No. 215

The Pennsylvania Railroad

ELECTRIC LOCOMOTIVES

Classes P5a, Modified P5a, and GG1

Engineman's Instruction Book

The Pennsylvania Railroad

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Classes P5a, Modified P5a, and GG1

ENGINEMAN'S INSTRUCTION BOOK

No. 1509

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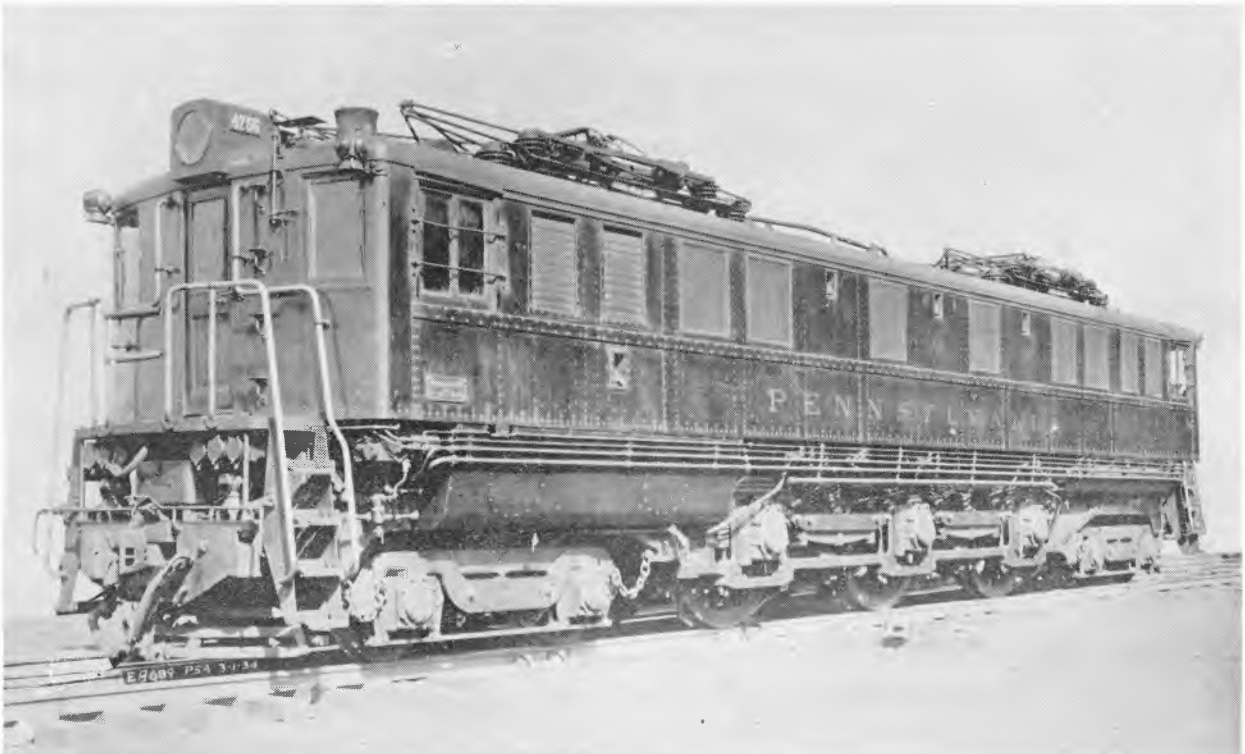
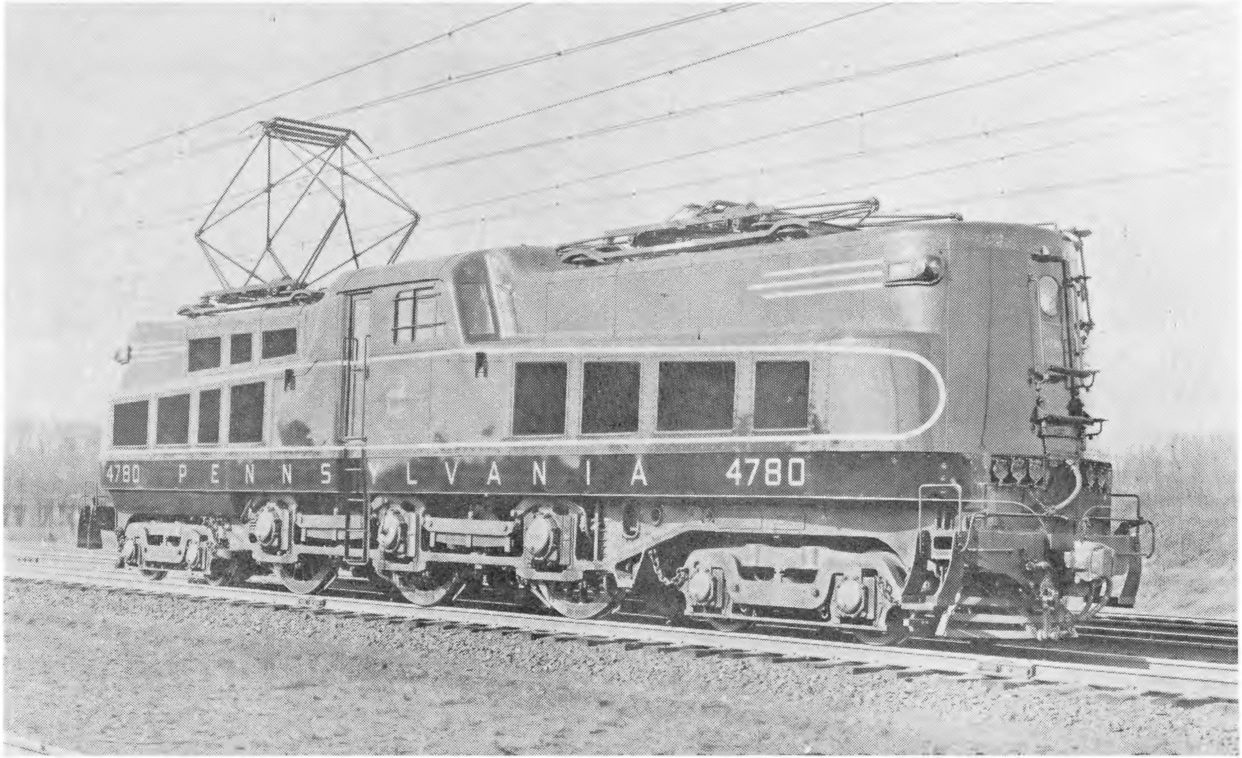


Electric Locomotive—Class P5a
(*Frontispiece A*)



Electric Locomotive—Class P5a Modified
(*Frontispiece B*)

Electric Locomotive—Class GG1
(*Frontispiece C*)

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General Notice

Safety is of the first importance in the discharge of duty.

Engine crews, train crews and other employes whose duties are associated with the handling of electric locomotives must be conversant with, and obey the instructions in the book designated as C. T. 290, Special Instructions for Employes in Electrified Territory, and must also understand and obey the Safety Rules, S-7.

No part of the 11,000-volt circuit, including the pantographs, roof bus, high voltage cable, and main transformer, nor live parts of the secondary circuits shall be touched without first lowering the pantograph and closing the grounding switches. This must be done by a qualified employe or under the supervision of a qualified employe.

Work must not be done on any auxiliary apparatus unless either the pantographs have been lowered and grounded, or the switches controlling the apparatus are opened and the fuses removed. The blower bus cutout switch must be opened and the blower fuses must be removed for any work on the blower circuits. The compressor contactor must be opened by means of the operating handle for any work on the compressor motor circuit. Fuses must not be removed from, nor replaced in, a circuit unless the switch for that circuit is open. Rubber gloves are provided and should always be used in removing and replacing fuses.

Enginemen are required to familiarize themselves with the name, location and purpose of all apparatus. They are required 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 contruction and details of the apparatus and method of making repairs.

J. A. APPLETON,
General Manager, New York Zone.

H. C. HIGGINBOTTOM,
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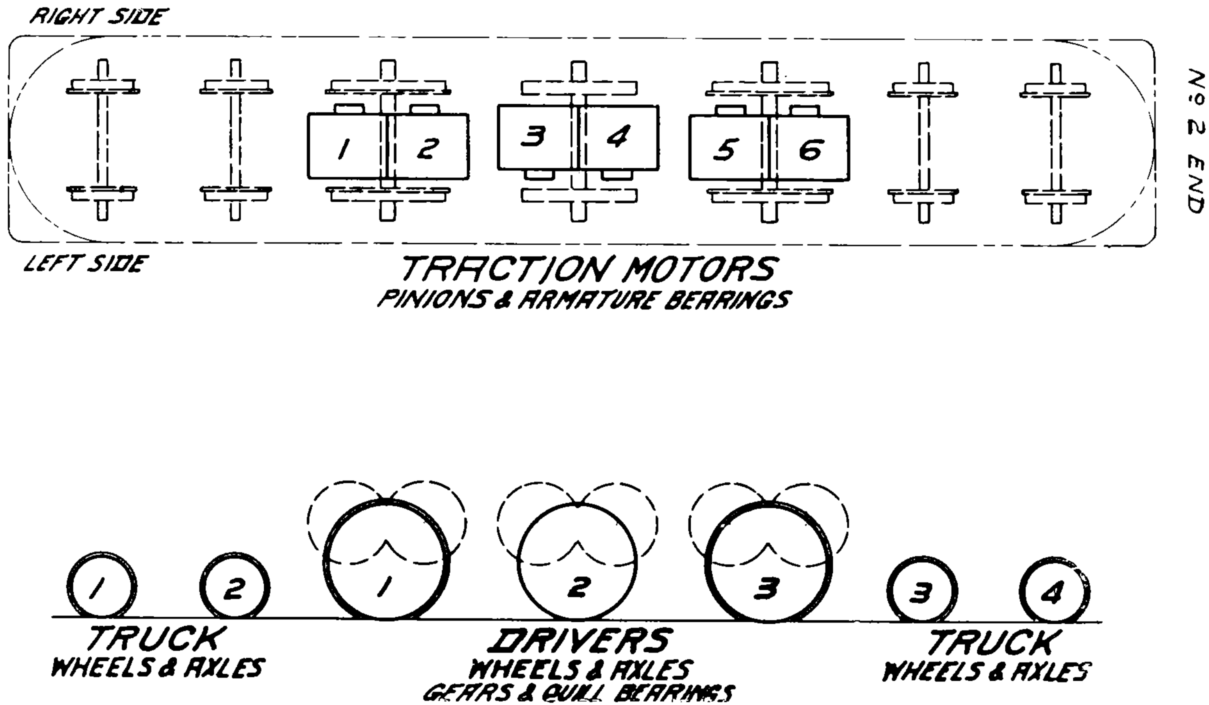


Fig. 1. Chassis Diagram—P5a and Modified P5a Locomotives

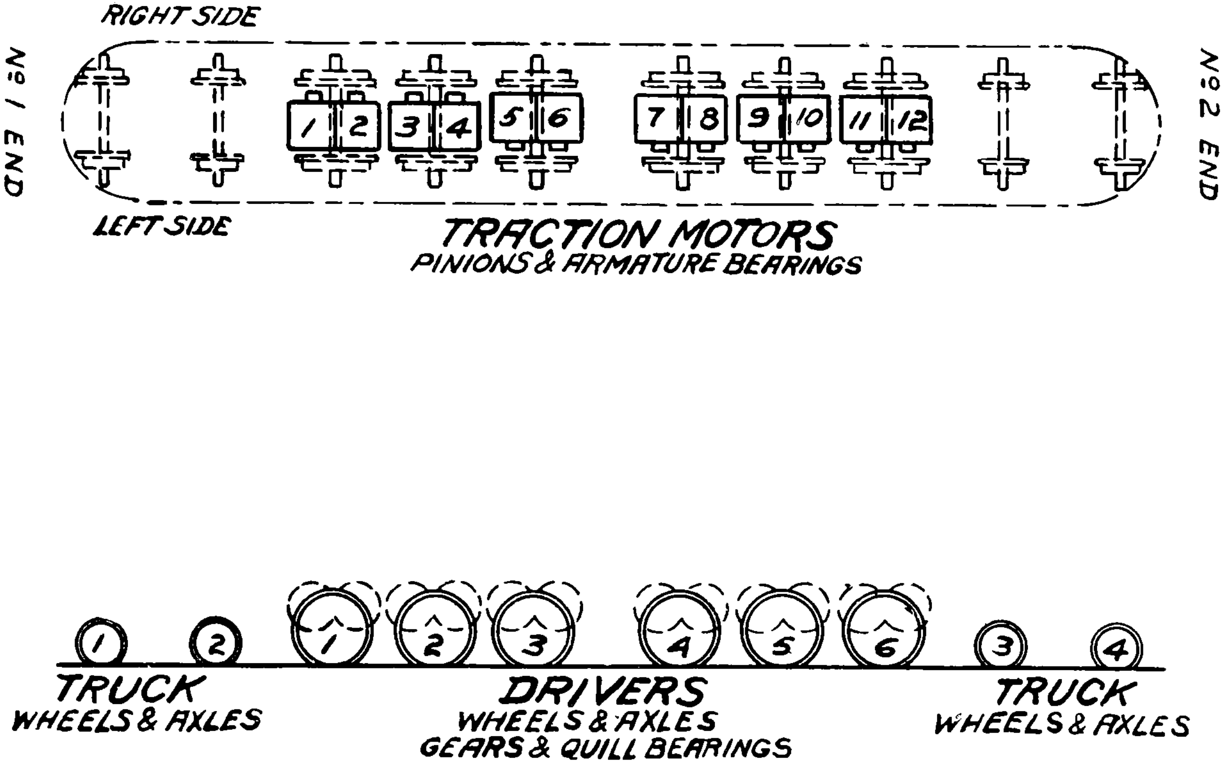


Fig. 2. Chassis Diagram—GG1 Locomotives

General Description of Locomotives

Electric locomotives of the P5a and Modified P5a classes have a 4-6-4 wheel arrangement. There is a four-wheel swinging truck at each end, and three pairs of driving wheels between. Electric locomotives of the GG1 class have a 4-6-0+0-6-4 wheel arrangement. There is a four-wheel swinging truck at each end, and two motor trucks. The motor trucks are hinged together by an articulation pin and each has three pairs of driving wheels.

Each pair of driving wheels is equipped with two motors mounted in a single frame. The motor pinions drive a gear mounted on the quill, the quill bearings being supported in the twin motor frames. Spring cup mechanisms are used to transmit torque from the gear and quill to the driving wheels.

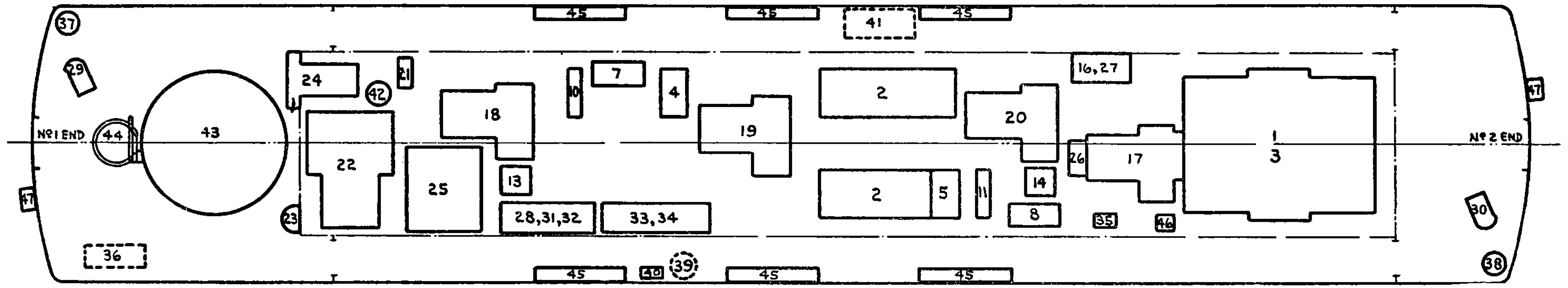
The front end of the locomotive, which is known also as the No. 1 end, is marked on the sides by the letter "F"; the other end is the No. 2 end. The locomotive is designed to operate with either end leading.

Electrical energy for the traction motors and auxiliaries is supplied by the **Power Apparatus,** which consists principally of of the pantographs and main transformer. The traction motors are operated by an electro-pneumatic control system which is divided into two parts, namely, the **Traction Motor Control Apparatus** and the **Master Control Apparatus,** the former being actuated by the latter.

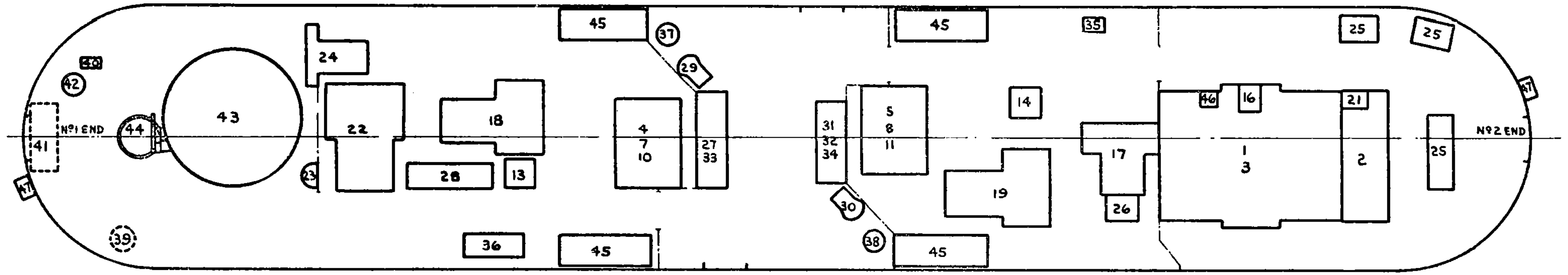
The **Traction Motor Control Apparatus** consists of those parts whose function is to carry and control the traction motor current. The **Master Control Apparatus** consists of those parts which, when actuated through the master controller or other devices by a low voltage current from a storage battery, function to admit compressed air to the operating cylinders of the traction motor control apparatus, thus controlling the latter. This remote type of control is necessary because the making and breaking of connections carrying traction motor current is too heavy a duty for a controller to perform practicably.

The master control system includes the multiple unit feature by means of which two or more locomotives may be coupled and

P5A LOCOMOTIVE



MODIFIED P5A LOCOMOTIVE



GG1 LOCOMOTIVE

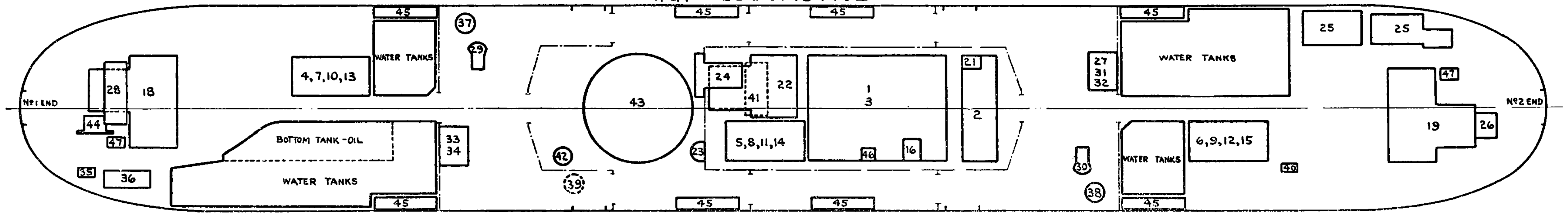


Fig. 3. Cab Diagrams

ITEM	APPARATUS
1	MAIN TRANSFORMER
2	TRANSFORMER TAP SWITCHES
3	PREVENTIVE COILS
4	No 1 MOTOR SWITCHES
5	No 2 " "
6	No 3 " " (GG1 ONLY)
7	No 1 REVERSER
8	No 2 "
9	No 3 " (GG1 ONLY)
10	No 1 MAIN FIELD SHUNTING SWITCHES
11	No 2 " " " "
12	No 3 " " " " (GG1 ONLY)
13	No 1 " " " REACTOR
14	No 2 " " " "
15	No 3 " " " " (GG1 ONLY)
16	BLOWER BUS CUTOUT SWITCH
17	TRANSFORMER BLOWER (P5A & MODIFIED P5A ONLY)
18	No 1 BLOWER
19	No 2 "
20	No 3 " (P5A ONLY)
21	AIR COMPRESSOR CONTACTOR
22	AIR COMPRESSOR
23	BOILER BLOWER SWITCH
24	BOILER BLOWER
25	BATTERY
26	GENERATOR
27	GENERATOR REGULATOR
28	CAB SIGNAL EQUIPMENT BOX
29	No 1 MASTER CONTROLLER
30	No 2 " "
31	MOTOR CUTOUT SWITCHES
32	SWITCHBOARD CABINET
33	RELAY CABINET
34	WATTHOUR METER
35	AIR COMPRESSOR GOVERNOR
36	DISTRIBUTING VALVE
37	No 1 PEDESTAL BRAKE VALVE
38	No 2 " " "
39	BRAKE PIPE VENT VALVE
40	DEADMAN APPLICATION VALVE
41	CONTROL RESERVOIR
42	PANTOGRAPH HAND PUMP
43	BOILER
44	HAND BRAKE STAND
45	SAND BOXES
46	GROUND CUTOUT SWITCH
47	GROUNDING SWITCH OPERATING HANDLE

Fig. 3. Cab Diagrams

their tractive operations placed under the control of one engine-man.

The **Auxiliary Apparatus** consists principally of motor-driven fans which take air through side-sheet louvers to ventilate the traction motors and transformer, and a motor-driven compressor which supplies air for the brake system and other pneumatic devices.

The **Cab Signal Apparatus** provides a continuous indication with a warning whistle and acknowledger.

The **Air Brake Apparatus** provides means for supplying compressed air to the locomotive and train, and for controlling the train and locomotive brakes.

The **Steam Heat Apparatus** consists principally of an oil-fired boiler which delivers steam to the train heating line.

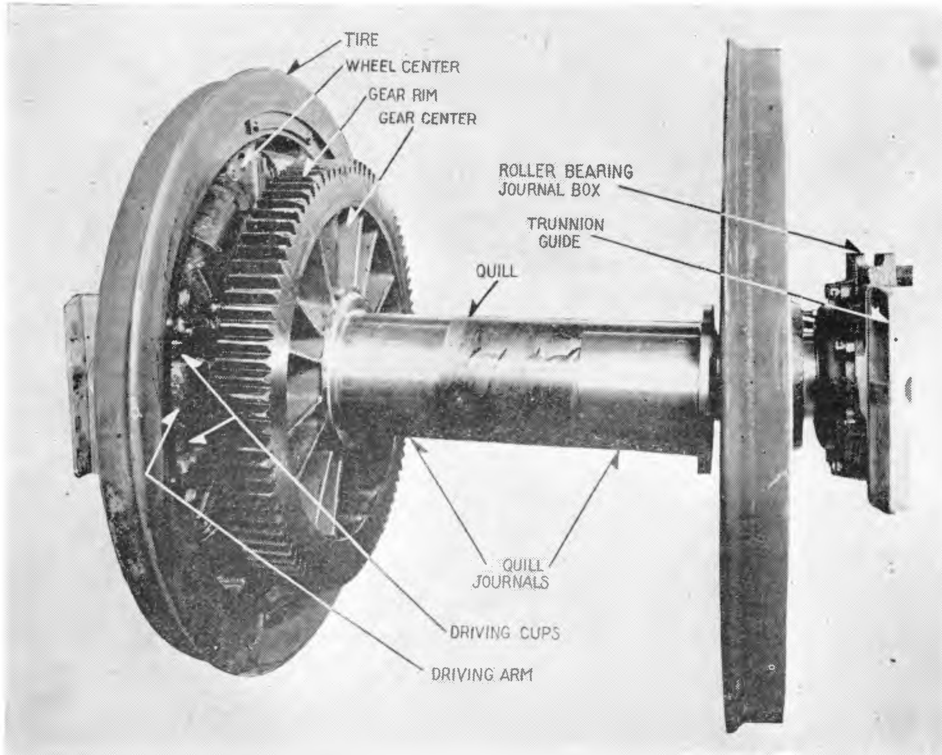


Fig. 4. Driving Wheels—P5a and Modified P5a Locomotives

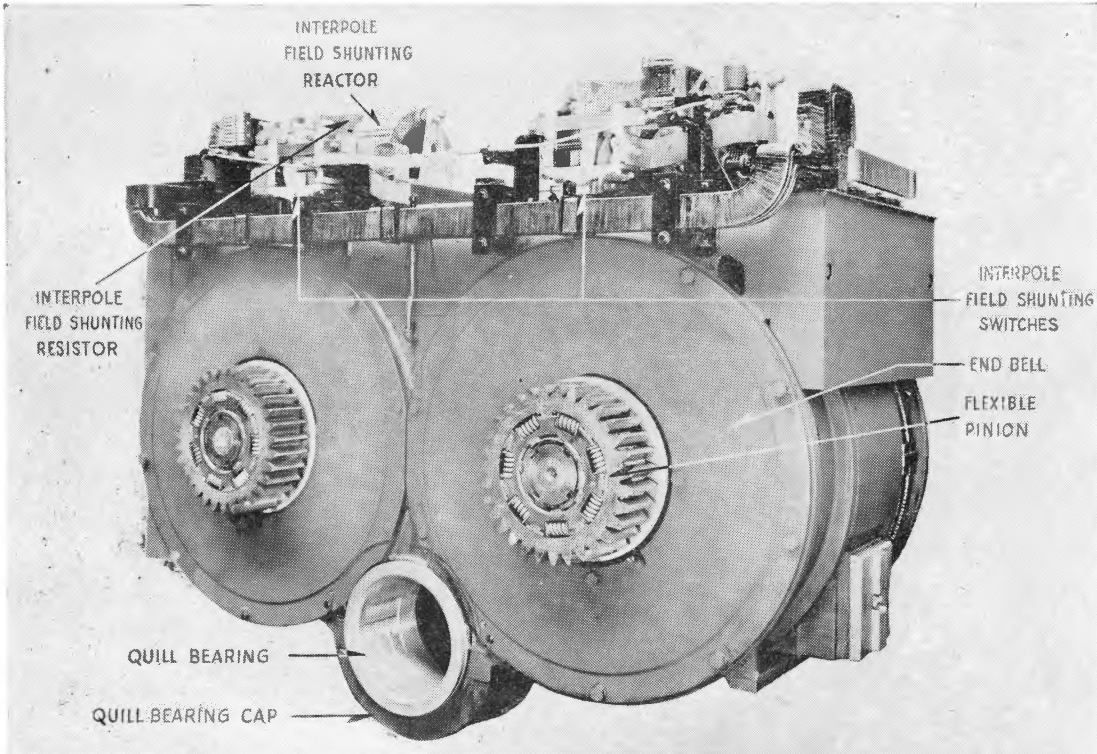


Fig. 5. Traction Motors—P5a and Modified P5a Locomotives
(Gear Case Removed)

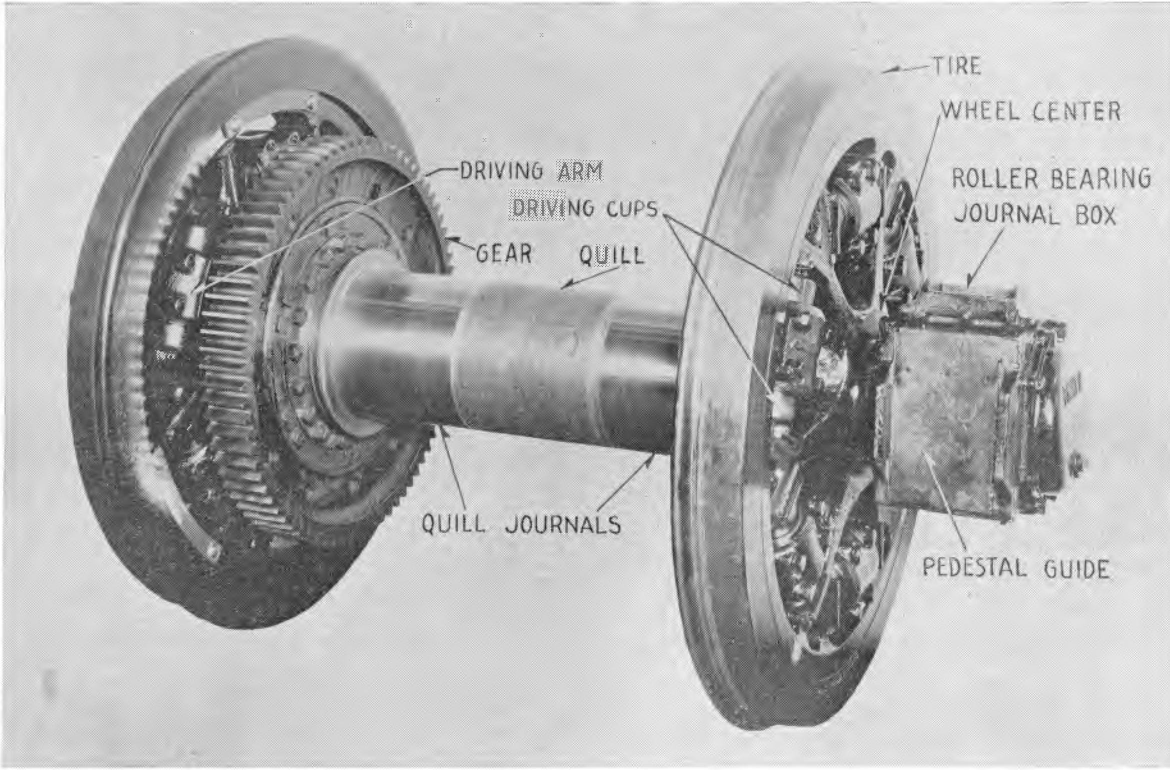


Fig. 6. Driving Wheels—GG1 Locomotives

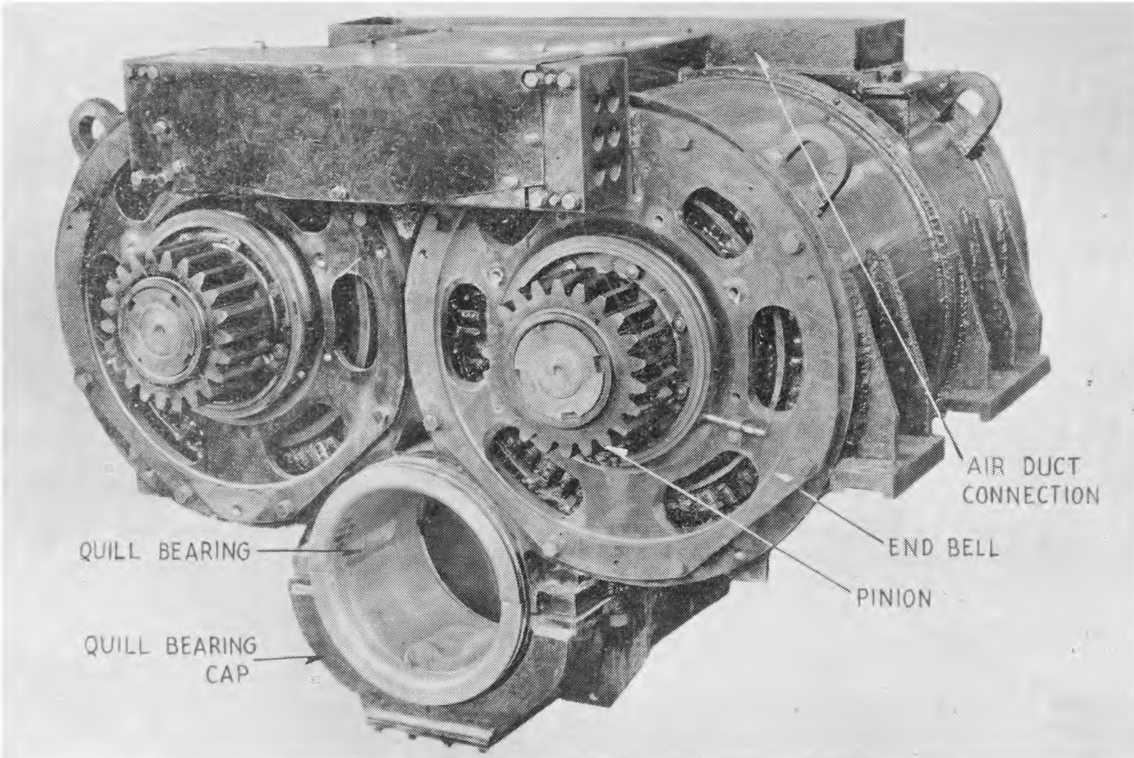


Fig. 7. Traction Motors—GG1 Locomotives
(Gear Case Removed)

P5a and Modified P5a Locomotives

General Data

Wheel Arrangement	4-6-4
Diameter of Truck Wheels	36 inches
Diameter of Driving Wheels	72 inches
Rigid Wheel Base	20′ 0″
Total Wheel Base	49′ 10″
Length Coupled	62′ 8″
Maximum Height Pantograph Latched	15′ 0″
Line Voltage	11,000 volts, 25 cycles
Traction Motors Hp. Rating	(6) 625 hp.
Type of Drive	Flexible Spring
Gear Ratio	31 : 91
Type of Traction Motor Control	Transformer Tap Switches
Type of Master Control	Electro-pneumatic
Master Control Voltage	32 volts d. c.
Compressor Hp. Rating	35 hp.
Compressor Capacity	150 c. f. m. displacement at 100 r. p. m.
Transformer Blower Hp. Rating	18-½ hp.
Traction Motor Blowers Hp. Rating	(3) 35 hp. on P5a locomotives (2) 35 hp. on Modified P5a locomotives
Maximum Speed	90 m. p. h.
Fuel Oil Capacity	3500 Lbs. (465 gallons)
Water Capacity	16,600 Lbs. (2000 gallons)
Weight on Drivers	220,000 Lbs. on P5a locomotives 229,000 Lbs. on Modified P5a locomotives
Total Weight	392,000 Lbs. on P5a locomotives 394,000 Lbs. on Modified P5a locomotives
Maximum Tractive Power	55,000 Lbs. on P5a locomotives 56,250 Lbs. on Modified P5a locomotives

GG1 Locomotives

General Data

Wheel Arrangement	4-6-0+0-6-4
Diameter of Truck Wheels	36 inches
Diameter of Driving Wheels	57 inches
Rigid Wheel Base	13′ 8″
Total Wheel Base	69′ 0″
Length Coupled	79′ 6″
Maximum Height Pantograph Latched	15′ 0″
Line Voltage	11,000 volts, 25 cycles
Traction Motors Hp. Rating	(12) 385 hp.
Type of Drive	Flexible spring
Gear Ratio	22 : 79
Type of Traction Motor Control	Transformer Tap Switches
Type of Master Control	Electro-pneumatic
Master Control Voltage	32 volts d. c.
Compressor Hp. Rating	35 hp.
Compressor Capacity	150 c. f. m. displacement at 100 r. p. m.
Blowers Hp. Rating	(2) 55 hp.
Maximum Speed	90 m. p. h.
Fuel Oil Capacity	2933 Lbs. (391 gallons)
Water Capacity	22,730 Lbs. (2715 gallons)
Weight on Drivers	300,000 Lbs.
Total Weight	460,000 Lbs.
Maximum Tractive Power	72,800 Lbs.

Electrical Circuits and Apparatus

Note: As it is impractical, if not virtually impossible, to show the entire path of the electric current by any single view of a piece of electrical apparatus, symbols have been made to represent in a purely diagrammatic way the various pieces of apparatus. Plates 1 to 20 inclusive are schematic diagrams in which the actual proportions, constructions, and locations have been disregarded in order to make the connections and operations more easily understood. An explanation of Symbols used on schematic diagrams is given on Figure 8.

PRIMARY CIRCUIT

The substations along the right-of-way supply the alternating current at 11,000 volts and a frequency of 25 cycles per second which is collected from the trolley wire by the pantograph. A section of trolley wire between two substations is usually fed from both ends. At the substation feeding point is the section break in the trolley wire which separates one such trolley section from the next trolley section. At crossovers, the trolley sections over adjacent tracks are separated by section breaks, also. The section breaks are of such construction that the pantograph shoes may slide from one section to the next without interruption of the current collection.

The trolley wire is fed through substation circuit breakers which open under overload or short-circuit conditions. The current collected by the pantograph is conducted to the main transformer primary winding through which it flows to the frame of the locomotive, thence through the wheels to the track rails, and thence to the substation. The rail-return circuit is made continuous past the insulated block joints by the use of impedance bonds which are supported on the ties between the rails. The impedance bond permits the flow of the 25-cycle current, but chokes the flow of signal current around the insulated rail joint.

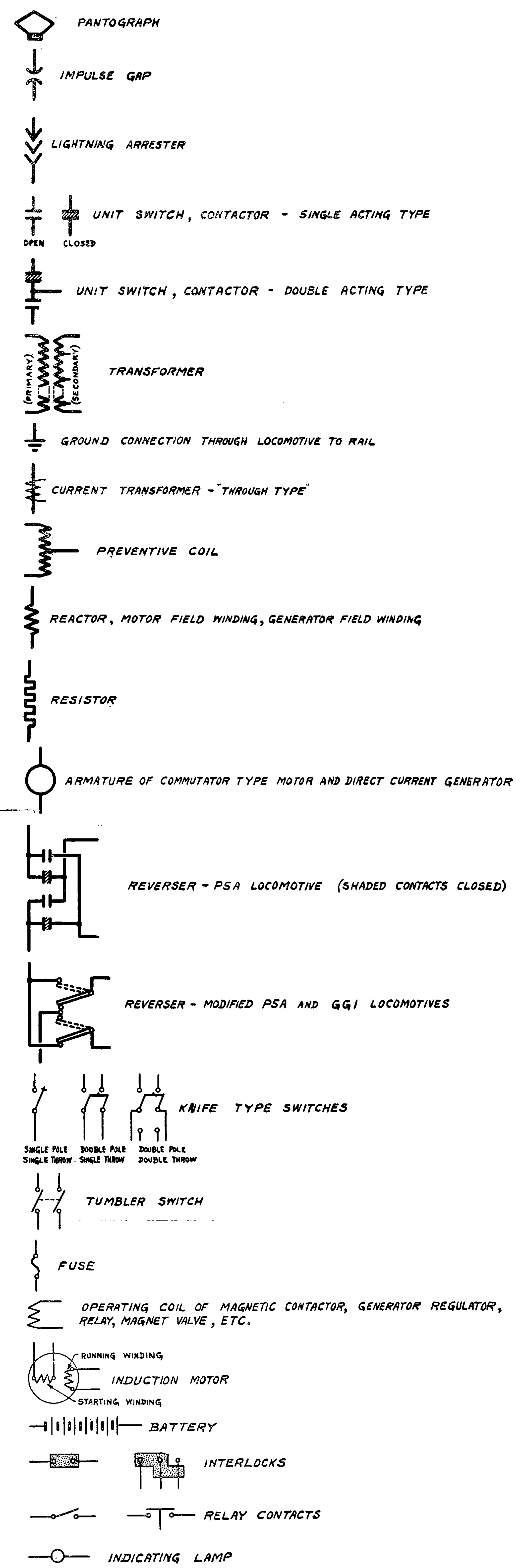


Fig. 8. Symbols Used on Schematic Wiring Diagrams

Power Apparatus

The principal pieces of apparatus in the power circuit (see Plates 1, 2 and 3) are listed as follows:

(a) Two pantographs, either or both of which can be used to collect current from the trolley wire.

(b) A grounding switch on each pantograph can be used to ground same; an auxiliary hook engages the upper frame of the pantograph to hold it down.

(c) An electro-pneumatic grounding contactor is associated with the roof bus on the P5a locomotives. On the Modified P5a and GG1 locomotives both pantographs have grounding contactors which operate simultaneously from one control circuit. The contact grounds the roof bus or pantograph, as the case may be, short-circuiting the primary circuit.

(d) The P5a and Modified P5a locomotives have an impulse gap adjacent to the base of each pantograph. An excessive voltage on the trolley wire, such as accompanies a lightning disturbance, is relieved by arc-over of the gap.

(e) The GG1 locomotives have a lightning arrester connected to the high tension lead of the main transformer.

(f) The main transformer is of the two-winding (primary and secondary) type with an iron magnetic structure. It transforms the electrical energy from the high voltage at which current is collected to the lower voltages at which current is used in the traction motors and auxiliary apparatus.

Pantographs

The pantographs, Fig. 9, have insulated mountings upon the roof. They consist principally of the contact shoes, upper frames, lower frames, and base. Operating springs and cylinders are mounted on the base. The pantograph is raised by its springs to make contact with the trolley wire and is lowered by its air-operated cylinders.

Two contact shoes, with end horns attached thereto, are flexibly mounted on the upper frames. A wind vane supported between the shoes helps to stabilize them against the action of air currents at high speed. Pivoted connections of the shoes

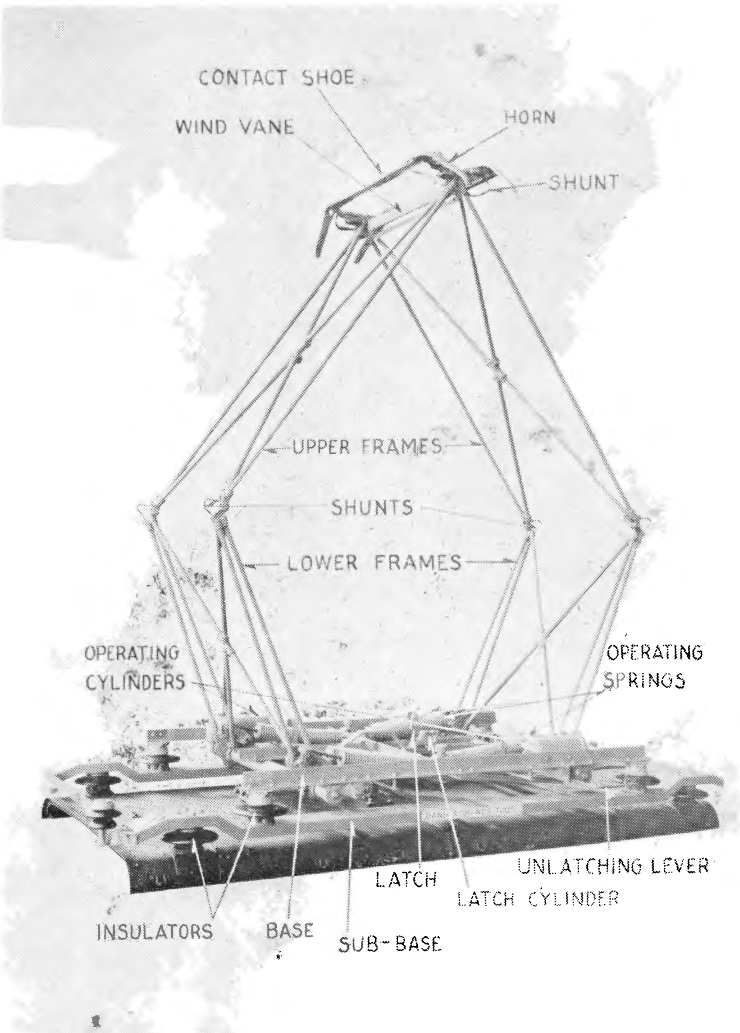


Fig. 9. Pantograph

(As mounted on hood hatch cover of Modified P5a Locomotives)

and frames are provided with shunts of copper braid to pass the current around the pivot fittings.

When the pantograph is lowered all the way, its latch engages and holds it down. A small air-operated cylinder serves to operate the latch for releasing the pantograph. The latch cylinder is charged through the pantograph "UP" magnet valve to release the latch. A two-way cock is provided in the piping of the latch cylinder so that the pantograph can also be unlatched by means of the hand pump.

The lowering cylinders are charged through the pantograph "DOWN" magnet valve to lower the pantograph and hold it down.

A wooden pantograph pole can be used with rubber gloves to raise or lower the pantographs. An unlatching lever is provided on each side of the pantograph base for operating with the hook end of the pole.

The hook can be engaged in the end horn of the contact shoe to lower the pantograph, also.

On the P5a locomotives the bases of the pantographs are connected by a roof bus. The high tension lead from the roof bus to the main transformer enters the cab through a roof bushing.

On the Modified P5a locomotives the bases of the pantographs are connected by cables. The high tension lead to the main transformer enters the cab through a roof bushing.

On the GG1 locomotives the high tension leads are brought directly from the pantographs to the main transformer in the cab of the locomotive.

Grounding Switches

Each pantograph is provided with a grounding switch (see Figs. 10, 11 and 12). An operating handle at the end of the cab controls the knife type switch and an auxiliary hook which engages the frame of the pantograph.

On the P5a and Modified P5a locomotives a baffle plate directly above the steps for ascending to the roof is attached to the operating rod. This baffle plate swings aside for ascending to the roof when the grounding switch and hook are engaged. A locking pin is provided to secure the operating handle in either position.

On the GG1 locomotives a baffle plate directly above the trap door is attached to the operating rod. This baffle plate swings aside to permit opening the trap door for ascending to the roof when the grounding switch and hook are engaged. Opening the trap door drops a latch which holds the operating rod in the engaged position. Closing the trap door lifts the latch, permitting the operating rod to be turned to the disengaged position. A locking pin is provided to secure the operating handle in either position.

Main Transformer

The main transformer on the P5a locomotives, Figs. 13 and 14, is of the air blast type with numerous taps on the secondary winding. Air for cooling enters at one end, passes through the duct spaces between the coils and out at the opposite end. The current in the primary winding induces a voltage in the secondary winding and the taps in the secondary winding supply current at various voltages. The secondary taps are connected to tap switches by long bus bars.

The main transformer on the Modified P5a locomotives, Figs. 15 and 16, is of the same general type as that used on the P5a locomotives. Tap switches are connected directly to the secondary taps and are, therefore, a part of the main transformer unit assembly.

The main transformer on the GG1 locomotives, Figs. 17 and 18, is of the oil-insulated type with numerous taps on the secondary winding. A glass gauge indicates the level of the oil in the transformer. The oil circulation is forced by a motor-driven pump. Air for cooling the oil passes around the radiating tubes at one end of the transformer. A thermostat in the transformer is connected in the circuit for the indicating lamps at the engineman's positions. The current in the primary winding induces a voltage in the secondary winding and the taps in the secondary winding supply current at various voltages. Tap switches are connected directly to the secondary taps and are, therefore, a part of the main transformer unit assembly.

SECONDARY CIRCUITS

The voltage induced in the secondary winding of the main transformer provides the source of current for the traction motors

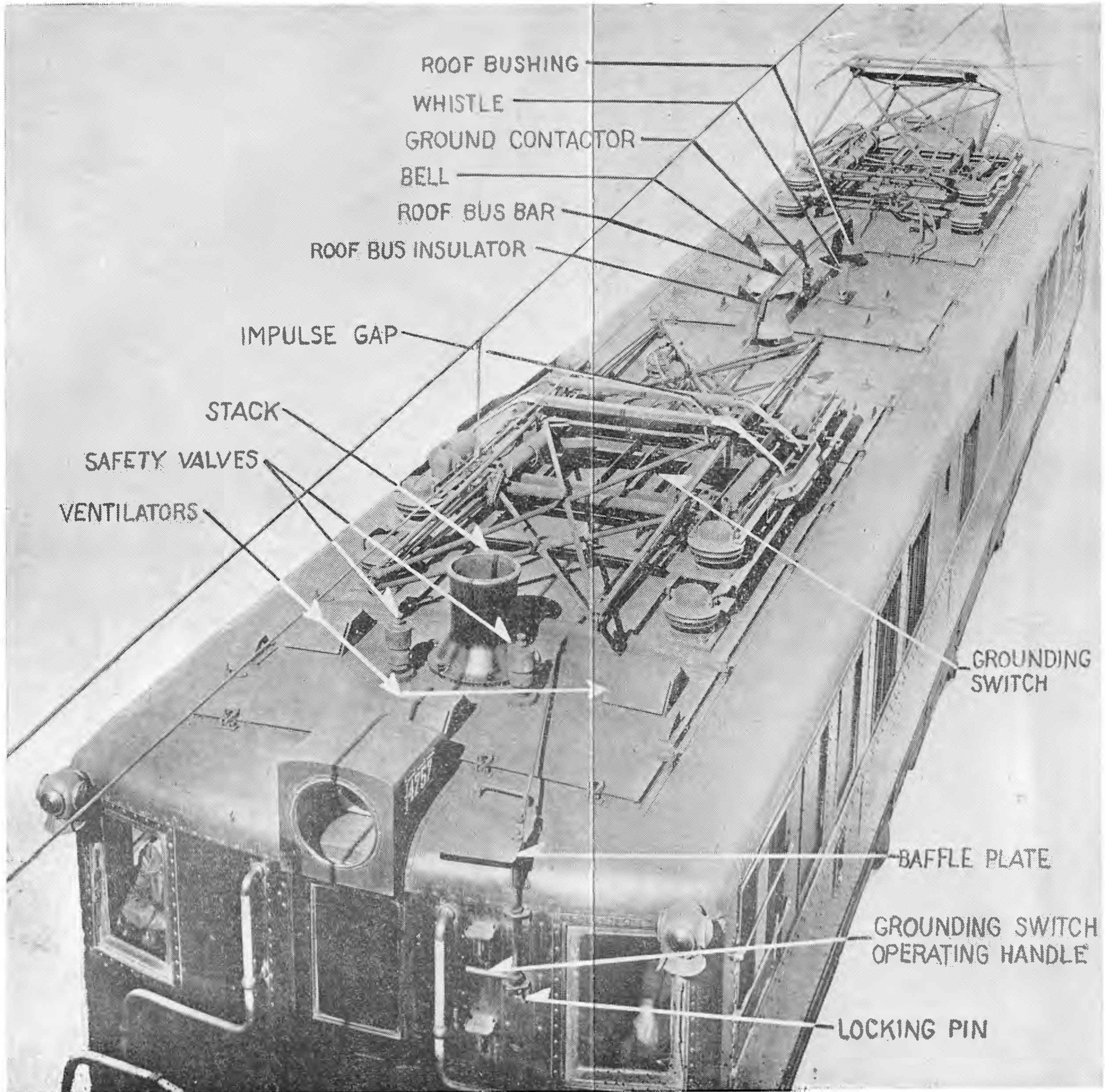


Fig. 10. Roof View—P5a Locomotives

Fig. 10. Roof View—P5a Locomotives

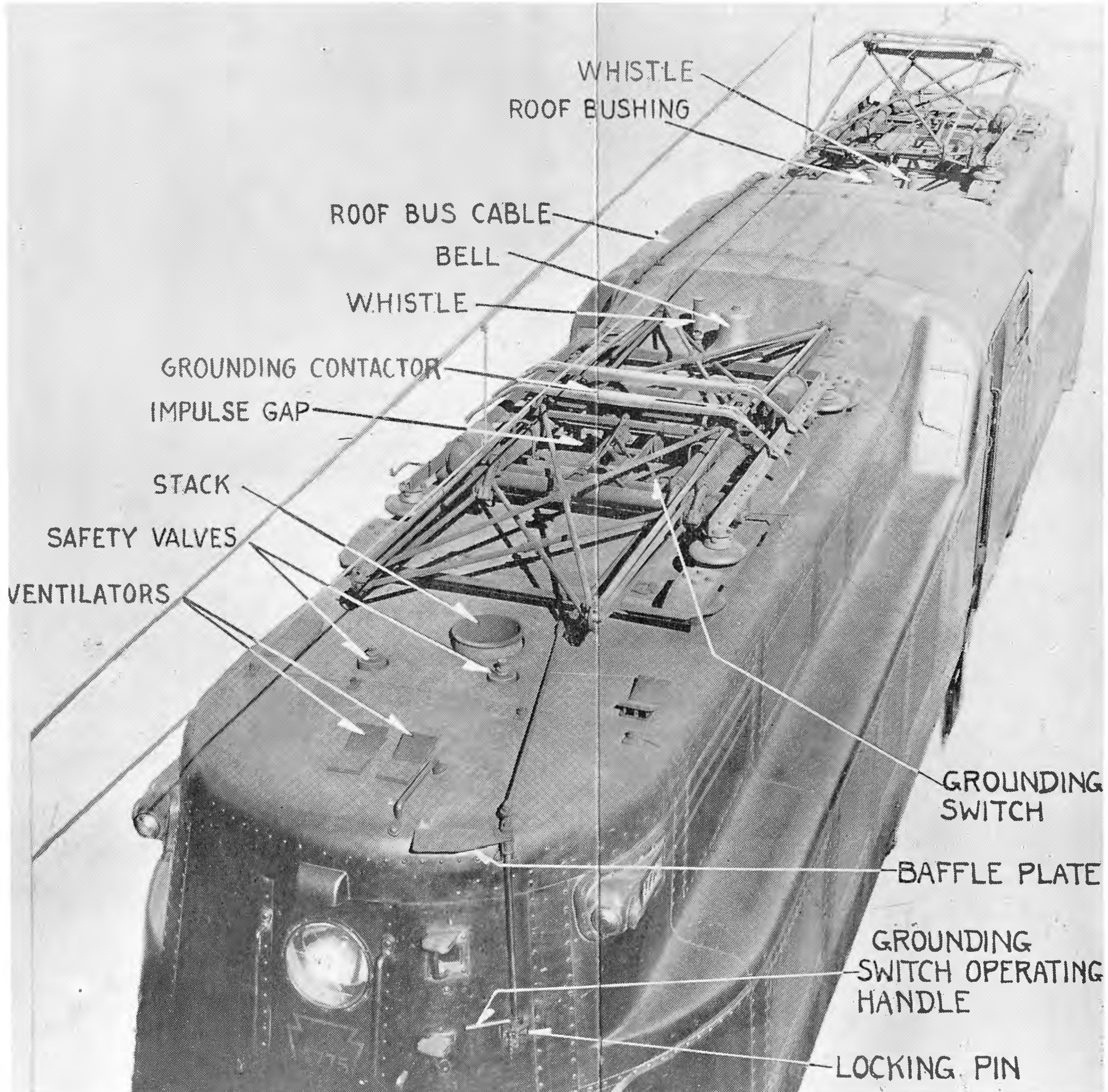


Fig. 11. Roof View—Modified P5a Locomotives

Fig. 11. Roof View—Modified P5a Locomotives

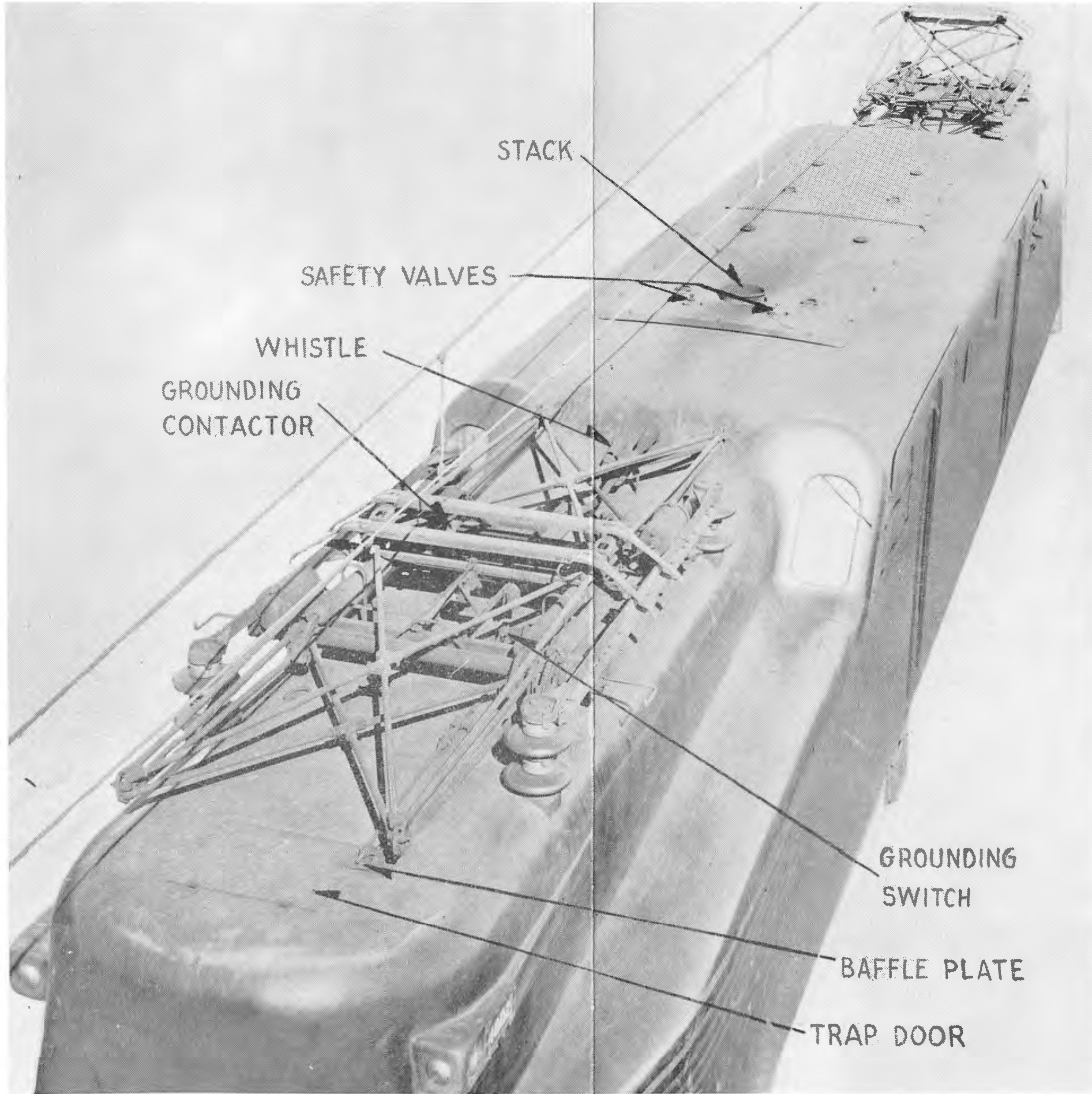


Fig. 12. Roof View—GG1 Locomotives

Fig. 12. Roof View—GG1 Locomotives

and auxiliaries. From a number of taps in the secondary winding current can be obtained at various voltages. The A tap is connected directly to the motor switches in one side of the traction motor circuits. The main transformer tap switches function to connect the other taps, through preventive coils, to the motor switches in the other side of the traction motor circuits. The purpose of the preventive coils is to avoid short-circuiting parts of the transformer winding momentarily while changing from one tap to another.

The traction motors are arranged in two series circuits of three motors each on the P5a and Modified P5a locomotives, and three series circuits of four motors each on the GG1 locomotives. The traction motor circuits are similar, and are sufficiently similar on the several classes of locomotives that a description of one motor circuit, which follows, will suffice.

Current passes through one motor switch to the reverser and main fields of the motors. For one position of the reverser the current is in a certain direction through the main fields; when the reverser is thrown to the opposite position the direction of current in the main fields is reversed and the motors will rotate in the reverse direction. The current passes through the armatures, the compensating fields and interpole fields and the other motor switch which terminates the traction motor circuit.

When the main field shunting switch is closed part of the motor current is bypassed from the main fields through the main field shunting reactor.

The interpole field shunts bypass part of the motor current from the interpole fields. These shunts, which are composed of resistors and reactors, are selective in three steps on the P5a and Modified P5a locomotives and two steps on the GG1 locomotives by the operation of the interpole field shunting switches.

A knife type blower bus cutout switch connects the proper transformer taps to the contactors in the blower motor circuits. The heater bus contactor and the air compressor motor contactor are connected directly to the proper transformer taps. On the P5a and Modified P5a locomotives a knife type switch connects a lighting transformer to the proper transformer taps.

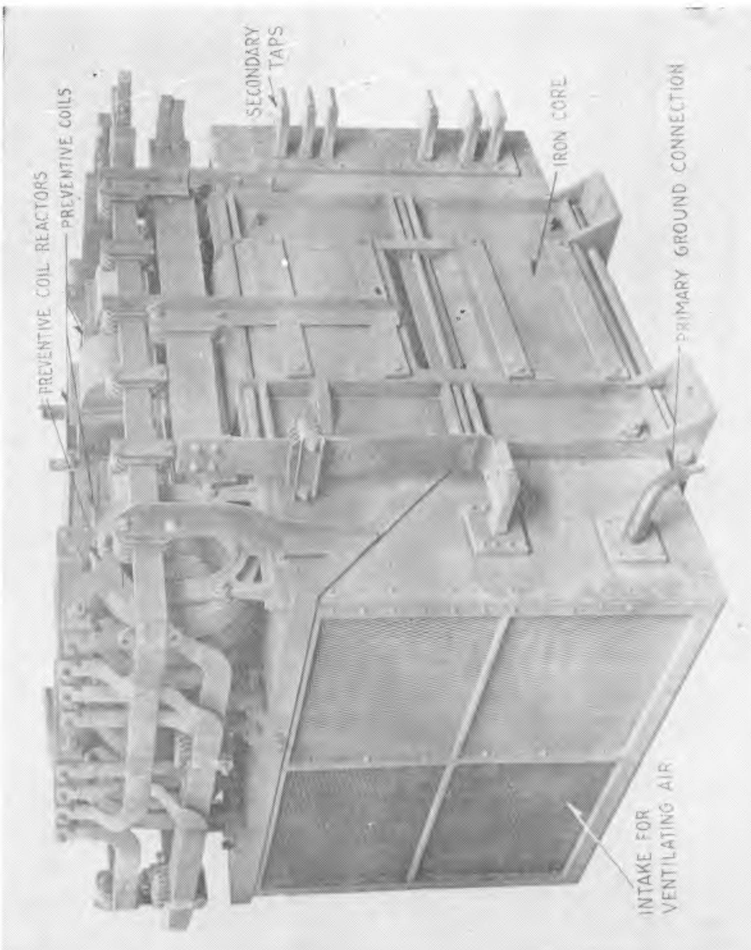


Fig. 13. Main Transformer Unit Assembly—P5a Locomotives

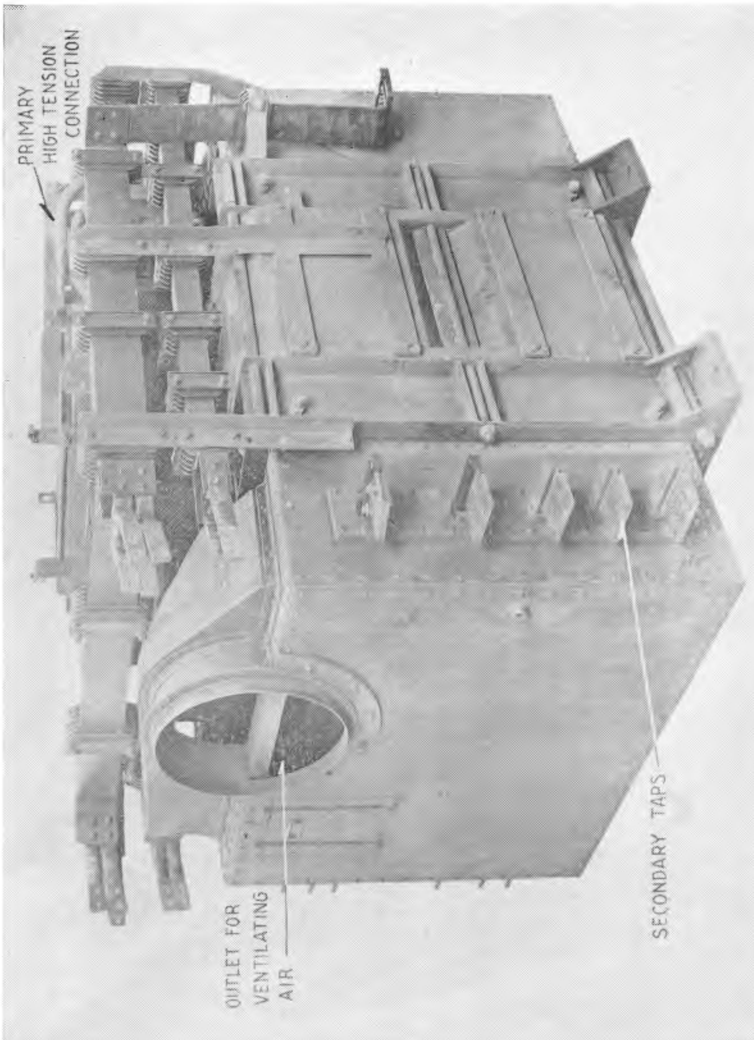


Fig. 14. Main Transformer Unit Assembly—P5a Locomotives

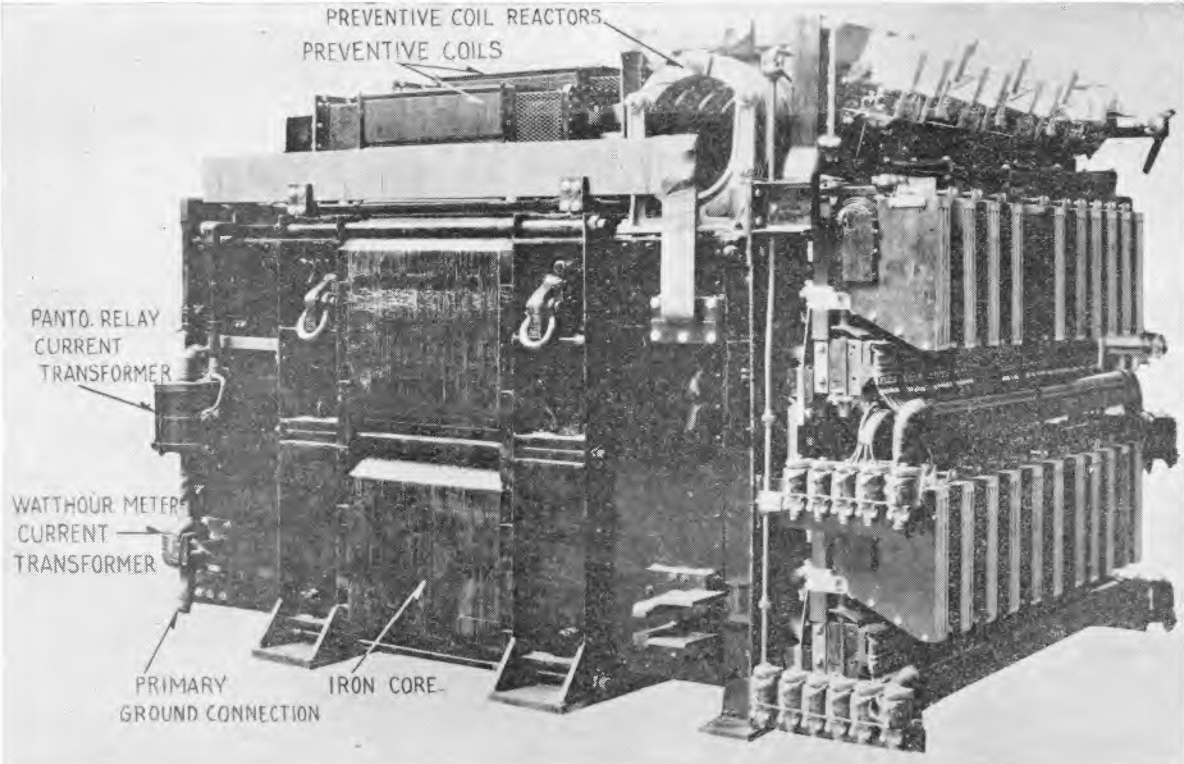


Fig. 15. Main Transformer Unit Assembly—Modified P5a Locomotives

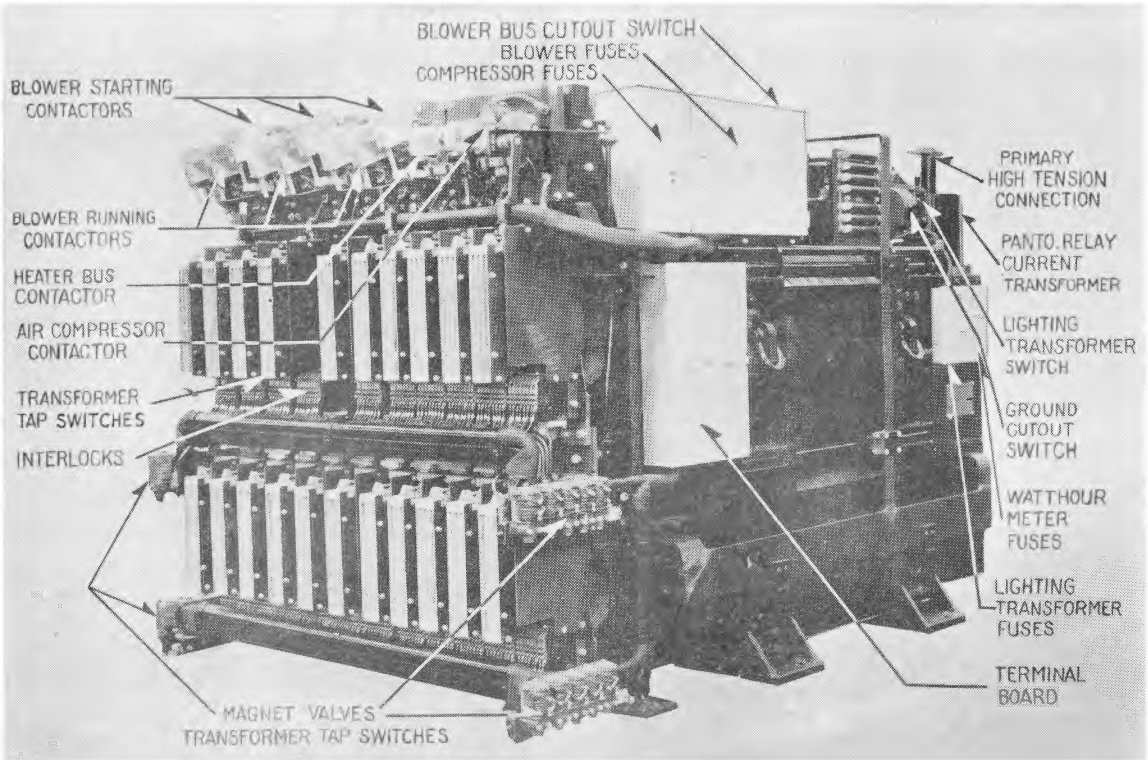


Fig. 16. Main Transformer Unit Assembly—Modified P5a Locomotives

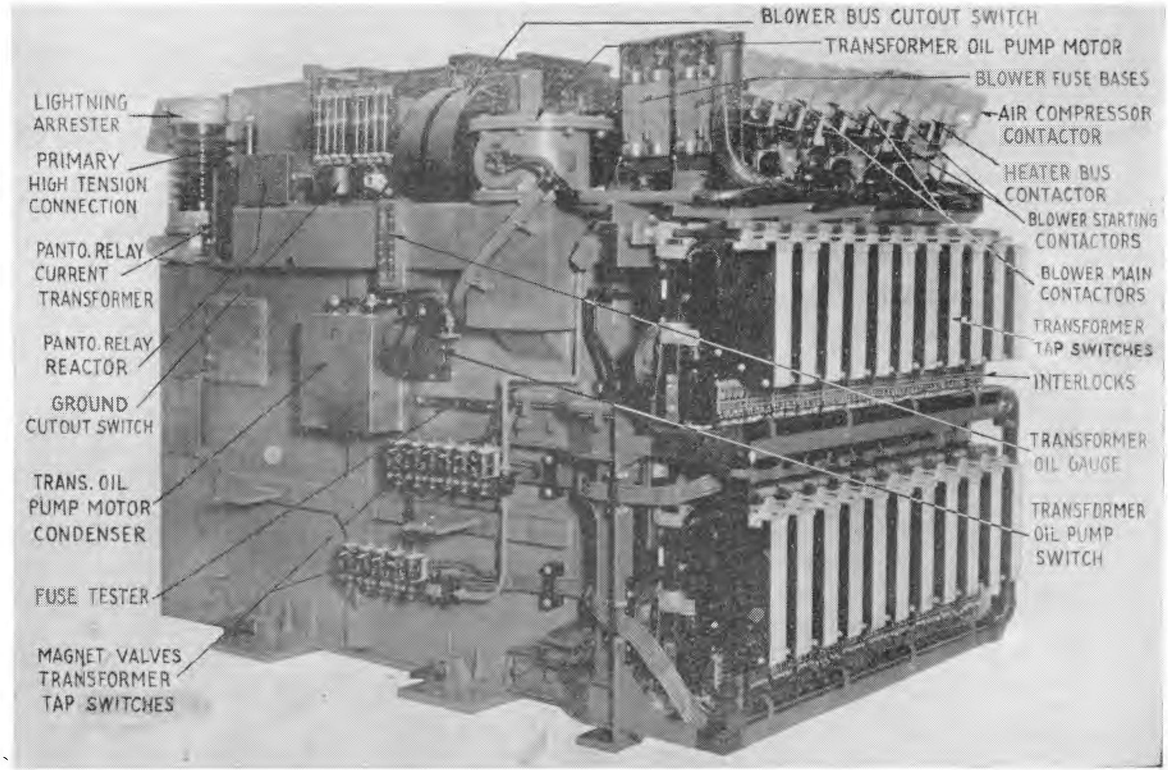


Fig. 17. Main Transformer Unit Assembly—GG1 Locomotives

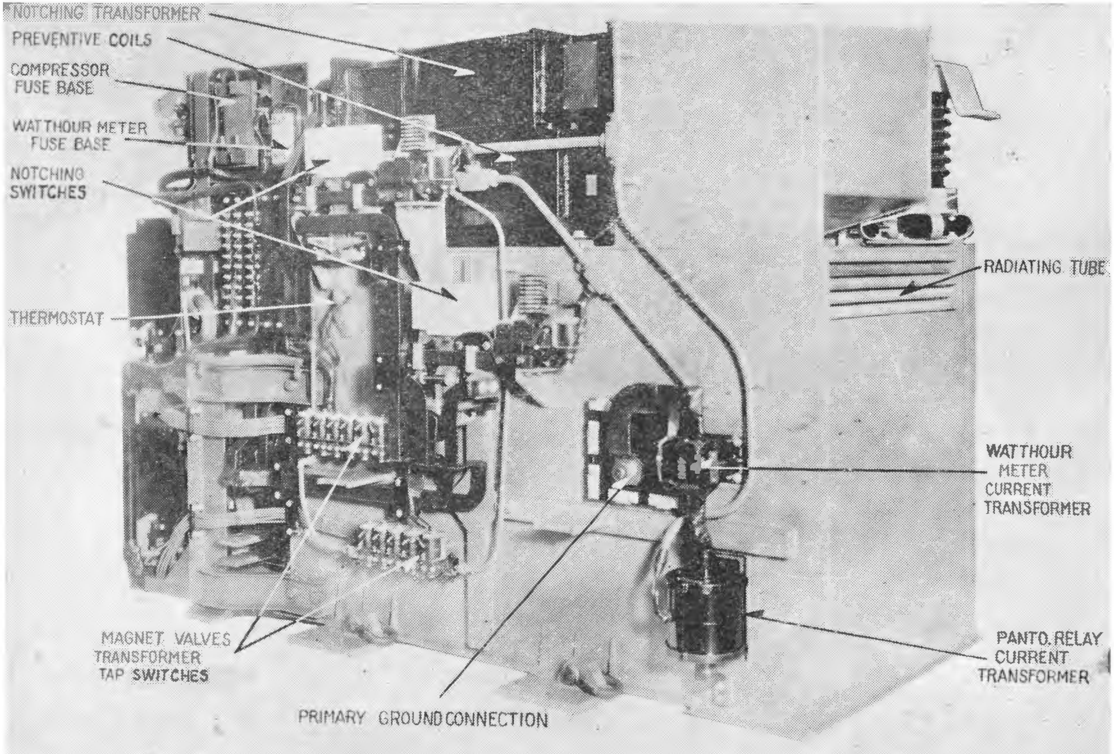


Fig. 18. Main Transformer Unit Assembly—GG1 Locomotives

Traction Motors and Control Apparatus

The principal pieces of apparatus in the traction motor and control circuits (See Plates 1, 2 and 3) are listed as follows:

(a) The main transformer tap switches are single-acting, electro-pneumatic unit switches. Numbered 1 to 21, inclusive, on the P5a and Modified P5a locomotives, and 1 to 22, inclusive, on the GG1 locomotives, they are connected to the secondary taps of the main transformer. Acceleration of the locomotive is accomplished by progressively increasing the voltage applied to the traction motors and this is done by operating the tap switches in the proper order. See Sequence Table on Plates 1, 2 and 3.

(b) The preventive coil reactors (P5a and Modified P5a locomotives) are coils of copper strap without an iron magnetic structure. Connected between the tap switches and the small preventive coils, they serve to reduce current surges when the tap switches operate.

(c) The preventive coils are three in number, two small ones and one large. These are reactors with iron magnetic structures. The winding is tapped at the mid-point. Air for cooling the reactor is passed through duct spaces.

(d) The notching transformer (GG1 locomotives) is of the two-winding (primary and secondary), air-blast type with an iron magnetic structure. Air for cooling the transformer is passed through duct spaces.

Current for the primary winding is taken through the notching switches, numbered 23 and 24, from the secondary taps of the main transformer. By proper operation of the notching switches the secondary winding produces the following:

(1) An induced voltage bucking the motor circuit voltage;
(2) No induced voltage;
(3) An induced voltage boosting the motor circuit voltage.

A resistor connected between the primary leads of the notching transformer serves to limit the surge voltages induced when the notching switches operate.

(e) The notching switches (GG1 locomotives) are double-acting, electro-pneumatic unit switches equipped with arc box but no blowout coil nor magnetic pole pieces.

By the action of the notching transformer and the notching switches, three steps in the progressive increase of motor circuit voltage is obtained for each step provided by the main transformer tap switches. Thus, the increasing voltage required for acceleration of the traction motors can be obtained in smaller steps than provided by the tap switches alone.

(f) The motor switches are single-acting, electro-pneumatic unit switches. Numbered M1-M3 and M2-M4 on the P5a and Modified P5a locomotives, and M1-M4, M2-M5 and M3-M6 on the GG1 locomotives, two of these switches are connected in each traction motor circuit. Besides normal operations, these switches function with various relays to open under condition of wheels slipping, motors overloaded, short-circuits, arc-over to ground, etc.

(g) The traction motors, numbered 1 to 6, inclusive, on the P5a and Modified P5a locomotives, and 1 to 12, inclusive, on the GG1 locomotives, supply all the tractive force of the locomotive.

(h) The main field shunting switches are single-acting, electro-pneumatic unit switches. Numbered FS1 and FS2 on the P5a and Modified P5a locomotives, and FS1, FS2 and FS3 on the GG1 locomotives, each is connected to a main field shunting reactor.

(i) The main field shunting reactors, numbered 1 and 2 on the P5a and Modified P5a locomotives, and 1, 2 and 3 on the GG1 locomotives, have iron magnetic structures. Cooling air is passed through duct spaces in the reactors on P5a and Modified P5a locomotives and is passed around the reactors on GG1 locomotives.

A reduced transforming effect in commutated coils of the traction motors is desirable when they are at standstill or turning slowly. To accomplish this, current is by-passed from the main fields through the main field shunting reactors.

(j) The interpole field shunting switches are double-acting, electro-pneumatic unit switches. Numbered 25 to 32, inclusive, on the P5a and Modified P5a locomotives, and 25, 26 and 27 on the GG1 locomotives, they are connected in the interpole field shunt circuits.

(k) The interpole field shunts consist of reactors and resistors. The reactors on the P5a and Modified P5a locomotives are coils of copper strap without iron magnetic structures. The reactors on the GG1 locomotives have iron magnetic structures. The resistors are of the cast grid type.

These shunts, whch are variable in three steps on the P5a and Modified P5a locomotives, and in two steps on the GG1 locomotives, by the operation of the interpole field shunting switches, by-pass current from the interpole fields to obtain interpole field strength approximately correct for all speeds and motor currents.

(1) The reversers numbered 1 and 2 on the P5a and Modified P5a locomotives, and 1, 2 and 3 on the GG1 locomotives, set up the main field connections of the traction motors for forward or reverse direction of movement.

Unit Switches

(General)

Electro-pneumatic unit switches play an important part in the control of the traction motors. The single-acting type, Fig. 19, consists of two insulated side members carrying a stationary contact at one end, a movable contact pivoted to the side members, and an air-operated cylinder at the other end. The movable contact has an insulated connection to the piston of the cylinder. The piston assembly carries an interlock block while the interlock fingers are mounted on an insulating block adjacent to the moving block.

The contacts are surrounded by an arc box of incombustible material. Magnetic pole pieces on each side are magnetized by the current through a blowout coil that is mounted on the stationary contact.

When the magnet valve is energized, air is admitted to the cylinder and the piston responds to close and hold the switch in

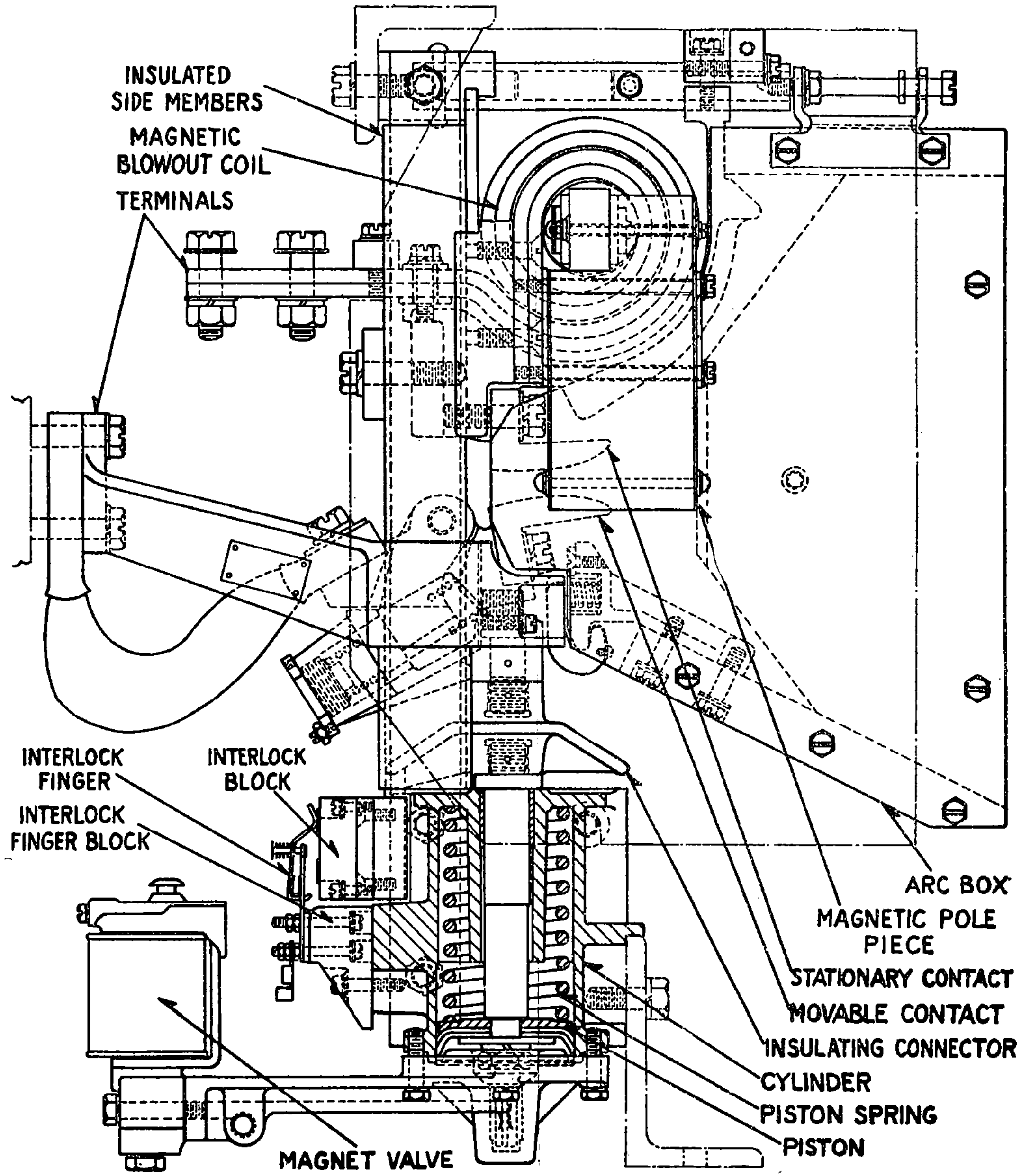


Fig. 19. Sectional Assembly View of Electro-Pneumatic Contactor, Single Acting Type
(Typical)

Fig. 19. Sectional Assembly View of Electro-Pneumatic Contactor, Single Acting Type
(Typical)

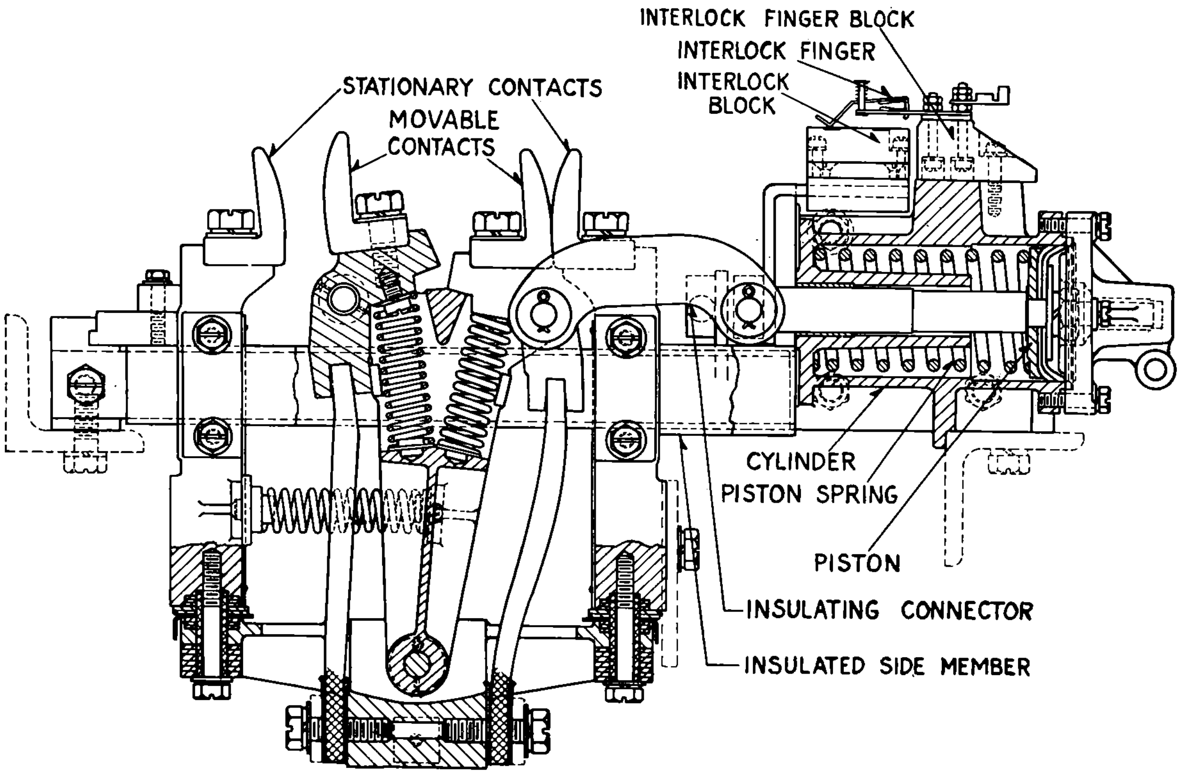


Fig. 20. Sectional Assembly View of Electro-Pneumatic Contactor, Double Acting Type
(Typical)

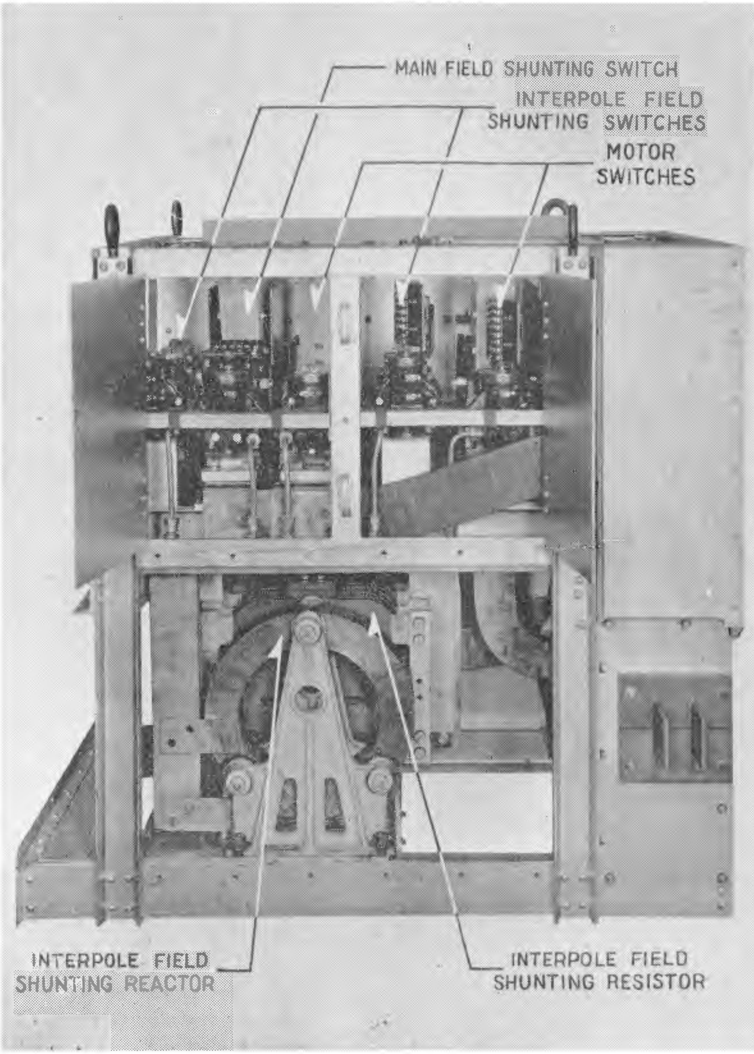


Fig. 21. Traction Motor Control Group—Modified P5a Locomotives

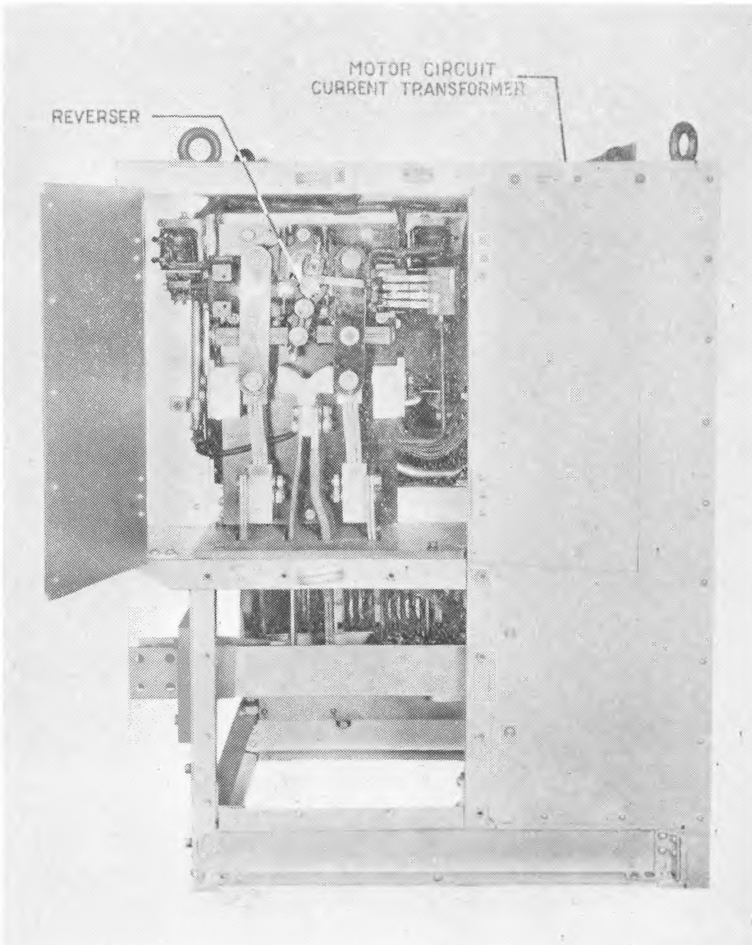


Fig. 22. Traction Motor Control Group—Modified P5a Locomotives

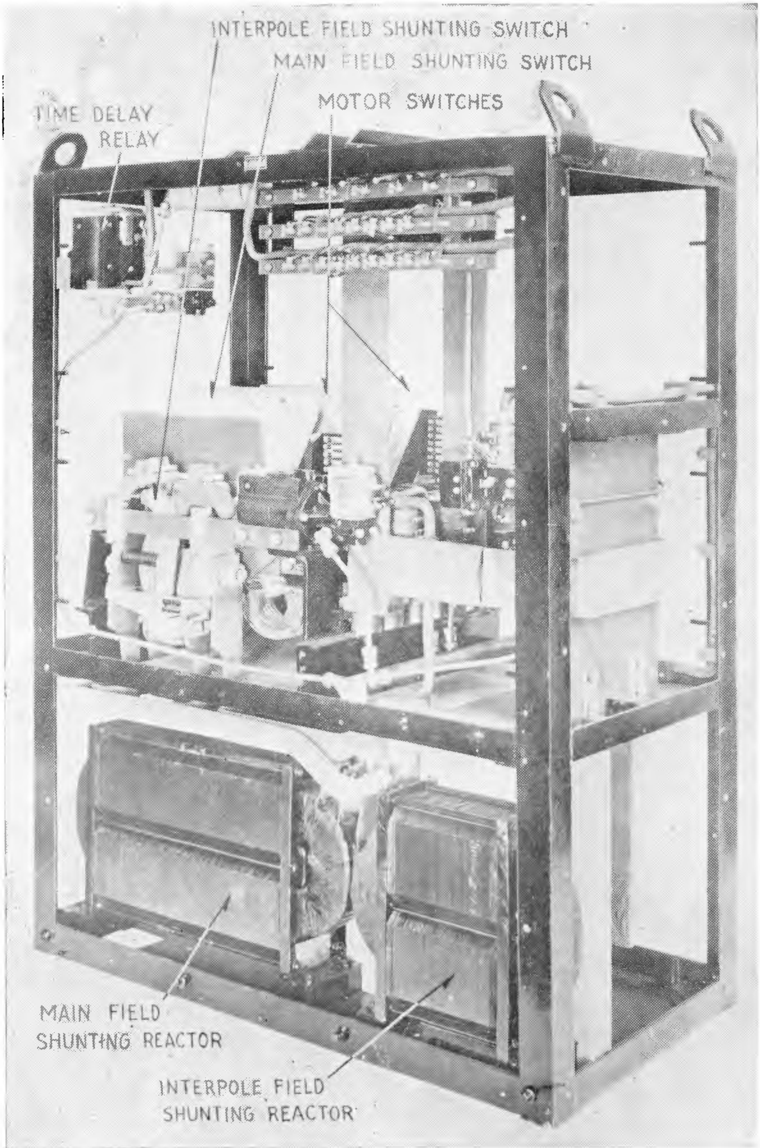


Fig. 23. Traction Motor Control Group—GG1 Locomotives

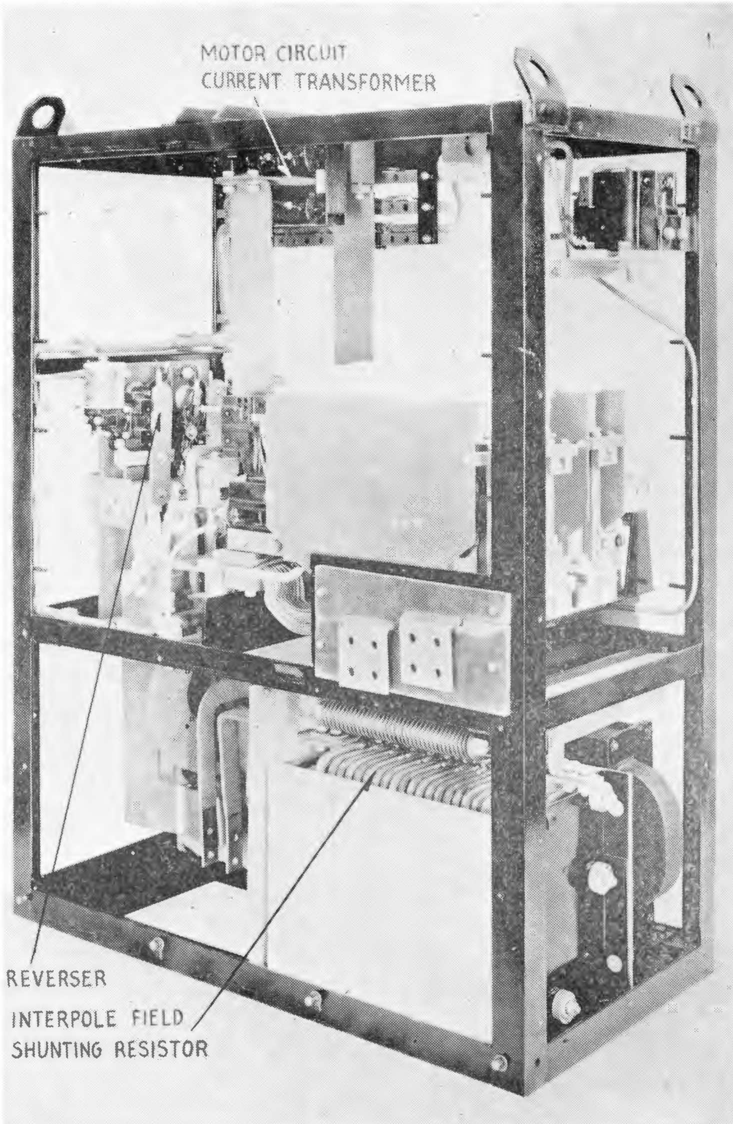


Fig. 24. Traction Motor Control Group—GG1 Locomotives

closed position. When the magnet valve is de-energized the air supply is cut off from the cylinder, the cylinder air exhausts to atmosphere, and the switch opens under the action of the piston spring.

When a switch, in opening, breaks current, the magnetic field of the arc box pole pieces draws out the arc and breaks it.

The double-acting type, Fig. 20, consists of two insulated side members carrying two stationary contacts with movable contacts operating between the stationary contacts, and an air-operated cylinder at one end. The movable contacts have an insulated connection to the piston of the cylinder. The piston assembly carries an interlock block while the interlock fingers are mounted on an insulating block adjacent to the moving block.

When the magnet valve connected to the cylinder is energized, air is admitted to the cylinder and the piston responds to open the nearer contacts and close the farther contacts. When the magnet valve is de-energized the air supply is cut off from the cylinder, the cylinder air exhausts to atmosphere, resulting in the farther contacts opening and the nearer contacts closing under the action of the piston spring.

Traction Motors

The traction motors, Figs. 5 and 7, are of the commutator type, series connected. The rotating part is the armature, which includes a commutator; the stationary part is the stator. Stationary carbon brushes bearing upon the commutator are in position to carry current to the armature winding. The stator includes the main field, compensating field and interpole field windings.

A rolled steel built-up frame carries each pair of motors. End bells support the armature shaft roller bearings. Each armature shaft has a pinion on one end meshing with the gear. The gear is mounted on a quill which rotates in bearings supported in the lower part of the motor frame. A gear case surrounds the gear and pinions to keep out dirt and to contain the lubricant.

Air for cooling enters the twin-motor frame through the duct connections at the top. Inside ducts distribute the air to the stator and armature structures, after which it discharges through openings in the end bells or through openings in the lower half of the motor frame.

The twin-motor frames have three-point suspension in the bed frame of the P5a and Modified P5a locomotives, and in the motor truck frames of the GG1 locomotives.

The interaction of the main field with the current passing through the armature conductors, produces the torque which causes the armature to rotate.

The current in the armature coils sets up a magnetic field which, if no provision were made to neutralize it, would distort the main field. The compensating field winding was provided to neutralize the magnetic field produced by current in the armature coils.

When an armature coil is undergoing commutation it is short-circuited by the brushes. Due to the ordinary voltage induced in the coil the current at short-circuit would be relatively high. In addition to this, there is a transforming effect in which the field coils act as the primary winding and the armature coil undergoing commutation acts as a short-circuited secondary winding. Thus, the ordinary induced voltage and the voltage induced by the transformer action would combine to produce exceedingly high commutating currents if no provision were made to neutralize the commutating voltages. The interpole field winding was provided to neutralize partially the magnetic field acting upon the armature coils undergoing commutation, thus reducing the commutating voltage and current. A minimum amount of sparking and burning at the brushes is good commutation.

Reversers

The reversers on the P5a locomotives, Fig. 25, are of a type built upon two end frames fastened together by two insulating rods. One rod carries four stationary contacts and the other rod carries the four arms mounting the movable contacts. A shaft, which is rotated by an air engine mounted on the outside of one end frame, carries four cams which force the movable contacts against the stationary contacts. Outside the other end frame and mounted on the shaft is an interlock drum. A handle

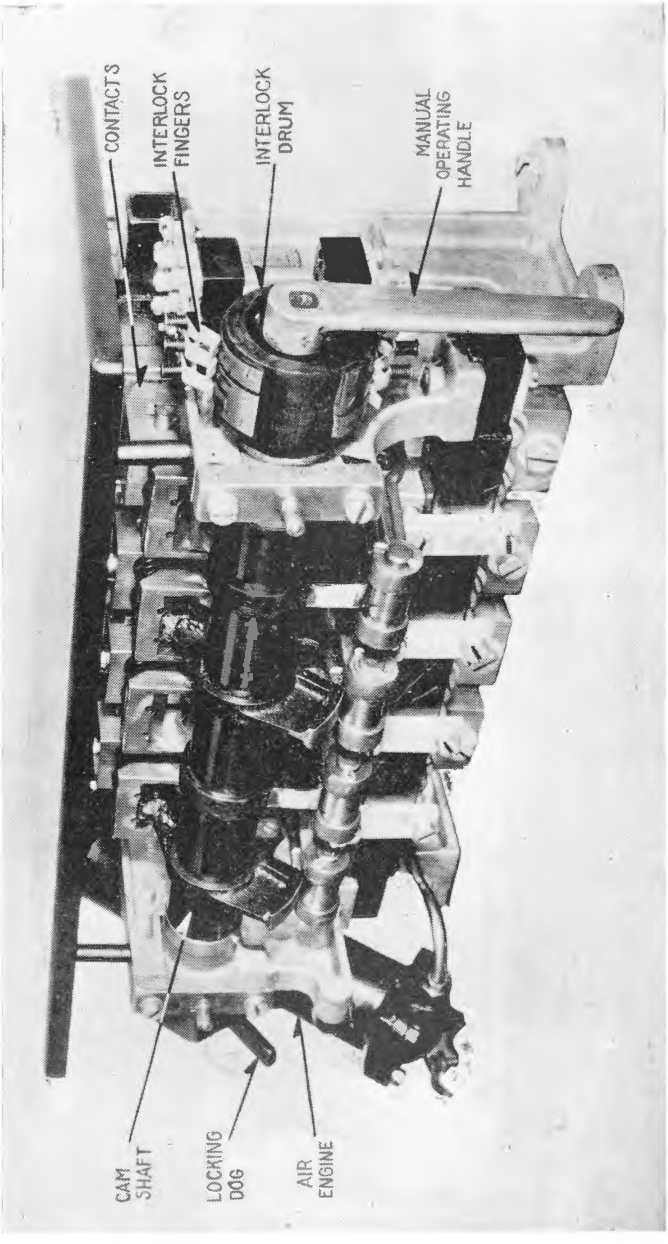


Fig. 25. Reverser—P5a Locomotives

attached to this end of the shaft provides for manual operation of the reverser.

There are three positions of the shaft. In one extreme position the first and third contacts are closed, and in the other extreme position the second and fourth contacts are closed. In the mid position, all contacts are open. The mid position can only be obtained when operating the reverser by hand. When in the mid position a small dog may be dropped in its slot for locking the reverser here. The dog must be disengaged by hand before

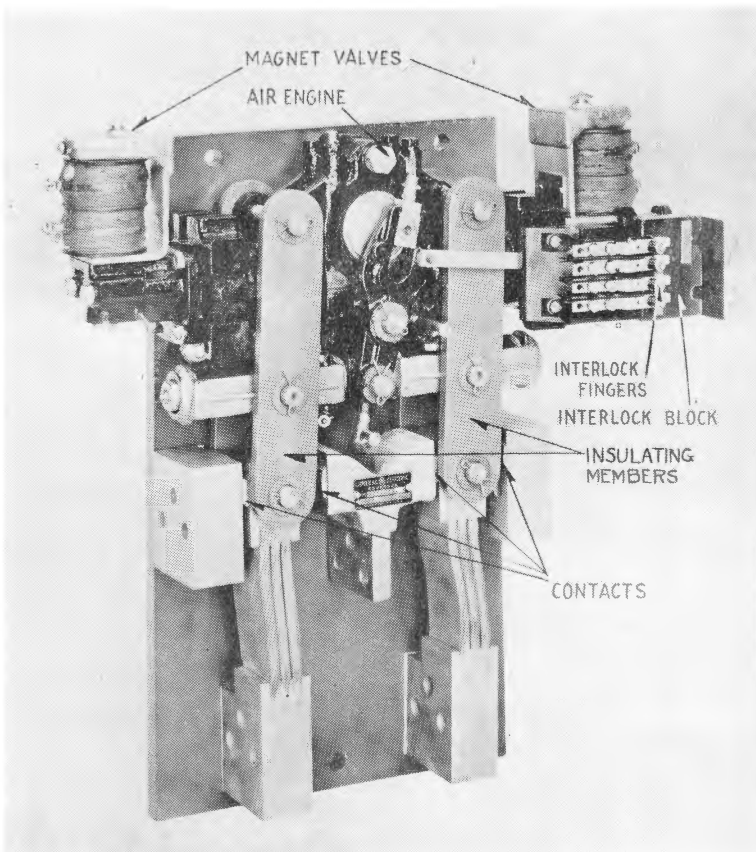


Fig. 26. Reverser—Modified P5a and GG1 Locomotives

the reverser can be operated by air. The contacts are not equipped with arc boxes or blowout coils as they are not intended to open or close with current flowing.

The air engine is built with two opposed cylinders and one piston rod with a piston on each end. A rack on the piston rod meshes with a gear sector fastened to the cam shaft. When one or the other magnet valves is energized air is admitted to the corresponding cylinder.

The one extreme position of the reverser makes up contacts for forward movement of the locomotive. The other extreme position of the reverser makes up contacts for reverse movement of the locomotive. The reversed rotation is obtained by changing the direction of current in the main field of the motors.

The reversers on the Modified P5a and GG1 locomotives, Fig. 26, are of a type built in panel assembly. The stationary contacts are mounted rigidly on the panel. The movable contacts are swung on insulating members which are pivoted to the air engine assembly. Operating levers, which are rotated by the air engine, force the movable contacts against the stationary contacts. A smaller lever operates the interlock block.

There are two positions of the reverser. The contacts are not equipped with arc boxes or blowout coils as they are not intended to open or close with current flowing.

The air engine is built with two opposed cylinders and one piston rod with a piston on each end. A rack on the piston rod meshes with a gear to which the operating levers are connected. When one or the other magnet valves is energized air is admitted to the corresponding cylinder.

The one extreme position of the reverser makes up contacts for forward movement of the locomotive. The other extreme position of the reverser makes up contacts for reverse movement of the locomotive. The reversed rotation is obtained by changing the direction of current in the main fields of the motors.

Auxiliaries and Control Apparatus

The principal pieces of apparatus in the auxiliary circuits (see Plates 4, 5 and 6) are listed as follows:

(Blower Circuits)

(1a) The blower bus cutout switch is a double-pole, single-throw, knife switch with quick-break attachments. It is equipped also with a pair of interlock fingers bearing on a plate fastened to the cross-bar. In the closed position of the switch the interlock circuit is closed. As the switch is opened the interlock circuit is broken first, which drops out the blower contactors (and the heater bus contactor on the P5a and Modified P5a locomotives), thus preventing the breaking of current on the main contacts of the switch.

(1b) The blower running contactors (P5a and Modified P5a locomotives) are magnetic contactors. Although they are double-pole type, both sets of contacts have been connected in one leg of the motor circuit. The operating coil takes alternating current.

The running contactor is connected in the circuit of the running winding of the motor.

(1c) The blower main contactors (GG1 locomotives) are double-pole, electro-pneumatic contactors.

The main contactor is connected in the circuit which feeds both the running winding and starting winding of the motor.

(1d) The blower starting contactors are single-pole, magnetic contactors. The operating coil takes alternating current.

The starting contactor is connected in the circuit of the starting winding of the motor.

(1e) The blower starting resistors have a ribbon element wound edgewise on porcelain spools.

The resistor, as connected in the circuit of the starting winding of the motor, is required for producing starting torque.

(1f) The blower motors, namely, the transformer, No. 1, No. 2 and No. 3 on P5a locomotives; the transformer, No. 1 and No. 2 on Modified P5a locomotives; the No. 1 and No. 2 on GG1 locomotives, drive fans mounted directly on the motor shaft. The transformer blower motor on P5a and Modified P5a locomotives, and the No. 2 blower motor on GG1 locomotives also drive an overhung generator.

(1g) The blower air relays (P5a and Modified P5a locomotives) function with the operation of the blower motors.

(1h) The blower centrifugal relays (GG1 locomotives) function with the operation of the blower motors.

(1i) The blower control switches are double-pole, single-throw tumbler switches.

(Battery and Generator Circuits)

(2a) The battery switch is a double-pole, single-throw knife switch.

(2b) A 16-cell lead-acid storage battery supplies direct current at about 32 volts for the master control system, and thence to the cab signal, direct current lighting, and boiler control systems.

(2c) The battery charging resistor (P5a and Modified P5a locomotives) has a ribbon element wound edge-wise on porcelain spools.

This resistor, connected in the battery charging circuit, can be adjusted to limit the charging current when necessary for a discharged battery.

(2d) The generator switch is a double-pole, single-throw knife switch.

(2e) The generator on the shaft of one of the blower motors supplies direct current to supplement the battery source, and also to maintain the charge of the battery.

(2f) The a. c. charging relay is a clapper type relay similar to the clapper type magnetic contactors. There are two sets of contacts which close in the energized position of the relay. The operating coil takes alternating current from the blower-generator motor circuit.

One set of contacts closes the control circuit for the d. c. charging relay and the other set closes the generator field circuit.

(2g) The d. c. charging relay is quite like the a. c. charging relay. The operating coil, however, takes direct current from the generator.

The two sets of contacts, connected in series, close the control circuit for the generator contactor.

(2h) The generator contactor is a single-pole, magnetic contactor. The operating coil takes alternating current from the blower-generator motor circuit.

The generator contactor is connected in the circuit through which the generator feeds the master control system and battery.

(2i) The generator regulator functions, by regulating the field strength, to maintain a uniform voltage on the generator.

(Heater, Boiler Blower, Transformer Oil Pump (GG1), and Air Compressor Circuits)

(3a) The heater bus contactor is a double-pole contactor of the magnetic type on the P5a and Modified P5a locomotives, and of the electro-pneumatic type on the GG1 locomotives.

The heater bus contactor is connected in the circuit to the cab heaters and boiler blower motor, also (on the GG1 locomotives) the transformer oil pump motor.

(3b) The heater switches are double-pole, rotary type snap switches with two "OFF" and two "ON" positions.

Each switch is connected to half of the heating elements of all heaters in the compartment.

(3c) Each heater has its elements arranged in two circuits so that one-half or full heating capacity can be utilized as desired.

(3d) The boiler blower switch is a double-pole, single-throw knife switch connected to the boiler blower motor.

(3e) The boiler blower starting contactor is a single-pole, magnetic contactor. The operating coil takes alternating current.

The starting contactor is connected in the circuit of the starting winding of the motor.

(3f) The boiler blower starting resistor has a ribbon element wound edge-wise on porcelain spools.

The resistor, as connected in the circuit of the starting winding of the motor, is required for producing starting torque.

(3g) The boiler blower motor is of the induction type with squirrel-cage rotor. It drives a fan mounted directly on the motor shaft.

(3h) The boiler blower air relay functions with the operation of the boiler blower motor.

(3i) The transformer oil pump switch (GG1 locomotives) is a double-pole, single-throw knife switch.

(3j) The transformer oil pump motor (GG1 locomotives) drives a centrifugal pump, mounted vertically in the main transformer. The motor is of the induction type with squirrel-cage rotor. A static condenser, connected in one leg of the motor winding, is necessary to produce starting torque.

(3k) The air compressor contactor is a double-pole, electro-pneumatic contactor of inverted type. The cylinder is arranged so that the piston spring holds the contactor closed when the cylinder is not charged with air and that the piston opens the contactor when the cylinder is charged with air. A handle assembly with shaft connected to the mechanism provides for manual operation.

(3l) The air compressor motor, Fig. 59, is of the commutator type, series connected, with main and interpole fields. An interpole field shunting resistor by-passes part of the motor current around the interpole field to obtain good commutation of the motor. An extension of the armature shaft provides for the worm drive of the air compressor. The motor is self-cooled.

(3m) The air compressor governor is an air-operated electric switch designed to open and close at predetermined pressures.

(3n) The governor cutout switch is a single throw tumbler switch.

(*Lighting Circuits*)

(4a) The lighting transformer switch (P5a and Modified P5a locomotives) is a double-pole, single-throw, knife switch.

(4b) The lighting transformer (P5a and Modified P5a locomotives) is a two-winding, dry type, transformer. The primary winding is supplied with current from the secondary taps of the main transformer. The secondary winding supplies current at 32 volts for the lighting system.

(4c) The lighting changeover contactor (P5a and Modified P5a locomotives), Fig. 29 is a magnetic contactor of double-pole, double-throw type. The operating coil takes alternating current from the lighting transformer. An interlock on this contactor carries an indicating lamp circuit. The interlock is closed when the contactor is de-energized.

This contactor, when energized, connects the lighting circuits to the lighting transformer supply of alternating current; when de-energized it connects the lighting circuits to the direct current supply system.

(4d) Lights are arranged in a number of separate circuits with protecting fuses and switches. On the P5a and Modified P5a locomotives these circuits are fed either with alternating current or direct current at 32 volts. On the GG1 locomotives the lighting circuits are fed only with direct current at 32 volts.

Contactors

(General)

Clapper type contactors play an important part in the control of the auxiliary apparatus. On the magnetic contactors, Figs. 27, 28 and 29, the clapper forms a part of the magnetic structure and the operating coil is on one leg of the magnetic structure. Energizing the coil closes the contactor; de-energizing the coil allows the contactor to drop open. On some contactors the contacts are surrounded by an arc chute equipped with a blow-out coil.

The electro-pneumatic contactors, Figs. 30 and 31, are quite similar to the magnetic contactors except that the magnetic structure and operating coil are supplanted by a magnet valve, and operating cylinder with piston spring inside. Except on the air compressor contactor, energizing the magnet valve admits air to the operating cylinder to close the contactor against the restraint of the piston spring; the piston spring opens the contactor when the magnet valve is de-energized. On the air com-

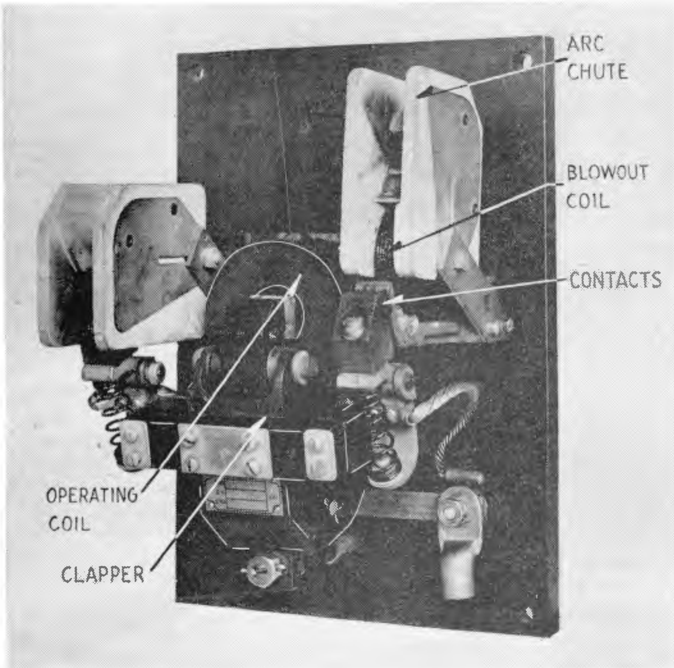


Fig. 27. Magnetic Contactor, Double Pole Type
(Typical)

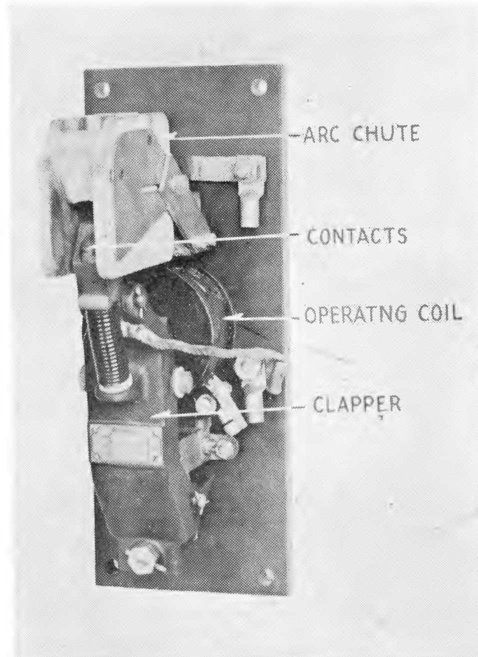


Fig. 28. Magnetic Contactor, Single Pole Type
(Typical)

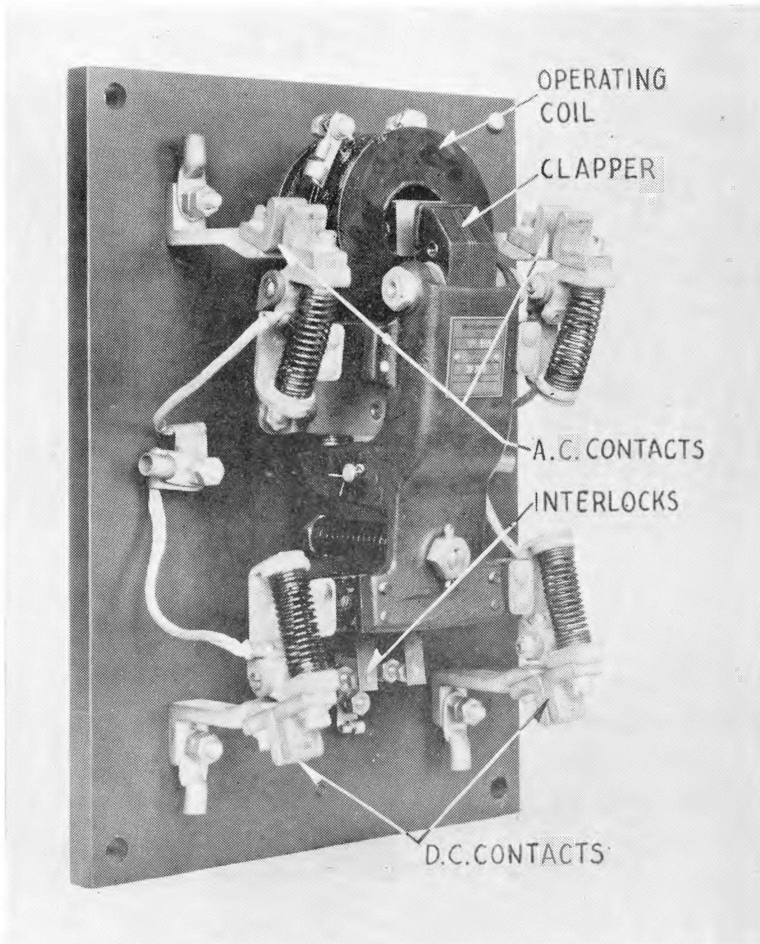


Fig. 29. Magnetic Contactor, Double-Pole, Double-Throw Type
(Lighting Changeover Contactor on P5a and Modified P5a Locomotives)

pressor contactor, energizing the magnet valve admits air to the cylinder to open the contactor against the restraint of the piston spring; the piston spring closes the contactor when the magnet valve is de-energized. The contacts are surrounded by an arc chute equipped with a blowout coil.

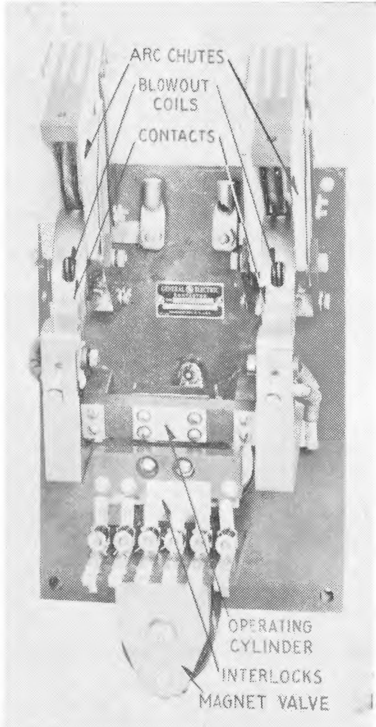


Fig. 30. Electro-Pneumatic Contactor, Plain Type
(Typical)

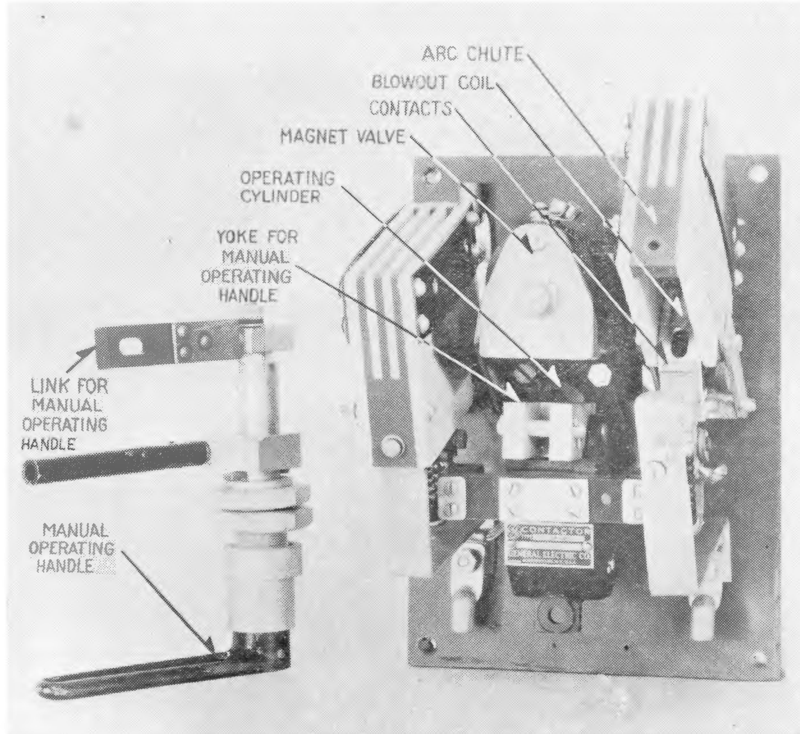


Fig. 31. Electro-Pneumatic Contactor, Inverted Type
(Typical for Air Compressor)

Blower Motors

The blower motors, Figs. 32 and 33, are of the induction type with squirrel-cage rotor. The rotor is the rotating part; the stationary part is the stator. The rotor conductors are short-circuited at both ends by conducting rings. The stator includes the running field and starting field windings.

A steel frame encloses each motor. End bells support the rotor shaft ball bearings. An extension of the shaft provides a mounting for the fan runner. On the blower-generator units, an extension of the shaft at the other end provides a mounting for the armature of the overhung generator. These motors are self-cooled by air-circulating vanes which are a part of the rotor assembly.

Current in the stator windings of these motors induces a voltage in the short-circuited rotor bars. Currents in the rotor bars and stator windings establish the reactionary magnetic fields necessary to produce rotation. The running field winding will sustain rotation after the motor has come up to, or nearly reached, running speed; but it will not by itself start the motor. The starting field along with the running field is energized during the period of starting and approaching running speed; then the starting field is de-energized by the opening of the starting contactor.

Blowers

On the P5a locomotives the transformer blower ventilates the main transformer and preventive coils. The No. 1 blower ventilates traction motors No. 1 and No. 2, the interpole field shunt of these motors and the No. 1 main field shunting reactor. The No. 2 blower ventilates traction motors No. 3 and No. 4 and the interpole field shunts of these motors. The No. 3 blower ventilates traction motors No. 5 and No. 6, the interpole field shunt of these motors and the No. 2 main field shunting reactor.

On the Modified P5a locomotives the transformer blower ventilates the main transformer and preventive coils. The No. 1 blower ventilates traction motors Nos. 1, 2 and 3, the interpole field shunts of these motors, and the No. 1 main field shunting reactor. The No. 2 blower ventilates traction motors Nos. 4,

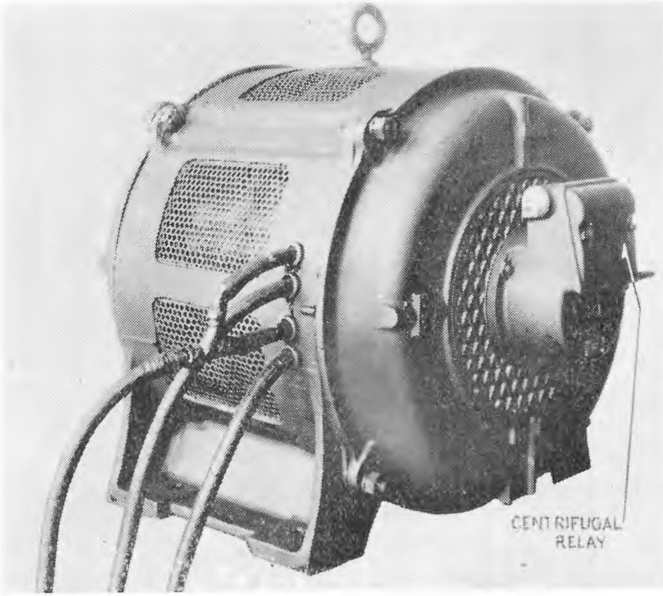


Fig. 32. Blower Motor
(Typical)

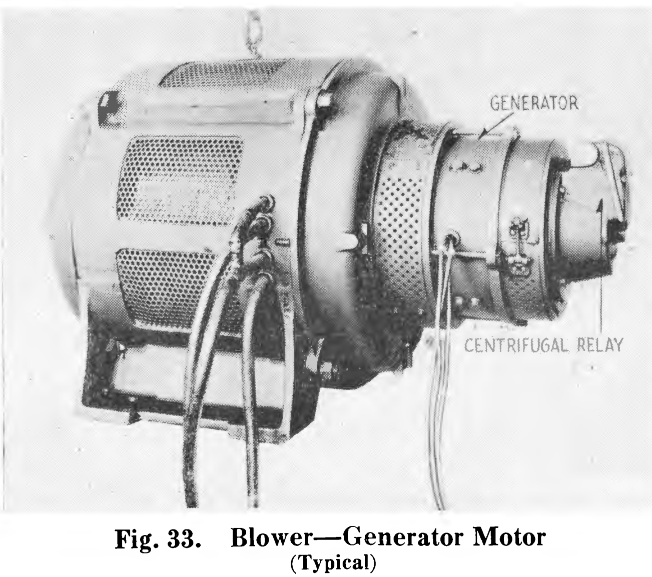


Fig. 33. Blower—Generator Motor
(Typical)

5 and 6, the interpole field shunts of these motors, and the No. 2 main field shunting reactor.

On the GG1 locomotives the No. 1 blower ventilates traction motors Nos. 1, 2, 3, 4, 5 and 6, the interpole field shunt of motors Nos. 1, 2, 3 and 4, and the No. 1 main field shunting reactor. The No. 1 blower delivers also one-half of the ventilating air for the following apparatus: the interpole field shunt of traction motors Nos. 5, 6, 7 and 8; the No. 2 main field shunting reactor, the main transformer, preventive coils and notching transformer.

The No. 2 blower ventilates traction motors Nos. 7, 8, 9, 10, 11 and 12, the interpole field shunt of motors Nos. 9, 10, 11 and 12, and the No. 3 main field shunting reactor. The No. 2 blower delivers also one-half of the ventilating air for the following apparatus: the interpole field shunt of traction motors Nos. 5, 6, 7 and 8; the No. 2 main field shunting reactor, the main transformer, preventive coils and notching transformer.

Blower Air Relays

(P5a and Modified P5a Locomotives)

The air relays, Fig. 34, are round box-shaped devices having two chambers separated by a diaphragm of flexible material. Two sets of contacts are connected to the diaphragm. If air at a pressure above atmosphere is applied to the lower chamber, or at a pressure less than atmosphere is applied to the upper chamber, the diaphragm will lift, opening the two sets of contacts.

If the ventilation is forced blowing, the lower chamber of the relay is pipe-connected to the air duct. If the ventilation is suction blowing, the upper chamber of the relay is pipe-connected to the air duct. The operation of the relay is the same in either case.

As the blower motor reaches or approaches running speed the pressure of the air causes the diaphragm to lift, opening both sets of contacts. One set of contacts drops out the starting contactor and the other set opens an indicating lamp circuit. When the blower motor is stopped, intentionally or otherwise,

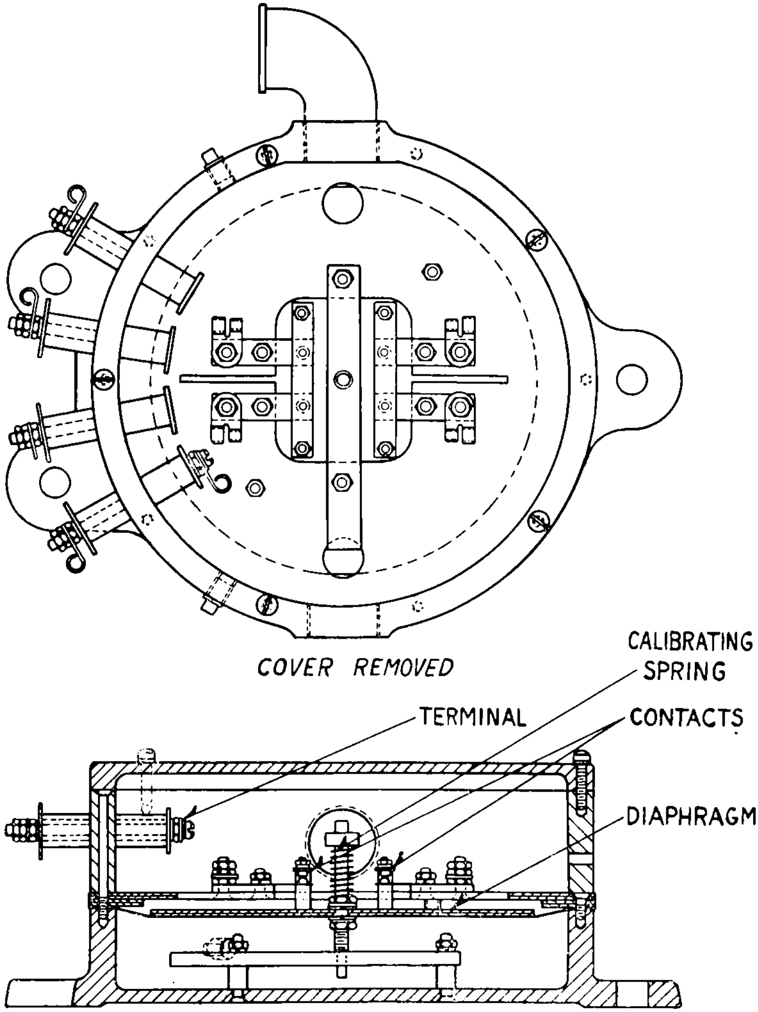


Fig. 34. Sectional View of Blower Air Relay—P5a and Modified P5a Locomotives

(Also used as Boiler Blower Air Relay)

the failing pressure of air causes the diaphragm to drop, closing the contacts for the starting contactor control circuit and the indicating lamp circuit.

Blower Centrifugal Relays

(GG1 Locomotives)

The centrifugal relays, Fig. 35, are on the shafts of the blower motors. Two sets of contacts are provided. As the blower motor reaches or approaches running speed the centrifugal force operates the relay, opening both sets of contacts. One set of contacts drops out the starting contactor and the other opens an indicating lamp circuit. When the blower motor is stopped,

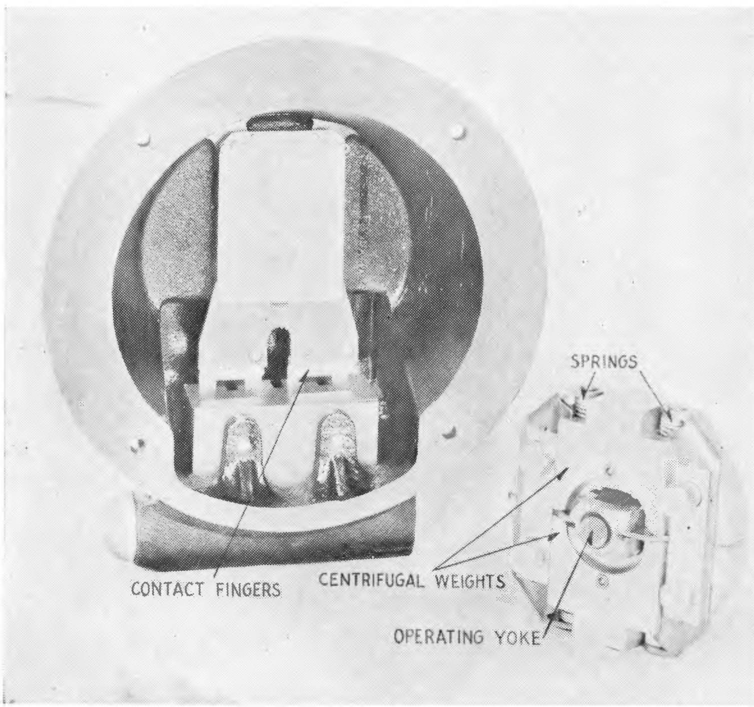


Fig. 35. Blower Centrifugal Relay, GG1 Locomotives

intentionally or otherwise, the failing centrifugal force operates the relay to close the contacts for the starting contactor control circuit and the indicating lamp circuit.

Generator

A generator on the shaft of one of the blower motors (see **Fig.** 33), supplies direct current to supplement the battery source and also to maintain the charge of the battery.

The construction of the armature, commutator, field, and the brush-boxes is essentially similar to that of ordinary commutator motors. Only a main field is provided and this is shunt connected, or parallel connected to the armature.

In any electric generator it is the voltage induced in the armature conductors which causes the current to flow. This voltage depends partly upon the speed of the generator and also upon the field strength. The speed of the blower-generator is uniform, while a tube-wound resistor connected in the field winding provides a means for the manufacturer's adjustment of the field strength and output voltage of the generator. The output voltage is about 36 volts.

Generator Regulator

The generator regulator, Fig. 36, is a voltage relay having a movable coil, carried by an arm on knife edges, suspended in a strong magnetic field. The pull of the movable coil is counterbalanced by a spring. The moving element carries a carbon contact for handling the current in the field circuit of the generator. The carbon contact moves between two stationary carbon contacts, and when in operation, is in continuous vibration. Tube resistors required for proper control and adjustment of the regulation are mounted upon the same panel.

The generator regulator functions, by regulating the field strength, to maintain a uniform voltage on the generator.

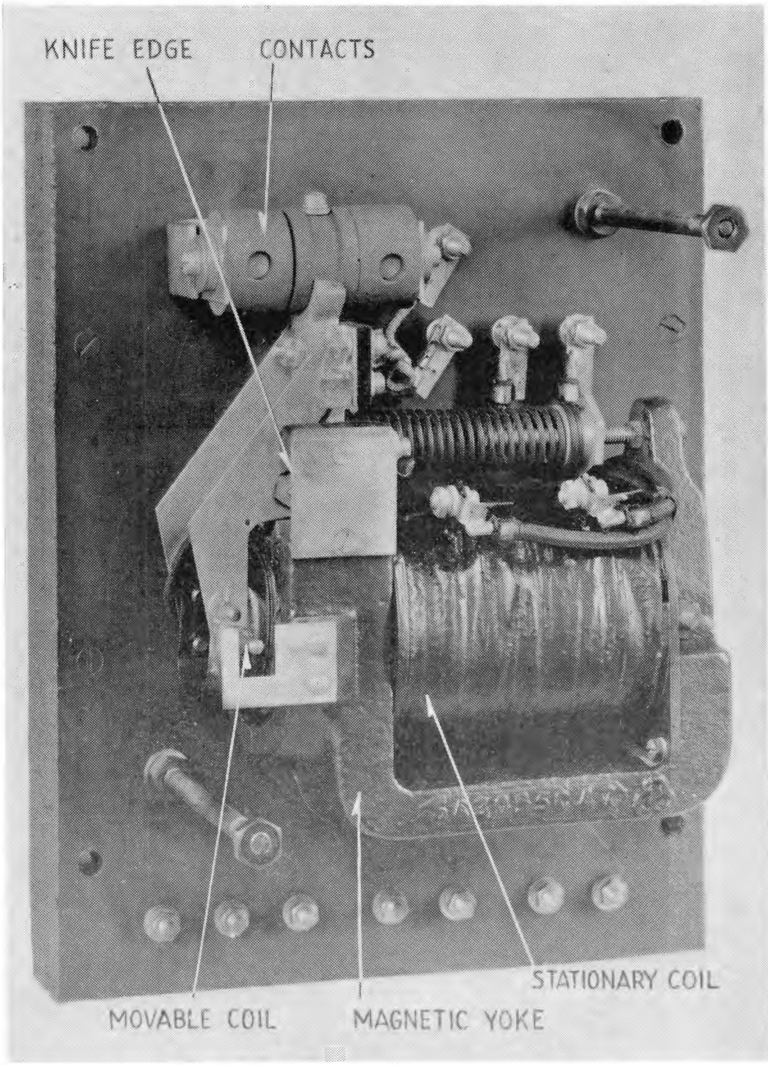


Fig. 36. Generator Regulator
(Tube Resistors Not Shown)

Master Control Apparatus

The principal pieces of apparatus in the master control circuits are listed as follows:

(See Plates 7, 8 and 9, for master control circuits.
See Plates 10, 11 and 12, for main field shunt control circuits.
See Plates 13 and 14, for interpole field shunt control circuits.
See Plates 15 and 16, for pantograph and sander control circuits).

(a) The emergency grounding switch at the engineman's position is a knife-type switch. The switch is normally open and should be closed only in emergencies to operate the grounding contactors.

(b) The control cutout and reset switch at the engineman's position is a rotary switch with three positions, "OFF," "ON" and "RESET." In the "OFF" position all circuits contained in it are open. In the "ON" position the control current feed to the master controller is established. In the "RESET" position a circuit is established for resetting the overload, slip and pantograph relays.

The handle can be applied to, or removed from, the switch only in the "OFF" position. The handle returns from "RESET" to "ON" position by the action of a spring.

(c) The pantograph push-button switch at the engineman's position contains two circuits. The "UP" button, which is normally held out by a spring, carries contacts for energizing a circuit to unlatch the pantographs. The "DOWN" button, which can remain in either the "out" or "in" position, carries contacts for energizing a circuit to lower the pantographs.

(d) The pantograph selector switches are double-pole, double-throw, tumbler switches.

(e) The master controller at the engineman's position, as operated by the engineman, serves to complete the connections between the 32-volt, direct current supply and the magnet valves of the unit switches, reversers, and other control devices.

(f) The master controller foot valve at the engineman's position is a spring-closed, plunger type valve connected to the master controller by air piping. When depressed it admits air to the small cylinder in the master controller top plate to prevent the release of the deadman's lever.

(g) Generally, the interlocks consist of metal segments embedded either in insulating blocks as used on unit switches, or in insulating drums as used on the old style reversers (P5a locomotives). The interlock fingers are mounted on insulating blocks. Interlocks of this type are arranged so that the circuit carried through the interlock fingers can be closed by the metal segments. Another type, used on some contactors, consists merely of a pair of contacts.

An interlock made up in the closed position of a switch or contactor is called an "IN" interlock; one made up in the open position is called an "OUT" interlock. The reversers have "F" interlocks, made up in the forward position, and "R" interlocks, made up in the reverse position of the reverser.

Interlocks are used to forestall the operation of switches and other devices at the wrong time, also to initiate operation of switches and other devices at the proper time. A large part of the interlocking on the locomotive belongs to the main transformer tap switches, since it is necessary to prevent coincident closing of those switches which would impose short circuits on the transformer secondary winding.

(h) The motor cutout switches are double-throw, knife switches which, in the "IN" position, carry the control circuits for the motor switches. Other circuits, described later, are also connected to these switches.

(i) The contacts on the overload, slip, pantograph, main field, and interpole field relays carry the control circuits to various switches and other devices.

(j) The magnet valves are the electrically controlled air valves associated with the unit switches, reversers, and other devices.

(k) The deadman application valve, controlled by the deadman magnet valve, functions to obtain an emergency application of the brakes.

(l) The terminal boards at several locations in the locomotive are the junction points of the wires of the master control system. Most of the wires are carried in ducts or in conduits of iron pipe; the terminal board studs are used to make proper connection of wires in the master control system.

(m) When two or more locomotives are coupled the operation is controlled from one engineman's position. This is called multiple unit control and it requires the use of train line wires which are brought out to receptacles at both ends of the locomotive (see Train Line Receptacles on Plates 7, 8 and 9). Jumpers are used to connect the train line wires of coupled locomotives.

A train line receptacle is an iron socket in which is mounted an insulating block containing the split plug contacts. Each contact plug is connected to one of the train line wires. A slot in the socket insures the use of the proper jumper in a particular receptacle and also prevents the jumper plug from being turned so as to engage the wrong contacts when inserted. A locking ring on the receptacle can be turned to secure the jumper plug when inserted. A hinged cover is provided to prevent dirt and moisture from getting on and around the contacts when not in use.

A train line jumper is a length of cable, made up of the required number of wires, terminating at each end in a jumper plug. The plug is an iron case in which is mounted an insulating block containing sleeve contacts. Each contact sleeve is connected to one of the jumper wires. Since a key projection on the jumper plug must fit into the receptacle slot, it is impossible to insert the jumper plug in the wrong receptacle.

(n) The main field relay functions to control the main field shunting of the traction motors.

(o) The time delay relay consists of the magnet valve and air cylinder portion of a unit switch with interlock attached. A small auxiliary air reservoir and the restricted port in the magnet valve delay the closing of the interlock. The interlock carries the control circuit for the main field shunting switches.

(p) The interpole field relays function to control the interpole field shunting of the traction motors.

(q) The sander push-button at the engineman's position is foot operated. The button which is normally held up by a spring carries contacts for energizing a circuit to operate the sand valves.

(r) The sand valves, controlled by the sand magnet valves, function to operate the sand traps.

Master Controllers

The master controllers (see Figs. 37 and 38) consist of a frame in which is mounted a main drum, the necessary fingers and finger

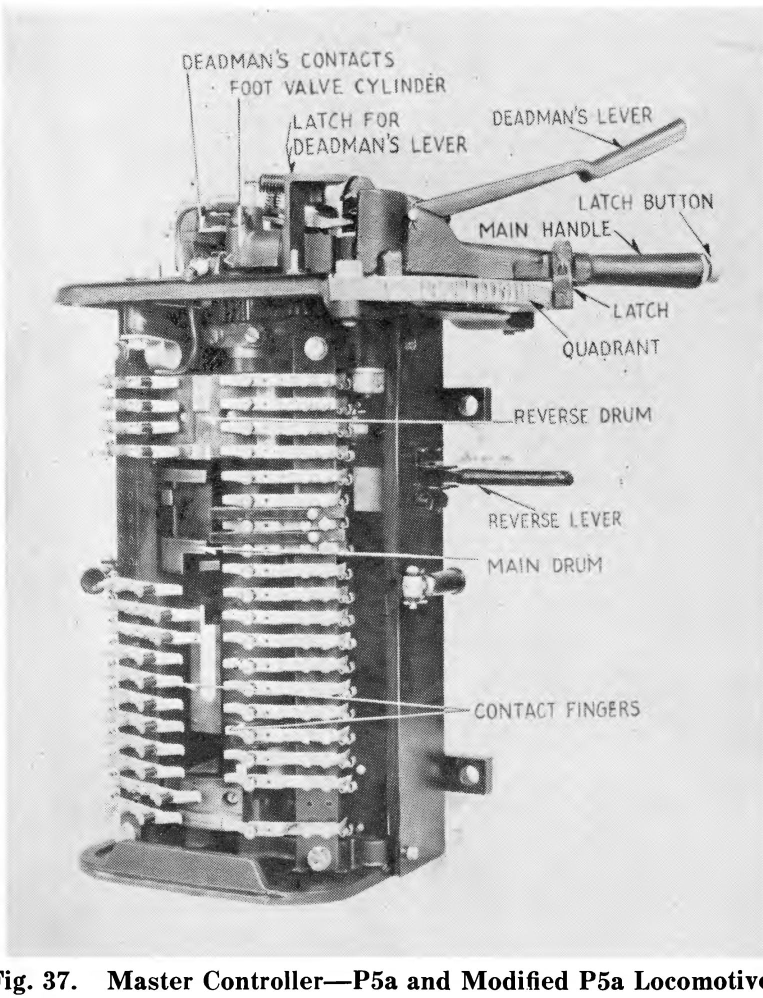


Fig. 37. Master Controller—P5a and Modified P5a Locomotives

bases, the main handle and its operating mechanism, a reverse drum and its operating mechanism, and a deadman's release feature.

The construction of the main drum is such that as it is rotated under the two or three rows of fingers, it makes contact with the fingers in proper sequence. The main drum, which is insulated from its operating mechanism, is operated from the main handle through a suitable gear segement and gear. The controller positions are determined by the engagement of a thumb latch on the main handle with the slots in the quadrant.

The reverse drum, mounted just above the main drum, has three positions, "FORWARD," "OFF" and "REVERSE." This drum is operated by means of a removable reverse lever, the mechanism of which is mechanically interlocked with the main drum so that it is impossible to move the reverse lever except when the main drum is in the "OFF" position. The reverse lever cannot be moved to the "OFF" position, or removed from the master controller, unless the main drum is in the "OFF" position.

The deadman's lever forms a part of the grip of the main handle and is normally held in position by the operator's hand. A spring operates to raise the lever, picking up a pair of contacts which open the control current feed to the main drum and energize the deadman magnet valve connected to the air brake system. Mechanical interlocks are arranged so that it is necessary to return the main drum to the "OFF" position before it is possible to reset the deadman feature for a release of the brakes and reapplication of power to the motors.

The master controllers of the GG1 locomotives have an additional provision for "buck and boost" notching. The "buck" position is the normal position of the main handle as it is moved into any notch. The "neutral" position for that notch, which is neither "buck" nor "boost," is obtained by lifting the main handle to the raised position. The "boost" position for that notch is obtained by restoring the main handle to normal position. An extension of the main handle operates a three-position contact mechanism on the controller top plate which carries the control circuit for the "buck" and "boost" switches.

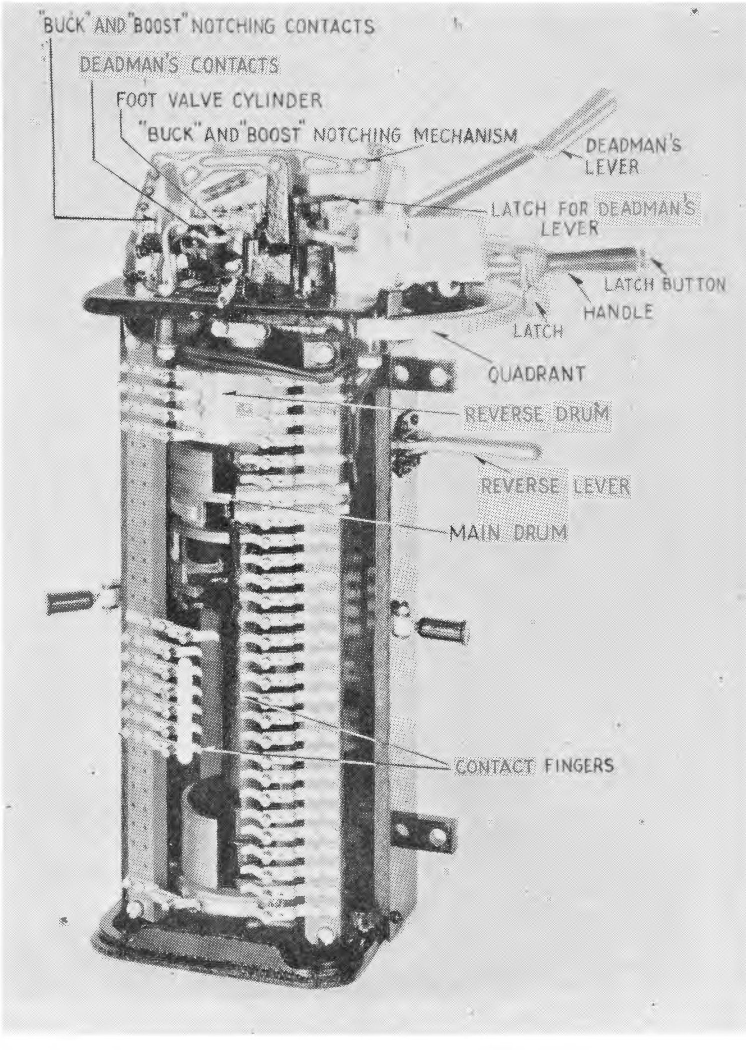


Fig. 38. Master Controller—GG1 Locomotives

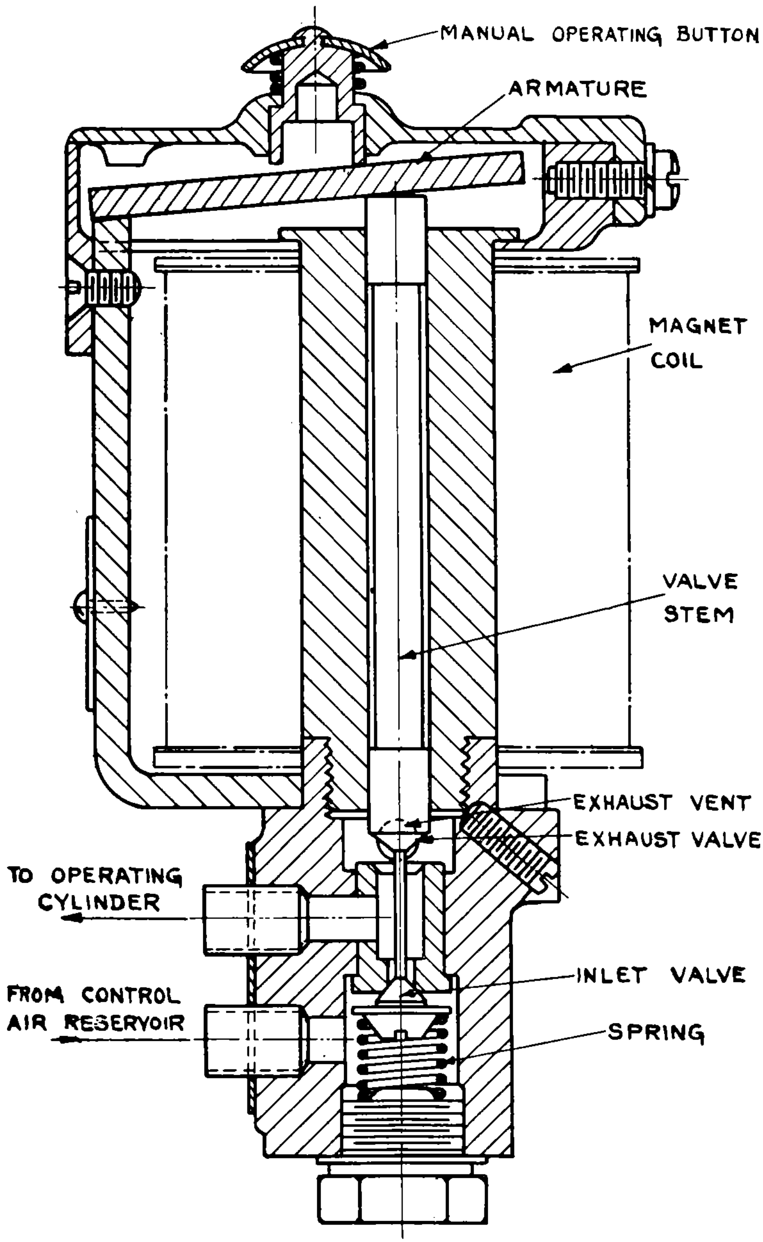


Fig. 39. Sectional View of Magnet Valve

In order to permit the engineman to have free use of his left hand when he desires, a foot-operated air valve is so arranged that it charges a small cylinder in the controller top plate. The piston of this cylinder engages the rear end of the deadman's lever if it is in its normal position and keeps it in its normal position as long as the cylinder is charged with air.

Magnet Valves

The magnet valves, Fig. 39, are electrically controlled air valves. The magnet coil actuates an armature which, in turn, operates the inlet and exhaust valves, thus admitting air to, or exhausting air from, an operating cylinder.

A spring and the pressure of the air normally holds the inlet valve closed and the exhaust valve open. When the magnet coil is energized, the armature is pulled down against this pressure. This closes the exhaust valve and opens the inlet valve, thus admitting air to the operating cylinder to which it is connected. De-energized, the inlet valve closes and the exhaust valve opens, thus exhausting air from the operating cylinder.

The deadman magnet valve, Fig. 40, is quite similar in construction to the ordinary magnet valve, but its function is some-

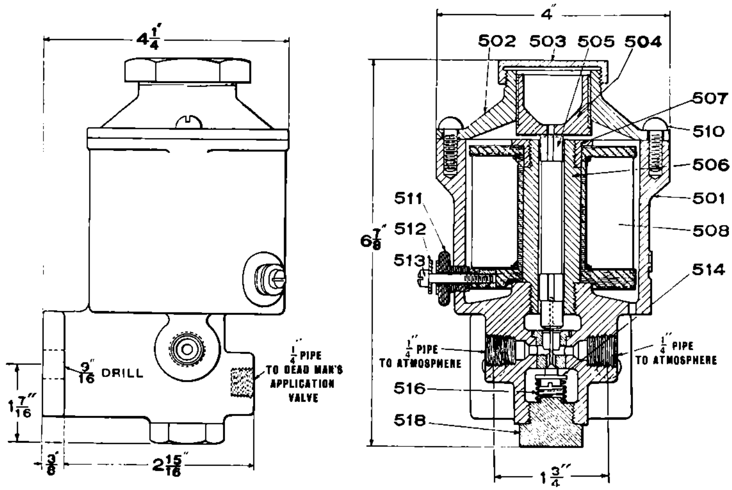


Fig. 40. Sectional View of Deadman Magnet Valve

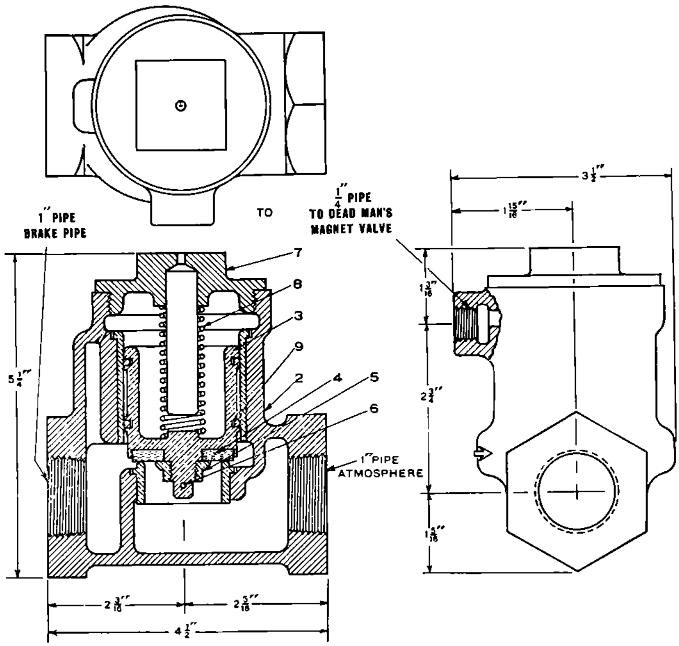


Fig. 41. Sectional Assembly View of Deadman Application Valve

what different. The magnet coil *508* actuates an armature *504* which, in turn, operates the inlet valve *514* to exhaust air to the atmosphere.

A spring *516* and the pressure of the air normally hold the inlet valve closed. When the magnet coil is energized, the armature is pulled down against this pressure. This opens the inlet valve, thus exhausting air to atmosphere. De-energized, the inlet valve closes, thus stopping the exhaust of air to atmosphere.

Deadman Application Valve

Referring to Fig. 41, deadman application valve, brake pipe pressure is present in the chamber surrounding the outer area of the piston valve *3* which is normally held seated by spring *8*. A choke port also permits brake pipe air to feed slowly into the chamber above the piston valve and through the connecting pipe to the deadman magnet valve.

When the deadman magnet valve is energized, air from the connecting pipe and the chamber above piston valve *3* is exhausted to atmosphere. Since the pressure above the piston valve can now escape much faster than brake pipe air can feed through the choke port, the higher pressure around the outer area of the piston valve will be able to unseat the valve against the pressure of spring *8*, and brake pipe pressure is free to flow past this valve to atmosphere at a rate sufficiently rapid to initiate an emergency application of the brakes.

Main Field Relay

(P5a Locomotives)

The main field relay on P5a locomotives, Fig. 42, is a motor type relay. The stator coils take current directly from secondary taps of the main transformer. The rotor coils take current from the main field relay transformer which is connected across the main fields of the traction motors. The interaction of the magnetic fields of the stator coil and the rotor coil causes the rotor to turn to a position where there is no torque. The position of the rotor for no torque depends upon the speed of the traction motors.

The auxiliary coil takes current from the master controller through the "AB" contacts on the relay. The auxiliary coil armature functions to maintain closed "AB" contacts until they are positively opened by the movement of the rotor.

The main field relay has "AB," "C" and "D" contacts. When the speed of the locomotive closely approaches the drop-out point of the relay its rotor has turned far enough to close the "D" contacts for the indicating lamp circuit. When the rotor reaches the drop-out position the "AB" contacts open, de-energizing the auxiliary coil, thereby opening the "C" contacts. The time delay relay is de-energized in this manner and thereby opens a circuit to drop out the main field shunting switches.

Tube resistors mounted on the relay are connected in the primary circuit of the main field relay transformer. This circuit is carried through the No. 1 motor cutout switch. In the "IN" position of the switch the main field relay transformer is connected across the main fields of traction motors Nos. 1, 2 and 3; in the "OUT" position of the switch it is connected across the main fields of traction motors Nos. 4, 5 and 6.

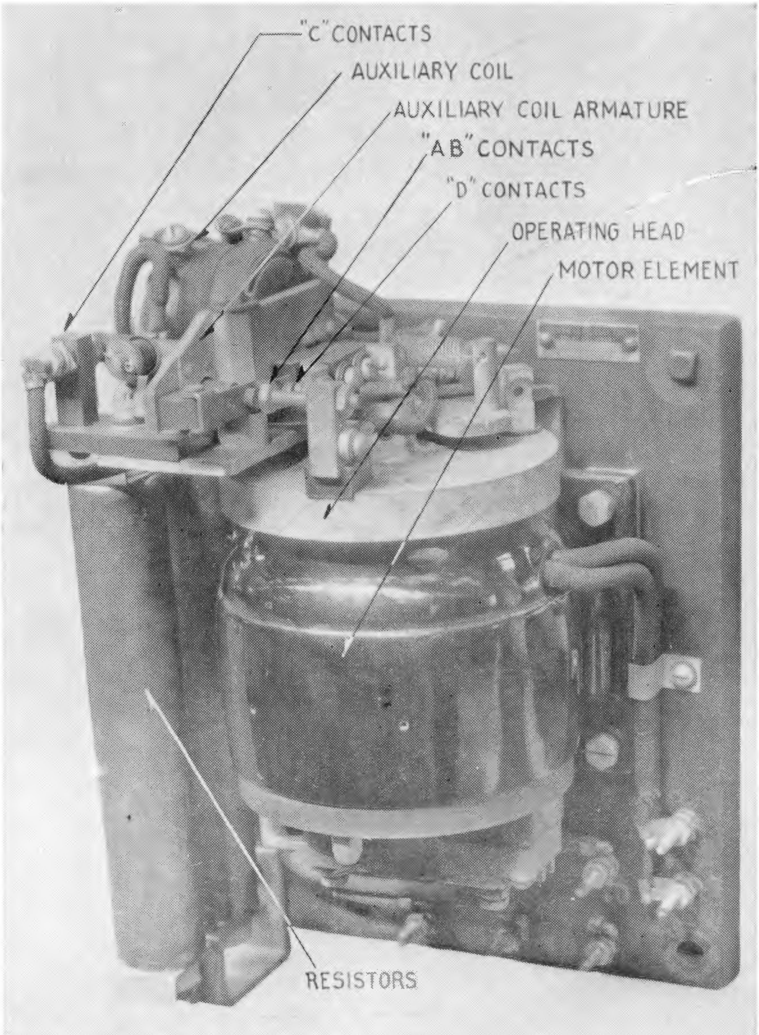


Fig. 42. Main Field Relay—P5a Locomotives

Main Field Relay

(Voltage Relay)

(*Modified P5a Locomotives*)

The voltage relay on the Modified P5a locomotives, Fig. 43, consists of a single-phase, shaded pole, induction motor with a panel attached thereto, upon which are mounted the various contacts and auxiliary mechanisms. A crosshead attached to the rotor shaft actuates the contacts and auxiliary mechanisms. The travel of the rotor is approximately one-quarter of one revolution.

The main coils of the relay span one of the armatures in a traction motor circuit and take current through the "D" contacts on the relay. This circuit is carried through the No. 1 motor cutout switch. In the "IN" position of the switch the relay is connected across the armature of traction motor No. 2; in the "OUT" position of the switch it is connected across the armature of traction motor No. 5. Thus, the current in the main coils depends on the current and speed of the traction motor. The rotor torque is restrained by the calibrating spring. When the rotor torque exceeds the setting of the spring, the crosshead turns completely through to the energized position and latches in this position if the holding coil is energized.

The holding coil takes current from the master controller through the "B" contact on the relay. The holding coil armature extension functions to engage the latch upon the crosshead. When the holding coil is de-energized the armature extension disengages the latch from the crosshead.

The auxiliary coil takes current from the master controller through an interlock on one of the main field shunting switches in the "out" position.

The voltage relay has "A," "B," "C," two "D" and two "E" contacts. When the voltage on the main coils closely approaches the energizing potential, the crosshead has turned far enough to close the "A" contact for the indicating lamp circuit.

When the crosshead reaches the energized position the "B" contact closes and the "C" contact opens, simultaneously. The "B" contact closes the holding coil circuit to latch the crosshead in the energized position, at which time the voltage is cut off

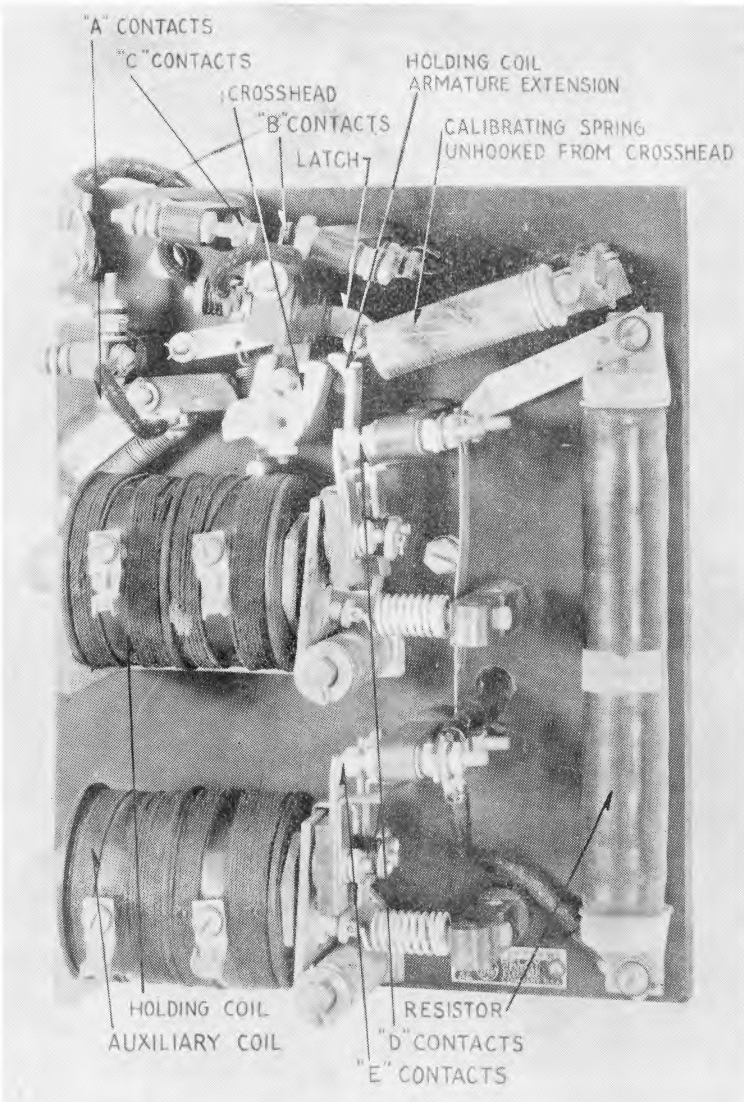


Fig. 43. Main Field Relay—Modified P5a Locomotives
(Voltage Relay)

of the main coils by the opening of the "D" contacts. The "C" contact opens the circuit to the time delay relay, and thereby opens a circuit to drop out the main field shunting switches.

When the holding coil is energized the "D" contacts open to protect the main coils from excessive current as the voltage across the armature of the traction motor increases.

When the auxiliary coil is energized, the "E" contacts open, thereby placing a tube resistor in series with the main coils. This resistor is necessary to obtain a relay drop-out with full field at the same traction motor current and speed as the relay pull-in with shunted field.

Main Field Relay

(GG1 Locomotives)

The main field relay on GG1 locomotives, Fig. 44, is a motor type relay. The stator coils take current directly from secondary taps of the main transformer. The rotor coils take current from the main field relay transformer which is connected across the main fields of the traction motors. The interaction of the magnetic fields of the stator coil and the rotor coil causes the rotor to turn to a position where there is no torque. The position of the rotor for no torque depends upon the speed of the traction motors.

The auxiliary coil takes current from the master controller through the "AB" contacts on the relay. The auxiliary coil armature functions to maintain closed "AB" contacts until they are positively opened by the movement of the rotor.

The main field relay has "AB" and "C" contacts. When the speed of the locomotive reaches the drop-out point of the relay its rotor has turned far enough to open the "AB" contacts, de-energizing the auxiliary coil, thereby opening the "C" contacts. The time delay relay is de-energized in this manner and thereby opens a circuit to drop out the main field shunting switches.

Tube resistors mounted on the relay are connected in the primary circuit of the main field relay transformer. This circuit is carried through the No. 1 motor cutout switch and may be carried through the No. 2 and No. 3 motor cutout switches as well.

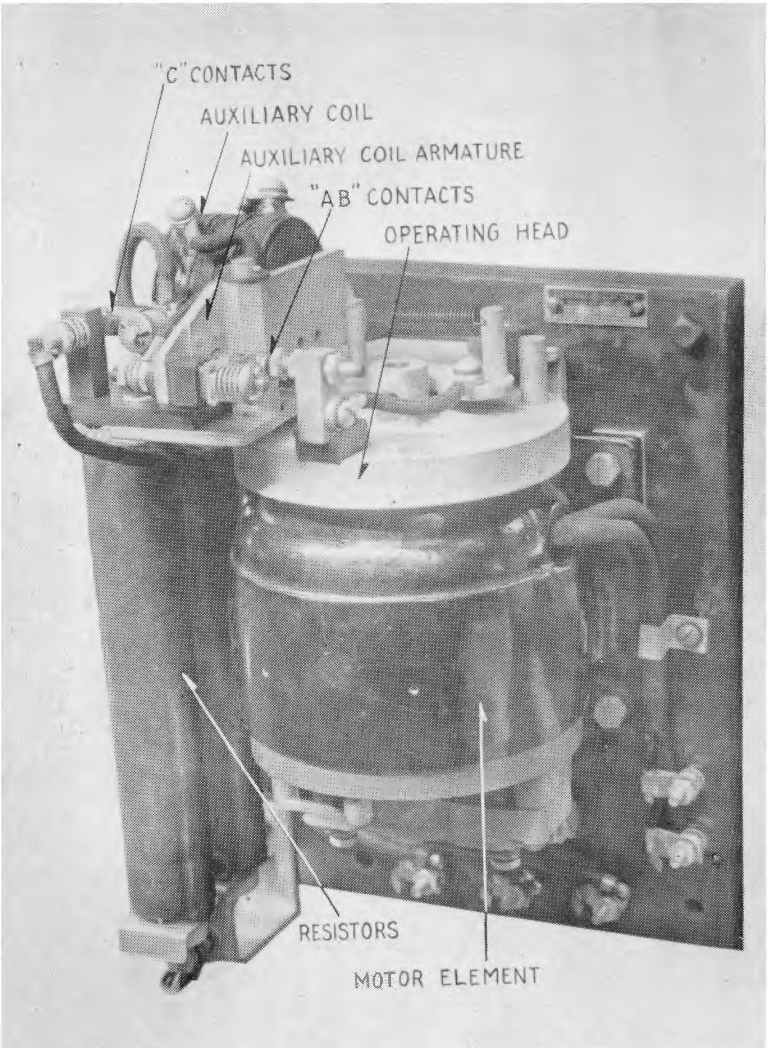


Fig. 44. Main Field Relay—GG1 Locomotives

In the "IN" position of No. 1 motor cutout switch the main field relay transformer is connected across the main fields of traction motors Nos. 1, 2, 3 and 4; in the "OUT" position of No. 1 motor cutout switch (when No. 2 motor cutout switch is in "IN" position) it is connected across the main fields of traction motors Nos. 5, 6, 7 and 8; when No. 1 and No. 2 motor cutout switches are both in "OUT" position (and No. 3 motor cutout switch is in "IN" position) it is connected across the main fields of traction motors Nos. 9, 10, 11 and 12.

Interpole Field Relays

(Speed Relays)

(P5a and Modified P5a Locomotives)

The intermediate speed relay and high speed relay, Fig. 45, are identical in construction but are adjusted to operate at different speeds. Each relay consists of two elements; the right hand element contains the current coil and the left hand element contains the voltage coil and compensating coil. Soft iron cores are suspended at opposite ends of a balanced beam and project part way into each element. With no power on any of the coils the beam should remain central. The double-acting contact is open in the central position and closed in either maximum position.

Mounted on the same base with each speed relay is its associated auxiliary relay. This is a clapper type relay with two operating coils and two moving contacts, one of which closes in both positions and the other only in the "IN" position.

Adjusting resistors for the voltage coils and current coils of the speed relays and for the main coils of the auxiliary relays are mounted near the relay panel. Selective secondary taps on the speed relay transformer provide for adjustment of the compensating coil circuits.

The voltage coils of the relays with their adjustable resistors are connected across a traction motor armature. This circuit is carried through the No. 1 motor cutout switch. In the "IN" position of the switch the relays are connected across the armature of traction motor No. 2; in the "OUT" position of the switch they are connected across the armature of traction motor No. 5. This voltage depends on traction motor current and speed. The

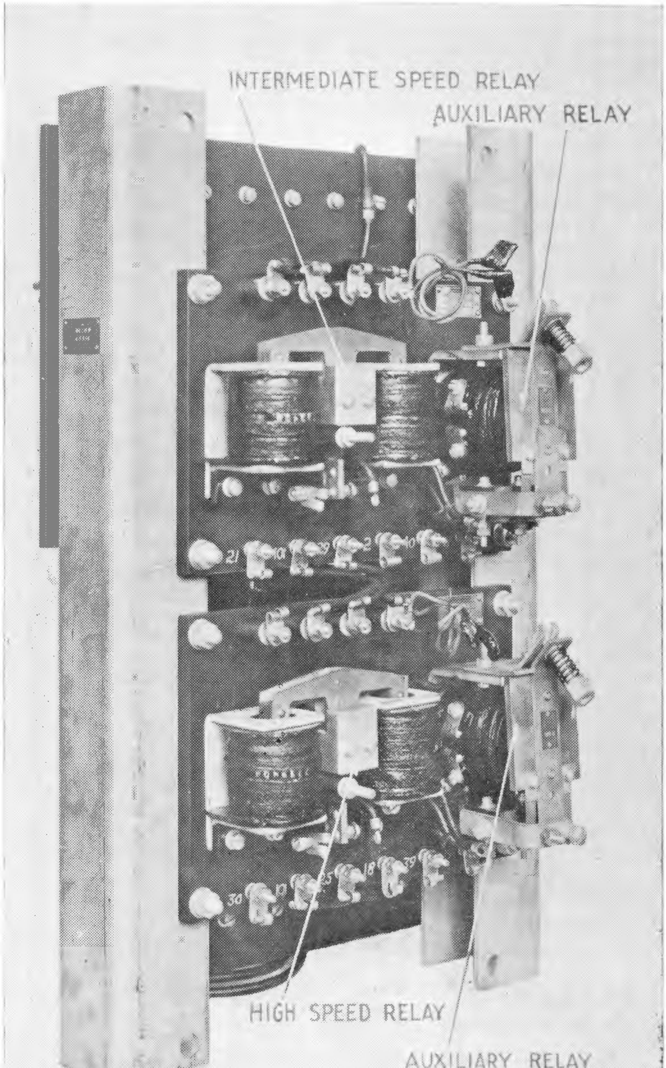


Fig. 45. Interpole Field Relays—P5a and Modified P5a Locomotives
(Speed Relays)

current coils of the relays are connected in series, and with an adjusting resistor in series, are connected across the main fields of the same traction motor circuit. This circuit is also carried through the No. 1 motor cutout switch. In the "IN" position of the switch the relays are connected across the main fields of traction motors Nos. 1, 2 and 3; in the "OUT" position of the switch they are connected across the main fields of traction motors Nos. 4, 5 and 6. This voltage is directly proportional to traction motor current. By proper proportioning of the voltage coil and current coil resistors each relay can be made to respond to a specified speed, irrespective of traction motor current. However, for most satisfactory commutation of the traction motors, the speed at which the speed relays should operate is lower for heavier traction motor current. To obtain this result the compensating coil of the relay assists the voltage coil. The compensating coil of each relay is connected to the speed relay transformer and thus is energized directly in proportion to the traction motor current. The primary circuit of the speed relay transformer is fed by the same current transformers which feed the ammeters and overload relays, and this circuit is carried through both the No. 1 and No. 2 motor cutout switches since tap changing on the primary of the speed relay transformer is necessary when either traction motor circuit is cut out.

The adjusting resistors in series with the voltage coil of the intermediate speed relay have three sections, two of which are short circuited by interlocks on the interpole field shunting switches. When the locomotive speed is low the intermediate speed relay and the high speed relay will be in the "low" positions and interpole field shunting switch 25 will be energized with its "IN" interlock closed (interpole field shunting switch 27 will be de-energized with its "OUT" interlock closed). As the locomotive speed increases, the intermediate speed relay moves to the "high" position, switch 25 is de-energized, and its "IN" interlock opens, inserting additional resistance in the voltage coil circuit to minimize the spread between the pull-in and drop-out speeds.

The adjusting resistors in series with the voltage coil of the high speed relay have two sections, one of which is short circuited by an "OUT" interlock on interpole field shunting switch 28. While the high speed relay is in the "low" position, switch 28 will be de-energized and the "OUT" interlock closed. As the locomotive speed increases, the high speed relay moves to the "high" position, switch 28 is energized and its "OUT" interlock opens, inserting additional resistance in the voltage coil circuit to minimize the spread between the pull-in and drop-out speeds of this relay.

Switch 27 is energized simultaneously with switch 28; the opening of an "OUT" interlock on switch 27 inserts an additional resistance in the voltage coil circuit of the intermediate speed relay. This is necessary to protect the voltage coil against high voltages as the speed increases since the intermediate speed relay is designed to operate at a comparatively low speed, and therefore low voltage.

The double-acting contact of the intermediate speed relay makes a circuit in the "low" position to energize the main coil of the associated auxiliary relay. In the "high" position this contact makes a circuit to short circuit the main coil of the auxiliary relay.

The double-acting contact of the high speed relay makes a circuit in the "low" position to short circuit the main coil of the associated auxiliary relay. In the "high" position this contact makes a circuit to energize the main coil of the auxiliary relay.

The auxiliary relays are identical in construction. The neutralizing coil, energized on all notches of the master controller, functions to hold the relay open (when the main coil is not energized), and to open the relay after the main coil has been short circuited through contacts of its associated speed relay. The main coil, when energized through contacts of the speed relay, functions to close the auxiliary relay against the restraint of the neutralizing coil.

One of the moving contacts on the intermediate speed auxiliary relay is double-acting. In the de-energized position a circuit is made to feed one set of interpole field shunting switches (25, 26, 29, 30) from the master controller through the time delay relay. In the energized position a circuit is made to feed the same switches directly from the master controller; the single-acting contact establishes the holding circuit for the main coil of the relay.

One of the moving contacts on the high speed auxiliary relay is double-acting. In the energized position a circuit is made to feed the other set of interpole field shunting switches (27, 28, 31, 32) directly from the master controller. The single-acting contact establishes the holding circuit for the main coil of the relay. In the de-energized position the double-acting contact serves also to feed this set of interpole field shunting switches directly from another finger on the master controller.

The two auxiliary relays function to prevent pumping of the interpole field shunting switches when the speed relays are near their respective balance points. In addition to this the auxiliary relays make and break the circuit for the magnet valves of the interpole field shunting switches, thus relieving the contacts of the speed relays from this duty.

Interpole Field Relay

(GG1 Locomotives)

The interpole field relay on GG1 locomotives, Fig. 46, consists of a single-phase, shaded pole, induction motor with a panel attached thereto, upon which are mounted the contacts and auxiliary mechanisms. A crosshead attached to the rotor shaft actuates the main contacts.

The main coils of the relay span two of the armatures in a traction motor circuit. This circuit is carried through the No. 1 motor cutout switch and may be carried through the No. 2 and No. 3 motor cutout switches as well. In the "IN" position of No. 1 motor cutout switch the relay is connected across the armatures of traction motors Nos. 1 and 2; in the "OUT" position of No. 1 motor cutout switch (when No. 2 motor cutout switch is in "IN" position) it is connected across the armatures of traction motors Nos. 7 and 8; when No. 1 and No. 2 motor cutout switches are both in "OUT" position (and No. 3 motor cutout switch in "IN" position) it is connected across the armatures of traction motors Nos. 11 and 12. Thus, the current in the main coils depends on the current and speed of the traction motors. The rotor torque is restrained by the calibrating spring.

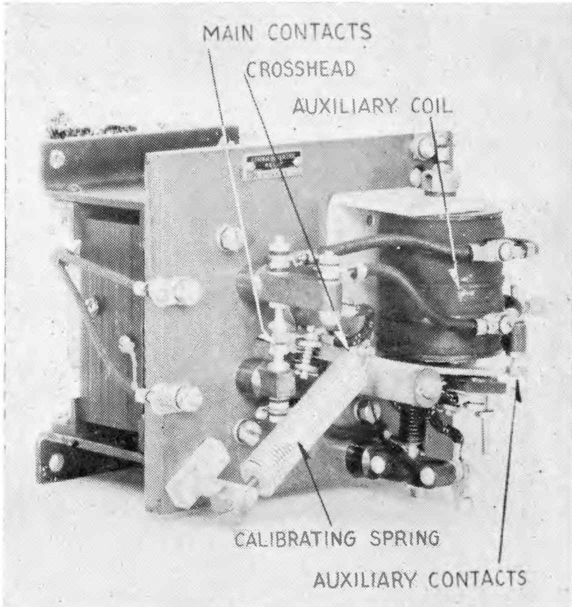


Fig. 46. Interpole Field Relay—GG1 Locomotives

The main contacts are double-acting, closing in the "low" position to short circuit the auxiliary coil, and closing in the "high" position to energize the auxiliary coil.

There are two sets of single-acting, auxiliary contacts, both of which are closed when the auxiliary coil is energized. One set closes to energize the interpole field shunting switches 25, 26 and 27; the other set closes to establish the holding circuit for the auxiliary coil.

The pick-up and drop-out range is narrow; therefore, the auxiliary mechanism is used to make and break the circuit for the magnet valves of the interpole field shunting switches, thus relieving the main contacts of the interpole field relay from this duty.

A tube resistor mounted on the relay is connected in the auxiliary coil circuit to limit the current when the auxiliary coil is short circuited by the main contacts of the relay.

Sand Valves

Referring to Fig. 47, sand valve, the differential piston *B* consists of the large piston, the small piston which is used to cut off the cleaning blast, and the piston stem that rests upon and opens the intake valve *D*. To prevent leakage around the piston *B*, a cup *C*, is used on top thereof.

When the sander magnet valve is energized, control reservoir pressure acts upon the upper area of cup *C*, depressing piston *B* thereby opening intake valve *D* which permits the intake of main reservoir air. The main reservoir air passes out through the cleaning and sanding pipes for cleaning the sand traps and pipes and sanding the rail. The cleaning blast, however, is active for an instant only during the travel of the piston. When the piston seats it cuts off the cleaning blast and leaves active the sanding blast only. Thus, the sand traps and pipes are cleaned both at the beginning and the ending of each sanding operation; the sanding is continuous as long as the sander magnet valve is energized.

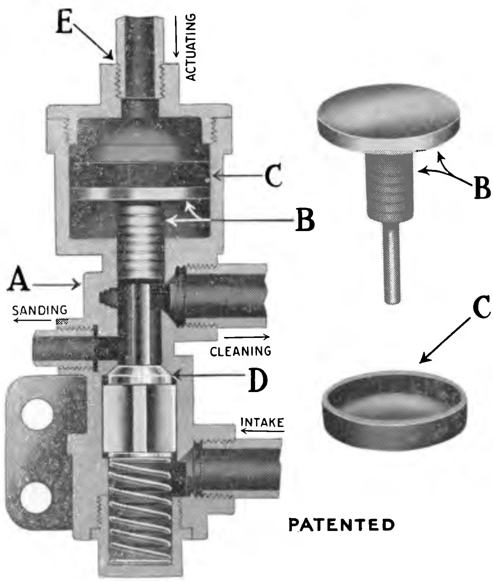


Fig. 47. Sectional View of Sand Valve

Cab Signal Apparatus

The principal pieces of apparatus in the cab signal circuits (see Plate 17) are listed as follows:

(a) The track receivers are mounted on the locomotive just ahead of the leading pair of wheels. The receiver bars are laminated iron with coils mounted thereon. This assembly constitutes the magnetic structure and secondary winding of a transformer of which the rail is the primary. With an alternating current in the rail, a voltage is induced in the receiver bar coil above it.

(b) The equipment box in the locomotive houses a vacuum tube amplifier with its master relay, a decoder, decoding relays, and acknowledging relays, also a dynamotor and terminal board.

(c) The indicators for cab signals of the position light type are located at the crew positions in the locomotive. The four signal aspects are as follows:

Clear
Approach restricting
Approach
Caution, slow speed

(d) A foot operated acknowledging switch by which sounding of the warning whistles may be suppressed is located at the engineman's position.

(e) The cutout cock is located in the air supply line to the magnet valve.

(f) An inverted type magnet valve opens when de-energized for passage of air to the warning whistles; when energized the valve is closed.

(g) The control cutout and reset switch is located at the engineman's position. In the "ON" position, this switch performs the following functions:

1. Closes a circuit to the directional set-up switch magnet valve.
2. Closes a circuit to the amplifier and dynamotor.
3. Short circuits a portion of the voltage regulating resistor in the direct current supply circuit.
4. Closes a circuit to the acknowledging switch.
5. Closes a circuit to the master controller.

In the "RESET" position, all circuits are maintained as in the "ON" position; in addition thereto, a circuit is closed for the resetting of various relays in the protective system of the locomotive. The switch is arranged for spring return from the "RESET" position to the "ON" position.

In the "OFF" position, no circuits are closed by this switch.

(h) The directional set-up switch is an electro-pneumatic switch operated by two air cylinders with accompanying magnet valves. This switch when closed performs the following functions:

1. Connects the cab signal equipment to the 32 volt direct current supply circuit.

2. Connects the proper track receiver (No.1 end or No. 2 end) to the amplifier.

3. Establishes ciruits in proper order when several locomotives are coupled together, to pass energy from the decoder on the leading locomotive to the master relay on the second locomotive, continuing in this sequence for a third or more locomotives for the purpose of repeating cab signal indications and whistle warnings on the trailing locomotives.

(i) The power switch is a double-pole, single-throw tumbler switch.

(j) The cutout switch is a double-pole, single-throw tumbler switch.

Cab Signal Magnet Valve

The cab signal magnet valve, Fig. 48, is an electrically controlled air valve. A spring holds the inlet valve unseated when the magnet coil is de-energized. When the magnet coil is energized, the armature is pulled down against the pressure of the spring seating the inlet valve and stopping the delivery of air to the warning whistle.

Directional Set-up Switch

The directional set-up switch, Fig. 49, is an electro-pneumatic rotary type switch operated by two air cylinders with accompanying magnet valves. Springs hold the mechanism in middle or "OFF" position when neither magnet valve is energized. Energiz-

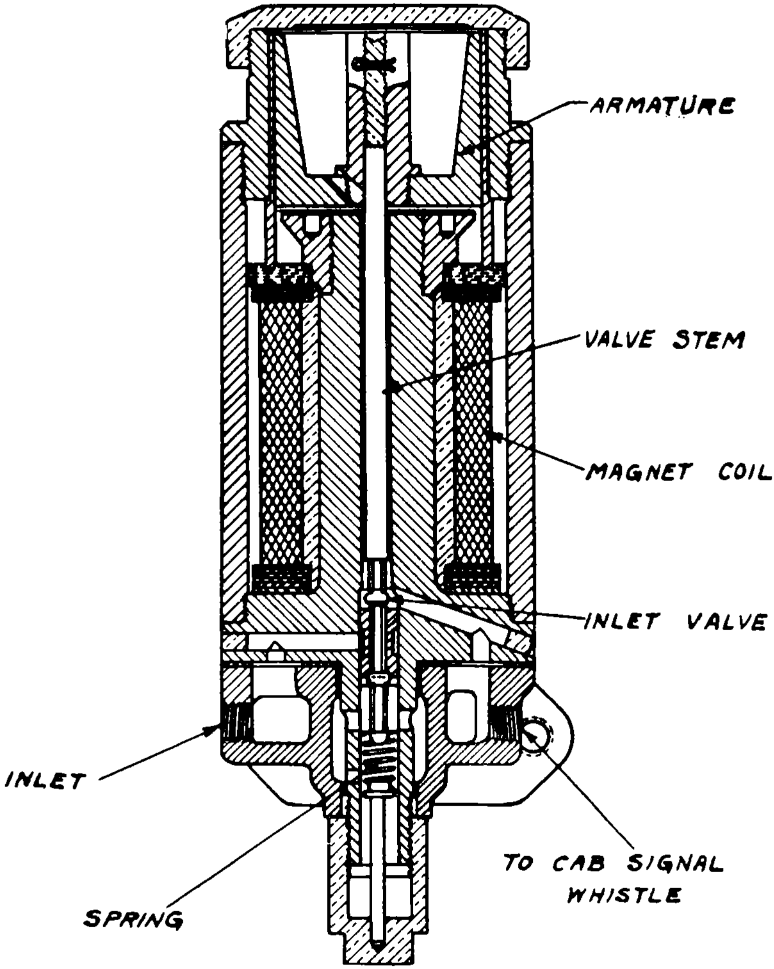


Fig. 48. Sectional View of Cab Signal Magnet Valve

ing one or the other magnet valve admits air to the respective operating cylinder to throw and hold the switch in proper position. The position of the switch is controlled by the control cutout and reset switch on a leading locomotive. When several locomotives are coupled, the position of the directional set-up switch on any but the leading locomotive is controlled by the position of the directional set-up switch on the preceding locomotive.

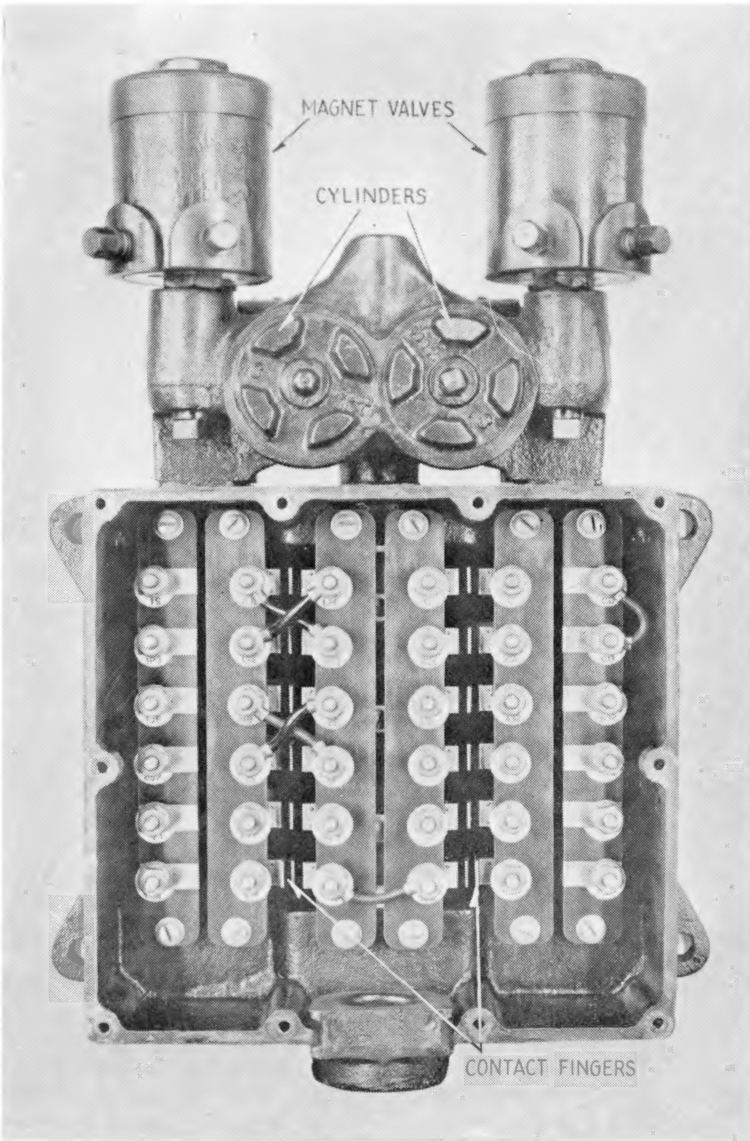


Fig. 49. Directional Set-up Switch

Protective Apparatus

(See Plates 18, 19 and 20 for protective circuits).

PRIMARY OVERLOAD

Since the currents in the high tension and ground leads of the main transformer are normally equal, the current in the secondaries of the two similar current transformers in these leads will be equal and the secondaries can be connected in series. The overload coils of the pantograph relay are connected in this circuit, and protect the transformer primary against overloads.

PRIMARY GROUND FAULT

In case a ground fault occurs in the main transformer primary circuit, anywhere between the two above mentioned current transformers, the current in the high tension and ground leads will not be the same and consequently the current transformer secondary currents will differ. These unbalanced secondary currents cause a flow through the differential coils on the pantograph relay. Thus, the pantograph relay will operate to protect the transformer primary against grounds, even though the current drawn is not sufficient to operate the overload element.

MOTOR OVERLOAD

In each traction motor circuit is a current transformer, the secondary of which is connected to ammeters and an overload relay. The relays are set to trip and open the corresponding motor switches when the motor current reaches a predetermined value. The current transformer secondary circuits are interlocked on the main field shunting switches which results in tap changing on the current transformers for the weak field and full field operation of the traction motors. Thus, the motor current required for tripping the relay is higher for weak field than full field operation.

DRIVING WHEELS SLIPPING

For each traction motor circuit, an auto-transformer having a number of adjustment taps at the center is connected across motors which drive adjacent wheels. The operating coil of a slip relay is connected between one of the taps on the auto-transformer and an equal voltage point of the spanned motor circuit. As long as the speed of the spanned motors is the same, there is no voltage on the relay coil. As soon as one pair of wheels slip, the voltages across the spanned motors are unequal and current flows in the slip relay coil. When the difference in speed of the wheels due to slipping reaches a predetermined amount the relay closes contacts to light an indicating lamp and sound an alarm buzzer at the engineman's positions. If the difference in speed of the wheels due to slipping reaches a greater amount the relay trips and opens the corresponding motor switches.

SECONDARY GROUND CONNECTION

The normal ground on the secondary winding of the main transformer is in effect mid-way between two of the taps. This is accomplished by the pantograph relay reactor which is connected to two transformer taps. The mid-point of the reactor is grounded through a ground cut-out switch and a current transformer. The secondary of this current transformer is connected to the differential coils of the pantograph relay. In case a ground fault occurs on any of the seondary connections the ground cut-out switch may be opened, inserting resistance in the circuit. This will reduce the current in the circuit between the fault ground and normal ground to a value insufficient to trip the relay. This is an emergency condition under which the locomotive can be continued in operation temporarily.

When the ground cutout switch is open a circuit is closed which lights an indicating lamp on the same panel. The lighted lamp is intended to draw the attention of the maintenance crew so that the fault will be cleared.

SECONDARY SHORT CIRCUIT

Short-circuit of any part of the secondary winding of the main transformer may cause overload current in the primary winding, and also in the overload coils of the pantograph relay. If the trouble is in any of the traction motor or auxiliary circuits, and is not cleared by overload relays or fuses in the individual circuits, it may be cleared by a "partial" tripping of the pantograph relay. However, if the short circuit is in the bus straps, or tap switches, a "partial" tripping will not clear the trouble and a "complete" tripping of the pantograph relay may take place.

SECONDARY GROUND FAULT

A ground fault on any of the secondary circuits causes a current through the fault ground and the normal ground which will energize the differential coils of the pantograph relay. If the trouble is in any of the traction motor or auxiliary circuits, and is not cleared by overload relays or fuses in the individual circuits, it may be cleared by a "partial" tripping of the pantograph relay. However, if the ground fault is in the bus straps, tap switches, or parts of circuits not cleared by a "partial" tripping a "complete" tripping of the pantograph relay takes place.

BOUNCING PANTOGRAPH

An alternating current holding coil on the pantograph relay is fed from secondary taps of the main transformer. In addition thereto, a circuit which closes through the "D" contacts energizes the differential coils of the relay from secondary taps of the main transformer. These circuits function during a succession of current surges and current interruptions, such as occur with a "bouncing" pantograph, to prevent the tripping of the relay.

Overload Relays

The overload relays, Fig. 50, consist of a single phase, shaded pole, induction motor with a panel attached thereto, upon which are mounted the various contacts and auxiliary mechanisms. A crosshead attached to the rotor shaft actuates the contacts and auxiliary mechanism. The travel of the rotor is approximately one-quarter of one revolution.

The main coils of the relay take current from a current transformer in the traction motor circuit causing a rotor torque which is restrained by the calibrating spring. When excessive current flows in the motor circuit the rotor torque exceeds the calibration setting of the spring. Then the crosshead turns completely through to the energized, or tripped position with a snap action, and latches upon the reset armature.

The reset coil takes current momentarily when the control cutout and reset switch is turned to "RESET" position. The reset armature unlatches the crosshead and the calibrating spring returns it to the de-energized, or reset position. The reset arma-

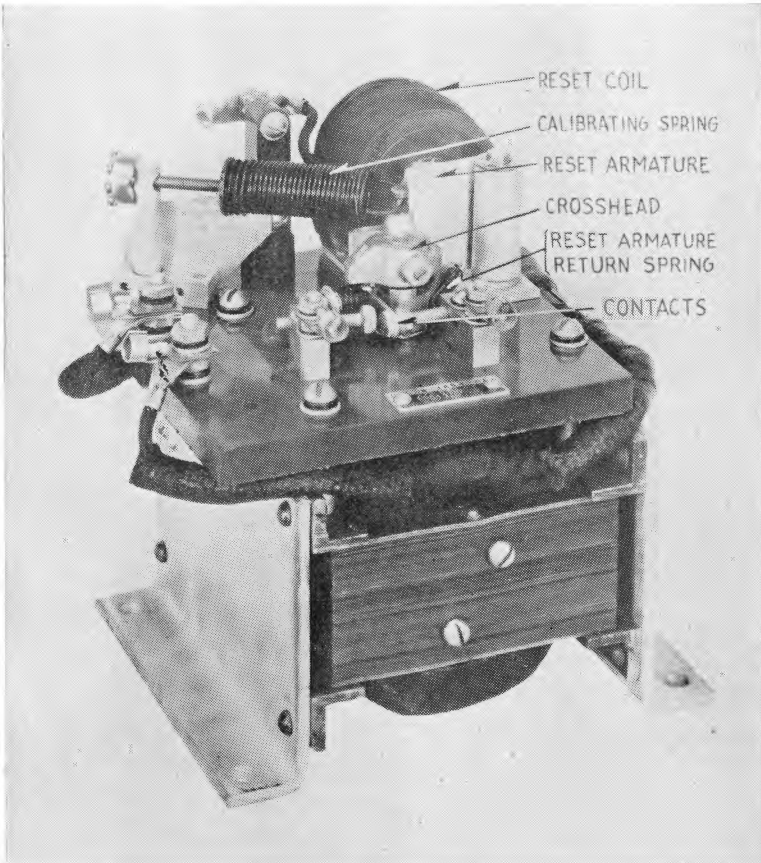


Fig. 50. Overload Relay

ture return spring restores the reset armature to proper position for a repeated functioning of the relay.

The overload relay has but one contact finger, which is double-acting, carrying a circuit to the corresponding motor switches in the de-energized, or reset position, and closing an indicating lamp circuit in the energized, or tripped position.

Slip Relays

The construction of the slip relays, Fig. 51, is quite similar to that of the overload relays.

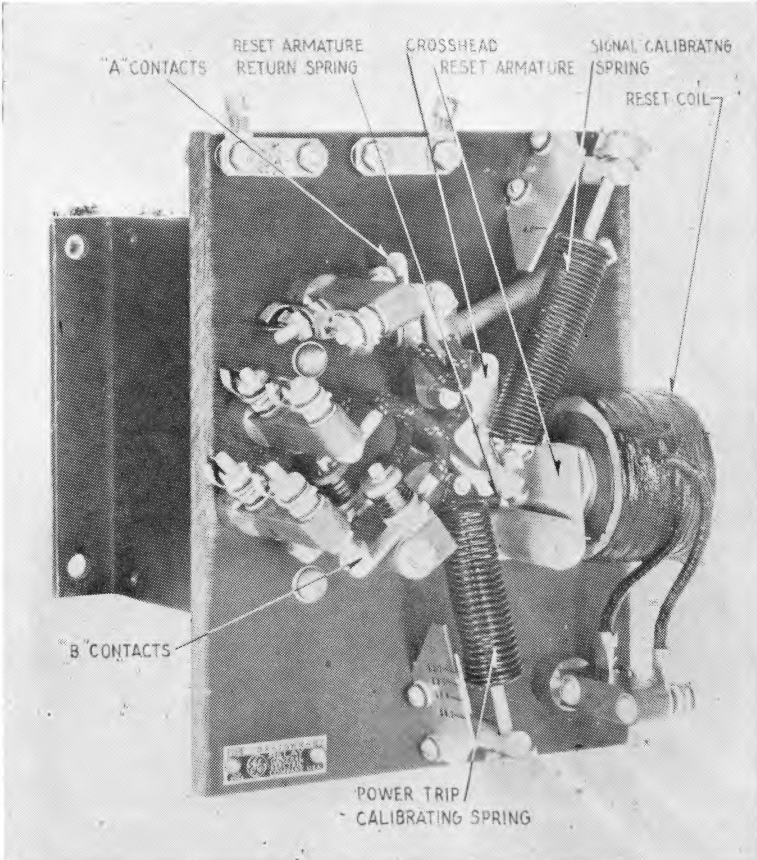


Fig. 51. Slip Relay

The main coils of the relay take current from the traction motor circuit through the slip relay auto-transformer. When current flows the rotor torque is restrained by the calibrating springs of the relay. When the difference in speed of the wheels due to slipping reaches a certain amount the rotor torque exceeds the setting of the signal calibrating spring. The crosshead turns through to the indicating position with a snap action. If the slipping decreases so that main coil current is reduced sufficiently, the signal calibrating spring returns the crosshead to the de-energized position. If the slipping increases to a greater amount the rotor torque exceeds the settings of both the signal and the power trip calibrating springs. Then the crosshead turns completely through to the energized, or tripped position with a snap action, and latches upon the reset armature.

The reset coil takes current momentarily when the control cutout and reset switch is turned to "RESET" position. The reset armature unlatches the crosshead and the calibrating springs return it to the de-energized, or reset position. The reset armature return spring restores the reset armature to proper position for a repeated functioning of the relay.

The slip relay has an "A" contact finger and two "B" contact fingers. The "A" contact closes an indicating lamp and buzzer circuit in the indicating and energized positions. The "B" contacts carry the circuits to the corresponding motor switches in the de-energized and indicating positions, and break in the energized, or tripped position.

Pantograph Relay

The construction of the pantograph relay, Fig. 52, is somewhat similar to that of the overload relays and slip relays. However, the rotor shaft, instead of carrying a crosshead, has a pinion extension in mesh with a large gear (see Fig. 53), which actuates the contacts and auxiliary mechanisms. The complete travel of the rotor is approximately seven revolutions.

The overload coils of this relay take current from two current transformers in the main transformer primary leads. The differential coils may take current from either of these current transformers, another current transformer in the main transformer secondary ground connection, or directly from the main transformer secondary taps. The calibrating spring, attached by chain to the large gear, restrains the turning when current in the overload coils or differential coils produces a rotor torque and retracts the gear after the current in the coils is reduced or interrupted.

The normal position of the relay is the reset position, Fig. 54, in which the tripping dog on the gear top operating plate is engaged with the "D" contact arm and the trip lever is in position

Fig. 52. Pantograph Relay

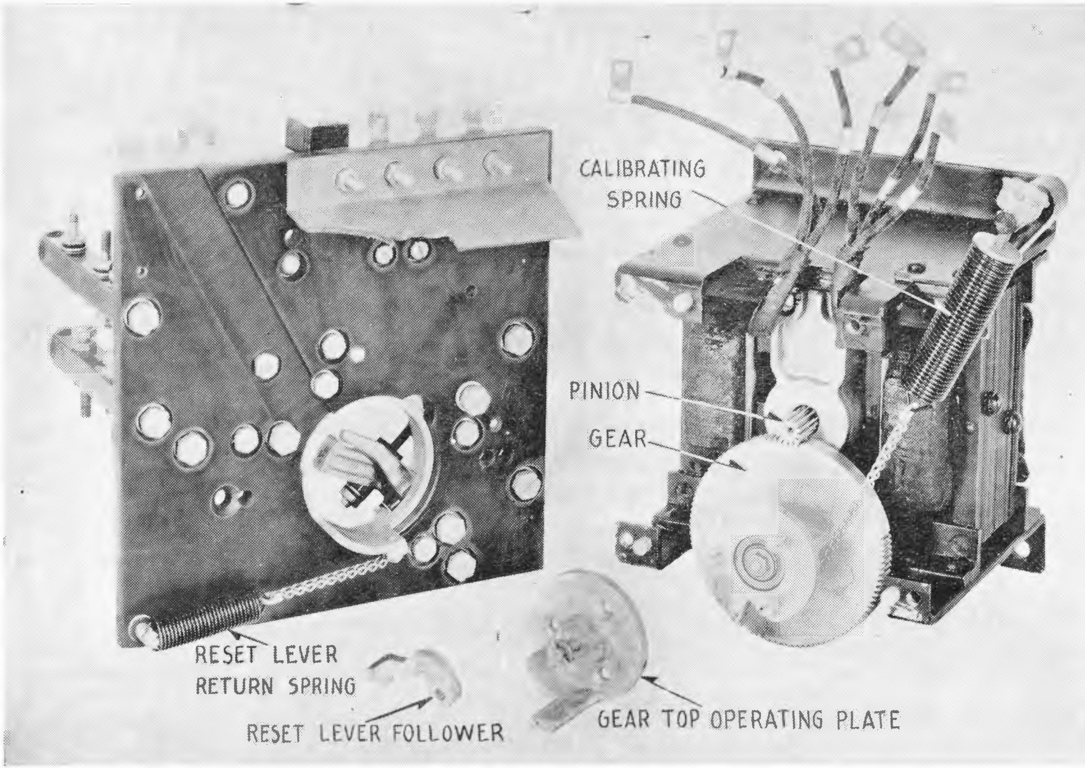


Fig. 53. Pantograph Relay, Partly Disassembled

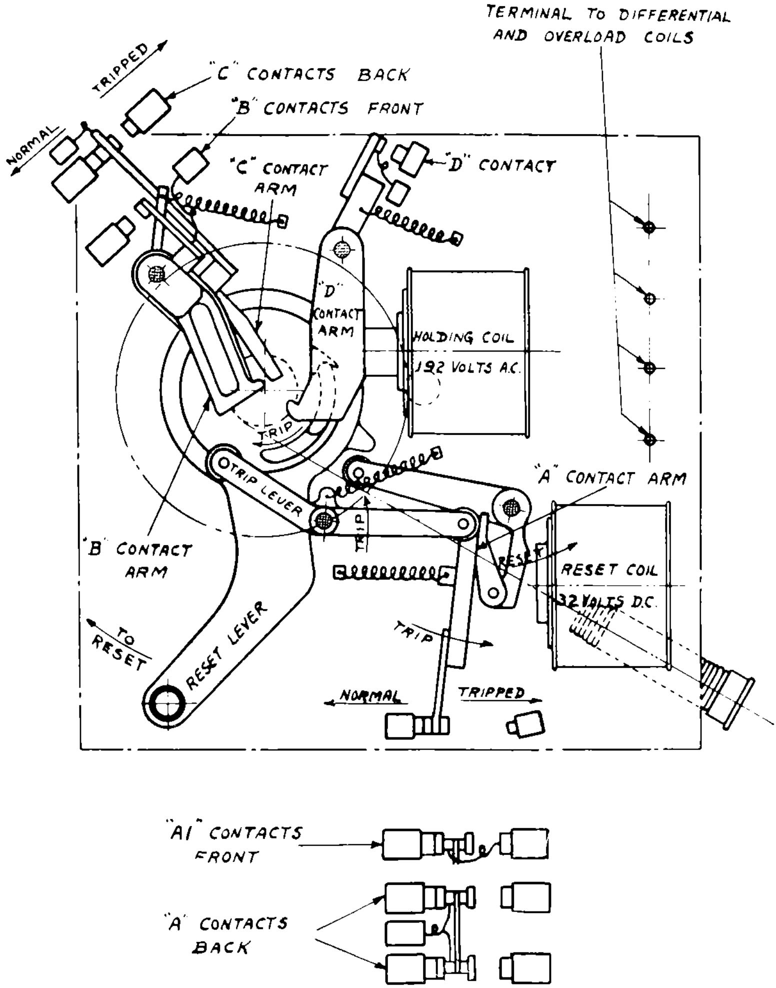


Fig. 54. Pantograph Relay, Diagrammatic View A
(Normal Position)

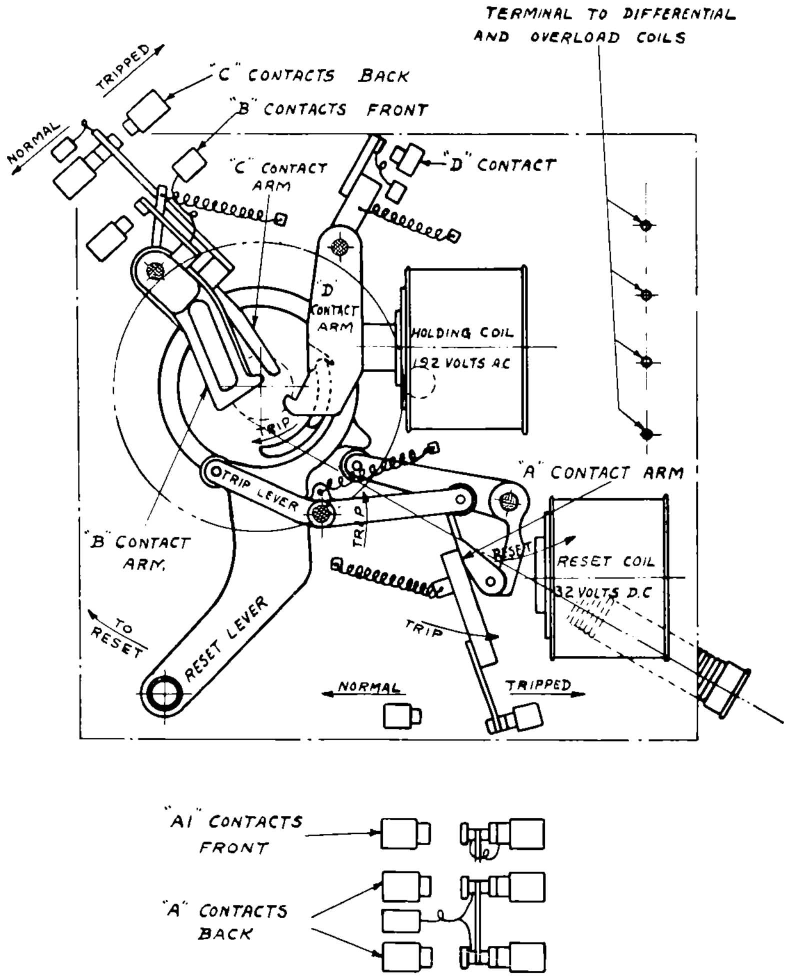


Fig. 55. Pantograph Relay, Diagrammatic View B
(Partial, Trip Position)

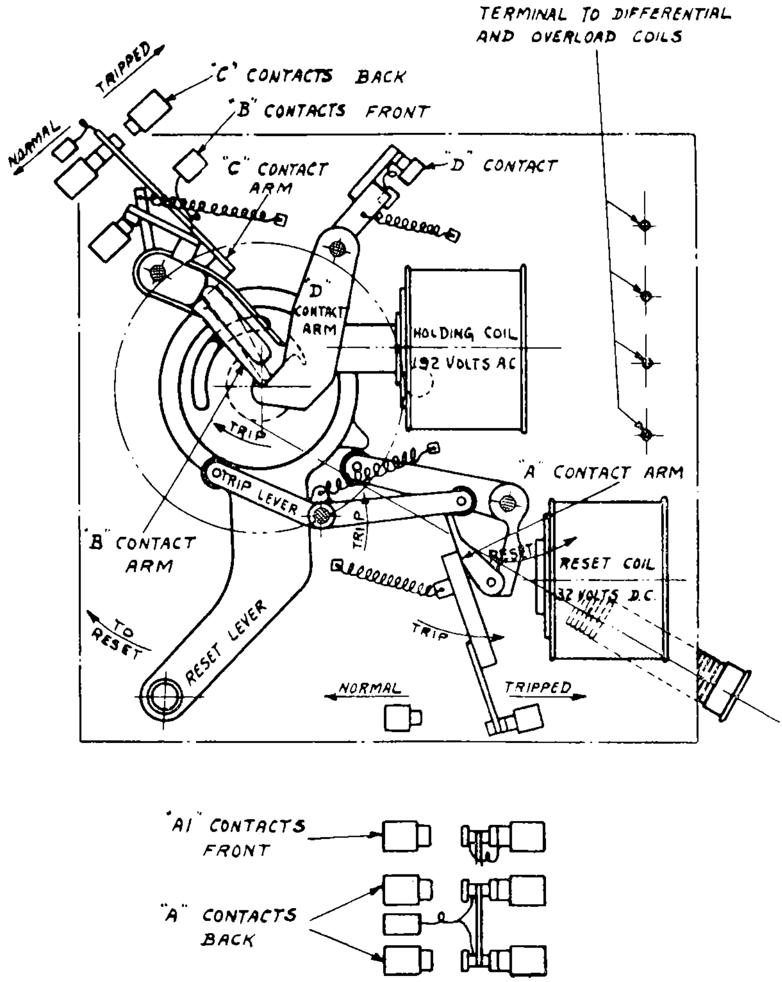


Fig. 56. Pantograph Relay, Diagrammatic View C
(Preliminary Stage of Complete Trip)

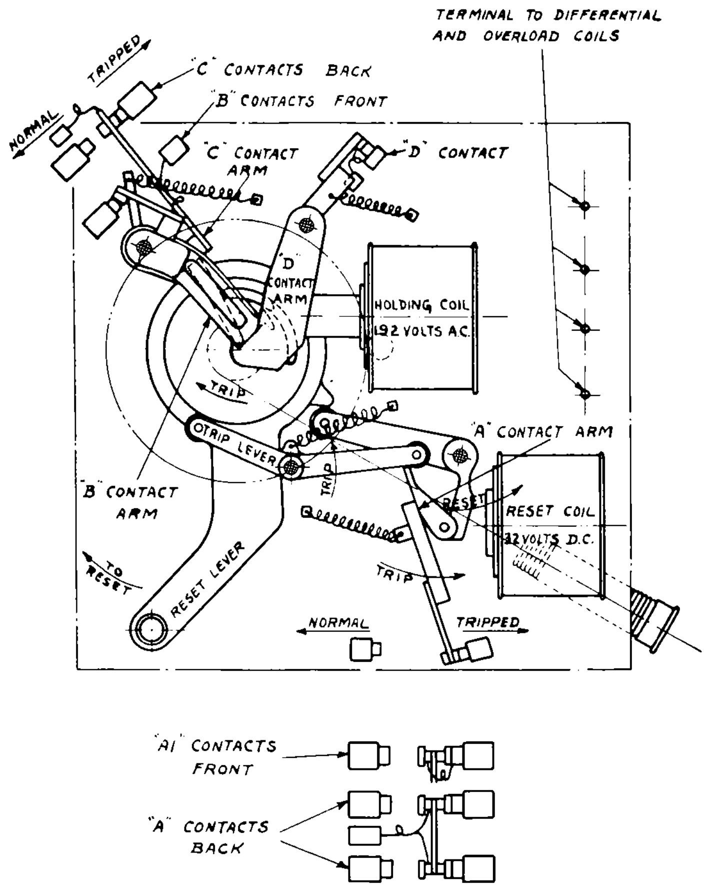


Fig. 57. Pantograph Relay, Diagrammatic View D
(Final Stage of Complete Trip)

for tripping. The "D" contact arm remains in this position when the dog is engaged therewith, also whenever the a. c. holding coil is energized.

An excessive current in the overload coils or differential coils turns the dog in clockwise direction away from its engagement with the "D" contact arm, to engage the trip lever, thereby tripping the "A" and "A1" contacts and latching this mechanism in tripped position. Both the partial tripping and complete tripping begin in this manner.

If the excessive current ceases with the tripping of the "A" and "A1" contacts, the dog retracts, in counter-clockwise direction under the action of the calibrating spring, into engagement with the "D" contact arm as shown in Fig. 55. This is the partial tripping.

If the excessive current continues after the tripping of the "A" and "A1" contacts, the dog continues to turn in clockwise direction engaging, at the end of its travel, the "B" contact arm. The closing of "B" contacts by this action operates the grounding contactor, thereby short-circuiting the primary circuit of the locomotive. The a. c. holding coil, thus de-energized, releases its armature and the "D" contact arm latches with the "B" contact arm (see Fig. 56). This is the preliminary stage of the complete tripping. As soon as short-circuit current ceases with the opening of the substation circuit breakers, the main coils of the relay are de-energized. The dog then retracts completely in counter-clockwise direction, passing the "D" contact arm which is not in position to engage it, engaging the "C" contact arm at the end of its travel. This is the final stage of a complete tripping as shown in Fig. 57.

The reset coil which is used to reset the relay after a partial tripping takes current momentarily when the control cutout and reset switch is turned to "RESET" position. This circuit is carried through an "OUT" interlock on the transformer blower running contactor on P5a and Modified P5a locomotives and through an "OUT" interlock on the heater bus contactor on GG1 locomotives. The reset armature resets the trip lever on the "A" contact arm. The reset armature return spring restores the reset armature to normal position and closes the "A" and "A1" contacts in reset position (Fig. 54).

The holding coil takes alternating current from the main transformer secondary taps. When the coil is energized, its armature holds the "D" contact arm in normal position, with the "D" contacts open, whether the dog is engaged therewith or not.

The reset lever which is used to reset the relay after a complete tripping is operated manually and is restrained by a return spring attached by chain to the reset lever. The reset lever and its follower move the dog which, at the start of its travel, releases the "C" contact arm. The "C" contact arm returns to reset position under action of its spring. A projection on the reset lever engages an arm from the reset armature and resets the trip lever on the "A" contact arm. At the end of its travel, the reset lever follower (not shown on Figs. 54 to 57) releases the "B" and "D" contact arms, resetting the "D" contact arm. The "B" contact arm returns to reset position under action of its spring. As the reset lever returns to normal position under action of its spring, the follower holds the "D" contact arm in reset position until the dog engages therewith. A projection on the reset lever then releases the follower from the "D" contact arm. As the reset lever completes its return to normal position, the "A" contact arm returns to reset position under action of the reset armature return spring. This is the reset position (Fig. 54).

The pantograph relay has two "A" contacts, "A1," "B," "C" and "D" contacts. The "A" contacts are double acting. In the normal position they carry the circuits to the traction motor switches; on a partial tripping and complete tripping they close a circuit for the indicating lamps, and (on the P5a and Modified P5a locomotives) another to open the air compressor motor contactor. The "A1" contacts open on a partial tripping and complete tripping to open the blower motor and heater bus contactors. (An "OUT" interlock on the heater bus contactor on the GG1 locomotives closes the circuit to open the air compressor motor contactor).

The "B" contacts are closed on a complete tripping to energize the grounding contactor. This action places a short circuit upon the primary circuit of the locomotive. The substation circuit breakers can thus be opened to interrupt the current fed to the locomotive at fault.

The "C" contacts are double acting. In the normal position they carry the circuit from the pantograph push-button sets for lowering the pantographs; they close in the completely tripped position to directly energize the pantograph "DOWN" magnet valves. The lowering of the pantograph after a complete tripping of the relay clears the faulty locomotive from the trolley circuit.

The "D" contacts have a special function which is best explained in relation to a "bouncing" pantograph. The current surge occasioned by the pantograph shoe striking the trolley wire may rotate the dog clockwise, out of engagement with the "D" contact arm. If the pantograph shoe in rebounding breaks contact with the trolley wire, the pantograph relay holding coil is de-energized, in which case the "D" contact arm releases and the "D" contacts close. Since the main coils are also de-energized, the dog retracts, passing the "D" contact arm which is not in position to engage it. The "D" contacts have closed a circuit to feed the differential coils of the relay directly from the main transformer secondary taps. In the next instant, if the pantograph shoe again contacts the trolley wire, the dog will rotate clockwise again. As soon as the dog passes the "D" contact arm, the holding coil, then energized can return the "D" contact arm to normal position, opening the "D" contacts. The dog then retracts, and if the holding coil is still energized, engages with the "D" contact arm. This resetting operation is accomplished by the relay without the manipulation of the control cutout and reset switch or the reset lever on the relay.

Metering Apparatus

The principal pieces of metering apparatus are listed as follows:

(See Plates 18, 19 and 20 for metering circuits).

(a) The watthour meter registers all the electric energy supplied to the locomotive. A current transformer in the ground lead of the main transformer primary winding is connected to the current coils of the watthour meter. The voltage coils of the watthour meter are connected to secondary taps of the main transformer.

The watthour meter registers are shown in Fig. 58. Each of the four or five dials must be read in the direction shown by the arrows. The first dial on the right should be read and the reading recorded, then the second dial from the right, third dial from the right, and so on until each dial has been read and the reading recorded. In deciding upon the reading of a pointer, the pointer to the right of it must be consulted first. Unless the latter pointer has reached or passed the "O," or, in other words, has completed a revolution, the other pointer has not completed the division on which it may appear to rest.

The pointer on the first dial on the right turns ten divisions or a full revolution while the pointer on the second dial from the right turns one division; the pointer on the second dial turns ten divisions or a full revolution while the pointer on the third dial turns one division, and so on from dial to dial in a right-to-left direction.

Fig. 58 shows typical readings for the four-dial and five-dial registers.

(b) The ammeters indicate the current in the respective traction motor circuits. A current transformer in each motor circuit is connected to the overload relay and ammeters. The secondary taps of the current transformer are interlocked on the main field shunting switch which results in tap changing on the current transformer for the weak field and full field operation of the motors. Thus, the motor current in weak field operation is actually higher than the ammeters indicate. In full field operation the true motor current is indicated by the ammeters.

(c) A battery charging indicator, connected in the battery circuit on the GG1 locomotives, indicates charging or discharging flow of current.

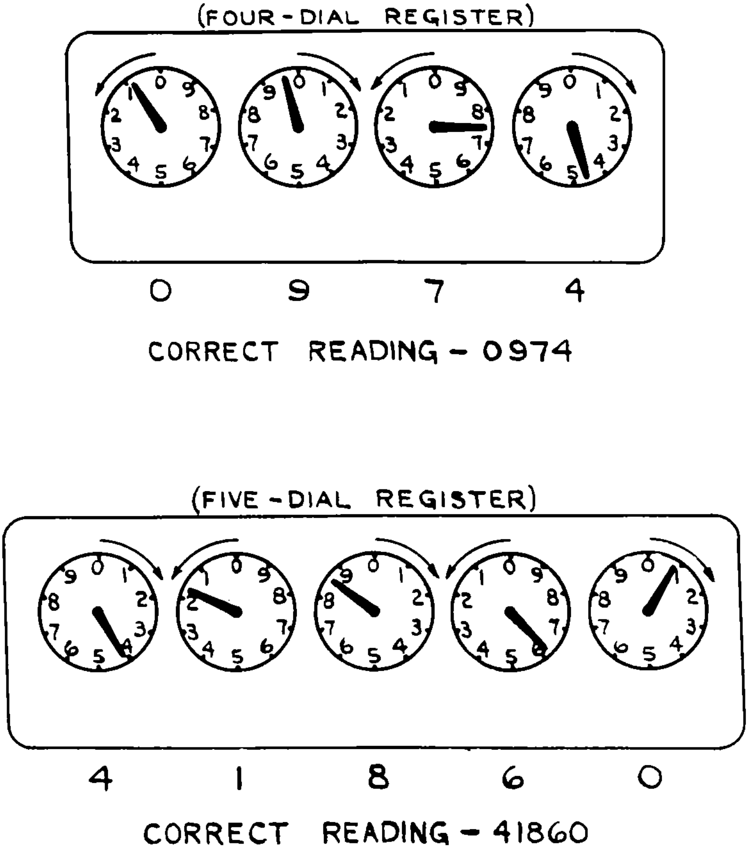


Fig. 58. Watthour Meter Registers

Operation of Electrical Apparatus

Since control of the locomotive is accomplished with an electro-pneumatic system, the operation of most of the control devices depends upon the supply of direct current from the battery or generator, and the supply of compressed air from the control air reservoir. Coupled locomotives, as mentioned hereafter, refers to two or more coupled locomotives with the train line jumpers inserted in the receptacles for multiple unit control.

Pantographs

The grounding switches on both pantographs should be open when a pantograph is to be raised for energizing a locomotive. The grounding contactors should be de-energized and open also.

The pantograph selector switches have two positions, "UP" and "DOWN". The selector switch for the pantograph desired for use should be thrown to "UP" position; the other selector switch should remain in "DOWN" position, unless both pantographs are desired for special reasons. The selector switch in "UP" position merely connects the pantograph control circuits for operation from the pantograph push-button switches at the engineman's positions. The selector switch in "DOWN" position energizes the "DOWN" magnet valve for that pantograph, charging the lowering cylinders with air to hold the pantograph down in addition to the latch engagement.

At the engineman's position it is necessary to engage the deadman lever in normal running position, apply the handle to the control cutout and reset switch, turning same to the "ON" position, and place the reverse lever in the master controller, turning same to "FORWARD" or "REVERSE" position, in order to release the pantograph with the push-button switch. (The deadman lever on the master controller must be engaged in normal running position before turning the control cutout and reset switch to "ON" position and must remain engaged until the control cutout and reset switch is returned to "OFF" position, to prevent undesired emergency brake operation).

To release a pantograph and allow it to rise, the "UP" button should be pressed and held in for a few seconds against the restraint of its spring. The contact closes a circuit which, through

"OUT" interlocks on the traction motor switches, and the selector switch energizes the "UP" magnet valve of the pantograph. In this manner the pantograph latch cylinder is charged with air to hold the pantograph latch disengaged so that the pantograph can rise by the action of its springs.

To lower a pantograph the "DOWN" button should be pressed. There is no spring action on this push-button. The contact closes a circuit which, through the "C" contacts on the pantograph relay and through the selector switch, energizes the "DOWN" magnet valve of the pantograph. This lowers the pantograph by the action of its lowering cylinders.

In the lowering operation it is not necessary for the control cutout and reset switch to be in "ON" position, nor for the reverse drum of the master controller to be in "FORWARD" or "REVERSE" position. Hence it follows that the pantograph, or pantographs, on one locomotive or several coupled locomotives, can be lowered by the push-button at any of the engineman's positions. It is apparent also that if the "DOWN" button is engaged at any of the engineman's positions the selected pantographs are held down by air in the lowering cylinders and cannot rise when the latch releases in response to the operation of the "UP" button.

When the pantograph relay reaches its completely tripped position the "C" contacts on the relay close a circuit through the selector switch to energize the "DOWN" magnet valve of the pantograph. This lowers the pantograph of the locomotive on which the relay tripped but does not lower pantographs of other coupled locomotives.

A hand-operated pump provides a means of raising a pantograph when the control reservoir supply of air is depleted. The selector switch for the pantograph desired for use should be thrown to "UP" position; the other selector switch should remain in "DOWN" position. The hand-pump cock in the air piping between the "UP" magnet valve and the latch cylinder of the selected pantograph should be turned to "hand pump" position. Operation of the hand pump charges the latch cylinder with air to release the pantograph and allow it to rise; perhaps not more than twenty strokes of the pump is required ordinarily. When the pantograph has raised it is important to return the hand-pump cock to normal position.

A wooden pantograph pole and rubber gloves are carried on the locomotive. The hook on the end can be used to engage the unlatching lever on the side of the pantograph base, thus releasing the pantograph and allowing it to rise. The selector switch for the pantograph should be thrown to "UP" position before performing this operation. The pole can be used to engage the pantograph shoe horn for lowering the pantograph, also. The last part of the downward pull should be somewhat forceful to insure latching of the pantograph.

Grounding Contactors

The emergency grounding switch at the engineman's position can be used in emergencies to energize and close the grounding contactors thereby imposing a short circuit on the primary circuit of the locomotive.

Grounding Switches

Either of the pantograph grounding switches can be used in emergencies to short circuit the primary circuit of the locomotive.

Transformer Oil Pump

(*GG1 Locomotives*)

The transformer oil pump knife switch is normally closed to energize the oil pump motor for forced circulation of the transformer oil whenever the main transformer is energized.

Air Compressor

If the air compressor contactor has been opened by its operating handle it can be closed only by movement of this handle. Thereafter it will be closed whenever its magnet valve is de-energized, and also whenever there is insufficient control reservoir pressure to open it.

The air compressor governor is pipe-connected to the main reservoirs. The electrical contacts are open when no air pressure is acting upon the governor and remain open until the pressure reaches the cutting-out point for which the governor is adjusted. While the governor contacts are open, the air compressor contactor, with magnet valve de-energized, is closed, operating the compressor to obtain full pressure in the reservoirs. The closing of the governor contacts energizes the magnet valve of the air compressor contactor to open it and stop the compressor.

When the pressure falls to the cutting-in point for which the governor is adjusted, the governor contacts open, the air compressor contactor closes, and the compressor operates to restore full pressure in the reservoirs.

The control circuit is carried into the train line to provide for operation of compressors on several coupled locomotives in response to the governor on any one of the locomotives. This provision can only be made use of when the coupled locomotives have their main reservoirs inter-connected. If normal operation of coupled locomotives does not call for interconnection of main reservoirs this control circuit is disconnected at the terminal boards.

On the P5a and Modified P5a locomotives the control circuit can be energized also through one of the "A" contacts on the pantograph relay when partially tripped or completely tripped, to open the air compressor contactor. An "IN" interlock on the heater bus contactor which carries this control circuit opens on partial trippings and complete trippings of the pantograph relay to prevent the energizing of air compressor contactors on other coupled locomotives. This provision is necessary only when the coupled locomotives have main reservoirs interconnected and the train line wire in use.

On the GG1 locomotives the control circuit can be energized also through an "OUT" interlock on the heater bus contactor to open the air compressor contactor. This interlock functions to open the air compressor contactor on a partial tripping or complete tripping of the pantograph relay. An "IN" interlock on the heater bus contactor which carries this control circuit opens on partial trippings and complete trippings of the pantograph relay to prevent the energizing of air compressor contactors on other coupled locomotives. This provision is necessary only when the coupled locomotives have main reservoirs interconnected and the train line wire in use.

A tumbler type switch is provided to cut out the governor control circuit. This switch should be closed for locomotives operating singly and also on locomotives operating coupled where main reservoirs are not interconnected nor the train line wire in use. Where the coupled locomotives have their main reservoirs interconnected and the train line wire in use this switch should be closed on one of the coupled locomotives only.

The operating handle on the air compressor contactor provides for manual control of the air compressor in emergencies.

Blowers

The control circuit for the blower contactors is carried through an interlock on the blower bus cutout switch and the "A1" contacts on the pantograph relay. A tumbler type switch is provided for each blower.

On the P5a and Modified P5a locomotives throwing the blower control switch to "ON" position energizes the running contactor and starting contactor. The starting contactor control circuit, however, is carried through contacts on the air relay. The air relay is constructed to open its contacts when the blower comes up to speed, thereby dropping out the starting contactor.

On the GG1 locomotives throwing the blower control switch to "ON" position energizes the main contactor. The main contactor, in closing, energizes the starting contactor. The starting contactor control circuit is carried through contacts on the centrifugal relay. The centrifugal relay is constructed to open its contacts when the blower comes up to speed, thereby dropping out the starting contactor.

The action of the air relay (P5a and Modified P5a locomotives) and the centrifugal relay (GG1 locomotives) is such that when a blower stops due to power interruption on the trolley, or some other cause, the control circuit will be properly set up for starting the blower when power is restored. A second set of contacts on the air relays and centrifugal relays carries the circuit for the indicating lamp at the engineman's position.

When the blower bus cutout switch is opened its interlock opens first and drops out the blower contactors, thereby breaking the load current before the switch opens. The "A1" contacts on the pantograph relay open on a partial tripping or complete tripping to drop out the blower contactors.

Generator

When the blower-generator is started the a. c. charging relay is energized. The a. c. charging relay closes one circuit to excite the generator field from the battery and another circuit to energize the d. c. charging relay from the generator. The d. c. charging relay closes a circuit to energize the generator contactor. The closing of the generator contactor connects the generator for feeding the master control and battery charging systems, and also for self-exciting the generator field.

The voltage regulator connected to the field of the generator functions through the action of its operating mechanism and the tube resistors to maintain the proper field strength for a uniform output voltage.

Lights

(*P5a and Modified P5a Locomotives*)

The lighting transformer switch normally remains in the closed position. The operating coil of the lighting change-over contactor, when energized from the lighting transformer, holds the contactor in "a. c." position to feed the lighting circuits with alternating current. When the operating coil is de-energized the contactor is spring-closed in "d. c." position to feed the lighting circuits with direct current.

When the lights are taking direct current an interlock on the lighting change-over contactor is closed to light an indicating lamp. This indication is provided to guard against use of direct current lighting for long periods with possible discharge of battery resulting.

Cab Signals

The direct current supply for the cab signal equipment is taken from the master control system through the cab signal power switch. A resistor is connected in this circuit to obtain the proper voltage under several conditions. The control cutout and reset switch in "ON" position short-circuits a portion of this resistor. An interlock, closed in the "OUT" position of the generator contactor, short-circuits all of this resistor.

Operation of the cab signal equipment on the locomotive requires closing the cab signal power switch and the cab signal cut-out switch. The cab signal cutout switch is connected in the control circuit for the directional set-up switch.

The code system of continuous cab signals with whistle and acknowledger is an adjunct of the automatic block signal system. Its purpose is to give a continuous indication in the cab of the locomotive, and to sound a warning whistle after a more restrictive indication is given, as well as to provide means for suppressing the sounding of the warning whistle.

Alternating current is supplied to the track rails by the wayside equipment. The code of the track current depends upon the conditions of the track-way in advance. The coded current is transmitted to the locomotive where the master relay selects the proper decoding relays and through a series of contacts, controls the cab signal indications and the magnet valve for the cab signal warning whistle.

The codes used in this system display signals as follows:

180 Interruptions per minute	Clear
120 Interruptions per minute	Approach restricting
80 Interruptions per minute	Approach
Steady current, or absence of current	Caution, slow speed

The energy from the rails is transmitted to the locomotive equipment by induction. The action between the rails and the track receiver may be thought of as a transformer in which the rail acts as the primary and the coil winding as the secondary.

The energy induced in the track receiver is amplified and then passed through the master transformer, to operate the master relay. The direct current for the cab signal indicator lamps, filaments of the vacuum tubes, the decoding relays and acknowledging relays, and dynamotor is taken from the master control system at 32 volts. The direct current for the plate circuits of the vacuum tubes is taken from the dynamotor at 350 volts.

Since the current induced in the track receiver coils is amplified and converted to operate the master relay at code speeds, the master relay repeats the code as furnished by the wayside equipment.

Direct current from the 32 volt supply is coded by the master relay and fed to the decoder. These codes will be the same as those picked up by the track receiver, namely, 180, 120 and 80 interruptions per minute. The decoder circuits are of such tuning that the decoding relays will assume the proper positions for each code, or for no code.

At 180 code the clear indication will be lighted and the warning whistle magnet valve energized, closing the valve. Upon change to 120, 80 or no code, the corresponding indication will be lighted and the warning whistle magnet valve de-energized, sounding the whistles. Closing the acknowledging switch momentarily after any change to more restrictive indication energizes the acknowledging relays which, in closing, form their own holding circuits. The acknowledgment sets up the circuit for energizing the warning whistle magnet valve thereby suppressing the sounding of the whistle. Upon any change to less restrictive indication the whistles do not sound and no acknowledgment is necessary.

The directional setup switch assumes the proper position when the control cutout and reset switch is turned to "ON" position. The train line wires obtain the proper setup of this switch on other coupled locomotives. This switch selects the proper track receiver for the desired direction of movement and energizes the decoder, relays, indicators and warning whistle magnet valve.

The circuits for energizing the amplifier and dynamotor are carried through the control cutout and reset switch in "ON" position. Therefore, when several locomotives are coupled the amplifier and dynamotor of only the leading locomotive are in use. The circuit for acknowledgment is also carried through the control cutout and reset switch in "ON" position. Hence, acknowledgment, even when several locomotives are coupled, can be made only from the position at which the engineman is operating.

When several locomotives are coupled the train line wires carry coded current from the decoder primary of the first locomotive to operate the master relay of the second locomotive, also from the decoder primary of the second locomotive to operate the master relay of the third locomotive and so on, to control the relays of each in turn according to the code picked up by the track receiver on the first locomotive. Thus, the coupled locomotives display the cab signal indications at each of the crew's positions. Upon any change to more restrictive indication the warning whistle magnet valve on each locomotive is de-energized, sounding the whistles. The acknowledging operation on the first locomotive is conveyed by the train line wires to suppress the sounding of whistles on the trailing locomotives.

Sanders

Operation of the sanders requires that the control cutout and reset switch be in "ON" position and the reverse drum of the master controller in "FORWARD" or "REVERSE" position. Pressing the sand pedal closes a circuit to energize the "FORWARD" or "REVERSE" sand magnet valve. The sand magnet valve operates the corresponding sand valves which in turn operate the corresponding sand traps. The sand pedal should be held down to obtain continuous sanding. "Pumping" the sand pedal wastes the air supply and the sand.

Whistle

(P5a Locomotives)

The whistle on P5a locomotives is electro-pneumatically controlled. The pull-switch at the engineman's position closes a circuit to energize the whistle magnet valve, thereby opening the whistle valve.

Traction Motors

The handle for the control cutout and reset switch can be applied or removed only in the "OFF" position of that switch. The reverse lever of the master controller can be applied or removed only in the "OFF" position of the reverse drum, and the reverse drum can be in "OFF" position only when the master controller main drum is in "OFF" position. The master controller main drum cannot be moved from "OFF" position unless the reverse drum is in "FORWARD" or "REVERSE" position. Therefore, the normal position when not in use for the control cutout and reset switch, the master controller main drum and reverse drum, is "OFF" position with the deadman lever released.

At the engineman's operating position the deadman lever should be engaged before turning the control cutout and reset switch to "ON" position. The reverse lever should be moved for the desired direction of movement. The master controller handle can then be moved from the "OFF" position. Care must be exercised to hold the deadman lever engaged either with the hand or by means of the foot valve.

The master controller handle should be advanced but one notch at a time allowing the latch to engage in each notch. When shutting off, the master controller handle should be moved easily without engaging in any notches and care should be taken to insure its return completely to the "OFF" position.

The first notch closes a main transformer tap switch and energizes the reverser magnet valves, throwing the reversers if they are not already set, for the desired direction of movement. When the reverser is in the position for the desired direction of movement the reverser interlock closes a circuit through the motor cutout switch to energize the magnet valves of the motor switches. The circuit for the motor switch magnet valves is carried through contacts on the overload relay, slip relay, and pantograph relay. Therefore, the motor switches cannot be closed, or remain closed, if any of these relays are in tripped position.

The principal function of the master controller, as the handle is advanced from notch to notch, is to increase the motor circuit voltage step by step. See Sequence Table on Plates 7, 8 and 9. This is accomplished by the main drum of the master controller closing in proper sequence circuits which energize magnet valves of the main transformer tap switches. As the switches on the higher voltage taps are energized the switches on the lower voltage taps must be de-energized and the metal segments on the main drum are properly arranged to do this.

The bus structure to which the main transformer tap switches and preventive coils are connected (see Plates 1, 2 and 3) provides four paths for carrying current to the traction motors. This arrangement requires that four main transformer tap switches be closed on each of the advanced notches of the master controller. A short circuit of part of the transformer secondary winding through any one of the four principal bus straps results if two or more switches connected to that bus strap are closed simultaneously. The interlocking of the magnet valve circuits of the main transformer tap switches (see Plates 7, 8 and 9) is arranged so that a switch will be energized only when other switches connected to that bus strap are in the "OUT" position.

On the master controller of the GG1 locomotives, as the handle is advanced to any notch, contacts are closed on the master controller top plate which energize the "buck" switch (23). Raising the main handle breaks these contacts, de-energizing the "buck" switch for the second step in that notch. Lowering the main handle closes other contacts which energize the "boost" switch (24) for the third step in that notch. Thus, three steps of motor voltage are obtained in each notch of the master controller. Use of the "buck" and "boost" notching is optional with the engineman. As the main handle is advanced to the next notch the "buck" position (notching switch 23 energized) is obtained whether the "buck" and "boost" notching is being used or not.

Another function of the master controller is to partially control the shunting of the main fields and interpole fields of the traction motors. These two subjects are treated separately.

After the pantograph relay, overload relays, or slip relays trip, the master controller should be returned to "OFF" position for resetting the relays. The circuit closed by the control cutout and reset switch in "RESET" position is interlocked through a main drum segment of the master controller in the "OFF" position.

Main Field Shunting

(P5a Locomotives)

The voltage across the main fields of traction motors Nos. 1, 2 and 3 in the No. 1 motor circuit (or traction motors 4, 5 and 6 in the No. 2 motor circuit when No. 1 motor circuit is cut out) is impressed on the main field relay transformer which energizes the rotor coils of the main field relay. The stator coils of the main field relay are energized from the secondary taps of the main transformer.

When the master controller main drum is turned to the second notch in starting, the main field relay auxiliary coil is energized through the "AB" contacts of the relay. The auxiliary coil closes the "C" contacts to energize the time delay relay. When the time delay relay has picked up, its "IN" interlock closes the circuit to energize the main field shunting switches. The closing of these switches by-passes part of the traction motor current around the main fields and through the main field shunting reactors.

As the speed of the locomotive approaches 10 m. p. h., the "D" contacts of the main field relay close the circuit for the field changeover indicating lamp. At a slightly greater speed the "AB" contacts open, de-energizing the auxiliary coil. The "C" contacts thus opened, de-energize the time delay relay. The time delay relay in dropping out de-energizes the main field shunting switches, thus restoring full field strength to the traction motors. The "IN" interlock on the main field shunting switch that carries the circuit for the field changeover indicating lamp opens to extinguish the light.

Satisfactory commutation of the traction motors below the sixteenth notch requires also that the weak field connection be re-established as the speed of the locomotive decreases below 10 m. p. h. with power still applied. As the speed decreases, the "AB" contacts of the main field relay close, energizing the auxiliary coil. The "C" contacts close to energize the time delay relay. When the time delay relay has picked up, its "IN" interlock closes the circuit to energize the main field shunting switches, thus re-establishing the weak field connection.

If the main field shunting switches have not been opened by the main field relay operation before the sixteenth notch is taken, they will then be de-energized from the master controller, thus restoring full field strength to the traction motors.

When the "AB" and "C" contacts of the main field relay are closed, the time delay relay is energized on notches 2 to 15, inclusive. The time delay relay causes a momentary delay in the closing of the main field shunting switches after the second notch is taken. The purpose of the delayed action is explained as follows: If the locomotive is drifting faster than the 10 m. p. h. speed required to operate the main field relay, and the master controller main drum is turned from the "OFF" position to the second notch, or beyond, the main field relay may not have sufficient time to open its "AB" contacts before its "C" contacts close. The delay in the pick-up of the time delay relay postpones the energizing of the main field shunting switches which, for these conditions, allows sufficient time that the main field relay will open its "AB" and "C" contacts, thereby de-energizing the time delay relay and forestalling the undesired closing of the main field shunting switches.

So that the engineman can avoid taking a notch at, or about, the same instant that the main field shunting switches open (which might cause an excessive increase in tractive effort), a field changeover indicating lamp is lighted through the "D" contacts on the relay. This indicates to the engineman that the changeover from weak field to full field is about to occur. He should not advance the master controller main drum until the changeover has occurred. When the main field shunting switches open, an "IN" interlock on one of them breaks the circuit to extinguish the light, indicating that the changeover has occurred.

Main Field Shunting

(Modified P5a Locomotives)

The voltage across the armature of No. 2 traction motor (or the armature of No. 5 traction motor if the No. 1 motor circuit is cut out) is impressed on the main coils of the voltage relay through its "D" contacts.

When the master controller main drum is turned to the second notch in starting, the time delay relay is energized through the "C" contacts on the voltage relay. When the time delay relay has picked up, its "IN" interlock closes the circuit to energize the main field shunting switches. The closing of these switches by-passes part of the traction motor current around the main fields and through the main field shunting reactors.

When the voltage of the armature approaches the adjusted operating point of the relay, the "A" contacts close the circuit for the field changeover indicating lamp. At the operating point of the relay, the "B" contacts close and the "C" contacts open simultaneously. On notches 6 to 20, inclusive, the closed "B" contacts energize the holding coil of the relay to hold the relay in the energized position, also to open the "D" contacts. The opening of the "D" contacts breaks the circuit to the main coils of the relay thereby protecting them from excessive current as the voltage of the armature increases. The opening of the "C" contacts de-energizes the time delay relay. The time delay relay in dropping out de-energizes the main field shunting switches, thus restoring full field strength to the traction motors. The "IN" interlock on the main field shunting switch that carries the circuit for the field changeover indicating lamp opens to extinguish the light.

Satisfactory commutation of the traction motors below the sixth notch requires also that the weak field connection be re-established as the voltage of the armature decreases below the operating point of the voltage relay with power still applied. For a given traction motor current and speed, the voltage of the armature in weak field connection is about 80 per cent of what it would be in full field connection. Therefore, it requires a high drop-out point to enable the relay to drop out at the same conditions of traction motor current and speed as it picked up. The auxiliary coil is energized from the master controller on notches 4 to 6 inclusive, through an "OUT" interlock on one of the main field shunting switches. The auxiliary coil energized, opens the "E" contacts inserting resistance in series with the main coils to obtain the high drop-out point. When the relay is in the picked-up position, however, the "D" contacts are open in the sixth notch and beyond; therefore, the high drop-out feature is obtained only in notches 4 and 5. Below the sixth notch the holding coil is de-energized from the master controller, thus "unlocking" the relay. De-energizing the holding coil closes the "D" contacts, thereby restoring voltage on the main coils of the relay. As the voltage of the armature decreases, the "C" contacts close and the "B" contacts open simultaneously. The "C" contacts energize the time delay relay. When the time delay relay has picked up, its "IN" interlock closes the circuit to energize the main field shunting switches, thus re-establishing the weak field connection.

If the main field shunting switches have not been opened by the voltage relay operation before the sixteenth notch is taken, they will then be de-energized from the master controller, thus restoring full field strength to the traction motors.

When the "C" contacts of the voltage relay are closed, the time delay relay is energized on notches 2 to 15, inclusive. The time delay relay causes a momentary delay in the closing of the main field shunting switches after the second notch is taken. The purpose of the delayed action is explained as follows: If the locomotive is drifting when the master controller main drum is turned from the "OFF' position to the second notch, or beyond, the voltage of the armature may be sufficient to operate the voltage relay but there may be not sufficient time for the "C" contacts to open before the second notch is taken. The delay in the pick-up of the time delay relay postpones the energizing of the main field shunting switches, which, for these conditions, allows sufficient time that the voltage relay will open its "C" contacts thereby de-energizing the time delay relay and forestalling the undesired closing of the main field shunting switches.

So that the engineman can avoid taking a notch at, or about, the same instant that the main field shunting switches open (which might cause an excessive increase in tractive effort) a field changeover indicating lamp is lighted through the "A" contacts on the relay. This indicates to the engineman that the changeover from weak field to full field is about to occur. He should not advance the master controller main drum until the changeover has occurred. When the main field shunting switches open, an "IN" interlock on one of them breaks the circuit to extinguish the light, indicating that the changeover has occurred.

Main Field Shunting

(GG1 Locomotives)

The voltage across the main fields of traction motors Nos. 1, 2, 3 and 4 in the No. 1 motor circuit (or the traction motors of either No. 2 motor circuit or No. 3 motor circuit when others are cut out) is impressed on the main field relay transformer which energizes the rotor coils of the main field relay. The stator coils of the main field relay are energized from the secondary taps of the main transformer.

When the master controller main drum is moved to the second notch in starting, the main field relay auxiliary coil is energized through the "AB" contacts of the relay. The auxiliary coil closes the "C" contacts to energize the time delay relay. When the time delay relay has picked up, its "IN" interlock closes the circuit to energize the main field shunting switches. The closing of these switches by-passes part of the traction motor current around the main fields and through the main field shunting reactors. An "IN" interlock on one of the main field shunting switches closes the circuit for the field changeover indicating lamp.

As the speed of the locomotive approaches 15 m. p. h., the "AB" contacts open, de-energizing the auxiliary coil. The "C" contacts, thus opened, de-energize the time delay relay. The time delay relay in dropping out de-energizes the main field shunting switches, thus restoring full field strength to the traction motors. The "IN" interlock on the main field shunting switch that carries the circuit for the field changeover indicating lamp opens to extinguish the light.

Satisfactory commutation of the traction motors below the fifteenth notch requires also that the weak field connection be re-established as the speed of the locomotive decreases below 15 m. p. h. with power still applied. As the speed decreases, the "AB" contacts of the main field relay close, energizing the auxiliary coil. The "C" contacts close to energize the time delay relay. When the time delay relay has picked up, its "IN" interlock closes the circuit to energize the main field shunting switches, thus re-establishing the weak field connection.

If the main field shunting switches have not been opened by the main field relay operation before the fifteenth notch is taken, they will then be de-energized from the master controller, thus restoring full field strength to the traction motors.

When the "AB" and "C" contacts of the main field relay are closed, the time delay relay is energized on notches 2 to 14, inclusive. The time delay relay causes a momentary delay in the closing of the main field shunting switches after the second notch is taken. The purpose of the delayed action is explained as follows: If the locomotive is drifting faster than the 15 m. p. h. speed required to operate the main field relay, and the master controller main drum is moved from the "OFF" position to the second notch, or beyond, the main field relay may not have sufficient time to open its "AB" contacts before its "C" contacts close. The delay in the pick-up of the time delay relay postpones the energizing of the main field shunting switches which, for these conditions, allows sufficient time that the main field relay will open its "AB" and "C" contacts, thereby de-energizing the time delay relay and forestalling the undesired closing of the main field shunting switches.

So that the engineman can observe the operation of the main field shunting switches a field changeover indicating lamp is lighted through an "IN" interlock on one of the switches. This indicates to the engineman that the weak field connection is established. When the main field shunting switches open, the "IN" interlock breaks the circuit to extinguish the light, indicating that the full field connection is established.

Interpole Field Shunting

(P5a and Modified P5a Locomotives)

The voltage across the armature of No. 2 traction motor (or No. 5 traction motor if the No. 1 motor circuit is cut out) is impressed on the voltage coils of the intermediate speed relay and the high speed relay. The voltage across the main fields of traction motors Nos. 1, 2 and 3 (or traction motors Nos. 4, 5 and 6 if the No. 1 motor circuit is cut out) is impressed on the current coil circuit of the speed relays. The voltages across the double secondary winding of the speed relay transformer are impressed on the compensating coils of the speed relays.

When the speed of the locomotive is in the "low" range (standstill to 44 m. p. h., approximately) both speed relays are in "low" position. In the "intermediate" range (approximately 44 m. p. h. to 66 m. p. h.), the high speed relay is still in "low" position but the intermediate speed relay is in "high" position. In the "high" range (above 66 m. p. h.), both speed relays are in "high" position.

The interpole fields are shunted at all times. However, double-acting switches are used to change the characteristics of the shunt circuits as the speed changes. In the "low" range of speed, switches 25, 26, 29 and 30 should be energized; switches 27, 28, 31 and 32 should be de-energized. In the "intermediate" range of speed, all of the aforementioned switches should be de-energized. In the "high" range of speed switches 25, 26, 29 and 30 should be de-energized; switches 27, 28, 31 and 32 should be energized.

When the master controller main drum is moved to second notch in starting, the intermediate speed relay in "low" position energizes the intermediate speed auxiliary relay. The double-acting contact of the latter closes to energize the interpole field shunting switches 25, 26, 29 and 30. The single-acting contact of the intermediate speed auxiliary relay closes to establish its holding circuit. The energizing of switches 25, 26, 29 and 30 short-circuits some reactance portions while switches 27, 28, 31 and 32 in the de-energized position short-circuit other reactance portions of the interpole field shunt circuits. Part of the traction motor current then by-passes around the interpole fields, through resistance shunt circuits adapted to the "low" range of speed.

When the locomotive speed has increased to the "intermediate" range the intermediate speed relay in "high" position de-energizes the intermediate speed auxiliary relay. The double-acting contact of the latter opens and switches 25, 26, 29 and 30 will be de-energized unless the main field changeover has not yet taken place. The single-acting contact of the intermediate speed auxiliary relay opens the holding circuit. The de-energizing of switches 25, 26, 29 and 30 short-circuits some resistance portions while switches 27, 28, 31 and 32, also in the de-energized position, short-circuit some reactance portions of the interpole field shunt circuits. Part of the traction motor current then by-passes around the interpole fields through resistance-reactance shunt circuits adapted to the "intermediate" range of speed.

When the locomotive speed has increased to the "high" range, the high speed relay in "high" position energizes the high speed auxiliary relay. The double-acting contact of the latter closes to energize the interpole field shunting switches 27, 28, 31 and 32. The single-acting contact of the high speed auxiliary relay closes to establish its holding circuit. The energizing of switches 27, 28, 31 and 32 short-circuits some resistance portions while switches 25, 26, 29 and 30 in the de-energized position short-circuit other resistance portions of the interpole field shunt circuits. Part of the traction motor current then by-passes around the interpole fields, through resistance-reactance shunt circuits adapted to the "high" range of speed.

"OUT" interlocks on switches 25, 26, 29 and 30 are connected so that switches 27, 28, 31 and 32 cannot be energized while switches 25, 26, 29 and 30 are energized.

When switch 27 is energized, its "OUT" interlock opens, inserting additional resistance in the voltage coil circuit of the intermediate speed relay. This is necessary to protect that voltage coil from the high voltage obtained at high speed.

Satisfactory commutation of the traction motors requires also that the proper interpole shunting be provided as the speed decreases while power is still applied. When switch 28 is energized, its "OUT" interlock opens, inserting additional resistance in the voltage coil circuit of the high speed relay to produce "drop-out" of that relay at approximately the same speed as the "pull-in." When the locomotive speed has decreased to the "intermediate" range the high speed relay in "low" position de-energizes the high speed auxiliary relay. The double-acting contact of the latter opens to de-energize switches 27, 28, 31 and 32. The single-acting contact of the high speed auxiliary relay opens the holding circuit. When switch 25 is de-energized its "IN" interlock is open, inserting additional resistance in the voltage coil circuit of the intermediate speed relay to produce "drop-out" of that relay at approximately the same speed as the "pull-in."

When the locomotive speed has decreased to the "low" range, the intermediate speed relay in "low" position energizes the intermediate speed auxiliary relay. The double-acting contact of the latter closes to energize switches 25, 26, 29 and 30. The single-acting contact of the intermediate speed auxiliary relay closes the holding circuit.

When accelerating a train, if switches 25, 26, 29 and 30 have not been de-energized by the intermediate speed relay operation before the sixteenth notch is taken, they will then be de-energized from the master controller, thus transferring from the "low" range shunting to the intermediate range shunting. If switches 27, 28, 31 and 32 have not been energized by the high speed relay operation before the nineteenth notch is taken they will then be energized from the master controller, thus transferring from the "intermediate" range shunting to the "high" range shunting.

When accelerating a train, if switches 25, 26, 29 and 30 are not energized by the operation of the intermediate speed relay and its auxiliary relay, they will be energized through the main field relay and the time delay relay (on P5a locomotives). (On the Modified P5a locomotive the same action is accomplished by the voltage relay and the time delay relay). By the same action, switches 25, 26, 29 and 30 will not be de-energized until the main field changeover has occurred.

The intermediate speed auxiliary relay and the high speed auxiliary relay, by virtue of their time increment in closing and opening, function to prevent pumping of the interpole field shunting switches when the speed relays are near their respective balance points. In addition to this, the auxiliary relays make and break the circuit for the magnet valves of the interpole field shunting switches, thus relieving the contacts of the speed relays from this duty.

Interpole Field Shunting

(GG1 Locomotives)

The voltage across the armatures and compensating fields of Nos. 1 and 2 traction motors in the No. 1 motor circuit (or traction motors of either No. 2 motor circuit or No. 3 motor circuit when others are cut out) is impressed on the coils of the interpole field relay.

The interpole fields are shunted at all times. However, double-acting switches are used to change the characteristics of the shunt circuits as the voltage changes. In the "low" range (such as exists when starting a train) switches 25, 26 and 27 should be de-energized. In the "high" range these switches should be energized.

When the master controller main drum is moved to first notch in starting, the interpole field relay in "low" position keeps the auxiliary coil de-energized and therefore switches 25, 26 and 27 will not be energized. In the de-energized position, these switches short-circuit the reactance portions of the interpole field shunt circuits. Part of the traction motor current then by-passes around the interpole fields, through resistance shunt circuits adapted to the low range.

When the voltage increases to the adjusted operating point of the interpole field relay, its "high" position contacts close to energize the auxiliary coil. One set of auxiliary contacts energize the interpole field shunting switches 25, 26 and 27; the other set of auxiliary contacts establish the holding circuit for the auxiliary coil. The energizing of switches 25, 26 and 27 short circuits part of the resistance portions of the interpole field shunt circuits. Part of the traction motor current then by-passes around the interpole fields, through resistance-reactance shunt circuits adapted to the high range.

Satisfactory commutation of the traction motors requires also that the proper interpole field shunting be provided as the speed decreases while power is still applied. When the speed has decreased to the operating point of the interpole field relay, its "low" position contacts close to short circuit the auxiliary coil and open the auxiliary contacts. One set of auxiliary contacts opens to de-energize switches 25, 26 and 27; the other set opens the auxiliary coil holding circuit.

The auxiliary coil and contacts function to prevent pumping of the interpole field shunting switches when the interpole field relay is near its operating point. In addition to this, the auxiliary contacts make and break the circuit for the magnet valves of the interpole field shunting switches, thus relieving the main contacts of the interpole field relay from this duty.

Heaters

The control circuit for the heater bus contactor is an extension of the control circuit for the blower contactors on the P5a and Modified P5a locomotives and is therefore carried through the interlock on the blower bus cutout switch and the "A1" contacts on the pantograph relay. On the GG1 locomotives the control circuit is carried through the "A1" contacts on the pantograph relay. The cab heaters are controlled by rotary type snap switches.

Boiler Blower

Closing the boiler blower knife switch energizes the running winding of the motor and the starting contactor. The starting contactor control circuit however is carried through contacts on the air relay. The air relay is constructed to open its contacts when the blower comes up to speed, thereby dropping out the starting contactor.

The action of the air relay is such that when a blower stops due to power interruption on the trolley, or some other cause, the control circuit will be properly set up for starting the blower when power is restored.

Air Brake Apparatus

Motion of trains is retarded or stopped by forcing brake shoes against the treads of the wheels. Force is transmitted to the brake shoes from the air brake cylinders by a system of rods and levers. The locomotive is equipped to supply the compressed air and to place the control of the train and locomotive brakes in the hands of the engineman.

The locomotive brakes may be used with or independently of the train brakes, without regard to the position of the locomotive in the train.

The locomotive brakes may be applied with any desired pressure between the minimum and the maximum, and this pressure will be automatically maintained in the locomotive brake cylinders regardless of ordinary leakage from them and of variation in piston travel, undesirable though these defects are, until released by the brake valve.

The locomotive brakes can be graduated on and off with either the automatic or independent brake valves; hence, in all kinds of service the train may be handled without shock or danger of parting, and in passenger service, smooth, accurate stops can be made.

It is always possible to release the locomotive brakes with the independent brake valve, even when automatically applied.

NO. 8-EL BRAKE EQUIPMENT

The No. 8-EL brake equipment, Plates 21 and 22, makes use of the K-6-KPD pedestal brake valve and the No. 8 distributing valve. It operates on the same basic principle as the No. 6-ET equipment used on steam locomotives, but it provides certain modifications and added features which are, briefly, as follows:

(a) Increased capacity of distributing valve.

(b) Synchronization of locomotive with train brakes in service application.

(c) Automatic brake operation affected only by the loss of the emergency maintaining feature with the application pipe broken.

(d) Automatic brake operation not affected by breakage of the independent release pipe.

(e) Brake failure due to broken pipes made remote by use of reinforced pipe fittings on principal devices.

(f) Brake operation not affected by location of distributing valve.

(g) Possibility of distributing valve pressure chamber overcharge greatly reduced, and therefore, undesired re-application of locomotive brakes minimized.

(h) More uniform brake action, both application and release, through modification of distributing valve equalizing piston and slide valve.

(i) Equalizing piston ring leakage has less effect on dependable operation.

(j) Distributing valve application portion improvements reduce maintenance, and greatly increase the sensitiveness and accuracy of its function.

(k) Emergency application always available even though the brake pipe cutout cock (double heading cock) on the brake valve pedestal is closed.

(l) Dead engine feature incorporated with the distributing valve.

(m) Effective dust protection for distributing valve.

(n) Safety valve mounted in more protected position on distributing valve.

(o) Distributing valve construction provides for drainage of moisture.

NO. 8A-EL BRAKE EQUIPMENT

The No. 8A-EL brake equipment, Plate 23, makes use of the K-8-PA pedestal brake valve and the No. 8-A distributing valve. It operates on the same basic principle as the No. 6-ET equipment also, but it provides all of the modifications and added features of the No. 8-EL equipment and certain other modifications and added features which are, briefly, as follows:

(a) Synchronization of locomotive with train brakes in emergency applications and the maximum locomotive brake cylinder pressure varied in accordance with the service in which the locomotive is used.

The Delay Cock, Fig. 73, in delay position, "F," and a choke in the distributing valve function to delay the build-up and reduce the maximum pressure obtained in the locomotive brake cylinders. The Delay Cock in non-delay position, "P," functions to produce the usual rapid build-up in the locomotive brake cylinders.

(b) Brake pipe service reduction automatically controlled to produce uniform reduction in all parts of the train.

First Service Position Cutout Cock (in the open position "IN") and choke *120* in the pedestal brake valve, Fig. 63, function in First Service position with the reduction limiting reservoir to produce an initial normal service rate, followed by a slower rate of brake pipe reduction. A maintaining valve in the pedestal brake valve functions in First Service position to assure that the normal service rate of reduction is not exceeded.

(c) Recharge of the distributing valve pressure chamber varied in accordance with the service in which the locomotive is used.

The Retarded Recharge Cock, Fig. 73, in the closed position, "F," and a choke in the distributing valve function to retard the recharging of the pressure chamber. The Retarded Recharge Cock in the open position, "P," and a by-pass choke in the distributing valve function to provide a faster rate of recharging the pressure chamber.

Since the No. 8-EL and the No. 8A-EL brake equipments are similar in most respects, no further reference will be made to the No. 8-EL brake equipment. Following hereafter is a description of the No. 8A-EL brake equipment.

The principal parts of the air brake apparatus are listed as follows:

(a) A motor driven air compressor with suction strainer supplies the compressed air for use in the brake system.

(b) Two or more main reservoirs store and cool the compressed air.

(c) A compressor governor controls compressor operation and regulates the air pressure maintained in the main reservoirs.

(d) A pedestal at the engineman's position carries the following:

(1) An automatic brake valve to control the operation of the train and locomotive brakes.

(2) An independent brake valve to control the operation of the independent brake on the locomotive.

(3) A feed valve which automatically maintains a predetermined normal air pressure in the brake system.

(4) A reducing valve which reduces main reservoir pressure for independent brake operation and supplies air for the air signal system.

(5) An equalizing discharge valve which functions to reduce brake pipe pressure at the proper rate regardless of the train length (with the automatic brake valve in Service position) and provides a relatively uniform reduction of brake pipe pressure through a long train with maximum permissible brake pipe leakage (with the automatic brake valve in First Service position).

(6) An emergency relay vent valve which provides that an emergency rate of brake pipe reduction may be obtained with the automatic brake valve under all operating conditions.

(7) A signal line fixture consisting of check valve, strainer and choke, supplying air from the reducing valve to the air signal system.

(8) A double-heading cock by means of which the automatic brake valve is cut out when not in use.

(9) A First Service position cutout cock which is used to cut out the First Service position of the automatic brake valve when desired.

(e) A combined equalizing and reduction limiting reservoir is used with the equalizing discharge valve to provide proper functioning of this device.

(f) Two duplex air gauges are mounted at the engineman's position; one indicates equalizing reservoir and main reservoir pressures, the other indicates brake pipe and locomotive brake cylinder pressures.

(g) A distributing valve, when actuated by the brake valves, operates to (a) permit air to flow into the brake cylinders; (b) maintain any desired pressure in the brake cylinders; (c) permit the air pressure to exhaust from the brake cylinders.

(h) A brake pipe vent valve insures the transmission of quick action originating on the locomotive to the train, and vice versa.

(i) Driver and truck brake cylinders have their pistons and rods so connected through the brake levers to the brake shoes that when the pistons are forced outward by air pressure this force is transmitted through the rods and levers to the brake shoes and applies them to the wheels.

(j) Three centrifugal dirt collectors are used to prevent the entrance of dirt and moisture to the distributing valve and the feed and reducing valves.

The principal pipes of the air brake system are listed as follows:

Discharge Pipe: Connects the air compressor to the first main reservoir.

Connecting Pipe: Connects the two or more main reservoirs. (Note: These pipes are also known as radiating pipes).

Main Reservoir Pipe: Connects the last main reservoir to the brake valve pedestals and to the distributing valve.

Governor Pipe: Connects the main reservoir pipe to the air compressor governor.

Brake Pipe: Connects the brake valve pedestals to the distributing valve and all triple valves or universal valves on the cars in the train.

Brake Cylinder Pipe: Connects the distributing valve to the driver and truck brake cylinders.

Application Pipe: Connects the distributing valve to the brake valve pedestals.

Independent Release Pipe: Connects the distributing valve to the brake valve pedestals.

Equalizing Reservoir Pipe: Connects the equalizing reservoir to the brake valve pedestal.

Reduction Limiting Reservoir Pipe: Connects the reduction limiting reservoir to the brake valve pedestal.

Signal Pipe: Connects reducing valve pressure from the brake valve pedestal to the air signal system.

Air Compressor

The air compressor, Figs. 59, 60 and 61, is of the cross compound double-acting type. On an extension of the armature shaft of the motor is the worm which engages the gear wheel on the compressor crank shaft. Connecting rods and crossheads transmit the force from the crank shaft to the piston rods.

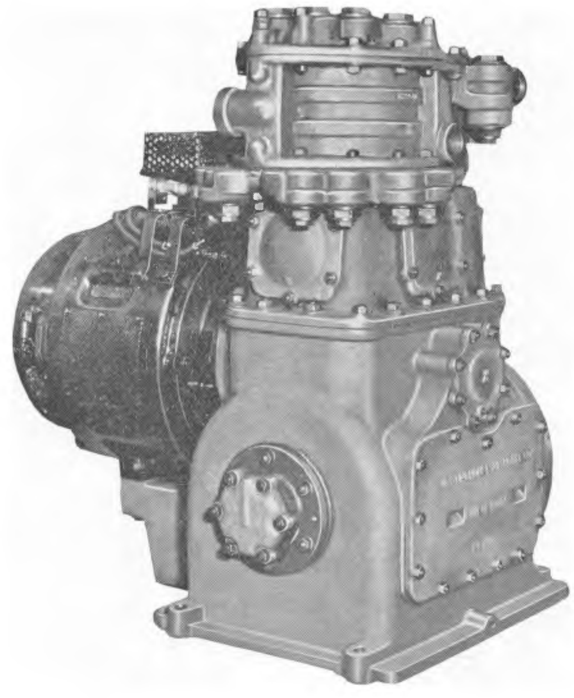


Fig. 59. CA-150 Air Compressor

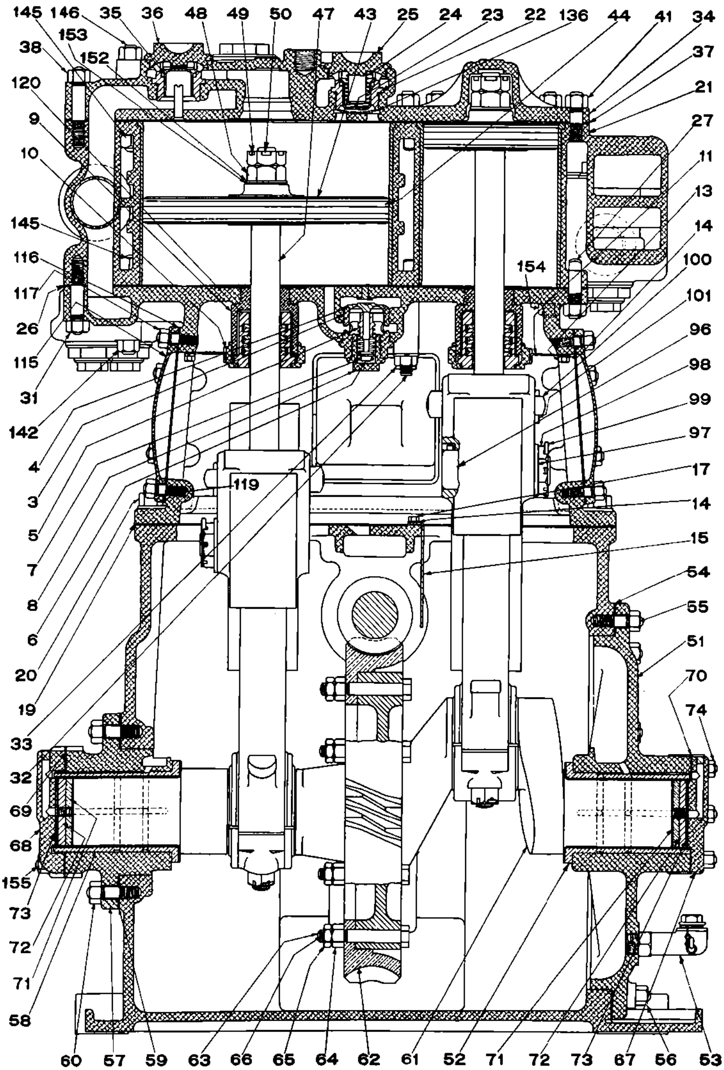


Fig. 60. CA-150 Air Compressor, Section Through Air Cylinders and Crank Shaft Main Bearings

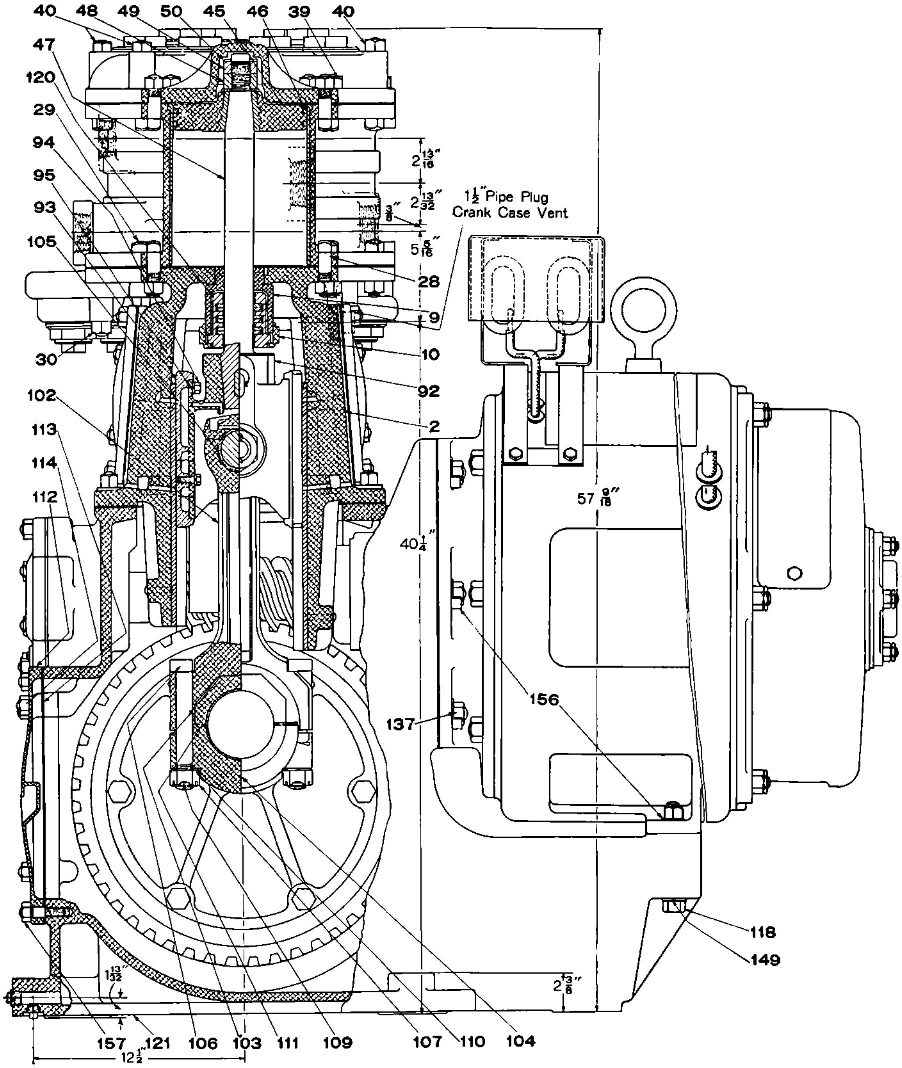


Fig. 61. CA-150 Air Compressor, Section Through the High Pressure Cylinder Showing Crosshead and Connecting Rod Details

The end of the air intake pipe is fitted with a strainer which excludes dirt and other foreign matter from the compressor inlet.

There is a total of 24 valves, 12 for the top of the two cylinders and 12 for the bottom ends. These are arranged as eight low pressure inlet valves, eight low pressure discharge valves, four high pressure inlet valves, and four high pressure discharge valves. An intercooler is connected between the low pressure and high pressure cylinders. A pop safety valve in the high pressure inlet pipe protects the intercooler against excessive pressure. Another safety valve in the discharge pipe protects against excessive main reservoir pressure.

Main Reservoirs

One type of main reservoir is a cavity in the bed frame casting of the locomotive. Rolled steel reservoirs of the demountable type are also used. Each reservoir is provided with a drain cock by means of which all residue may be drawn off at frequent intervals, as water or oil collecting will soon materially decrease the air storage capacity.

Air Compressor Governor

The air compressor governor is an air-operated electric switch designed to cut in and cut out at predetermined pressures. It controls the operation of the air compressor contactor so that the motor driven air compressor will maintain the main reservoir pressure between these limits.

Referring to Fig. 62, with the compressor in operation and main reservoir pressure building up, main reservoir pressure is delivered to the face of the cutout valve *38*, also to the underside of the tail valve *43* of the cut-in valve *39*, by way of the main reservoir pipe connection, passage *r*, chamber *A*, through strainer *49* to passages *a* and *q*.

(*Cutting Out*)

The main reservoir pressure building up against the face of cutout valve *38* eventually becomes sufficiently high to overcome the tension of the cutout 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

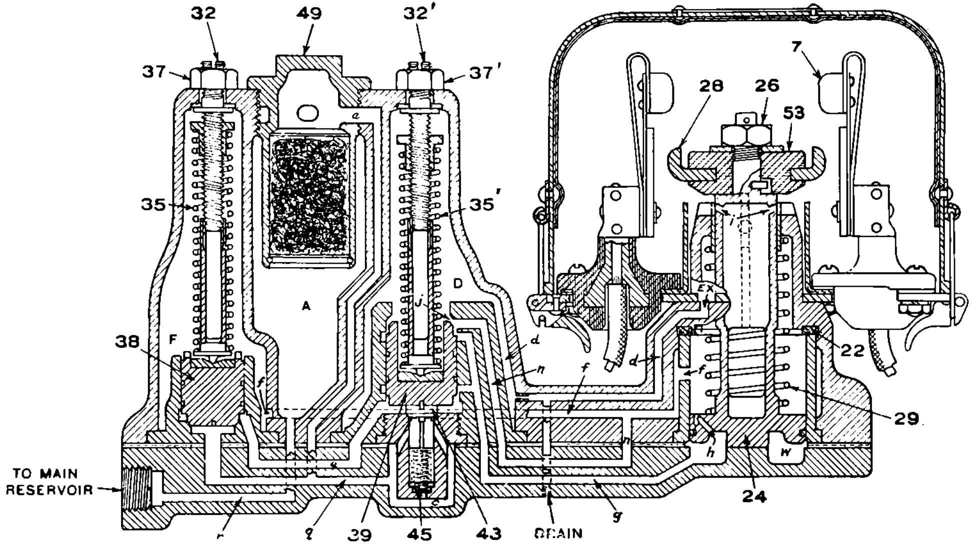


Fig. 62. S-16-B Air Compressor Governor, Diagrammatic View in Cut-in Position

pressure by way of 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 *39* 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 closing the curcuit which is made through the switch piston spider *53* and the contact fingers *7* and, at the same time, the main reservoir pressure which is supplied to the opposite side of piston *24* through port *h* in the piston and into the hollow piston stem, will be forced out through ports *i*, these ports being partially uncovered by the initial movement of the piston and fully opened at the time when the circuit is closed through spider *53* and the finger contacts *7*.

As the switch piston completes its full travel toward the cut-out position, the piston will seat against piston seal *22*, thereby preventing further loss of main reservoir pressure through port *h* and, by the same movement of the piston, main reservoir pressure will be connected to the cutout regulating spring chamber *F* through port *f*, resulting in equalizing the air pressure on each side of cutout valve *38*, whereupon the tension of the regulating spring *35* will then move the cutout valve to its seat.

After cutout 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* which is unseated by its spring *45*, and through port *g* to chamber *W*. The switch piston remains in the cutout 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'*.

(*Cutting In*)

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, seating the tail valve *43* against the tension of 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*.

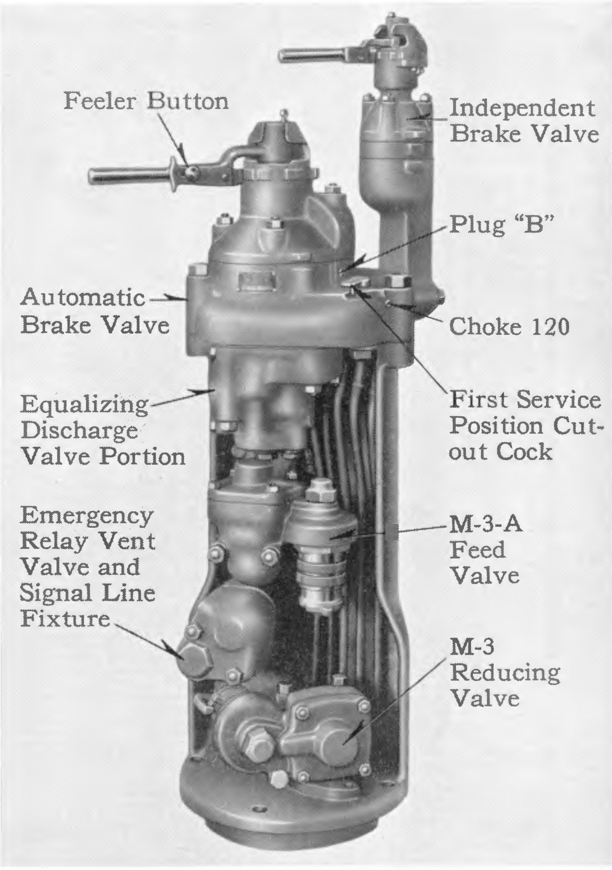


Fig. 63. K-8-PA Pedestal Brake Valve

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 cutout regulating spring chamber *F* and the atmosphere, through passages *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 cutout 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.

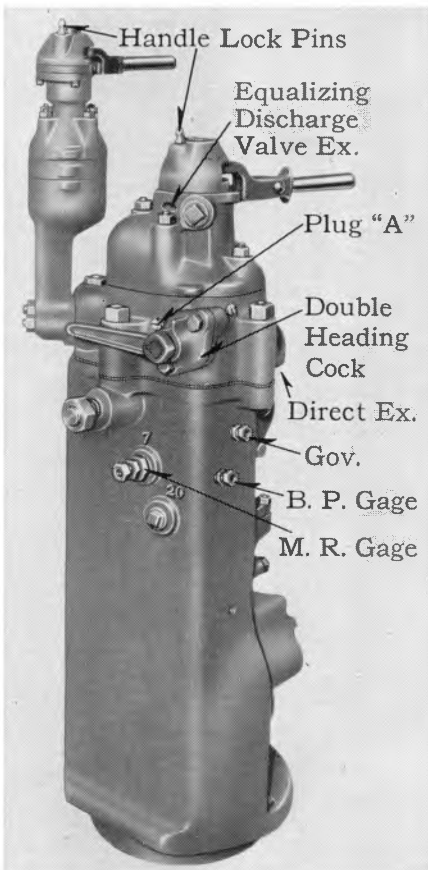


Fig. 64. Rear View of the K-8-PA Pedestal Brake Valve

As the exhaust port *Ex* opens into the switch portion under the cover, the venting of main reservoir pressure through this port during the cutting-in operation insures the discharge of all copper gases from the cover.

(Adjustment)

Loosen check nuts *37* and *37'* and screw cutout 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 or to decrease the range and back it off to lower the cutting-in point or to increase the range.

Pedestal Brake Valve

Located on the pedestal are the following portions:

Automatic Brake Valve portion.
Independent Brake Valve portion.
Equalizing Discharge Valve portion.
Feed Valve.
Reducing Valve.
Combined Emergency Relay Vent Valve and Signal Line Fixture.

AUTOMATIC BRAKE VALVE PORTION

The automatic brake valve portion is attached to the top of the pedestal, as shown by Fig. 65. Automatic brakes are controlled by handle *113*, which has six positions, shown by Fig. 66. Movement of the handle is transmitted through key *105* (Fig. 65) to the rotary valve *112* which is thereby rotated to establish port connections according to its position.

The six brake valve handle positions are, from left to right: Release, Running, First Service, Lap, Service, Emergency. The handle-off position is Lap.

The port connections as controlled by the rotary valve are shown in Fig. 67, and are explained for each handle position under "Operation of Air Brake Apparatus."

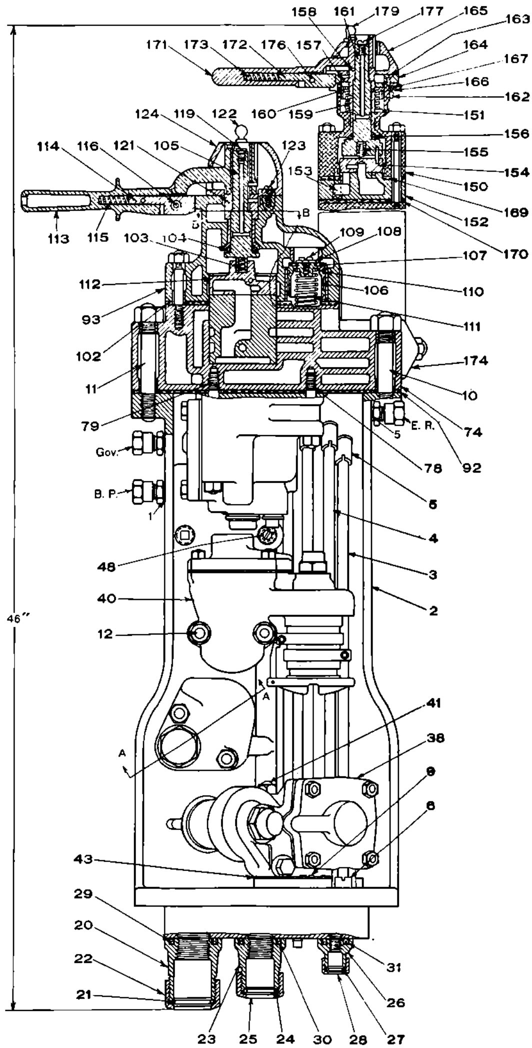


Fig. 65. Sectional Assembly View of the K-8-PA Pedestal Brake Valve

The brake valve handle has a Feeler Button, Fig. 63, which moves in and out as the latch passes over the quadrant shoulders and notches during handle movement. It falls naturally under the engineman's hand so that he can "feel" the handle position from its movement. A feeler button on both sides of the handle provides for either right or left hand operation.

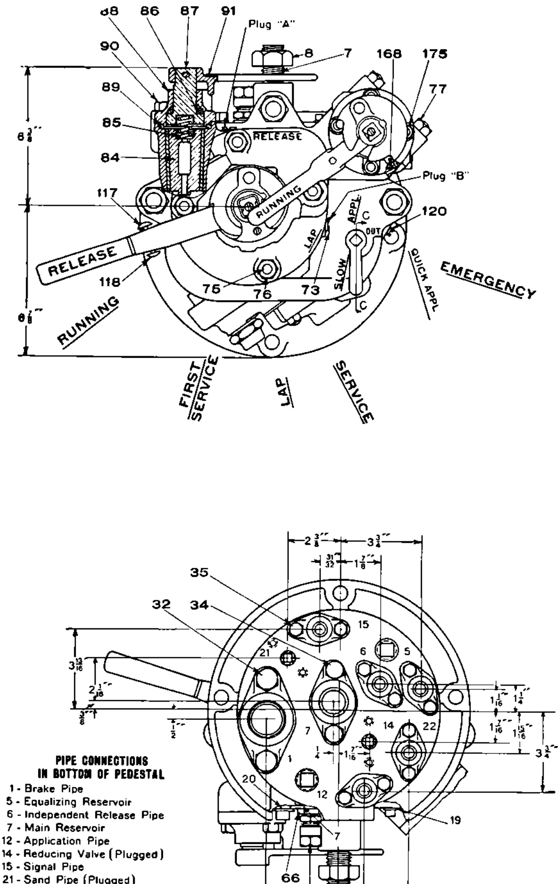


Fig. 66. Top and Bottom Views of the K-8-PA Pedestal Brake Valve

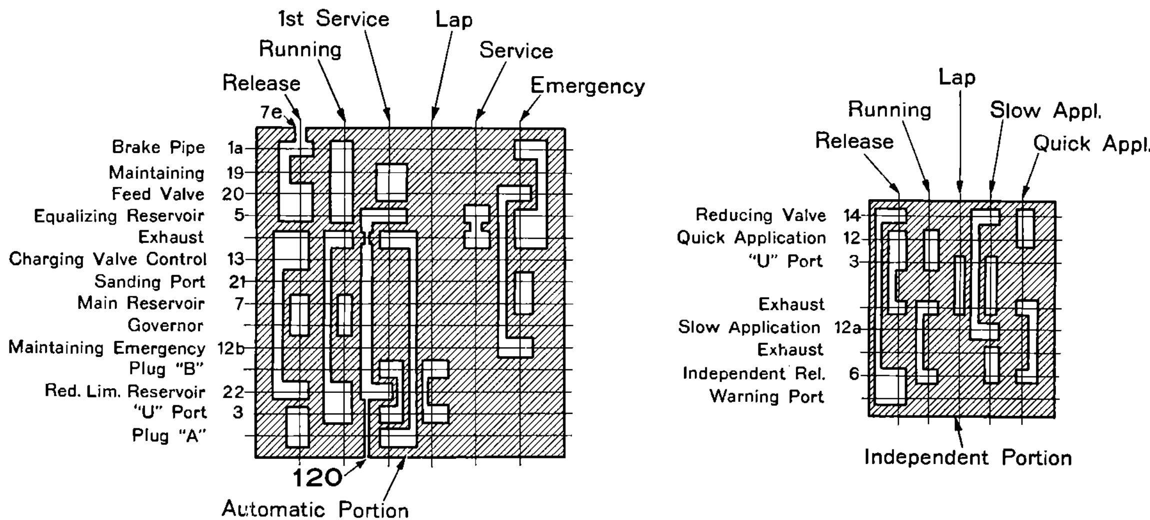


Fig. 67. Position Diagram of the K-8-PA Pedestal Brake Valve

Charging valve *106*, Fig. 65, supplies main reservoir air for rapid charging of the brake pipe in Release Position.

Choke *120*, Fig. 66, controls the rate of equalizing reservoir reduction in First Service Position.

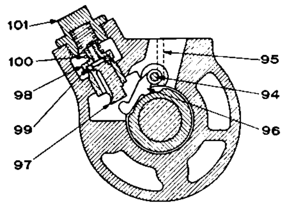


Fig. 68. Sectional View Showing Exhaust Valve Pawl

Exhaust valve pawl *96*, Fig. 68 (which is section B-B of Fig. 65), is operated by a cam on the rotary valve key which raises the pawl in First Service, Service, Lap and Emergency positions. The pawl, in turn, unseats Exhaust Valve *97* opening the brake valve exhaust. In the remaining positions spring *100* holds the exhaust valve seated and the exhaust closed.

EQUALIZING DISCHARGE VALVE PORTION

The equalizing discharge valve portion is attached to the underside of the automatic brake valve. Its function is to control the rate of brake pipe reduction in First Service and Service positions of the brake valve handle. The chamber above equalizing piston *126*, Fig. 69, is connected to the equalizing reservoir; the chamber beneath it to brake pipe pressure. In Release and Running positions of the brake valve handle both chambers charge equally so that the piston and its operating lever *136* are balanced and spring *134* holds discharge valve *130* seated, closing the brake valve exhaust. When the brake valve handle is moved to Service position, pressure above the piston and in the equalizing reservoir is reduced through the preliminary exhaust port of the automatic brake valve. Brake pipe pressure in the lower chamber then raises the piston; operating lever *136* is carried with it, the short end of the lever rotating around pin *137*, thereby engaging collar *129* and unseating discharge valve *130*, past which brake pipe air escapes to the brake valve exhaust. When the brake pipe

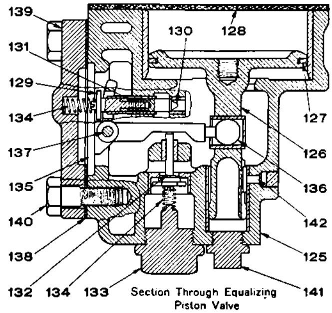


Fig. 69. Sectional View of the Equalizing Discharge Valve Portion

reduction equals that made in the equalizing reservoir the piston moves downward, permitting valve *130* to close and terminating the brake pipe reduction. This feature thus accomplishes an Automatic Brake Pipe Reduction at a controlled rate regardless of train length. The engineman makes the desired reduction in equalizing reservoir pressure and the equalizing portion automatically reduces the brake pipe pressure a corresponding amount.

In First Service, the pressure above the equalizing piston is reduced at a controlled rate into the reduction reservoir. Maintaining Valve *132* is held on its seat by spring *134*. The chamber beneath it is connected through the rotary valve to feed valve pressure. If brake pipe pressure reduction occurs at a faster rate than equalizing reservoir reduction, the higher equalizing reservoir pressure above the piston forces the latter to its lower position, depressing operating lever *136* and unseating maintaining valve *132*. Sufficient feed valve air is supplied past the valve to limit the rate of brake pipe reduction to that of the controlled equalizing reservoir reduction. This is the Uniform Brake Pipe Reduction Feature for long trains.

INDEPENDENT BRAKE VALVE PORTION

The independent brake valve is supported on its bracket *174*, Fig. 65, which is attached to the lower portion of the automatic brake valve. Rotary valve *154* is operated by handle *171* to establish port connections petween passages in the bracket as later described.

The five positions of the brake valve handle are, from left to right: Release, Running, Lap, Slow Application and Quick Application. The handle-off position is Lap.

A detailed explanation is given under "Operation of Air Brake Apparatus" of the various port connections in the different positions of the brake valve handle and same are shown in Fig. 67.

The passage in the independent brake valve bracket are tapped at the bracket face, permitting the application of choke plugs, when it is desired to control the independent application and release rates.

The purpose of return spring *160,* Fig. 65, is to automatically move the handle *171* from Release to Running position or from Quick Application to Slow Application position. The automatic return from Release to Running position is to prevent leaving the handle in Release position, which would make it impossible to operate the locomotive brake with the automatic brake valve. As a warning to the engineman in case of a broken return spring, reducing valve air is allowed to escape to the atmosphere through the rotary valve in Release position with sufficient noise to attract his attention. The action of the spring between the Quick Application and Slow Application position serves to make the latter more prominent, so that in rapid movement of the handle, the engineman is less likely to unintentionally pass over to the Quick Application position, thereby obtaining a heavy application of the locomotive brake when only a light one is desired.

COMBINED EMERGENCY RELAY VENT VALVE AND SIGNAL LINE FIXTURE

These two devices have separate and distinct functions but are combined in one portion, Fig. 70, (section A-A of Fig. 65), which is a removable unit. The relay vent valve functions only in an automatic emergency application. At other times spring *50* holds vent valve piston *49* in normal position, and springs *42* and *37* hold pilot valve *39* and vent valve *36* seated. In emergency position of the brake valve handle the relay vent valve provides a large direct opening from the brake pipe to atmosphere, as described under "Operation of Air Brake Apparatus."

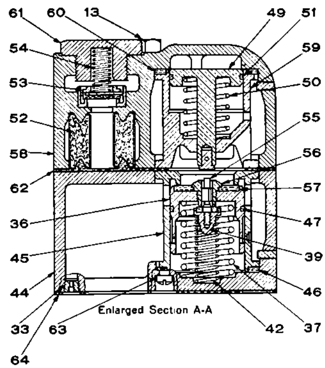


Fig. 70. Sectional View of the Combined Emergency Relay Vent Valve and Signal Line Fixture

The signal line fixture consists of curled hair strainer *52*, check valve *53*, spring *54*, and choke *33*. As shown on Plate 24, reducing valve air supplied through passage *14b*, *14* and *14a*, flows through strainer *52*, unseats check valve *53*, and charges the Signal Pipe through passage *15a*, choke *33* and passage *15*. The strainer protects the check valve, choke fitting and signal valve from the effects of dirt. The check valve prevents air flowing back from the signal pipe when the independent brake is applied. Choke *33* prevents the pressure in the signal pipe increasing at a rate which would interfere with the proper operation of the signal valve. The air pressure in the signal pipe is slightly lower than reducing valve pressure (normally 45 pounds) due to the spring loading of check valve *53*.

DOUBLE HEADING COCK

The double heading cock, Fig. 64, is located in the back face of the pedestal where it is protected against unintentional handle movement. The cock is open with the handle down, and closed with the handle up parallel with the pedestal.

Feed Valve
Reducing Valve

The M-3-A Feed Valve regulates the pressure in the brake pipe with the automatic brake valve in Running position, and the M-3 Reducing Valve reduces main reservoir pressure for use in independent brake operation and the train air signal system.

Mounted on the brake valve pedestal, both valves are identical except that the M-3-A is provided with adjustable stops for double pressure control. The following description of operation applies equally to the M-3-A and M-3 valves.

The diagrammatic views, Figs. 71 and 72, picture the valve with all parts in one plane in order to facilitate description. Main reservoir air is present on both sides of piston *20*, the underside through slide valve chamber and chamber *k*, and chamber *m* on top through passage *n*, bypass choke *25*, passage *p* and chamber *k*. Passage *n* also leads to the top of regulating valve *7* while the diaphragm chamber under this valve is always in communication with delivery pressure through passage *o*.

(*Opening*)

Main Reservoir air enters the opening marked "Supply" and flows to chamber *k* and the slide valve chamber under piston *20*. Above the piston is spring pressure and delivery pressure combined which, however, is less than the main reservoir pressure in the slide valve chamber under the piston. Consequently, the piston and slide valve will move up to the position shown in Fig. 71 and main reservoir air will flow to the delivery port *z* through ports *b* and *b′* in slide valve *22* and ports *a* and *a′* in the seat.

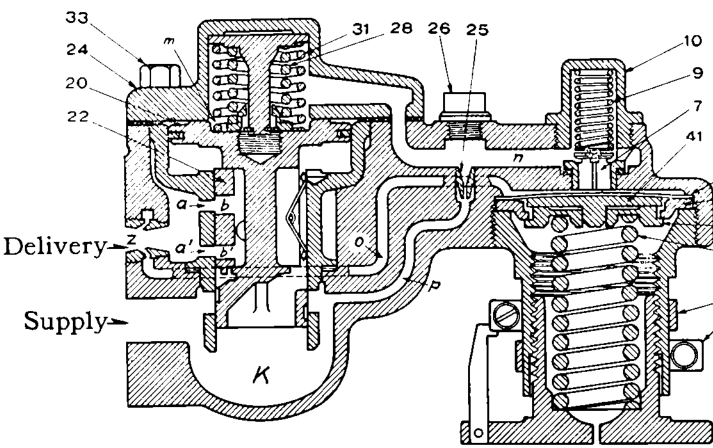


Fig. 71. Diagrammatic View of the M-3-A Feed Valve in OPEN Position

Main reservoir air also flows from chamber *k* through port *p* and bypass choke *25* to passage *n* and above the piston. Passage *n* is connected to regulating valve *7* (held open at this time by regulating spring *15* under diaphragm *11*) so that air passing through the bypass choke is free to flow past the regulating valve and through passage *o* to the delivery port. Consequently, so long as the regulating valve is open, the pressure above piston *20* will be less than that underneath and the piston and attached slide valve will remain in open position as illustrated.

It will be noted that there are two ports through the slide valve and the slide valve seat. When delivery pressure has been reduced a considerable amount below the adjustment of regulating spring *15*, regulating valve *7* will be fully open and piston *20* will move upward to its extreme position opening both ports in the slide valve, as the bypass choke so restricts the flow of main reservoir air that pressure cannot build up in the chamber above piston *20* as long as valve *7* is fully unseated. If a limited reduction of delivery pressure has been made, the regulating valve will not be fully opened and pressure flowing through the bypass choke will result in a lower differential acting on piston *20* which will move upward only far enough for port *b* in the slide valve to register with port *a* in the seat.

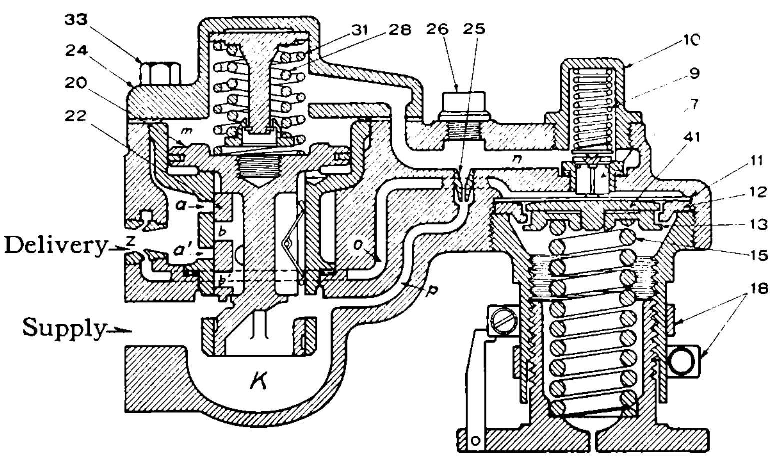


Fig. 72. Diagrammatic View of the M-3-A Feed Valve in CLOSED Position

(*Closing*)

When delivery pressure above diaphragm *11* (connected through port *o*) becomes greater than spring pressure acting under the diaphragm, the diaphragm will move downward permitting spring *9* to seat the regulating valve *7*. Main reservoir air flowing through bypass choke *25* to chamber *m* above piston *20* will quickly equalize with the pressure underneath, and springs *28* and *31* will force the piston and slide valve downward to closed position, Fig. 72, thus cutting off the flow of main reservoir air to the delivery port through the slide valve.

The parts will remain in this position until delivery pressure above diaphragm *11* becomes less than the tension of regulating spring *15* when the diaphragm will move upward, unseating the regulating valve and again connecting the top of piston *20* to delivery pressure. The piston and slide valve will then be moved upward to open position by reason of the higher main reservoir pressure under the piston as compared to the lower delivery pressure above in chamber *m*.

(*Venturi Tube Action*)

The function of venturi tube *z* is to obtain a sustained air delivery flow from the main reservoir to the delivery passage up to the point of pressure for which the feed valve is adjusted. Its operation is on the same principle as a steam injector. The main reservoir air in flowing through the venturi tube to the lower pressure in the delivery passage develops an increased velocity at the small section of the venturi tube with a corresponding decrease in pressure at this point. Passage *o* leads into the venturi tube at this small section, or throat, which causes the pressure to be reduced in the diaphragm chamber below the delivery pressure and permits the regulating spring *15* to open the regulating valve *7* more fully, thus allowing a greater flow of air with consequently greater reduction of pressure on the face of supply piston 20.

As the delivery pressure approaches the pressure for which the valve is adjusted, the velocity of flow through the venturi tube diminishes. Therefore, its effect of reducing the pressure in the diaphragm chamber becomes proportionately less, thus permitting accumulation of pressure in the diaphragm chamber, which tends to close the regulating valve at its true setting.

(*Adjustment*)

The M-3-A Feed Valve has two adjustable stops *18* encircling the spring box, split through the lugs and closed with a machine screw. When setting the valve, which is adjusted by turning up or backing off the regulating nut, set the valve at the low brake pipe setting, loosen the machine screw and move the lower stop *18* against the stop pin which is a part of the regulating nut and tighten the machine screw. Then, set the valve at high pressure and set the upper stop *18* to hit the stop pin in the same manner. Thereafter by turning the regulating nut until the pin hits either stop, the Feed Valve is regulated from high to low pressure.

The M-3-A feed valve adjustable stops should be placed to give 110 pounds brake pipe pressure for passenger service and 70 pounds brake pipe pressure for freight service.

The M-3 Reducing Valve is adjusted by turning up, or backing off, the regulating nut.

The M-3 valve should be set to supply 45 pounds pressure for the independent brake and the signal system.

Combined Equalizing and Reduction Limiting Reservoir

These two reservoirs are combined in one welded tank. The larger volume is the Equalizing Reservoir which is, in effect, an enlargement of chamber *D* above the equalizing piston of the automatic brake valve, providing an operating volume sufficient to stabilize the equalizing piston against brake pipe volume underneath. The smaller volume is the Reduction Limiting Reservoir into which the equalizing reservoir equalizes at the beginning of a brake application from First Service position of the brake valve.

Distributing Valve

The distributing valve consists of three main portions (a) a "double-chamber" reservoir, the two chambers of which are named the "pressure chamber" and the "application chamber"; (b) a pipe bracket, to which all pipe connections are made, and containing a "reduction chamber"; (c) the operating portion, containing the pistons, slide valves and other devices that control the flow of air.

Chamber *A*, on the face of the application piston *23*, (See Plate 24), is called the "application cylinder," and is connected through the equalizing slide valve to the application chamber.

Air delivered to the application cylinder from either an automatic or an independent brake application, causes movement of the application piston, which in turn operates the application valve to deliver an equivalent pressure direct from the main reservoirs to the locomotive brake cylinders.

The pressure chamber, reduction chamber and application chamber are used for automatic brake applications as controlled by the equalizing slide valve and piston. In automatic brake applications, air stored in the pressure chamber flows first into the reduction chamber, and, after a pre-determined development of reduction chamber pressure, into the application chamber and application cylinder *A*.

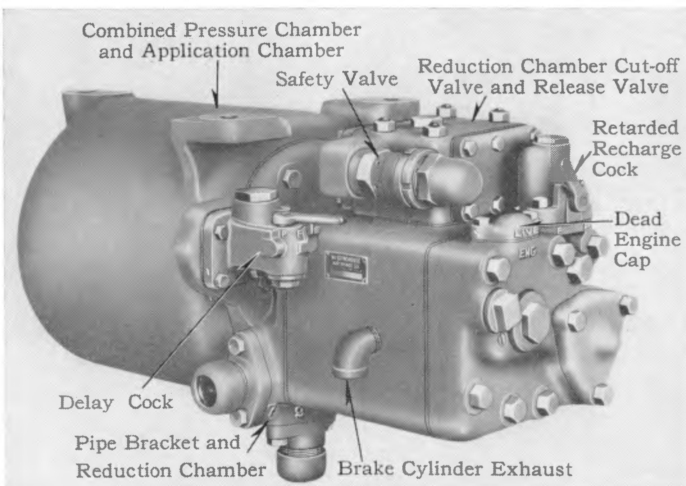


Fig. 73. No. 8-A Distributing Valve with Direct Control Delay Valve

The purpose of allowing air to flow from the pressure chamber to the reduction chamber during the initial stage of an automatic brake application is to harmonize the development of braking force on the locomotive with that on cars in a train, as described under "Operation of Air Brake Apparatus."

In independent brake application, reducing valve air is delivered direct to the application chamber and application cylinder *A* from the independent brake valve, through the Application Pipe.

The operation of the locomotive brake, therefore, depends upon the admitting of air to and releasing of air from the application cylinder; in independent applications, direct by means of the independent brake valve; in automatic applications, by means of the equalizing piston and slide valve from the air pressure stored in the pressure chamber.

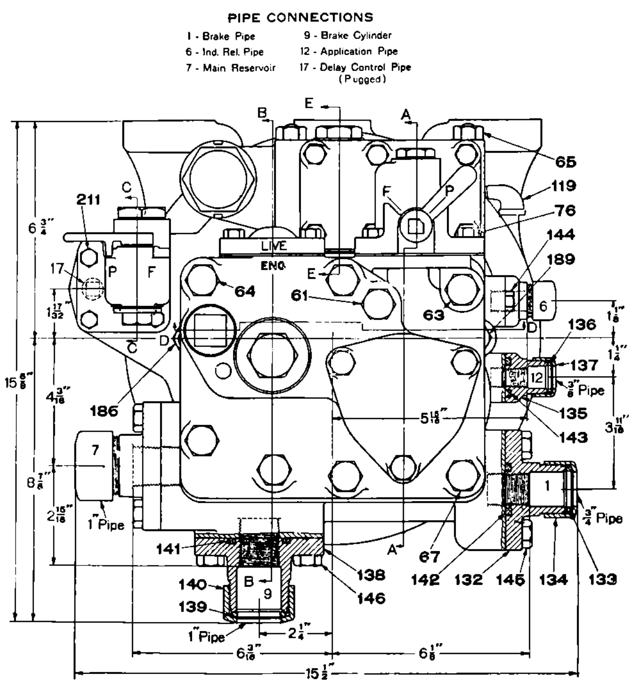


Fig. 74. Outline End View of No. 8-A Distributing Valve With Direct Control Delay Valve

As the air admitted to the brake cylinders comes direct from the main reservoirs, the supply is practically unlimited. Any pressure in the application cylinder will force the application piston to close the exhaust valve, open the application valve and admit air from the main reservoirs to the locomotive brake cylinders until their pressure equals or slightly exceeds that in the application cylinder; whereupon the application piston and valve will be returned to lap position, closing the application valve. Also, any variation of application cylinder pressure will be exactly duplicated in the locomotive brake cylinders, and the resulting pressure maintained regardless of ordinary brake cylinder leakage.

The parts and functions of the operating portion are described on the following pages:

(a) The equalizing piston *10*, Fig. 75, (which is section A-A of Fig. 74) responds to variations in brake pipe pressure and moves in its cylinder accordingly.

(b) The equalizing graduating valve *16* moves with the piston and controls the flow of air during automatic service application: 1. From the pressure chamber (equalizing slide valve chamber) through the slide valve to the reduction chamber cut-off slide valve. 2. From the application chamber and cylinder through the slide valve to the safety valve.

(c) The equalizing slide valve *18* moves with its piston and permits the flow of air through ports and passages as follows:

In Release Position

1. From reduction chamber to equalizing slide valve exhaust.

2. From application chamber to application cylinder.

3. From both faces of the reduction chamber cut-off piston, and from the safety valve, to the application chamber and cylinder.

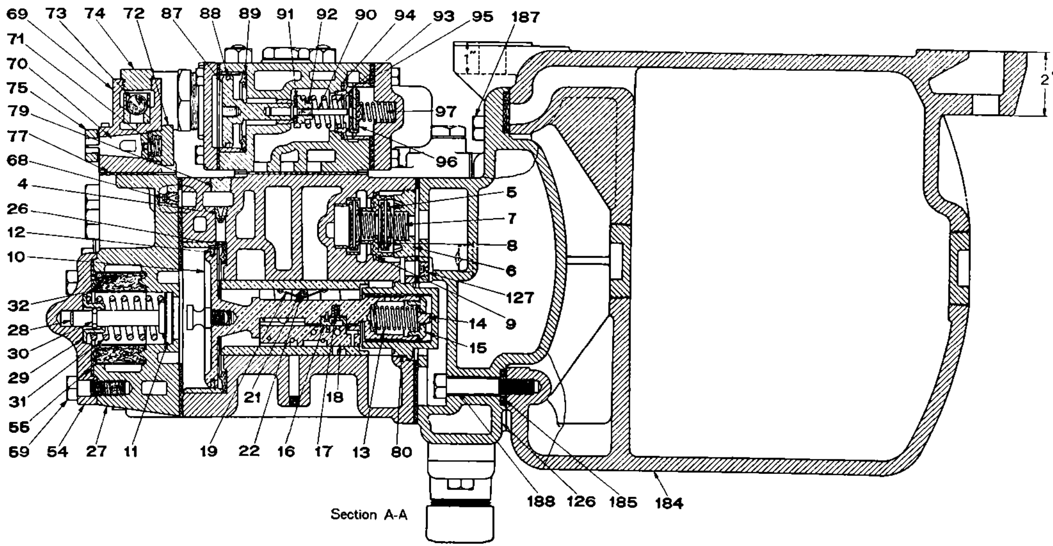


Fig. 75. Sectional View of No. 8-A Distributing Valve With Direct Control Delay Valve

In Service Position

1. From the pressure chamber (equalizing slide valve chamber), past the graduating valve to cavity of the reduction chamber cut-off slide valve.

2. From the application chamber to the application cylinder.

3. From the application cylinder and chamber through the graduating valve to the safety valve.

4. From the spring side of the reduction chamber cut-off piston to the equalizing slide valve exhaust.

5. From the slide valve side of the reduction chamber cut-off piston to the pressure chamber (equalizing slide valve chamber).

In Emergency Position

1. From the pressure chamber (equalizing slide valve chamber) to the application cylinder, safety valve, and the reduction chamber cut-off slide valve cavity and slide valve chamber.

2. From spring side of reduction chamber cut-off piston to equalizing slide valve exhaust.

(d) The reduction chamber cut-off piston *98*, Fig. 76, (which is section E-E of Fig. 74), slide valve *101*, and spring *106*, control the flow of air from the pressure chamber to the reduction chamber, at the start of an automatic service application, permitting 30 pounds pressure to build-up in the reduction chamber, after which the valve moves to cut-off position, where the slide valve

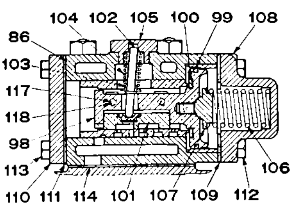


Fig. 76. Sectional View of Reduction Chamber Cut-off Valve

blanks the passage to the reduction chamber and opens the pressure chamber passage from the equalizing slide valve to the application cylinder and chamber. Slide valve strut *102* and its spring *104* serve to keep the slide valve seated in the absence of pressure in the cut-off slide valve chamber at start of the application.

(e) The delay cock *202*, Fig. 77, (which is section C-C of Fig. 74) controls the rate of brake cylinder pressure development in automatic emergency application, to provide a fast (non-delay) build-up of cylinder pressure for short freight trains and passenger trains, or a delayed build-up for long freight trains. The setting is accomplished by turning the cock to "P" (non-delay) or "F" (delay) position as indicated on the bracket. The cock is moved to "P" position when a short train is hauled and to "F" position for a long train.

In non-delay ("P") position, the application cylinder is cut-off from the application chamber so that, in emergency application, the pressure chamber equalizes into the application cylinder only, thus producing a rapid application. In delay ("F") position, the application chamber and cylinder are connected so that the pressure chamber equalizes through choke *128*, Fig. 77, into the combined application cylinder and chamber volumes, thus producing a delayed, controlled rate of application. Ball check *206*, rubber-seated check *207*, and spring *208*, Fig. 77, are for the purpose of bypassing choke *128* when an Independent Release is made after an Automatic Emergency application with the delay cock in delay position.

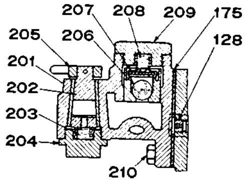


Fig. 77. Sectional View of Direct Control Delay Valve

(f) The application piston *23*, Fig. 78, (which is section B-B of Fig. 74) directly controls brake cylinder pressure in accordance with the pressure conditions existing in chamber *A* on its face called the application cylinder. When air is delivered to the application cylinder from the pressure chamber in an automatic brake application, or from the Application Pipe in an independent brake application, the piston acts to reproduce in the brake cylinder, the equivalent pressure condition existing in application cylinder *A*.

(g) Exhaust slide valve *25* moves with the application piston, opening and closing the brake cylinders to the exhaust in accordance with the position of the piston.

(h) Application valve *37* and pilot valve *40* are operated by the application piston to supply air from the main reservoir to the brake cylinders. On application, the end of the application piston first engages and unseats the pilot valve, allowing air from the spring chamber to flow to the brake cylinders.

While the air escapes rapidly past the pilot valve, choke *36* meanwhile supplies just enough air to the spring chamber to partially balance the pressures on both faces of the application valve by the time the

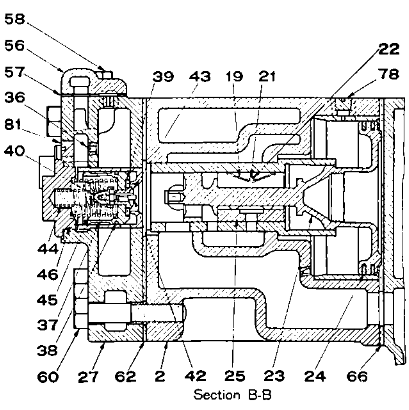


Fig. 78. Sectional View of the Application Portion

piston stem engages the application valve. In this way the application valve is prevented from opening abruptly, and resistance to movement is reduced.

(i) Springs *44* and *45* promptly close the pilot and application valves when the application piston moves to lap after required brake cylinder pressure is obtained. Therefore, a very light differential is required on the application piston to move it to release.

(j) Strainer *32*, Fig. 75, located in the front cover, filters the brake pipe air, removing fine dirt particles and protecting the equalizing portion.

(k) Release and application checks *5* with their springs *7*, by-pass brake pipe flow around the strainer in case of strainer restriction.

(l) Equalizing piston seal *26*, affords a seal for piston, closing off the feed groove and retarding the rate of pressure chamber recharge to the capacity of choke *4* in retarded recharge position.

(m) Retarded recharge spring *13* returns the equalizing piston from retarded recharge to normal charging position when pressure chamber air is built up to approximately brake pipe pressure.

(n) Retarted recharge cock *70* provides a faster rate of pressure chamber recharge than that provided through choke *4* in retarded recharge position of the equalizing piston. Cast letters on the bracket "F" and "P" indicate the two positions of the cock, for freight and passenger service, respectively. In "F" position the recharge is retarded through choke *4*, while in "P" position it is augmented by flow through choke *68*, thus providing a faster rate of recharge.

(o) Cut-off valve *96* affords protection against loss of the automatic brake with a broken application pipe, and provides the same brake cylinder development for a given brake pipe reduction with a short application pipe (as used with a steam locomotive) or a very long application pipe (as used with an electric locomotive)

(p) Independent release piston *87* operates to provide independent release of locomotive brakes. In Release position of the independent brake valve reducing valve air pressure moves the piston to unseat cut-off valve *96*, opening the application cylinder to the Application Pipe. In all other positions the piston is held in normal position by return spring *93*.

(q) Choke *127* provides a predetermined rate of release with both brake valves in Running position.

(r) Maintaining check valve *47* and spring *49*, Fig. 79, (which is section D-D of Fig. 74), comprise the Application Pipe maintaining feature. In automatic service applications the check valve opens and charges the Application Pipe to brake cylinder pressure (less the value of spring *49*). A subsequent release will, therefore, occur at the normal rate as determined by release choke *127*, Fig. 75, avoiding a rapid initial drop of brake cylinder pressure, which would otherwise occur owing to the rapid initial reduction of pressure from a charged application cylinder and chamber into an empty Application Pipe.

(s) Choke *34*, Fig. 79, restricts the flow of brake cylinder air to the Application Pipe. In case of Application Pipe breakage, the automatic brakes will be available as the leakage at the break will be restricted to the capacity of the choke which is small and easily maintained from main reservoir supply.

(t) The "Dead Engine" feature, consisting of Check Valve *52*, spring *51* and choke *35* (see Plate 24) controls the

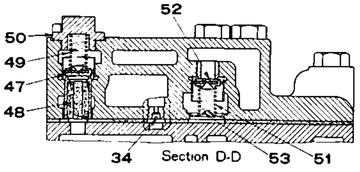


Fig. 79. Sectional View Showing Maintaining Valve, Choke 34 and "Dead Engine" Check Valve

charging of the main reservoirs on a locomotive hauled "dead" in a train, when cover *56* is set in "Dead Engine" position.

(u) Plug *78*, Fig. 78, is used when testing the valve on the test rack to determine the individual leakage of each of the two application piston packing rings.

(v) Safety valve, Fig. 80, is used to vent pressure at a predetermined point in order to prevent excessive brake cylinder pressure on the locomotive.

When the pressure in cavity *A* under valve *4* is sufficient to overcome the pressure exerted by the tension of spring *6*, valve *4* is raised from its seat, which upward movement closes the upper end of port *d* in the valve bushing and opens port *C*, permitting air to flow from cavity *A* through chamber *B* and port *C* to the atmosphere. As the pressure below valve *4* decreases, the tension of spring *6* forces valve *4* downward, which restricts the opening through port *C* to the atmosphere and opens the upper end of port *d* to the spring chamber *E*. Although chamber *E* is open to the atmosphere at all times, the connecting ports *f* in the body are sufficiently small to restrict the exhaust, so that the pressure builds up very rapidly in chamber *E* and assists spring *6* in forcing valve *4* quickly to its seat.

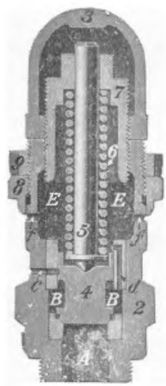


Fig. 80. Sectional View of the E-7 Safety Valve

To adjust the safety valve for the maximum or opening pressure, which in this case is 68 pounds, remove the cap nut *3* and screw down or back off regulating nut *7*, as required, after which replace the cap nut. The minimum or closing pressure for the safety valve, used with the equipment referred to, is 65 pounds, and can be adjusted by changing the size of ports *f*, using regulating nut *8* for the purpose. After adjustment, screw down jam nut 9.

Brake Pipe Vent Valve

The purpose of the Brake Pipe Vent Valve is to provide a means of propagating quick action, which has been increasingly more difficult to obtain due to increased brake pipe volume and many right angle bends and elbows. In construction it is entirely separate from, and in operation independent of, the service operating parts of other brake devices, and is, therefore, not affected by the condition or operation of them. Thus, the stability and reliability of the vent valve is uniformly insured; at the same

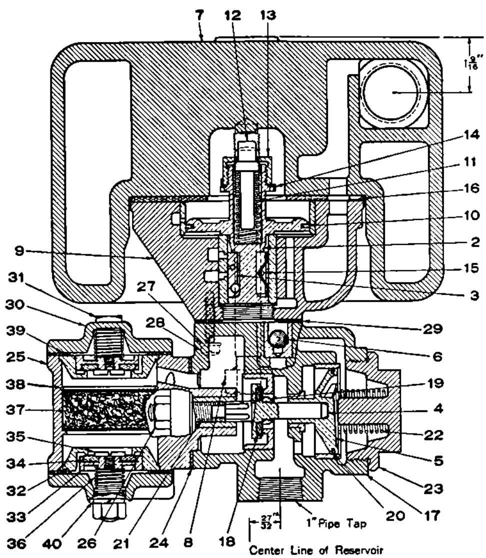


Fig. 81. Sectional View of No. 4-B Brake Pipe Vent Valve

time, undesired quick action due to erratic action of the service parts of the distributing valve or to the overcharging of the brake pipe on the locomotive is eliminated.

Fig. 81 shows a sectional view of the No. 4-B Brake Pipe Vent Valve. This device comprises an emergency piston *2*, with its slide valve *3*, a quick action valve *4* and quick action piston *5*, an actuating volume called the quick action chamber. Strainer *37* protects the piston and slide valve from dirt. Check valve *33* with the spring *36*, and duplicate parts on the opposite side of the strainer (Fig. 81) by-pass air flow around the strainer in case of dirt restriction in the latter; check valve *33* for out-flow on brake pipe reductions, its duplicate for in-flow, in release and charging.

The operation of the vent valve is described in connection with "Operation of Air Brake Apparatus."

Centrifugal Dirt Collectors

Centrifugal dirt collectors are used with this equipment as shown on the piping diagrams, Plates 21, 22 and 23.

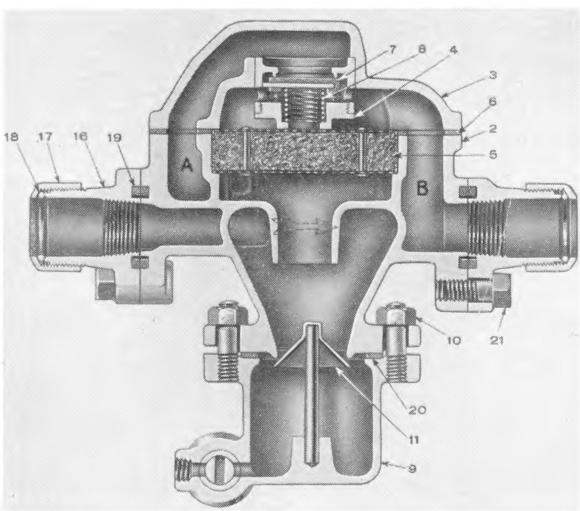


Fig. 82. Sectional View of Combined Dirt Collector and Strainer

The standard design comprises two separate portions; the upper or body portion to which the pipe connections are made, and the lower or dirt chamber portion which contains the brass umbrella shaped check valve. The two portions are bolted together and the joint between is protected by means of a rubber gasket.

The purpose of the check valve is to hold in the dirt chamber the collected dirt under all conditions of air brake operation. The body portion has a machined seat against which the check valve seats when a heavy reduction in pressure occurs above it, such as that during an emergency application or recharging an empty equipment, thereby shutting off communication between the dirt chamber and the dirt collector outlet. The check valve is so designed and placed on the valve stem as to permit of a rocking motion whereby any fine dust which may collect on top of the check valve will be shaken off into the dirt chamber. A drain cock permits drainage of the dirt chamber.

In addition to the above features, the combined type, Fig. 82, has a curled hair strainer *5* which prevents passage of fine dust. By-pass check *7* operates if the strainer should become clogged with dirt because of improper maintenance. Normally spring *8* holds valve *7* seated but if strainer restriction amounts to two pounds differential between the pressures in passages *A* and *B* the greater pressure in passage *A* unseats valve *7* and allows main reservoir air to flow from passage *A* directly to passage *B*.

Operation of Air Brake Apparatus

As it is impossible to show all the ports and connecting passageways by any single section taken through the Brake Valve and Distributing Valve, Plates 24 to 33, inclusive, have been made to show in a purely diagrammatic way the relation of the various parts to each other, for the different operating positions. The actual proportions and mechanical construction of the parts have been disregarded where necessary in order to make the connections and operation more easily understood.

Plates 24 to 33, inclusive, show the L-8-PA brake valve as used with the No. 8-ET equipment for steam locomotives. Double end equipment as used on electric locomotives involves two pedestal brake valves with removable handles. The K-8-PA brake valve is similar to the L-8-PA brake valve in construction and operation.

The "Gov." passage in the L-8-PA brake valve is intended for use with a double pressure compressor governor as used with a steam driven air compressor. The "Gov." passage in the K-8-PA brake valve is plugged.

AUTOMATIC BRAKE

Full Release and Charging
Plate 24

With main reservoirs charged and the handle of the automatic brake valve in Release position, Plate 24, air flows through the Dirt Collector in the main reservoir pipe to the brake valve. Entering through passage *7*, main reservoir air flows through passage *7c* to the upper outer area of piston valve *106*, which is called the charging valve. Passage *13*, from the underside of valve *106*, is connected through port *r* in the rotary valve to the exhaust port *Ex.* This vents pressure from the underside of charging valve *106*, and main reservoir pressure from passage *7c* forces the valve from its seal, allowing main reservoir air to flow to passage *7e* thence to chamber *A* above the rotary valve. From passage *7b* main reservoir air passes through the M-3-A feed valve, from which it is discharged at a reduced pressure to passage *20* leading to chamber *A* above the rotary valve *112*.

Main reservoir air above the rotary valve flows through port *E* to passages *1a* and *1* through double heading cock *84*, thus charging the brake pipe throughout the train at a fast rate. At the same time, Chamber *D* above the equalizing piston *126*, and the equalizing reservoir are charged through port *s* in the rotary valve and passage *5* in the seat.

The reduction limiting reservoir is connected to the automatic brake valve exhaust *Ex.*, through passage *22* in the pedestal, First Service position cut-out cock *80* and cavity *F* in the rotary valve, or is connected to atmosphere through passage *22* and choked exhaust plug *120* when cock *80* is turned to "Out" position.

Main reservoir passage *7* in the brake valve is connected through port *e* in the rotary valve to the passage marked "Gov."

Main reservoir air enters the reducing valve through passage *7d* and is delivered to passage *14b* at a maximum of 45 pounds. This air flows through passage *14* to chamber *X* above the independent rotary valve *154*. Reducing valve air also flows through passage *14a*, strainer *52*, past check valve *53* and through port *15a* and choke *33* to the signal pipe *15*.

Air from the main reservoir pipe flows through the combined Dirt Collector and Cut-out Cock to passage *7* of the distributing valve, thence to chamber *M* surrounding the outer area of the seat of application valve *37*. From chamber *M* air flows through choke *36* to chamber *M-1* and the spring side of application valve *37* and pilot valve *40*.

Air from the brake pipe flows through a dirt collector in the branch pipe to the distributing valve, through passage *1*, the curled hair strainer *32*, and passage *1a* to chamber *B* on the face of equalizing piston *10*, causing the piston and its slide valve to move to the left. The inside of strainer *32* is connected through passage *1b* to the spring side of by-pass check valve *5a*. Brake pipe air from passage *1f* is present on the right side of check *5a*. If the strainer *32* should be clogged by dirt sufficient to create a two-pound differential, the higher pressure in passage *1f* will unseat check *5a* and flow through passage *1b* to chamber *B*, thus by-passing the strainer *32*.

With no air pressure on the left of the equalizing piston *10*, brake pipe pressure on the face forces the piston and slide valve *18* toward the left; retarded recharge spring *13* will be compressed and the inner face of the piston will contact with seal *26*. With retarded recharge cock *70* in "F" position (closed), air then flows to the slide valve chamber *F* through feed groove *v*, charging choke *4* and passage *a*, and from the slide valve chamber through passage *1d* to the pressure chamber. When pressure in the pressure chamber and slide valve chamber *F* builds up to within a few pounds of brake pipe pressure, the retarded recharge spring *13* in the end of equalizing piston *10* will cause the piston to move to the right as shown on Plate 25. In this position, charging of the pressure chamber is not restricted by choke *4*, but is controlled by the larger feed groove *v*.

The purpose of seal *26* and choke *4* is to limit the rate of charging the pressure chamber during initial charging of the brake system and during the time the brake is being released, thereby preventing overcharging the pressure chamber. A slower rate of charging the pressure chamber is obtained than is possible with a feed groove of sufficient size to provide against the brake applying with permissible brake pipe leakage; therefore, overcharging the pressure chamber while releasing train brakes is guarded against by the use of the seal and choke, while in normal release position of the equalizing piston the feed groove provides stability against undesired brake application owing to moderate fluctuations of brake pipe pressure.

With retarded recharge cock *70* in "P" or open position, air from the brake pipe charges the slide valve and pressure chambers through passage *v2*, cock *70*, past ball check *73*, through passage *a* and choke *68*, in addition to flow through choke *4*. Thus in retarded recharge position of the equalizing piston a faster rate of pressure chamber recharge is provided for passenger train service.

On Plate 24, the delay cock *202* is shown in "P" (non-delay) position.

If the brake valve handle were allowed to remain too long in Release position, the brake system would be charged to main reservoir pressure. To avoid this, the handle must be moved to

Running position after a short interval in Release position. To prevent the engineman forgetting this, passage *13* discharges main reservoir air to the atmosphere in Release position. A port in the charging valve *106* allows a small volume of main reservoir air from passage *7c* to pass to the underside of the piston, thence through passage *13* and port *r* in the rotary valve to the brake exhaust cavity *Ex.* The noise of this escaping air serves to attract the engineman's attention to the position of the handle.

Brake pipe air entering the Vent Valve, Fig. 83, flows through passage *a* to chamber *E* at the left of quick action valve *4* and thence through strainer *37* and passages *b2* and *b* to chamber *A* above the emergency piston *2*, forcing the piston to its lowest position. This opens charging port *c* in the piston bush, permitting brake pipe air to flow past ball check valve *6* and through passage *c2* to the slide valve chamber *B* and thence through passage *d* to the quick action chamber, charging the latter to brake pipe pressure. Spring *36a* holds check valve *33a* on its

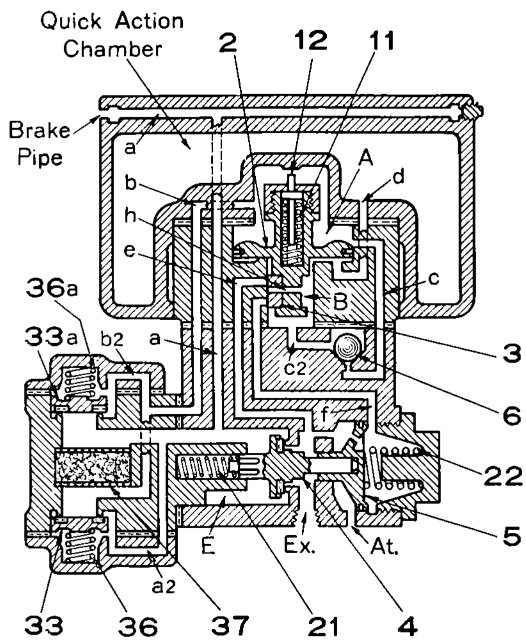


Fig. 83. Brake Pipe Vent Valve in Normal Position

seat unless the strainer is dirty, in which event a two-pound restriction will overcome the spring, unseat the check valve and allow air to flow through passage *b2* directly, thus by-passing the strainer.

Running
Plate 25

In Running position of the automatic brake valve, Plate 25, passage *13* is blanked by the rotary valve. Therefore, main reservoir pressure from passage *7c* builds up under the charging valve *106*, through the small port in the piston valve, until equal pressures are obtained on both upper and lower faces, after which spring *111* forces this valve to its upper seat, preventing further main reservoir air flow from passage *7c* to *7e*. Therefore, only the feed valve supplies air to chamber *A* above the rotary valve, and through port *E*, passage *1a* and *1*, supplying the brake pipe so that the latter will charge up as rapidly as the feed valve can supply the air, but cannot attain a pressure above that for which the feed valve is adjusted.

It will be noted that the charging valve *106* supplies main reservoir air for rapid recharge in Release position. In doing this, it admits main reservoir pressure to chamber *A* above the rotary valve only in Release position. In all other positions of the brake valve handle, chamber *A* is supplied from the feed valve through passage *20*. Therefore, the pressure in chamber *A* acting to force the rotary valve *112* to its seat, is the feed valve pressure, which makes it easy to operate the brake valve handle. In Release position, main reservoir pressure above the rotary valve equalizes with the brake pipe pressure beneath it, thus balancing the rotary valve so that the handle is as easily moved as in other positions.

Port *s* continues to supply feed valve pressure air to passage *5*, charging the equalizing reservoir and the equalizing piston chamber *D*. Also, a branch *1b* from brake pipe passage *1* charges chamber *N* beneath the equalizing piston *126*, so that both chambers *D* and *N* and the equalizing reservoir charge uniformly with the brake pipe. The equalizing piston and its attached lever *136*, therefore, remain in balanced position, where spring *134a* holds discharge valve *129* seated.

Port *E* in the rotary valve also supplies feed valve air to passage *19*, thence to passage *19a*, with the First Service position cut-out cock *80* turned to "In" position, where further flow is stopped by maintaining valve *132*, which is held seated by spring *134*. Exhaust passage *1d* is closed by exhaust valve *97*, which is held seated by spring *100*. Cavity *e* in the rotary valve connects passages *7* and "Gov." The reduction limiting reservoir is open to atmosphere through passage *22*, First Service position cut-out cock *80*, cavity *F* and exhaust port *Ex.*, or through passage *22* and choked exhaust plug *120* with cock *80* turned to "Out" position.

In the distributing valve, brake pipe pressure continues to charge the slide valve chamber *F* and the pressure chamber, as described under "Full Release and Charging," with the equalizing piston *10*, moving back from seal *26* where charging is controlled through feed groove *v*.

In this position of the equalizing slide valve *18*, port *b* is connected to chamber *S* on the spring side of the reduction chamber cut-off piston *98* through port *b2* and passage *19*; port *b* is also connected to the slide valve side of the cut-off piston through port *b1* and passage *18a*. Therefore, with equal pressures (atmospheric, at this time) on both sides of the cut-off piston, spring *106* holds the piston and slide valve to the right. Application cylinder *A* is connected through passage *12d* and cock *202* to passage *12b*. The application chamber also is connected to passage *12b*, through passage *11* and cavity *b5* in the equalizing slide valve. Passage *12b*, in turn, is connected through a cavity in the reduction chamber cut-off slide valve *101*, to passage *12a*, through choke *127* and to passage *12*, leading to the Application Pipe.

As both brake valves are in Running position, as shown on Plate 25, the Application Pipe is connected through passage *12* in the brake valve pedestal, ports *p* and *v* of the independent rotary valve, to passage *3*, cavity *F* in the automatic rotary valve and to *Ex*. Therefore, both the application chamber and the application cylinder *A* are open to atmosphere.

With application cylinder *A* thus open to atmosphere, application piston *23* is in release position, where exhaust slide valve

25 connects the brake cylinder to atmosphere by way of passage *9* and *9a* to slide valve chamber *C*, thence through the slide valve seat ports to *Ex*.

The reduction chamber is connected to atmosphere by passage *8a*, cavity *c* in the equalizing slide valve and port *At*, in the seat.

Chamber *E* on the face of release piston *87* is open to atmosphere through passage *6*, Independent Release pipe, passage *6* in the brake valve pedestal, ports *w* and *Z* in the independent brake valve rotary valve and the exhaust port *Ex*.

Service
Plate 26

This position of the brake valve produces the proper rate of brake pipe pressure reduction to cause a service brake application. Port *f* in the rotary valve *112* registers with passage *5* in the valve seat, allowing air from equalizing piston chamber *D* and from the equalizing reservoir to escape through the exhaust *Ex*. As all other ports are closed, the fall of pressure in chamber *D* causes the higher brake pipe pressure in chamber *N* to raise the equalizing piston *126*. As the piston moves upward it carries attached lever *136*, which is thereby rotated to compress spring *134a* and unseat discharge valve *129*. Brake pipe air from chamber *N* then escapes past the unseated discharge valve to passage *1d*.

In service position of the brake valve handle, pawl *96* actuated by a cam on the rotary valve key, forces exhaust valve *97* from its seat. Brake pipe air from passage *1d*, therefore, escapes past this valve to atmosphere at *At*. Port *f* and passage *1d* are restricted by means of chokes so that the pressure in the equalizing reservoir and chamber *D*, as well as in the brake pipe, is reduced at a controlled rate.

When the pressure in the equalizing reservoir and chamber *D* is reduced the desired amount, the brake valve handle is moved to Lap position (Plate 27), thus stopping any further reduction. As exhaust valve *97* is still held open in Lap position, air continues to discharge from the brake pipe until the pressure has fallen slightly lower than that retained in chamber *D*, permitting the pressure in this chamber and the equalizing reservoir to force the equalizing piston downward. The short end of angle lever *136* is rotated to the right with the piston movement, thus allowing spring *134a* to close the discharge valve *129* as the piston moves down. As the piston movement is influenced by the rate at which the brake pipe pressure is reduced, the valve will close more slowly with a long train than with a short train. It will be seen, therefore, that the amount of reduction in the equalizing reservoir determines that in the brake pipe, regardless of the length of the train.

The controlled reduction in brake pipe pressure is to prevent quick action, and the gradual stopping of this discharge is to prevent the brake pipe pressure at the head end of the train being built up by the air flowing from the rear, which action might cause some of the head brakes to "kick off."

Progress of the brake pipe reduction at the brake valve is reflected immediately in chamber *B*, on the face of the distributing valve equalizing piston *10*. Air flows from this chamber through passage *1a* and strainer *32* to passage *1*, thence through the brake pipe to the brake valve exhaust. This reduction also occurs on the left face of by-pass check valve *5* through passage *1f*, so that if strainer *32* should be clogged with dirt to an extent sufficient to cause a two-pound differential across the check valve, the greater pressure on the right will overcome spring *7*, unseating the check valve. Air from chamber *B* then flows through passage *1b* past the check valve *5* to passage *1f* and the brake pipe, thus by-passing the strainer.

With the drop in pressure on the face of piston *10*, the greater pressure on the inside face, (chamber *F*) moves the piston toward the right. The first movement closes the feed groove and moves the graduating valve to a position where service port *f*, through equalizing slide valve *18*, is uncovered. As the piston continues its movement, the shoulder on the end of its stem engages the equalizing slide valve *18*, which is then also moved to the right until the piston strikes graduating stem *28*, graduating spring *31* preventing further movement. Port *f*, in the equalizing slide valve registers with passage *12c* in the seat, and as equalizing slide valve chamber *F* is always in communication with the pressure chamber through passage *1d*, air now flows from the pressure chamber through passage *12c,* a cavity in the reduction chamber cut-off slide valve *101* and passage *8a* to the reduction chamber, as shown on Plate 26A. The opening from the reduction chamber, to atmosphere has been cut off by the movement of the equalizing slide valve.

A branch of passage *8a* is now connected by cavity *C* in equalizing slide valve *18* to passage *18a* and the slide valve chamber *K* of reduction chamber cut-off piston *98.* Passage *19,* connected to the left of piston *98* is now connected to atmosphere by port *d1* in the equalizing slide valve *18* and exhaust port *At*; therefore, there is spring pressure only acting on the left of piston *98.* When the pressure in the reduction chamber and on the slide valve side of piston *98* is built up to 30 pounds, the force of the spring *106* on the left of the piston is overcome and the piston and its slide valve move to the left, the piston contacting with its seal as shown in the view of Plate 26. The cut-off piston is then held in cut-off position by pressure chamber air supplied to its slide valve face through passage *13.*

The purpose of allowing air to flow from the pressure chamber to a reduction chamber during the initial stage of an automatic brake application is to synchronize the development of braking force on the locomotive with that on cars in a train. With car brakes, the movement of the brake cylinder piston must be displaced with air pressure from the auxiliary reservoir; therefore, the braking effect is negligible for the first few pounds of brake pipe reduction. This effect is duplicated on the locomotive by the initial flow of pressure from the pressure chamber to the reduction chamber, thereby duplicating the action of the car brakes.

With the reduction chamber cut-off piston *98* in cut-off position, slide valve *101* blanks passage *8a* leading to the reduction chamber, and connection is made between passages *12c* and *12b.* Air from the pressure chamber now flows through service port *f,* passage *12c,* cavity in cut-off slide valve *101,* to passage *12b,* thence in two directions: (a) through cavity *b5* in equalizing slide valve *18* and passage *11* to the application chamber; (b) through cock *202* to passage *12d,* to the application cylinder *A* on the face of application piston *23.*

As pressure builds up in chamber *A* on the left of application piston *23*, the piston and attached exhaust slide valve *25* are moved to the right, closing off the exhaust ports from slide valve chamber *C* and connected brake cylinder port *9a*. As the piston continues its movement, the end of its stem contacts application pilot valve *40*, forcing the latter from its seat, allowing main reservoir air in chamber *M-1* to flow to the slide valve chamber *C*, thence through passages *9c*, *9a* and *9* to the brake cylinders, and through passage *9b* and choke *3* to the right of the application piston.

With the pilot valve unseated, pressure is reduced in chamber *M-1* faster than it can be restored from main reservoir pressure through choke *36*; therefore, the application valve *37* approaches a balanced condition in which it is unseated by a slight excess of application cylinder pressure on the left of the application piston (chamber *A*) over brake cylinder pressure on the right of the piston. With application valve *37* unseated, main reservoir air in chamber *M* is free to flow through a large capacity opening. This provides an adequate rate of brake cylinder build-up for the large brake cylinder volume used on modern locomotives, with a very light differential across the application piston.

Brake cylinder air from passage *9c* flows to the right through passage *9* to and through strainer *48*, unseats check valve *47* and continues to the Application Pipe by way of passage *12f*, and choke *34* in passage *12*, charging this pipe to approximate brake cylinder pressure (less the value of spring *49*). This prevents a sudden drop in application cylinder, and likewise brake cylinder pressure, on a subsequent automatic release, which otherwise would occur, due to connecting the charged application cylinder to the uncharged Application Pipe, particularly if the latter were long. Also, any leakage from the Application Pipe is compensated from the main reservoir without affecting brake cylinder pressure as passage *12f* is supplied directly from brake cylinder pressure which, in turn, is supplied from the main reservoirs. This arrangement also provides against loss of the automatic brake in case of breakage of the Application Pipe as, in that event, leakage is restricted to the capacity of choke *34*, which is adequately compensated for by the flow from the main reservoirs.

In service position of equalizing slide valve *18*, the application cylinder and application chamber are connected to the safety valve by passage *11*, port *b3* in the equalizing slide valve, cavity *P* in the graduating valve, port *g* in the slide valve and passage *10*, preventing excessive pressure in the locomotive brake cylinders.

The amount of pressure developed in the application cylinder and locomotive brake cylinders for a given brake pipe reduction is controlled by the volume relation of the pressure chamber to that of the combined reduction chamber, application chamber and application cylinder, which is the same as that obtained with car brakes. That is, any given brake pipe reduction will result in an application cylinder and locomotive brake cylinder pressure approximately the same as obtained in car brake cylinders up to a maximum of 50 pounds at the point of equalization from a pressure chamber charged to 70 pounds. With higher brake pipe pressure and, therefore, higher pressure chamber pressure the maximum obtainable will be proportionately higher.

It will be noted that in Service position, cut-off valve *96* definitely cuts off the application chamber and cylinder from the Application Pipe. These volumes, therefore, are always constant and not liable to variation with application pipe length, as was the case in earlier distributing valve design. For this reason a given brake pipe reduction always produces a given application cylinder and resultant brake cylinder pressure as previously described, regardless of the length of the Application Pipe.

The reduction in brake pipe pressure during a service application takes place at the Vent Valve also, and the air flows from the piston chamber *A*, Fig. 84, through passages *b* and *b2*, and strainer *37*, to chamber *E*, thence through passage *a* to the brake pipe. If the strainer restriction should exceed the two-pound value of spring *36*, application check valve *33* is unseated and flow proceeds through passage *a2* to chamber *E*, thus by-passing the strainer. The pressures on the emergency piston *2* are unbalanced and it moves upward until its piston stop *12* strikes the cap where spring *11* prevents further travel of the piston. The charging port *c* is now closed by the piston and the slide valve chamber *B* is connected through the slide valve port *h* to the exhaust passage *e*. This permits quick action chamber

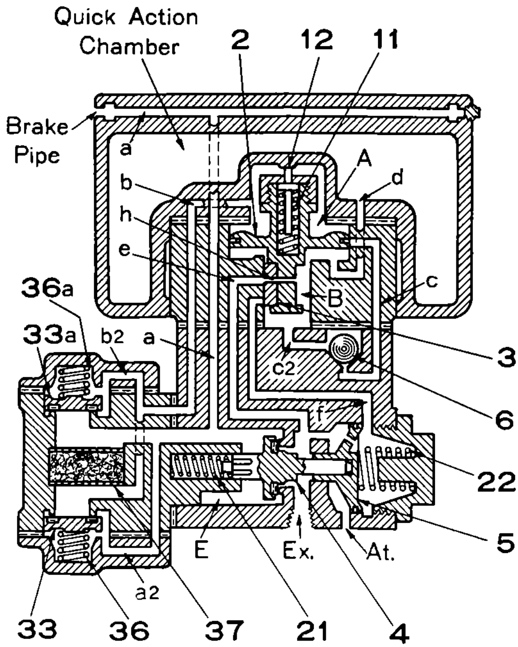


Fig. 84. Brake Pipe Vent Valve in Service Position

pressure to reduce in pressure at the same rate as the brake pipe pressure, thus preventing operation of the quick action valve during service applications. (When the brakes are released, the quick action chamber is again charged as previously described under "Full Release and Charging.")

Service Lap
Plate 27

As described under "Service," when the desired brake pipe pressure reduction is obtained the brake valve handle is moved to Lap position.

When the brake pipe reduction is not enough to cause a full service application, the flow of air pressures in the distributing valve continues until the pressure in the pressure chamber, by reducing into the application chamber and cylinder, is slightly below brake pipe pressure. Brake pipe pressure on the right of equalizing piston *10* now being higher than pressure chamber pressure on the left, the piston and graduating valve *16* move to the left until the piston strikes the equalizing slide valve *18*. In this position, graduating valve *16* covers port *f* in the slide valve, cutting off further flow of air from the pressure chamber to the application chamber and cylinder. Passage *10* between the application chamber and cylinder and the safety valve, is cut off by cavity *P* in the graduating valve moving away from passage *g* in the slide valve; therefore, any leak from the safety valve cannot reduce application cylinder pressure and consequently brake cylinder pressure.

The flow of main resevoir air past application valve *37* to the brake cylinders continues until pressure at the right of application piston *23* slightly exceeds application cylinder pressure at the left of the piston, when the piston will move to the left. Springs *44* and *45* then close application valve *37* and pilot valve *40*, preventing further flow of air to the brake cylinders.

A greater differential of pressure on application piston *23* is required to move the piston and exhaust slide valve than to move the piston alone; therefore, the piston stops when it comes into contact with the slide valve. Here the exhaust slide valve *25* still blanks the exhaust ports *Ex.* In this lap position the pressures on both sides of the piston are balanced. Under this condition, if brake cylinder pressure should be reduced by leakage, the piston will move to the right, open the pilot valve or application valve far enough to restore brake cylinder pressure to approximately that of the application cylinder, when the piston will again be moved to lap position. This constitutes the brake cylinder pressure maintaining feature.

Release and Recharge

Release position of the automatic brake valve is used to release the train brakes after an automatic application without releasing the locomotive brakes as described under "Full Release and Charging." It produces a rapid recharge while holding the locomotive brakes applied. In Running position both the train and locomotive brakes are released.

As described under "Full Release and Charging" and "Running" when the brake valve handle is returned to either position the brake pipe pressure is built up at the brake valve.

As the brake pipe pressure rises, the pressure acting on the right of the distributing valve equalizing piston *10* is increased above that of the pressure chamber acting on the left of the piston. This causes the piston to move to the left, carrying with it the slide valve and graduating valve, and making a joint against seal *26*, as shown on Plate 24. (The purpose of the seal has already been explained under "Full Release and Charging.") Air now flows from the brake pipe to the pressure chamber through feed groove *v* and charging choke *4* until pressure chamber pressure is increased to slightly less than brake pipe pressure, when the piston will be moved to the right by the force of the compressed recharge spring *13*, breaking the contact between the piston and seal, after which the pressure chamber is charged to brake pipe pressure through feed groove *v*.

In this position of the equalizing slide valve, the air pressure acting on reduction chamber cut-off piston *98* is balanced, by passage *19* on the spring side of the piston being connected to passage *18a* on the slide valve side through ports *b1* and *b2* in the equalizing slide valve. The force of compressed spring *106* acting on the left of the piston, therefore, moves the piston and slide valve to the right.

With the equalizing slide valve *18* in release position and the reduction chamber cut-off slide valve *101* to the right, the application chamber is connected through passage *11* and cavity *b5* in the equalizing slide valve *18* to passage *12b*. Application cylinder *A* is also connected to passage *12b* by way of passage *12d* and cock *202*. Passage *12b*, in turn, is connected through a cavity in the cut-off slide valve *101*, to passage *12a* and through choke *127* to passage *12*, leading to the Application Pipe.

With the brake valve handle in Release position, Plate 24, the Application Pipe is connected through passage *12*, ports *v* and *p* in the independent rotary valve, passage *3* and port *R* in the automatic rotary valve, to passage *3a* in the seat, where plug *A* blanks the latter, preventing discharge of application cylinder pressure. Therefore, the locomotive brakes cannot be released in Release position of the automatic brake valve.

But with the automatic brake valve handle in Running position, Plate 25, cavity *F* connects passage *3* to the exhaust port *Ex.*, thereby opening the Application Pipe to atmosphere, thus reducing pressure from the left of the application piston *23*. The higher brake cylinder pressure on the right of the piston then moves the piston and exhaust slide valve *25* to release position, allowing air from the brake cylinders, which are connected through the brake cylinder pipe and passages *9* and *9a* to the exhaust slide valve chamber *C*, to flow to atmosphere through the two exhaust ports in the exhaust slide valve seat and exhaust port *Ex*. The rate of release in Running position is controlled by choke *127* in passage *12a* and will, therefore, be the same for any installation regardless of length of the Application Pipe.

Where it is desired to release locomotive brakes in Release position of the automatic brake valve (independent brake valve in Running position) it can be accomplished by removing plug "*A*." "U" port *3* is connected to passage *3a* by port *R* in the rotary valve. Thus, air can flow to atmosphere from the application cylinder and chamber of the distributing valve to the Application Pipe, through passage *12* of the brake valve and "U" port *3*, and port *R* to open passage *3a*.

If a graduated release is desired, the brake valve handle may be manipulated between Running and Lap positions to reduce application cylinder pressure a desired amount, and as brake cylinder pressure on the right of the application piston becomes slightly lower than the remaining application cylinder pressure acting on the left, the application piston and slide valve will move to the right far enough to close the exhaust ports. Further reductions of application cylinder pressure will result in corresponding reductions of brake cylinder pressure.

If it is desired that the locomotive brakes release in Lap position following a release operation, this can be accomplished by removing Plug "*B*" from the automatic brake valve portion. As shown on Plate 27, this opens "U" passage *3* through ports *m* and *h* in the rotary valve to passage *3b* and the atmosphere so that following an automatic service brake application, and the brake valve handle has been moved to Release or Running position, the brake pipe is recharged so that the distributing valve equalizing piston and slide valve, and the cut-off piston and slide valve, move to release position. When the brake valve handle is returned to Lap position, the distributing valve remains in Release position, and application cylinder air flows to exhaust through the opening "*B*." Therefore, the locomotive brakes are released.

First Service
Plate 28

This position is for use with long trains with which the brake pipe pressure is usually progressively lower from front to rear of the train. As a result, the normal service brake pipe reduction tends to develop the braking force at the head end of the train faster and to a higher value than on the rear, causing slack action. First Service position overcomes this by reducing the brake pipe pressure more uniformly on all parts of the train.

When the brake valve handle is placed in First Service position, equalizing reservoir air flows from passage 5, through restricted port *n* and port *m* in the rotary valve to passage *22* (through First Service position cutout cock *80*) leading to the reduction limiting reservoir. The volume relation between the equalizing and reduction limiting reservoirs is such as to permit the reduction to continue at the normal service rate until about six pounds reduction is obtained in the equalizing reservoir pressure, with 70 pounds brake pipe pressure. Thereafter the reduction continues at a much slower rate through choked exhaust plug *120* (located in the automatic brake valve portion) which vents pressure from the reduction limiting reservoir passage *22*.

In this manner the equalizing reservoir is reduced quickly by an amount sufficient to initiate quick service on the train brakes, after which the reduction continues at a slow rate predetermined by the size of choke *120*. The equalizing reservoir is connected by passages *5* and *5a* to chamber *D* on the face of equalizing piston *126*, while the brake pipe is connected by passages 1 and *1b* to chamber *N* on the opposite side of the piston. As pressure is reduced from the equalizing reservoir side of the piston, the higher brake pipe pressure raises the piston and carries the long end of angle lever *136* upward. This causes the short end of the lever *136* to move to the left, engage with a collar on discharge valve *129* and unseat the valve, allowing brake pipe air to escape to atmosphere through passage *1d* and past exhaust valve *97*, which is unseated when the brake valve handle is in First Service, Lap, Service and Emergency positions. When the brake pipe pressure becomes slightly lower than equalizing reservoir pressure, which may be due to the slow reduction of equalizing reservoir pressure, piston *126* will move down and allow the short end of lever *136* to move to the right out of contact with discharge valve *129*. Spring *134a* will then cause the discharge valve to close and prevent further reduction of brake pipe pressure past this valve.

With the handle of the brake valve in First Service position, feed valve air in chamber *A* above the brake valve rotary valve is connected through port *E* of the rotary valve and passages *19* and *19a* to maintaining valve *132*.

If, for any reason, brake pipe pressure reduces at a faster rate than the controlled rate of equalizing reservoir pressure reduction imposed in first service position, brake pipe pressure acting on the lower side of the equalizing piston *126* will be less than equalizing reservoir pressure acting on the upper side of the piston. This will cause the piston to move down, lever *136* will contact with maintaining valve *132* and move it from its seat, as shown in the supplemental view "Maintaining Valve Open," Plate 28, allowing feed valve air from passage *19a* to flow into chamber *N*, thence through passage *1b* to the brake pipe and prevent brake pipe pressure reducing at a faster rate than equalizing reservoir pressure is being reduced. This action causes the brake pipe pressure reduction to be more uniform throughout the train than would otherwise be possible, thereby accomplishing a more uniform control of the braking force and eliminating slack action.

First Service position may be cut out by turning Cock *80* to "Out" position which closes seat passages *19* and *22* leading to the maintaining valve and the reduction limiting reservoir, respectively. First Service position may then be used as a Lap position, as the cutout cock closes the active ports. Ports *d* and *b* connect the "U" port *3* to passage *3b* so that locomotive brakes may be released, as in Service Lap position by removing plug *B*.

Emergency
With Rapid Brake Cylinder Pressure Development for Short Trains
Plate 29

In Emergency position of the Automatic Brake Valve, port *F* in the rotary valve makes a large and direct connection between brake pipe passages *1* and *1a* and the exhaust port *Ex.*, causing a sudden and heavy discharge of brake pipe air; and port *k* registers with passage *5*, permitting equalizing reservoir pressure to reduce rapidly to zero through the exhaust *Ex.*

Main reservoir air flows from passage *7* through ports *g* and *e* in the rotary valve to passage *21* and thence through passage *21a* to chamber *S* on the face of the relay valve piston *49*. This pressure rapidly moves the piston to the right, the piston stem engaging and unseating pilot valve *39*. Brake pipe air on the spring side of vent valve *36* escapes past the pilot valve to the atmosphere at *Ex.*, the capacity of the unseated pilot valve being such that the spring chamber is exhausted to atmosphere at a more rapid rate than brake pipe pressure is supplied through the choked port from chamber *U*. This balances the vent valve *36* so that continued movement of the piston stem quickly unseats the vent valve, thus providing a large, direct exhaust of brake pipe air from passages *1c*, *1* and the brake pipe. This operation of the relay valve is not affected by the closing of the double heading cock. A heavy reduction of brake pipe pressure therefore occurs on the locomotive.

The exhaust valve *97* is also open in emergency position and, since the equalizing reservoir pressure is reduced to zero as above explained, the equalizing piston *126* moves quickly upward, unseating the discharge valve *129* and opening chamber *N* to atmosphere through passage *1d*.

With the sudden reduction of brake pipe pressure in chamber *B* on the face of the distributing valve equalizing piston *10*, the greater pressure in slide valve chamber *F* moves the piston promptly to the right with sufficient force to compress graduating spring *31*. The equalizing slide valve and graduating valve are thereby carried to emergency position where pressure chamber air flows through port *5* in the seat, to cavity *b5* in the slide valve and passage *12b* in the seat. Passage *19,* at the left of the reduction chamber cut-off piston *98,* is connected to atmosphere through port *d1* and cavity *d* in the equalizing slide valve *18,* while the right face of piston *98* is connected to the pressure chamber by passage *18a,* cavity *c* and port *c1* in the slide valve, and passage *5* in the seat; therefore, the cut-off piston *98* and its slide valve *101* are moved promptly to the left, as shown, where passage *8a* is blanked, cutting off the reduction chamber, and connecting passage *12c* to *12b.* This quick movement of the cut-off piston eliminates the delay involved in building up the reduction chamber as during a service application.

The reduction chamber cut-off piston is held in cut-off position by pressure chamber air supplied to its right face through passage *13.* The equalizing slide valve *18* blanks passage *11,* leading to the application chamber. Thus, with both the reduction chamber and application chamber cut off, pressure chamber air flows rapidly from port *5* in the equalizing slide valve seat, through cavity *b5* in the slide valve to port and passage *12b*; and also through port *N* in the equalizing slide valve, to passage *12c,* cavity in the cut-off slide valve to passage *12b* whence the combined flow passes through cock *202,* thence through passage *12d* to the application cylinder *A.* Thus, the air flows directly from the pressure chamber to the application cylinder *A* only (instead of to the reduction chamber and application chamber also, as in service) so that the two volumes quickly become equalized. The application cylinder volume, being small, and connected to that of the pressure chamber at 70 pounds pressure, equalizes at about 65 pounds. As a result of this rapid, direct equalization, the application piston *23* is moved promptly to the right, opening the application valve *37* fully, which then produces a fast build-up of brake cylinder pressure as described under "Service."

At the same time that port *N* in equalizing slide valve *18* supplies pressure chamber air to the application cylinder through passage *12c,* it is also connected through passage *10* to the safety valve. Thus, while the pressure chamber equalizes into the small volume of the application cylinder producing a higher value than during a service brake application, its maximum value and consequently, that of brake cylinder pressure, is under the control of the safety valve. Meanwhile, at the automatic brake valve, feed valve air from chamber *A* is supplied through maintaining port *E* in the rotary valve to passage *12b* in the seat, thence through passage *12* to the Application Pipe and distributing valve, where it flows through passages *12* and *12e,* unseats cut-off check valve *96* and flows through passage *12h* to passage *12b,* which is connected to the application cylinder *A* as already described. The equalized pressure chamber and application cylinder are connected through passage *10* to the safety valve, as previously described.

The rate of flow from feed valve to application cylinder is controlled by a choke in passage *12b* in the brake valve rotary valve seat, and the flow from the equalized application cylinder and pressure chamber to the safety valve is controlled by restricted port *10,* the capacity of these two ports being so proportioned that a balanced maximum application cylinder pressure is constantly maintained.

The brake cylinder pressure thus obtained in Emergency will vary with the feed valve adjustment, depending on the relation between feed valve pressure and safety valve setting. Consequently, higher locomotive brake cylinder pressure will be obtained with the higher brake pipe pressure used in passenger service. This will correspond with the increased brake cylinder pressure obtained on passenger trains, as compared to freight trains.

An emergency rate of brake pipe reduction also occurs at the Vent Valve. With the sudden pressure drop in chamber *A,* Fig. 85, the higher Quick Action Chamber pressure in chamber *B* forces the piston upward, compressing spring *11,* and carrying slide valve *3* to its limit of travel, which uncovers port *f.* Quick action chamber air in chamber *B* then flows through passage *f* to the outer face of quick action piston *5,* and since there is no air pressure on the opposite face of the piston, it is moved to left, unseating quick action valve *4.* This creates a direct opening from chamber *E* to the atmosphere and accomplishes a rapid venting of brake pipe air from passage *a* and the brake pipe, thus propagating quick action to adjacent cars.

A small vent port through the quick action piston allows quick action chamber air to bleed down until spring *21* can force

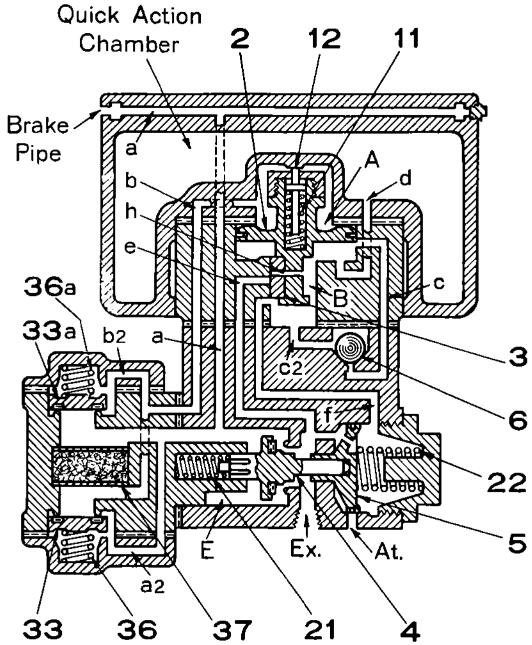


Fig. 85. Brake Pipe Vent Valve in Emergency Position

both the valve and piston to their normal position, thus closing the outlet to the atmosphere and permitting the brake pipe (and quick action chamber) to be recharged when desired, as already explained.

Emergency

(With Delayed Brake Cylinder Pressure Development for Long Trains. Plate 29—Supplemental View)

When a delayed build-up of emergency brake cylinder pressure is desired, the delay cock is left in delay ("F") position, as shown on the supplemental view on Plate 29—Direct Control Delay Valve (Delay Position).

In this position of the delay cock, pressure chamber air in passage *12b* will flow through choke *128* and passage *12d,* to the the face of application piston *23,* and through cock *202* to passages *11a* and *11* to the application chamber. The delayed build-up of application cylinder pressure, and, therefore, brake cylinder pressure, is caused by the slow build-up of pressure through choke *128* into the combined volume of the application chamber and application cylinder.

The ball check and the rubber seated check are for the purpose of by-passing choke *128* during a release of locomotive brakes with the independent brake valve, with the equalizing slide valve in emergency position. The rubber seated check valve provides added protection against possible leakage from passages *12b* and *12g* past the ball check, which would thereby by-pass choke *128*.

Automatic Release After Emergency

The movable parts of the valve remain in the position shown on Plate 29 until the brake cylinder pressure slightly exceeds the application cylinder pressure when the application piston and application valve move back to lap, as described under "Service." The equalizing piston remains in its full emergency position until pipe pressure is restored. When the automatic brake valve handle is returned to Release position, the supply of main reservoir air to passages *21* and *21a* is cut off. Pressure in chamber *S* on the face of relay valve piston *49* escapes to atmosphere through a small bleed port in the piston, after which spring *50* forces the piston to release. This allows springs *42* and *37* to seat the pilot valve *39* and vent valve *36*, closing the atmospheric exhaust. The brake pipe pressure is then restored as described under "Full Release and Charging." As it builds up in chamber *B* on the face of the equalizing piston, the latter is forced to release position. In non-delay position of the delay cock the application chamber is cut off from the application cylinder in emergency position so that it is at atmospheric pressure. As the equalizing piston returns to release, Plate 24, the slide valve cavity *b5* connects passages *12b* and *11*. The emergency pressure in the application cylinder at once expands into the application chamber until these pressures are equal, which results in a drop in the total pressure. Brake cylinder air is then released by the application piston and slide valve *25* to a pressure corresponding to that in the application cylinder. Consequently, in releasing after an emergency application, using the Release position of the automatic brake valve, the brake cylinder pressure will automatically reduce to approximately 15 pounds, where it will remain until the automatic brake valve handle is moved to Running position.

However, when the delay cock is in delay position, the application cylinder and chamber are connected in emergency position so that this rapid pressure reduction in the application cylinder does not occur when the brake valve handle is returned to Release, but the entire pressure is retained until the handle is moved to Running position.

INDEPENDENT BRAKE

Running

Plate 25

This is the position in which the independent brake valve handle should be carried at all times when the independent brake is not in use. Chamber *X* above the rotary valve *154* is charged to reducing valve pressure from passage *14*. Ports *p* and *v* in the rotary valve connect passages *3* and *12*, thus establishing communication between the Application Pipe and the automatic brake valve rotary valve. Therefore, with the automatic brake valve also in Running Position the application cylinder and chamber of the distributing valve are connected to the automatic brake valve *Ex.*, and the locomotive brake cylinders are open to atmosphere at the exhaust port *Ex.* of exhaust slide valve *25*. Exhaust cavity *Z* in the independent rotary valve connects port *w* to the independent *Ex.*, thus opening the Independent Release Pipe (through passage *6*) to atmosphere; therefore, in the distributing valve, passage *6* and chamber *E* of the release valve are at atmospheric pressure so that spring *93* holds release piston *87* to the right and spring *97* holds cut-off check valve *96* seated, closing communication between passages *12e* and *12h.*

Quick Application

Plate 30

To obtain a quick application of the independent brake, the independent brake valve handle is moved to Quick Application position, Plate 30. Port *t* then connects chamber *X* to passage *12* in the seat, allowing reducing valve air at 45 pounds pressure to flow rapidly to the Application Pipe, thence to the distributing valve where it flows through passages *12* and *12e,* unseats cut-off check valve *96,* and flows through passage *12h* to passage *12b.* With the delay cock in "P" (non-delay) position, the air flows from passage *12b* in two directions: (1) through the delay cock *202* to passage *12d* to the application cylinder and (2) through cavity *b5* in the equalizing slide valve and passage *11* to the application chamber. With the delay cock in "F" (delay) position, as shown in the supplemental view, air flows from passage *12b* to the application chamber through cavity *b5* in the equalizing slide valve and passage *11*, and through passage *11a*, delay cock *202*, to passage *12d* and the application cylinder, thus by-passing choke *128*.

The air pressure then built up in chamber *A* on the face of Application piston *23*, forces the piston to the right, where the exhaust slide valve *25* closes the brake cylinder exhaust port, and the pilot and application valves are opened to admit main reservoir air to the locomotive brake cylinders, as described under "Service." The amount of brake cylinder pressure is dependent upon the pressure admitted to the application chamber and cylinder by means of the independent brake valve. Since the supply pressure to the independent brake valve is fixed by the setting of the reducing valve to 45 pounds, this is the maximum brake cylinder pressure that can be obtained. As the value of cut-off check valve spring *97* is approximately five pounds, the cut-off check valve *96* will be closed by the spring when 40 pounds pressure is built up, after which the remaining five pounds build-up takes place from passage *12a* through choke *127*, cavity in the reduction chamber cut-off valve slide valve *101*, to passage *12b*, thence to the application cylinder and chamber.

Slow Application

Plate 30—Supplementary View

The only operative difference between Slow Application position and Quick Application position is in the size of opening in the rotary valve seat through which reducing valve air is admitted to the application pipe. As shown in the supplementary view of the independent brake valve on Plate 30, Slow Application position, passage *12* is blanked by the rotary valve and port *t* registers with slow application port *12a*, permitting air to flow through the choke *178* to passage *12*, thence to the Application Pipe and distributing valve, where it causes brake application as described under "Quick Application." The choke in the slow application port *12a* imposes a slower build-up than that produced in Quick Application position.

Lap

Plate 31

Lap position is used to hold the independent brake applied after the desired brake cylinder pressure is obtained. Passages *12* and *12a*, leading to the application pipe, are blanked by the independent rotary valve. When brake cylinder pressure is slightly higher than pressure in the distributing valve application cylinder, springs *44* and *45* return the pilot and application valves *40* and *37* to their seats, and the application piston *23* moves to the left until stopped by the resistance of exhaust slide valve *25*. The brake cylinder exhaust port is blanked by the slide valve, retaining the brake cylinder air. As long as the independent rotary valve is in Lap position, brake cylinder pressure will be maintained equal to that in the application cylinder by the maintaining feature of the application piston, described under "Service."

Independent Release—Automatic Brakes Released

Plate 25

With the automatic brake valve in Running position, an independent brake application may be released by placing the independent brake valve handle in Running position. This connects the Application Pipe to the automatic brake valve exhaust port *Ex.* by way of passage *12*, ports *v* and *p* in the independent brake valve rotary valve, passage *3* to automatic brake valve and cavity *F*. The air is thus allowed to escape from the distributing valve application cylinder *A* through passage *12d*, delay cock *202* to passage *12b*; and from the application chamber through passage *11*, cavity *b5* in the equalizing slide valve and passage *12b*, whence the combined flow escapes through cavity in the reduction chamber cut-off slide valve *101* to passage *12a*, choke *127*, and passage *12* to the Application Pipe. If the delay valve is in delay position (see supplemental view) application cylinder air flows direct from passage *12d*, through delay cock *202* to passages *11a* and *11*, where it combines with flow from the application chamber through cavity *b5* in the equalizing slide valve *18,* to passage *12b,* cavity in the reduction chamber cut-off piston *101,* to passage *12a,* choke *127* and passage *12* to the Application Pipe. Choke *127* thus controls the escape of air to a predetermined rate. With the resultant reduction on the face of application piston *23* the piston and slide valve move to the left, the exhaust ports are uncovered, and brake cylinder pressure is reduced at a corresponding rate.

If the independent brake valve handle is returned to Lap before all the application cylinder pressure has escaped, the application piston *23* will return to Independent Lap position, Plate 31, as soon as brake cylinder pressure is reduced a little below that remaining in the application cylinder, thus closing exhaust *Ex.*, and holding the remaining pressure in the brake cylinder. In this way, the independent release may be graduated as desired.

Independent Release after Automatic Service Application Plate 32

If the brakes have been applied throughout the train by means of the automatic brake valve, and it is desired to release the locomotive brakes, the handle of the independent brake valve is placed in Release position, Plate 32, (Automatic Valve in Lap).

In this position the Application Pipe is connected through pedestal passage *12* to port *Z* in the independent brake valve rotary valve and the exhaust *Ex.*

Reducing valve air from chamber *X* of the independent brake valve flows through port *y* to passage *6* in the brake valve pedestal to the Independent Release Pipe.

At the distributing valve, the reducing valve air flows through passage *6* to chamber *E* on the face of release piston *87*, forcing this piston to the left and unseating cut-off check valve *96*.

With check valve *96* unseated, communication is open between passage *12h* (connecting with application cylinder *A* and application chamber) and passage *12e*, which connects direct with passage *12* and the application pipe (now open to exhaust through the independent brake valve, as already explained).

Under this condition, application cylinder air flows through passage *12d* and the delay cock *202* (non-delay position) to passage *12b* to which the application chamber is also connected by way of passage *11* and cavity *b5* in the equalizing slide valve. With the delay cock *202* in delay position, application cylinder passage *12d* is connected to application chamber passages *11a* and *11*, combining the air from these two volumes.

Air from these combined volumes flows from passage *12b* through passage *12h*, past the unseated check valve *96*, and through passage *12e* to passage *12*, the application pipe, and to atmosphere through the exhaust port of the independent brake valve.

It will be noted that release choke *127* in passage *12a* of the distributing valve is by-passed and, therefore, a much faster release is obtained than when releasing in Running position of the independent brake valve.

This fast rate of release may be obtained under all conditions by using Release position of the independent brake valve. As the pressure in the application chamber and cylinder is reduced, brake cylinder pressure forces the application piston *23* and exhaust valve *25* to release position, where the brake cylinders are opened to *Ex.*, allowing a corresponding reduction in brake cylinder pressure.

Port *t* in the independent brake valve rotary valve registers with the *W. P.* port in the seat of the independent brake valve, thus allowing reducing valve air from chamber *X* to escape to the exhaust port in Release position. The blow of the escaping air acts as a warning to the engineman in case the return spring is broken and he fails to return the handle to Running position.

Independent Release after Automatic Emergency Application

An independent release of locomotive brakes may also be made in the same manner, after an emergency application. With the delay cock in "P" (non-delay) position, the application cylinder releases through passage *12d*, cock *202*, passages *12b*, *12h*, *12e* and *12* to the independent brake valve exhaust. With the delay cock in "F" (delay) position, the combined application cylinder and chamber volumes flow through passage *12k*, past ball check

206, and rubber-seated check *207* to passage *12g*, thus by-passing choke *128* to passages *12b*, *12h*, *12e* and *12* to the independent exhaust. This provides a normal fast release around choke *128*.

In Emergency position, the automatic brake valve supplies the application cylinder through the maintaining port *E* in the rotary valve (see Plate 29). The handle of the independent brake valve must be held in Release position to prevent the locomotive brakes from reapplying, so long as the handle of the automatic brake valve remains in Emergency position. The equalizing portion of the distributing valve will remain in Emergency position as shown on Plate 29, while the application portion will assume Release position as shown on Plate 32.

Independent Application after an Independent Release Automatic Brakes Applied

Plate 33

If it is desired to reapply the locomotive brakes after independent release, with the automatic brake applied, this may be accomplished by moving the handle of the independent brake valve to either Slow or Quick Application position. Reducing valve air from chamber *X* then flows through port *t* in the independent brake valve rotary valve to passage *12* in the brake valve pedestal and to the Application Pipe. At the distributing valve the air then flows through passages *12* and *12e*, unseats cut-off check valve *96*, and flows to passages *12h*, *12b*, cavity *b5* in the equalizing slide valve and passage *11* to the application chamber; from passage *12b* air also flows through delay cock *202* (in its "P," non-delay, position) to passage *12d* and to the left of application piston *23*, which is thereby moved to open the application valve *37* and develop brake cylinder pressure as already explained. With the delay cock in its "F" (delay) position, the flow to the application chamber is through cavity *b5* in the equalizing slide valve to passages *11* and *11a*, and delay cock to passage *12d*.

The application cylinder and chamber pressures are limited to 40 pounds by cut-off check valve spring *97*, with the equalizing slide valve in Lap position, since passage *12a* is blanked by the reduction chamber cut-off slide valve *101*, and no further build-up of these pressures can take place through choke *127*, as in release position of the equalizing slide valve.

DEAD ENGINE FEATURE

Plate 24

The "Dead Engine Feature" is incorporated in the distributing valve body and is cut in or out by the positioning of Cap *56*. Its position is indicated by the words "LIVE" and "DEAD" on the cap, and "ENG" on the distributing valve body. With the word "LIVE" over "ENG," the cap is in "Live Engine" position and with the position of the cap reversed the word "DEAD" is over "ENG," indicating "Dead Engine" position.

With the cap set for "Dead Engine" operation, as indicated in the supplemental view at the upper right on Plate 24, brake pipe air from passage *1* flows through strainer *32* and passage *1b*, unseats spring loaded check valve *52*, and flows through passage *1c* and choke *35* to passages *7b* and *7*, charging the main reservoirs on the "dead" engine. As brake pipe air in passage *1b* must pass through strainer *32*, the check valve and choke are protected against the effect of dirt.

With the dead engine cap set for "Dead Engine" operation, the maintaining port to the application pipe is cut out and there is no flow of air from the main reservoirs to the brake valve exhaust on a dead engine such as occurs on a helper locomotive to indicate when the locomotive brakes are applied.

The spring *51* on check valve *52* is of a value to insure ample pressure in the main reservoirs of a "dead" locomotive to properly apply the brakes, and also provides for brake pipe pressure being enough higher than main reservoir pressure on the "dead" locomotive to prevent back flow to the brake pipe when the brakes are applied. Choke *35* is small enough to prevent a reduction in brake pipe pressure which might apply the brakes when a "dead" locomotive with empty main reservoirs is connected to a charged brake pipe.

Other Pneumatic Apparatus

Other pieces of pneumatic apparatus are listed as follows:

(See Plate 34 for control air piping.
See Plate 35 for pantograph air piping.
See Plate 36 for sander air piping.
See Plates 21, 22 and 23 for train air signal piping).

(a) A reducing valve which reduces main reservoir pressure to supply air for the electro-pneumatic control system.

(b) A control reservoir stores the compressed air for the electro-pneumatic control system. This reservoir is provided with a drain cock by means of which all residue may be drawn off at frequent intervals.

(c) An air gauge is connected to the control reservoir.

(d) A quick application and release valve (GG1 locomotives) functions to supply air to the auxiliary contactors as long as a predetermined minimum air pressure is maintained in the control air reservoir; it cuts off and vents the supply of air when control reservoir pressure drops below the minimum.

(e) The pantograph hand pump can be used to supply air for unlatching the pantographs when control reservoir pressure is not available.

(f) The sand traps function to deliver sand from the sand boxes to the rails.

(g) The car discharge valves, connected to the train air signal pipe, can be used by the helper in signaling to the engineman, and vice versa.

(h) The signal valve functions in response to the operation of car discharge valves on the locomotive or cars in the train to sound the signal whistle at the engineman's position.

(i) The locomotive whistle, controlled from the engineman's position, uses main reservoir air.

(j) The locomotive bell, controlled from the engineman's or helper's position, is equipped with a ringer using main reservoir air.

(k) The window wipers use main reservoir air.

Control Air Reducing Valve

The control air reducing valve, shown diagrammatically in Figs. 86 and 87, is pictured with all parts in one plane in order to facilitate description. The valve consists of two portions—the supply and regulating portions. The supply portion consists of a slide valve *7* and a piston *6*, Fig. 86. The slide valve *7* opens or closes communication from the main reservoir to the control reservoir and is moved by piston *6*, which is operated by main reservoir air entering through passage *a* on one side or by the pressure of piston spring *9* on its opposite side. The regulating portion consists of a brass diaphragm *17*, on one side of which there is a diaphragm spindle *18*, held against the diaphragm by the regulating spring *19*, and on the other side a regulating valve *12*, held against the diaphragm or its seat, as the case may be, by spring *13*. Chamber *L*, on the face of the diaphragm, is open to the control reservoir through passages *e* and *d*.

Suppose spring *19* to be compressed so as to exert a force equivalent to a 90-pound air pressure on the opposite side of the diaphragm. Then, as long as the air pressure in the main reservoir and chamber *L* is less than 90 pounds, the spring holds the diaphragm over as far to the left as possible, as shown in Fig. 86. This holds the regulating valve off its seat, thus opening port *K*, which permits air to flow through port *K* from passage *h* and chamber *G* at the back of the supply piston *6*. Consequently, as long as the air pressure in *G*, *h*, *e* and *d* is less than 90 pounds, the higher main reservoir pressure on the opposite side of piston *6* forces it to the extreme left, compressing spring *9* and opening port *c* as shown in Fig. 86. Air, therefore, continues to flow from the main reservoir through *a*, *c* and *d* to the control reservoir, increasing its pressure and the pressure in chamber *L*, acting on diaphragm *17*, until it reaches 90 pounds. The air pressure on the diaphragm is then able to overcome the spring pressure on the opposite side and force the diaphragm to the right by "buckling" it slightly in that direction. This allows the regulating valve spring *13* to return the regulating valve *12* to its seat, which closes port *K*. Chambers *G* and *H* are then no longer open to the control reservoir passage *d* at 90 pounds pressure, and being small, are instantly raised to main reservoir pressure by the

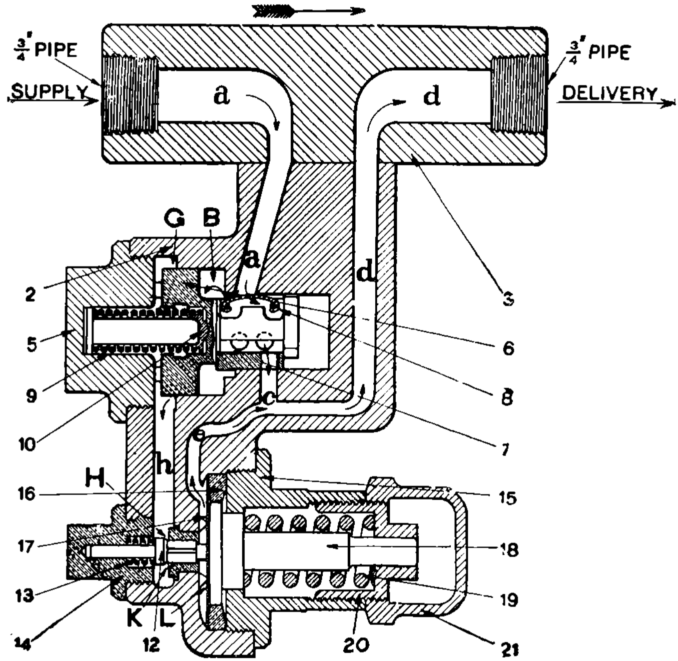


Fig. 86. Diagrammatic View of the C-6 Reducing Valve in OPEN Position

slight leakage of air past the supply piston, which is made loose fitting for this purpose. As the air pressures become nearly equal on the opposite sides of the supply piston, the piston spring *9* forces the piston and its slide valve to closed position, Fig. 87, which prevents further flow of air from the main reservoir to the control reservoir. The operation of the valve as described, after the pressure in the control reservoir has reached 90 pounds, is almost instantaneous; so that the control reservoir pressure is held constant at 90 pounds until it is slightly reduced by leakage so that its pressure on diaphragm *17* is no longer able to withstand the pressure of the regulating spring, which then forces the diaphragm back, lifting the regulating valve from its seat and again opening port *K*. This allows the air (at main reservoir pressure) in chambers *G* and *H* to flow through *K* to chamber *L*, thus dropping the pressure behind piston *6* below that of the main reservoir acting on the opposite side of the

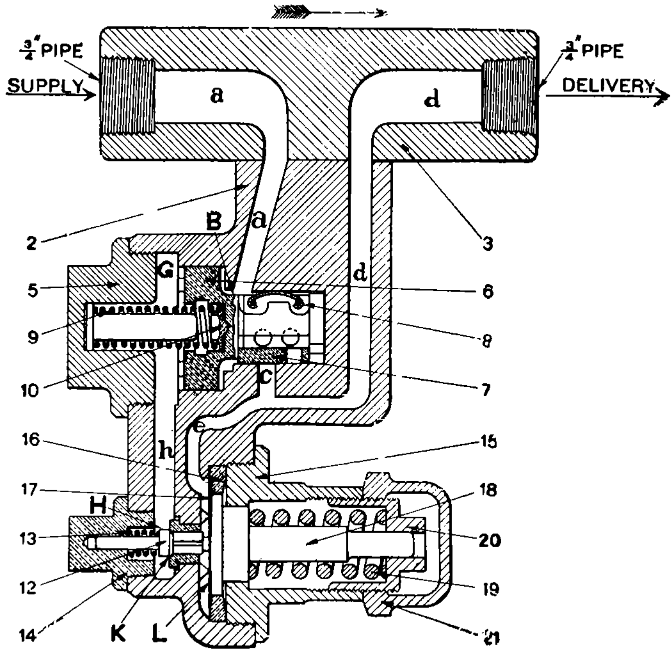


Fig. 87. Diagrammatic View of the C-6 Reducing Valve in CLOSED Position

piston. The higher pressure then forces the piston over into open position, as shown in Fig. 86, and allows sufficient air to flow through port *c* to the control reservoir to again raise its pressure to 90 pounds, when the reducing valve closes.

The reducing valve acts as a maintaining valve in this manner, keeping the control reservoir pressure constant at the amount for which the regulating valve is adjusted. The valve is adjusted to work at the required pressure by increasing or decreasing the tension on spring *19*, by screwing regulating nut *20* either in or out.

Quick Application and Release Valve

The quick application and release valve is shown diagrammatically in Fig. 88. Piston *3* holds its seal *4* to blank off control

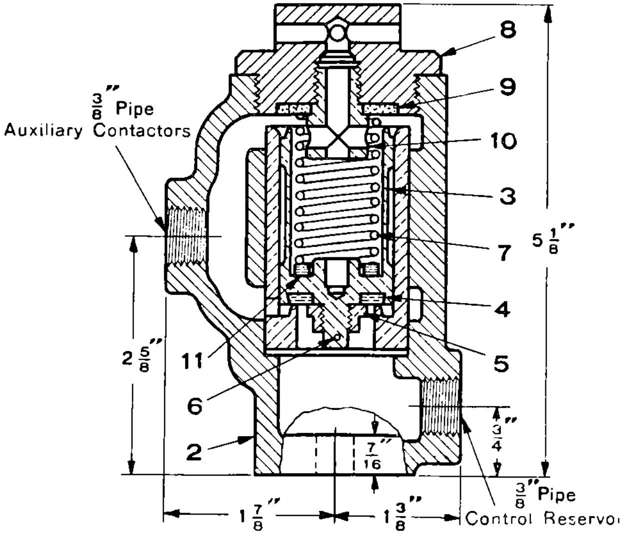


Fig. 88. Sectional View of Quick Application and Release Valve

reservoir pressure until a pressure of 70 pounds is obtained which is sufficient to overcome pressure of spring *7*. Piston *3* then quickly lifts, seating against seal *9* to prevent the escape of air through vent cap *8*. A greater area of piston *3* is thus exposed to control reservoir pressure to hold the valve open and permit flow of air to the auxiliary contactor supply pipe. Whenever control reservoir pressure drops below 70 pounds, piston *3* is forced by spring *7* to close the valve, thus cutting off flow of air to the auxiliary contactor supply pipe and exhausting the air from that pipe through vent cap *8*.

Sand Traps

A cut-away view of a sand trap is shown in Fig. 89. Sand supplied through pipe *H* lies trapped around and in front of the nozzle tube *B* when not in operation.

The momentary cleaning air blast which occurs at the beginning and ending of each sanding operation acts through pipe *C* and port *E* to blow out any obstruction to sand flow in the sand delivery pipe *I*. The cleaning blast acts also through passage *X* and sand delivery jet *D*. This jet is closed at the upper end

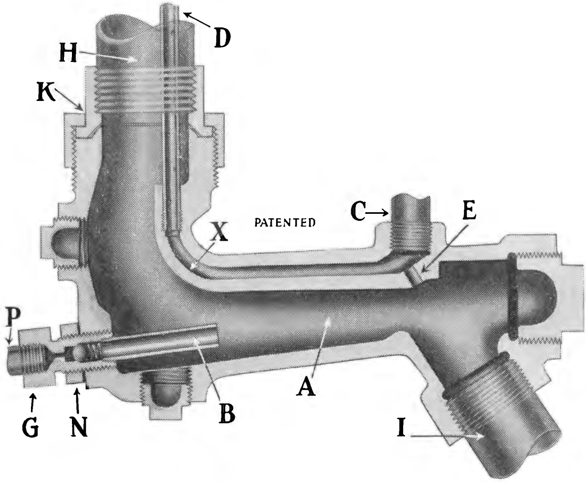


Fig. 89. Sectional View of Sand Trap

but around its sides small holes serve to send a swirling downward blast through the sand supply pipe and the trap to break up and dispose of any clot that may be obstructing the sand flow at that point.

The sanding air blast acts through pipe *P*, nozzle *G* and nozzle tube *B* to keep sand flowing through the trap to the sand delivery pipe *I* and thence to the rail.

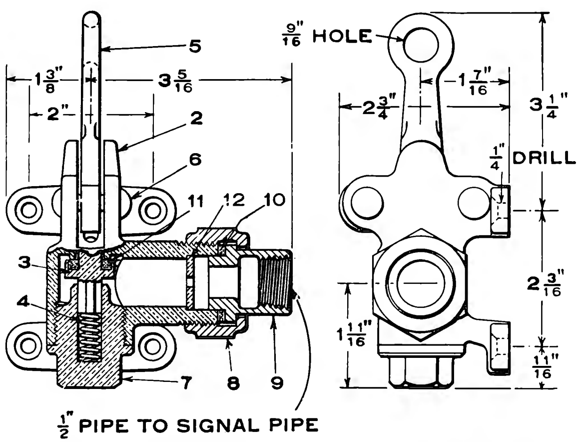


Fig. 90. Sectional View of Car Discharge Valve

Car Discharge Valves

The car discharge valve is shown in Fig. 90. A pull on lever *5* causes valve *3* to open permitting a small quantity of air to escape to the atmosphere, thereby reducing signal pipe pressure and causing the signal valve to operate to blow the signal whistle.

Signal Valves

The signal valve comprises three portions—a body *2*, a top cover *3*, and the volume chamber (or bottom cover) *17*, see Fig. 91. Each of the three portions is a separate chamber, divided by the parallel diaphragms *5* and *5a* of the body portion. Signal pipe pressure is always present in chamber *A* above diaphragm *5*. Air in this chamber can flow through port *G* and through passages around seated upper valve seal *8* to chamber *C* between the two diaphragms. From this chamber, air flows through choke *F* into (and charges) the volume chamber *B* under the lower diaphragm *5a*.

When a reduction of signal pipe pressure in chamber *A* is made at a faster rate than air can flow from volume chamber *B* through choke *F*, pressure in chamber *C* above diaphragm *5a* will be lower than that below in volume chamber *B*, and both diaphragms will be deflected upward since they are rigidly connected by means of diaphragm spacers. The upward diaphragm movement will unseat whistle valve (upper valve seal) *8* and allow air to flow from chamber *C* through choke *D* to the whistle.

Chamber *C* is connected to the signal pipe through port *G* and to volume chamber *B* through choke *F*, so that air flows to the whistle from both the signal pipe and the volume chamber *B*. Port *G* is larger than choke *F* and, therefore, most of the air used to blow the whistle is taken from the larger volume or the signal pipe. Because of the small size of choke *F* as compared to port *G*, the pressure in chamber *C* between the diaphragms will drop at a faster rate than that in volume chamber *B*, and the diaphragms will move upward far enough so that with a given rate of signal pipe reduction, check valve *14* will be unseated and supplement the flow of air through choke *F* from volume chamber *B*.

With this additional opening, the pressure in volume chamber *B* will be reduced at a faster rate than the signal pipe pressure in chamber *A*, and the diaphragms (assisted by spring *10*) will be deflected downward, allowing check valve *14* to seat and also seating the whistle valve *8*, thereby preventing further flow of air to the whistle. The upper stem of valve *14* is tapered and has a close fit in its guide when the valve is seated. The purpose of this is to obtain approximately the same length whistle blast regardless of train length.

With a very short train, the rate of reduction of signal pipe pressure will be fast and there will be considerable drop of pressure in chamber *A*. This causes the diaphragms to deflect upward their full travel and check valve *14* will have its maximum opening past the tapered stem, which will reduce the pressure in volume chamber *B* at a rapid rate below signal pipe pressure, resulting in a quick downward deflection of the diaphragms and a short whistle blast.

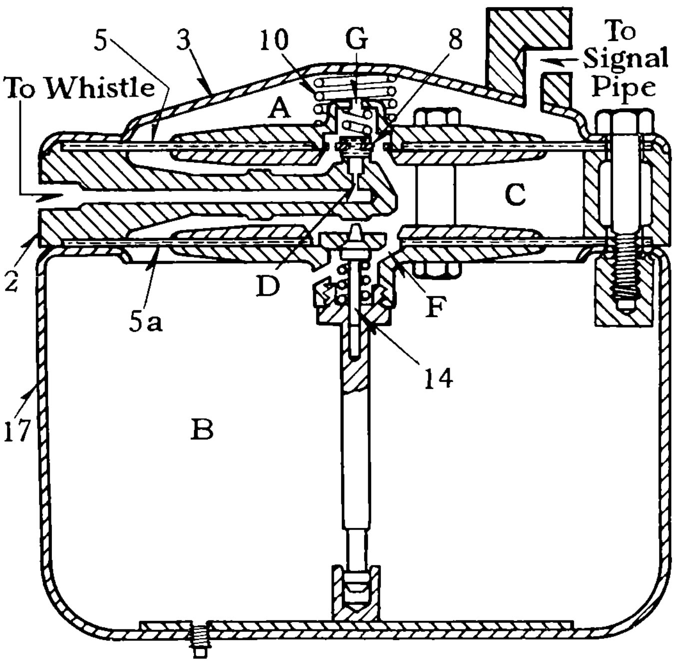


Fig. 91. Sectional View of Signal Valve

With long trains, the rate of signal pipe reduction will be slow and the amount of reduction for a given length of discharge valve opening will be small. The upward diaphragm deflection will be less than with a fast rate of signal pipe reduction. As check valve *14* will be only partially opened, the stem will restrict the valve opening and the reduction of pressure in volume chamber *B* (necessary to create a closing differential on the diaphragms) will be at a rate which will insure whistle valve *8* remaining unseated long enough to provide approximately the same length of whistle blast as that obtained with a short train.

Port *G* and diaphragm *5* are for the purpose of providing the proper relation of pressure between the signal pipe and volume chamber *B* necessary to blow the whistle. This diaphragm makes a seal between chambers *A* and *C* except for port *G*. The size of this port is fixed to supply signal pipe air to the whistle, and at the same time, not prevent flow of air from volume chamber *B*, which is necessary for the upward diaphragm deflection and the closing of whistle valve *8*.

Choke *F* (No. 69 drill) fixes the charging rate of chamber *B* and is of the proper size to provide desired sensitiveness of operation.

Choke *D* (No. 50 drill), by restricting the rate of air flow to the whistle, provides the proper balance of pressures in chambers *B* and *C*.

Lower diaphragm *5a* opens and closes the whistle valve *8* as a pressure differential is created between that in the signal pipe and in the volume chamber *B*.

Check valve *14* provides for a uniform length of whistle blast for varying train lengths.

The main function of diaphragm spring *10* is to stabilize the valve and to prevent false signals.

Operating Instructions for the Locomotive

PREPARATION

Inspection of the outside and inside of the locomotive when preparing for service should be a careful examination to disclose any noticeable defects. Position of the pantograph grounding switches should be noted, also the presence of chocks, skates or chains under the wheels and the state of the hand brake gear. Extra precautions must be taken before preparation work is started to ascertain if any person is working in or around the locomotive.

Certain switches on the locomotive should normally be in the closed position while others should be open. Likewise, certain cocks should normally be open while others remain closed. Familiarity with the electrical circuits and air piping of the locomotive will establish these practices.

Only one set of control handles should be available and these should be in the care of the engineman in order to avoid any misuse of them. Handles required are those of the control cut-out and reset switch, reverse drum of the master controller, independent brake valve and automatic brake valve. When two or more locomotives are coupled one set of handles for the independent brake valve and automatic brake valve are necessary for each trailing locomotive.

To prepare the locomotive the battery switch should be closed and one pantograph selector switch thrown to "UP" position, the other remaining in "DOWN" position. See that both pantograph grounding switches are open and secured with the pins provided before the pantograph is raised.

When compressed air is available for raising the pantograph from the push-button set, the "DOWN" button should be operated momentarily to first charge the lowering cylinders with air. The charged cylinders will dampen the force of the pantograph in rising when the "UP" button is pressed. When compressed air is not available, the hand pump should be used to raise the pantograph.

When the transformer is energized, it produces a low humming sound which is fairly audible near the transformer. The absence of this humming sound may serve as a useful indicator when power is interrupted on the trolley circuit; however, absence of this humming sound must never be interpreted as proof that any part of the primary or secondary circuits are de-energized.

The transformer oil pump on GG1 locomotives should start as soon as the main transformer is energized.

See that the governor cutout switch is closed. Closing the air compressor contactor should operate the air compressor under the control of the governor to charge the main reservoirs and control reservoir of the locomotive.

The transformer blower on P5a and Modified P5a locomotives (the No. 2 blower on GG1 locomotives) should be started at once to supply ventilating air to the transformer. Other blowers should be started as soon as required for hauling a train.

The cab signal power switch and the cab signal cutout switch should be closed. The cab signal cutout cock should be opened.

Handles for the control cutout and reset switch, the reverse drum of the master controller, the independent brake valve and the automatic brake valve should be applied at the engineman's operating position. The double-heading cock on that brake valve pedestal must be open.

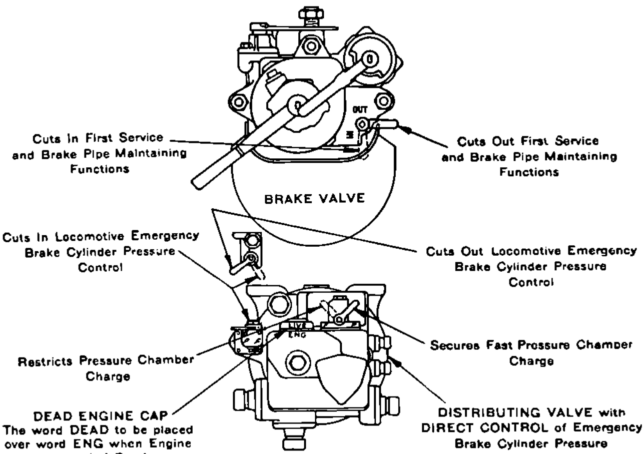


Fig. 92. Proper Positions of the First Service Position Cock, the Delay Cock, and the Retarded Recharge Cock

In order to have the First Service Position of the automatic brake valve operative, the handle of the cock must be to the left over the word "IN" cast on the body. If it is desired to cut out this feature the handle of the cock should be placed to the right over the word "OUT" on the body, when this position of the brake valve handle becomes a lap position. For a delayed emergency brake application on the locomotive, the handle of the delay cock on the distributing valve must be to the right over the letter "F;" for a non-delayed emergency brake application on the locomotive, this handle must be to the left over the letter "P." For a retarded recharge of the pressure chamber, the handle of the retarded recharge cock on the distributing valve must be to the left over the letter "F;" for a fast recharge of the pressure chamber, this handle must be to the right over the letter "P." See Fig. 92.

When operating two or more locomotives coupled, the same preparation is required for each locomotive with a few exceptions. The engineman should assure himself that the handle for the control cutout and reset switch and the reverse lever of the master controller for each trailing locomotive have been laid aside to avoid any misuse of them. The engineman should also assure himself that one set of brake handles on each trailing locomotive has been applied to the independent and automatic brake valves and that these valves have been placed and keyed in "RUNNING" position. All double-heading cocks on trailing locomotives must remain in double-heading or closed position.

RUNNING

The brakes should be released before starting. The deadman lever must be engaged, first by the hand on the master controller main handle; thereafter, its engagement can be maintained either by the hand on the master controller main handle, or by foot engaging the master controller foot valve. The control cutout and reset switch should then be turned to "ON" position and the reverse lever of master controller to "FORWARD" (or "REVERSE") position.

In hauling a train there are many things for the engineman to watch among which could be listed the track, the wayside signals, the cab signals, air gauges, indicating lights and ammeters. Practice proves that the desired observation can be given to all cab instruments without fixing the engineman's attention thereon to the extent that it hazards the safe handling of the train. Occasional observation of the cab instruments is necessary for safely handling a train, and such observation of the ammeters is particularly desirable while accelerating a train.

The first notch of the master controller closes the motor switches as well as a transformer tap switch and operates the reversers if they are not already in position for the desired direction of movement. Therefore, when notching up on the master controller a short hesitation in the first notch is proper after which succeeding notches may be taken as rapidly as the latch will engage each notch and release. However, the first few notches should not be taken so rapidly as to roughly take up the slack in the train. The master controller handle should be advanced one notch at a time until motor current as indicated by the ammeters has reached the apparent limit obtainable without slipping, or the maximum limit obtainable without tripping the overload relays. If this current will not start the train the master controller handle must be moved to "OFF" position since the motors can be badly damaged by standing with power applied.

Each succeeding notch increases the voltage impressed upon the motors which at standstill results in increased current and increased tractive power up to the point of slipping wheels or tripping overload relays. If the train has started, each succeeding notch results in increased speed or increased tractive power, or both.

Acceleration to running speed should be accomplished as rapidly as practicable, advancing but one notch at a time and observing the ammeters. The ammeters indicate the motor current and it must be borne in mind, particularly in rapid notching, not to exceed the apparent current limit obtainable for the existing rail conditions without slipping, nor the maximum current limit obtainable without tripping the overload relays.

On the GG1 locomotives, the voltage impressed upon the motors may be increased in smaller stages by the practice of "buck" and "boost" notching. This feature should be of special advantage in accelerating heavy trains, and also in accelerating on wet rails.

The field changeover indicator on the P5a and Modified P5a locomotives lights when the changeover is about to occur. The light goes out when the changeover has occurred. The changeover from shunted field to full field is accompanied by a substantial increase in motor current and tractive power. Therefore, it is inadvisable for the engineman to advance the master controller handle on these locomotives while the field changeover indicator is lighted.

The field changeover indicator on the GG1 locomotive is lighted continuously while the motors are operating with shunted field. The light goes out when the changeover has occurred.

Notches 1, 2 and 3 must not be used as running notches when hauling a train.

When advancing the master controller handle the latch should be allowed to engage in each succeeding notch and the handle should be advanced but one notch at a time. When backing off the master controller handle the latch need not be engaged in the notches. The handle should be backed off slowly, except in emergencies, into any lower running notch or to the "OFF" position, as desired. In emergencies the master controller handle should be returned to "OFF" position quickly without slamming.

Release of the "deadman" lever produces a quick drop-off of power to the motors, followed by an emergency application of the brakes. The emergency application of the brakes thus obtained is not as quickly responsive as an emergency application with the automatic brake valve. Therefore, the "deadman" feature should not be operated in preference to the automatic brake valve emergency application.

In shutting off, care must be exercised always so that the master controller handle is in the "OFF" position before the locomotive comes to standstill. Considerable damage results to motors in violation of this practice. For similar reasons, reversing the motors to stop even a light locomotive should not be attempted.

When making a normal train stop or to reduce speed, the master controller handle must be moved to "OFF" position before applying brakes except in cases when change in train slack is found to be objectionable; then the master controller may be left in the fifth or sixth notch until after the initial brake pipe reduction has been made, after which the controller must be moved to the "OFF" position.

When making running test of brakes, the controller may be left partly open, so that excessive motor current is not drawn, if conditions make it desirable not to stop the train when making test.

In case the train tonnage and track conditions make sanding the rail necessary, sand should be applied one full locomotive length before the train comes to a stop, in order that the rail is properly sanded for the next start.

Slipping of wheels is indicated by a reduction of current in the motor circuit and also by an indicating lamp at the engineman's position. In many cases the master controller handle can be backed off a few notches, or returned to "OFF" position to stop the slipping and extinguish the indicating lamp. However, if the slipping was sufficient to trip a slip relay, the indicating lamp will not be extinguished by returning the master controller handle to "OFF" position and the control cutout and reset switch should be used to reset the tripped relay and extinguish the indicating lamp.

Overloading of the motors to the tripping point is indicated by a loss of current in the motor circuit and also by an indicating lamp at the engineman's position. It is necessary to return the master controller handle to "OFF" position and use the control cutout and reset switch to reset the tripped relay and extinguish the indicating lamp.

SHUTTING DOWN

Inspection of the inside and outside when leaving locomotive at the terminal should be a careful examination to disclose any noticeable defects. Windows should be closed. Hand brake, chocks, skates or chains should be used wherever necessary to prevent locomotive drifting away after the air brakes have been released or have leaked off.

Switches for the heaters and all blower motors, and the air compressor contactor should be opened before lowering the pantograph. Although the pantograph has been lowered by operating the "DOWN" button, the pantograph selector switch should be thrown to "DOWN" position.

The cab signal cutout cock should be closed. The cab signal cutout switch and the cab signal power switch should be opened. Lights should be turned off and the battery switch opened.

Where two or more coupled locomotives are involved, the treatment of each locomotive at the terminal is the same.

CHANGING ENDS

When changing operating positions, a service application with the automatic brake valve should be made, after which the double-heading cock should be closed. The handles from both brake valves, the control cutout and reset switch and the reverse lever on the master controller should then be removed. The handles should then be taken to and applied at the other operating position, after which the double-heading cock should be opened. The double-heading cock should always be closed before removing the brake valve handles, and the handles should always be placed on the brake valves before opening the double-heading cock.

DOUBLE-HEADING WITH CREWS

When double-heading with a crew in each locomotive, such as would be necessary when a P5a or Modified P5a locomotive assists a GG1 locomotive, the brake valve handles on the trailing locomotive must be carried but not keyed in "RUNNING" position and the double heading cock must be in double-heading, or closed position.

HAULING DEAD ENGINE

On a "dead" engine in a train, the dead engine cap should be changed to dead engine position in which the word "DEAD" on the cap is over the word "ENG" on the distributing valve body. The double-heading cock should be closed, and the handles of independent and automatic brake valves carried and keyed in "RUNNING" position.

Steam Heat Apparatus

The heating of passenger trains with steam supplied from the locomotive to the train line is accomplished with an oil-fired boiler. The fuel is atomized at the burner with steam. Air to support combustion in "medium flame" and "high flame" operation is supplied by a motor driven blower. Fuel oil is delivered by a motor driven pump, and feedwater by a steam driven pump and an injector.

A feedwater regulator controls the operation of the feedwater pump to maintain the proper level of water in the boiler. In response to variations in boiler pressure a motor-operated combustion controller regulates the oil, steam, and air supplied to the firebox for "low flame-medium flame" operation or "low flame-high flame" operation to meet the steam demand. A regulating valve in the steam header reduces the steam pressure for train line requirements.

Reservoirs for water and fuel oil are a part of the locomotive equipment.

The principal pieces of steam heat apparatus are listed as follows:

(See Plate 37 for Boiler Piping)

(a) The boiler is of the vertical fire-tube type.

(b) The steam heat regulator functions to feed steam to the train line in sufficient quantity to maintain the train line pressure for which the regulator is adjusted.

(c) The train line steam gauge indicates the pressure of steam delivered to the train heating line.

(d) The feedwater regulator controls the feedwater pump operation to maintain under steady load on the boiler a normal water level (middle gauge cock) plus or minus ¼ inch with the locomotive at standstill and plus or minus ½ inch with the locomotive running.

(e) The feedwater pump delivers water through a check valve to the feedwater heating coil and thence through a combination check and stop valve to the boiler.

(f) A lifting injector which delivers water through a combination check and stop valve provides an auxiliary means of supplying water to the boiler.

(g) A steam operated syphon provides means for transferring water from the tanks at the far end of the locomotive to the tanks adjacent to the boiler.

(h) Water strainers are provided in the feedwater pump suction line, injector suction line, and the syphon suction line. The screens can be removed for cleaning without disturbing the lines.

(i) The water reservoirs on P5a and Modified P5a locomotives are cavities in either end of the bed frame casting. The wet stick type of gauge can be used to determine the water level.

The water reservoirs on the GG1 locomotives are built into the cab structure. The pet cocks can be used to determine the water level.

(j) The fuel reservoir on P5a and Modified P5a locomotives is a cavity in the bed frame casting immediately underneath the boiler. The fuel reservoir on the GG1 locomotives is built into the water tank structure adjacent to the boiler. The wet stick type of gauge can be used to determine the fuel oil level.

(k) The burner is of the flat flame, steam or air atomizing type located to direct the flame across the bottom of the firebox.

(l) The air-steam pressure gauge indicates the pressure of atomizing air or steam delivered to the burner.

(m) The steam control valve is a rotary disc type valve actuated by the combustion controller for control of the atomizing steam or air supplied to the burner. A choke fitting in the steam line regulates the steam supplied to this valve so that a pressure of 15 to 20 lbs., in "low flame," 20 to 25 lbs., in "medium flame", and 50 to 60 lbs., in "high flame" is obtained at the burner.

(n) The fuel control valve is a rotary plug type valve actuated by the combustion controller for control of the fuel oil supplied to the burner.

(o) The fuel pressure relief valve is a pressure regulated valve for returning to the fuel tank excess fuel delivered by the pump.

This valve is adjusted so that 15 to 20 lbs. fuel oil pressure is obtained at the burner.

(p) The jet type stack blower operates with steam or air and provides means for inducing draft for high flame operation whenever the boiler blower is inoperative.

(q) The micro-vernier valve provides for fine adjustment of the fuel supplied to the burner for manual operation of the boiler.

(r) The fuel pump is of the gear type driven by a direct current motor.

(s) The oil pressure gauge indicates the pressure of fuel oil delivered by the pump.

(t) Two fuel oil strainers are located in the suction line of the fuel pump. These strainers are connected through three-way cocks so that either strainer can be opened and cleaned without disturbing operation of the pump.

(u) The air control damper in the boiler blower air duct is actuated by the combustion controller. This damper controls the air supplied to the firebox.

(v) The boiler blower, driven by an alternating current motor, is connected to the firebox by a duct.

(w) The auxiliary low water cutout device is a float operated steam valve for actuating the auxiliary low water cutout switch.

The electrical pieces of steam heat apparatus are listed as follows:

(See Plate 38 for Boiler Circuits)

(a) The boiler blower motor and appurtenances are described under "Auxiliaries and Control Apparatus."

(b) The boiler control switch is a double-pole, single-throw, tumbler switch.

(c) The fuel pump switch is a double-pole, single-throw, tumbler switch.

(d) The water level relay is a double-pole, clapper type relay with no voltage release-manual reset feature. The operating coil takes direct current.

(e) The emergency fuel pump cutout switches located at the engineman's positions are single-pole, single-throw, knife switches. In emergencies the fuel pump can be stopped by opening either of these switches.

(f) The fuel pump contactor is a double-pole, magnetic contactor. The operating coil takes direct current.

(g) The fuel pressure control switch is a sylphon-operated single-pole, single-throw switch connected to the fuel supply line. Pressure in the sylphon of this switch closes the contacts which are connected in the coil circuit of the high flame relay.

(h) The control selector switch is a manually operated plunger type switch, with three positions: 1. "Start-Low Flame," 2. "Run-Medium Flame," and 3. "Run-High Flame."

(i) The boiler control transformer is a small voltage transformer. The primary is connected to the boiler blower motor circuit and the secondary to the coil circuit of the high flame relay.

(j) The high flame relay is a double-pole, double-throw, clapper type relay. The operating coil takes alternating current.

(k) The combustion controller contains a system of levers for operating the fuel control valve, the steam control valve and the air control damper. The mechanism is actuated through a reduction worm gear by a direct current motor.

(l) The low water alarm switch is a single-pole, single-throw switch operated by the lever arm of the feedwater regulator. This switch closes the circuit for indicating lamps and buzzers at the engineman's positions. It is adjusted to close its contacts at a water level of 1/4 inch in the gauge glass.

(m) The low water cutout switch is a single-pole, single-throw switch operated by the lever arm of the feedwater regulator. When the water level drops to 1 1/2 inches below the gauge glass its contacts open to de-energize the fuel pump contactor.

(n) The auxiliary low water cutout switch is a sylphon-operated single-pole, single-throw switch connected to the auxiliary low water cutout device. When the water level drops to 1 1/2 inches below the gauge glass, steam pressure admitted to the sylphon of this switch opens its contacts to de-energize the fuel pump contactor.

(o) The steam pressure control switch is a sylphon-operated single-pole, double-throw switch connected to the boiler. Its contacts close in "low" position with a low boiler pressure (180 lbs., or less) to energize the combustion controller for one direction of movement and close in "high" position with a high boiler pressure (190 lbs., or more) to energize the combustion controller for the other direction of movement.

Steam Heat Boiler

The steam heat boiler, Fig. 93, is of the vertical fire-tube type. Forming part of the base is a foundation ring which has an opening for the blower duct connection and the burner. The base portion of the firebox is lined with firebrick.

The barrel is constructed upon a mud ring at the bottom and a smoke box ring at the top. Upper and lower flue sheets support the tubes. A fire door opening is provided in the water leg of the boiler.

The smoke box contains two spiral pipe coils, one an economizer coil for feedwater heating and the other for steam superheating. The smoke box lid has openings for the feedwater heater and superheater connections and for the stack. The smoke box lid also incorporates a steam jet stack blower.

The boiler equipment includes a steam gauge, glass water gauge, water gauge cocks, safety valves, main steam valve, blow-off valve and blowoff cock.

Feedwater Regulator

The feedwater regulator, Fig. 94, uses a thermostatic expansion tube to control a steam valve in the steam supply line to the feedwater pump, varying the speed of the pump to maintain the desired water level in the boiler. The steam valve is mounted on the thermostat channels. The thermostatic expansion tube is in tension on the channels and is equipped with an adjusting nut.

Steam and water connections from the boiler to the expansion tube are as shown in the illustration. When the water is low

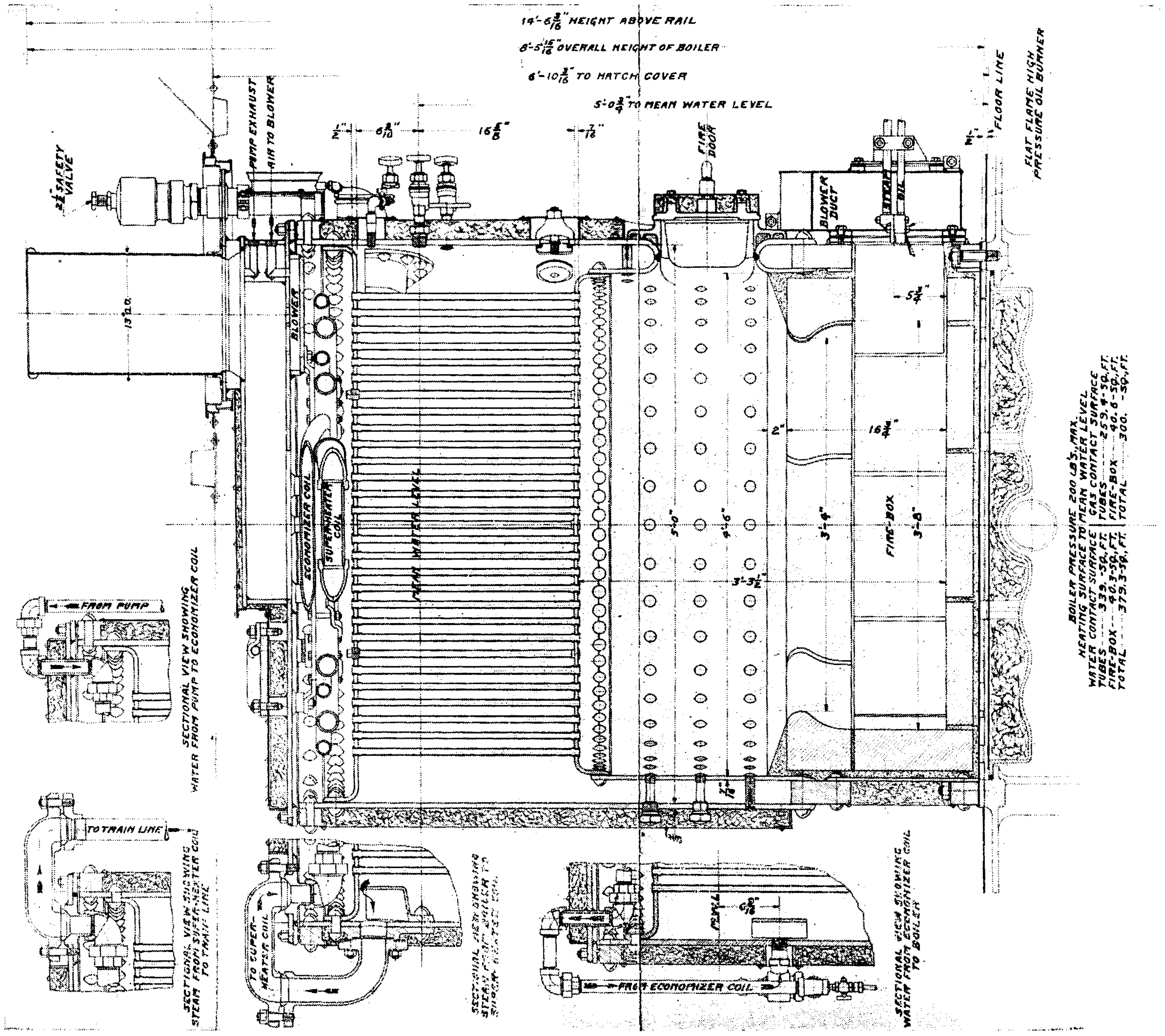


Fig. 93. Sectional View of the Steam Heat Boiler
(As installed in P5a Locomotives)

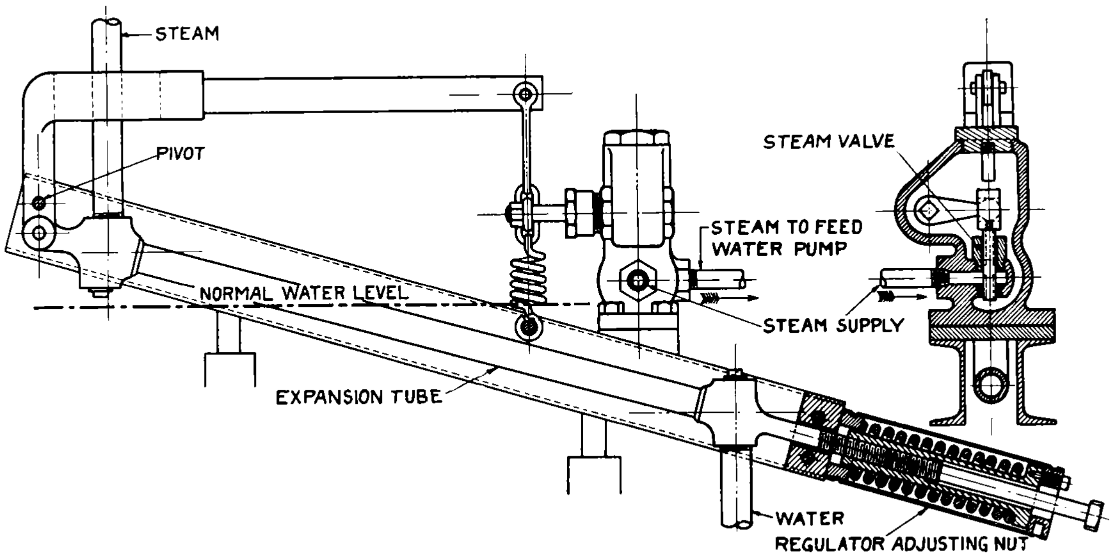


Fig. 94. Sectional View of the Feedwater Regulator

the heat of the steam in the thermostat tube causes an expansion of the tube and a movement of the operating lever to open the steam valve, admitting steam to the feedwater pump. High water acting upon the thermostatic tube causes a contraction of the tube and a movement of the operating lever to close the steam valve and stop the admission of steam to the feedwater pump.

Feedwater Pump

The feedwater pump, Fig. 95, is a duplex direct-acting piston pump consisting essentially of two single pumps, arranged side by side, and so combined that the piston rod of one pump in making its stroke, acts through a simple mechanism to move the valve which admits steam to the cylinder of the other, after which it finishes its stroke and waits for its own steam valve to be acted upon by the movement of the piston of the other side before it can make its own return stroke. As one or the other of the cylinder steam ports is always open, there is no dead point and, therefore, the pump is always ready to start when steam is admitted. The steam valves have no outside or inside lap; consequently, when in central position, just cover the steam ports leading to opposite ends of the cylinder.

There is a lost motion between the slide valve and the valve rod operating it so that the slide valve does not move until the piston on the other side, which operates it, has traveled some distance. The lost motion is provided for by means of a valve rod nut threaded on the valve rod, which is a loose fit between lugs on the slide valve, the amount of space between the two constituting the lost motion. The lost motion is not adjustable, being fixed for the best general performance of the pump. This affords a short pause in the flow of water at the end of a stroke and gives the water valves an opportunity to seat quietly before the reverse stroke takes place; the piston of the other side in the meantime having renewed its movement, the water delivery is uniform and free from pressure fluctuation.

Feedwater Pump Lubricator

The feedwater pump lubricator, Fig. 96, consists of a cast iron reservoir containing the lubricator unit. The plunger *A* is operated by lever arm *B* which is rigidly fastened to stroke

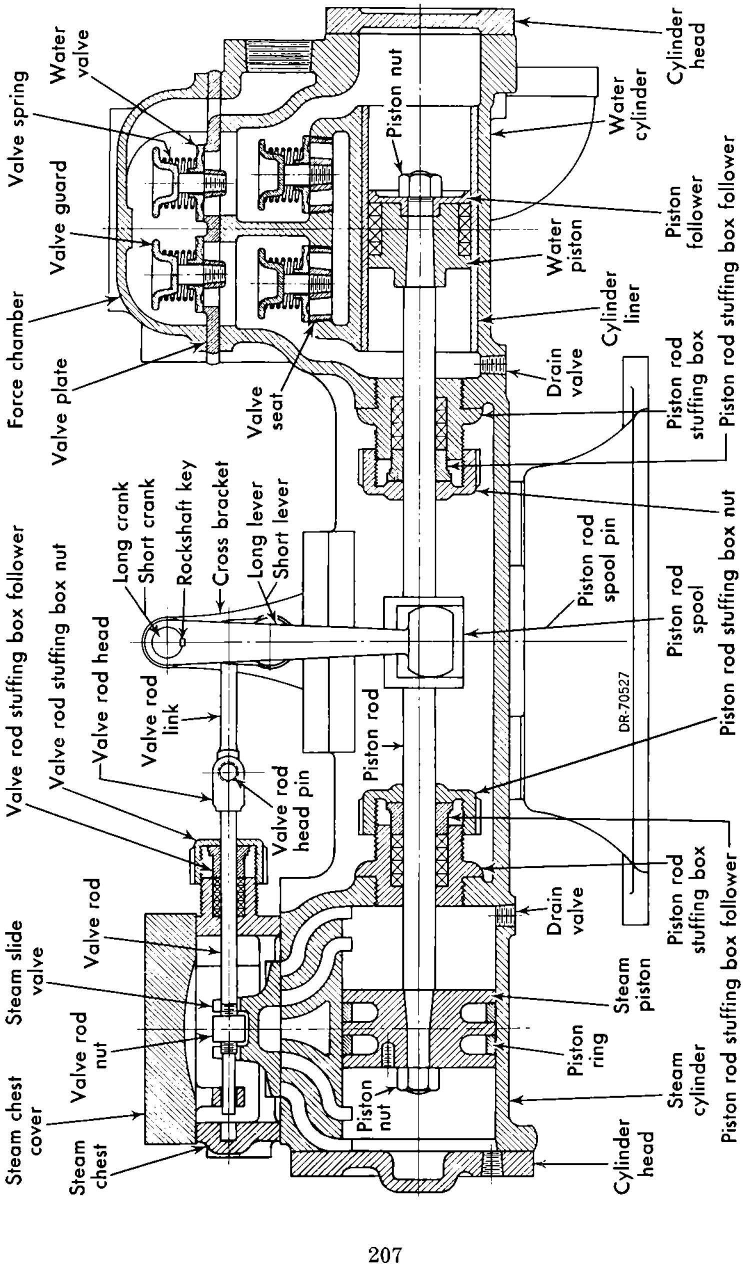


Fig. 95. Sectional View of the Feedwater Pump

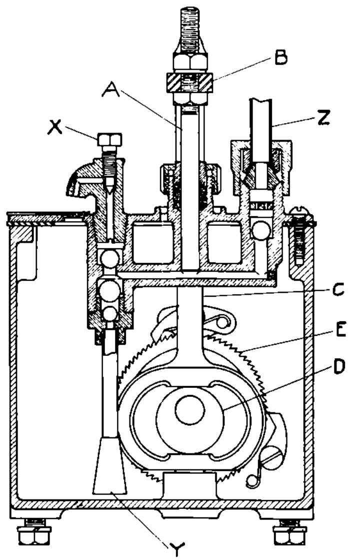


Fig. 96. Sectional View of the Feedwater Pump Lubricator

shaft *C*. Stroke shaft *C* is driven by eccentric *D* which is revolved by ratchet mechanism *E*. Ratchet mechanism *E* is driven by a shaft extending through a stuffing box. The extended shaft mounts the oscillating crank arm. On the upward stroke of the plunger the oil is drawn from the bottom of the reservoir, through strainer tube *Y*, and on the downward stroke of the plunger the oil is delivered to the feedwater pump steam supply line through distributing line *Z*.

Injector

The injector, Fig. 97, is of the lifting type. Steam from the boiler is admitted to the lifting nozzle by drawing the starting lever *33* about one inch, which does not withdraw the plug on the end of the spindle *7* from the central part of the steam nozzle *3*. Steam then passes through the small diagonal-drilled holes and discharges by the outside nozzle, through the upper part of the combining tube *2* and into the overflow chamber, lifts the overflow valve *30*, and issues from the waste-pipe *29*. When water is lifted the starting lever *33* is drawn back, opening the forcing steam nozzle *3*, and the full supply of steam discharges into the

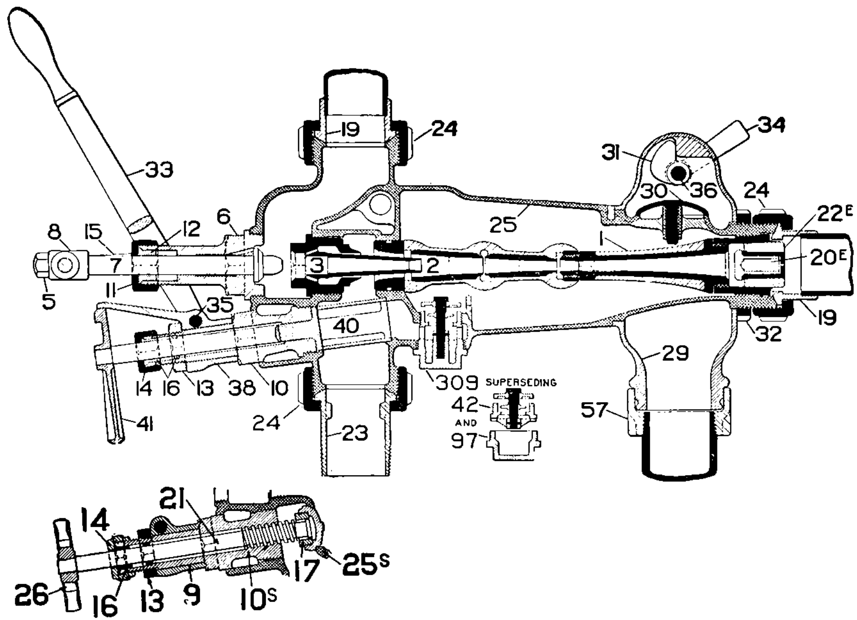


Fig. 97. Sectional View of the Injector

combining tube *2*, forcing the water through the delivery tube *1*, into the delivery pipe.

Side openings in the combining tube produce a vacuum in the overflow chamber which is utilized to draw an additional supply of water into the combining tube by opening the inlet valve *309*; the water is forced by the jet into the boiler, increasing the capacity of the injector about 20 per cent.

The water regulating valve *17* is of the screw type as shown in the supplementary view and is used only to adjust the flow to suit the needs of the boiler.

The cam lever *34* is turned toward the steam pipe to prevent the opening of the overflow valve *30* only in applications where it is desired to use the injector as a tank heater or for cleaning the strainer in the suction line.

Auxiliary Low Water Cutout Device

The auxiliary low water cutout device, Fig. 98, is a float operated steam valve. Steam and water connections from the boiler to the float chamber are as shown in the illustration. Water supports the float to keep the steam valve closed. When the water level approaches the minimum for safe operation of the boiler the float opens the valve admitting steam pressure to the auxiliary low water cutout switch.

Combustion Controller

The combustion controller, Fig. 99, contains a small direct current motor constructed with two field windings for simplicity in reversing rotation. A worm reduction gearing connects the motor shaft to the operating levers. The main lever is linked to the fuel control valve, the steam control valve, and the air control damper. An auxiliary lever is linked to the switch mechanism which provides for operating the combustion controller to "low flame," "medium flame" or "high flame" position. An operating handle is provided for manual movement of the controller by removal of the operating lever fulcrum pin.

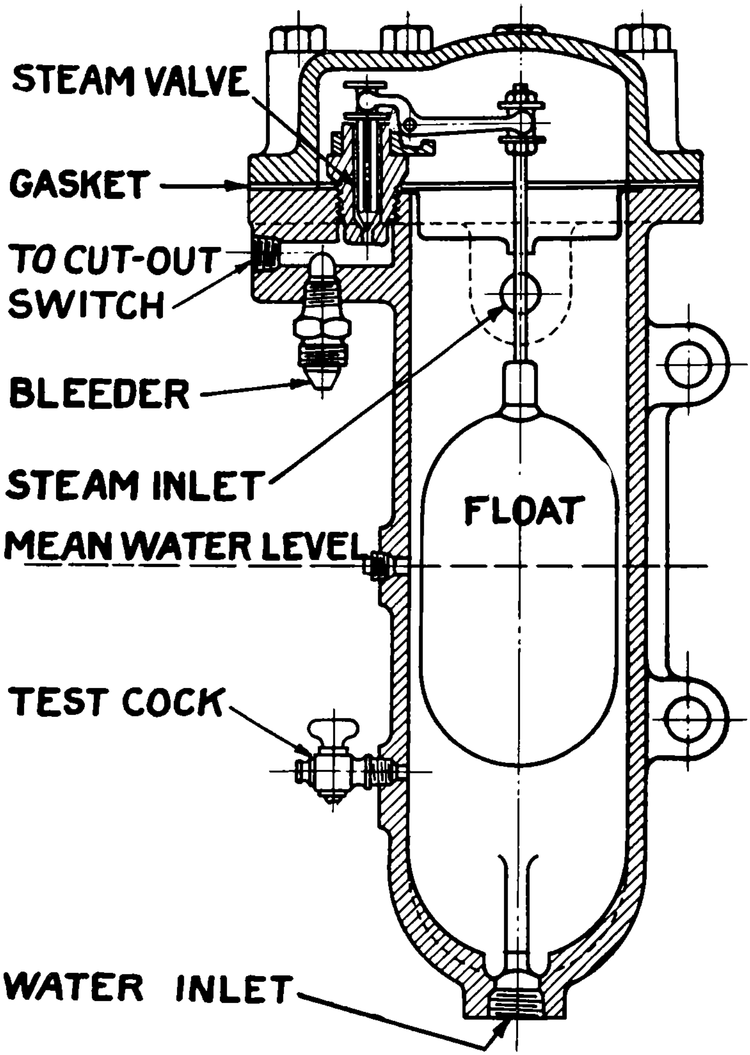


Fig. 98. Sectional View of the Auxiliary Low Water Cutout Device

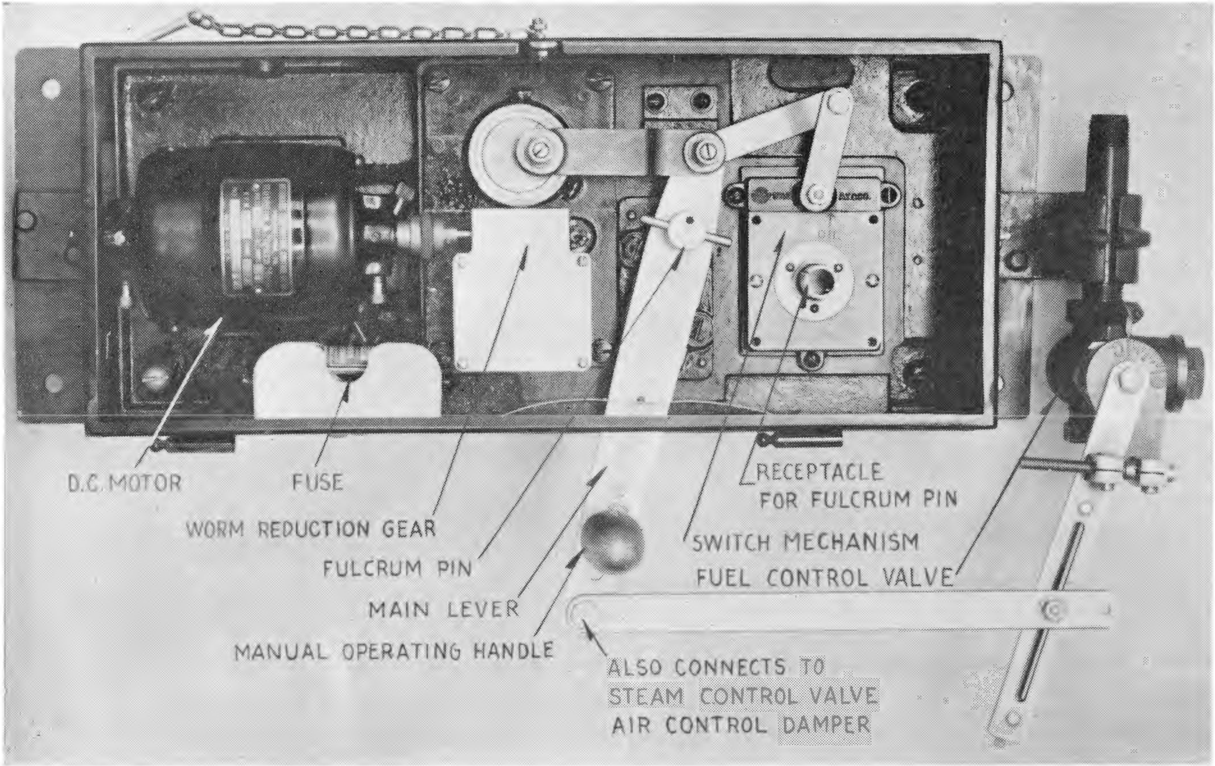


Fig. 99. Combustion Controller

Operation of Steam Heat Apparatus

The steam heat apparatus has been designed so as not to require constant attendance under normal operation and to provide means for manual operation in the event of power interruption on the trolley circuit for an extended period of time.

Normal operation requires alternating current as well as direct current. Operation of the boiler blower energizes the alternating current control devices. Closing the boiler control switch energizes the direct current control devices. Thereafter, closing the fuel pump switch, then the water level relay, energizes the fuel pump motor. The fuel pressure, as indicated by the oil pressure gauge, operates the fuel pressure control switch to close its contacts. A connection from the main air reservoir supplies compressed air through a check valve and cutout cock for operating the feedwater pump, stack blower, and burner until steam pressure is available for these purposes.

At starting, the control selector switch should be placed in "START-LOW FLAME" position 1. Opening the burner fuel valve and burner air (or steam) valve provides the combustible mixture in quantity desirable for "low flame" operation. The burner air-steam pressure gauge indicates the pressure of air (or steam) for atomization. The boiler can be heated gradually by keeping the control selector switch in position 1. While pressure is rising in the boiler the gauge cocks, glass water gauge, feedwater regulator, auxiliary low water cutout device and the feedwater pump cylinder cocks can be blown.

After sufficient steam pressure is available the feedwater pump can be transferred from air to steam operation. The feedwater regulator can be cut into service after blowing out the steam and water connections thereto. Steam can be by-passed around the feedwater regulator to operate the feedwater pump if necessary. The fuel atomization at the burner can be transferred from air to steam by gradually opening the steam valve, at the same time gradually closing the air valve.

After the boiler has gradually heated by "low-flame" operation the control selector switch can be placed in "RUN-MEDIUM FLAME" position 2 for medium steam demand or "RUN-HIGH

FLAME" position 3 for high steam demand. The combustion controller then operates to "medium flame" position or "high flame" position (depending on the position of the control selector switch), increasing the delivery of oil, steam and air to the firebox. When the boiler steam pressure reaches 190 pounds, the steam pressure control switch closes its "high" contacts, energizing the combustion controller to return to "low flame" position. Upon a subsequent drop in boiler steam pressure to 180 pounds, the steam pressure control switch closes its "low" contacts again, energizing the combustion controller to operate to "medium flame" position or "high flame" position, as determined by the position of the control selector switch.

Steam can be admitted to the train line by opening the main steam valve and adjusting the steam heat regulator for the desired pressure. The train line steam gauge indicates the pressure obtained.

When the water level in the boiler drops to one-quarter inch in the gauge glass the feedwater regulator closes the low water alarm switch to light the indicating lamps and sound the buzzers. If the water level drops to 1½ inches below the gauge glass the feedwater regulator opens the low water cutout switch to drop out the fuel pump contactor; at the same water level, the auxiliary low water cutout device admits steam pressure to the auxiliary low water cutout switch, thereby opening other contacts to drop out the fuel pump contactor.

When the fuel pump contactor drops out from any cause the water level relay opens and will not close again unless manually reset by means of the pushbutton.

If the alternating current supply to control devices fails when operating in "RUN-MEDIUM FLAME" position 2 or "RUN-HIGH FLAME" position 3 the high flame relay drops out, energizing the combustion controller to return to "low flame" position, and prevents normal operation either in "medium flame" or "high flame" under automatic control. When the alternating current supply is restored after a momentary interruption, normal operation under automatic control is also restored.

Operating Instructions for the Steam Heat Apparatus

Inspection of the steam heat apparatus when preparing for service should be a careful examination to disclose any noticeable defects. Certain cocks and valves should normally be open while others remain closed. Likewise, certain switches should normally be closed while others remain open. Familiarity with the piping and the electrical circuits of the steam heat apparatus will establish these practices. The supply of water and fuel in the reservoirs should be gauged. The water in a cold boiler must reach a level between the first and second gauge cocks.

The fire starting operation is best accomplished after the locomotive has been prepared for service, since compressed air and alternating current are required as well as direct current. Compressed air can be supplied to the feedwater pump, stack blower and the burner by opening the air cutout cock and thereafter the several valves connected to these units. (The valves which supply steam to these units should be tightly closed before compressed air is used).

The boiler blower must be started and the damper opened for several minutes by manual operation of the combustion controller before starting a fire. The firebox is scavenged in this manner of any possible accumulation of gases.

The stack blower must be in operation when the fire door is opened. An ignited fire starter should be tossed into the firebox ahead of the burner position and the fire door securely closed. With the control selector switch in "START-LOW FLAME" position 1, close the boiler control switch and the fuel pump switch, then the water level relay. Open the burner fuel valve and then the burner air valve. The atomized fuel should ignite for "low flame" operation of the boiler.

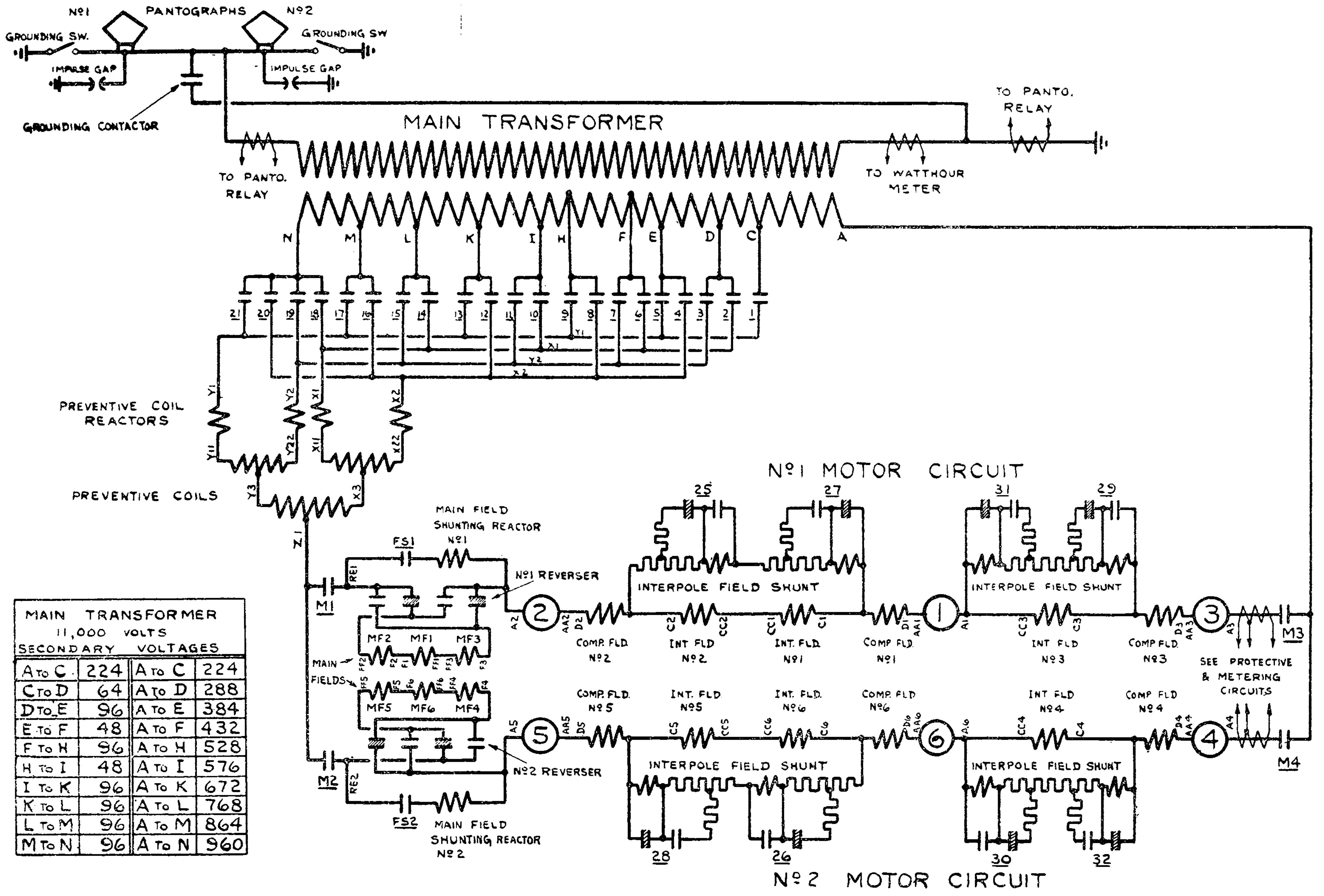
"Low flame" operation should continue for at least 15 minutes to allow a cold boiler to expand slowly. During this warming period there is ample opportunity for blowing out the gauge cocks, glass water gauge, auxiliary low water cutout device and the cylinder cocks on the feedwater pump. When the boiler pressure is five to ten pounds the feedwater regulator should be cut into service by opening the atmospheric valve for a moment to blow out the regulator and pipe connections. With the feedwater pump air valve closed tightly the steam valve should be opened slowly to operate the pump with cylinder cocks open until cylinders are purged of water. Two or three turns of the hand wheel on the feedwater pump lubricator are necessary for proper lubrication when starting. Under normal conditions of pump operation controlled by the feedwater regulator the steam by-pass valve should be tightly closed.

When the boiler pressure reaches 80 pounds the change from air to steam atomization should be made. Before doing this, however, the main steam valve, the steam heat regulating valve and the train line valves should be opened to purge the system, including the superheater coil, of condensate. After the boiler has thoroughly heated the control selector switch may be placed in "RUN-MEDIUM FLAME" position 2 or "RUN-HIGH FLAME" position 3.

During operation of the boiler the fuel and water supplies should be gauged at intervals and the syphon used as required to replenish the water reservoirs adjacent to the boiler.

When shutting down, the main steam valve should be closed and the control selector switch placed in "START-LOW FLAME" position 1. The fuel pump switch and the boiler control switch should be opened and the burner fuel and steam valves closed. The burner steam valve should remain closed long enough for steam to condense in the line after which the decarbonizing valve should be opened and the burner steam valve opened slowly to blow out oil which might otherwise accumulate at the burner tip. The combustion controller should be moved to "high flame" position by manual operation for several minutes scavenging after which it should be returned to "low flame" position. The decarbonizing valve and the burner steam valve should then be closed. The boiler blower switch should be opened and the feedwater pump steam valve closed. Any additional water required in the hot boiler after shutting down should be furnished by means of the injector.

Where there is danger of freezing see that all drain cocks and valves are opened and pipes freed of entrapped water.



MAIN TRANSFORMER 11,000 VOLTS SECONDARY VOLTAGES			
A to C	224	A to C	224
C to D	64	A to D	288
D to E	96	A to E	384
E to F	48	A to F	432
F to H	96	A to H	528
H to I	48	A to I	576
I to K	96	A to K	672
K to L	96	A to L	768
L to M	96	A to M	864
M to N	96	A to N	960

SEQUENCE TABLE

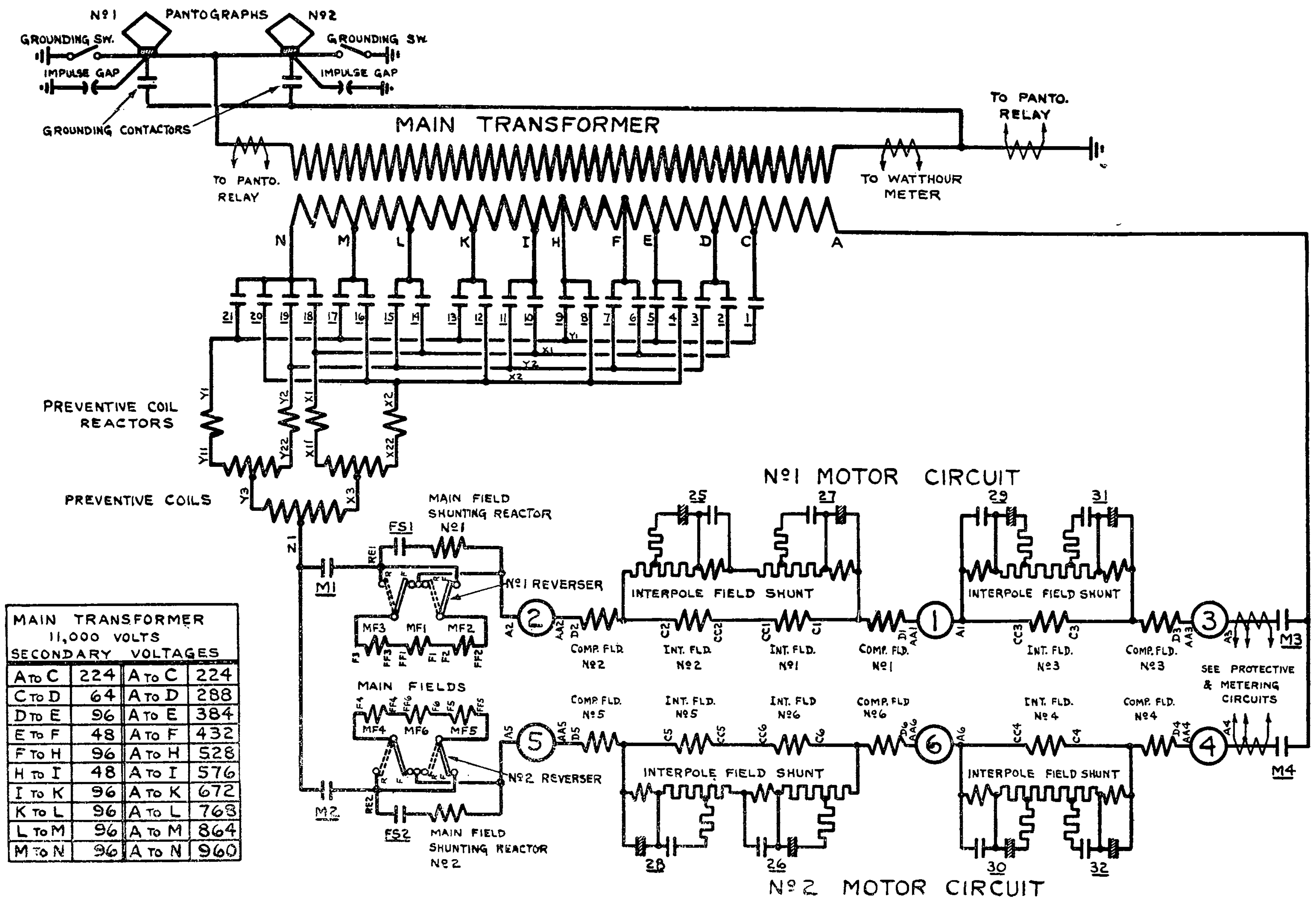
NOTCH	SWITCHES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	FS1, FS2	M1, M3	M2, M4	MOTOR CIRCUIT VOLTAGE AT NO LOAD
1		O																					O	O	
2	O	O																				O	O	O	
3	O	O		O																		O	O	O	
4	O	O	O	O																		O	O	O	296
5		O	O	O	O																	O	O	O	336
6			O	O	O	O																O	O	O	372
*6			O	O	O	O																	O	O	372
7				O	O	O	O																O	O	408
8					O	O	O	O															O	O	444
9						O	O	O	O														O	O	480
10							O	O	O	O													O	O	516
11								O	O	O	O												O	O	552
12									O	O	O	O											O	O	588
13										O	O	O	O										O	O	624
14											O	O	O	O									O	O	672
15												O	O	O	O								O	O	720
16													O	O	O	O							O	O	768
17														O	O	O	O						O	O	816
18															O	O	O	O					O	O	864
19																O	O	O	O				O	O	912
20																		O	O	O	O		O	O	960

SPEED RANGE	25, 26, 29, 30	27, 28, 31, 32
LOW	O	
INTERMEDIATE		
HIGH		O

* OPENING (AND CLOSING) OF FS1 & FS2 SWITCHES MAY TAKE PLACE ON ANY NOTCH FROM 2 TO 15 INCL., UNDER CONTROL OF THE MAIN FIELD RELAY.

Plate 1. Main Circuits—P5a Locomotives

Plate 1. Main Circuits—P5a Locomotives



MAIN TRANSFORMER 11,000 VOLTS SECONDARY VOLTAGES			
A to C	224	A to C	224
C to D	64	A to D	288
D to E	96	A to E	384
E to F	48	A to F	432
F to H	96	A to H	528
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I to K	96	A to K	672
K to L	96	A to L	768
L to M	96	A to M	864
M to N	96	A to N	960

SEQUENCE TABLE

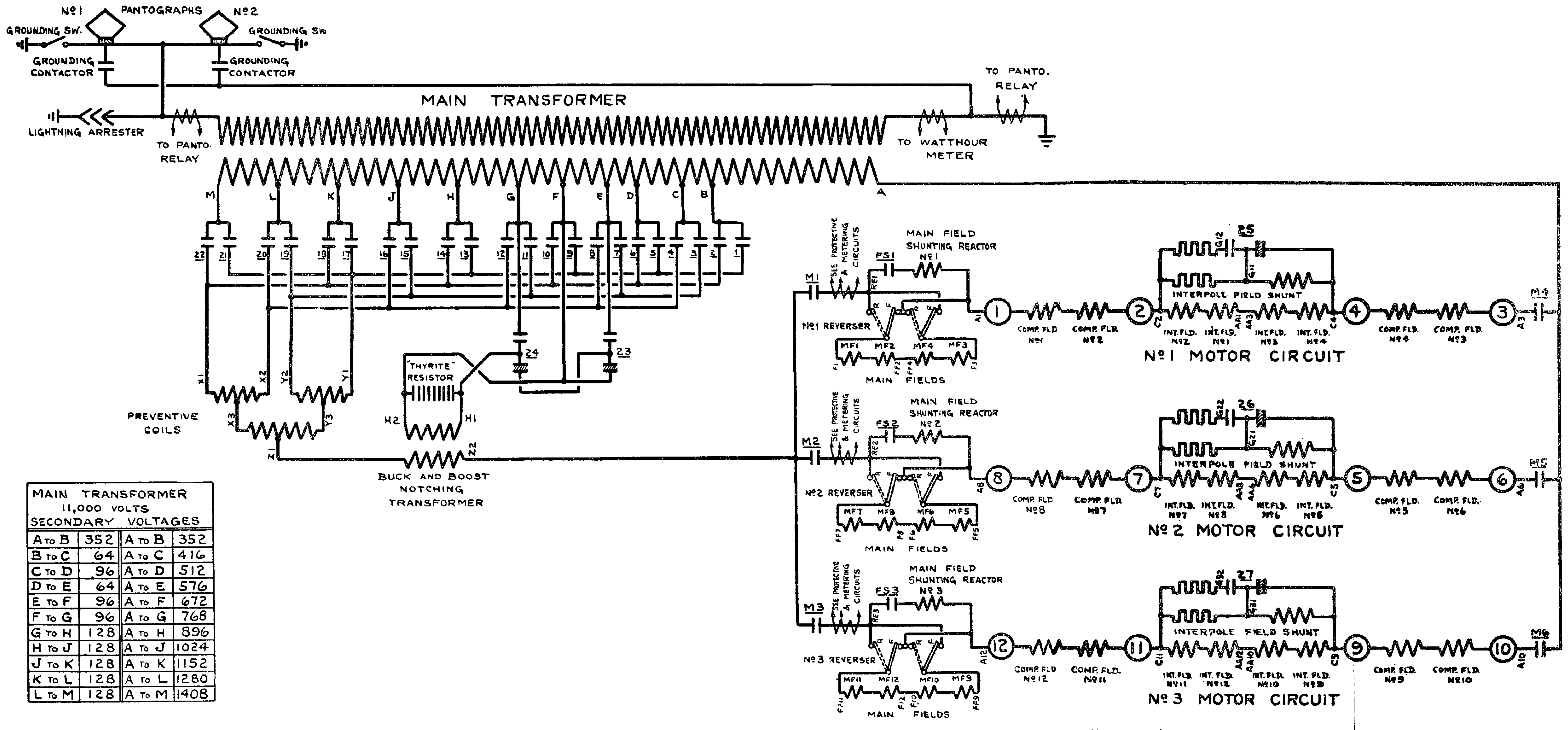
NOTCH	SWITCHES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	FS1, FS2	M1, M3	M2, M4	MOTOR CIRCUIT VOLTAGE AT NO LOAD
1		O																					O	O	
2	O	O																				O	O	O	
3	O	O		O																		O	O	O	
4	O	O	O	O																		O	O	O	296
5		O	O	O	O																	O	O	O	336
6			O	O	O	O																O	O	O	372
*6			O	O	O	O																	O	O	372
7				O	O	O	O																O	O	408
8					O	O	O	O															O	O	444
9						O	O	O	O														O	O	480
10							O	O	O	O													O	O	516
11								O	O	O	O												O	O	552
12									O	O	O	O											O	O	588
13										O	O	O	O										O	O	624
14											O	O	O	O									O	O	672
15												O	O	O	O								O	O	720
16													O	O	O	O							O	O	768
17														O	O	O	O						O	O	816
18															O	O	O	O					O	O	864
19																O	O	O	O				O	O	912
20																		O	O	O	O		O	O	960

SPEED RANGE	25, 26, 29, 30	27, 28, 31, 32
LOW	O	
INTERMEDIATE		
HIGH		O

* OPENING (AND CLOSING) OF FS1 & FS2 SWITCHES MAY TAKE PLACE ON ANY NOTCH FROM 2 TO 15 INCL., UNDER CONTROL OF THE MAIN FIELD (VOLTAGE) RELAY.

Plate 2. Main Circuits—Modified P5a Locomotives

Plate 2. Main Circuits—Modified P5a Locomotives



MAIN TRANSFORMER 11,000 VOLTS SECONDARY VOLTAGES			
A to B	352	A to B	352
B to C	64	A to C	416
C to D	96	A to D	512
D to E	64	A to E	576
E to F	96	A to F	672
F to G	96	A to G	768
G to H	128	A to H	896
H to J	128	A to J	1024
J to K	128	A to K	1152
K to L	128	A to L	1280
L to M	128	A to M	1408

SEQUENCE TABLE

NOTCH	SWITCHES 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	FS1, FS2, FS3	M1, M2, M3	M4, M5, M6	** MOTOR CIRCUIT VOLTAGE AT NO LOAD
1	O																							O	O	
2	O			O																			O	O	O	
3	O		O	O																			O	O	O	
4	O	O	O	O																			O	O	O	368
5		O	O	O	O																		O	O	O	408
6			O	O	O	O																	O	O	O	448
*6			O	O	O	O																		O	O	448
7				O	O	O	O																	O	O	488
8					O	O	O	O																O	O	528
9						O	O	O	O															O	O	568
10							O	O	O	O														O	O	608
11								O	O	O	O													O	O	656
12									O	O	O	O												O	O	704
13										O	O	O	O											O	O	760
14											O	O	O	O										O	O	816
15												O	O	O	O									O	O	880
16													O	O	O	O								O	O	944
17														O	O	O	O							O	O	1008
18															O	O	O	O						O	O	1072
19																O	O	O	O					O	O	1136
20																	O	O	O	O				O	O	1200
21																		O	O	O	O			O	O	1264
22																			O	O	O	O		O	O	1328

MAIN HANDLE POSITION	23	24
"BUCK" (NORMAL)	O	
"NEUTRAL"		
"BOOST"		O

SPEED RANGE	25	26	27
LOW			
HIGH	O	O	O

* OPENING (AND CLOSING) OF FS1, FS2, FS3 SWITCHES MAY TAKE PLACE ON ANY NOTCH FROM 2 TO 14 INCL., UNDER CONTROL OF THE MAIN FIELD RELAY.

** THIS IS THE "BUCK" (OR NORMAL) POSITION VOLTAGE. ADD 16 VOLTS FOR THE "NEUTRAL" POSITION. ADD 32 VOLTS FOR THE "BOOST" POSITION.

Plate 3. Main Circuits—GG1 Locomotives

Plate 3. Main Circuits—GG1 Locomotives

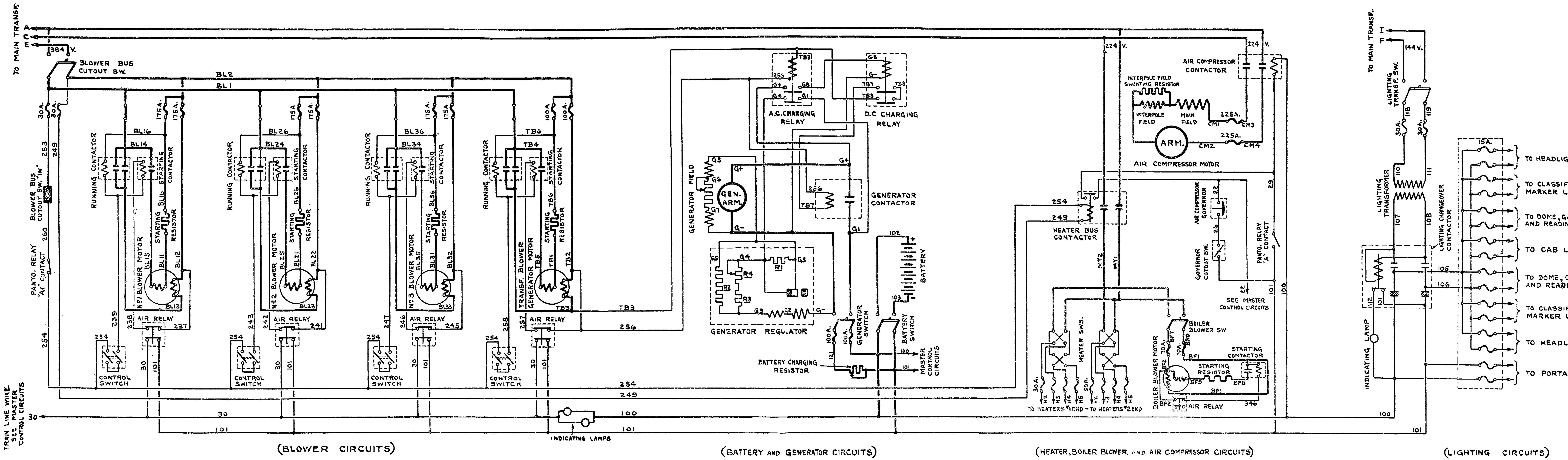


Plate 4. Auxiliary Circuits—P5a Locomotives

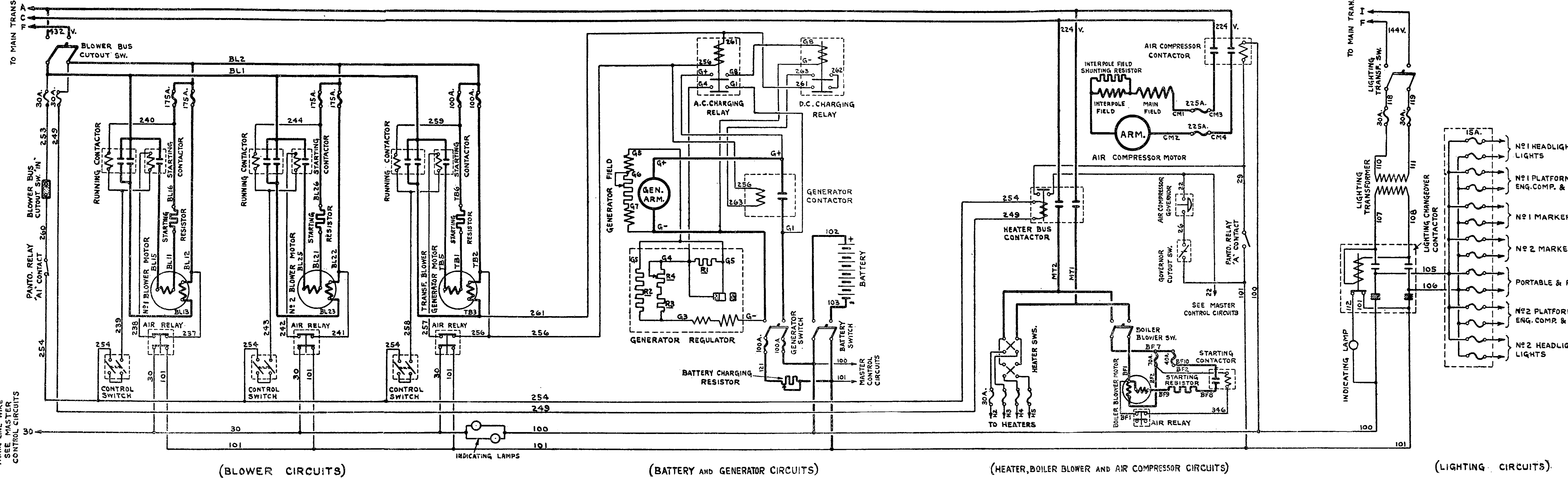


Plate 5. Auxiliary Circuits—Modified P5a Locomotives

Plate 5. Auxiliary Circuits—Modified P5a Locomotives

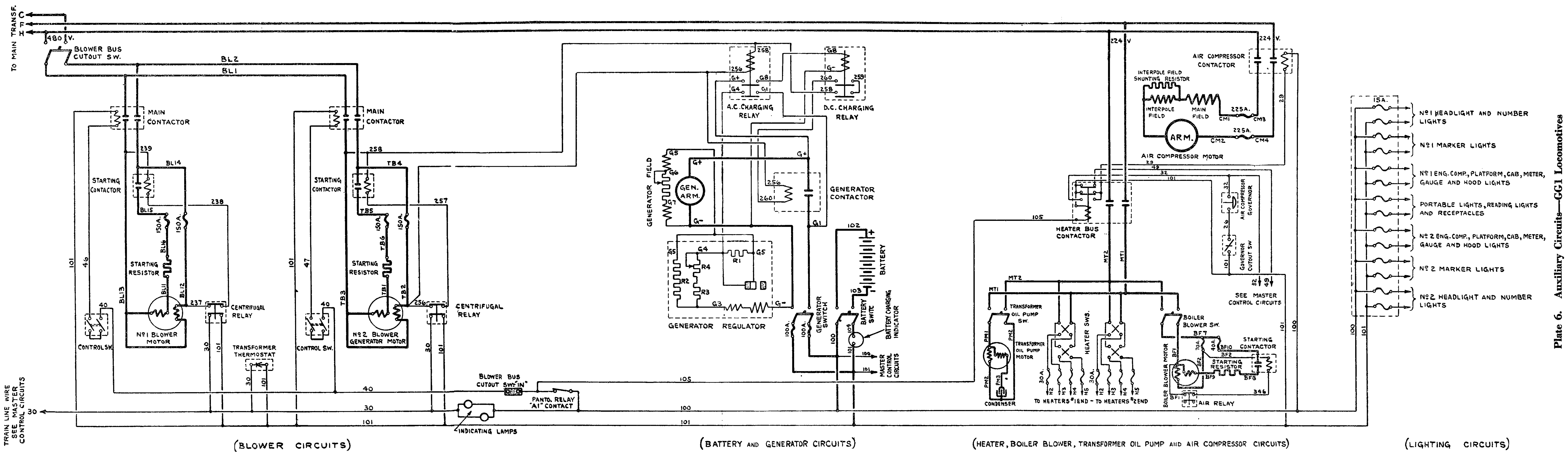
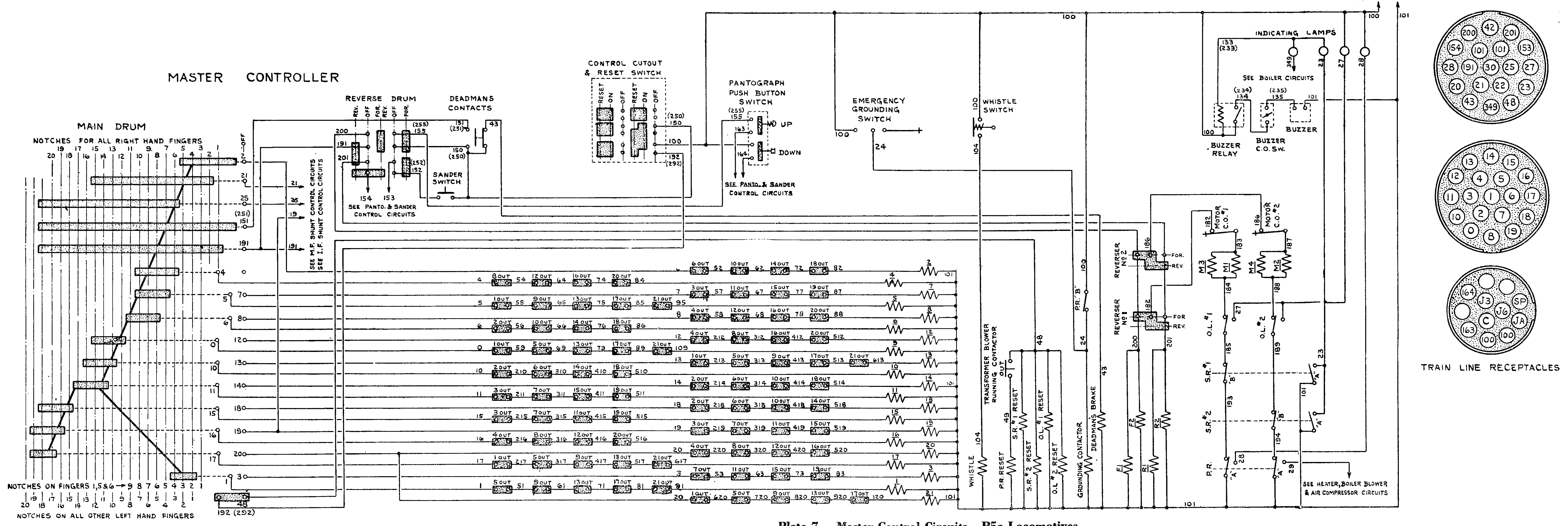


Plate 6. Auxiliary Circuits—GG1 Locomotives

Plate 6. Auxiliary Circuits—GG1 Locomotives



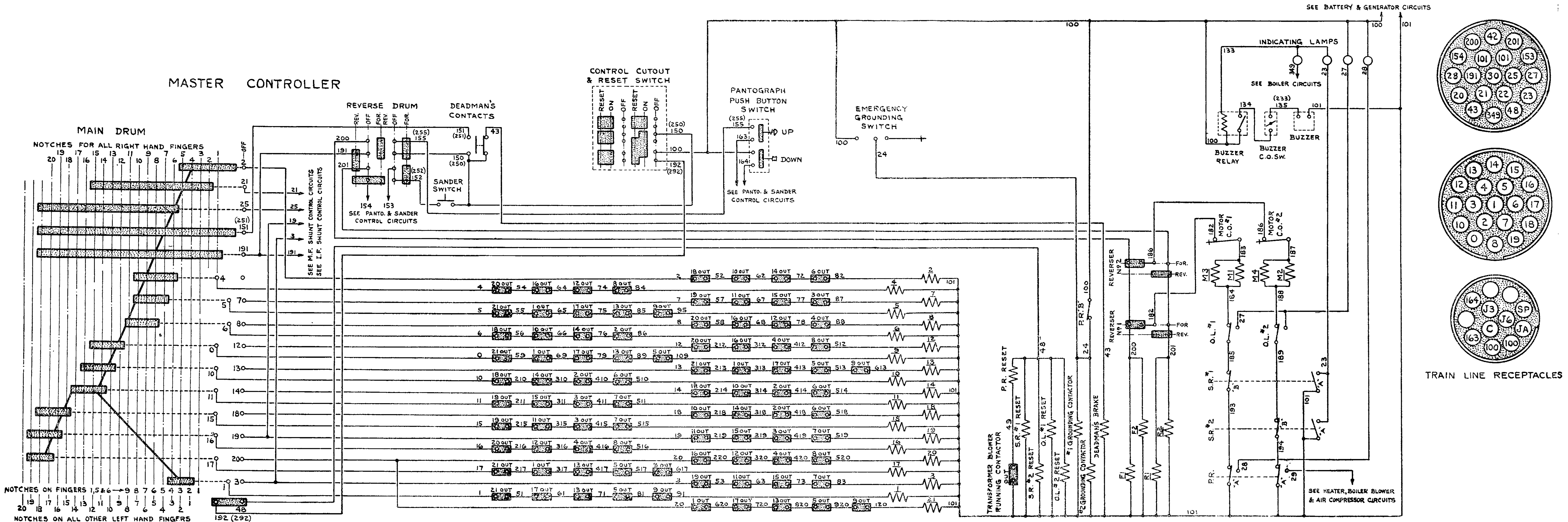
SEQUENCE TABLE																									
NOTCH	SWITCHES																								MOTOR CIRCUIT VOLTAGE AT NO LOAD
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	FS1, FS2	M1, M3	M2, M4	
1		O																					O	O	
2	O	O																				O	O	O	
3	O	O		O																		O	O	O	
4	O	O	O	O																		O	O	O	296
5		O	O	O	O																	O	O	O	336
6			O	O	O	O																O	O	O	372
*6			O	O	O	O																	O	O	372
7				O	O	O	O																O	O	408
8					O	O	O	O															O	O	444
9						O	O	O	O														O	O	480
10							O	O	O	O													O	O	516
11								O	O	O	O												O	O	552
12									O	O	O	O											O	O	588
13										O	O	O	O										O	O	624
14											O	O	O	O									O	O	672
15												O	O	O	O								O	O	720
16													O	O	O	O							O	O	768
17														O	O	O	O						O	O	816
18															O	O	O	O					O	O	864
19																O	O	O	O				O	O	912
20																		O	O	O	O		O	O	960

SPEED RANGE	25, 26, 29, 30	27, 28, 31, 32
LOW	O	
INTERMEDIATE		
HIGH		O

* OPENING (AND CLOSING) OF FS1 & FS2 SWITCHES MAY TAKE PLACE ON ANY NOTCH FROM 2 TO 15 INCL., UNDER CONTROL OF THE MAIN FIELD RELAY.

Plate 7. Master Control Circuits—P5a Locomotives

Plate 7. Master Control Circuits—P5a Locomotives



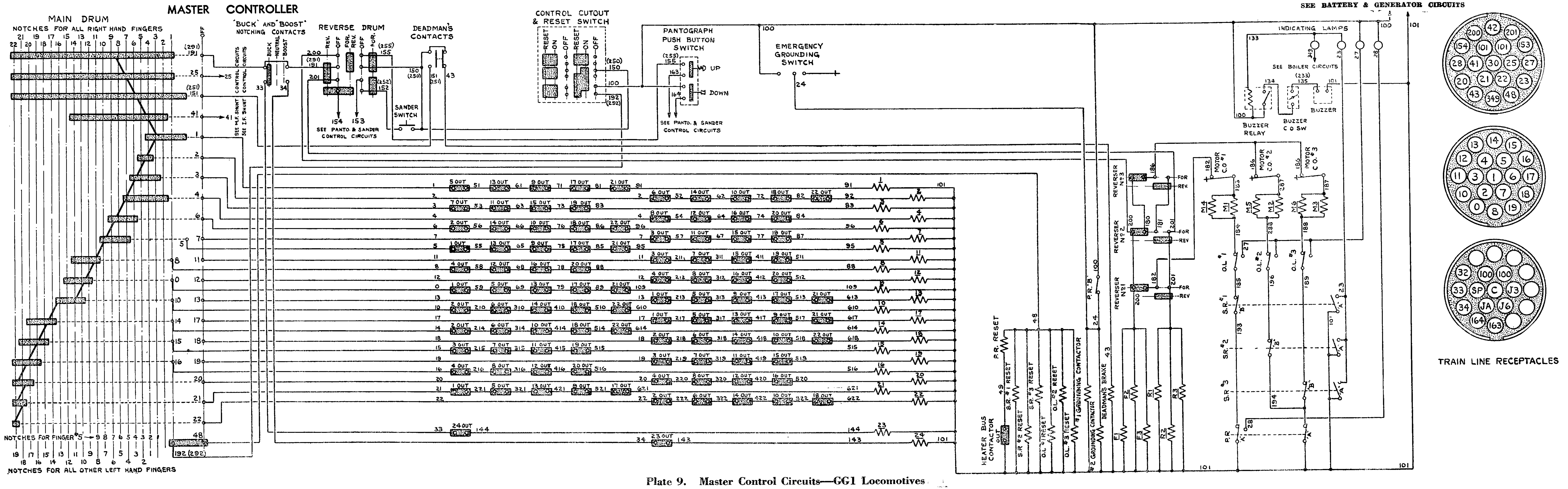
SEQUENCE TABLE																									
NOTCH	SWITCHES																								MOTOR CIRCUIT VOLTAGE AT NO LOAD
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	FS1,FS2	M1,M3	M2,M4	
1		o																					o	o	
2	o	o																				o	o	o	
3	o	o		o																		o	o	o	
4	o	o	o	o																		o	o	o	296
5		o	o	o	o																	o	o	o	336
6			o	o	o	o																o	o	o	372
*6			o	o	o	o																	o	o	372
7				o	o	o	o																o	o	408
8					o	o	o	o															o	o	444
9						o	o	o	o														o	o	480
10							o	o	o	o													o	o	516
11								o	o	o	o												o	o	552
12									o	o	o	o											o	o	588
13										o	o	o	o										o	o	624
14											o	o	o	o									o	o	672
15												o	o	o	o								o	o	720
16													o	o	o	o							o	o	768
17														o	o	o	o						o	o	816
18															o	o	o	o					o	o	864
19																o	o	o	o				o	o	912
20																		o	o	o	o		o	o	960

SPEED RANGE	25,26,29,30	27,28,31,32
LOW	o	
INTERMEDIATE		
HIGH		o

* OPENING (AND CLOSING) OF FS1 & FS2 SWITCHES MAY TAKE PLACE ON ANY NOTCH FROM 2 TO 15 INCL., UNDER CONTROL OF THE MAIN FIELD RELAY.

Plate 8. Master Control Circuits—Modified P5a Locomotives

Plate 8. Master Control Circuits—Modified P5a Locomotives



NOTCH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	*FS1, FS2, FS3	M1, M2, M3	M4, M5, M6	** MOTOR CIRCUIT VOLTAGE AT NO LOAD
1	O																						O	O	O	
2	O			O																			O	O	O	
3	O		O	O																			O	O	O	
4	O	O	O	O																			O	O	O	368
5		O	O	O	O																		O	O	O	408
6			O	O	O	O																	O	O	O	448
*6			O	O	O	O																		O	O	448
7				O	O	O	O																	O	O	488
8					O	O	O	O																O	O	528
9						O	O	O	O															O	O	568
10							O	O	O	O														O	O	608
11								O	O	O	O													O	O	656
12									O	O	O	O												O	O	704
13										O	O	O	O											O	O	760
14											O	O	O	O										O	O	816
15												O	O	O	O									O	O	880
16													O	O	O	O								O	O	944
17														O	O	O	O							O	O	1008
18															O	O	O	O						O	O	1072
19																O	O	O	O					O	O	1136
20																	O	O	O	O				O	O	1200
21																		O	O	O	O			O	O	1264
22																			O	O	O	O		O	O	1328

MAIN HANDLE POSITION	23	24
"BUCK" (NORMAL)	O	
"NEUTRAL"		
"BOOST"		O

SPEED RANGE	25	26	27
LOW			
HIGH	O	O	O

* OPENING (AND CLOSING) OF FS1, FS2, FS3 SWITCHES MAY TAKE PLACE ON ANY NOTCH FROM 2 TO 14 INCL., UNDER CONTROL OF THE MAIN FIELD RELAY

** THIS IS THE "BUCK" (OR NORMAL) POSITION VOLTAGE. ADD 16 VOLTS FOR THE "NEUTRAL" POSITION. ADD 32 VOLTS FOR THE "BOOST" POSITION.

Plate 9. Master Control Circuits—GG1 Locomotives

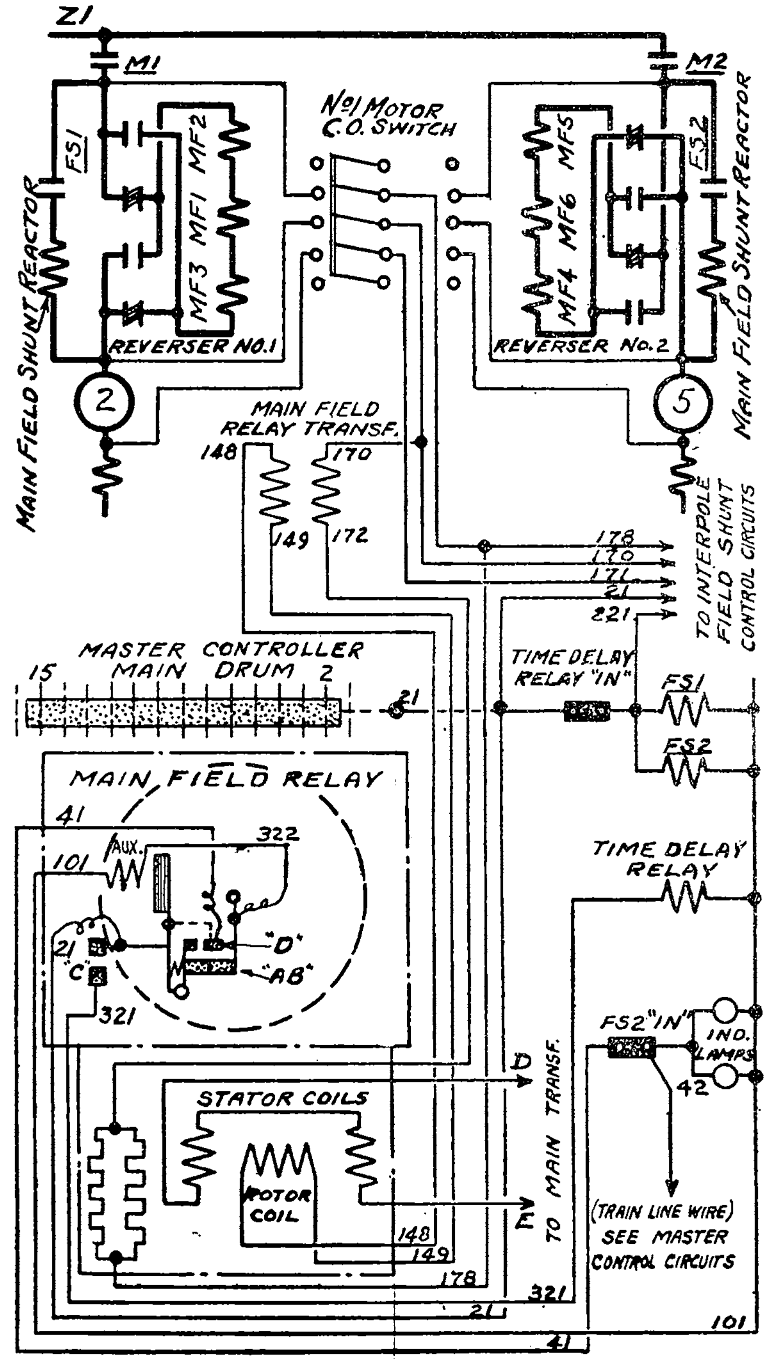


Plate 10. Main Field Shunt Control Circuits—P5a Locomotives

Plate 10. Main Field Shunt Control Circuits—P5a Locomotives

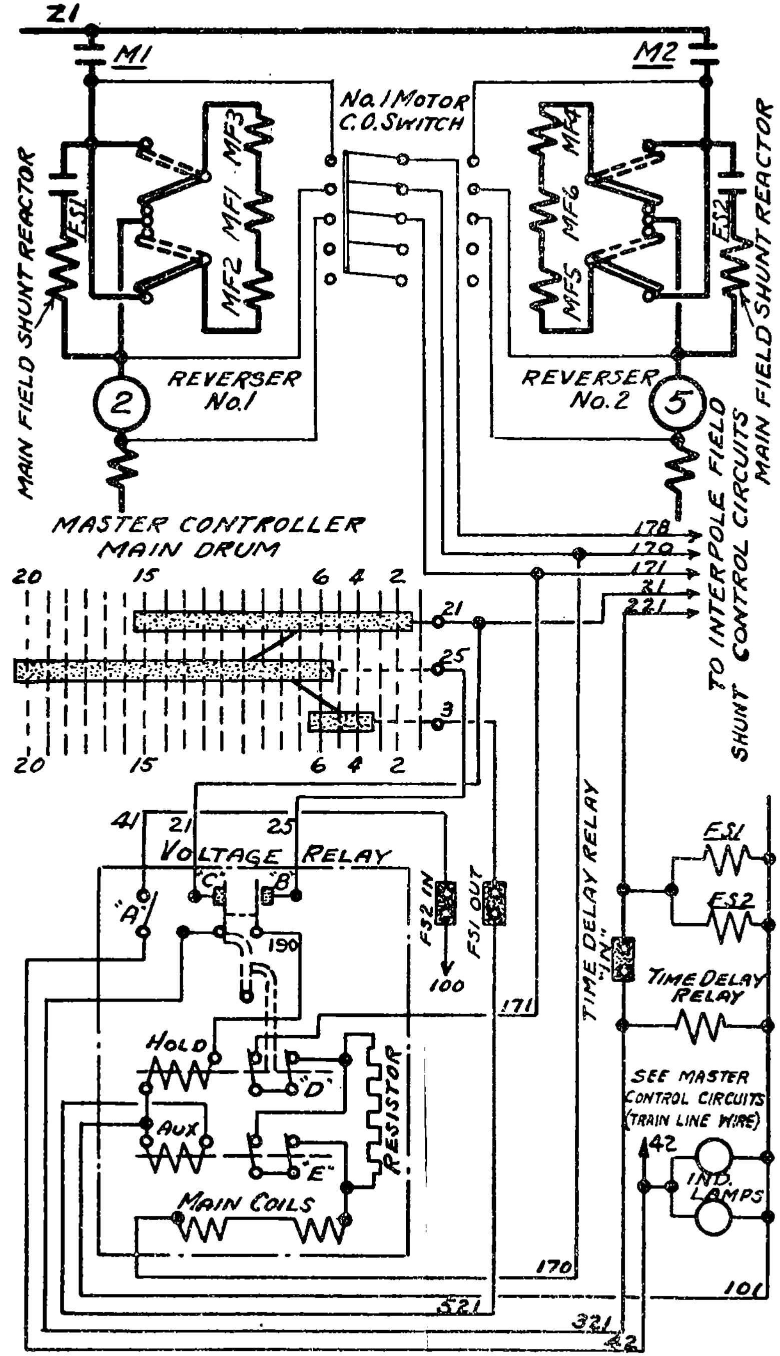


Plate 11. Main Field Shunt Control Circuits—Modified P5a Locomotives

Plate 11. Main Field Shunt Control Circuits—Modified P5a Locomotives

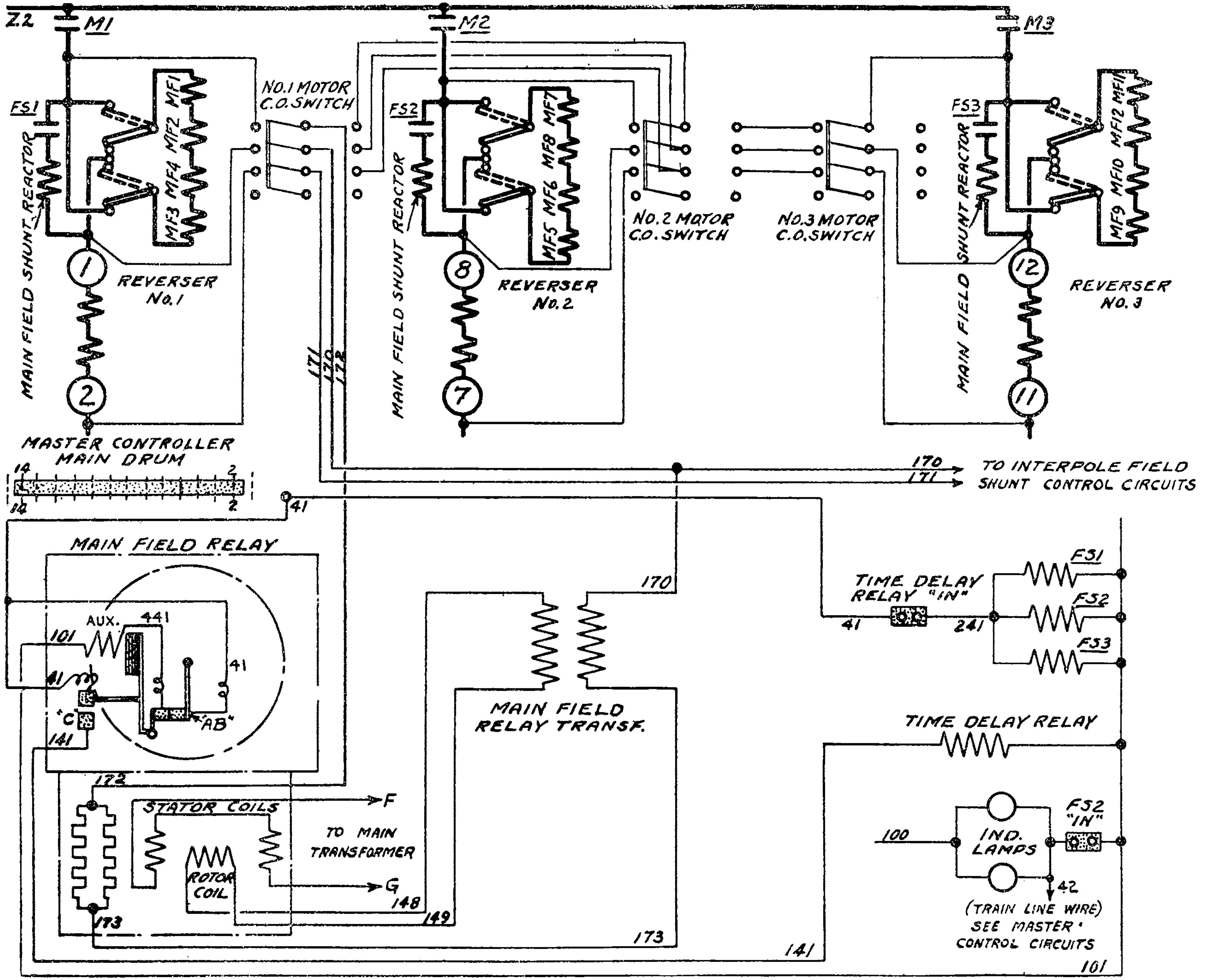


Plate 12. Main Field Shunt Control Circuits—GG1 Locomotives

Plate 12. Main Field Shunt Control Circuits—GG1 Locomotives

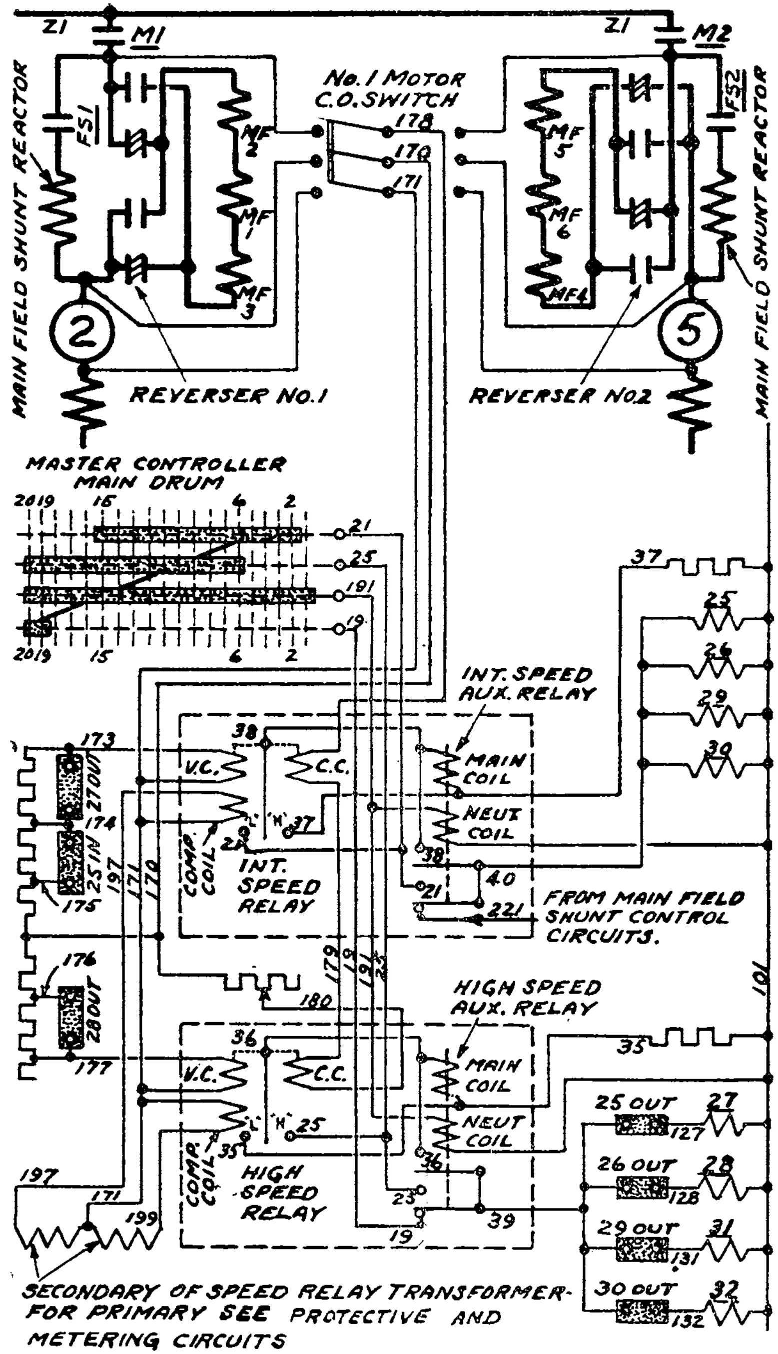


Plate 13. Interpole Field Shunt Control Circuits—P5a and Modified P5a Locomotives

Plate 13. Interpole Field Shunt Control Circuits—P5a and Modified P5a Locomotives

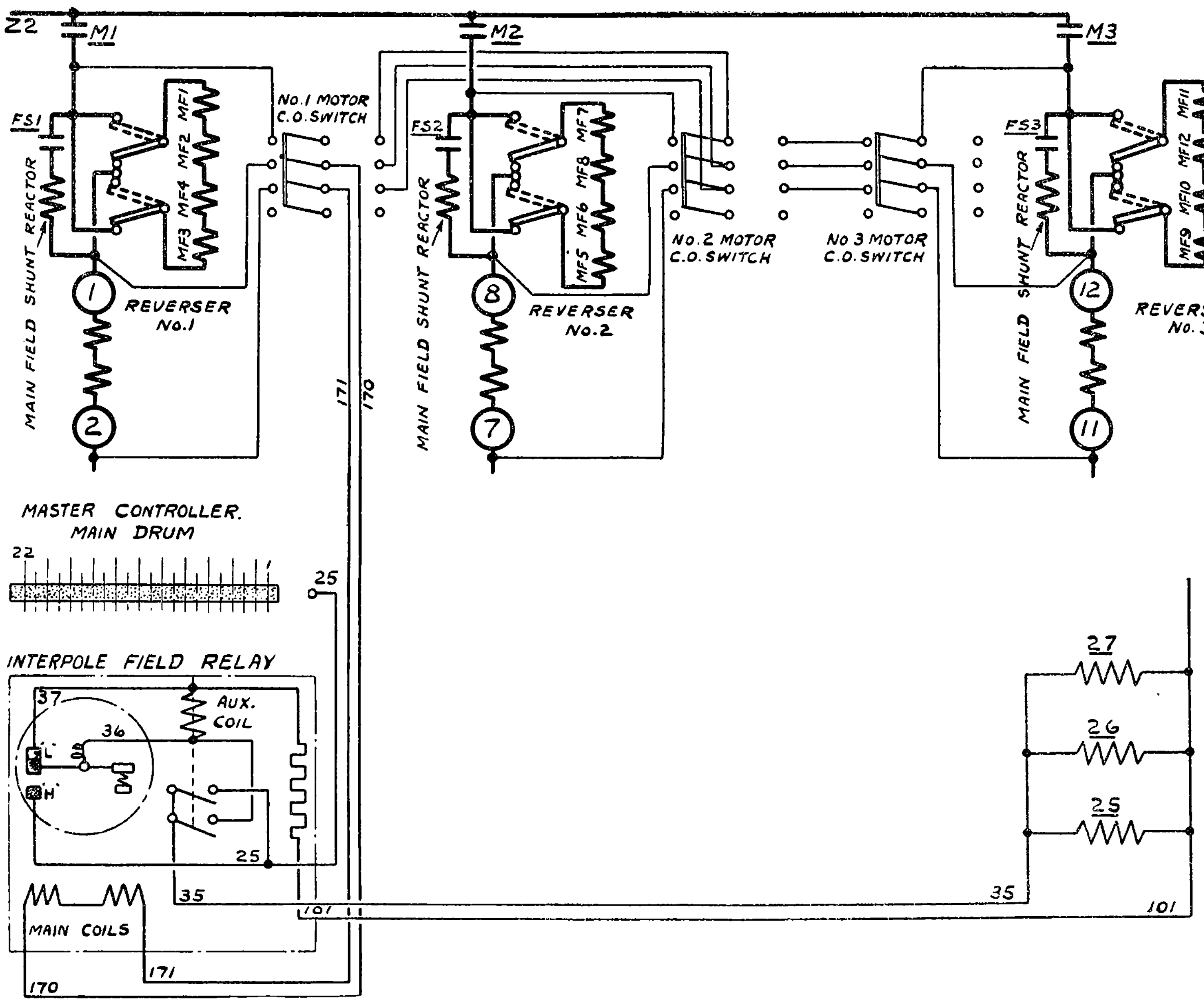


Plate 14. Interpole Field Shunt Control Circuits—GG1 Locomotives

Plate 14. Interpole Field Shunt Control Circuits—GG1 Locomotives

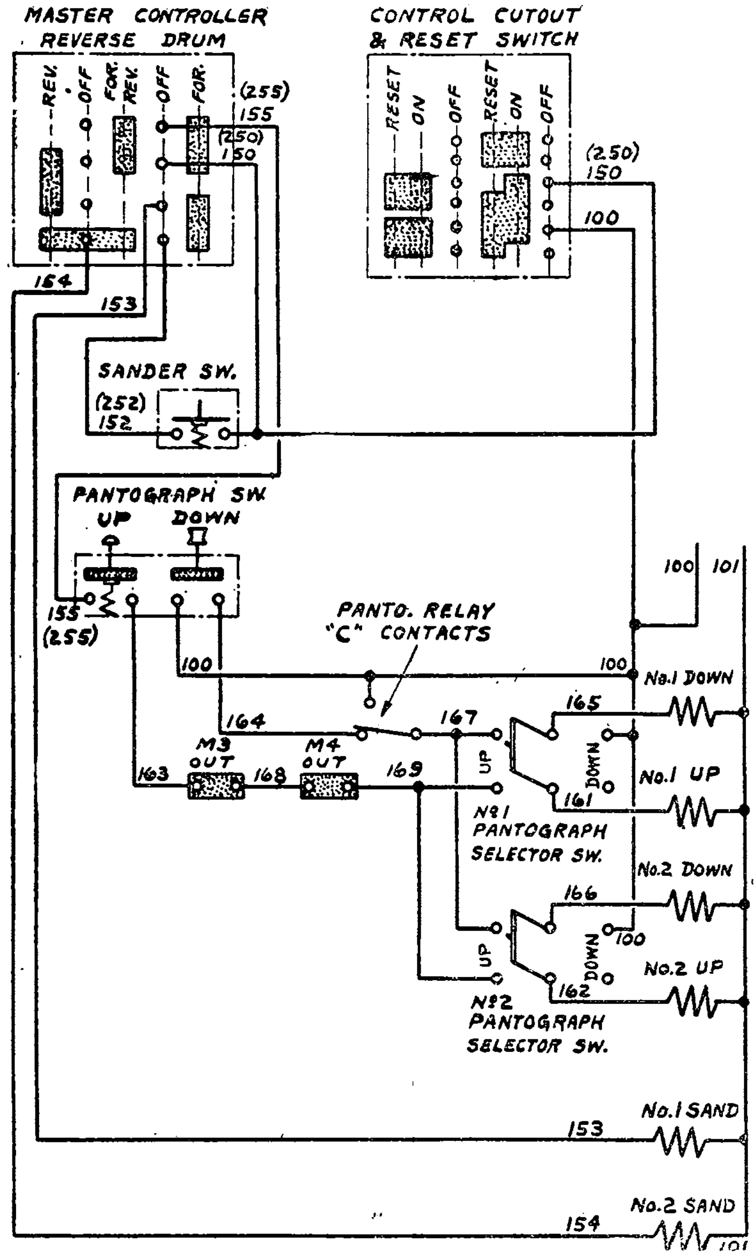


Plate 15. Pantograph and Sander Control Circuits—P5a and Modified P5a Locomotives

Plate 15. Pantograph and Sander Control Circuits—P5a and Modified P5a Locomotives

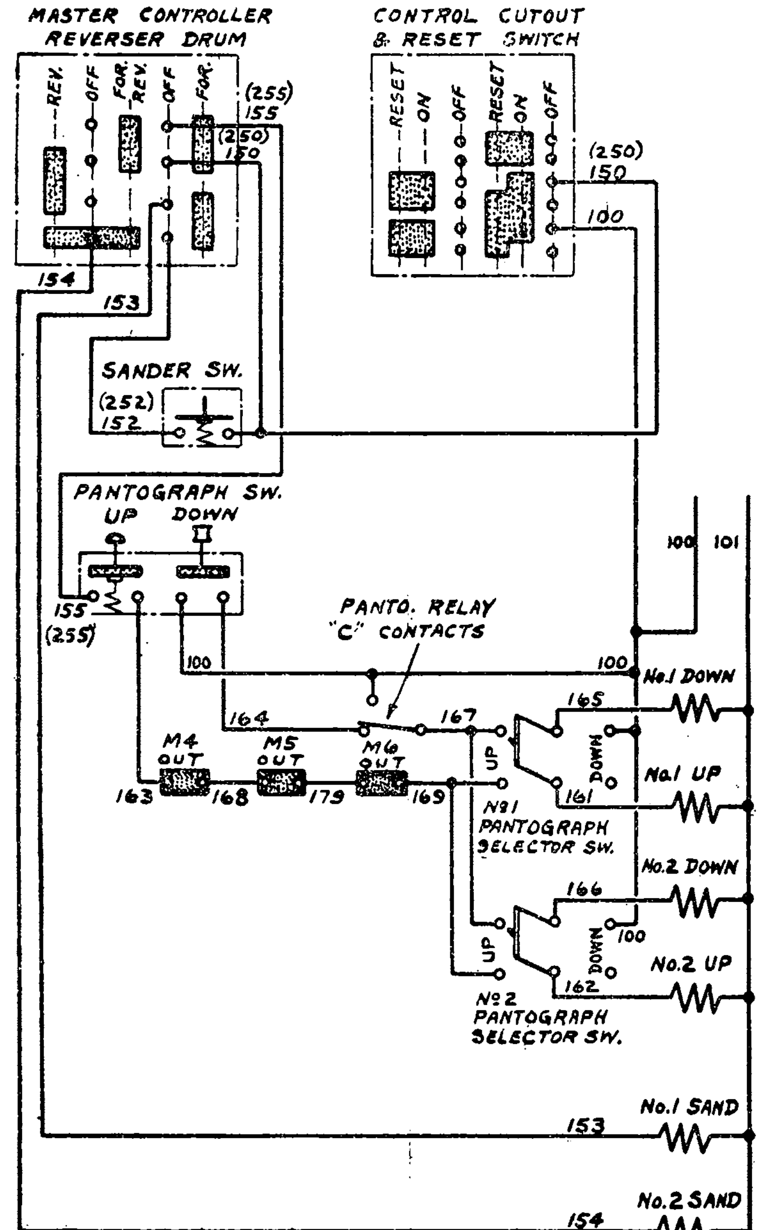
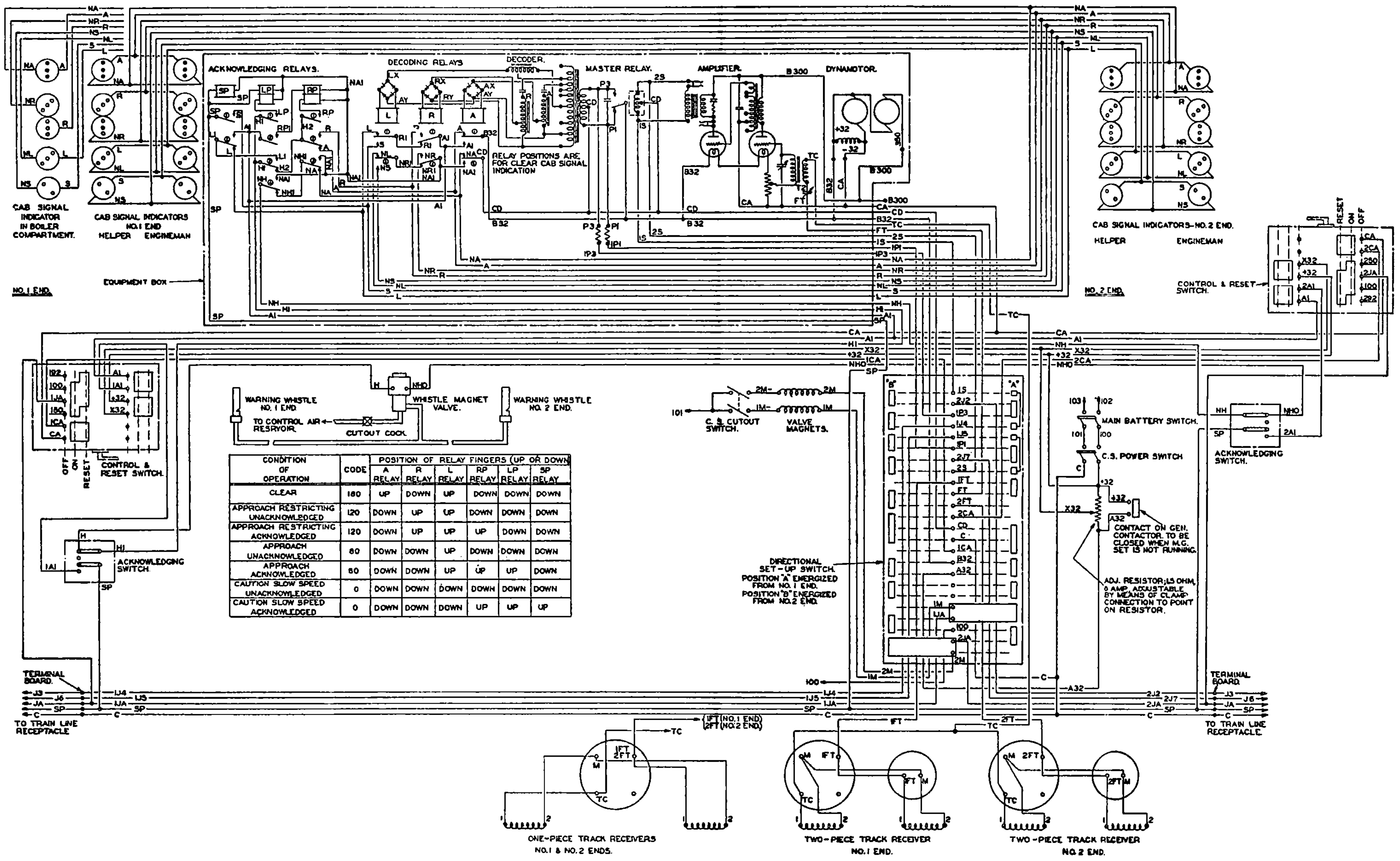


Plate 16. Pantograph and Sander Control Circuits—GG1 Locomotives

Plate 16. Pantograph and Sander Control Circuits—GG1 Locomotives



CONDITION OF OPERATION	CODE	POSITION OF RELAY FINGERS (UP OR DOWN)					
		A RELAY	R RELAY	L RELAY	RP RELAY	LP RELAY	SP RELAY
CLEAR	180	UP	DOWN	UP	DOWN	DOWN	DOWN
APPROACH RESTRICTING UNACKNOWLEDGED	120	DOWN	UP	UP	DOWN	DOWN	DOWN
APPROACH RESTRICTING ACKNOWLEDGED	120	DOWN	UP	UP	UP	DOWN	DOWN
APPROACH UNACKNOWLEDGED	80	DOWN	DOWN	UP	DOWN	DOWN	DOWN
APPROACH ACKNOWLEDGED	80	DOWN	DOWN	UP	UP	UP	DOWN
CAUTION SLOW SPEED UNACKNOWLEDGED	0	DOWN	DOWN	DOWN	DOWN	DOWN	DOWN
CAUTION SLOW SPEED ACKNOWLEDGED	0	DOWN	DOWN	DOWN	UP	UP	UP

Plate 17. Cab Signal Circuits

Plate 17. Cab Signal Circuits

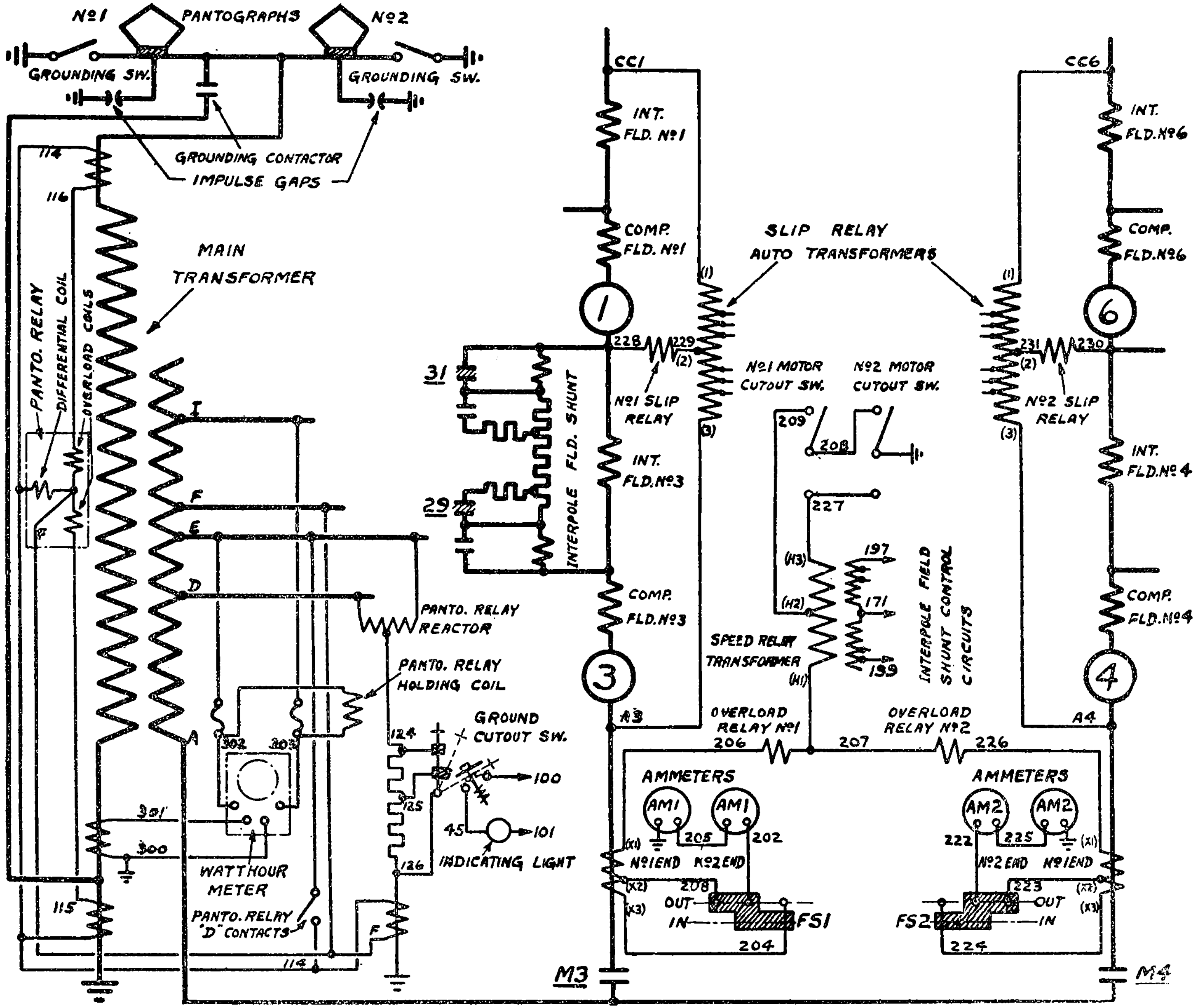


Plate 18. Protective and Metering Circuits—P5a Locomotives

Plate 18. Protective and Metering Circuits—P5a Locomotives

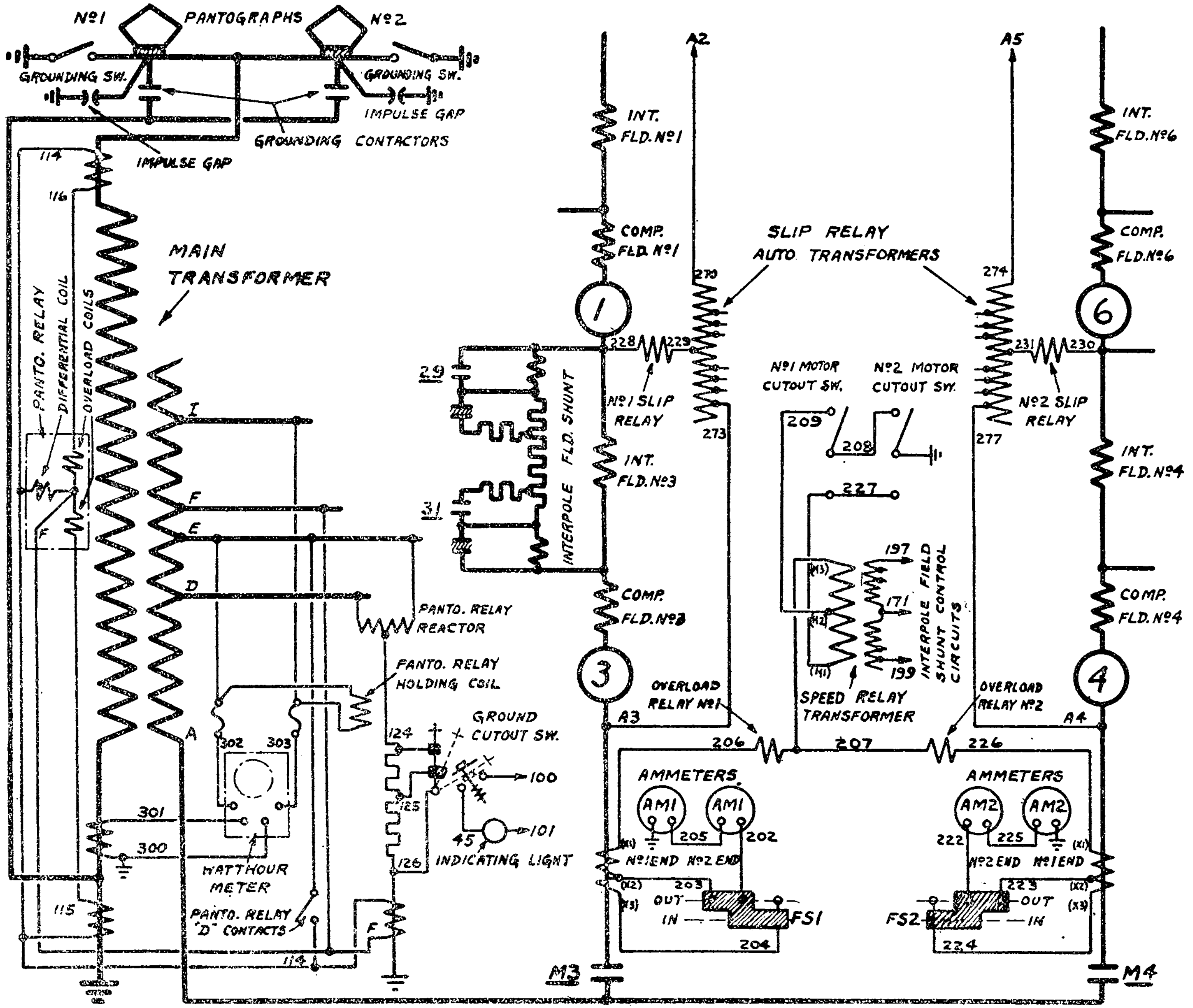


Plate 19. Protective and Metering Circuits—Modified P5a Locomotives

Plate 19. Protective and Metering Circuits—Modified P5a Locomotives

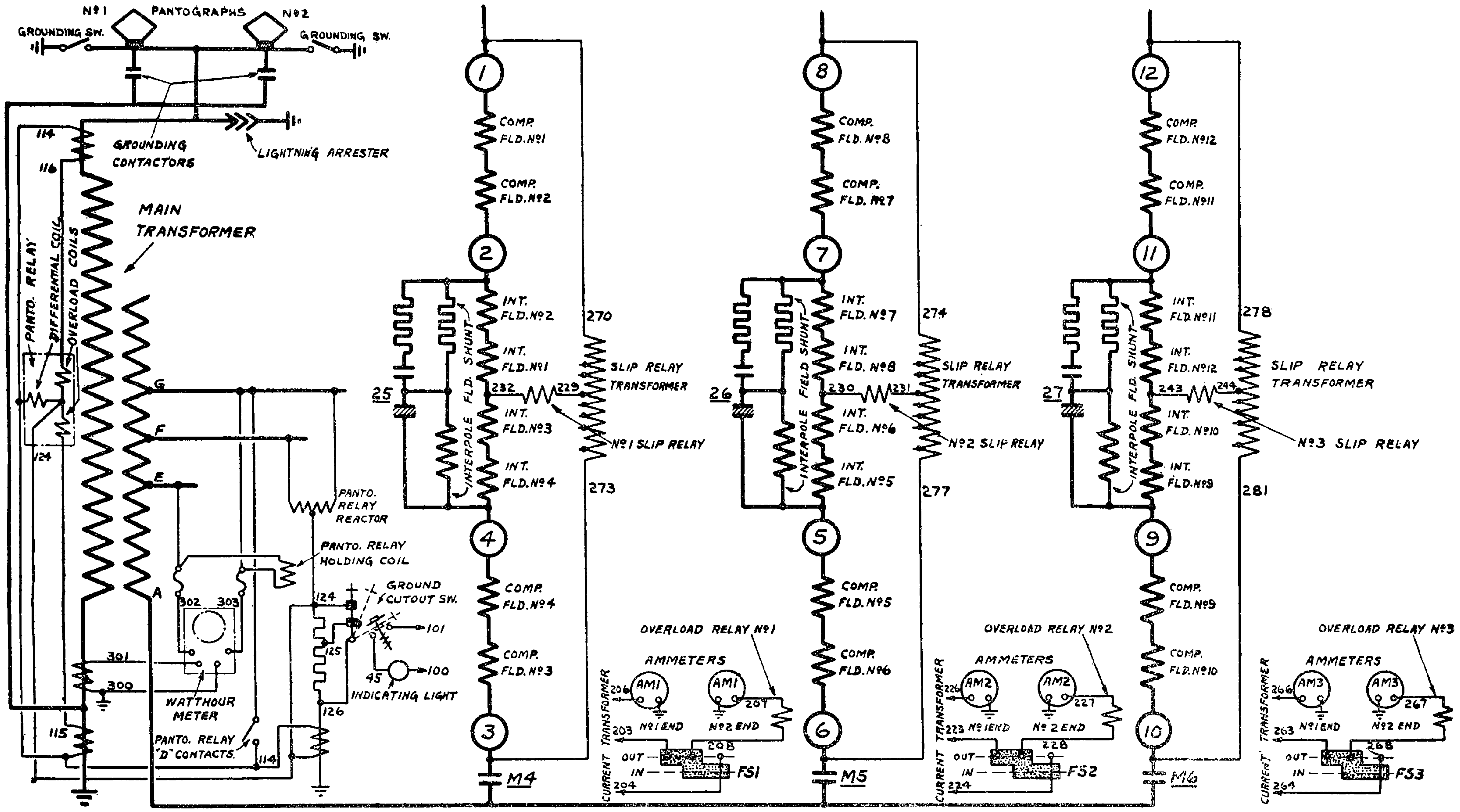


Plate 20. Protective and Metering Circuits—GG1 Locomotives

Plate 20. Protective and Metering Circuits—GG1 Locomotives

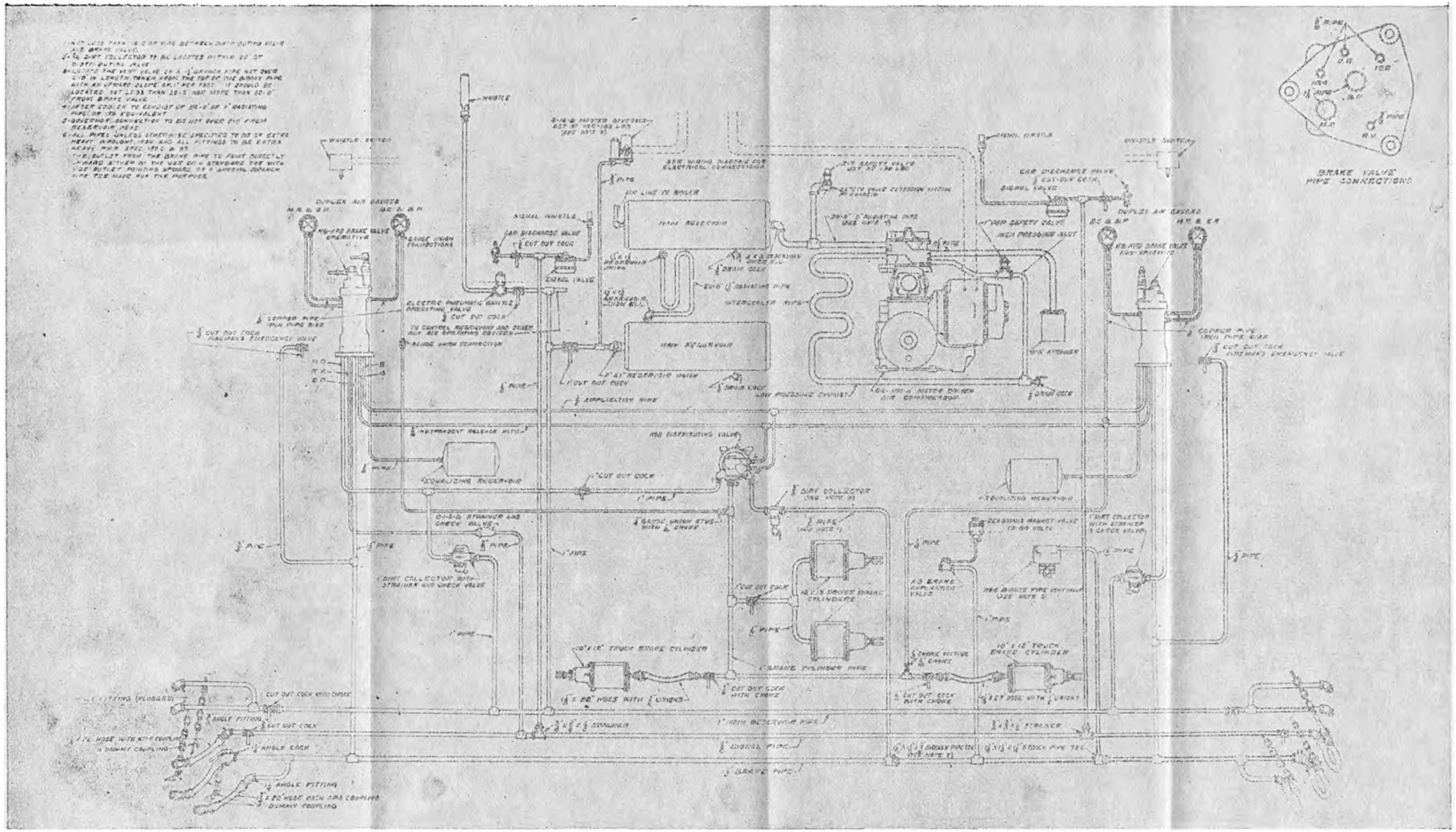


Plate 21. Air Brake Piping—P5a Locomotives

Plate 21 Air Brake Piping—P5a Locomotives

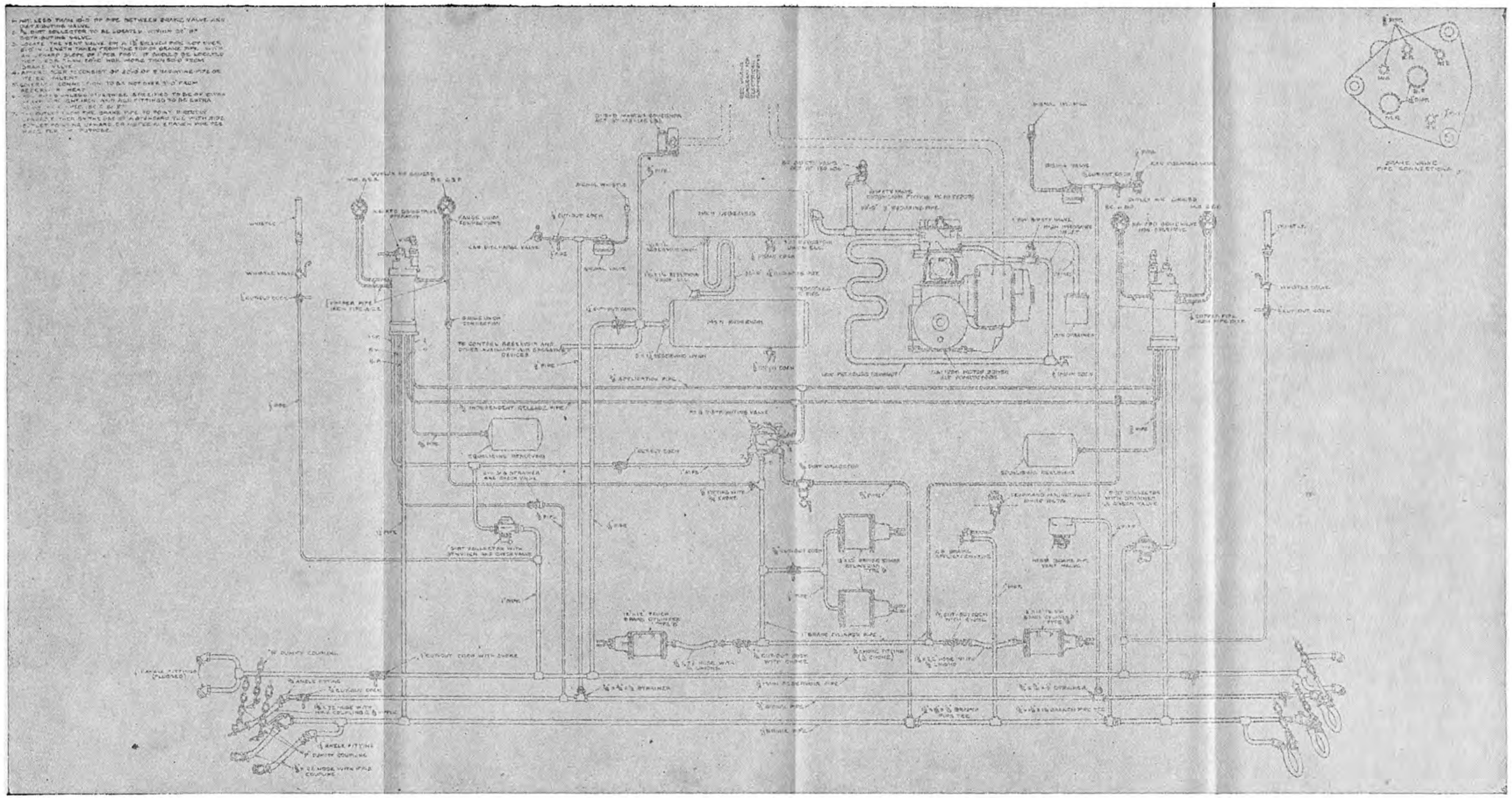


Plate 22. Air Brake Piping—Modified P5a Locomotives

Plate 22. Air Brake Piping—Modified P5a Locomotives

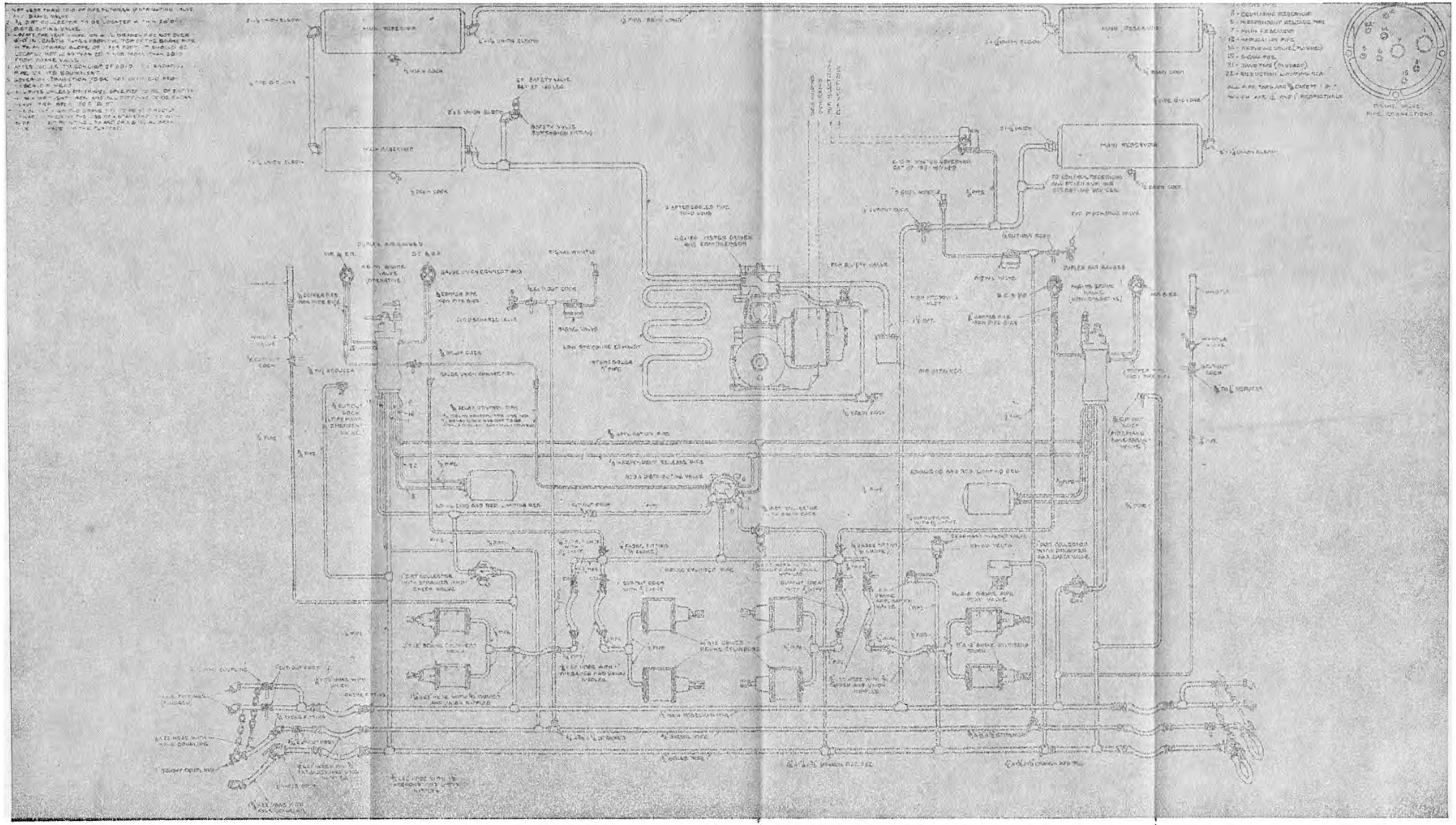


Plate 23. Air Brake Piping—GG1 Locomotives

Plate 23. Air Brake Piping—GG1 Locomotives

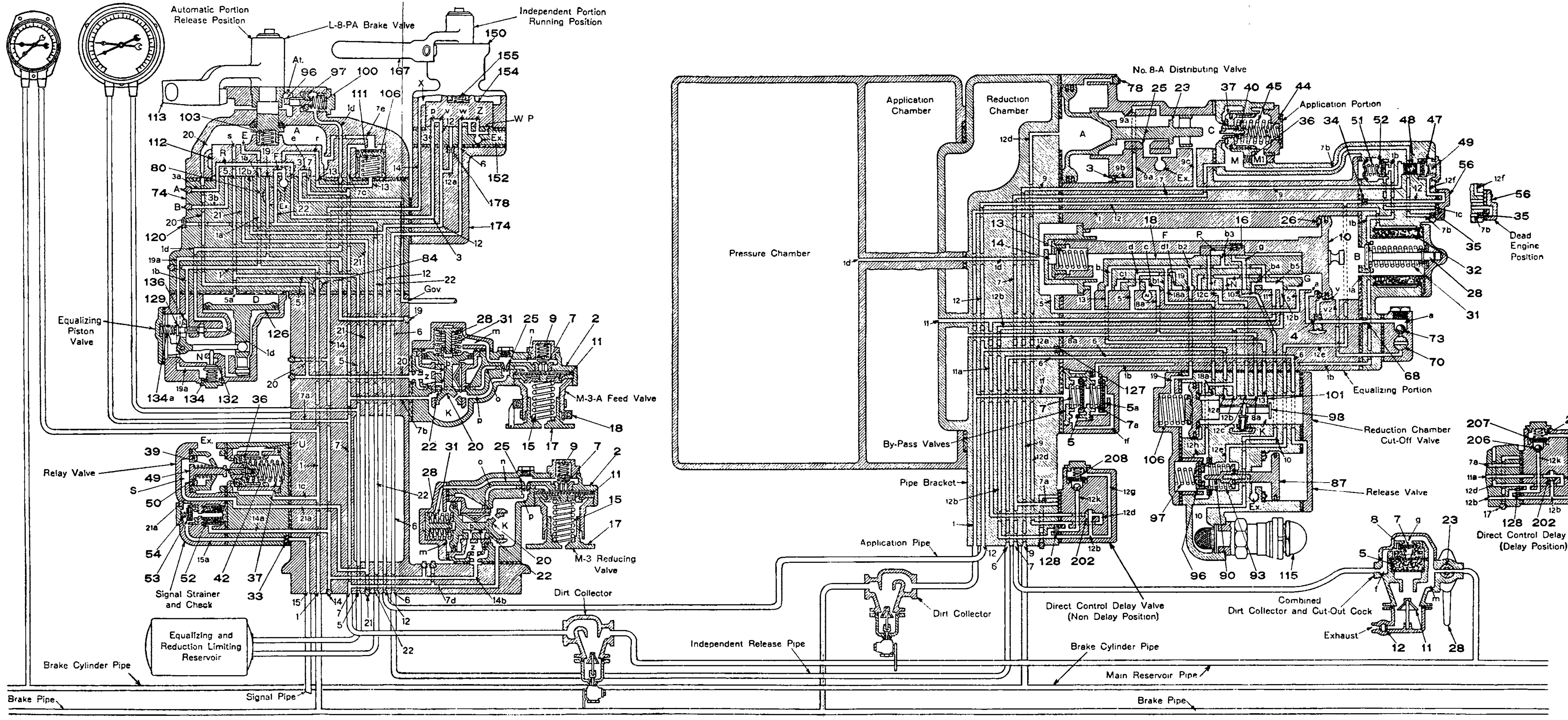


Plate 24. RELEASE Position—Charging the Brake System

Plate 24. RELEASE Position—Charging the Brake System

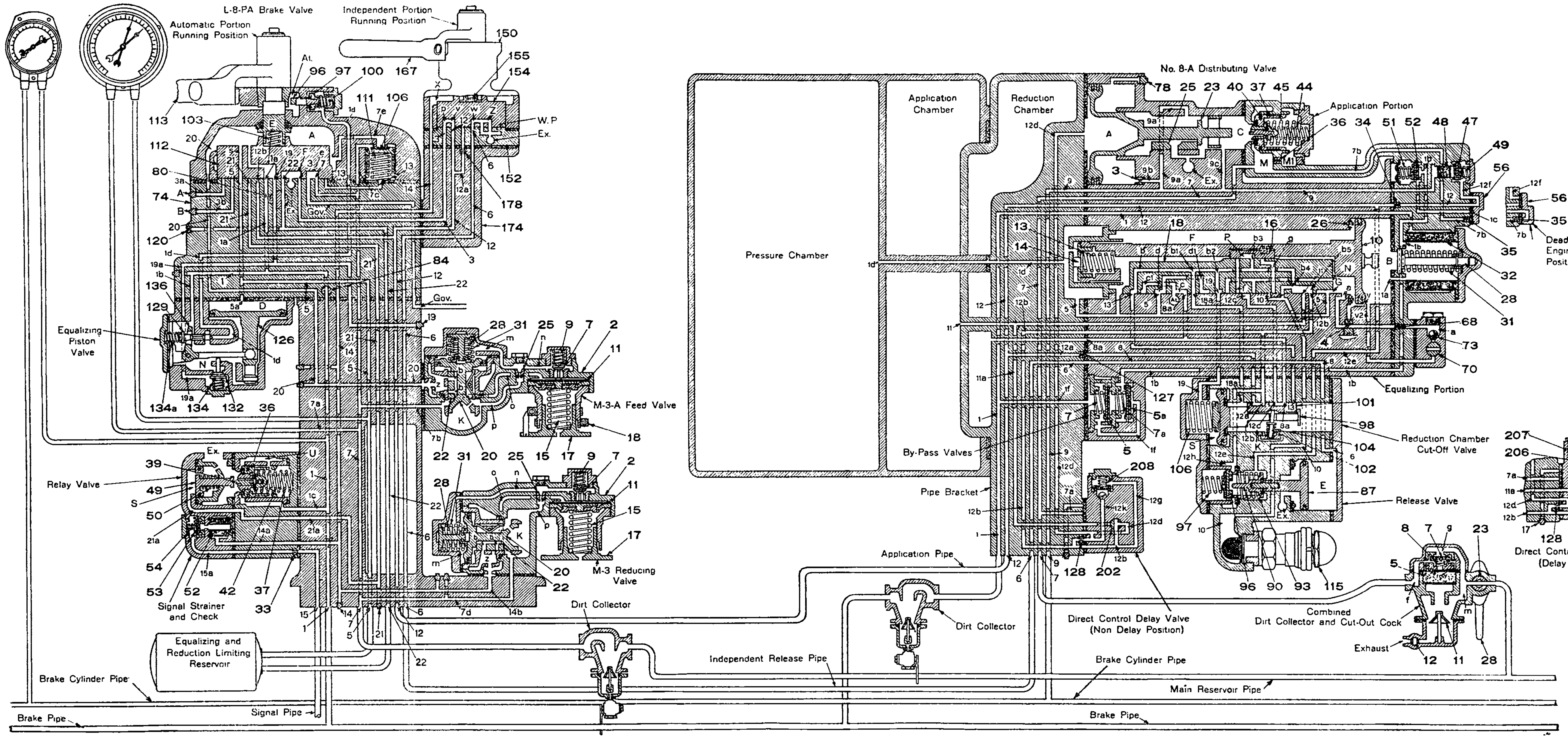


Plate 25. RUNNING Position with Brakes Fully Released and Equipment Fully Charged

Plate 25. RUNNING Position with Brakes Fully Released and Equipment Fully Charged

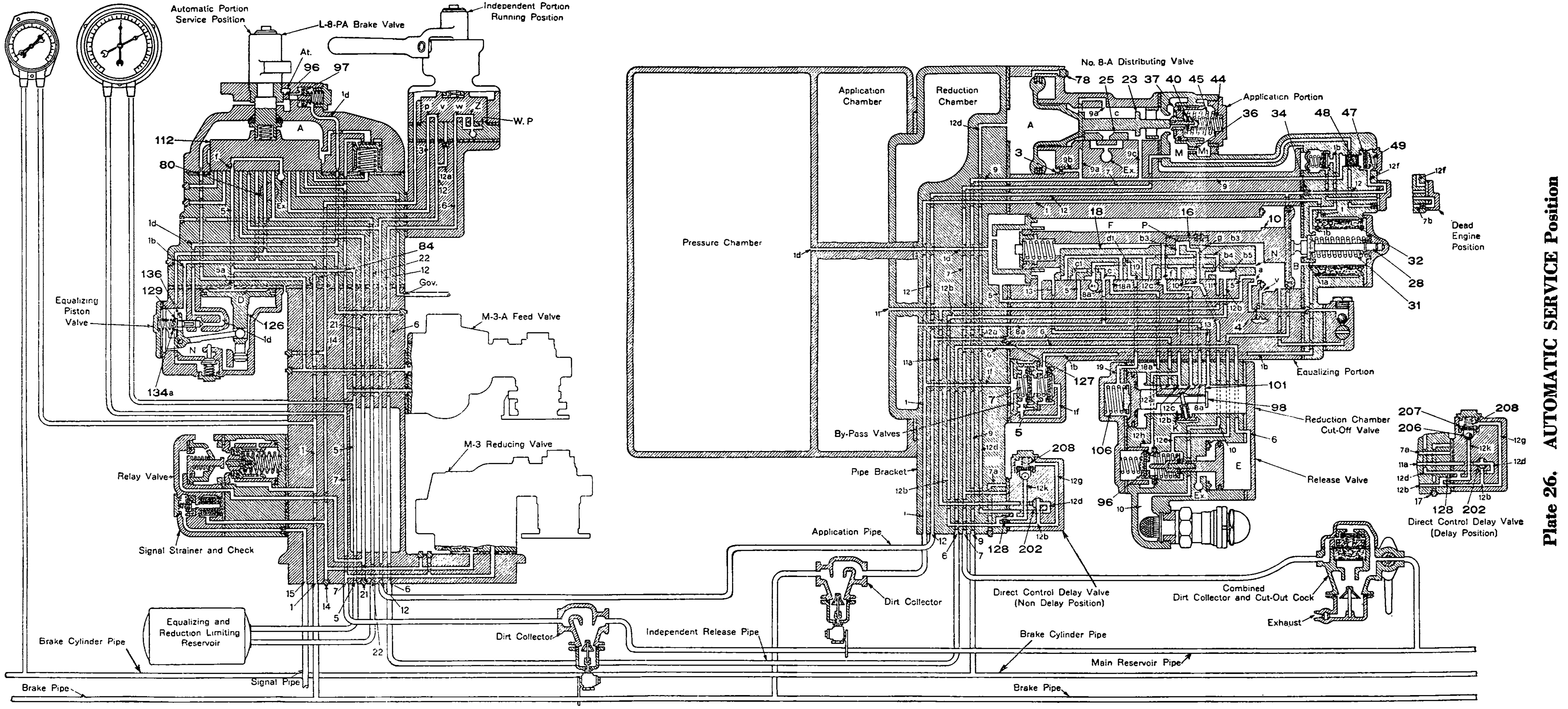


Plate 26. AUTOMATIC SERVICE Position

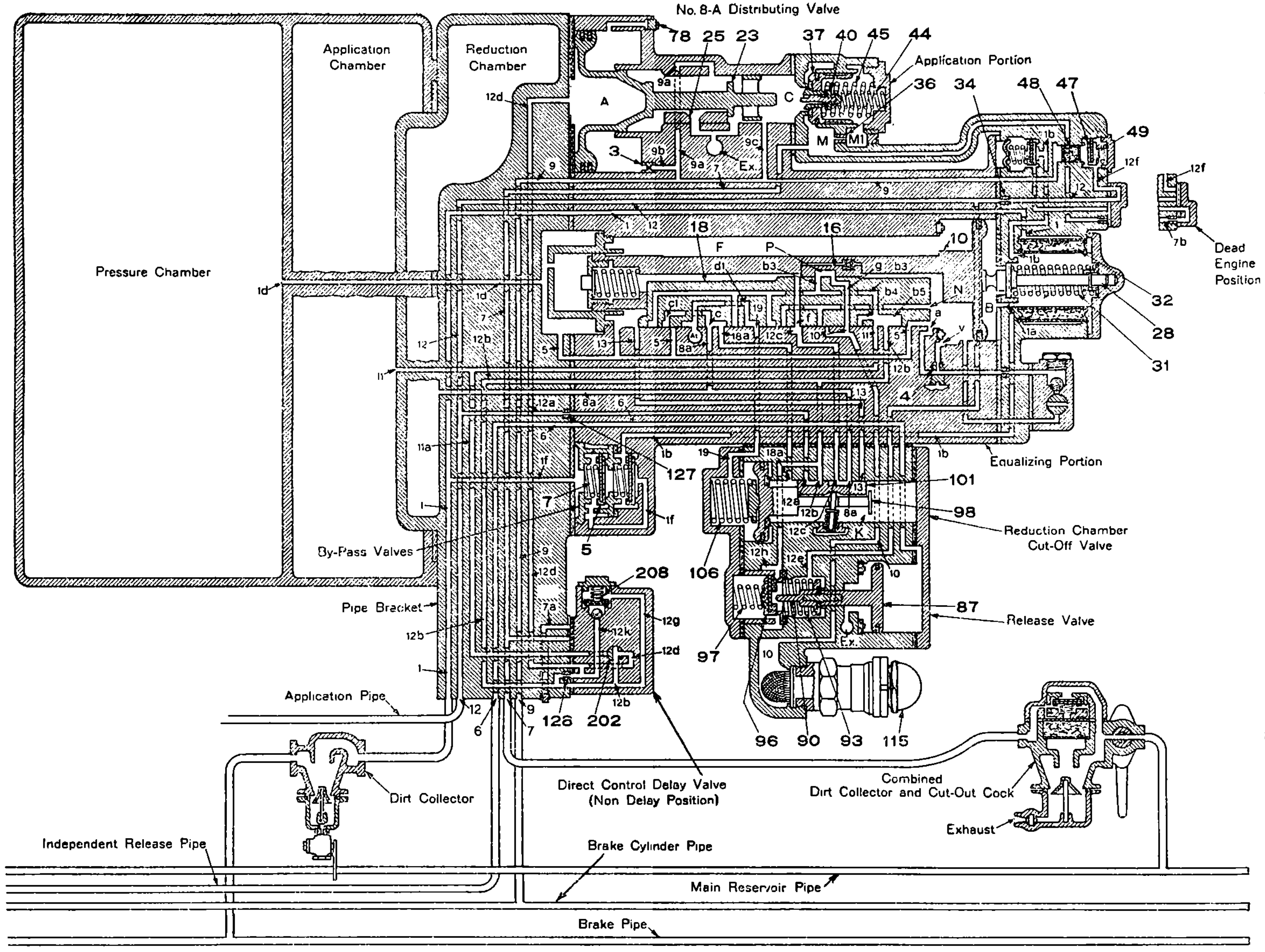


Plate 26A. FIRST STAGE SERVICE Position of the Distributing Valve

Plate 26A. FIRST STAGE SERVICE Position of the Distributing Valve

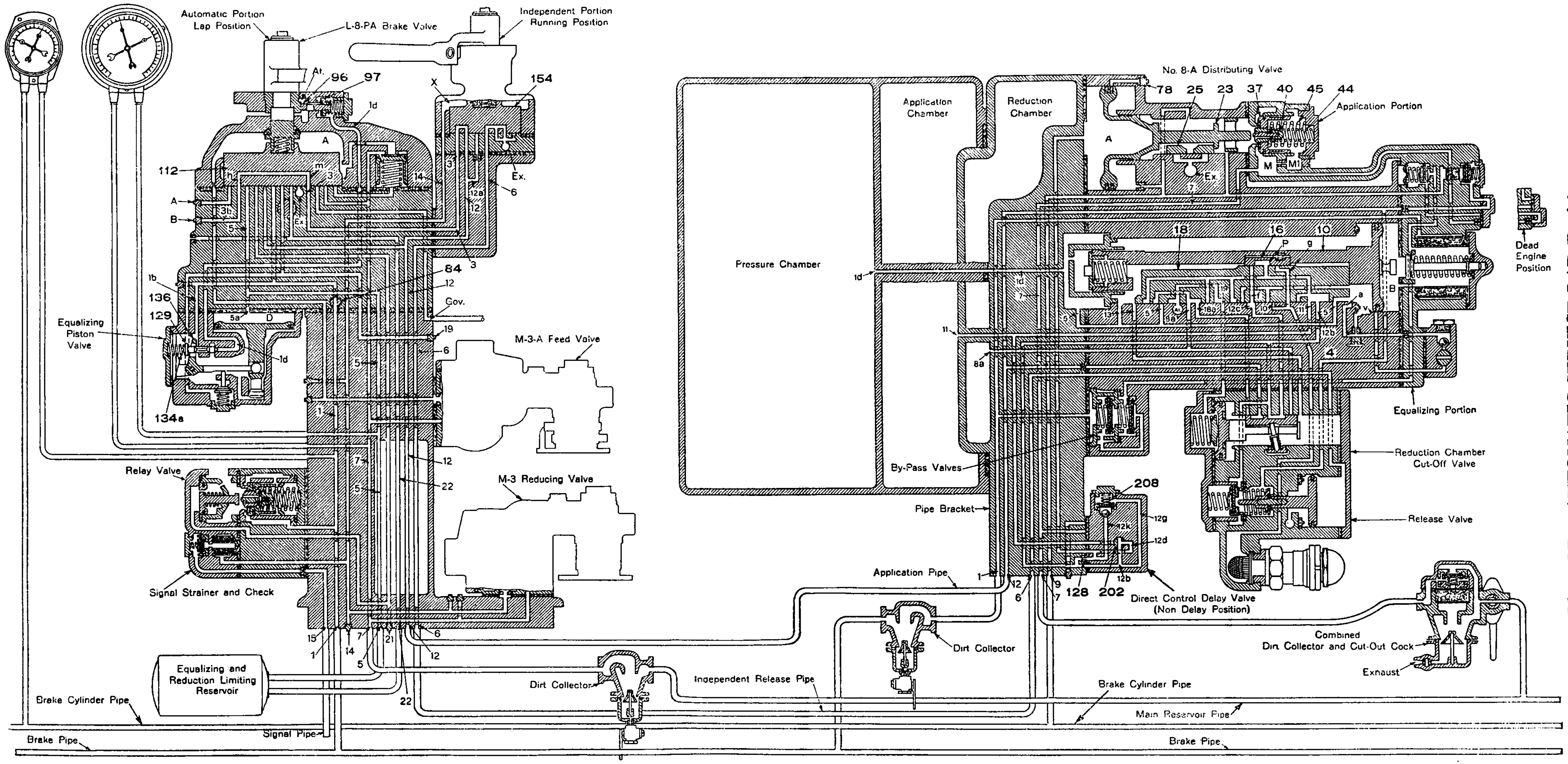


Plate 27. AUTOMATIC SERVICE LAP Position

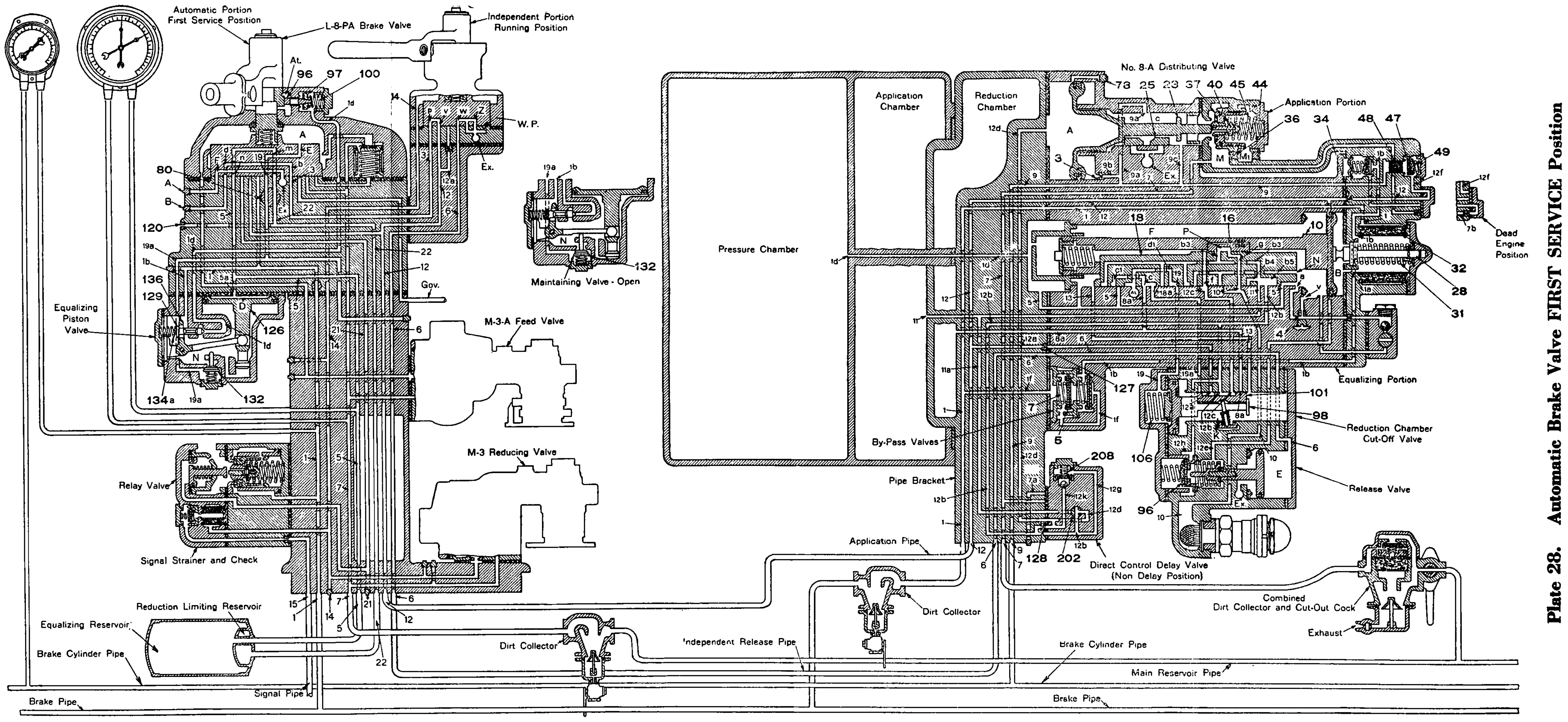


Plate 28. Automatic Brake Valve FIRST SERVICE Position

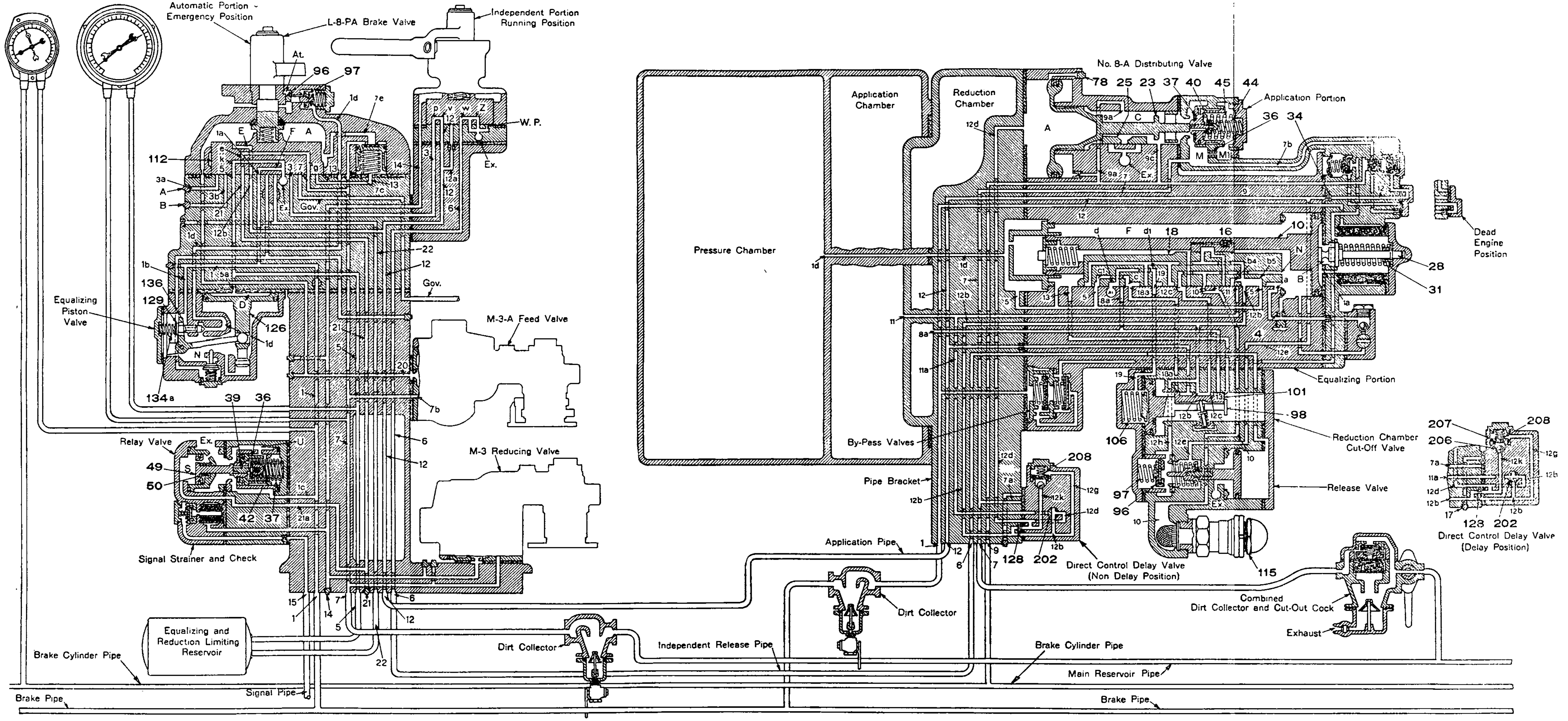


Plate 29. EMERGENCY Position

Plate 29. EMERGENCY Position

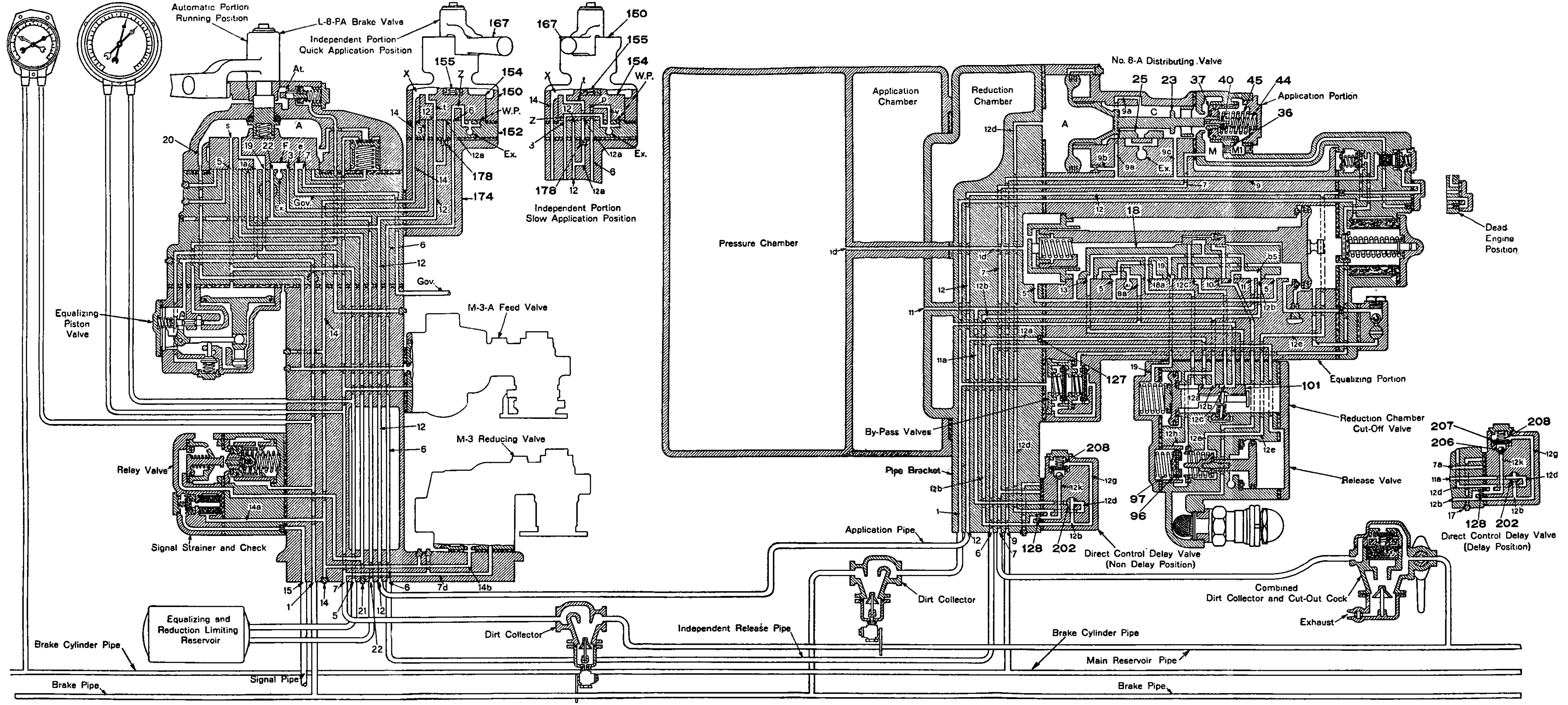


Plate 30. INDEPENDENT APPLICATION Position

Plate 30. INDEPENDENT APPLICATION Position

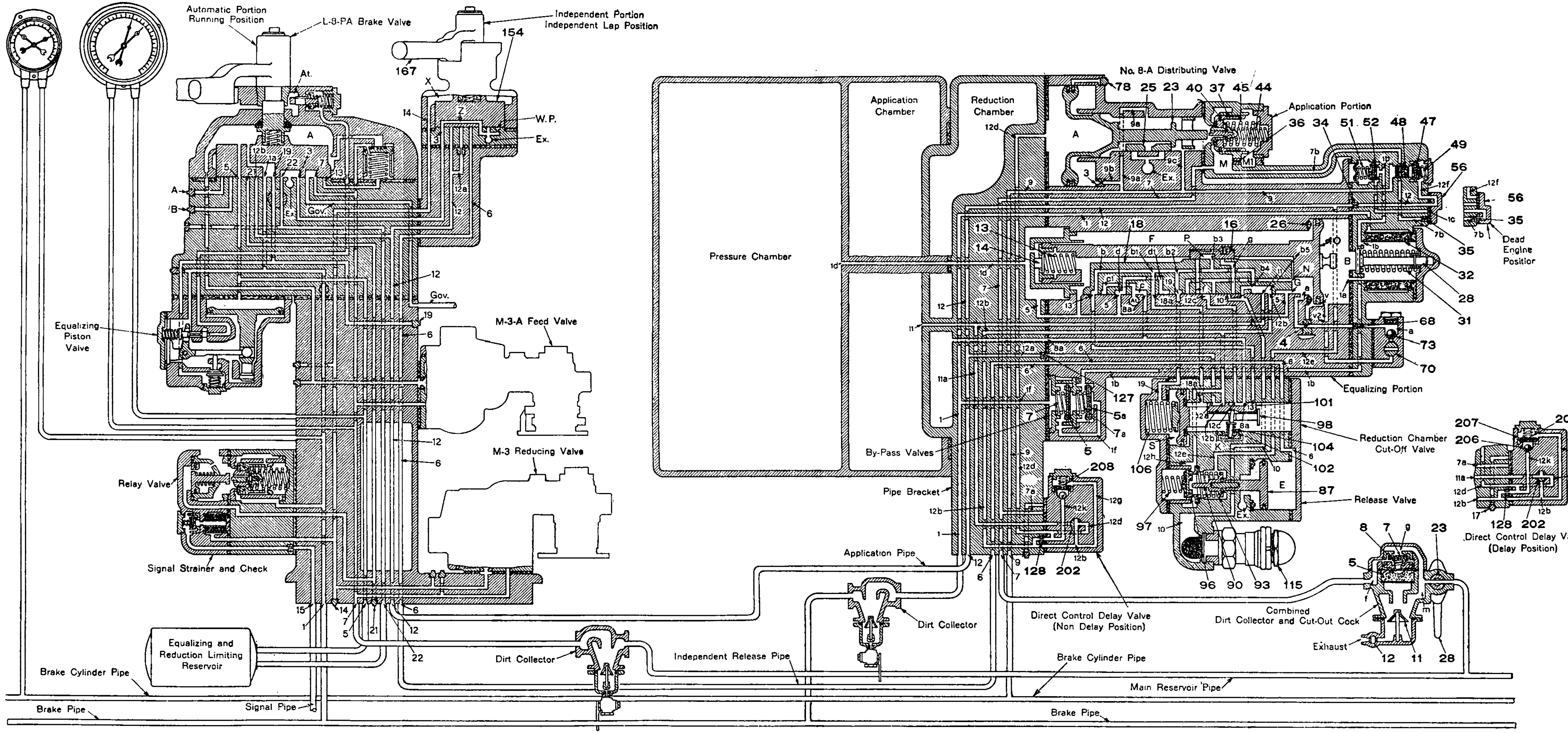


Plate 31. INDEPENDENT LAP Position

Plate 31. INDEPENDENT LAP Position

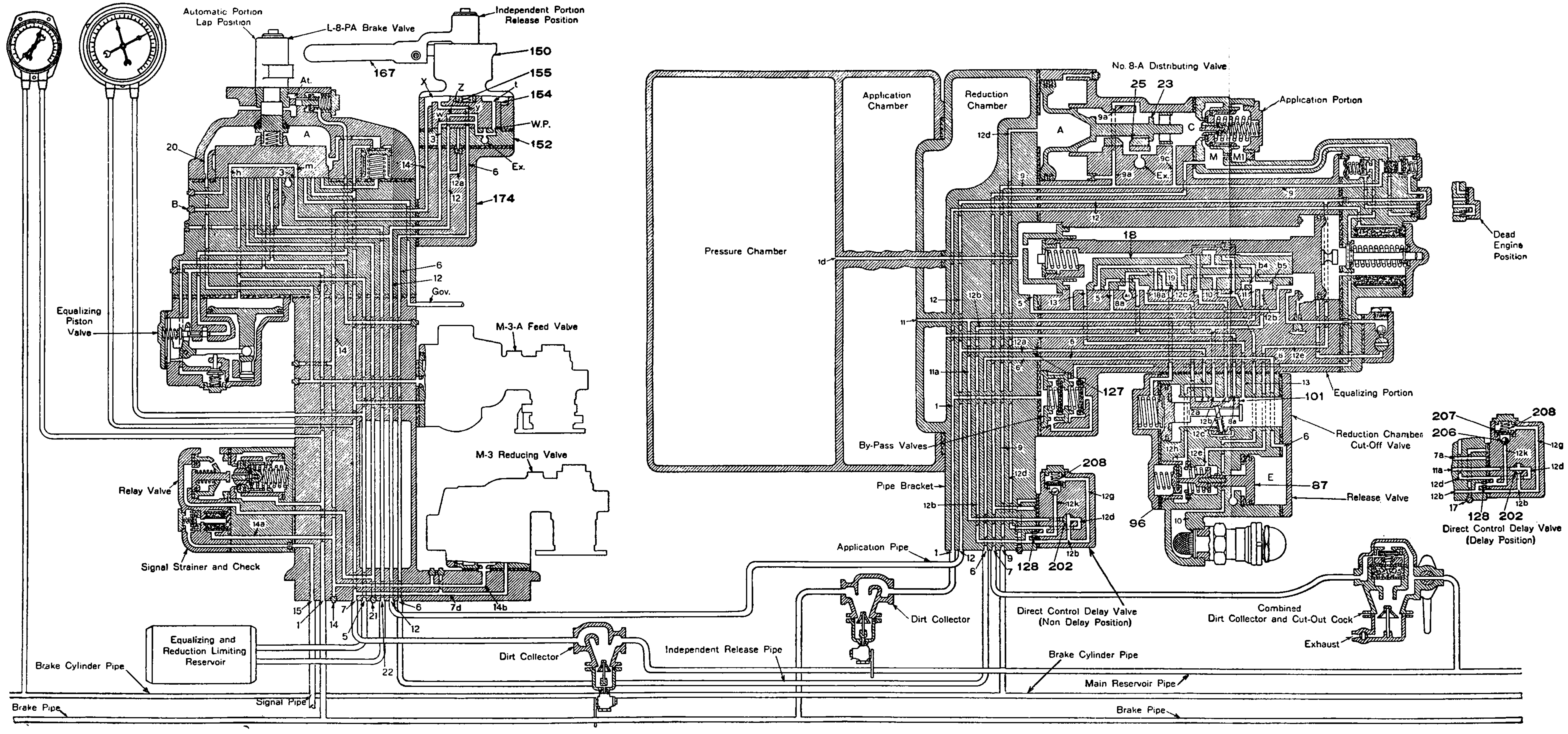


Plate 32. **INDEPENDENT RELEASE** Position after Automatic Service

Plate 32. INDEPENDENT RELEASE Position after Automatic Service

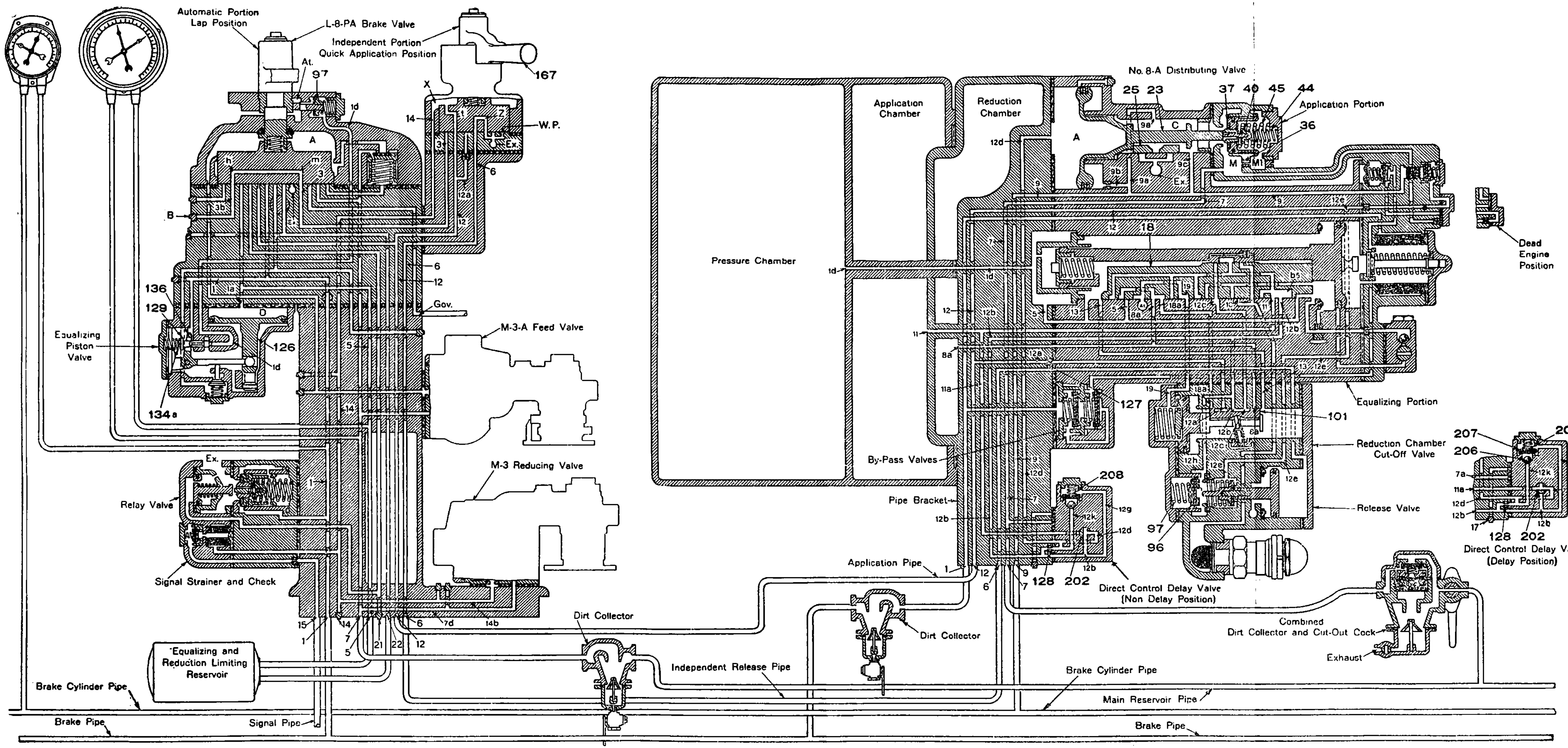
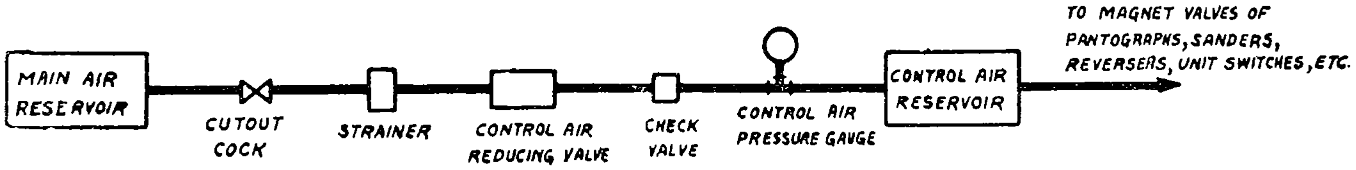
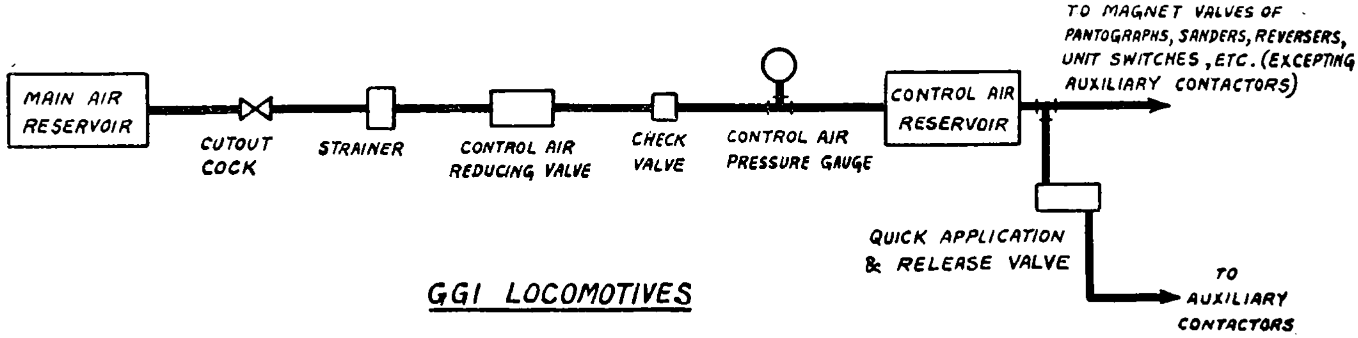


Plate 33. INDEPENDENT APPLICATION after Independent Release—Automatic Brake Applied

Plate 33. INDEPENDENT APPLICATION after Independent Release—Automatic Brake Applied



P5A AND MODIFIED P5A LOCOMOTIVES



GG1 LOCOMOTIVES

Plate 34. Control Air Piping

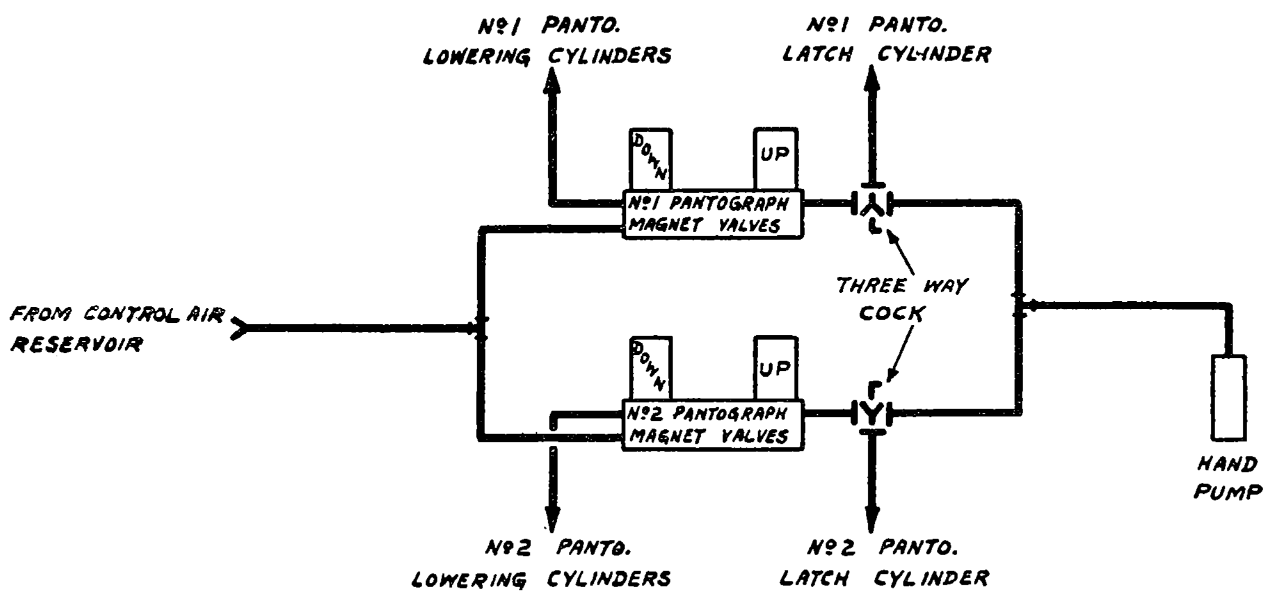


Plate 35. Pantograph Air Piping

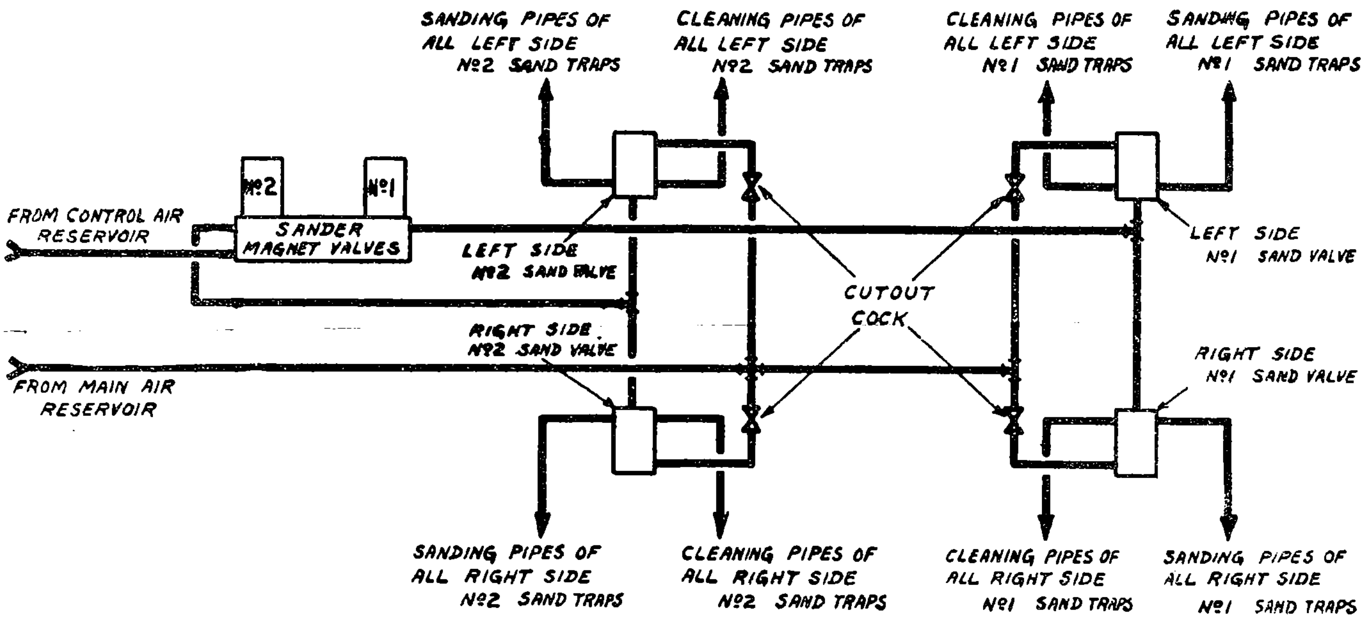


Plate 36. Sander Air Piping

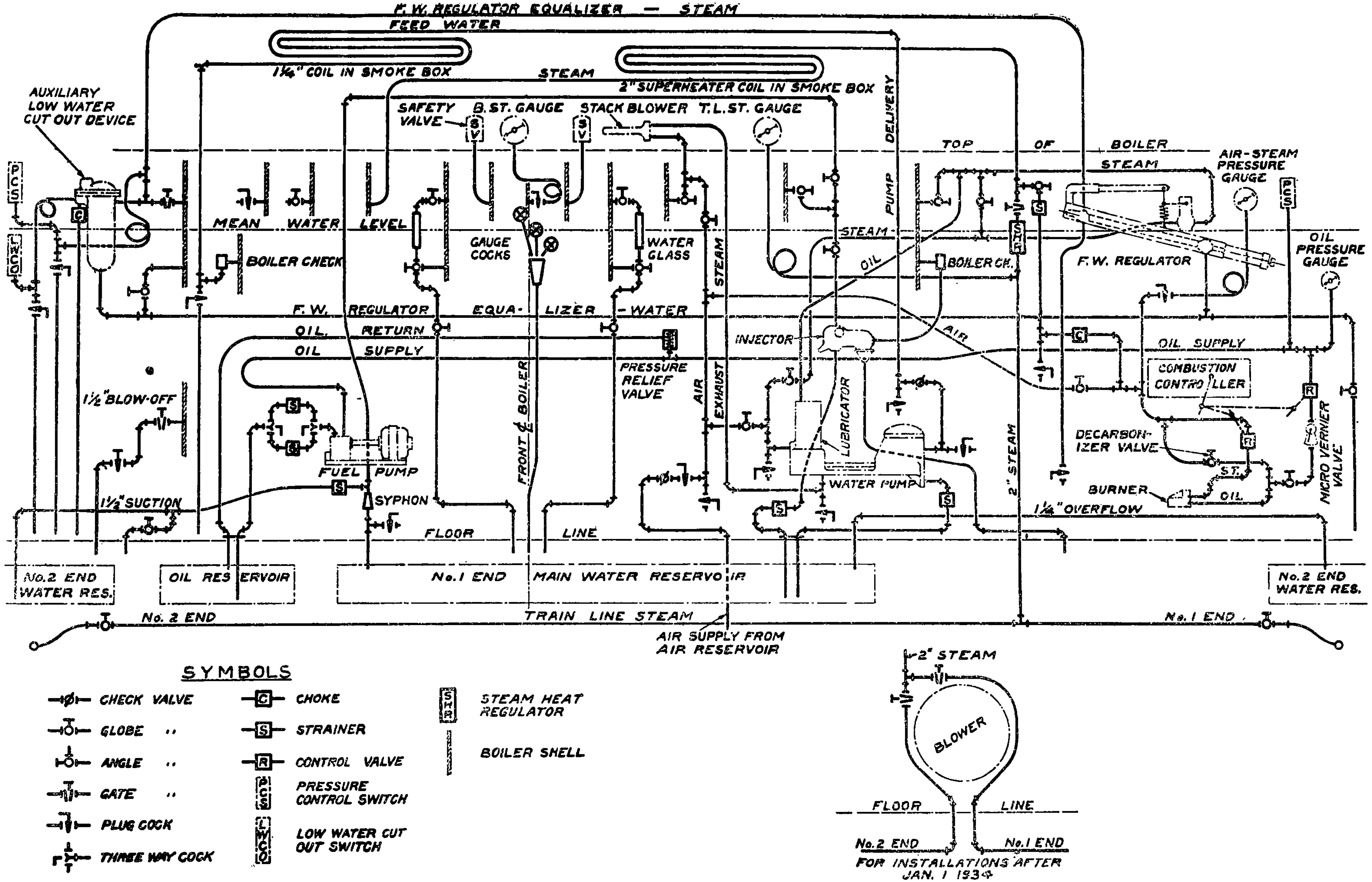


Plate 37. Boiler Piping

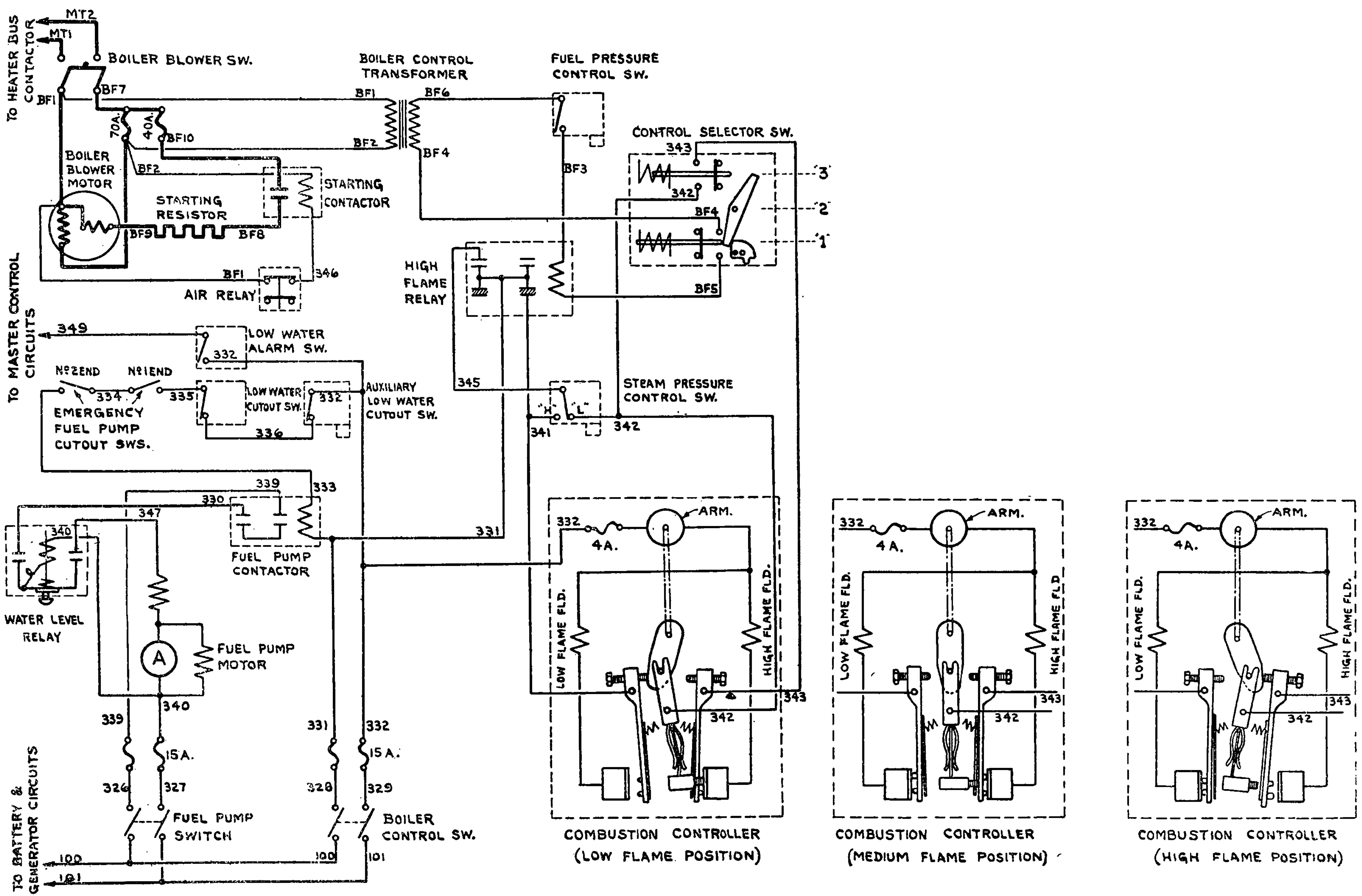


Plate 38. Boiler Circuits