipe air enters the universal valve through passage a and flows in two directions—to the Quick Action Portion and to the Equalizing Portion. (See Fig. No. 32.)

Brake pipe air, entering through passage a, flows through passage g-1 to the upper side of the quick action
valve 85 which is then held seated by air pressure as well as by the tension of spring 90. The protection valve 111 will be on its brake pipe (lower) seat when there is no air in the system. When the brake pipe reaches approximately 45 lbs., this valve will be forced from its brake pipe seat to its atmospheric (upper) seat, allowing brake pipe air to flow through passage a-2. Ball check 153 prevents direct flow to chamber A so that pressure built up in this chamber must be through choke 157 into port a-5 and thence to chamber A. This prevents such a sudden build-up of pressure in chamber A as would “slam” the emergency piston to its release position.

Brake pipe pressure also flows around the protection valve to the left, through passage a-2, past ball check 99', through passage a-3 and past the ball charging choke 102 in the emergency graduating valve, thus charging the slide valve chamber B. The quick action chamber is charged to brake pipe pressure from chamber B through passage e and the quick action closing chamber through cavity e-1 in the slide valve and passage d in the slide valve seat. Charging ball choke 102, by virtue of the clearance between it and the walls of its cavity, governs the rate of charge for slide valve chamber B, the quick action chamber and the quick action closing chamber.

Brake pipe air flows through passage b to the equalizing piston chamber C. In the absence of pressure in the slide valve chamber G the equalizing piston 4, with graduating valve 7 and slide valve 3, are forced to full release position as shown in Fig. 32, the graduated release piston 30 being held to its lower position by spring 32. The release piston 16 is held in its release position by spring 21. The lower end of this piston (inner seal) is connected to the exhaust through passages g and f, and cavity D in the graduating valve. Port h leading to the upper end of the release piston is blanked by the equalizing slide valve. The release slide valve 19 now connects the brake cylinder port w to the exhaust port x through cavity
k-1, and also opens the various charging ports as explained later.

Brake pipe air can flow from the equalizing piston chamber C in two directions:

1. Through the feed groove k to the slide valve chamber G, and thence through passage m to the auxiliary reservoir, thus charging it, and through passage s-1 to the bottom face of the charging valve 34 which is thus forced upward connecting passages r and s. The resistance increasing cavities T in the face of the equalizing slide valve are also connected to auxiliary reservoir pressure.

2. Through passage l past ball check 12' to the release slide valve chamber I. From this chamber air flows through passages v-2 and v to the emergency reservoir, thus charging it. Air also flows from this same chamber through passages p, q and r, around charging valve, thence through passage s, port t in the release slide valve, passage u-1 and under ball check 12", into passage u to the service reservoir, thus charging it.

Chamber L below graduated release piston 30 is connected to chamber I, which in turn is connected to the emergency reservoir. Passages p and q connect chamber I with the cavity r of the charging valve. The top face of the charging valve is connected to service reservoir from passage s through passage q-1.

Air can also flow from the release slide valve chamber through passages c-2 and c-1 to the back of the high pressure valve 123 and then through passage m-1 to the back of the intercepting valve 117, the middle cavity of which is in direct communication with the emergency
reservoir through passages v-1 and v. The inner face of the intercepting valve 117 is connected to the service reservoir through passages u-2 and u. This valve will then be held seated by the spring 121. The face of the high pressure valve 123 is connected to atmosphere through passage o and cavity N in the emergency slide valve 78. The cut off valve 141 is held to its lower seat by the spring 146.

The initial charging operation is the same regardless of whether the Graduated Release Cap is in direct or graduated release position.

136. Re-charging after an application with the graduated release cap in direct release position, the auxiliary reservoir recharges directly from the brake pipe through the feed groove k, port n, leading from chamber I (emergency reservoir pressure) to the auxiliary reservoir through passage m, being blanked by the graduated release cap. Port q leading from the emergency reservoir to the top of the charging valve is also blanked by the graduated release cap, and port s (service reservoir pressure) is now connected to the top of the charging valve, through port q-1. When the auxiliary reservoir is being recharged from the brake pipe through the feed groove, and the auxiliary reservoir pressure becomes about three pounds higher than that in the service reservoir, the charging valve moves upward, and the service reservoir is then recharged from the emergency reservoir until the service reservoir pressure is slightly greater than the auxiliary reservoir pressure, when the charging valve again moves downward. It moves upward again when the auxiliary reservoir pressure again becomes about three pounds higher than service reservoir pressure, and this cycle is repeated until both reservoirs are fully charged. The service reservoir is thus re-charged from the emergency reservoir at the same rate that the auxiliary reservoir is charged from the brake pipe.
The quick action and quick action closing chambers are charged in the same manner as initially and after an application.

137. To apply the brakes on the train, a suitable brake pipe reduction is made with the engineman's brake valve. (See Fig. No. 33.)

This reduces the pressure in passage a leading to the emergency portion, thence through passage a-2 to the top of ball check 153, which is momentarily lifted by greater pressure beneath it, thereby reducing pressure in chamber A on the face of the emergency piston. The differential across the emergency piston thus created causes the piston to move, carrying the graduating valve to quick service position, where cavity w-6 establishes connection between the two slide valve ports a-4 and w-5. Brake pipe pressure from passage a-2 now lifts ball check 99' and flows through passage a-3, port a-4, cavity w-6, port w-5, passage w-4 past ball check 99, passage w-3, thence through choke 233 into passage w to brake cylinder.

A light reduction of brake pipe pressure is required to obtain the foregoing operation because the emergency piston moves only the graduating valve. This quick service function causes a practically simultaneous reduction of brake pipe pressure on each car of the train, resulting in the brakes applying uniformly and preventing harsh slack action.

In quick service position the quick action chamber is connected to atmosphere through a vent port in the graduating valve and port j-1 in the emergency slide valve, thereby reducing quick action chamber pressure at the same rate as brake pipe pressure is being reduced. The vent port in the graduating valve is of such a size that a movement of the emergency slide valve to emergency position will not occur until brake pipe pressure is reduced at an emergency rate.
Ball check 99 prevents back flow from the brake cylinder to brake pipe in the event brake pipe pressure should become lower than brake cylinder pressure.

Ball check 99' prevents the quick action and the quick action closing chamber volumes being added to brake pipe volume during the service reduction.

The quick service choke 233 is inserted in brake cylinder passage w-3 for the purpose of controlling quick service activity.

Coincident with the quick service previously described, the initial reduction also reduces the pressure in chamber C on the brake pipe side of the equalizing piston 4 below that in the auxiliary reservoir, acting on the opposite side of the piston in chamber G.

The slightest differential pressure created first causes the piston only to move upward and close the feed groove k and charging port l. (This reduces to a minimum the back flow of air from the auxiliary reservoir to the brake pipe through the feed groove; and prevents air flowing from the emergency reservoir into chamber C if charging check valve 12' is leaking. This insures that the brake pipe reduction will be more effective in accomplishing what is obviously desired.)

Following this, as the reduction continues, the graduating valve 7 is moved upward by the piston, connecting cavities T in the slide valve to the atmosphere through cavity D in the graduating valve. This increases the force holding the slide valve to its seat and insures that a very light reduction will not apply the brakes, thus giving the valve needed stability. The resistance cavities T are now made so that the resistance to movement during application is less than with the U-12 Universal Valve. When
the differential acting on the piston reaches the prede­
termined desired value, the slide valve 3 is moved upward
to its service position as shown in Fig. No. 33.

The release piston 16 has been held in release posi-
tion by spring 21 and because the inner area of the lower
end of the piston was connected to the atmosphere
through passages g and f and cavity D. With the equal-
izing slide valve now in service position passage g is
blanked and passage h leading to the upper end of the
release piston is open to the atmosphere through cavity E.

It will be noted that emergency reservoir pressure is
always in chamber I, and that the upper end of piston 16
is larger than the lower end. The force tending to hold
the piston in release position is therefore spring pressure
plus emergency reservoir pressure acting on the area of
the lower piston inside of the seal, while the force tending
to move the piston upward is emergency reservoir pres-
sure acting over the whole area of the upper end. Con-
sequently there is sufficient differential built up to force
the release piston to its upper seat, or into service posi-
tion. (Emergency reservoir air will then equalize into
passage g through the small port in the lower end of
the piston.)

It should be noted that a movement of the equalizing
slide valve was required to actuate the release piston. This
insures against the possibility of the piston and
graduating valve "floating" over and causing the release
piston and slide valve to close the exhaust port, which
might cause trouble should the brakes creep on due to
leakage. With the release slide valve now in service
position the brake cylinder exhaust port is closed as well
as the service reservoir charging port u-l and the quick
recharge port n.
The equalizing slide valve now being in service position, the service reservoir is in communication with slide valve chamber G through passage u-1 and past service reservoir check valve 12", the auxiliary reservoir being always in communication with this chamber. Air can now flow from the combined volume of these reservoirs by way of chamber G through passages z and z-1 past the service port check valve 12 and through passage w to the brake cylinder and thus apply the brakes. The brake cylinder is in communication with the safety valve through passages w and w-1 which limits the brake cylinder pressure to 63 lbs. in service applications.

It will be noted that cavity S in the face of the equalizing piston slide valve has performed no function thus far. Should there be an excessive amount of friction between the graduating valve and slide valve such as would prevent a relative movement, it will be evident that while the slide valve might be in service position, yet the service port z would be blanked by the graduating valve.

In such event cavity S connects chamber G to the brake cylinder through port m, thus insuring against a possible brake failure from this cause.

138. The safety valve limits the brake cylinder service pressure to 60 lbs. The cylinder is connected to the safety valve by passages w and w-1. The safety valve can be adjusted to the pressure desired by the adjusting nut.

LAP

139 To hold the brake applied, the engineman's brake valve is moved to lap position in which further escape of air from the brake pipe is prevented; neither is there an increase of pressure. (See Fig. No. 34.) When the flow of air from the auxiliary and service reservoir to the brake cylinder has reduced the pressure in cham-
ber G slightly below that remaining in chamber C, the differential pressure will move the equalizing piston and graduating valve down to Service Lap position. In this position port z is blanked, and flow of air to the brake cylinder is thereby stopped. Further movement is prevented by the shoulder of the piston stem striking the end of the slide valve 3. The slight difference of pressure which was sufficient to move the piston and graduating valve is unable to overcome the added resistance of the slide valve, hence there is no further movement.

In the quick service previously described, emergency slide valve chamber pressure is reduced through port j-1 at the same rate as pressure is removed from the face of the piston. When pressure in chamber B has been reduced slightly below brake pipe pressure in front of the emergency piston, the piston and graduating valve are moved to the left, preventing further flow of quick action chamber air to atmosphere and of brake pipe air to brake cylinder.

It will be noted that the equalizing slide valve 3 remains in Service position, a movement of the piston and graduating valve only being required to lap the valve. Consequently when in this position, but a slight reduction in brake pipe pressure is required to again bring the piston and graduating valve into Service position. In this manner the brakes may be applied in a series of steps, or as is usually stated, "graduated on."

If more than a full service reduction is made before the brake valve is lapped, air will pass from the auxiliary and service reservoirs to the brake cylinder and to the atmosphere through the safety valve until the pressures in the three volumes have become equalized at the safety valve setting. Such an over reduction is obviously only a waste of air. If continued below the protection valve setting, an emergency application will result.
140. To release the brakes, the brake valve handle is placed in Release-and-Running position.

An increase in brake pipe pressure causes the pressure in chamber C above the equalizing piston to increase. As the pressure in chamber G does not change, sufficient force is exerted upon the piston to move it downward. The first movement of the graduating valve toward lap position, as just described, has connected resistance increasing cavities T to the slide valve chamber G, so that while these cavities increase the slide valve resistance when an application is made, they decrease the resistance to release. When the pressure in chamber C has sufficiently increased, the slide valve is moved downward toward release position.

It will go all the way to release as shown in Fig. No. 32 if the cap is set for direct release, since piston 30 is balanced (auxiliary reservoir pressure above and below) and held seated as in Fig. No. 32. The lower end of the release piston 16 is connected to the atmosphere through passages g, f and cavity D in the graduating valve and passage h leading to the upper end is blanked by the graduating valve in the former case and by the slide valve in the latter. The force now tending to hold the release slide valve in service position is emergency reservoir pressure acting on the area of the upper piston inside of the seal while the force tending to move the piston downward is emergency reservoir pressure acting over the whole area of the lower piston plus the tension of the spring 21. Consequently there is sufficient differential to force the release piston downward to its lower seal, or to release position, (emergency reservoir air will then equalize into passage h through the small port in the end of the piston).

Brake cylinder air will then exhaust to the atmos-
phere through passage w, cavity k-l, and ports x and y-l thus releasing the brakes.

The movement to full release position is made positive by momentarily connecting chamber G below the equalizing piston to atmosphere, so that after the release movement has commenced it is certain to be completed. The equalizing piston moves from service to release position before the release piston moves correspondingly. When the equalizing slide valve is approaching release position, passage F registers with port d-l, connecting chamber G to atmosphere through passages j, F, d-l and cavity k-l. This connection is not broken until the release slide valve moves to its release position, which only occurs after the equalizing slide valve has moved to its full release position. This feature prevents the creation of such an equilibrium of pressures as to cause the parts to halt in “cracked port” position with the feed groove and exhaust port barely open, and insures a positive and unrestricted release.

At the same time the parts are in release position, the system is being recharged, as explained in detail under the heading of “Recharging After an Application.” It should be noted that during this operation the pressures on the brake pipe and auxiliary reservoir sides of the equalizing piston are always in balance. This insures a quick response of the brakes to any reduction or increase of brake pipe pressure, irrespective of what operation may have occurred just preceding, so that as many applications and releases in quick succession as may be desired can be made without depleting the system.

**EMERGENCY APPLICATION**

141. Any reduction in brake pipe pressure faster than a predetermined rate causes an emergency application of the brakes throughout the train, obtaining a
high cylinder pressure in a very short time. (See Fig. No. 35.)

142. The equalizing portion operates the same in emergency as it does in service operation, so that the description need apply to the emergency portion only. When the brake pipe pressure is suddenly reduced, the pressure in chamber A in front of the emergency piston is also reduced, since this chamber is connected to the brake pipe through holes in the spring stop 134, passage a-2, past the emergency check valve 153 past the protection valve to passage a. The pressure on the emergency piston is therefore unbalanced, causing it to move to emergency position, carrying with it the graduating valve 80 and slide valve 78. In passing to emergency position, and before the slide valve has moved, the graduating valve uncovers port R in the slide valve. Air is thus admitted from the quick action and quick action closing chambers to the underside of quick action piston 88 through passages R and f-1 forcing this piston upward, opening the quick action valve 85, and venting brake pipe air to the atmosphere. This venting which is thus initiated very quickly, serves to shorten the time required to transmit quick action throughout the train.

When the emergency slide valve has moved into emergency position, the quick action chamber is cut off and the quick action closing chamber is connected to the underside of the quick action piston 88 through passages d, e-1 and f-1, so that this volume of air causes the quick action piston to remain open a definite time until the pressure is reduced to a certain value through the small hole in the quick action piston. The purpose of this is two-fold—first to insure transmission of quick action, and second to insure closure of the exhaust so that the brake pipe pressure can be restored when desired.
The emergency slide valve has connected the back of the high pressure valve 123 to the atmosphere through passage c-1, cavity t in the release slide valve, passage b-1, and cavities N and N' in the emergency slide valve. As the back of the intercepting valve 117 is connected to the back of the high pressure valve by passage m-1, the pressure back of the former becomes atmospheric momentarily. Service reservoir pressure, present upon the front of the intercepting valve moves it to the right, so that air from this reservoir can flow from ports u, and u-2 to port x-1, open the high pressure valve 123, lift the cut off valve 141 to its upper seat, and flow through passages w-1 and w to the brake cylinder.

This causes a quick drop of service reservoir pressure acting on the left of the intercepting valve and as brake cylinder pressure is present on the right of this valve, the pressures acting on the valve equalize and spring 121 then moves the valve to the left and prevents further flow of pressure from the service reservoir.

Auxiliary reservoir pressure flows to brake cylinder through the service port in the same manner as during a service application but does not flow so quickly as service reservoir pressure and therefore does not equalize with brake cylinder until after the service reservoir pressure is cut off by the intercepting valve. Consequently, auxiliary reservoir pressure is higher than service reservoir pressure but is prevented from flowing into the service reservoir by ball check 12″.

With the intercepting valve to the left, emergency reservoir pressure, present in passage v-1, flows through the cavity in the intercepting valve to passage x-1 and on to brake cylinder. As brake cylinder pressure increases above that in the auxiliary reservoir it is prevented from flowing into the auxiliary reservoir by ball check 12.
As the cut-off valve renders the safety valve inoperative, a high pressure is secured in the brake cylinder and, due to large passages it is secured in a very short time.

In order to insure the brake cylinder exhaust being closed before the emergency parts function, the release slide valve moves to closed position before pressure is vented from behind the high pressure valve.

The quick action chamber is connected to the brake cylinder through passages o-2 in the emergency slide valve seat o-1, o, past cut-off valve 141, thence through passage w-1 to w. This is to maintain the pressure in this chamber against possible leakage and insure that the emergency piston and valves remain in emergency position.

143. The protection valve causes an emergency application when the brake pipe pressure falls below 35 lbs. Normally this valve is held to its atmospheric seat, but when the brake pipe pressure becomes less than the predetermined minimum, the spring 115 moves the valve to its brake pipe seat (as shown in Fig. No. 35), connecting passage a-2 to the atmosphere through the vent in the protection valve cap. This produces an emergency rate of reduction so that the emergency piston is actuated with the results as just described.

144. Release, after an emergency application. When the brake pipe pressure is being restored after an emergency application the protection valve 111 will be the first to go back to normal position, this taking place when the pressure has reached approximately 45 lbs. Brake pipe air will then be admitted to chamber A, through passage c but since the quick action chamber pressure is maintained equal to that in the brake cylinder, the brake pipe pressure is as yet insufficient to move the emergency piston to release position. When the brake pipe pressure acting on the face of the equalizing
piston has been built up slightly higher than that remaining in the auxiliary reservoir, from the first stage of the equalization, this piston with its valves will be returned to release position which will in turn cause the release piston and slide valve to return to their position in the manner previously described. This permits air to flow from chamber I through passages c-2 and c-1 to the back of the high pressure valve 123 which will be thus balanced and returned to its normal position by the spring 128, cutting off communication between passages w and x-1 and consequently between the brake cylinder and the emergency reservoir. During this time air has been exhausting from the brake cylinder through port w, cavity k-1 in the release slide valve and through passages x and y-1.

When the pressure in the emergency slide valve chamber B has thus been reduced to a point where the brake pipe air in chamber A (combined with spring 135) has the balance of power the emergency piston will return the slide valve to release position. An additional exhaust is then provided for brake cylinder air through passages w-1 and o, and cavity N in the emergency slide valve seat, until the cut off valve 141 closes, after which the remaining air escapes through the usual exhaust passages.

The reservoirs and chambers will then be recharged in the usual manner.

ELECTRO-PNEUMATIC OPERATION

145. An electric service application is brought about by making a brake pipe reduction on each car, which, as the reduction is made at several points instead of one, causes the brakes to apply in a much shorter time than when the brakes are applied pneumatically. In addition, all brakes apply simultaneously, which prevents any undesirable slack action. The local reduction is made by
the service magnet valve, the service magnet opening this valve when energized, by placing the brake valve in service position, with the electrical control operative (Fig. No. 40). When the magnet valve has opened, brake pipe air can flow to the brake cylinder by passages a, b, p-1, d-2, e-2, electric service port check valve U, w-2 and w, (Fig. No. 33). The rate of flow must be limited to the usual service rate, for otherwise an emergency application would result. This limiting is accomplished by leading the service magnet exhaust through the service port check. The flow from the service magnet valve to the brake cylinder can then take place at no faster rate than the flow from the auxiliary reservoir to the cylinder, which insures that the rate will be such as to produce a service application only. Venting the brake pipe air to the brake cylinder also makes certain that the brake pipe pressure will not be reduced below that of the brake cylinder.

146. An electric release is made possible by placing a magnet valve in the passage leading from the brake cylinder exhaust to atmosphere. When the brake valve is moved to electric holding position, all the equalizing parts move to release position, as in pneumatic operation, on account of the increase in brake pipe pressure, and in addition, the release magnet is energized, which closes the release magnet valve and prevents escape of brake cylinder air. As the equalizing parts are in release position, recharging takes place, although the brakes are applied. But by moving the brake valve to release-and-running position the release magnet is de-energized, opening the release magnet valve and permitting brake cylinder air to pass to atmosphere. Thus by alternate movements of the brake valve handle between electric holding and release-and-running positions, the brake cylinder pressure may be reduced as desired.
147. An electric emergency application is secured by opening the brake pipe to atmosphere on each car by means of the emergency magnet valve of the universal valve, which is opened when the emergency magnet is energized by placing the brake valve in emergency position, or by allowing the master controller handle to move to emergency position. The emergency magnet valve (Fig. 35) opens and permits brake pipe air to flow to the top of the emergency switch piston through passages a, r-1, r-2, s-2 and chamber x, moving piston downward and thus transmitting quick action simultaneously throughout the train. Brake pipe air also flows to the underside of the quick action piston through passages a, r-1, r-2, s-2, l-2, l-1 and f-1, thereby opening the quick action valve and venting brake pipe air to atmosphere.

148. A rapid reduction in brake pipe pressure, such as comes from a hose bursting or opening of conductor’s valve, will cause the emergency piston to move to emergency position. Quick action chamber air then flows to the underside of the quick action piston, causing it to open the quick action valve. At the same time, quick action chamber air can flow to the emergency switch piston (passage e, R, f-1, l-1, l-2, to chamber x) and moves the piston downward. The contacts are then connected by the switch and energize the emergency magnets, thus transmitting quick action simultaneously throughout the train.

THE AUTOMATIC SLACK ADJUSTER

149. The slack adjuster automatically limits the brake cylinder piston travel to a predetermined value. Fig. 36 shows the application of the adjuster to a cylinder and Fig. 37 shows the method of operation. The slack adjuster, Figs. 36 and 37, consists principally of the following parts: The cylinder 2, the piston 19, the piston
spring 21, the piston stem 23, the pawl 22, the ratchet wheel 27 and the take up screw 4.

150. **The operation** of the slack adjuster is dependent upon the piston travel exceeding its proper value. When the port \( a \) in the brake cylinder is uncovered, it permits brake cylinder air to pass to the cylinder 2 through pipe \( b \). The cylinder air moves forward piston 19, so that the pawl 22 passes over several teeth of the ratchet wheel 27. When the brakes have been released, port \( a \) is connected to atmosphere and therefore cylinder 2. The compressed spring 21 consequently causes piston 19 to return to its release position and in so doing rotates the ratchet wheel 27 upon screw 4. This draws lever 5 in the direction of the slack adjuster cylinder and thus shortens the piston travel. The projection \( a \) causes the pawl to be disengaged from the ratchet wheel when the piston has returned to its release position.

161. **To apply new shoes**, casing 1, Fig. 36, should be returned to the left until sufficient slack in the rigging is obtained. To bring the shoes closer to the wheels, turn casing 1 to the right. The slack adjuster should be cleaned and oiled at the same time as the brake cylinder, and should afterwards be tested.

**THE ELECTRO-PNEUMATIC TRAIN SIGNAL SYSTEM**

152. **The electro-pneumatic signal system** on each car consists of the following:

- **Two signal whistles**, one on each end of the car, which give the communicating signal.

- **Two magnet valves**, one on each end of the car, which admit the air to operate the signal whistles.
One electro-pneumatic car discharge valve, which is operated when it is desired to transmit signals.

Accessories, which include the necessary switches, strainers, cutout cocks, etc.

153. The signal whistles are operated by compressed air from the main reservoir or feed valve pipe, admitted to the whistle by the magnet valve. A cut-out cock is located in the pipe leading to the magnet valve which must be open at the point where the brakes are being operated.

154. The magnet of the magnet valve is operated by the control circuit for the electrical apparatus, and, when energized, opens a valve which permits main reservoir air to flow to the signal whistle.

A snap switch is placed in the control circuit near each signal magnet valve, and when in the open position it will prevent the whistle on that end of car from blowing. On the leading car, or the one on which the brake is being operated, this switch should always be closed, in order that this whistle will be operative.

155. The electro-pneumatic car discharge valve, shown in Figs. 38 and 39, is located above the master controller in the end compartment in which the switchboard is placed. Either type may be applied to a car, the operation of both being the same. Only the electric portion of the valve is operative as the branch pipe connecting it with the main reservoir or signal pipe is removed. However, by having the proper operating switches closed, it is possible to operate the train signal apparatus, whether the car is in steam or electric service.

One terminal of the car discharge valve switch is
connected to one battery wire and the other to the signal wire, which extends throughout the train (Fig. 40). One terminal of the magnet valve is connected to the other battery wire and the other to the signal wire. Consequently, when any car discharge valve switch is closed, one side of the battery is connected to the signal wire. Current can then flow from one side of the battery along the signal wire throughout the train and through any signal magnet valve which has the snap switch mentioned in preceding paragraph closed, back to the battery. Opening and closing the discharge valve switch by pulling the cord will give signals corresponding to the number of times the switch is closed. These signals can be given as promptly as desired.

With these cars in steam service the signal whistle on the engine can be operated in the same manner. Care should be taken to see that the procedure outlined in paragraph No. 160 is followed.

156. In case the 7-point jumper should be removed from between cars for any reason whatever, it will cause the signal system to become inoperative back of the point where the jumper has been removed.

ALARM WHISTLE

157. Each car is fitted with two alarm whistles, one located at each end of the roof above the engineman's compartment. The whistle is operated by compressed air from the main reservoir pipe through a lever valve located above the brake valve.

GENERAL SERVICE INSTRUCTIONS

158. The main reservoir pressure should be between 105 and 120 lbs., and the brake pipe pressure 90 lbs. in electric service. The reservoirs should be drained at least once a day.
159. To make up a train for electric service, couple the brake pipe and the main reservoir pipe securely between all cars by means of the hose provided. Then open the main reservoir pipe cocks. At the ends of the train, the hose couplings should be fastened to the dummy couplings hung from the end of the cars, and on the end of the car from which the train is to be operated the signal magnet valve switch should be closed.

In order to operate the pneumatic features of the brake electrically, both train cable jumpers must be properly placed in the receptacles between each car in the train, and the control plug should be inserted its full length in the master controller cut-out receptacle on the end of the car from which the brake is to be operated.

160. To change a train from electric to steam service, couple the signal line of the engine to the main reservoir line of the train, close the main and control reservoir cut-out cocks, close the cut-out cock in the main reservoir line between the first and second car and open the cut-out cocks in the line to both signal magnet valves and close both signal magnet valve snap switches on the first car. This permits the operation of the signal whistle on the engine from any car in the train, provided all jumpers are between cars and battery switches closed.

161. To charge the brake system, place the brake valve handle on the brake valve to be operated, move the handle into release position, and open the cut-out cock in brake pipe. Only one brake valve, usually the one on the front end of the forward car, should be used at a time. All other brake valves must be in handle-off position with the handle removed.

162. To test the brakes, move the controller handle to “off” position, insert the control plug in the cut-out
receptacle, move the brake valve handle to service position until a 25-pound reduction is made, after which move the brake valve handle to electric holding position. The inspectors should then go over the train, noting whether all the brakes are applied. Upon the signal to release the brakes, (four blasts of the signal whistle given from the rear car), the engineman will place the brake valve handle in service position, making a further reduction of 25 pounds and then let controller handle take the vertical position. (This will apply brake in emergency, therefore, testing this feature of the master controller.) Place the brake valve in emergency position until brake pipe pressure is depleted, return the control handle to “off” position, place the brake valve handle in release-and-running position, then the inspector will go over the train and see that all brakes are released. The inspector will then advise engineman and conductor as to the condition of the brakes and the number of cars in the train. The brakes must be tested after every change in the make-up of the train. Before starting, engineman and conductor must know that the brakes have been tested.

163. To make a service application, the brake pipe pressure should be reduced the amount desired, not exceeding 25 pounds, by moving the brake valve handle to service position, after which it should be moved to lap position.

164. To graduate the release, which can only be done electrically, the control plug must be inserted all the way in the cut-out receptacle. Move the controller handle to “off” position, make a service application of the brake and move the brake valve handle to lap position momentarily to allow the pressures to equalize after which move the brake valve handle to electric holding position. By moving the brake valve handle alternately between electric holding and release positions, the brake will be released in steps, effecting a smooth stop.
165. To make an emergency application, move the brake valve into emergency position and leave it there until the train stops. An emergency application can be made from within the car by pulling the chain of the conductor's valve and holding it until the train stops. Whenever the engineman finds that an emergency application has been made by some other means than the brake valve, he should place the brake valve in emergency position until the train stops and should move the controller handle to its emergency position. If an emergency application occurs as a result of the controller accidentally moving to emergency position, the brake valve must first be moved to its emergency position until all brake pipe pressure is vented to atmosphere before attempting to release the brakes.

166. To cut out a defective brake, close the brake cylinder and branch pipe cut-out cocks, and drain the three reservoirs.

167. To cut off a car, make a 25 pound reduction, move the brake valve handle to emergency position, close the cocks in the main reservoir pipes, uncouple the hose and hang up properly by means of the dummy couplings. Never let the hose be pulled apart by the cars separating.

168. Cars in yards and on sidings should have the air brake released and the hand brake applied.

**BRAKE FAILURES**

169. A release after a service application is caused either by an increase in brake pipe pressure or a decrease in auxiliary reservoir pressure. The brake pipe pressure may be increased by a partially lapped brake valve or a leaking rotary valve. A partially lapped brake valve can
be discovered by inspection. To find a leaking rotary valve, close all brake valve cut-out cocks except the cock of the valve being operated. Then make a brake pipe reduction, after which place the brake valve in lap position. If the gauge shows that the brake pipe pressure is increasing, a leaking rotary valve is indicated. The auxiliary reservoir pressure may be decreased by leakage through gaskets, piping, slide valve seats, etc.

170. If the brakes cannot be released after making a slight brake pipe reduction, it is probably because ring leakage has permitted the equalizing piston chamber pressure to equalize with the brake pipe pressure. Increasing the reduction to 20 pounds will frequently enable a release to be obtained. If the brake does not release, reduce the auxiliary reservoir pressure until it does.

170. In case of defective feed valve on the head end of a train, engineman should screw adjusting nut all the way in and the governor cut-out cock on one car in the train should be closed. This practice will sometimes prevent brakes from sticking even where there is no feed valve trouble.

172. If any defects develop in the electrical features of the brake, the brake plug must be withdrawn from the cut-out receptacle about one inch, thereby cutting out the electric features; the brake can then be operated pneumatically. A defective 7-point jumper will cause the rear portion of a train to run into the front portion when making a brake application. To ascertain if the trouble is caused by this, proceed as in Par. No. 178, for it may also be caused by unequal piston travel. If it is necessary to remove a 9-point jumper from between two cars, the 7-point jumper must also be removed, or the control plug partially withdrawn to prevent trouble with the electric features of the brake.
173. If a main reservoir pipe hose bursts, close the cut-out cocks immediately ahead and behind the burst hose and proceed.

If a main reservoir pressure of 90 pounds cannot be maintained, the defective hose must be replaced and cut-out cocks again opened.

174. If a brake pipe hose bursts, remove the hose and replace with a new hose. A road test of the brakes must be made before the train proceeds.

175. If the branch brake pipe breaks on the Universal Valve side of the cut-out cock, close the cut-out cocks in branch pipe and brake cylinder pipe and drain the three reservoirs.

176. Under no circumstances should trains be run with less than 85 per cent. of the cars in the train having their air brakes properly coupled up and in operative condition, without specific instructions from the superintendent.

177. The application of the brakes should be adapted to the speed. At a high speed, a full application should be made and the release graduated until at the moment of stop, the cylinder pressure is very low. If the train is on a level, complete release; if on a grade, hold the brakes until the signal to start is given.

**TRAIN SIGNAL FAILURE**

178. Defects in train signal. If signal whistle blows when cord is pulled on car in forward part of a train, but not from rear cars, examine the seven-point jumper back of the last car from which the signal operates properly. Remove the jumper, hang it in dummy receptacle and apply the spare jumper on the opposite side.
The train signal whistle may blow continuously due to any of the following causes: Short signal cord; defective car discharge valve (probably on car where cord was last pulled), which often may be corrected by lightly tapping the valve; stuck signal magnet valve which may be corrected by tapping same.

COMPRESSOR AND GOVERNOR FAILURES

179. If compressor discharge pipe breaks, close main reservoir cut-out cock and open governor switch on switchboard. If car is equipped with separately driven air compressor, the compressor motor switch should be opened also; otherwise, leave the compressor-blower motor switch closed.

180. In case main reservoir drain cock breaks, or main reservoir safety valve becomes unseated, proceed as in Par. No. 179.

181. If governor pipe on cars equipped with a compressor-blower motor breaks between the governor and the governor cut-out cock, close this cock and open the governor switch on switchboard. If the break occurs between the cut-out cock and main reservoir, close the main reservoir cut-out cock and open governor switch on switchboard.

182. If the governor pipe on cars equipped with separately driven compressor, or the compressor switch pipe breaks between the governor or compressor switch and the governor-compressor-switch cut-out cock, close this cock, open the governor switch on switchboard, and in addition open the compressor motor switch unless there is no other supply of compressed air when it will be necessary to leave compressor motor switch closed and compressor running. If the break occurs between the cut-out cock and main reservoir, close main reservoir cut-out cock, and open the governor and compressor motor switches on switchboard.
183. **If the clutch pipe breaks**, close cut-out cock in clutch pipe and leave the compressor run continuously.

**MISCELLANEOUS**

184. **It should be known** before the train departs that the alarm whistle on the front and rear units are in operating condition.

185. **When MU cars are moved in freight service**, the safety valve on the U. C. valve should be set at 35 pounds.

**APPENDIX**

**PARTS OF UE-12-B UNIVERSAL VALVE**

Following is a list of the parts referred to in the description of operation of the UE-12-B Universal Valve (Fig. 32).

3. Equalizing Slide Valve.
4. Equalizing Piston.
7. Equalizing Graduating Valve.
12. Service Port Check.
12'. Emergency Reservoir Charging Check.
12''. Service Reservoir Check.
16. Release Piston
34. Charging Valve.
76. Emergency Piston.
78. Emergency Slide Valve.
80. Emergency Graduating Valve.
85. Quick Action Valve.
88. Quick Action Piston.
90. Quick Action Valve Spring.
99'. Quick Action Chamber Charging Check Valve.
99. Quick Service Port Check Valve.
102. Ball Charging Check.
111. Protection Valve.
115. Protection Valve Spring.
117. Intercepting Valve.
121. Intercepting Valve Spring.
123. High Pressure Valve.
128. High Pressure Valve Spring.
134. Emergency Piston Stop.
135. Emergency Piston Stop Spring.
141. Cut-Off Valve.
146. Cut-Off Valve Spring.
149. Safety Valve.
252. Electric Service Port Check.
261. Contacts.
281. Emergency Switch Piston.
283. Emergency Switch.
284. Emergency Switch Piston Spring.
285. Contact Spring.
303. Release Magnet Valve.
313. Release Magnet Valve Spring.
323. Emergency Magnet Valve.
332. Emergency Magnet Valve Spring.
343. Service Magnet Valve.
352. Service Magnet Valve Spring.
NOTES:
1. THIS DIAGRAM SHOWS NEEDED APPARATUS AND THEIR SEQUENCE, BUT THE ACTUAL LOCATION OF EACH PART WITH RESPECT TO THE OTHERS IS LEFT TO THE INSTALLER. THE SHORTEST LENGTH OF PIPE WILL CONNECT THEM CONSISTENT WITH ACCESSIBILITY, ETC.
2. ALL UNIONS IN THE LINE MUST BE OF THE FLANGED TYPE.
3. SPECIAL ADJUSTING DEVICES TO BE LOCATED AS RECOGNIZED BY THE INSTALLER.
4. THE LOCATION OF EACH PART WITH RESPECT TO THE OTHERS IS SUCH THAT THE SHORTEST LENGTH OF PIPE WILL CONNECT THEM CONSISTENT WITH ACCESSIBILITY, ETC.
5. THE INSTALLER IS TO USE PREVENTIVE MEASURES TO PROTECT THE VALVES.
6. THE BRAKE PIPE TO BE CONNECTED DIRECTLY TO THE AIR COMPRESSOR.
7. THE AIR STRAINER TO BE LOCATED AS RECOGNIZED BY THE INSTALLER.
8. THE DISTRIBUTION BOX TO BE LOCATED AS RECOGNIZED BY THE INSTALLER.

DIAGRAM OF CONNECTIONS OF MAIN JUNCTION BOX

PIPING AND WIRING DIAGRAM
Par. No. 80
FIGURE No. 2

1. THIS DIAGRAM SHOWS NECESSARY APPARATUS AND THEIR SEQUENCE. THE ACTUAL LOCATION OF EACH PART WITH RESPECT TO THE OTHER MAY BE AFFECTED BY ITS OPERATION.

2. ALL REGULATING DEVICES SHOULD BE LOCATED IN ONE PLACE.

3. LOCATE ALL STRAINERS AS CLOSE AS POSSIBLE TO THE VENTS.

4. DIRT COLLECTOR TO BE LOCATED WITHIN 24 INCHES OF UNIVERSAL VALVE.

5. THE OUTLET FROM THE BRAKE PIPE TO POINT DIRECTLY UPWARD, EITHER BY THE USE OF A COMMERCIAL TEE WITH SIDE OUTLET POINTING UPWARD, OR A SPECIAL BRANCH PIPE TEE MADE FOR THE PURPOSE.

6. RADIATING PIPE TO BE PUT IN OR LEFT OUT AS CONDITIONS OF LOCALITY REQUIRE BUT NEVER TO BE OF GREATER LENGTH THAN SPECIFIED HERE.

7. POSITION OF ALL CUTOFF COCKS SHOULD BE SUCH AS TO PREVENT HANDLE BEING JAMMED IN A CLOSED POSITION.

8. PAR. NO. 20 PIPING AND WIRING DIAGRAM
FIGURE No. 3

D-2-R MOTOR DRIVEN AIR COMPRESSOR.
Par. No. 82.

FIGURE No. 4

D-2-R MOTOR DRIVEN AIR COMPRESSOR.
Unassembled View.
Par. No. 82.
FIGURE No. 5

FOUR-CYLINDER MOTOR DRIVEN AIR COMPRESSOR.
Par. No. 87.

FIGURE No. 6
FIGURE No. 7

E-7 SAFETY VALVE.
Par. No. 97.
FIGURE No. 8

TYPE J ELECTRIC COMPRESSOR GOVERNOR, WITH COVER REMOVED.
Par. No. 99.
FIGURE No. 9

TYPE J ELECTRIC COMPRESSOR GOVERNOR,
DIAGRAMMATIC VIEW.

 Pars. Nos. 100 and 101.
FIGURE No. 10

TYPE S-16 COMPRESSOR GOVERNOR WITH COVER REMOVED.
Par. No. 99.
FIGURE No. 11

DIAGRAMMATIC VIEW OF THE S-16 GOVERNOR IN CUT-IN POSITION.

Pars. Nos. 105 and 106.
FIGURE No. 13

ENGINE MAN'S BRAKE VALVE, ME-23.
Par. No. 112.
ENGINE MAN'S BRAKE VALVE ME-23, SECTIONAL VIEW.
Par. No. 112.
FIGURE No. 15
RELEASE AND RUNNING POSITION
Pars. Nos. 116 and 121

FIGURE No. 16
HOLDING POSITION
Par. No. 122

FIGURE No. 17
HANDLE OFF POSITION
Par. No. 124

ENGINEMAN'S BRAKE VALVE—ME-23
FIGURE No. 18

REDUCTION LIMITING RESERVOIR
EXHAUST
EQUALIZING RESERVOIR

LAP POSITION
Par. No. 119

FIGURE No. 19

REDUCTION LIMITING RESERVOIR
EXHAUST
EQUALIZING RESERVOIR

SERVICE POSITION, PARTIAL REDUCTION
Par. No. 117

FIGURE No. 20

REDUCTION LIMITING RESERVOIR
EXHAUST
EQUALIZING RESERVOIR

SERVICE POSITION, OVER REDUCTION
Par. No. 117

FIGURE No. 21

REDUCTION LIMITING RESERVOIR
EXHAUST
EQUALIZING RESERVOIR

EMERGENCY POSITION
Par. No. 123

ENGINEER'S BRAKE VALVE, ME-23
FIGURE No. 22

C-6 FEED VALVE.
Par. No. 125.

FIGURE No. 23

DIAGRAMMATIC VIEW C-6 FEED VALVE.
Par. No. 126.
FIGURE No. 24

FRONT VIEW OF M-3-A FEED VALVE.
Par. No. 125.
FIGURE No. 25

DIAGRAMMATIC VIEW OF THE M-3-A FEED VALVE.

Par. No. 130.
FIGURE No. 28

TWO VIEWS OF UE-12-B PIPE BRACKET.
Par. No. 133.
FIGURE No. 29

EQUALIZING PORTION OF UE-12-B UNIVERSAL VALVE.
Par. No. 133.

FIGURE No. 30

EMERGENCY PORTION OF UE-12-B UNIVERSAL VALVE.
Par. No. 133.
FIGURE No. 31

ELECTRIC PORTION OF UE-12-B UNIVERSAL VALVE.
Par. No. 135.
FIGURE No. 32

CHARGING AND RELEASE
Pars. Nos. 135 and 136
APPLICATION OF AUTOMATIC SLACK ADJUSTER TO BRAKE CLENDER.

Par. No. 149.
FIGURE No. 37

AUTOMATIC SLACK ADJUSTER CYLINDER.
Par. No. 149.
FIGURE No. 40

BRAKE SYSTEM—DIAGRAM OF CONNECTIONS
Pars. Nos. 110, 111, 114, 145 and 155