AIR BRAKES

LUDY

AIR BRAKES

AN UP-TO-DATE TREATISE ON THE WESTINGHOUSE AIR BRAKE
AS DESIGNED FOR PASSENGER AND FREIGHT SERVICE
AND FOR ELECTRIC CARS, WITH RULES FOR
CARE AND OPERATION

BY

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ILLUSTRATED

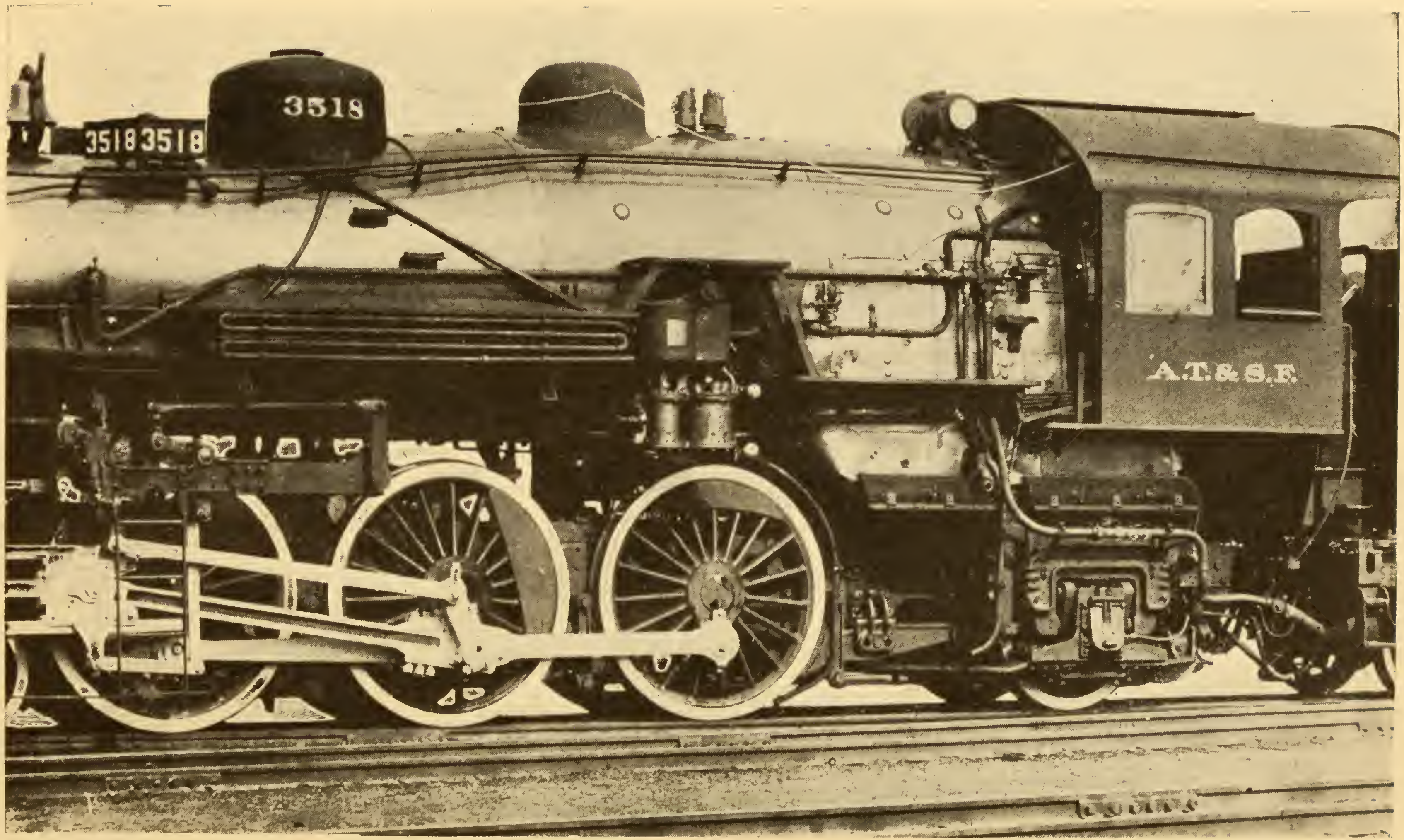
AMERICAN TECHNICAL SOCIETY
CHICAGO
1918

INTRODUCTION

THE HISTORY of braking devices for railroad trains describes a long series of mechanisms from the simple hand form to the complicated electric type. Some of these sprang rapidly into prominence and then disappeared quite as rapidly into the dump-heap. Others persisted for several years, but were finally laid away by their friends with evident reluctance. The one device which has had an uninterrupted success since the invention by Westinghouse is the air brake, and today this type of brake is almost exclusively used on both railroad and electric trains.

¶ The essential quality of any braking device is reliability. It must work in season and out, night and day, in good weather and bad, in excessive heat or cold—in fact, nothing under any circumstances must interfere with its efficient action for the lives of many passengers and the safety of thousands of dollars worth of property absolutely depend upon the ability of these brakes to bring the train to a stop as desired by the engineer. Such a device is the air brake and the present equipment is so reliable that railroad accidents are almost never due to any fault of the brakes.

¶ The author has chosen the Westinghouse system as being the most typical and most widely used and has carefully analyzed the various types of equipment for freight and passenger service. Copious diagrams indicate the action of the brake under various positions of the operating lever and rules for operating and care of the equipment make the article especially valuable. The article treats as well the types of equipment which have been developed especially for electric cars. The treatment of all of the equipment is strictly up-to-date and should be of value either to the practical railroad man or to the layman who wants the "know how" of things.



CHARACTERISTIC AIR-BRAKE EQUIPMENT FOR PASSENGER LOCOMOTIVE
Courtesy of Baldwin Locomotive Works, Philadelphia, Pennsylvania

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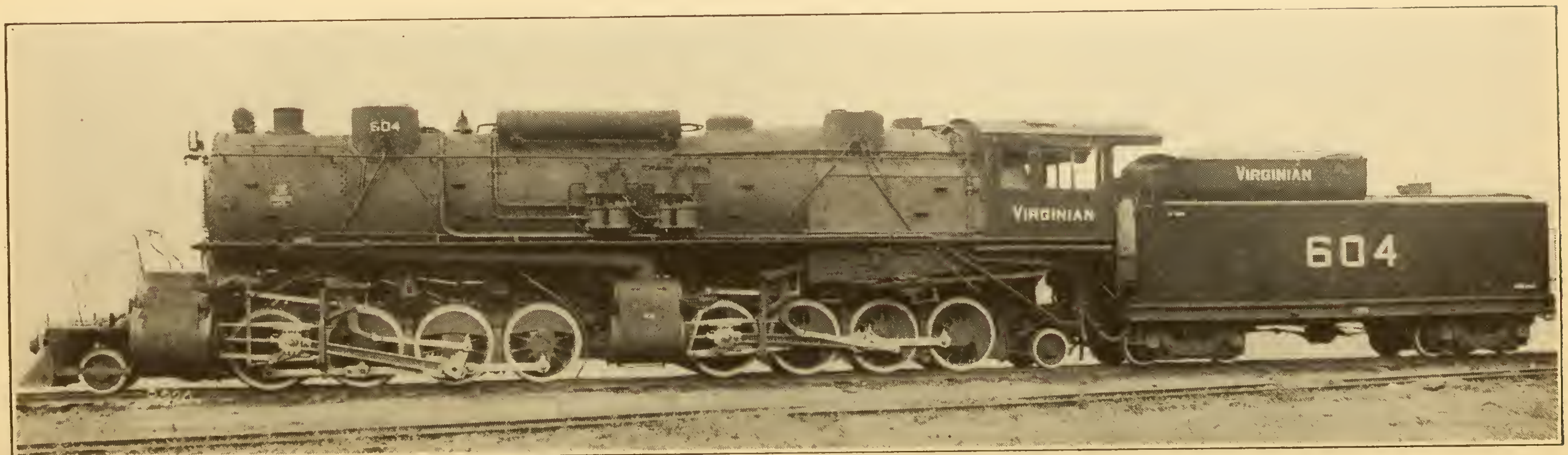
FREIGHT ENGINE, 2-8-2 TYPE BUILT FOR THE HOCKING VALLEY RAILROAD

Courtesy of American Locomotive Company, New York City



MALLETT ARTICULATED COMPOUND LOCOMOTIVE

Courtesy of American Locomotive Company, New York City

AIR BRAKES

PART I

INTRODUCTION

Braking an Outgrowth of Speed. The development of the many accessory appliances with which the rolling stock of our railways is fitted has been the subject of a great deal of study and investigation. Of the many appliances which have received careful and systematic study, the braking apparatus is one of the most important.

The time when the question of braking first received attention dates back farther than the time when highways became sufficiently well made and well maintained to permit of vehicles being drawn at a moderate rate of speed. When wheeled vehicles, drawn at speeds of ten or fifteen miles per hour, first made their appearance, it was found necessary to provide means by which they could be easily and quickly stopped in case of emergency. The first carts and wagons, built for agricultural purposes, were of such construction that the resistance of the earth and axle were sufficient to bring them to rest in a reasonable length of time on ordinary roads. In cases of steep grades, the motion was retarded by one or both wheels being locked with chains, or by a stone or piece of timber being chained to the axle and dragged along the ground behind the vehicle.

It is interesting to note that the question of braking has steadily increased in importance as the demand for higher speed has increased. This applies equally well to all classes of vehicles, including railway trains, street and interurban cars, automobiles, and wagons. The first forms of braking apparatus adopted have formed the basis of almost all brake appliances since employed for the same vehicles.

Early Forms of Brake. *Stagecoach Type.* Perhaps one of the first forms of brake used was that found on the early stagecoach. It consisted of an iron shoe which was chained to the fore part of the coach, and it was used only on steep grades. To apply this brake, the shoe was removed from its hook under the carriage and placed on the ground in front of the rear wheel in such a position that the wheel would roll on it. As the wheel rolled on the shoe, the chain became taut, with the result that both the shoe and wheel slid over the surface of the ground.

First Railroad Type. A railroad is known to have existed as early as 1630, although it would hardly be called by that name today. The construction of the track, as well as that of the cars, was almost entirely of wood. Even with this crude construction it was found necessary to provide a brake to control the speed of the cars on the slight grades. The form of brake devised to meet the conditions consisted of a wooden lever pinned to the frame of the car at one end in such a manner as to permit of its being pressed against the tread of the wheel by hand. When not in use, the lever was held off the wheel by means of a chain. The principle employed here in resisting the motion of the car is the same as that employed today on all railroads, namely, of applying the braking or resisting force to the periphery of the wheel.

Developments Due to Steam Locomotive. As railroads increased in number and their construction improved, braking apparatus became more and more a necessity. As a result, inventors brought out a number of simple braking appliances. The question of braking, however, did not become a very important or a very serious one until the advent of the steam locomotive. Previous to its coming, the cars were small and were drawn by animals, and the speeds were low; but, with the steam locomotive in existence, an efficient brake became an absolute necessity.

This problem received the close attention of inventors and investigators; and, at the close of 1870, the automatic, electro-magnetic, steam, vacuum, and air brakes were found in use on the railroads in the United States. These types of brakes differed chiefly in the manner in which the braking power was obtained. Other devices were invented, but could not stand the test of actual practice and did not come into prominence.

Cramer Spring Type. It might be interesting to note briefly one or two rather unique types of brakes not included in any class yet mentioned. The Cramer brake, brought out in 1853, might be mentioned as one of these. Its principal feature consisted of a spiral spring, which was connected to the brake staff at the end of each car. This spring was wound up by the brakeman before leaving the station, and the brake apparatus on each car was under the control of the engineer through the medium of a cord. This cord was connected to the mechanism of the several brakes and passed through the cars, terminating in the cab on the engine. The engineer, desiring to stop his train, would shut off the steam and give the cord a pull, which action resulted in releasing the coil springs on the various cars and applied the brakes by winding up the brake chains.

Loughridge Chain Type. The Loughridge chain brake, another unique brake, was introduced in 1855. This brake consisted of a combination of rods and chains which extended from a winding drum under the engine throughout the entire length of the train. This continuous chain joined other chains under each car, which, in turn, were connected to the brake levers. The winding drum located under the engine was connected by a worm gear to a small friction wheel. In operating the brake, a lever in the cab was thrown which brought the small friction wheel in contact with the periphery of one of the driving wheels, thereby causing the drum to rotate and wind up the chain. The movement of the chain, which was experienced throughout the entire length of the train, served to actuate levers and rods under each car which, in turn, applied the brake shoes to the treads of the wheels.

Hand Types. The early types of hand brakes underwent many changes as years went on and as experience suggested improvements. Although during many years of early railroading, the braking on all trains was done by hand, nevertheless there was a constant desire and demand for a practical automatic brake. The rather crude and inefficient types already referred to were obtained only after a great many failures. Since about 1870, all forms of brakes have differed chiefly in but one respect, that is, in the appliances which are used in operating the foundation brake gear. The foundation brake gear is made up of the rods, levers, pins, and beams located under the frame of the car, the operation of which causes the brake shoes to be pressed against the periphery or tread of the wheel. The present scheme of applying the brake shoe to the periphery of the car wheel—which was in use long before the first locomotive made its appearance—later experience has proved to be the most practicable.

Many forms of brakes were devised prior to the year 1840, but, at that time, few locomotives were equipped with braking apparatus. About this period, however, when the locomotive tender began to take on some definite form, we find the tender fitted with braking appliances. Previously, when brakes were provided, they were usually found fitted to the cars only. It is only within the last thirty-five years that locomotives have been built with brakes fitted to the drivers. Today it is not uncommon to find all wheels on both the locomotive and the tender equipped with braking apparatus.

First Westinghouse Air Type. In 1869, the first Westinghouse air brake made its appearance. This brake is now referred to as the "straight air brake". It was not an automatic brake. It consisted chiefly of a steam-driven air compressor and storage reservoir located on the engine; a pipe line extending from this reservoir throughout the length of the train, a brake cylinder on each car, and a valve located in the cab for controlling the brake mechanism. The train line was connected between cars by means of flexible rubber hose with suitable couplings. Each car was fitted with a simple cast-iron brake cylinder and piston located underneath the frame, the piston rod of which connected with the brake rigging in such a manner that, when air was admitted into the cylinder, the piston was pushed outward and the brake thereby applied. In operating the brake, air was admitted into the train line from the storage reservoir by means of a three-way cock located in the cab. The air was conducted to the brake cylinder under the various cars by means of the train pipe. The release of the brakes was accomplished by discharging the air in the various brake cylinders and the train pipe into the atmosphere through the three-way cock in the cab. This was the simplest and most efficient brake invented up to the time of its appearance, and was adopted by many railroad companies in this country.

Westinghouse Plain Automatic. The straight air-brake system, however, possessed three very objectionable features: *First,* in case of a break-in-two or of a hose bursting, the brake at once became inoperative; *second,* it was very slow to respond in applying and releasing the brakes; and, *third,* the brakes on cars nearest the engine were applied first, causing jamming and surging of the cars, which sometimes proved destructive to the equipment. In order to overcome these undesirable qualities, Mr. George Westinghouse invented the Westinghouse automatic air brake in 1872. This form of brake, which has since gone out of service on steam railroads, was known as the "plain automatic air brake". This brake retained the principal features of the straight air brake, but in addition, each car was provided with an air reservoir, which supplied the air for operating its particular brake cylinder. The charging of this auxiliary reservoir with air, the admitting of this air into the brake cylinder, and the discharge of the air from the brake cylinder to the atmosphere, were accomplished by an ingenious device known as the triple valve. A detailed description of this valve will be given later.

Vacuum Brake. The vacuum brake was also invented in the year 1872, but, on account of its many undesirable features, it never gained very great prominence in this country. This brake was spoken of as the "plain vacuum brake", and was followed later by the "automatic vacuum brake". The principal parts of the air brake were, in general, embodied in the vacuum brake. One marked difference existed, however, in that, instead of an air compressor, an ejector was installed on the locomotive, which exhausted the air from the train pipe when the system was in operation.

At the close of the year 1885, there could be found in use on the railroads of the United States a number of different types of brakes. These could be grouped into two general classes: continuous, or air brakes, and independent, or buffer brakes. In the buffer brake, the brake shoes were actuated by rods and levers, which in turn received their motion from the movement of the drawbar. It is easily seen that, with such a variety of different forms of braking apparatus, it would be impossible to control a train properly if it were made up of cars from different railroads having different brake systems.

Work of Master Car Builders' Association. *Interchangeable Brake System.* The one agency which has had an important part in bringing the braking appliances of our railroads to the present high standard of perfection is the Master Car Builders' Association. This association, realizing the increasing demand for the interchange of cars, saw the need of interchangeable brake systems. It was principally through the research of their committees that the brake systems of today are interchangeable and efficient.

The first experiment conducted by the committee in 1886 clearly showed that any further attempt to use the independent or buffer brake was not desirable, on account of the severe shocks resulting when stopping the train. The effect of the report of the committee was the withdrawal of this type of brake from the attention of the railroad officials. This left almost the entire field open to the continuous or air-brake system. The committee continued its work the following year and, from the results of a large number of tests, reported that the best type of brake for long freight trains was one operated by air in which the valves were actuated by electricity. This type of brake stopped the train in the shortest possible distance, reduced all attending shocks to a minimum, was released instantaneously, and could be applied gradually. Although the results of tests pointed to the superiority of the air brake in which the valves were operated by electricity, yet it is only recently that a successful system has been adopted.

From the time of these tests, the different brake companies turned their attention to the style of brake represented by the Westinghouse "automatic air-brake" system. In this system, the most important parts are the triple valve, located on the brake cylinder of each car, and the controlling, or engineer's brake valve, located in the cab. By the year 1893, a number of triple valves and engineer's brake valves had been placed on the market and representative ones were exhibited at the Columbian Exposition in Chicago in that year.

Triple-Valve Tests. The committee of the Master Car Builders' Association, being conscious of the fact that the actions of the valves made by the different companies were so widely different, proposed a series of tests of triple valves and asked the different companies to submit valves for the said tests. The object of the proposed tests was to obtain data from which a code of tests for triple valves could be formulated which would be satisfactory to all parties concerned. The ultimate aim of the committee was to secure triple valves which would operate with the same ultimate effect when subjected to identical conditions, and which would operate successfully when intermingled with each other in a train.

Such tests were conducted on a specially constructed air-brake testing track in the year 1894. Five companies responded with valves for the series of tests, of which the valves representing the Westinghouse and New York companies gave the best results. From the results obtained the committee prepared a code of tests for triple valves, which code was soon after adopted by the association

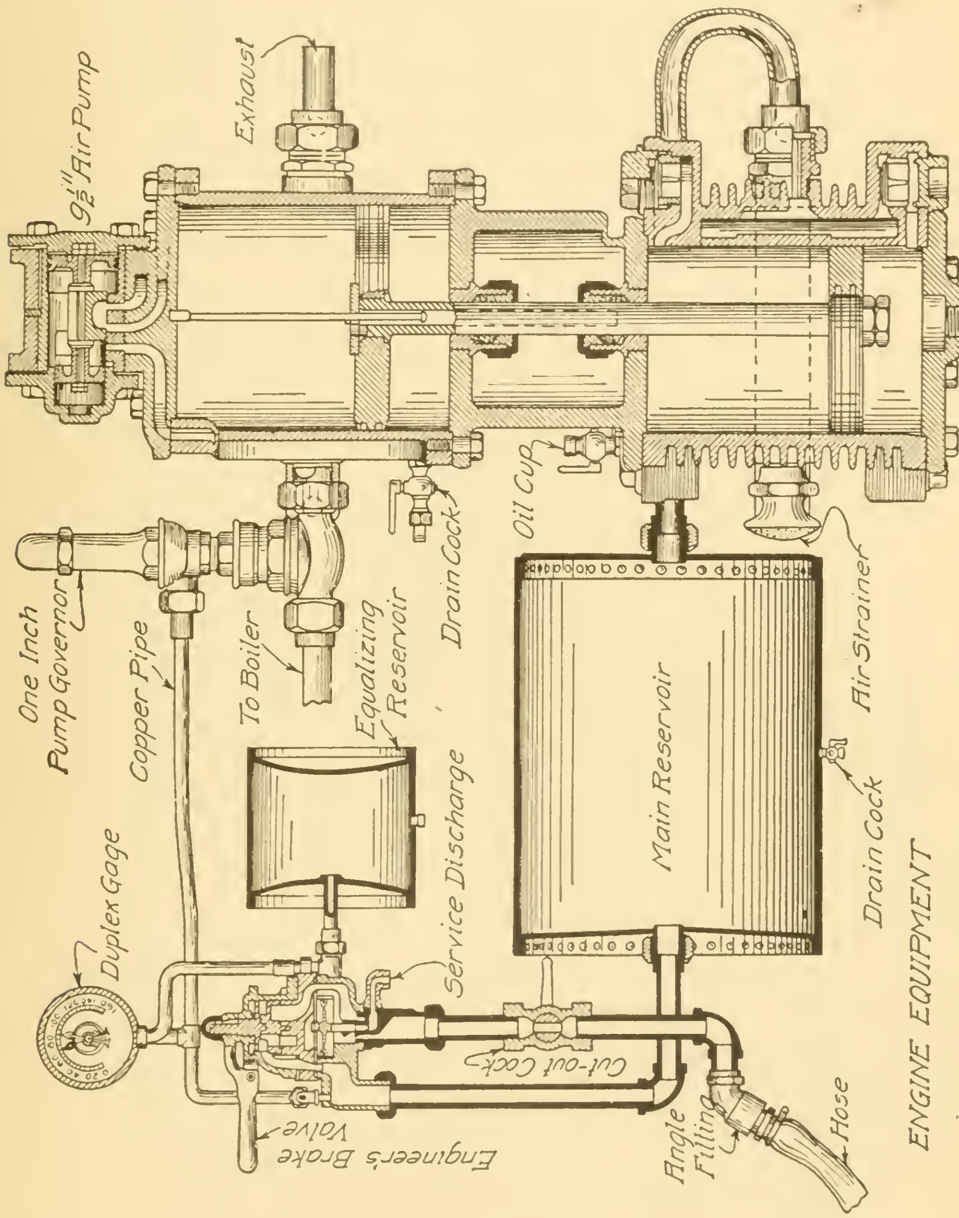


Fig. 1. Diagram Showing Basic Air-Brake Equipment for Locomotive under Westinghouse System

as standard. As a result of this action, makers of air-brake apparatus endeavored to produce triple valves which would give results as specified in the code. This naturally led to interchangeable air-brake systems—one of the objects which the committee hoped to attain. Many triple-valve tests have since been made, and the code has been changed from time to time to meet new conditions which have developed.

Studying the Air Brake. Air-brake study should be carried on

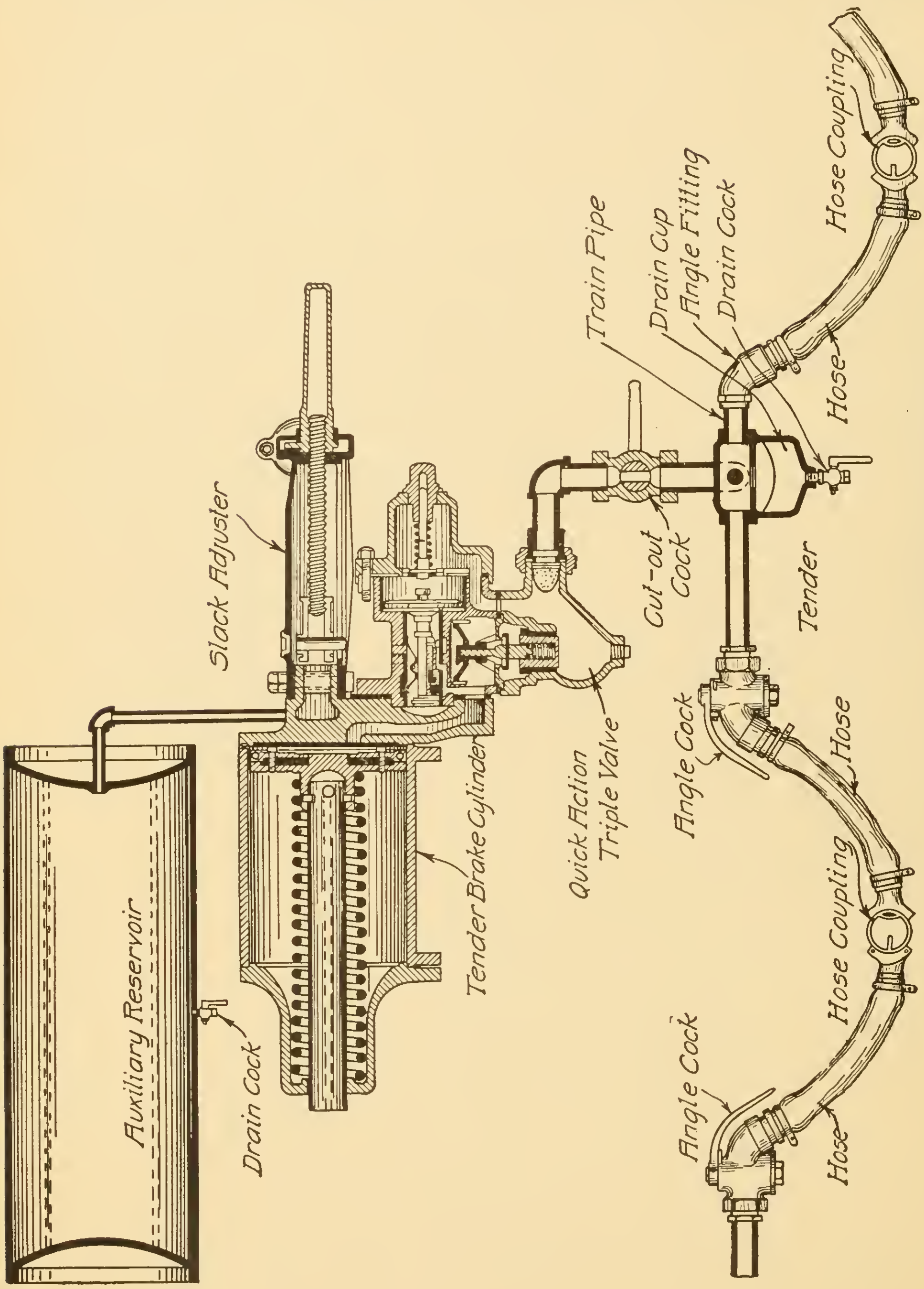


Fig. 2. Diagram Showing Basic Air-Brake Equipment for Locomotive Tender under Westinghouse System

from two standpoints, namely, the theoretical and the practical, keeping them as closely associated as possible.

First, the name of every complete part of the air-brake apparatus and its connections on the engine, tender, and car should be learned. The next thing to be taken up is the function of each part, but neglecting the interior mechanism, ports, passages, etc. In other words, one should learn how the air brake looks on the outside and

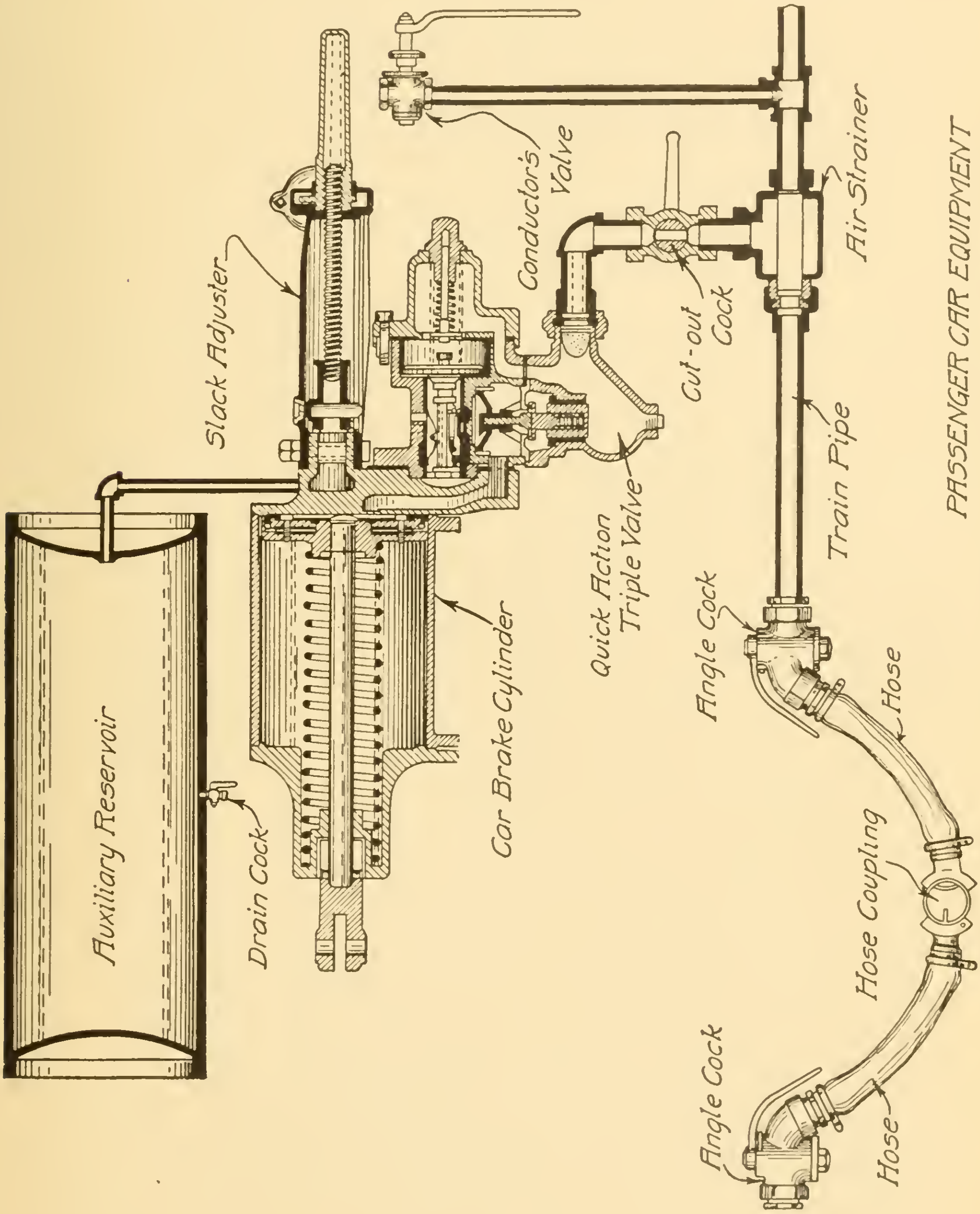


Fig. 3. Diagram Showing Basic Passenger-Car Air-Brake Equipment under Westinghouse System

how it is connected, as shown in Figs. 1, 2, and 3, as this is the basic principle of installation of all automatic railway air brakes now in service. Until this is so well learned that it can be pictured in the mind without reference to the engine, car, or illustration, the student is not ready to study the interior construction and operation of any part.

Today there are mainly two air-brake systems in general use on steam railroads in this country, namely, the *Westinghouse* system and the *New York* system. A few years ago the two systems were quite different, the construction and operation of the different valves being worked out on entirely different principles. Today the various parts comprising the two systems are so much alike in both appearance and principle of operation that the layman cannot distinguish any difference. For this reason it seems advisable to confine the work entirely to a discussion of the Westinghouse system.

WESTINGHOUSE AIR-BRAKE SYSTEM*

GENERAL CHARACTERISTICS OF SYSTEM

Brakes are used to prevent the movement of cars or engines when at rest and, when in motion, to control the speed while descending grades or to stop when it is desired to do so. These results are obtained through friction resulting from pressing the brake shoes against the wheel faces or treads. An air brake is one in which compressed air instead of hand power is used to cause the brake-shoe pressure.

Essential Elements. The automatic air brake has the following ten important parts which, with their connections, are shown in Figs. 1, 2, and 3.

1. A *steam-driven air pump or compressor* located on the engine to compress the air for use in the brake system and signal system when used.

2. A *main reservoir* located somewhere on the engine or tender for the following purposes: (a) to receive and store the air compressed by the pump or compressor; (b) to act as a cooler for the compressed air and to catch the moisture and oil which are precipitated from the air by cooling; (c) to act as a storage chamber for excess pressure or backing volume for the purpose of releasing the brakes and recharging the air-brake system.

3. An *engineer's brake valve*, located in the cab in easy reach of the engineer, with feed valve attachment, through which (a) Air from the main reservoir may be admitted to the brake pipe either (1) direct, as when charging the train or releasing the brakes; and (2) through the feed valve, as when running over the road and maintaining pressure in the system. (b) Air from the brake pipe

*In presenting the discussion and description of the Westinghouse system, free use has been made, where necessary, of literature on the subject published by the Westinghouse Company.

may be allowed to escape to atmosphere when applying the brakes. (c) The flow of air to or from the brake pipe and brake system may be prevented, as when holding the brakes applied.

4. A *double-pointed air gage,* so connected that one hand indicates the main-reservoir pressure and the other indicates the brake-pipe pressure.

5. An *air-pump or compressor governor* to control the operation of the pump by automatically decreasing or closing off the steam supply to the pump to prevent the accumulation of more than the predetermined main-reservoir pressure.

6. A *brake pipe,* including branch pipe, flexible hose, and couplings, which connects the engineer's brake valve and the conductor's valve, with the triple valve on each car. Angle and cut-out cocks are provided in the brake pipe on each car, the former for opening or closing the brake pipe at any desired point in the train, and the latter to cut out, or in, individual triple valves.

7. A *triple valve* on each vehicle, to which the brake pipe, the auxiliary reservoir, and the brake cylinder are connected by separate openings and which, by connecting these openings, control the flow of air between these parts so as to enable the auxiliary reservoir to be charged and the brakes to be applied and released. The functions of the triple valve may be briefly stated as follows: (a) When charging and maintaining the pressure in the brake system (1) to permit air to flow from the brake pipe to the auxiliary reservoir; (2) to prevent air from flowing from the auxiliary reservoir to the brake cylinder; and (3) to keep the brake cylinder open to the atmosphere. (b) When applying the brakes (1) to close communication from the brake pipe to the auxiliary reservoir; (2) to close communication from the brake cylinder to the atmosphere; and (3) to permit air to flow from the auxiliary reservoir to the brake cylinder. (c) When holding the brakes applied, to close all communications between the brake pipe, auxiliary reservoir, brake cylinder, and atmosphere. (d) When releasing the brakes and recharging the system: (1) to keep the brake cylinder open to the atmosphere; (2) to permit the air to flow from the brake pipe to the auxiliary reservoir; and (3) to prevent air from flowing from the auxiliary reservoir to the brake cylinder.

8. An *auxiliary reservoir,* in which the compressed air is stored for applying the brake on its individual car.

9. A *brake cylinder* provided with a leather-packed piston and piston rod connected with the brake levers in such a manner that when the piston is moved by the air pressure the brakes are applied.

10. A *pressure-retaining valve,* not shown in either Figs. 1, 2, or 3, but connected to the exhaust or discharge port of the triple valve. In its ordinary or cut-out position it permits the brake-cylinder pressure to be freely discharged to the atmosphere, but when cut in, as required when descending heavy grades, it retards the discharge of air from the brake cylinder down to a predetermined amount, and then retains that amount when the triple valve is in its release position.

The operation of these parts referred to above will be described in detail under the proper heading later in the work.

The triple valve performs its various functions by variations between brake-pipe and auxiliary-reservoir pressures. If the brake-pipe pressure is made the higher of the two, then the triple valve will move to a position for releasing the brake and charging the auxiliary reservoir. But if the auxiliary-reservoir pressure is made higher than that in the brake pipe—a condition obtainable only through reducing the brake-pipe pressure by the engineer's brake valve or conductor's valve, burst hose or pipe, or train parting—then the triple valve will move to a position for brake application.

Definition of Terms. *Increase in Brake-Pipe Pressure.* Whenever air is passing into the brake pipe more rapidly than it is escaping so as to produce a raise in pressure, it means a brake-pipe pressure increase, and will cause the triple valves to release the brakes and recharge the brake system; but the student must bear in mind that there are two sources of drain on the brake pipe which will operate to prevent an increase in pressure, namely, leakage from the brake pipe through any of its many connections, and also by feeding into the auxiliary reservoirs. All of these losses must be overcome before a raise in brake-pipe pressure can be obtained.

The brake-pipe pressure is maintained by a piece of apparatus known as a feed valve, which forms a part of the engineer's brake valve. This feed valve automatically supplies the brake-pipe losses as fast as they take place through any source whatever, provided the handle of the engineer's brake valve is kept in running position.

Brake-Pipe Reduction. The term "brake-pipe reduction" means that air is escaping or being discharged from the brake pipe faster than it is being supplied. Therefore, it must be understood that losses from the brake pipe which are not supplied will constitute a brake-pipe reduction and will cause the triple valves to move toward application position.

Lap. The term "lap" is used to designate the position of the engineer's brake valve, triple valve, or distributing valve, in which all operative ports are closed to the air in any direction.

Brake Application. By brake application is meant a sufficient reduction of brake-pipe pressure, no matter how made, to cause the triple valves to move to application position and, if made through the service position of the engineer's brake valve, may consist of one or more brake-pipe reductions.

Service Application. Service application is accomplished by a gradual reduction of brake-pipe pressure, so as to cause the triple valves to assume this position and produce the desired result, such as is made by operators for a known train stop or slow down.

Emergency Application. Emergency application is accomplished by a quick, heavy reduction of brake-pipe pressure which will cause the triple valves to assume the emergency position and produce quick action, such as is made by operators with the brake valve, or by train men with the conductor's valve, for the purpose of saving life or property. It is also made automatically whenever the brake pipe is broken or the train parts.

Operation of Westinghouse Air Brake. When the brakes are in operating condition, the pump governor is usually set to maintain a pressure of 90 pounds in the main reservoir. The feed valve is set to maintain a pressure of 70 pounds in the brake pipe when the engineer's brake valve is in running position. The operation of the brake is controlled by the engineer's brake valve, which has five fixed positions for its handle. These positions named in order, beginning from the left, are: *release, running, lap, service,* and *emergency.*

To make a service application of the brakes, the handle of the engineer's brake valve is placed in *service* position, thereby closing connection between the main reservoir and the brake pipe and permitting air to escape from the brake pipe to the atmosphere through ports in the valve. The handle of the engineer's brake valve is left in this position for a short time only, when it is placed in the lap position.

In the *lap* position, all working ports are closed and the brakes are held applied.

When it is desired to release the brake after either a service or an emergency application, the handle of the engineer's brake valve is placed in *release* position. In this position, direct connection is made between the main reservoir and the brake pipe. The handle of the brake valve is left in this position only long enough to insure the release of all of the triple valves and then it is placed in running position. This is done to prevent an overcharged brake pipe. The brakes will release when the engineer's brake valve is placed in *running* position, but they will do so very slowly.

When it is necessary to make an emergency application, the handle of the engineer's brake valve is placed in *emergency* position and direct connection is made between the brake pipe and the atmosphere. This causes a sudden reduction of pressure in the brake pipe and gives a higher pressure in the brake cylinder than is obtained in service applications. If the handle of the engineer's valve is left in the emergency position until a brake-pipe pressure reduction of from 20 to 25 pounds is obtained and it is then placed in lap position, the maximum braking power is obtained. This will be made clear when the study of the quick-action triple valve is taken up.

AIR COMPRESSORS

Single-Stage Type. The Westinghouse single-stage air compressor consists of an air cylinder, in which the air drawn from the atmosphere is compressed; a steam cylinder, located above the air cylinder, the two being connected by a center piece; and a steam cylinder valve motion which for the most part is contained in the upper steam cylinder head.

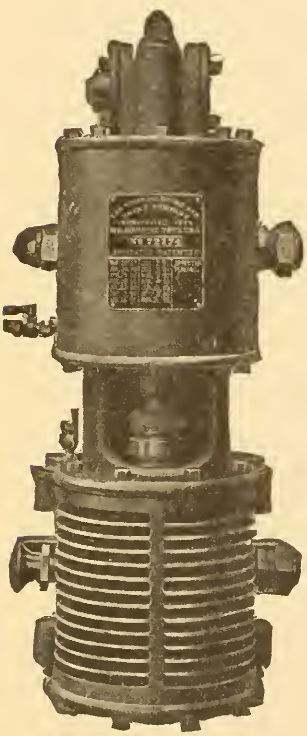


Fig. 4. 9½-inch Steam-Driven Air Compresser
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

The compressor is of the double-acting direct-connected type, steam being admitted alternately to the under and to the upper side of the steam piston, causing it to move up and down. As the air piston is directly coupled to the steam piston by the piston rod, it moves up and down with the steam piston. On the upward stroke of the air piston, the air above it is compressed and discharged into the main reservoir while the space below it is being filled with air drawn from the atmosphere. On the down stroke this operation is reversed. The exhaust steam is usually piped to the smokestack.

Sizes. The compressor is built in different sizes. Table I gives the principal dimensions, actual air delivery, and weight of the single-stage compressors.

All of the sizes of single-stage air compressors now being built operate on the same principle. Fig. 4 illustrates the general appear-

TABLE I

General Dimensions, Capacity, and Weight of Westinghouse Standard Steam-Driven Air Compressors

Diameter of Steam Cylinder	8 in.	$9\frac{1}{2}$ in.	11 in.
Diameter of Air Cylinder	8 in.	$9\frac{1}{2}$ in.	11 in.
Stroke	10 in.	10 in.	12 in.
Steam Admission Pipe	1 in.	1 in.	1 in.
Steam Exhaust Pipe	$1\frac{1}{4}$ in.	$1\frac{1}{4}$ in.	$1\frac{1}{2}$ in.
Air Admission Pipe	$1\frac{1}{2}$ in.	$1\frac{1}{2}$ in.	$1\frac{1}{2}$ in.
Air Delivery Pipe	$1\frac{1}{4}$ in.	$1\frac{1}{4}$ in.	$1\frac{1}{4}$ in.
Nominal Speed, single strokes per minute	120	120	100
Actual capacity in cu. ft. of free air per min. actually delivered when operating continuously, at above speed, against 100 pounds pressure	20 cu. ft.	28 cu. ft.	45 cu. ft.
Over-all Dimensions: (Approximate) Height	$42\frac{1}{4}$ in.	$42\frac{1}{4}$ in.	$51\frac{1}{4}$ in.
Width	18 in.	$18\frac{1}{4}$ in.	22 in.
Depth	$13\frac{3}{4}$ in.	$14\frac{1}{2}$ in.	16 in.
Average Net Weight	450 lb.	525 lb.	850 lb.

ance of the $9\frac{1}{2}$-inch size. Views of the compressor, with steam and air cylinders and valve mechanism in section, are shown in Figs. 5 and 6. Figs. 7 and 8 are distorted or "diagrammatic" illustrations designed to show as clearly as possible the connections of the various ports and passages but not the actual construction of the parts.

Method of Action in Steam End of Compressor. Considering first the steam end of the compressor, and referring to the above-mentioned figures, steam from the supply enters at the connection marked "from boiler", Fig. 6 (or "steam inlet", Figs. 7 and 8), and flows through the passageways *a* and a^2 (see also Fig. 5), to the chamber *A*, above the main valve *83* and between the pistons *77* and *79*, and through passage *e* to chamber *C*, in which is reversing valve *72*. The supply and exhaust of steam to and from the steam cylinder is controlled by the main valve *83*, which is a **D** type of slide valve. It is operated by the two pistons, *77* and *79*, of unequal diameters and connected by the stem *81*. The movement of these two pistons and the main valve is controlled by the reversing valve *72*, which is in turn operated by the main steam piston *65*, by means of the reversing rod *71* and the reversing plate *69*. As will be seen from the following description, the duty of the reversing valve *72* is to alternately admit or discharge steam from chamber *D* at the right of piston *77*, thus alternately balancing or unbalancing this piston. The reversing valve is operated by the reversing rod *71*. This rod is alternately moved up and down by reversing plate *69*, which engages reversing shoulder *j* on the upward stroke of the steam piston and button *k* at the end of the rod, on the downward stroke.

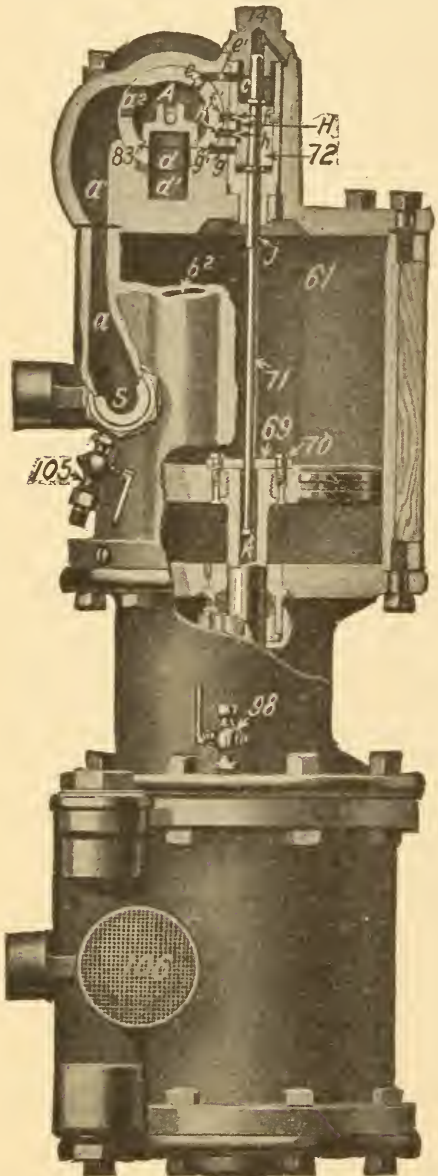


Fig. 5. Section of Air Compressor through Reversing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

Chambers *A* and *C* are always in free communication with each other and with the steam inlet through port *e*, e^1 as shown in the figures. Live steam is therefore always present in these chambers *A* and *C*. Chamber *E*, at the left of small piston *79*, is always open to the exhaust passage *d* through the ports *t* and t^1, shown in the main valve bushing, Fig. 5, and diagrammatically in Figs. 7 and 8. Exhaust steam, practically at atmospheric pressure, is therefore always present in chamber *E*.

A balancing port *s* runs diagonally to the right in the reversing-valve cap nut and meets a groove down the outside of the reversing valve bush, where it enters the upper end of the cylinder through a small port in the head. The object of this is to assure the same pressure above as below the reversing rod, whether there is live or exhaust steam in the upper end of the cylinder, thus balancing it so far as steam pressure is concerned.

When the reversing slide valve *72* is in its lower position, as shown in Figs. 5 and 7, chamber *D* is connected (through ports *h*, h^1, reversing-valve exhaust-cavity *H* and ports *f* and f^1) with main exhaust passage *d*, d^1, d^2, and there is, therefore, only atmospheric pressure at the right of piston *77*.

Therefore, as chamber *E*, at the left of piston *79*, and chamber *D*, at the right of piston *77*, are both connected to the exhaust,

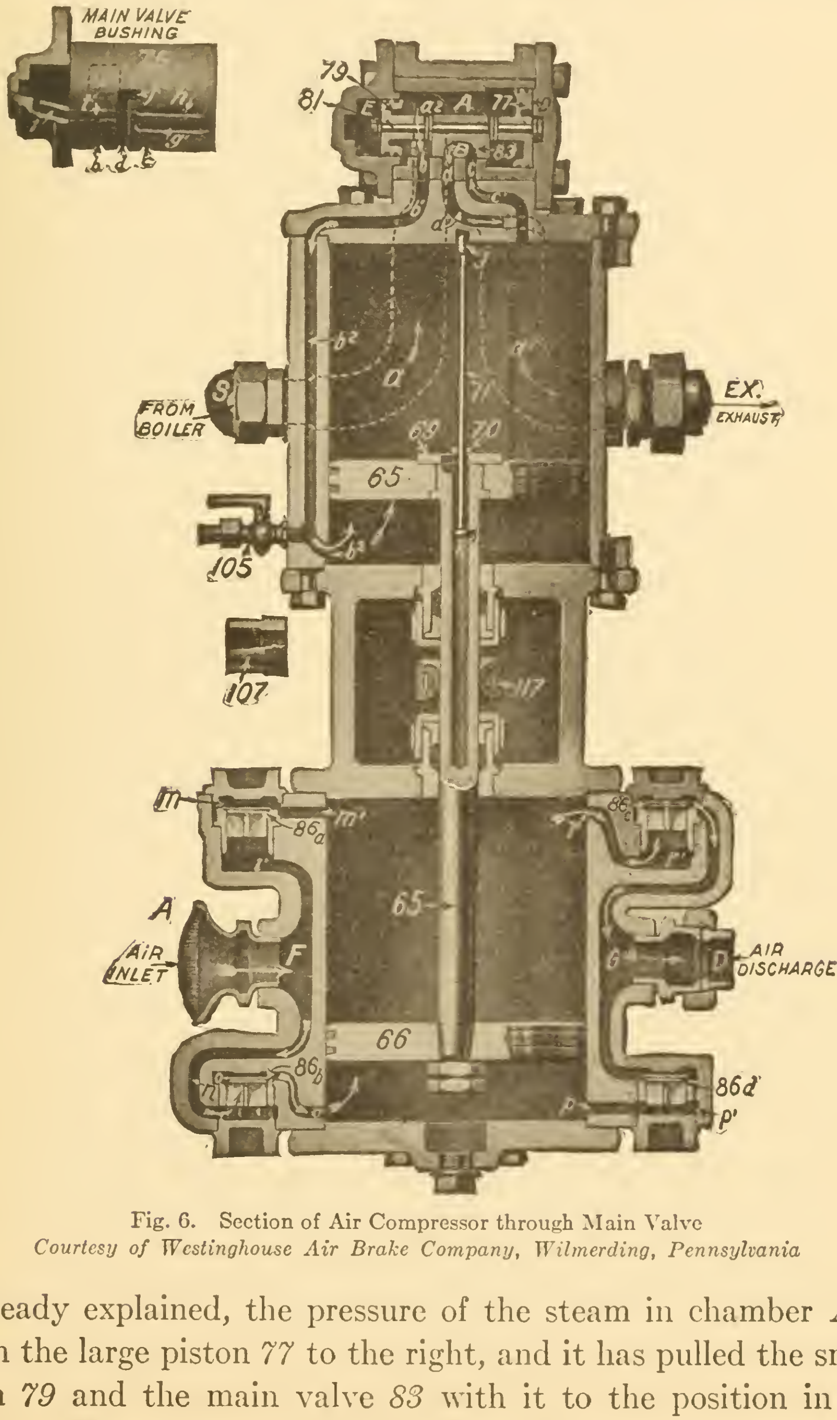


Fig. 6. Section of Air Compressor through Main Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

as already explained, the pressure of the steam in chamber *A* has driven the large piston *77* to the right, and it has pulled the smaller piston *79* and the main valve *83* with it to the position in Figs. 6 and 7. The main valve *83* is then admitting steam below piston

65 through port *b*, b^1, b^2. Piston *65* is thereby forced upward, and the steam above piston *65* passes through port c^1, *c*, exhaust cavity *B* of main valve *83*, port *d*, and passage d^1, d^2 to connection *Ex*, at which point it leaves the compressor and discharges through the exhaust pipe into the atmosphere.

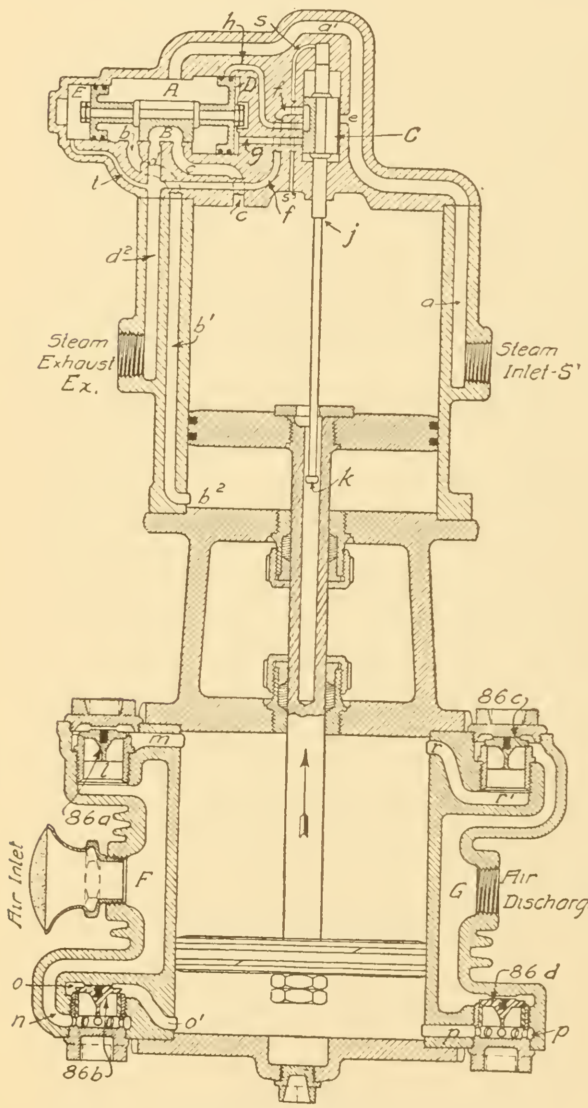


Fig. 7. Diagram of Westinghouse Compressor for the Up-Stroke

When piston *65* reaches the upper end of its stroke, reversing plate *69* strikes shoulder *j* on rod *71*, forcing it and reversing slide valve *72* upward sufficiently to open port *g*. Steam from chamber *C* then enters chamber *D* through port *g* and port g^1 of the bushing. The pressures upon the two sides of piston *77* are thus equalized or balanced. Considering piston *79*, the conditions are different. Chamber *E*, as already stated, is always open to the exhaust. As piston *77* is now balanced, the steam pressure in chamber *A* forces piston *79* to the left, drawing with it piston *77* and main valve *83* to position shown in Fig. 8.

With main valve *83* in the position, steam is admitted from chamber *A*, through port *c*, c^1, above piston *65* forcing it down; at the same time the steam below this piston is exhausted to the atmosphere through port b^2, b^1, *b*, exhaust cavity *B* in the main valve, port *d*, d^1, d^2 and the exhaust pipe connected at *Ex*.

When piston *65* reaches the lower end of its stroke, reversing plate *69* engages reversing button *k*, and draws rod *71* and reversing valve *72* down to the positions shown in Figs. 6 and 7, and one complete cycle (two single strokes) of the steam end of the compressor has been described.

Method of Action in Air End of Compressor. The movement of steam piston *65* is imparted to air piston *66* by means of the piston rod *65*. As the air piston *66* is raised, the air above it is compressed and air from the atmosphere is drawn in beneath it; the reverse is true in the downward stroke.

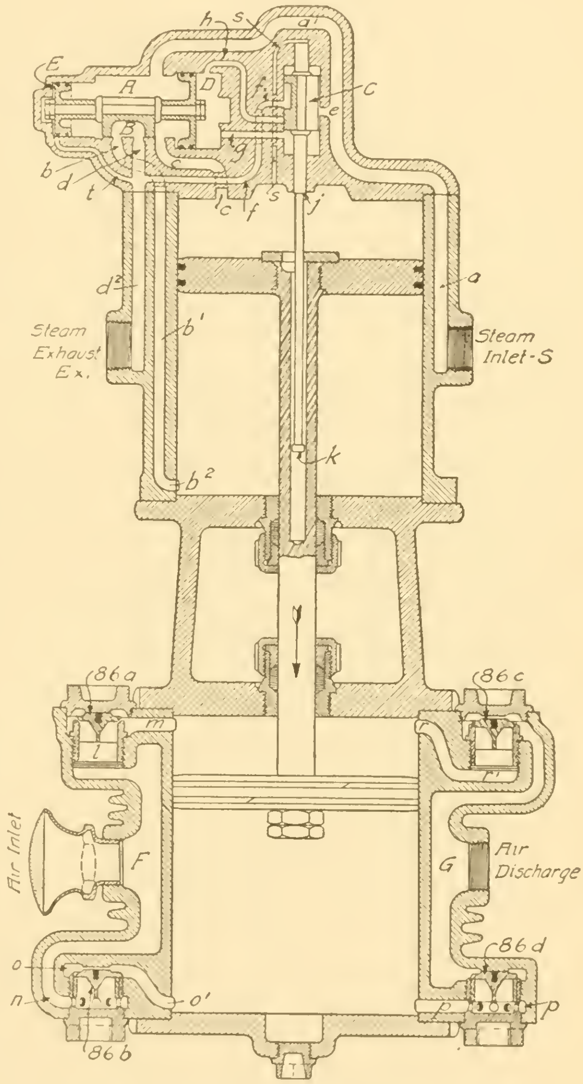


Fig. 8. Diagram of Westinghouse Compressor for the Down Stroke

On the upward stroke of piston *66*, the air being compressed above it is prevented from discharging back into the atmosphere by the upper inlet valve *86a*. As soon as the pressure in ports *r*, r^1 below upper discharge valve *86c* becomes greater than the main reservoir pressure above it, the discharge valve *86c* is lifted from its seat. The air then flows past this valve down through chamber *G*, out at "air discharge" and through the discharge pipe into the main reservoir.

The upward movement of the air piston produces a partial suction or vacuum in the portion of the cylinder below it. The air pressure below piston *66* and on top of the lower left-hand inlet valve *86b* becomes, therefore, less than that of the atmosphere in port *n* underneath this valve. Atmospheric pressure, therefore, raises valve *86b* from its seat, and atmospheric air is drawn through strainer *106* at "air inlet", into chamber *F*, and port *n* below the inlet valve *86b*, thence past that valve through ports *o* and o^1 into the lower end of the air cylinder, filling same. Air cannot enter this part of the cylinder by flowing back from the reservoir through *D* and *G* and lower discharge valve *86d*, since this valve is held to its seat by the main-reservoir pressure above it.

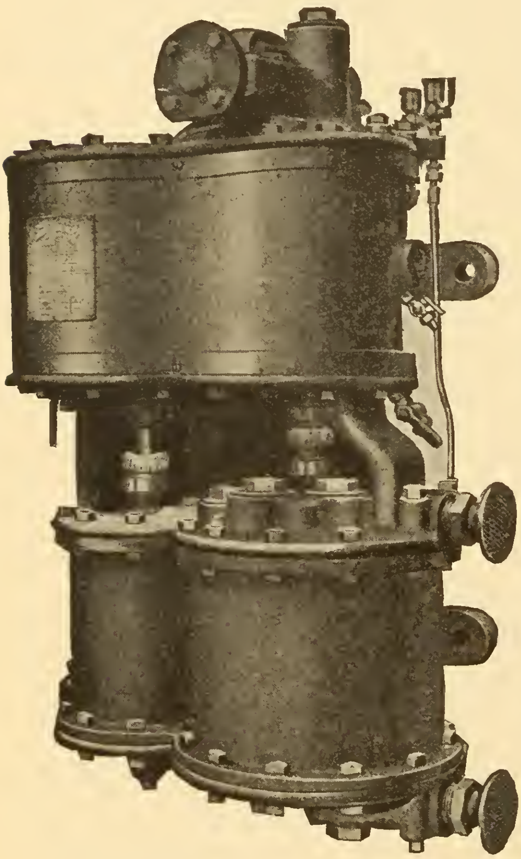


Fig. 9. 8½-Inch Cross-Compound Compressor, Showing Air-Inlet Side
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

The lower inlet valve *86b* seats by its own weight as soon as the up-stroke of the air piston *66* is completed.

On the downward stroke of the compressor, the effect just described is reversed, the air below piston *66* being compressed and forced out through ports *p* and p^1 past lower discharge valve *86d* and through chamber *G* and the air discharge pipe into the main reservoir. At the same time air is being drawn in from the atmosphere through "air inlet" through chamber *F* and port l^1, upper inlet valve *86a* and ports *m* and m^1 into the upper end of the air cylinder above the air piston *66*.

Two-Stage Type. The Westinghouse two-stage air compressor, known as the "8½-inch cross-compound compressor", is controlled or operated by a valve gear quite similar to that used in the single-stage type. The following description covers in a general way the chief differences in the operation of the two types of compressors:

Comparison with Single-Stage Type. The cross-compound pump is coming into use as a result of the growing demand for more air on long freight trains. Its capacity is about three and one-half times that of the $9\frac{1}{2}$-inch pump shown in Fig. 4. As illustrated in Figs. 9 and 10, this pump is of the duplex type, having two steam

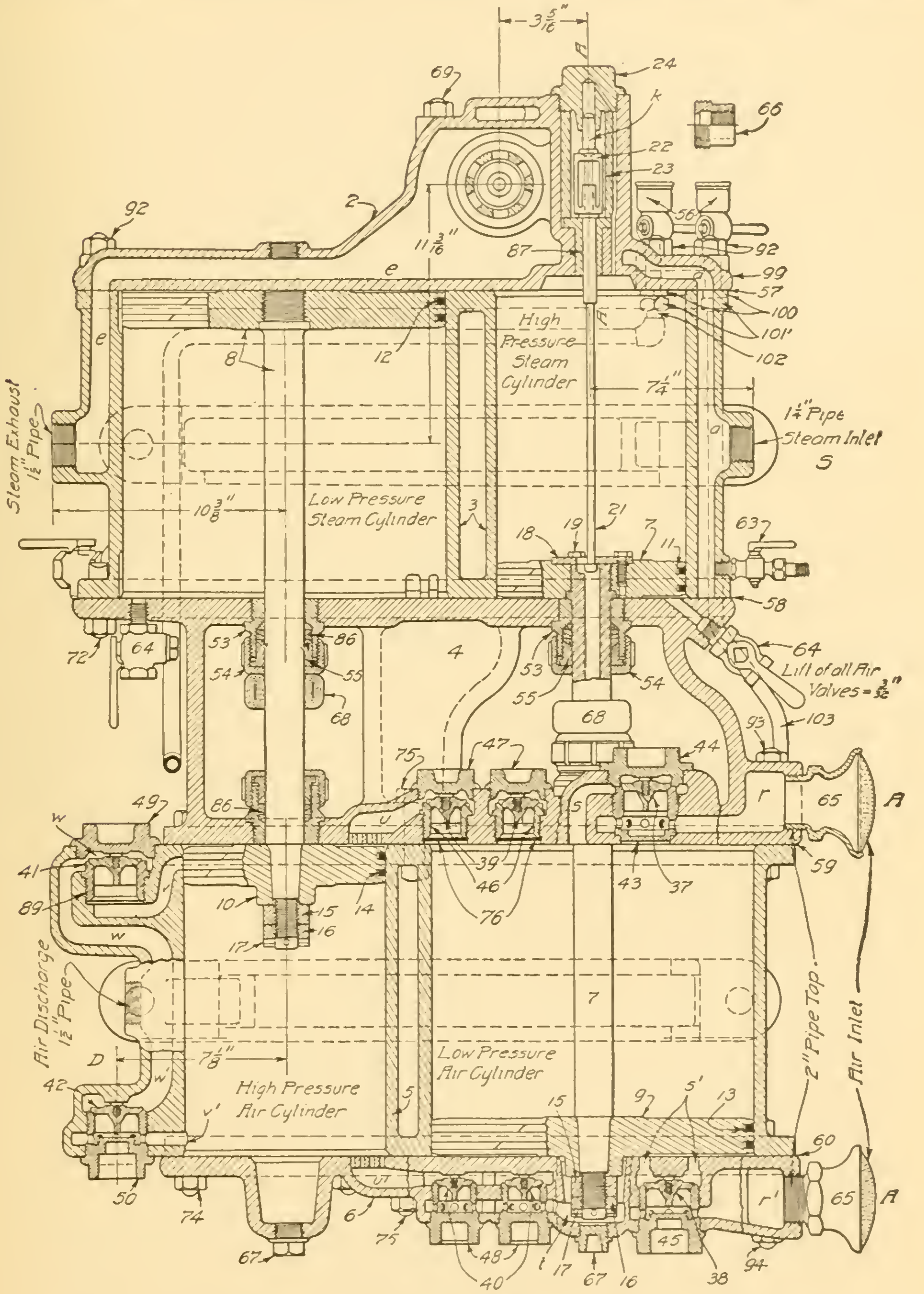


Fig. 10. Vertical Section of Westinghouse $8\frac{1}{2}$-Inch Cross-Compound Compressor

and two air cylinders arranged with the steam cylinders above and the air cylinders below. The high-pressure steam cylinder is $8\frac{1}{2}$ inches in diameter, and the low-pressure $14\frac{1}{2}$ inches in diameter, both having a 12-inch stroke. The low-pressure air cylinder is $14\frac{1}{2}$ inches in diameter, and is located under the high-pressure steam cylinder. The high-pressure air cylinder is 9 inches in diameter and is located under the low-pressure steam cylinder. The valve gear is

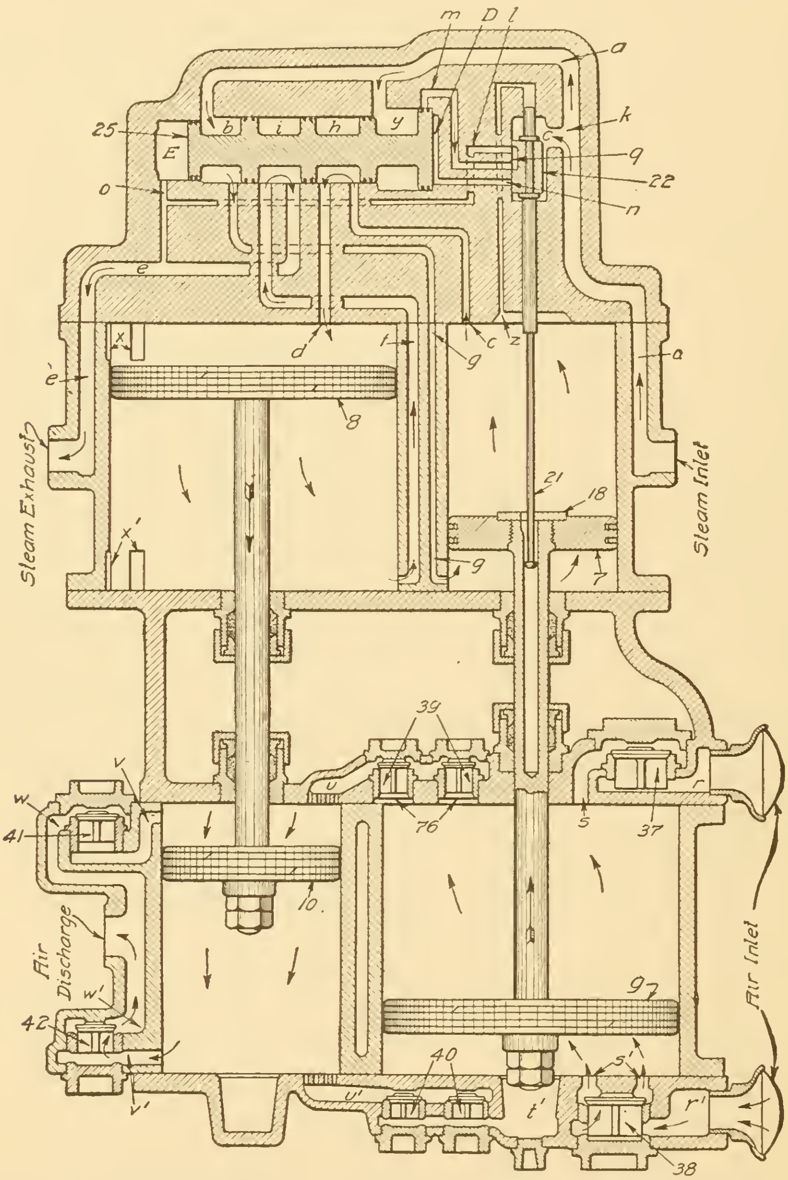


Fig. 11. Diagram of Westinghouse 8½-Inch Cross-Compound Compressor, Showing High-Pressure Steam (Low-Pressure Air) Piston on the Up-Stroke

located on the top head of the high-pressure steam cylinder and is very similar to that of the $9\frac{1}{2}$-inch pump already described. Figs. 11 and 12 show diagrammatically a cross section through the pump, Fig. 11 showing the parts during an up-stroke of the high-pressure steam side, and Fig. 12 during a down-stroke of the high-pressure steam side. The high-pressure steam piston is shown on the right and the low pressure on the left. The high-pressure steam piston, with its hollow rod, contains the reversing-valve rod and operates

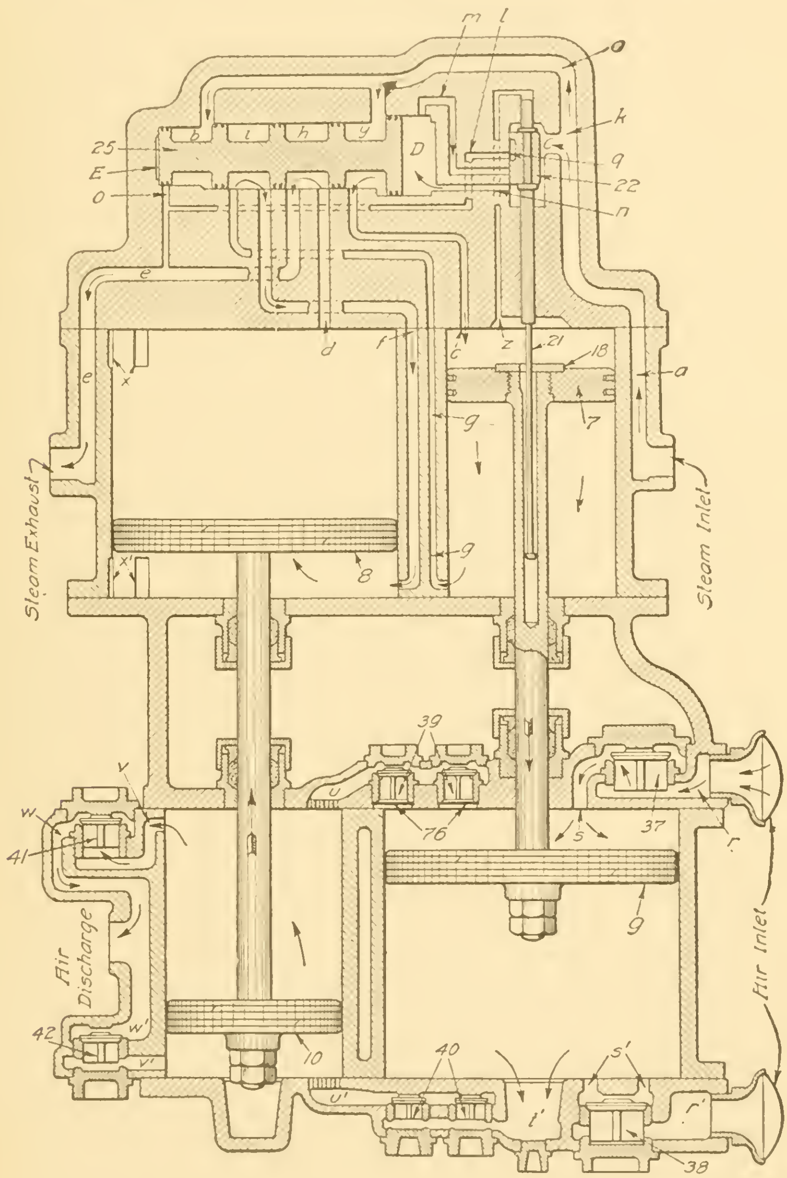


Fig. 12. Diagram of Westinghouse $8\frac{1}{2}$-Inch Cross-Compound Compressor, Showing High-Pressure Steam (Low-Pressure Air) Piston on the Down Stroke

the reversing valve in the same manner as that of the $9\frac{1}{2}$-inch pump. This valve operates the main valve in the same manner as that described in the case of the $9\frac{1}{2}$-inch pump. The main slide valve controls the steam admission to, and the exhaust from, both the high- and the low-pressure steam cylinders. It is provided with an exhaust cavity and, in addition, has four steam ports in its face. The two outer and one of the intermediate ports communicate with cored passages extending longitudinally in the valve, which serve to make the connection between the high- and the low-pressure cylinders during the expansion of steam from one to the other. The other port controls the admission of steam to the high-pressure cylinder.

The valve seat has five ports. Of these, the two outside, shown in Figs. 11 and 12, lead to the upper and to the lower ends of the high-pressure steam cylinder. The second and fourth from the right lead to the upper and to the lower ends of the low-pressure steam cylinder; and the middle one leads to the exhaust. By following the arrows in Figs. 11 and 12, the flow of air and steam through the pump can be easily traced.

The principle of compounding employed in this pump enables it to compress air much more economically than is possible with the simple or single-stage compressor.

Disorders of Air Compressors. The compressor is an important part of the air-brake system and must be kept in perfect working condition. Without its use the brake system is worthless. For this reason it is important that it be given proper attention in the matter of lubrication, repairs, etc. The Westinghouse Company gives the following directions for remedying disorders of the compressor:

Compressor Refuses to Start. Cause: Insufficient oil, from scant or no feed; water in cylinder; worn main-piston rings; or rust having accumulated during time compressor has lain idle. Remedy: Shut off steam, take off cap nut, put in a tablespoonful of valve oil (not too much), let the oil soak down for one or two minutes, and then turn on steam quickly. In many cases when the compressor will not start when steam is first turned on, if steam is then turned off and allowed to remain off for one or two minutes and then turned on quickly, it will start without the use of any oil except that from the lubricator.

Compressor Groans. Cause: (1) Air cylinder needs oil. Remedy: (1) Put some valve oil in air cylinder and saturate piston swab with valve oil, then replace it on the rod. Cause: (2) Steam cylinder needs oil. Remedy: (2) Increase lubricator feed. Leakage past the air-piston packing rings or past a discharge valve causes heating, destroys lubrication, and results in groaning. Piston-rod packing dry and binding is another cause of groaning.

Uneven Strokes of the Compressor. Cause: Probably (1) leakage past air-piston packing rings and sticky air valves: (2) unequal lift of air valves; (3) clogged discharge valve passages; or, (4) leaky air valves. Remedy: Locate cause, if possible, and correct it by cleaning out clogged or dirty passages, adjusting lift of valves, or replacing leaky valves or rings.

Slow in Compressing Air. Cause: (1) Leakage past the air-piston packing rings, due to poor fit, or wear in cylinder or rings; (2) valves and passages dirty; or, (3) air-suction strainer clogged. Remedy (1) and (2): To determine which is causing the trouble, obtain about 90 pounds air pressure, reduce the speed to from 40 to 60 single strokes per minute, then listen at the "air inlet" and note if air is drawn in during only a portion of each stroke, and if any blows back. If the latter, an inlet valve is leaking. If the suction does not continue until each stroke is nearly completed, then there is leakage past the air-piston packing rings or back from the main reservoir past the air-discharge valves. The leaking of one of these valves will cause an uneven stroke. Remedy: (3) Clean strainer thoroughly.

Compressor Erratic in Action. Cause: Worn condition of valve motion. Remedy: Renew it.

Compressor Heats. Cause: (1) Air passages are clogged; (2) leakage past air-piston packing rings; or, (3) the discharge valves have insufficient lift. Remedy: (1) Clean air passages; (2) renew air-piston rings; (3) regulate lift of discharge valves to $\frac{3}{32}$ of an inch on the $8\frac{1}{2}$-inch and to $\frac{5}{32}$ of an inch on the $10\frac{1}{2}$-inch compressor. A compressor in perfect condition will become excessively hot and is liable to be damaged if run very fast and continuously for a long time.

Compressor Pounds. Cause: (1) Air piston is loose; (2) compressor either not well secured to boiler or causes some adjacent pipe to vibrate; (3) the reversing valve plate *18* is loose; or (4) the reversing rod or plate may be worn so that the motion of compressor is not reversed at the proper time. Remedy: Repair and renew worn parts and tighten loose connections.

Steam Compressor Governors. The steam compressor governor, sometimes called the air-pump governor, is used, as the name implies, for governing the air pump or compressor, causing it to stop operation when it has compressed the air in the main reservoir to a certain predetermined pressure and to resume operation when the pressure has dropped below this point.

Single Top "S" Type. This governor is located in the steam supply pipe close to the air compressor. Figs. 13 and 14 show the governor in closed and open positions. When in operation steam enters at *B* and flows past the steam valve *26*, when open, to the pump at *P*. The governor is operated by air pressure from the main reservoir, which is always open to the connection *MR* and the under side of the diaphragm *46* through a small pipe leading from the main reservoir pipe near the engineer's brake valve shown in Fig. 1. As long as the main reservoir pressure in chamber *a* below diaphragm *46* is not able to overcome the pressure of the spring *41*, acting on the top of the diaphragm, spring *41* holds the diaphragm *46* down and thereby holds the small pin valve *d* to its seat. The chamber above the governor piston *28* is open through passage *b* and the small relief port *c* to the atmosphere, which permits the spring *31* below piston *28* to hold the latter and the attached steam valve *26* in the open position.

When the main-reservoir pressure in chamber *a* below diaphragm *46* becomes slightly greater than the spring pressure above the diaphragm, the diaphragm is raised, unseating pin valve *d* and allowing air from chamber *a* to flow through passage *b* to the chamber above piston *28*. This forces piston *28* down to the closed position, compressing piston spring *31* and seating steam valve *26*, thus cutting off the supply of steam to the air compressor, except for the slight amount which can pass through the small port shown in steam valve *26*. This is just sufficient to keep the compressor operating slowly so as to supply the air leakage and avoid troubles from steam condensation.

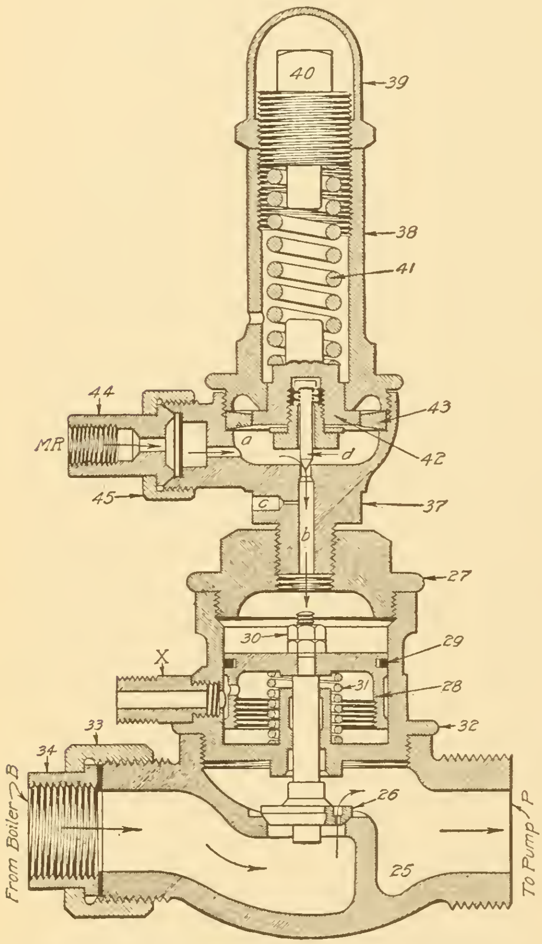


Fig. 13. Westinghouse Type "S" Single-Top Steam Compressor Governor Closed

The chamber below piston *28* is open to the atmosphere through the drip-pipe connection on the left. This is to permit the escape of any steam that may leak past the stem of valve *26* or air that may leak past piston *28*. To avoid troubles from freezing and stopping up, the drip pipe should be as short as practicable.

The governor is adjusted by means of adjusting nut *40*, which regulates the pressure of spring *41* upon the diaphragm. To change the adjustment of the governor, remove cap nut *39* and screw down regulating nut *40* to increase the main-reservoir pressure or back off the regulating nut *40* to lower the main-reservoir pressure, replacing the cap nut *39* after the desired adjustment is made. The governor is usually set to cut off at 90 pounds main-reservoir pressure.

For many years this type of governor was the standard and was used in all classes of service. It has now been superseded by governors of improved design and is used only on comparatively short trains and where the main-reservoir capacity is sufficiently great to supply charging demands.

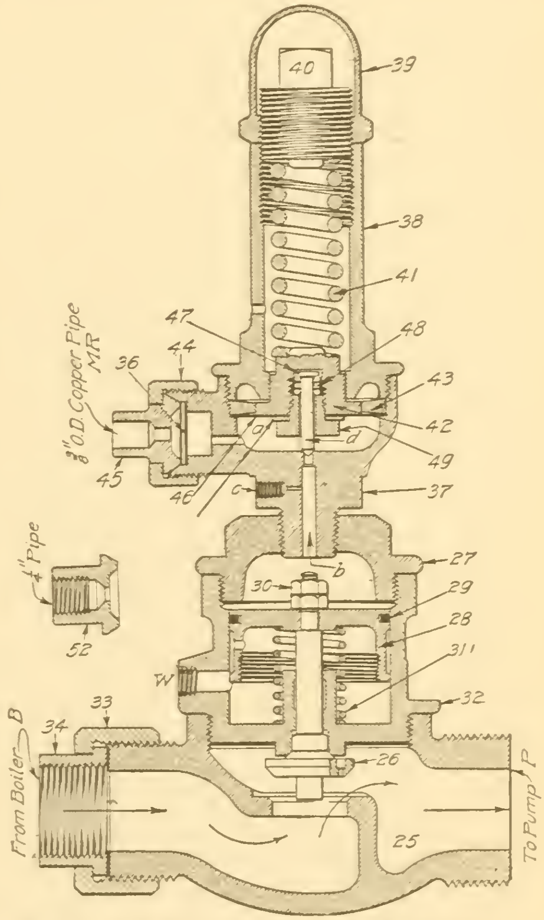


Fig. 14. Westinghouse Type "S" Single-Top Steam Compressor Governor Open

Double-Top or Duplex "SD" Type. This type of governor has been developed to operate in connection with the engineer's brake valve, permitting the air pump to anticipate demands upon the main reservoir and to have an excess pressure stored there for releasing brakes and charging trains of greater length than the usual main-reservoir capacity will permit. Its general construction is shown in Fig. 15. It is arranged to obtain what is known as "duplex main-reservoir regulation". As will be seen from the cut, the "duplex" governor is the same as the Type "S" governor except that two regulating portions or "tops" are used, with a T or "Siamese" fitting to connect them to the steam portion of the governor. The adjustment of the two heads varies according to local conditions, but is usually 90 pounds for the "low-pressure" and 120 pounds for the "high-pressure" top.

The low-pressure top, on the left, is connected to a port in the brake valve through which air from the main-reservoir port flows to the feed valve when the brake-valve handle is in *running* position. When running over the road, therefore, with the brakes released, the low-pressure top of the governor controls the operation

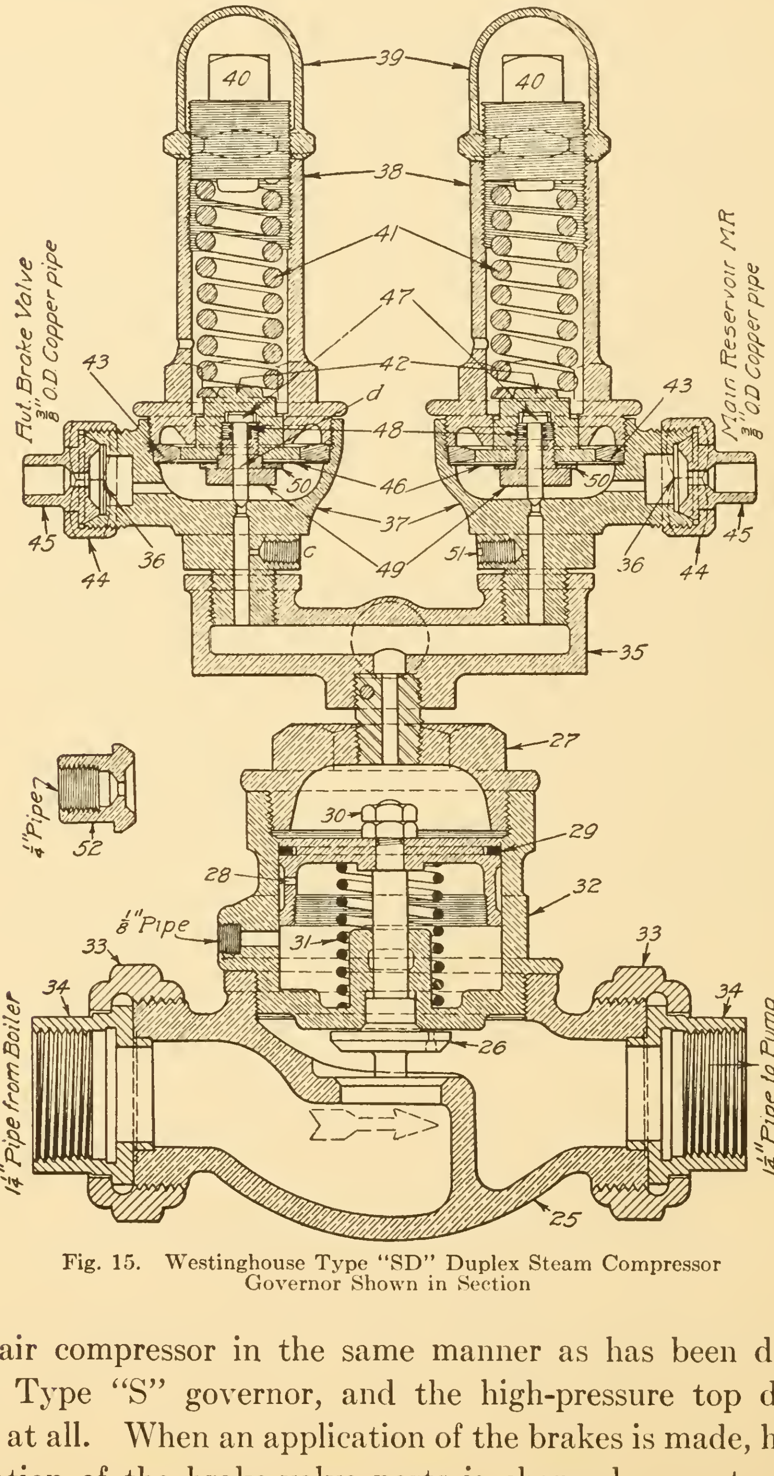


Fig. 15. Westinghouse Type "SD" Duplex Steam Compressor Governor Shown in Section

of the air compressor in the same manner as has been described for the Type "S" governor, and the high-pressure top does not operate at all. When an application of the brakes is made, however, the relation of the brake-valve ports is changed so as to shut off the supply of air to the underside of the diaphragm of the low-pressure governor top, and its pin valve *d* remains held to its seat. Meanwhile, air from the main-reservoir pipe can flow direct to the connection marked *MR* of the high-pressure governor top and to the chamber beneath its diaphragm. This governor top will consequently control the operation of the air compressor as described for the Type "S" governor until the brakes are released and the brake-valve handle again placed in *running* position. Only one vent port, *c*, should be open, the other being plugged by a small screw, *51*, as shown in Fig. 15. This arrangement permits the compressor to operate while the brakes are released against a comparatively low main-reservoir pressure, which is, however, ample to keep the system properly charged and to supply any leakage which may exist, and requires it to operate against the maximum main-reservoir pressure only during the time that the brakes are applied, which relieves the compressor of an unnecessary burden of work and at the same time provides for a high main-reservoir pressure to insure a prompt release and re-charge of the brakes.

Double-Top "SF" Type. The principal difference between the "SD" and "SF" types is in the arrangement of the low-pressure head, or, as it is called in the "SF" governor, the "excess-pressure" head. The low-pressure head of the "SD" governor is arranged to maintain a fixed main-reservoir pressure during the times that the brakes are released, while the excess-pressure head of the "SF" governor maintains a fixed "excess" of main-reservoir pressure over the brake-pipe pressure under the same conditions. The high- or maximum-pressure heads of both types are alike in construction and operation. Its general arrangement is illustrated in Fig. 16.

The excess-pressure head of the "SF" governor has two air connections. That marked *ABV* corresponds to the similar connection of the "SD" governor. That marked *FVP* leads from the feed-valve pipe, so that air, at whatever pressure the feed valve is adjusted for, is always present in chamber *f* above diaphragm *28*. The total pressure on the top of diaphragm *28* is, therefore, the pressure in the feed-valve pipe plus the pressure of spring *27*, which is usually adjusted for 20 pounds. The main-reservoir pressure in chamber *d* below diaphragm *28* will, therefore, not be able to raise the diaphragm and its pin valve, and thus shut off the compressor, until it has risen about 20 pounds above the pressure determined by the feed-valve setting. Consequently, whether the

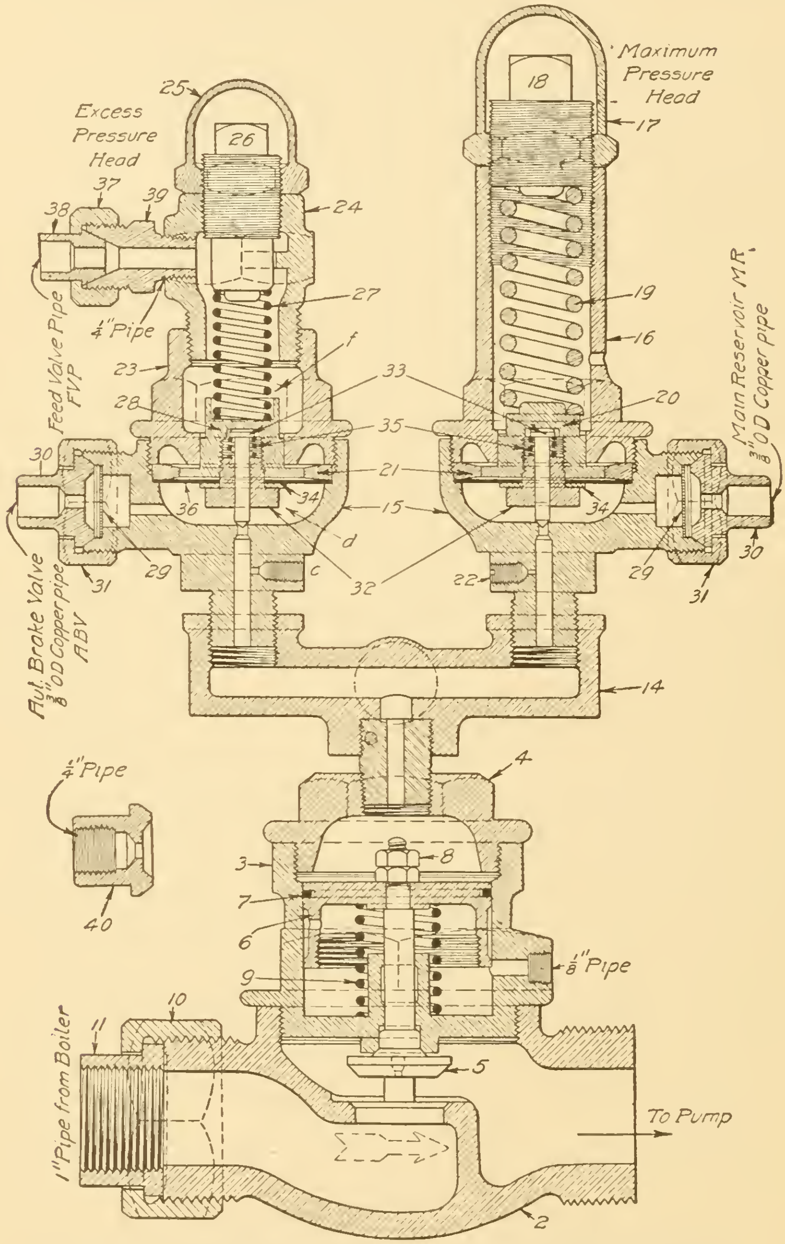


Fig. 16. Westinghouse Type "SF" Duplex Steam Compressor Governor Shown in Section

setting of the feed valve be changed by accident or design, the same excess pressure, 20 pounds, is always maintained. The operation of the steam and air pistons of the governor are the same as already explained for the "single" and "duplex" types, except that the total pressure on top of diaphragm *28* of the excess-pressure head is always feed-valve pressure plus 20 pounds instead of a fixed pressure, as in the former types. With the feed valve set for 70 pounds, approximately 90 pounds main-reservoir pressure would be obtained and maintained.

Troubles with Steam Compressor. In correcting troubles which have been reported in connection with the use of this governor, the Westinghouse Company have issued the following instructions:

If the cutting-out pressure gradually increases without any change having been made in the adjustment of the governor, it is probable that dirt has accumulated on the pin valve or its seat, thus slightly raising the valve and increasing the compression of the regulating spring.

If the governor fails to stop the compressor when the desired pressure has been reached, examine the drip-pipe connection to see that it has not frozen or become closed. Also, if the small hole in the spring box becomes closed and there is a slight leakage of air past the diaphragm, pressure may accumulate above the latter sufficiently to prevent the pin from raising and stopping the compressor.

If, after being stopped by the governor, the compressor fails to start upon a slight reduction in air pressure, examine the pin valve for leakage at the relief port, *c*, when the air pressure is a few pounds less than that for which the governor is regulated. Also, if the relief port itself should become stopped up, the compressor would fail to start when the air pressure fell.

Keep all parts of the mechanism clean, particularly the strainers, *29*, Fig. 16, in the air connections. Keep the joints at the stem unions absolutely tight to prevent any escape of oil or steam. Oil will escape with even no sign of steam leakage, and the compressor is thereby deprived of part of its lubrication.

Main Reservoir. The use of the main reservoir is for storing an abundant air supply to be used in charging and releasing the brakes. A large reservoir is of great importance, especially in freight service, since it provides air for an immediate re-charging of the auxiliary reservoir without running the pump intermittently at high rates of speed. The main reservoir should have a capacity of not less than 35,000 cubic inches on passenger engines and not less than 50,000 cubic inches on freight. The main reservoir is usually located somewhere on the engine, but sometimes it is placed on the tender, although the latter location necessitates two extra pipe connections between the engine and the tender, which is not good practice. A good practice is to divide the main reservoir and place half on each side under the running board.

The air is then delivered to one side and taken out of the other, the two reservoirs being connected. This system has two decided advantages over the others, one being that the air is cooled, thus causing the moisture to be collected in the reservoir. The other advantage is that the distance between the inflow and out-take prevents much of the dirt and oil from being carried into the brake pipe. The main reservoir should always be drained after each trip is completed.

VALVES AND VALVE APPLIANCES

AUTOMATIC BRAKE VALVES

Several types of automatic brake valves, or engineer's brake valves, have been developed and are now in use on American railroads. The one most commonly met with is that known as the "G-6" type. It is now found in use on most locomotives not equipped with what is known as the "ET" equipment.

"G-6" Automatic Brake Valve. The general construction of the "G-6" brake valve is illustrated in Figs. 17, 18, and 19. It is of the rotary type, and is connected as shown in Figs. 1, 2, and 3. Air from the main reservoir flows to the chamber above the rotary valve and, by means of a pipe leading from the brake-valve connections, to the duplex air gage (red hand) and compressor governor. It has pipe connections to the main-reservoir pipe, brake pipe, equalizing-reservoir pipe, gage (red hand, main reservoir) and governor pipe, and gage (black hand, brake pipe) pipe. All of these connections are clearly shown in Figs. 18 and 19. There are five different positions of the brake-valve handle as indicated in Fig. 19. Beginning from the left and naming them in order they are as follows: *release, running, lap, service-application,* and *emergency-application* positions.

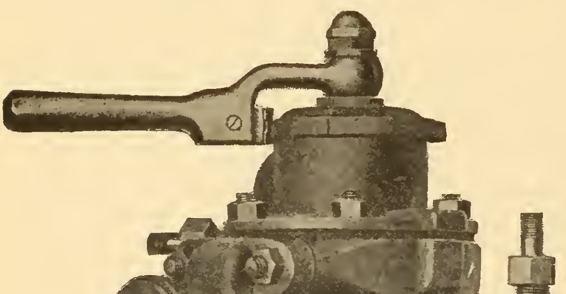


Fig. 17. "G-6" Automatic Brake Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

In describing the operation of the brake valve when the handle is placed in any of the five different positions, reference will be made to the diagrammatic views shown in Figs. 20, 21, 22, 23, and 24.

Running Position. In charging the system, compressed air flows from the main reservoir to the brake valve, entering it through passage *A*, Fig. 20, and flowing to chamber *A* above the rotary valve (see cross section of brake valve, Fig. 18). Port *j* through

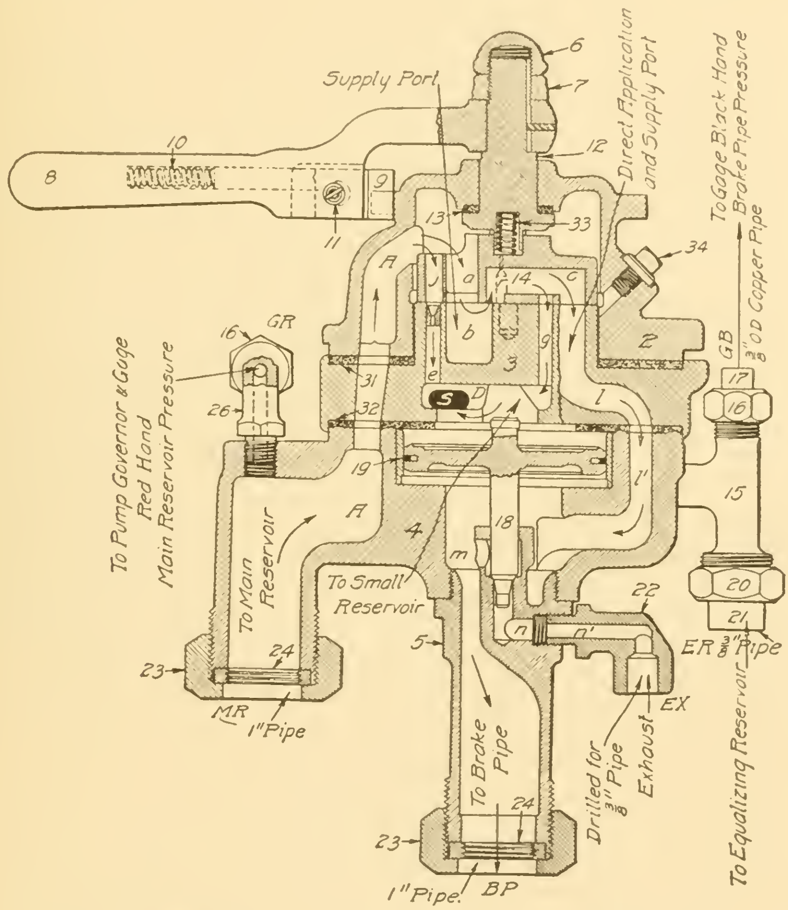


Fig. 18. Westinghouse "G-6" Brake Valve in Release Position

the rotary valve registers with port *f* in the seat, allowing air to flow to the feed valve, which is attached directly to the brake valve as shown. The feed valve reduces the pressure of the air from that carried in the main reservoir to that which is to be carried in the brake pipe. From the feed valve the air re-enters the brake valve through port *i*, which has two branches.

One branch leads to port *l* in the seat through which the air flows to the cavity *c* in the rotary valve, thence to the equalizing port *g* in the seat, and through this to the chamber *D* above the equalizing piston in the lower part of the brake valve.

Chamber *D* is connected through port *s* and pipe connections, as shown, to the qualizing reservoir.

The purpose of the equalizing reservoir is to furnish a volume to chamber *D* above the equalizing piston larger than could be permissible within the brake valve proper.

From the equalizing-reservoir pipe a connection is made to

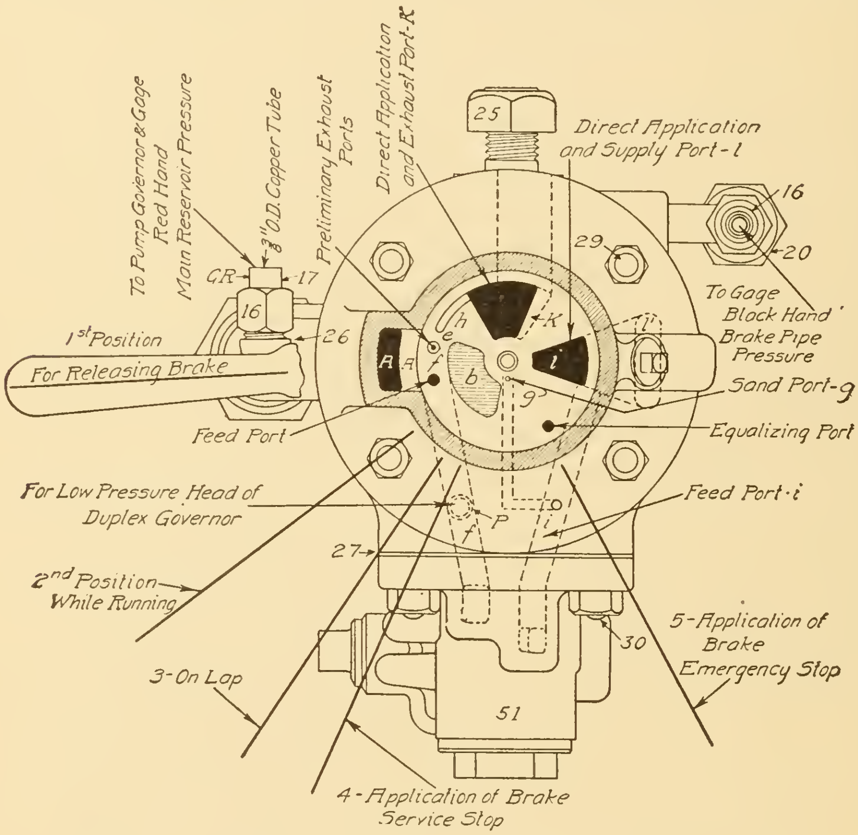


Fig. 19. Westinghouse "G-6" Automatic Brake Valve, Shown in Plan

the *black hand* of the duplex air gage, which registers the pressure in chamber *D* and the equalizing reservoir.

The other branch of port *i* leads from the feed valve to the brake-pipe connection at *Y* and to the underside of the equalizing piston. With the brake handle in *running* position, the feed valve maintains a constant pressure—usually 70 pounds is carried in freight service—in the brake pipe and on the underside of the equalizing piston as well as the same pressure in chamber *D* and the upper side of the piston. The equalizing-discharge valve *m* is kept on its seat, due to the fact that, while the pressure on the opposite sides of the piston is equal, the area of the upper side is greater by an amount equal to the area of the equalizing-discharge valve spindle.

During the time the brake-valve handle is in *running* position, air flows from the main reservoir through the brake valve and the

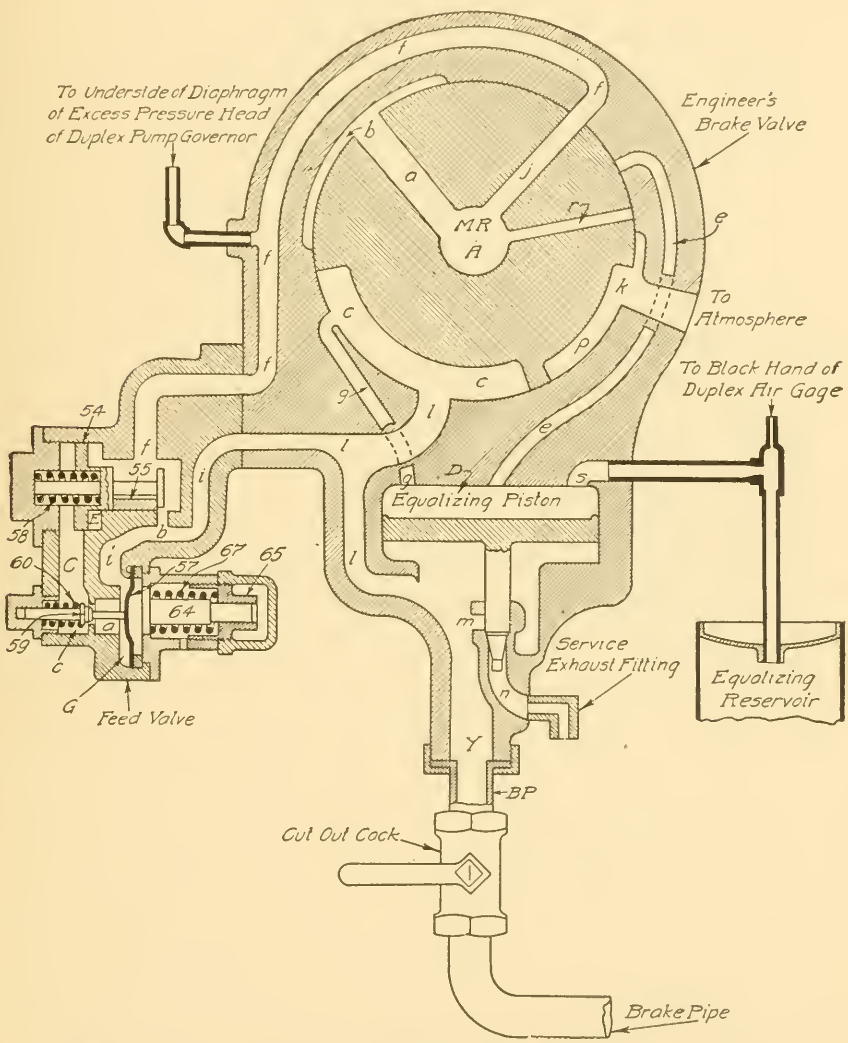


Fig. 20. Horizontal Section of Westinghouse Brake Valve, Showing Running Position

feed valve into the brake pipe, keeping the train charged, which is the normal condition of the brake system while a train is running over the road and the brakes are not being used.

Application Position. To apply the brakes in service, the brake-valve handle is moved to *service-application* position, which will permit of a brake-pipe reduction. This cuts off all air supply to the brake pipe and equalizing reservoir, as shown in Fig. 21, and opens the small port *e* called the preliminary exhaust port, leading to chamber *D* and the equalizing reservoir. This permits air to escape from above the equalizing piston through port *e* in

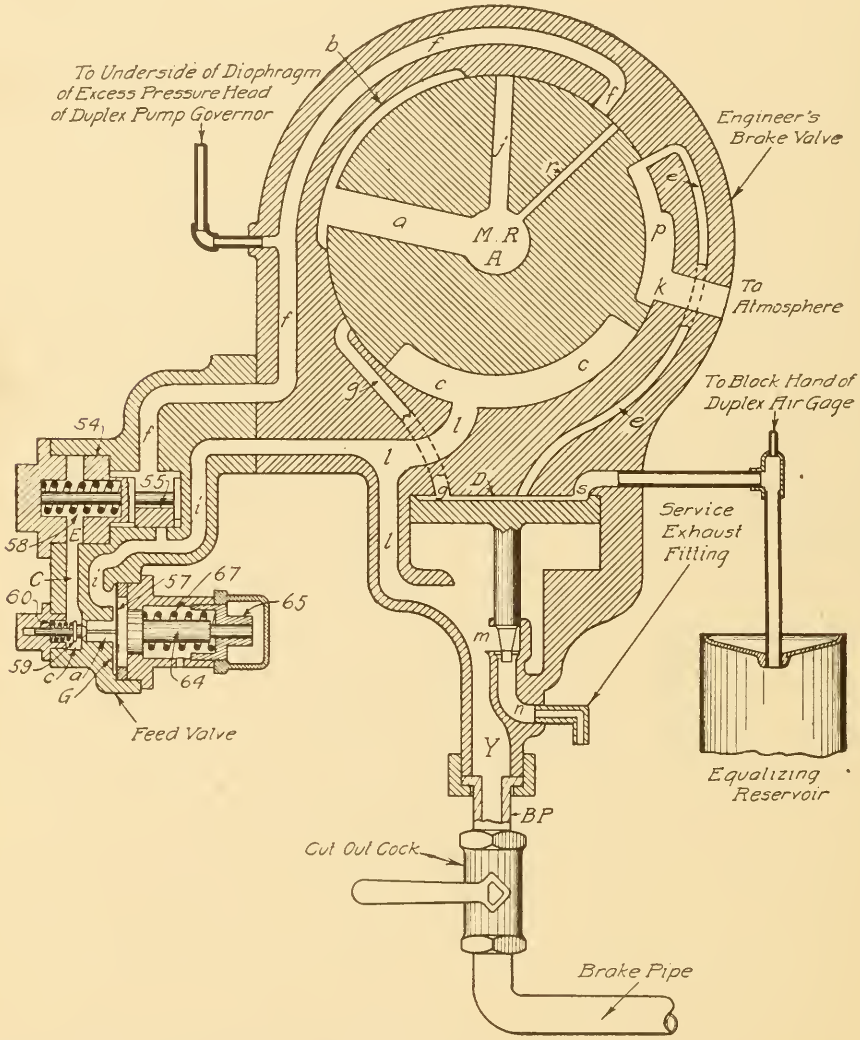


Fig. 21. Horizontal Section of Westinghouse Brake Valve, Showing Service Position

the rotary valve seat, cavity *p* in the rotary valve, and the direct application and exhaust port *k* to the atmosphere. This reduces the pressure of the air on top of the equalizing piston below the pressure of the air in the brake pipe under the piston. This condition causes the piston to lift, carrying the equalizing-discharge valve from its seat and allowing air from the brake pipe to escape through the opening *m* past the valve and thence through passage *n* and service exhaust fitting into the atmosphere.

Without the equalizing reservoir the pressure in chamber *D* would drop almost instantly to zero, and consequently it would be nearly impossible to make a moderate brake-pipe reduction. With an

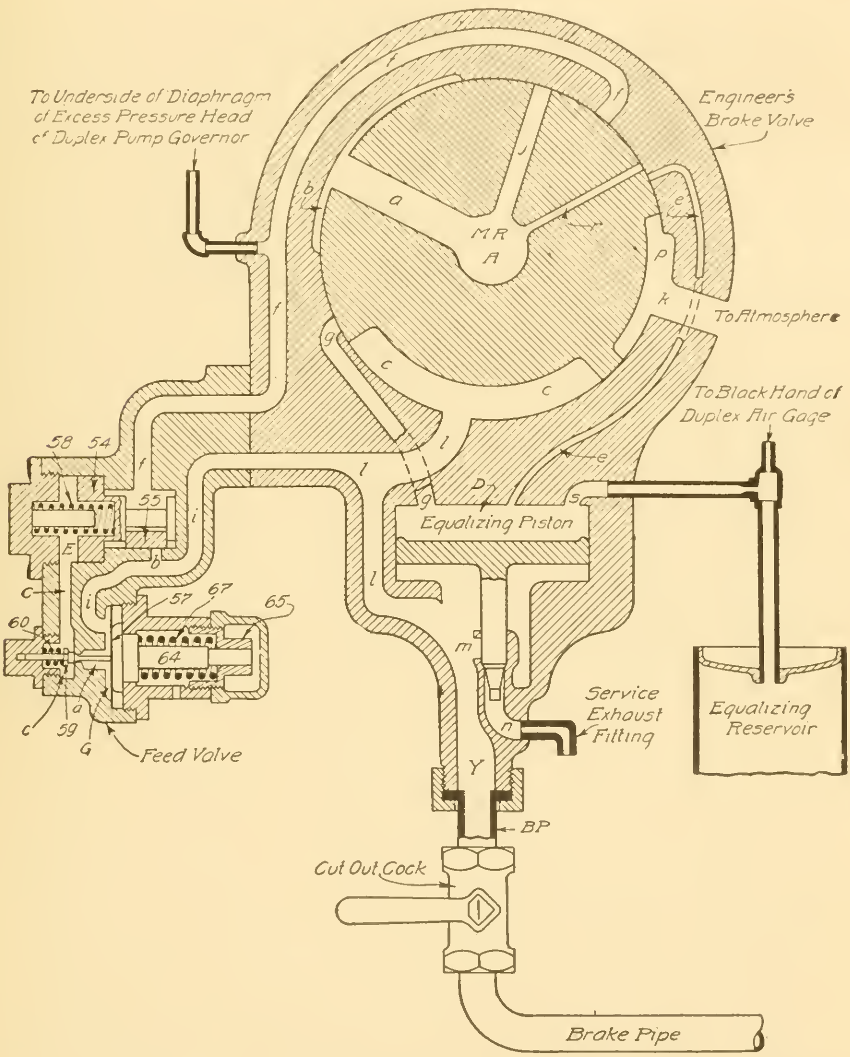


Fig. 22. Horizontal Section of Westinghouse Brake Valve, Showing Lap Position

equalizing reservoir of sufficient capacity, it takes 6 to 7 seconds to make a reduction of 20 pounds, which is slow enough to permit of the reduction to be stopped at any desired point as indicated by the air gage by moving the brake-valve handle to *lap* position.

When the equalizing-discharge valve lifts, the discharge of air from the brake pipe is rapid, decreasing in amount slowly as the pressure in the brake pipe approaches the pressure in chamber *D,* and the equalizing piston causes the equalizing-discharge valve to close, stopping further discharge of air from the brake pipe. This gradual stopping of the brake-pipe discharge prevents the air from surging in the brake pipe, a condition which tends to cause

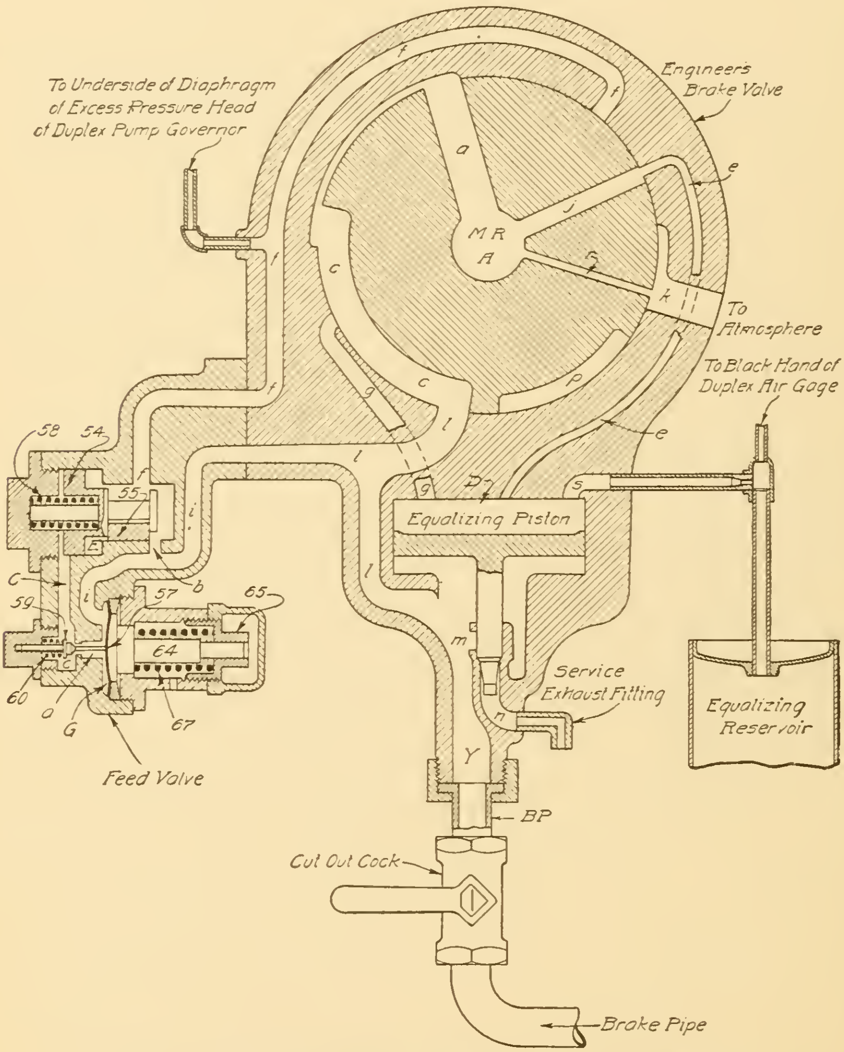


Fig. 23. Horizontal Section of Westinghouse Brake Valve, Showing Release Position

an undesired movement of the triple-valve pistons, which might cause some of the head brakes to release.

The length of time that the air will continue to discharge from the brake pipe after the brake-valve handle has been placed in *lap* position depends upon whether the train is a long or short one. With a short train, the brake-pipe volume is small and will not take as long to discharge as in the case of a long train where the brake-pipe volume is great. It can be readily seen that the equalizing reservoir, together with the equalizing piston, is nothing more than an automatic means of measuring the amount of air to be discharged from the brake pipe and to govern the rate of flow to the atmosphere.

Lap Position. Lap position of the brake valve, as illustrated in Fig. 22, prevents the movement of air to or from any part of the brake equipment through the brake valve.

This position of the brake-valve handle on locomotives equipped with either type of governor previously described causes the low-pressure, or the under, side of the diaphragm in the excess-pressure head to become inoperative, due to the feed valve being cut off from the main reservoir. What air under pressure is left in the feed valve escapes through the vent port in the governor. This permits the compressor to pump up a supply of air under high pressure in the main reservoir to insure a quick release and recharge of the brake pipe.

Lap position is the holding position—the position used when it is desired to hold the brake applied for any considerable length of time.

Release Position. The brakes in the train are released by placing the brake-valve handle in *release* position. This opens direct communication through the brake valve between the main reservoir and the brake pipe, increasing the pressure in the brake pipe and releasing the brakes throughout the train.

When the brake valve is in *release* position, as shown in Fig. 23, air from the main reservoir flows through port *a* in the rotary valve to cavity *b* in its seat, then through cavity *c* in the rotary valve to port *l*, and thence directly into the brake pipe. At the same time, air in cavity *c* also flows through the equalizing port *g*, to chamber *D* above the equalizing piston and to the equalizing reservoir. Air also flows from the main reservoir through port *j* in the rotary valve into the preliminary-exhaust port *e* and to chamber *D*.

While in the *release* position, air from the main reservoir flows through the warning port *r* in the rotary valve to the direct application and exhaust port *k* and the atmosphere with considerable noise. This loud exhaust indicates to the engineer that the handle of the brake is in *release* position and attracts his attention in case the handle is left in that position by mistake.

After the handle has been in *release* position the proper length of time, it is moved to the *running* position, which closes the warning port, stops the direct flow of air from the main reservoir to the

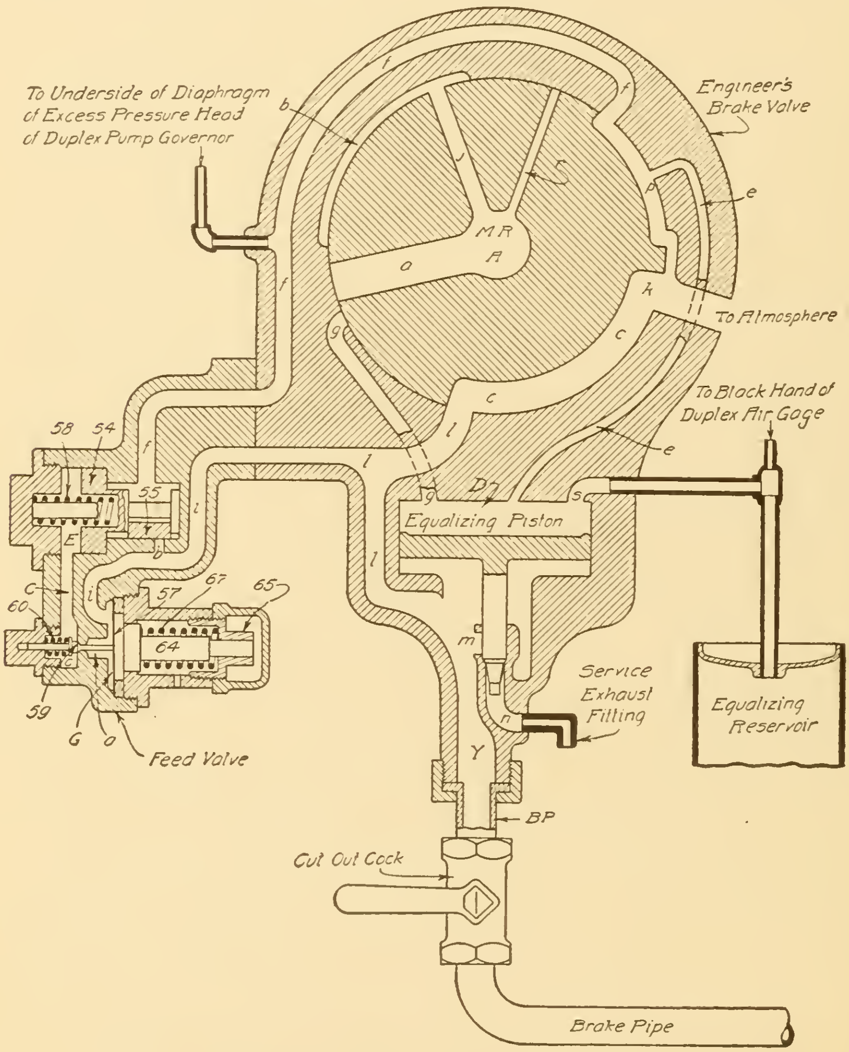


Fig. 24. Horizontal Section of Westinghouse Brake Valve, Showing Emergency Position

brake pipe, chamber *D*, and the equalizing reservoir, and opens the supply of air to these parts through the feed valve. In this position, the brake pipe, chamber *D*, and the equalizing reservoir are charged up and maintained at the standard pressure by the feed valve.

The brakes can be released and the brake pipe and system re-charged by placing the brake-valve handle in *running* position directly without first being placed in *release* position, but a much longer time will be required.

Emergency-Application Position. When it is desired to make the shortest possible stop, the brake-valve handle is placed in *emergency* position, as illustrated in Fig. 24. In this position the brake pipe is opened directly to the atmosphere through the large port *l*, cavity *c*, and port *k*, causing a sudden and rapid drop in brake-pipe pressure. In this position, cavity *p* in the rotary valve connects

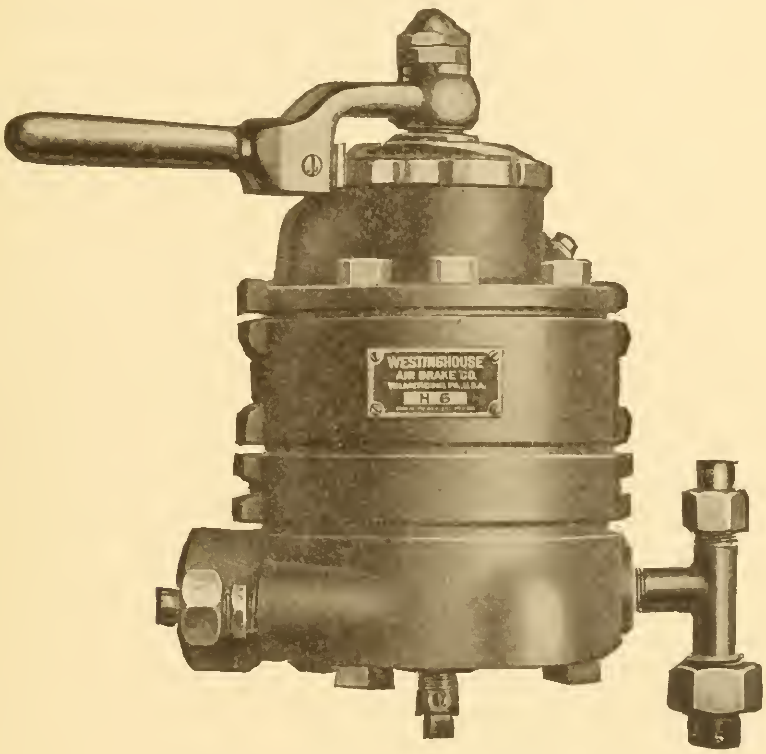


Fig. 25. "H-6" Automatic Brake Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

the feed port *f* and the preliminary exhaust port *e* to the exhaust port *k*, thus allowing the air in the feed port, chamber *D*, and the equalizing reservoir to escape to the atmosphere. The whole *emergency-application* action depends solely upon the suddenness of the brake-pipe reduction.

"H-6" Automatic Brake Valve. The "H-6" automatic brake valve not only performs the functions of the "G-6" brake valve but has some additional features necessary for its use in connection with the "No. 6" distributing valve and the "S-6" independent brake valve of the "ET" locomotive-brake equipment. In this brake valve, the feed valve is not directly attached to the body of the valve but is located elsewhere in a convenient place and connected by suitable pipes. Its general appearance is shown in Fig. 25, while Fig. 26 shows two views, the upper one being a horizontal section through the top case, showing the rotary valve seat, also showing the different positions of the handle, the lower one being a vertical section.

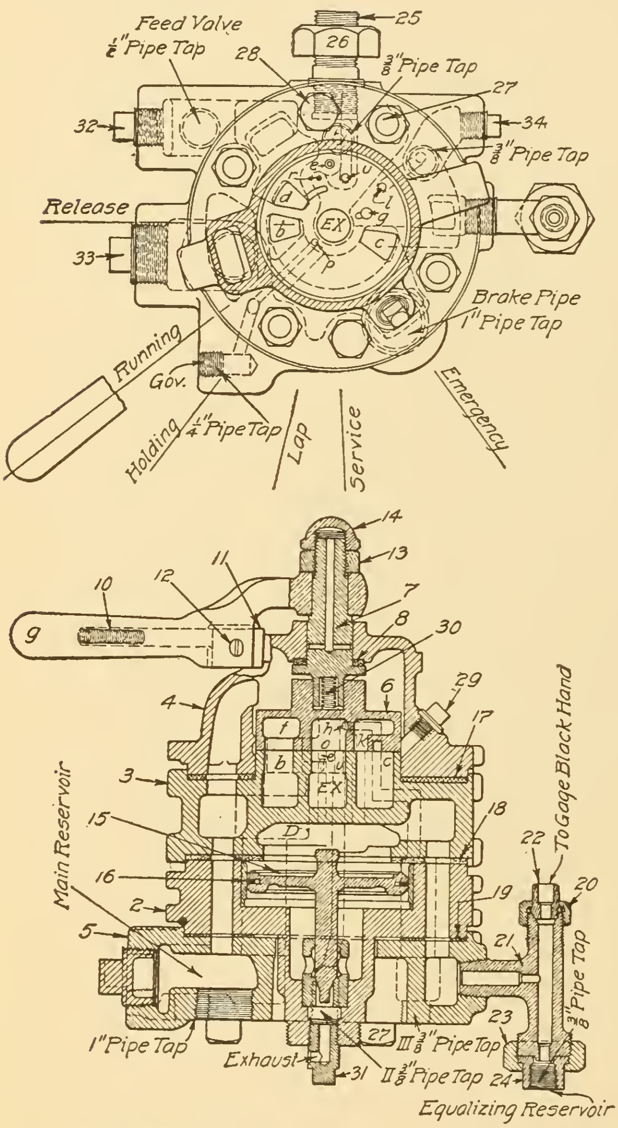


Fig. 26. Plan and Sectional Elevation of Westinghouse "H-6" Automatic Brake Valve

In describing the operation of the brake valve, the different positions will be taken up in the order in which they are most generally used. As shown in Fig. 26, there are six positions for the brake-valve handle. Beginning from the extreme left, they are: *release, running, holding, lap, service,* and *emergency.* In the operation of the valve the air flows through ports in a manner quite similar to that of the "G-6" brake valve. For this reason, the flow of air through the "H-6" brake valve, with the handle in its different positions, will not be traced.

Release and Charging Position. The purpose of this position is to provide a large and direct passage from the main reservoir to the brake pipe, to permit a rapid flow of air into the latter (1) to charge the train brake system; (2) to quickly release and re-charge the brake; but (3) not to release the locomotive brakes if they are applied. If the handle is allowed to remain in this position, the brake system would be charged to main-reservoir pressure. To avoid this, the handle must be moved to *running* or holding position. To prevent the engineer from forgetting this, a small port discharges feed-valve-pipe air to the atmosphere in release position.

Running Position. This is the proper position of the brake-valve handle (1) when the brakes are charged and ready for use; (2) when the brakes are not being operated; and (3) to release the locomotive brakes. This position affords a large direct passage from the feed-valve pipe to the brake pipe, so that the latter will charge up to the pressure for which the feed valve is adjusted.

If the brake valve is in *running* position when uncharged cars are cut in, or if, after a heavy brake application and release, the handle of the automatic brake valve is returned to *running* position too soon, the governor will stop the compressors until the difference between the hands on duplex gage No. 1, Fig. 92, is less than 20 pounds. The stopping of the compressor from this cause calls the engineer's attention to the seriously wrong operation on his part, as *running* position results in delay in charging and is liable to cause some brakes to stick. *Release* position should be used until all brakes are released and nearly charged.

Service Position. This position gives a gradual reduction of brake-pipe pressure to cause a *service application.* The gradual reduction of brake-pipe pressure is to prevent quick action, and the gradual stopping of this discharge is to prevent the pressure at the head end of the brake pipe being built up by the air flowing from the rear, which might cause some of the head brakes to "kick-off".

Lap Position. This position is used while holding the brakes applied after a service application until it is desired either to make a further brake-pipe reduction or to release the brakes. All ports are closed and the excess-pressure head of the governor is made inoperative, permitting the pump to increase the main-reservoir pressure to the pressure at which the high-pressure head will cause it to stop.

Release Position. This position is used for releasing the train brakes after an application without releasing the locomotive brakes.

When the brake-pipe pressure has been increased sufficiently to cause this, the handle of the brake valve should be moved to either *running* or *holding* position; the former when it is desired to release the locomotive brakes, and the latter when they are to be still held applied.

Holding Position. This position is so named because the locomotive brakes are held applied while the train brakes are being released and their auxiliary reservoirs recharged to feed-valve pressure. The only difference between the *running* and *holding* positions is that in the former the locomotive brakes are released, while in the latter they are held applied.

Emergency Position. This position is used (1) when the most prompt and heavy application of the brakes is required, and (2) to prevent loss of main reservoir air and insure that the brakes remain applied in event of a burst hose, a break-in-two, or the opening of a conductor's valve. Plug *29*, Fig. 26, is placed in the top of the case at a point to fix the level of an oil bath in which the rotary valve operates. Valve oil should be used.

"S-6" Independent Brake Valve. The general appearance of this valve is shown in Fig. 27. Fig. 28 shows two views of the "S-6" brake valve; the lower one being a vertical section through the center of the valve, and the upper one a horizontal section through the valve body, showing the rotary valve seat and the different positions of the valve handle. There are five positions of the brake-valve handle which, beginning from the extreme left, are: *release, running, lap, slow application,* and *quick application.*

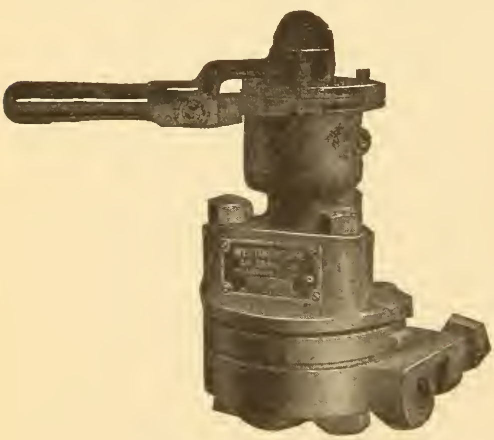


Fig. 27. Westinghouse "S-6" Independent Brake Valve

This brake valve is used in connection with the "H-6" automatic brake valve and is to permit the engineer to operate the locomotive or independent brakes through the distributing valve independently of the train brakes.

Running Position. This is the position that the independent brake valve should occupy at all times when the independent brake is not in use. It can be noted that if the automatic brake valve is in running position and the independent brakes are being operated, they can be released by simply returning the independent valve to

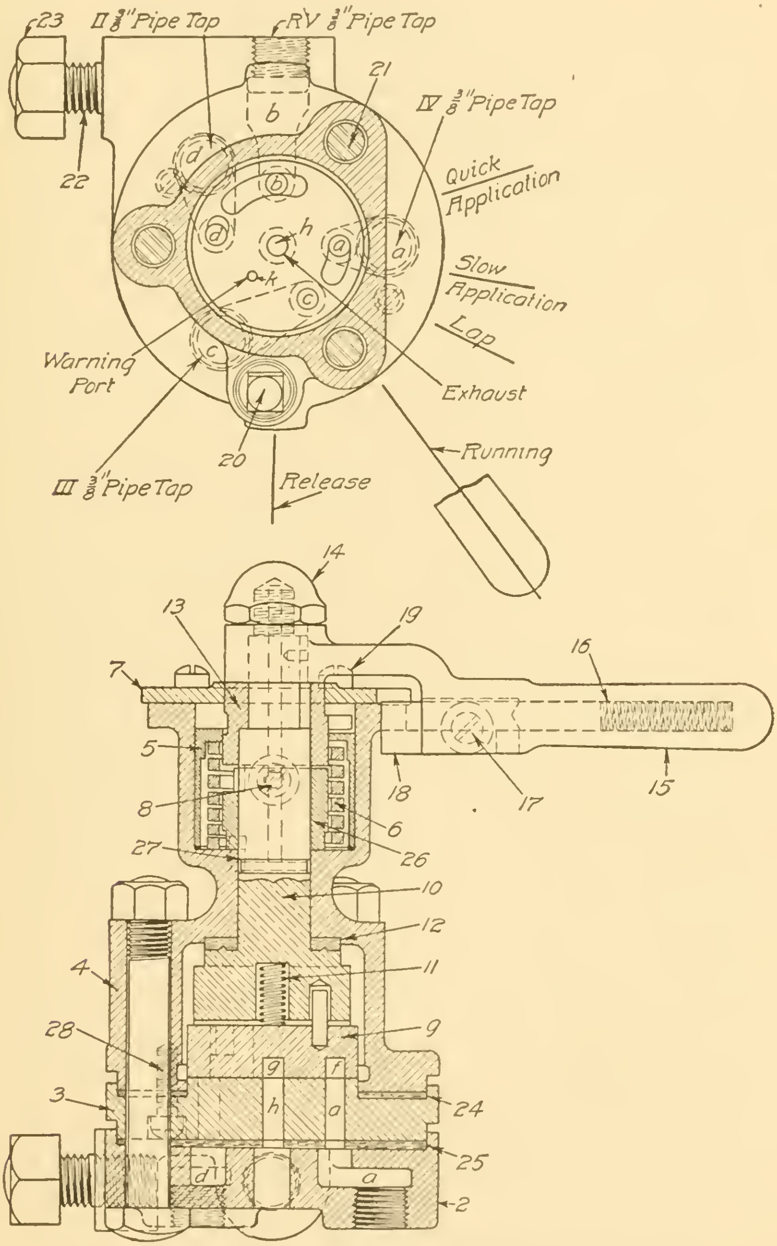


Fig. 28. Plan and Sectional Elevation of Westinghouse "S-6" Independent Brake Valve

running position, as the application-cylinder pressure can then escape through the release pipe and the automatic brake valve.

Slow-Application Position. This position is used for light or gradual applications of the independent or locomotive brake.

Quick-Application Position. This position is used for quick applications of the independent or locomotive brake.

Lap Position. This position is used to hold the independent or locomotive brake after the desired cylinder pressure is obtained. In this position all communication between ports is closed.

Release Position. This position is used to release the pressure from the application cylinder when the automatic brake valve is not in *running* position.

The supply pressure in the independent brake valve is limited by a reducing valve to 45 pounds. Connected to the handle of

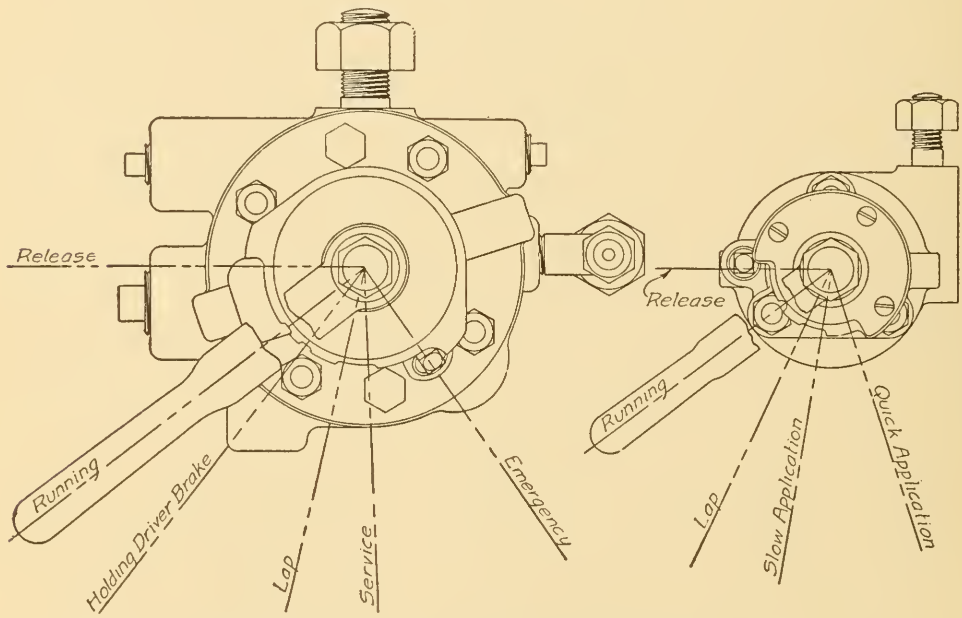


Fig. 29. Diagrams Showing Positions of Valve Handles for Westinghouse Automatic and Independent Brake Valves

the independent brake valve is a return spring, the purpose of which is to return the handle from the *release* to the *running* position, or from the *quick-application* to the *slow-application* position. The automatic return from *release* to *running* is to prevent leaving the handle in that position and make it impossible to operate the independent brake by the automatic brake valve. The spring return from *quick application* to *slow application* is to give a resistance to unintentional moving of the valve handle to *quick-application* position when only a slow application is desired.

The operation of the "H-6" and "S-6" brake valves will be studied further in connection with the study of the "ET" equipment.

The plan view of both the "H-6" and "S-6" brake valves shown in Fig. 29 presents a little more clearly the different positions of the brake-valve handles.

Duplex Air Gage. The duplex air gage previously referred to is located on a convenient place in the cab in plain view of the engineer. In the ordinary equipment only one gage is required. In the "ET" equipment two are provided. The gage, see Fig. 30, is of the Bourdon type and has two pipe connections to the brake valve, one of which is in constant communication with the main reservoir (red hand) and the other is in constant communication with the equalizing reservoir (black hand). The second gage furnished with the "ET" equipment has one of its two pipes connected to the brake cylinder (red hand) and the other to the brake pipe (black hand).

Fig. 30. Westinghouse Duplex Air Gage

FEED VALVES

The function of the feed valve has already been explained. In the "G-6" brake valve it forms a part of the valve. The two forms most commonly found in service are the single-pressure and double-pressure types.

"C-6" Single-Pressure Feed Valve. This feed valve is of the slide-valve type and consists of two portions, the supply and regulating portions. Its appearance detached from the brake is shown in Fig. 31. Figs. 32 and 33 show actual sections taken through the spring box and through the slide valve. Figs. 34 and 35 are diagrammatic sections illustrating the operation of the valve and will be referred to in the description of its action when in service.

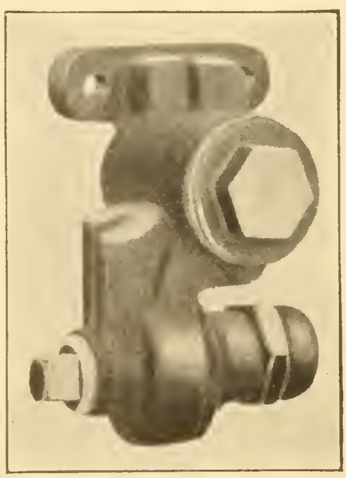


Fig. 31. Westinghouse "C-6" Feed Valve

The supply portion consists of a slide valve *7* and a piston *6*. The slide valve *7* opens or closes communication from the main reservoir to the brake pipe, and is moved by the piston *6*, which is operated by main-reservoir air entering through passage *a* on one side or by the pressure of the piston spring *9* on its opposite side.

The regulating portion consists of a brass diaphragm *17*, on one side of which there is the 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 brake pipe through passage *e* and *d*.

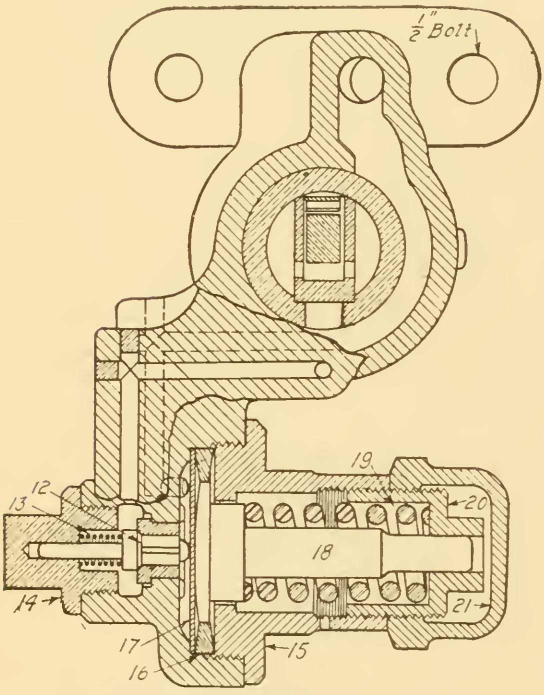


Fig. 32. Section of Westinghouse "C-6" Feed Valve through Spring Box

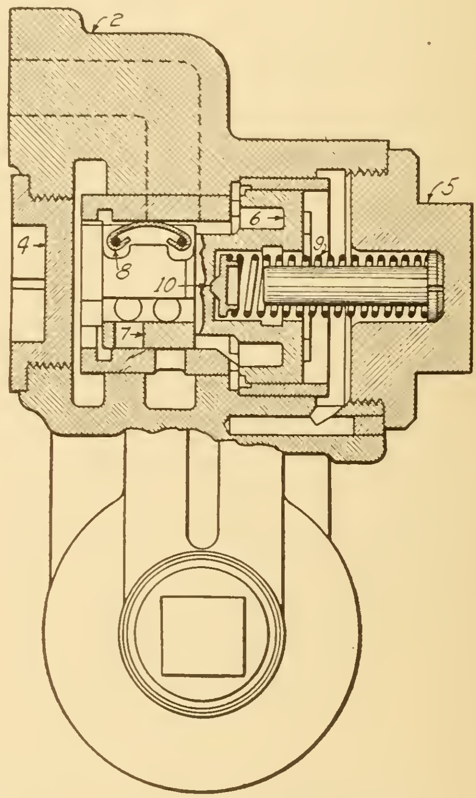


Fig. 33. Section of Westinghouse "C-6" Feed Valve through Slide Valve

The feed valve is adjusted by screwing regulating nut *20* in or out, thus increasing or decreasing the pressure exerted by the spring on the diaphragm.

This feed valve, when applied to the "G-6" brake valve, is usually adjusted for 70 pounds brake-pipe pressure. Suppose spring *19* to be compressed so as to exert a force equivalent to a 70-pound air pressure on the opposite side of the diaphragm. Then, as long as the air pressure in the brake pipe and chamber *L* is less than 70 pounds, the spring holds the diaphragm over as far to the left as possible, as shown in Fig. 35. This holds the regulating valve *12* off its seat, thus opening port *K*, which permits air to flow through port *K* and from passage *H* to 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 70 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. 35. Air, therefore, continues to flow from the main reservoir through *a, c,* and *d* to the brake pipe, increasing its pressure and the pressure in chamber *L*, acting on diaphragm *17*, until it reaches 70 pounds.

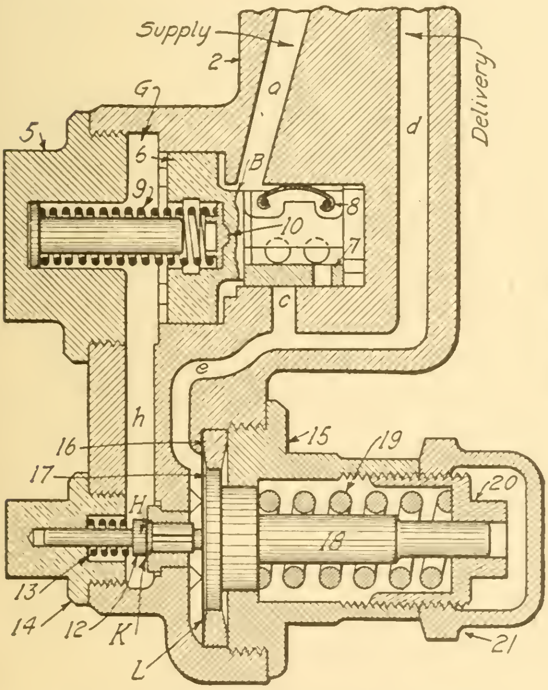


Fig. 34. Diagrammatic Section of Westinghouse "C-6" Feed Valve in Closed Position

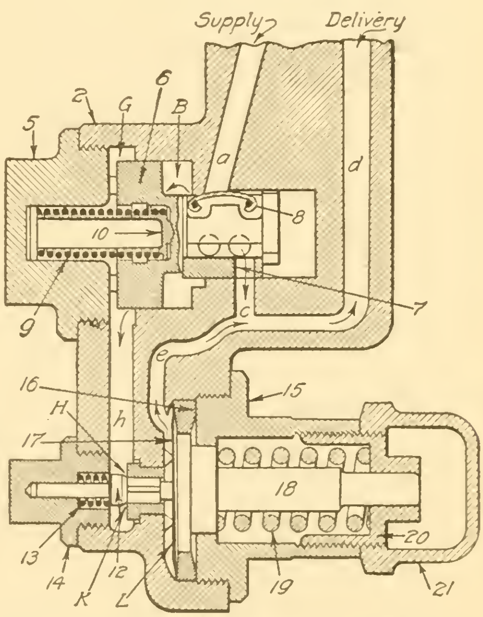


Fig. 35. Diagrammatic Section of Westinghouse "C-6" Feed Valve in Open Position

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 brake-pipe passage *d* at 70 pounds pressure and, being small, are instantly raised to main-reservoir pressure by the 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. 34, which prevents further flow of air from the main reservoir to the brake pipe. The operation of the valve as described, after the pressure in the brake pipe has reached 70 pounds is almost instantaneous, so that the brake-pipe pressure is held constant at 70 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*.

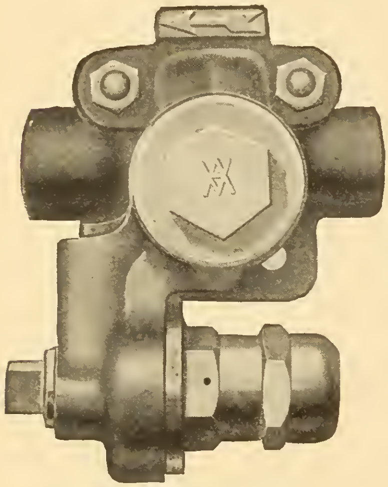


Fig. 36. Westinghouse "C-6" Reducing Valve

The feed valve acts as a maintaining valve in this manner, keeping the brake-pipe pressure constant at the amount for which the regulating valve is adjusted as long as the brake-valve handle is in proper position for the feed valve to be operative.

When the "C-6" type feed valve is fitted for pipe connections to be used in connection with the distributing valve of the "ET" equipment, it is called a *reducing* valve. It is usually adjusted to reduce to 45 pounds pressure. The arrangement used is illustrated in Fig. 36.

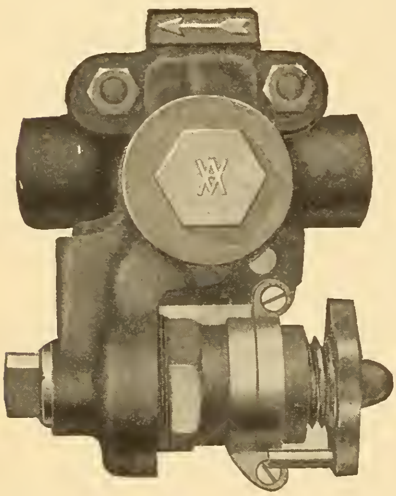


Fig. 37. Westinghouse "B-6" Feed Valve, Showing Valve and Pipe Bracket Complete

"B-6" Double-Pressure Feed Valve. The "B-6" feed valve is furnished with the high-speed and double-pressure control apparatus, and also with the "ET" equipment, to permit the use of either low- or high-brake pipe pressure. The features of this feed valve are the same as for the "C-6" feed valve with the exception of having a *regulating handle* in place of a regulating nut. The extreme movement of the regulating handle is controlled by stops, as shown in Fig. 37. To adjust this valve, slacken the screw which allows the stops to turn around the spring box. The regulating handle should then be turned until the valve closes at the lower brake-pipe pressure desired, the stop should then be brought in contact with the handle pin, at which point it should be securely fastened by the tightening screw. The regulating handle should then be turned until the higher brake-pipe pressure is obtained and the stop is brought in contact with the handle pin and securely fastened. The usual and recommended pressures for low and high pressures are 70 pounds and 110 pounds, respectively.

The "B-6" feed valve, like the "C-6" feed valve, is also used

Fig. 38. "B-6" Feed Valve, Showing Valve Removed from Pipe Bracket
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

as a reducing valve. When used in this capacity it is fitted to a pipe bracket as illustrated in Fig. 38.

TRIPLE VALVES

In the study of the triple valve it is well to keep in mind that its essential parts consist of a cylinder fitted with a piston, the movement of which operates a slide valve. As long as the pressure remains the same on each side of the piston it cannot move, but when the pressure on one side is changed the piston will move toward the side having the least pressure. It is of vital importance that this principle be thoroughly understood, as practically all automatic devices of the air brake are constructed along this line. This principle, as stated by the Westinghouse Company, is as follows:

The devices used in connection with the air brake, which are automatic in their action, and of which the triple valve is one, depend for their operation upon the movements of one or more diaphragms or pistons. The piston or diaphragm is a movable partition separating two sources of pressure. As long as these pressures are equal no movement occurs, but as soon as the equality of pressure is destroyed, and the pressure on one side becomes higher than that on the other, the piston or diaphragm tends to move toward the lower pressure and, as soon as the balance of pressure is again restored, the tendency to move ceases. This condition holds true whether the pressures involved are due to compressed air or to springs, or to a combination of the two.

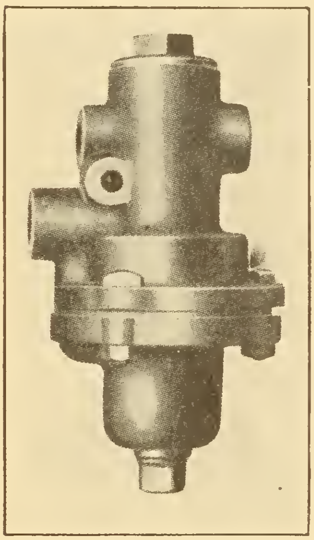


Fig. 39. Plain Triple Valve for Air Brake Equipment
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

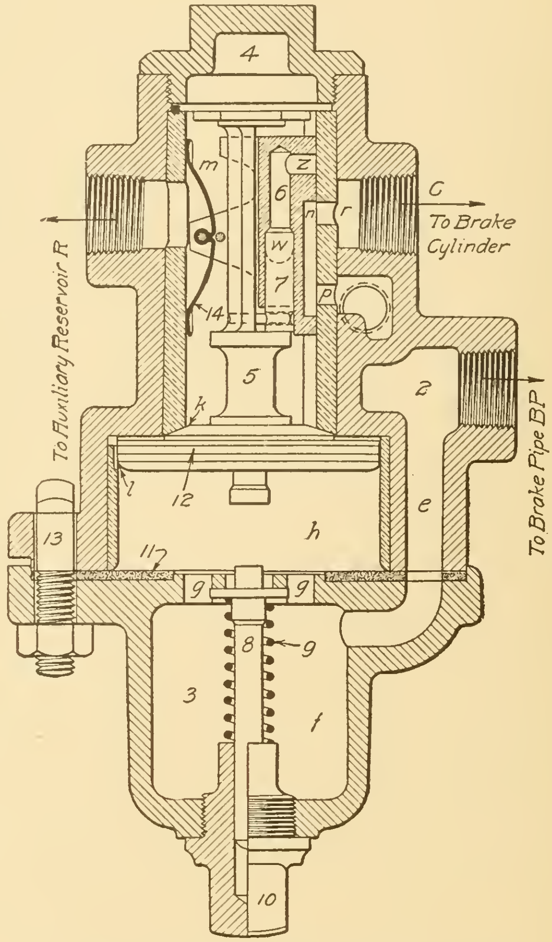


Fig. 40. Section through Westinghouse Plain Triple Valve

In the case of the triple valve, the variations in pressure necessary to cause it to operate are due to the increase or decrease in brake-pipe pressure caused by movements of the engineer's brake valve, burst hose, opening of conductor's valve, etc., on one side of the triple-valve piston, or on the other side of the piston by a decrease in the auxiliary-reservoir pressure caused by a flow of air into the brake cylinder from the auxiliary reservoir.

As previously stated, the triple valve forms one of the most important parts of the air-brake equipment. The different Westinghouse air-brake equipments make use of the following types of triple valves: plain, quick-action, "K", and "L". The first two types mentioned are rapidly passing out of service and those of later development are taking their place.

Plain Triple Valve. The plain triple valve, the general appearance of which is shown in Fig. 39 and in vertical section in Fig. 40, has a cast-iron body with pipe connections to the brake pipe *BP,* to the auxiliary reservoir *R,* and to the brake cylinder *C,* and has an outlet to the atmosphere shown by dotted and full lines to the right of port *p.*

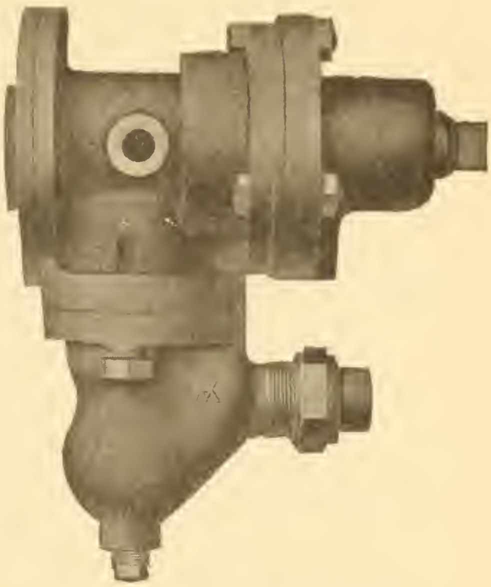


Fig. 41. Westinghouse Quick-Action Triple Valve

The operating parts consist of a slide valve *6,* in which the graduating valve *7* moves, the piston *5,* and the graduating stem *8,* with its spring *9.* The graduating valve is attached to the stem of piston *5* by a pin shown in dotted lines.

Quick-Action Triple Valve. The quick-action triple valve, Fig. 41, is shown in vertical section in Fig. 42. Its constructional features are quite similar to those of the plain triple valve, one of the noticeable differences being that the operating piston and slide valve occupy a horizontal position, while in the plain triple valve they have a vertical position. It also differs from the plain triple valve in having additional quick-

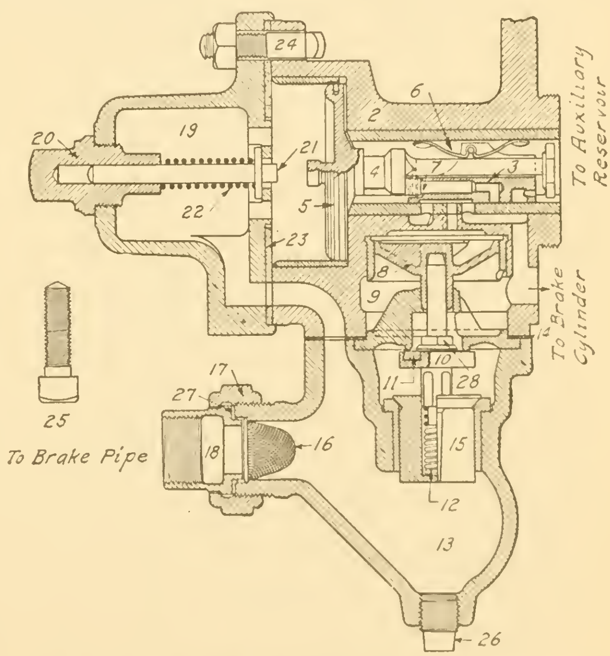


Fig. 42. Westinghouse Quick-Action Triple Valve Shown in Section

action parts, consisting of an emergency piston *8*, emergency valve *10*, and check valve *15*. This triple valve is arranged so as to be bolted to the pressure head of the brake cylinder in passenger equipments or to the cast-iron auxiliary reservoir in freight equipments, thus making the brake-pipe connection the only pipe connection necessary to the triple valve.

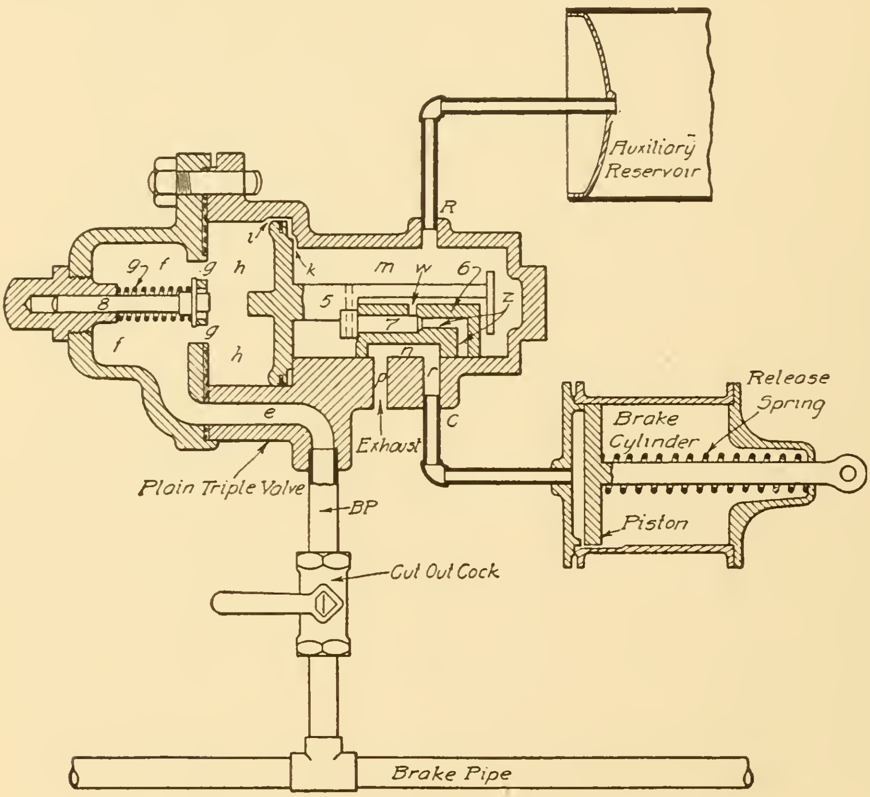


Fig. 43. Diagram of Westinghouse Plain Triple Valve, Showing Running and Release Position

The plain triple valve was developed to overcome the defects of the straight air brake, chief among which may be mentioned the following: a brake that was inoperative in event of a train parting; a brake that could not be used successfully in trains of over ten cars in length; and a brake requiring considerable time to operate.

The plain triple valve overcame these defects in a large measure but soon had to give way to a more refined type of triple valve, a valve whose action was more rapid and did not give such severe shocks between cars in long trains—say 50 cars—when an emergency application of the brakes was made.

The quick-action triple valve overcame the defects of the plain triple valve. The general operation of these two valves is so much alike that a description for either type will apply to the other with the exception of the quick-action or emergency feature.

It will be remembered that the brake pipe extends from the engineer's brake valve on the locomotive throughout the train, the connections between the locomotive and cars being made by a hose and coupling. The essential pipe equipment on each car

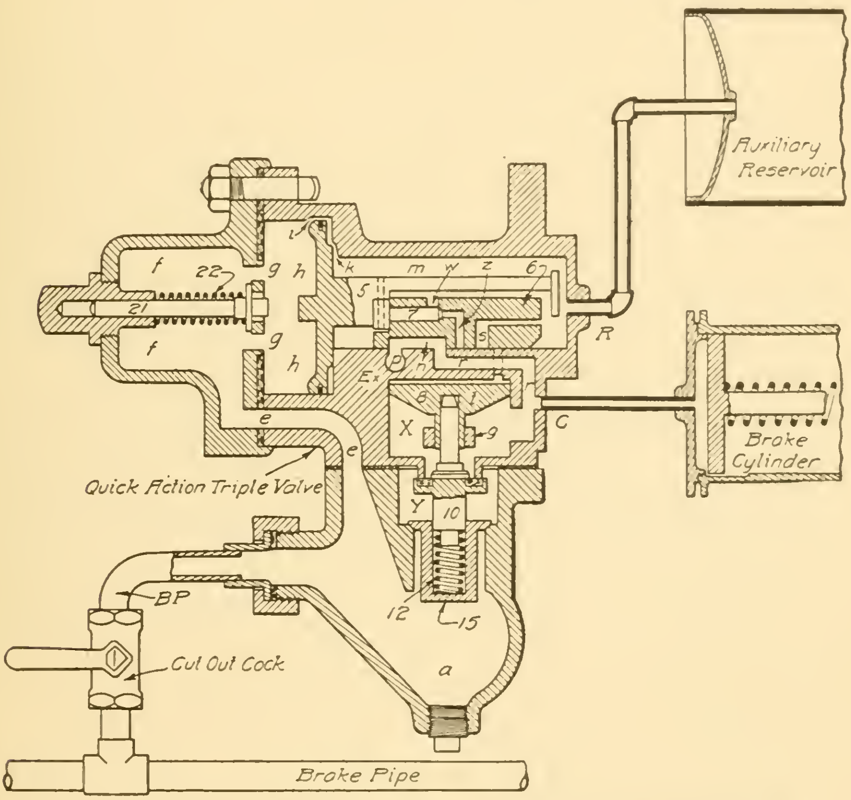


Fig. 44. Diagram of Westinghouse Quick-Action Triple Valve, Showing Running and Release Position

is the brake pipe, and a branch pipe which connects the triple valve to the brake pipe through a cut-out cock. In giving the description of the action of both the plain and the quick-action triple valves, reference will be made to diagrammatic views shown in Figs. 43 to 48. Like the engineer's brake valve, the triple valve is spoken of as having certain definite positions, such as running or release, service, service-lap, and emergency positions.

Running Position. Air enters the triple valve through port *e*, Figs. 43 and 44, to chamber *f* and through passages *g* to chamber *h*, in which the triple valve piston *5* moves. The air pressure in chamber *h*, acting on the face of the piston, forces it to its extreme position to the right, which is *release* and *charging* position. In this position air can flow from chamber *h* around the piston through feed groove *i* in the bushing and *k* in the piston seat into chamber *m*, and thence through the pipe connection at *R*, as shown, to the auxiliary reservoir.

From the figures it will be seen that the triple-valve piston *5* has a stem on which are two collars. Between these two collars is a slide valve *6*, shorter than the distance between the collars on the piston stem, so that there is a certain amount of clearance or "lost motion" between the piston stem and the slide valve.

The function of this slide valve *6* is to make proper connections between the space *m* (auxiliary-reservoir pressure) and the brake-cylinder port *r* in the seat of the valve; or between the brake-cylinder port *r* and the exhaust port *p*, also in the seat; or to close these ports—according to the positions to which the slide valve is moved by the triple-valve piston in order to perform certain functions. In the *release* position shown, air at auxiliary pressure is acting above and on all sides of the slide valve, but cannot flow past or through it since all ports through the valve are closed. The exhaust cavity *n* in the face of the valve, however, makes an opening across from the brake cylinder port *r* in the seat to the exhaust port *p*, so that the brake cylinder is then connected through the pipe connection to the triple valve and the ports named to the exhaust opening and atmosphere. Any compressed air contained in the brake cylinder will flow to the atmosphere, thus permitting the release spring acting on the opposite side of the piston to force it back to the *release* position and release the brake shoes from the wheels.

The normal condition of the triple valve when the train is running over the road and the brakes are not being used is with the triple-valve pistons and slide valve in *release* position, the brakes released, and the auxiliary reservoirs charged and maintained at the pressure for which the feed valve—engineer's brake valve—is adjusted.

Service Position. As the brake pipe is connected to the chamber *h*, Fig. 45, of each triple valve. a reduction in brake-pipe pressure will lower the pressure on the brake-pipe side of the triple-valve piston below that of the auxiliary reservoir on the opposite side. The higher auxiliary-reservoir pressure will then cause the piston to move in the direction of the weaker pressure, thereby closing communication between chamber *h* and the auxiliary reservoir through feed groove *i*. Attached to the piston stem is a pin valve *7* called the "graduating valve", which when seated, Fig. 46, closes communication between port *w* leading from chamber *m* to the

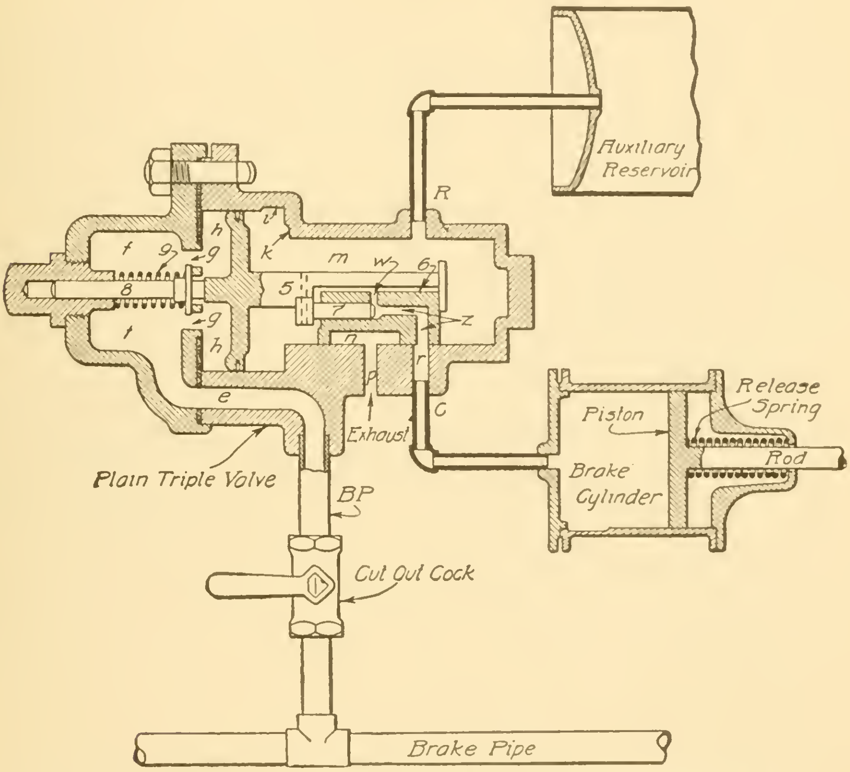


Fig. 45. Westinghouse Plain Triple Valve, Showing Service Position

graduating-valve seat in the slide valve and the service port *z* leading from the graduating-valve seat to the face of the slide valve. The first movement of the triple-valve piston unseats the graduating valve *7*, so that the air in chamber *m*, entering port *w*, flows to the service port *z*.

There is a small amount of clearance between the slide valve *6* and the collar, or "spider", on the end of the triple-valve piston stem, so that the first movement of the piston, which closes the feed groove *i* and opens the graduating valve *7*, does not move the slide valve but brings the spider on the stem against the end of the valve. Further movement of the piston causes the slide valve to move until it has closed communication between the brake-cylinder port *r* and the exhaust port *p* and opened port *r* to the auxiliary reservoir through port *z* and *w*, as shown in Fig. 45. The piston then comes into contact with the graduating stem and the resistance of the graduating spring, combined with the reduction in the auxiliary-reservoir pressure then taking place, prevents further movement of the parts. The valve is then in *service* position

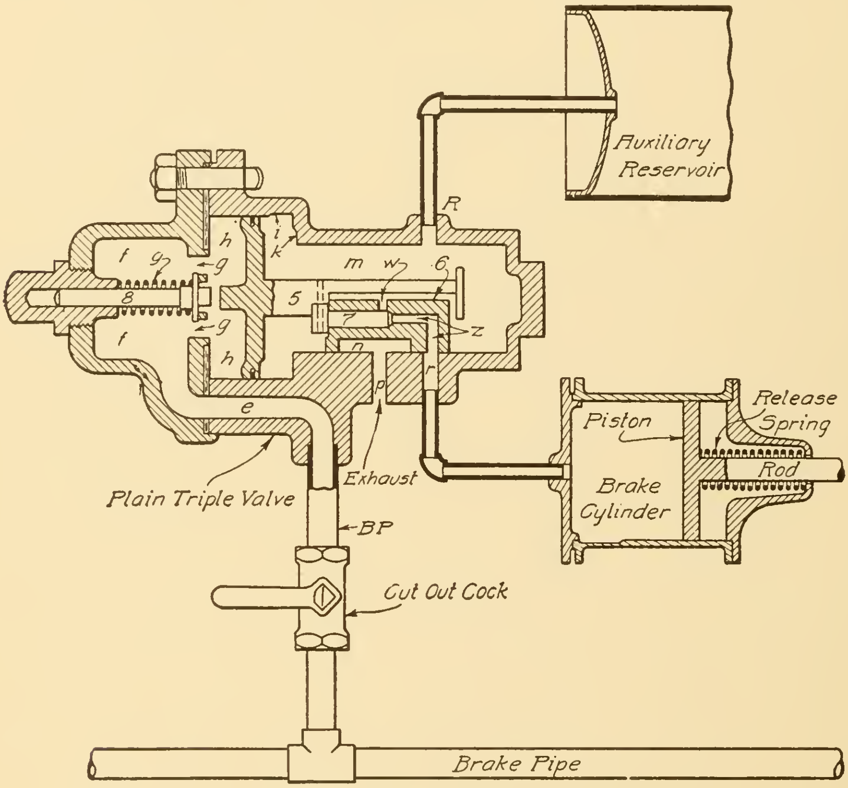


Fig. 46. Westinghouse Plain Triple Valve, Showing Service Lap Position

and air from the auxiliary reservoir flows through the service port to the brake cylinder, forcing its piston outward and applying the brake. While the brake-cylinder pressure rises, that in the auxiliary reservoir falls and tends to become lower than that in the brake pipe. As soon, however, as the pressure on the auxiliary-reservoir side of the triple-valve piston falls slightly below that on the brake-pipe side, the higher pressure causes the piston to move back—toward *release* position—until the graduating valve is seated, closing communication between ports *w* and *z*. This further flow of air from the auxiliary reservoir—the pressure in which is then practically equal to that in the brake pipe—prevents further movement of the triple-valve piston toward *release* position, because the slightly higher pressure on the brake-pipe side of the piston, which was able to move the piston and graduating valve alone, is not sufficient to move the slide valve. The triple valve is then in *service-lap* position.

If a further reduction in brake-pipe pressure is made, the reduction in pressure on the brake-pipe side of the triple-valve piston below that on the auxiliary-reservoir side causes the piston and its attached graduating valve to move to the same position as for the first *service* application of the brakes. The slide valve, however, is already in service position, consequently as soon as the graduating valve is opened air from the auxiliary reservoir flows to the brake cylinder and increases the pressure therein, thus increasing the pressure of the brake shoes against the wheels. If the brake-pipe reduction is continued indefinitely, the auxiliary-reservoir pressure will continue to fall and the brake-cylinder pressure to rise until they become equal, or "equalize". This occurs at about 50 pounds cylinder pressure when carrying 70 pounds brake-pipe pressure with a properly proportioned cylinder and auxiliary reservoir. Nothing is gained in reducing the brake-pipe pressure below the equalization point in *service applications*.

Service-Lap Position. When the triple valve is in *service lap*, Fig. 46, and assuming that there is no leakage, the brake-pipe and auxiliary-reservoir pressures will remain balanced and the brake-cylinder pressure held constant until the brake-pipe pressure is further reduced, in order to apply the brakes harder; or increased in order to release the brakes.

The brake-cylinder leakage, as well as brake-pipe leakage, is generally very severe and it is not good policy to keep brakes applied for too great a period at one time, permitting the pressure in the brake system to leak off.

Release and Recharge. To release the brakes and recharge the auxiliary reservoir, air is admitted to the brake pipe. This increases the pressure on the brake-pipe side of each triple-valve piston above that on the other side, causing the piston and slide valve to move back to release position, which permits the air in the brake cylinder to flow to the atmosphere through the triple-valve exhaust port, thus releasing the brakes. The charging of the auxiliary reservoir has been explained under "Running Position"

Emergency Position. Up to this point, all statements made regarding the operation of the triple valve have applied equally to the plain, or quick-action triple valve, but during an *emergency* application their action is different.

When the piston and slide valve of the plain triple valve move to the *emergency* position, Fig. 47, the brake-cylinder port *r* is un-

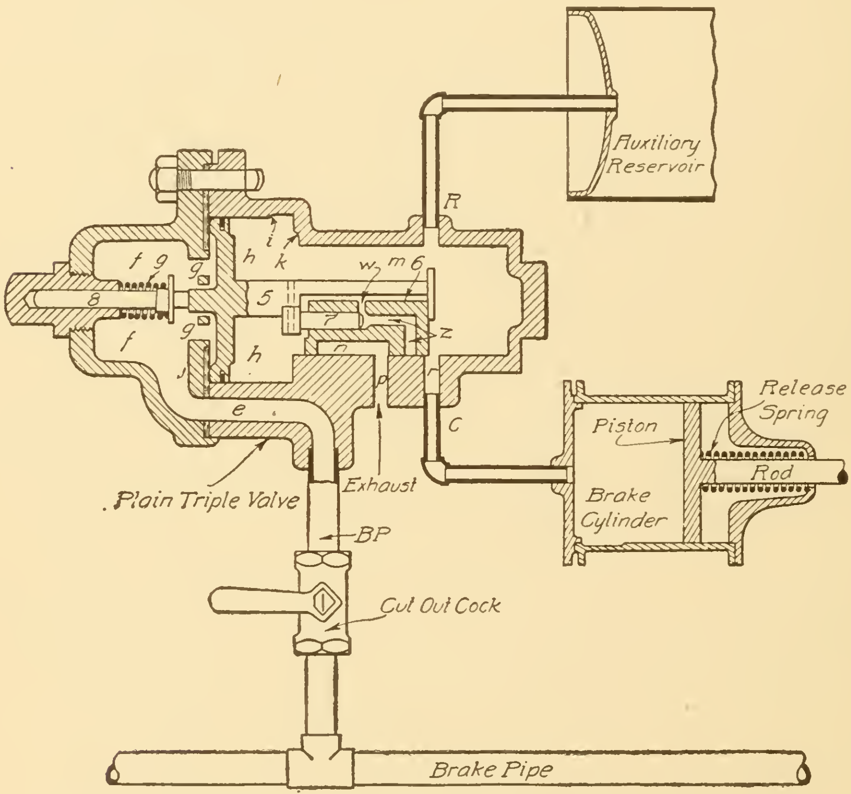


Fig. 47. Westinghouse Plain Triple Valve, Showing Emergency Position

covered and air from the auxiliary reservoir flows past the end of the valve directly through port *r* into the brake cylinder until the brake-cylinder and auxiliary-reservoir pressures become equalized. The pressure obtained in the brake cylinder is no higher then when a full-service application is made, but the maximum pressure is obtained more quickly.

When the piston and slide valve of the quick-action triple valve move to the *emergency* position, Fig. 48, port *s* in the slide valve registers with port *r* in the seat, allowing air to flow from the auxiliary reservoir to the brake cylinder. Port *s* is small, however, and in this position the slide valve also opens port *t* in its seat, allowing air to flow from chamber *m* through port *t* to the chamber above the emergency piston *8*. The other side of emergency piston *8* is connected to the brake cylinder, in which there is no air pressure, consequently the emergency piston is forced downward, pushing the emergency valve *10* from its seat and allowing air in chamber *Y* above the check valve *15* to flow past the emergency valve *10* to chamber *X* and the brake-cylinder. Brake-pipe air in *a* below the

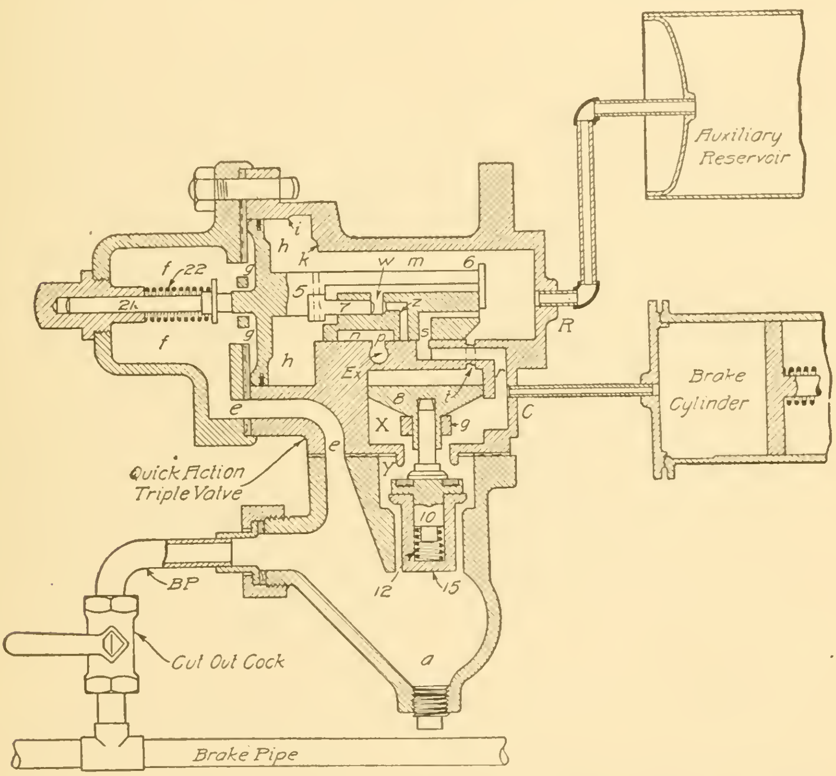


Fig. 48. Westinghouse Quick-Action Triple Valve, Showing Emergency Position

check valve *15*, then raises the check valve and flows to the brake cylinder through the passages mentioned. During an emergency application, therefore, the quick-action triple valve supplies air to the brake cylinder from the brake pipe as well as from the auxiliary reservoir.

Approximately 60-pound brake-cylinder pressure is obtained on emergency applications, the air from the brake pipe increasing the cylinder pressure about 20 per cent above the maximum obtainable with a full-service application.

This "venting" the brake-pipe pressure into the brake-cylinder aids the speed of an emergency application, as each triple valve reduces the brake-pipe pressure sufficiently to set the next triple valve in the train to emergency.

The release after an emergency application is obtained in the same manner as for a service-application release.

The plain triple valve is now only used for locomotives in freight and switching service that are not equipped with the "ET" distributing valve.

Type "K" Freight Triple Valve. The standard form of quick-action triple valve commonly used in freight service has until recently proved very satisfactory. In the last few years, however, with heavier locomotives capable of handling 100-car trains fitted with air-brake equipment, they have failed to meet all the requirements. Realizing the changed conditions and the importance of meeting them, the Westinghouse Company has developed and perfected the "K" triple valve.

Objections to Other Valves Overcome by "K" Type. Some of the undesirable features of the standard quick-action triple valve, which the "K" triple overcomes are as follows:

(a) The failure of a portion of the brakes in a long train to apply.

(b) A complete release of the brakes at the forward end of the train before the brake-pipe pressure which has brought this about can reach the triple valves near the end of the train. This action permits the slack to run out hard, and creates excessive strains on the draft gears, often resulting in a break-in-two.

(c) Overcharging the auxiliary reservoirs at the forward end of the train while releasing the brakes. The result of this action is a reapplication of the forward brakes when the brake-valve handle is placed in running position.

The outward appearance of the "K" triple valve when attached to the auxiliary reservoir is so much like the standard quick-action triple that a thin web is cast on the top part of the body as a distinguishing mark. The designating mark "K-1" or "K-2" is also cast on the side of the body. The "K" triple is made in two sizes —the "K-1" for use with the 8-inch freight-car brake cylinder, and the "K-2" with the 10-inch freight-car brake cylinder, Fig. 49.

This "K" triple valve embodies every feature possessed by the standard quick-action triple valve and three additional ones, namely, quick service, uniform release, and uniform re-charge. It operates in perfect harmony with the standard triple and often improves the action of the latter when the valves are mixed in the same train. The two types of valves have many parts in common and are interchangeable. The standard triple may be transformed into the "K" triple by preserving all of the old parts except the body, slide-valve, bush, and graduating valve. This transformation can be done at a minimum cost when the valves are returned to the works for heavy repairs.

The above-mentioned features of quick action, quick service, uniform release, and uniform re-charge have proved so desirable that the valve has been accepted as standard by so many railroads that it can be said to be the "standard" freight triple valve of today.

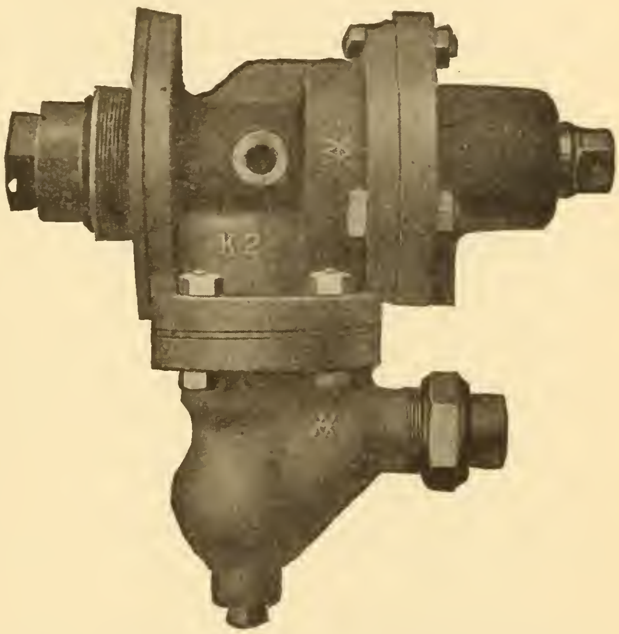


Fig. 49. Westinghouse Type "K" Freight Triple Valve

Quick-Service Feature. The quick-service feature brings about a more uniform and a quicker application of the brakes in a long train during service applications.

The rate of brake-pipe reduction for service applications in the brake system is determined by the exhaust port in the brake valve and by the frictional resistance of the pipe. These being constant, it is plain that the longer the train the slower will be the pressure reduction in the brake pipe, and, as the distance from the head of the train increases toward the rear of long trains, only a very slow reduction, if any, takes place, and consequently a very slow application, if any at all, takes place. This slow rate of brake-pipe reduction not only results in a slow application but many times in the failure of individual brakes to apply. This is due to one of two things, namely, the air from the auxiliary reservoir passing back to the brake pipe through the feed groove; or, in case of a movement of the triple-valve piston, by the air leaking out past the packing leather in the brake cylinder.

The quick-service feature gives a rapid serial operation of all brakes in service application. This is accomplished by using the principle of the standard quick-action triple valve in emergency applications, namely, that of discharging brake-pipe air into the brake cylinder; that is, in service applications some air from the brake pipe passes into the brake cylinder. The result is that the quick-service feature insures the operation of every brake, reduces the amount of air exhausted at the engineer's brake valve and the possible loss of air due to flowing back through the feed groove, and effects a saving of air.

Uniform Release. Uniform release tends to permit the rear brakes to release as soon as those at the head of the train. The rate of increase of brake-pipe pressure takes place more and more slowly as the distance from the head of the train increases; consequently, in long trains the head end brakes are fully released before the rear brakes have commenced to release. The uniform-release feature is accomplished by automatically restricting the exhaust of air from the brake cylinder in the forward portion of the train and allowing the others to release freely. This retarded release of the forward brakes is due to the increased pressure which exists in the forward end of the brake pipe when the brake valve is in release position. The effect is noticeable on about the first thirty cars of a long train.

Uniform Re-Charge. Uniform re-charge permits the auxiliary reservoirs through the entire length of the train to re-charge uniformly. With the ordinary quick-action triple valve, the slowness in brake-pipe pressure increase in long trains permitted the head end auxiliary reservoirs to become overcharged while those at the rear end were undercharged; consequently, when the brake-valve handle was returned to running position the head-end brakes would re-apply. The uniform re-charge of the auxiliary reservoirs is due to the fact that when the valve is in the retarded-release position, the ports connecting the brake pipe with the auxiliary reservoir are automatically restricted. In other words, as long as the exhaust from the brake cylinder is retarded, the recharge is restricted. This feature not only prevents the overcharging of the auxiliary reservoirs on the front end of the train but, by drawing less air from the brake pipe, permits the increase in brake-pipe pressure to travel more rapidly to the rear cars where it is most needed for releasing and re-charging those brakes.

Fig. 50 is a vertical cross section and end view of the "K" triple valve and the names of the various parts are as follows: *2* valve body; *3* slide valve; *4* main piston; *5* piston ring; *6* slide-valve spring; *7* graduating valve; *8* emergency piston; *9* emergency-valve seat; *10* emergency valve; *11* emergency-valve rubber seat; *12* check-valve spring; *13* check-valve case; *14* check-valve case gasket;

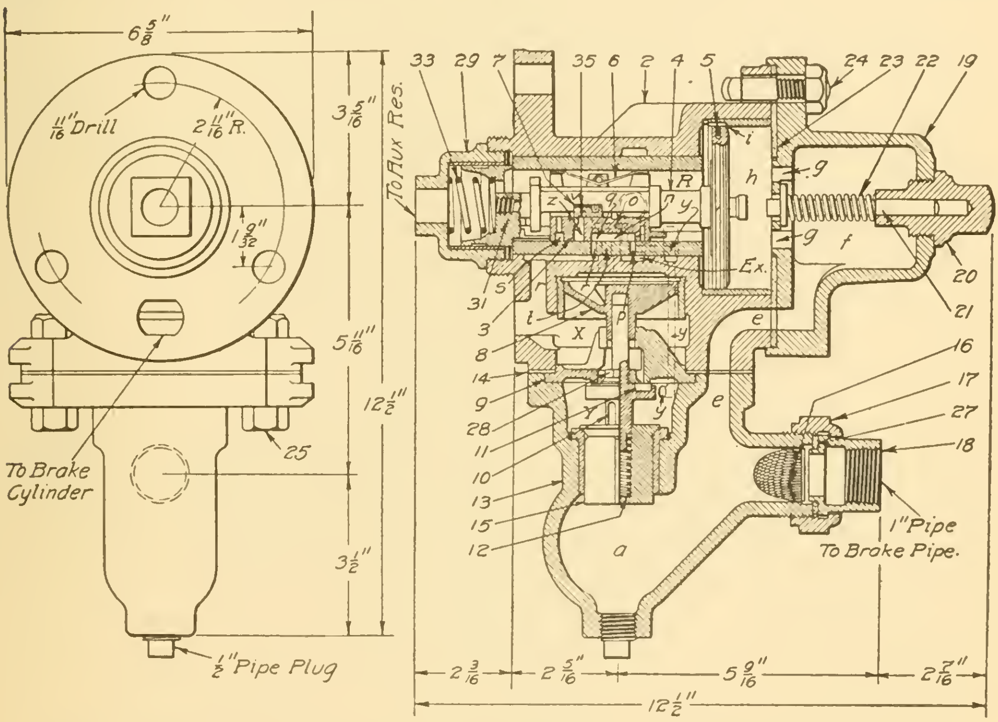


Fig. 50. Westinghouse Type "K" Triple Valve, Shown in End View and Actual Section

15 check-valve; *16* air strainer; *17* union nut; *18* union swivel; *19* cylinder cap; *20* graduating stem nut; *21* graduating stem; *22* graduating spring; *23* cylinder-cap gasket; *24* bolt and nut; *25* cap screw; *27* union gasket; *28* emergency-valve nut; *29* retarding device body; *31* retarding stem; *33* retarding spring; *35* graduating valve spring.

The different recognized positions of the parts of a type "K" triple valve are six in number, namely, full-release and charging, quick-service, full-service, lap, retarded-release and charging, and emergency positions. In explanation of the operation of the valve, reference will be made to the diagrammatic views of this device shown in Figs. 51 to 56 and, for the sake of clearness, the description given in literature published by the Westinghouse Company will be largely made use of.

Full-Release and Charging Position. In this position air from the brake-pipe flows through passage *e*, Fig. 51, cylinder-cap ports *f* and *g* to chamber *h* on the face of the triple-valve piston; thence

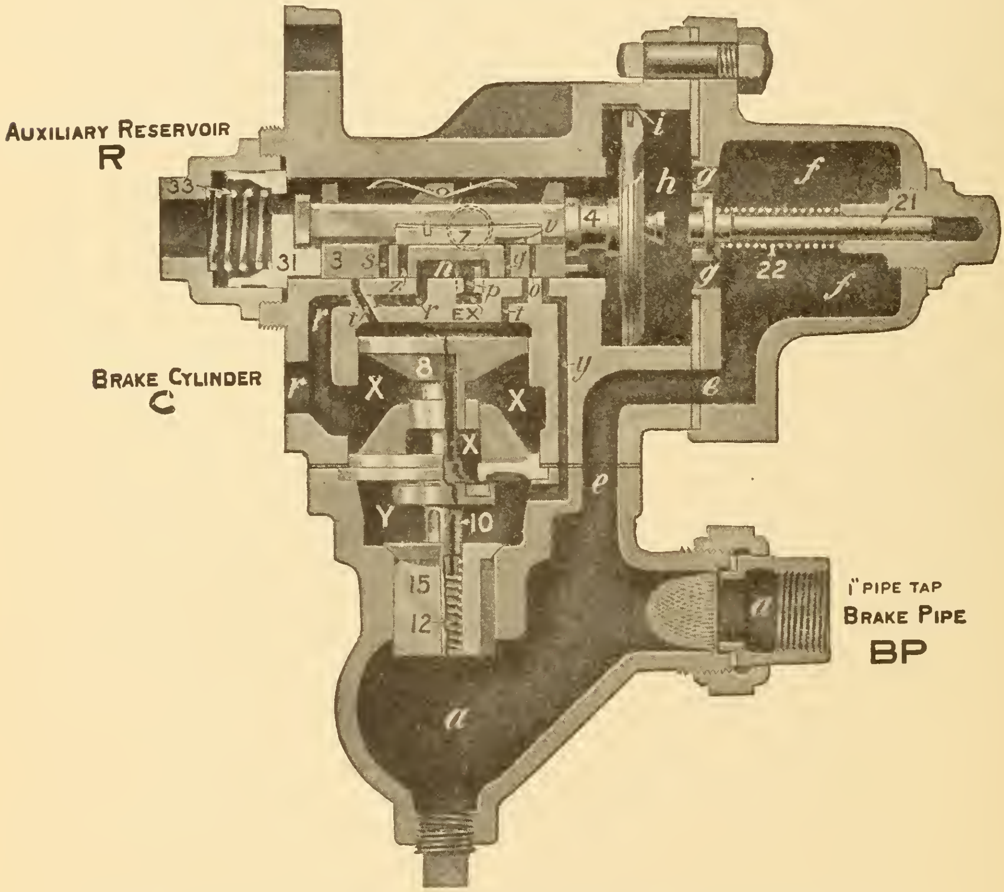


Fig. 51. Type "K" Triple Valve, Shown in Full-Release and Charging Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

through feed groove *i*, now open, to chamber *R* above the slide valve, which is always in free communication with the auxiliary reservoir. In the "K" triple valve, the feed groove *i* is of the same dimension as that of the old standard triple valve. Air flows from the brake pipe to the auxiliary reservoir, as described, until their pressures become equalized.

Quick-Service Position. To make a quick-service application of the brakes, the air pressure in the brake pipe, and thereby in chamber *h,* Fig. 52, is gradually reduced. As soon as the pressure in chamber *h* has been sufficiently reduced below that in chamber *R* on the other side of the triple-valve piston, the higher pressure on the auxiliary-reservoir side of the piston is able to overcome the friction of the piston *4* and its attached graduating valve *7* and to move these parts to the right until the shoulder on the end of the piston stem strikes against the left-hand end of the slide valve.

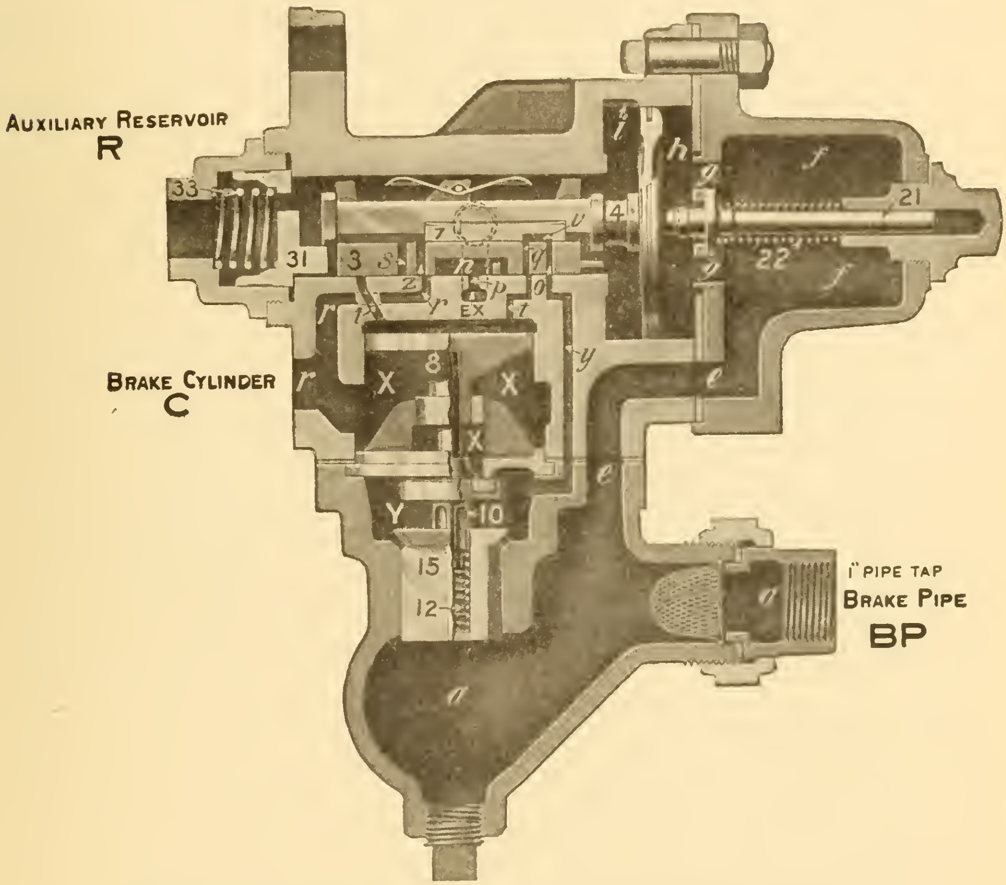


Fig. 52. Type "K" Triple Valve, Shown in Quick-Service Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

The latter is then moved to the right until the piston strikes the graduating stem *21,* which is held in place by the compression of the graduating spring *22.* The parts of the valve are then in the position shown in Fig. 52. The first movement of the piston *4* closes the feed groove *i* and prevents air from feeding back into the brake pipe from the auxiliary reservoir, and at the same time the graduating valve opens the upper end of port *z* in the slide valve. The movement of the latter closes the connection between port *r* and the exhaust port *p* and brings port *z* into partial registration with port *r* in the slide-valve seat. Air from the auxiliary reservoir then flows through port *z* in the slide valve and port *r* in the seat to the brake cylinder.

At the same time, the first movement of the graduating valve connects the two ports *o* and *q* in the slide valve through the cavity *v* in the graduating valve, and the movement of the slide valve brings port *o* to register with port *y* in the slide-valve seat and port *q* with port *t*. Consequently, the air in chamber *Y* flows through ports *y, o, v, q,* and *t,* thence around the emergency piston *8,* which fits loosely in its cylinder, to chamber *X* and the brake cylinder. When the pressure in chamber *Y* has reduced below the brake-pipe pressure remaining in *a,* the check valve *15* is raised and allows brake-pipe air to flow past the check valve and through the ports above mentioned to the brake cylinders. The size of these ports is so proportioned that the flow of air from the brake pipe to the top of emergency piston *8* is not sufficient to force the latter downward and thus cause an emergency application, but at the same time takes enough air from the brake pipe to cause a definite local reduction in brake-pipe pressure at that point, which is transmitted in like manner to the next triple valve, and in turn to the next, thus increasing the rapidity with which the brake-pipe reduction travels through the train.

Full-Service Position. With short trains, the brake-pipe volume being comparatively small will reduce more rapidly for a certain reduction at the brake valve than with long trains. Under such circumstances it might be expected that the added reduction at each triple valve by the quick-service feature would bring about so rapid a brake-pipe reduction as to cause quick action and an emergency application when only a light application was intended, but this is automatically prevented by the triple valve itself. From Fig. 52 it will be noted that in the quick-service position port *z* in the slide valve and port *r* in the seat do not fully register. Nevertheless, when the train is of considerable length, the opening is sufficient to allow the air to flow from the auxiliary reservoir to the brake cylinder with sufficient rapidity to reduce the pressure in the auxiliary reservoir as fast as the pressure is reducing in the brake pipe; but if the brake-pipe reduction is more rapid than that of the auxiliary reservoir, which may be the case on short trains, the difference in pressure on the two sides of piston *4* becomes sufficient to slightly compress the graduating spring and moves the slide valve to the position shown in Fig. 53 called *full service.* In this position, quick-service port *y* is closed, so that no air flows from the brake pipe to the brake cylinder; also, in full-service position ports *z* and *r* are fully open, allowing the auxiliary-reservoir

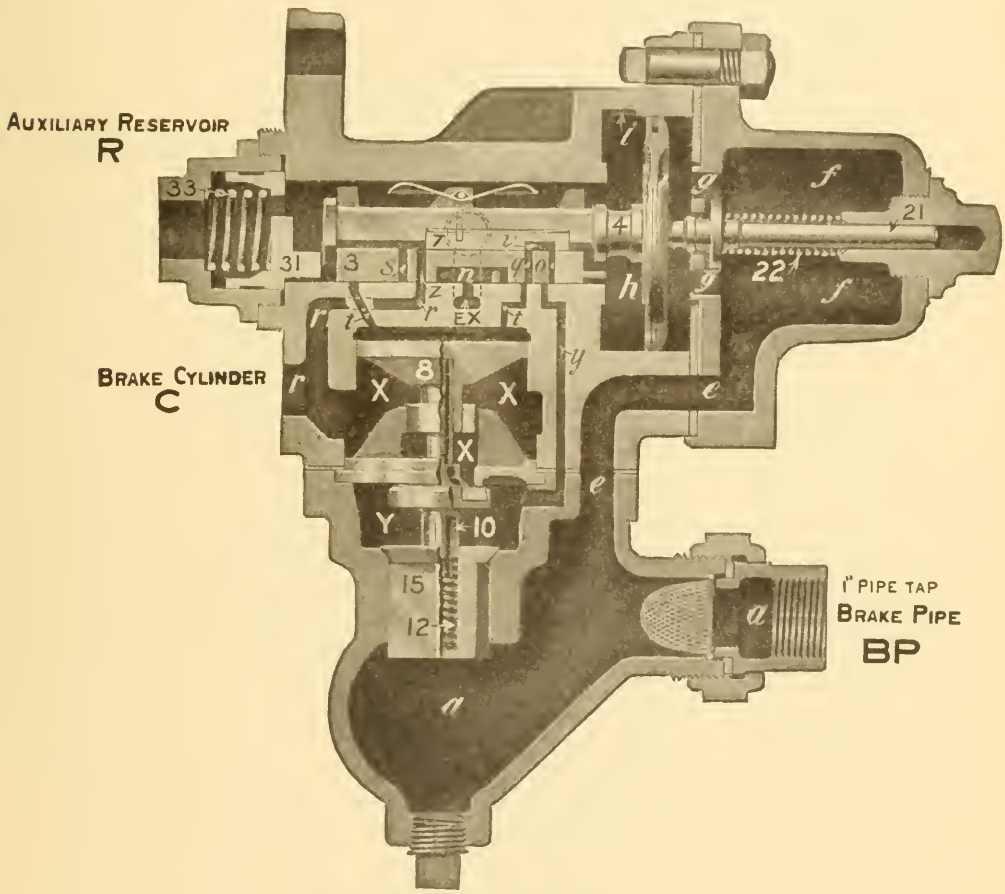


Fig. 53. Type "K" Valve Shown in Full-Service Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

pressure to reduce more rapidly, so as to keep pace with the more rapid brake-pipe reduction.

Lap Position. When the brake-pipe reduction ceases, air continues to flow from the auxiliary reservoir through ports *z* and *r* to the brake cylinder until the pressure in the chamber *R* becomes enough less than that of the brake pipe to cause piston *4* and graduating valve *7* to move to the left until the shoulder on the piston stem strikes the right-hand end of slide valve *3*. As the friction of the piston and graduating valve is much less than that of the slide valve, the difference in pressure which will move the piston and graduating valve will not be sufficient to move all three; consequently, the piston stops in the position shown in Fig. 54. This movement has caused the graduating valve to close port *z*, thus cutting off any further flow of air from the auxiliary reservoir to the brake cylinder and also to port *o*, thus preventing further flow

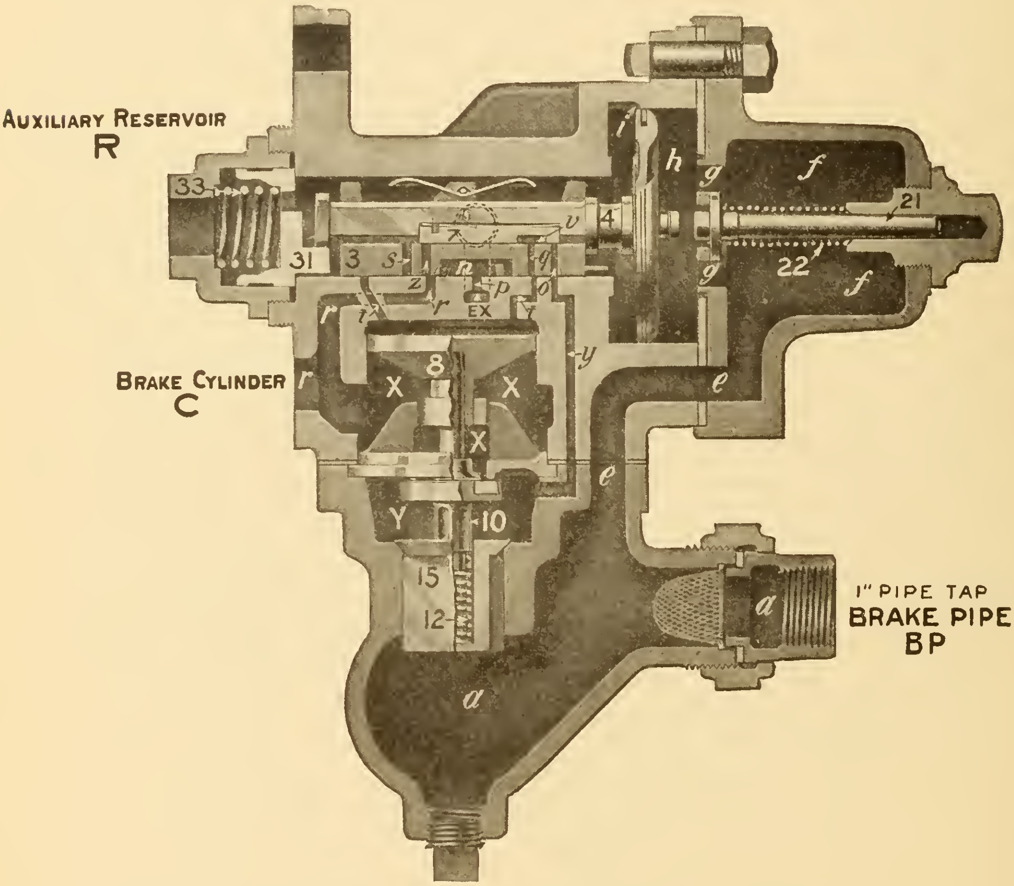


Fig. 54. Type "K" Triple Valve Shown in Lap Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

of air from the brake pipe through the quick-service ports. Consequently, no further change in air pressures can occur, and this position is called *lap* because all ports are *lapped* or closed.

It will be seen that the exact position of the slide valve *3* in *lap* position depends upon whether its previous position was that of *quick service,* Fig. 52, or *full service,* Fig. 53. If the former, the *lap* position assumed would be *quick-service lap* position, as shown in Fig. 54. If the slide valve had previously moved to *full-*

service position, however, the *lap* position assumed would be *full-service lap* position, in which the slide valve would still remain in *full-service* position, Fig. 53, but with the graduating valve moved back so as to blank ports *z* and *o* in the slide valve, and with the shoulder on the piston stem in contact with the right-hand end of slide valve *3*, as shown in Fig. 54. About 20 pounds brake-pipe reduction will give full equalization.

Retarded-Release and Charging Position. The "K" triple valve has two release positions, namely, full release and retarded release. It is well known that in a freight train, when the engineer releases the brakes, those cars toward the front, receiving the air first, will have their brake-pipe pressure raised more rapidly than those in the rear. With the old standard apparatus, this is due to two things: (1) the friction in the brake pipe; (2) the fact that the auxiliary reservoirs in the front begin to re-charge, thus tending to reduce the pressure head by absorbing a quantity of air and holding back the flow from front to rear of the train. The *retarded-release feature* overcomes the second point mentioned, taking advantage of the first while doing so. The friction of the brake pipe causes the pressure to build up more rapidly in the chamber *h* of the triple valves toward the front end of the train than in those at the rear. As soon as the pressure is enough greater than the auxiliary-reservoir pressure remaining in chamber *R*—after the application as above described—to overcome the friction of piston, graduating valve, and slide valve, all three are moved toward the right until the piston stem strikes the retarding stem *31*. The latter is held in position by retarding spring *33*. If the rate of increase of the brake-pipe pressure is small—as, for example, when the car is near the rear of the train—it will be impossible to raise the pressure in chamber *h* three pounds higher than that in the auxiliary reservoir on account of the flow of air which is going on at the same time from chamber *h* through feed groove *i* into the auxiliary reservoir, the triple-valve parts will remain in this position, as shown in Fig. 51, the brakes will release and the auxiliary reservoirs re-charge, as described under "Full Release and Charging". If, however, the triple valve is near the head of the train and the brake-pipe pressure builds up more rapidly than the auxiliary reservoir can re-charge, the necessary excess of pressure in chamber *h* over that in the auxiliary reservoir will be attained quickly and will cause the piston to compress retarding spring *33* and move the triple valve parts to the position shown in Fig. 55.

Exhaust cavity *n* in the slide valve now connects port *r* leading to the brake cylinder with port *p* to the atmosphere, and the brake will release; but, as the small "tail-port" extension of cavity *n* is over exhaust port *p*, the discharge of air from the brake cylinder

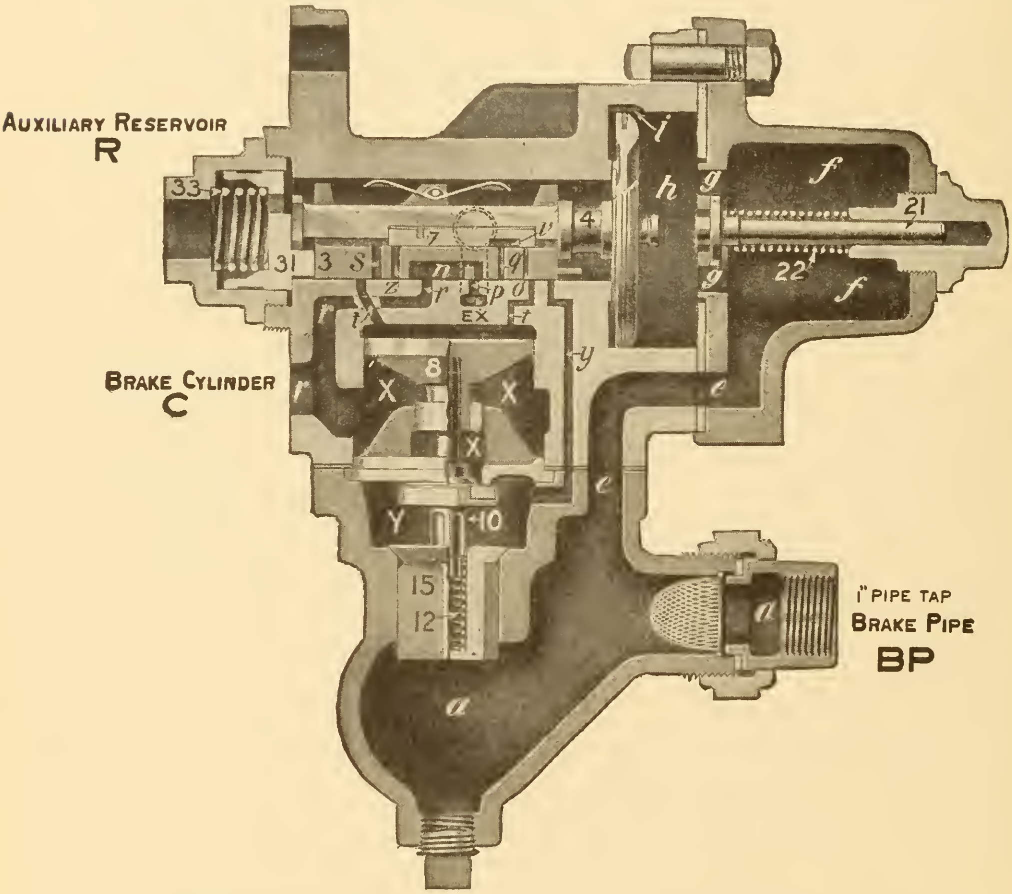


Fig. 55. Type "K" Triple Valve Shown in Retarded-Release and Charging Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

to the atmosphere is quite slow. In this way, the brakes on the front end of the train require a longer time to release than those on the rear. This feature is called the *retarded release*, and, although the triple valves near the locomotive commence to release before those in the rear, as is the case with the standard quick-action triple valve, yet the exhaust of air from the brake cylinder in retarded-release position is sufficiently slow to hold back the release of the brakes at the front end of the train long enough to insure a practically simultaneous release of the brakes on the train as a whole. This permits of releasing the brakes on very long trains at low speeds without danger of a severe shock or break-in-two.

At the same time, the back of the piston is in contact with the end of the slide-valve bush, and, as these two surfaces are ground to an accurate fit, the piston makes a tight "seal" on the end of the bush except at one point, where a feed groove is cut in the

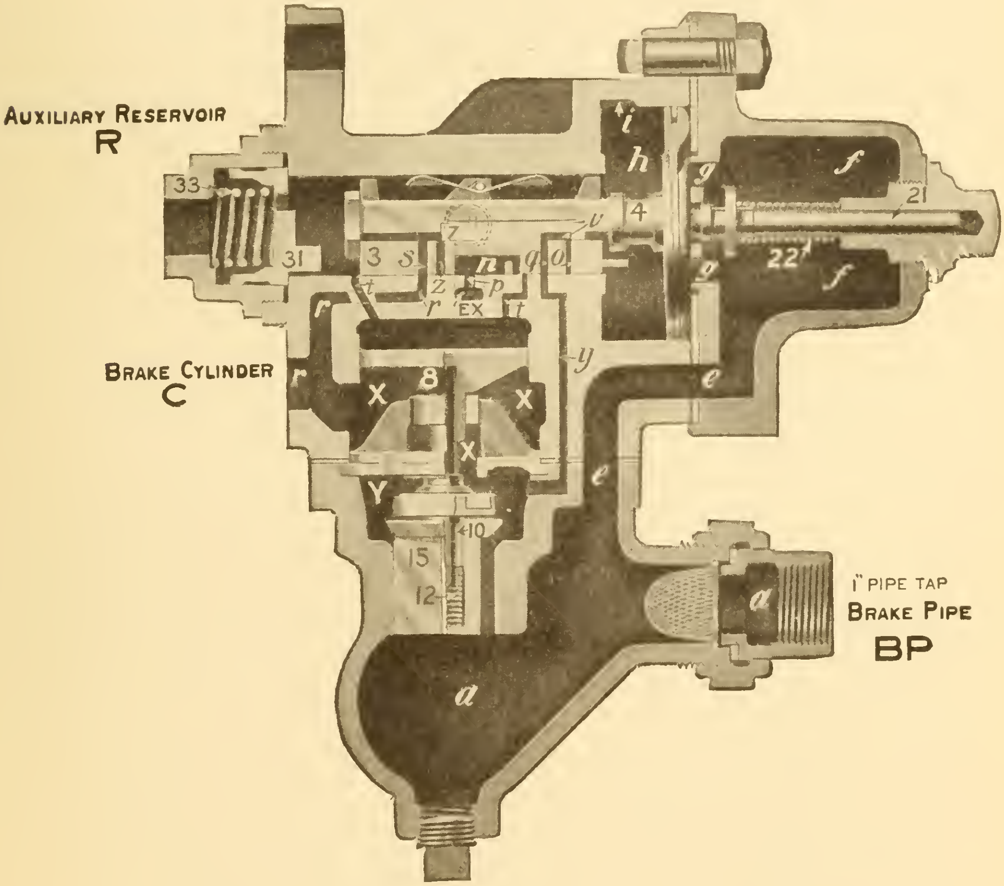


Fig. 56. Type "K" Triple Valve Shown in Emergency Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

piston to allow air to pass around the end of the slide-valve bush into chamber *R* and the auxiliary reservoir, Fig. 55. This feed groove is much smaller than the standard feed groove *i* in the piston bush, so that when the triple-valve piston is in retarded-release position, the re-charge of the auxiliary reservoir takes place much more slowly than when it is in full-release position. This feed groove is larger in the "K-2" than in the "K-1" triple valve so as to maintain the proper rate of recharge of their respective auxiliary reservoirs in retarded-release position.

As the auxiliary reservoir pressure rises and the pressures on the two sides of piston *4* become nearly equal, the retarding spring *31* forces the retarding stem, piston, slide valve, and graduating

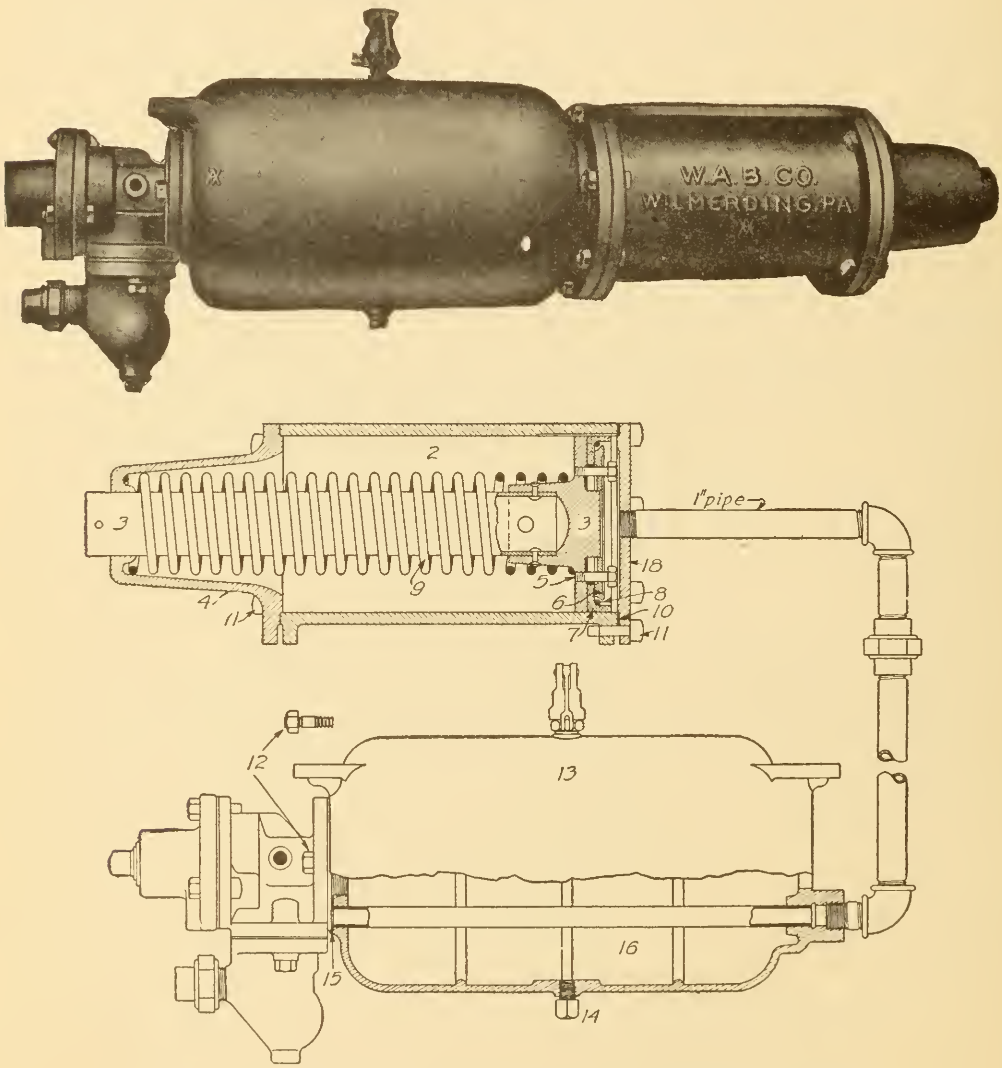


Fig. 57. Westinghouse Type "KC" Combined Freight Brake Equipment (Upper) and Type "KD" Detached Freight Brake Equipment (Lower)

valve back to the full-release position shown in Fig. 51, when the remainder of the release and re-charging will take place as described above under "Full Release and Charging".

Emergency Position. Emergency position is the same with the "K" triple valve as with the standard quick-action type. Quick action is caused by a sudden and considerable reduction in brake-pipe pressure below that in the auxiliary reservoir, no matter how caused. This fall in break-pipe pressure causes the difference in pressure on the two sides of piston *4* to increase very rapidly, so that by the time the piston has traveled to its full-service position, as already explained, there is sufficiently higher pressure on the auxiliary-reservoir side of the triple-valve piston to cause it to compress the graduating spring *22*, forcing back the stem and spring until the piston seats firmly against the gasket *23*, as shown in Fig. 56. The resulting movement of the slide valve opens port *t* in the slide-valve seat and allows air from the auxiliary reservoir to flow to the top of emergency piston *8*, forcing the latter downward and opening emergency valve *10*. The pressure in chamber *Y*, being thereby instantly relieved, allows the brake-pipe pressure to raise the check valve *15* and flow rapidly through the chambers *Y* and *X* to the brake cylinder until brake-cylinder and break-pipe pressures nearly equalize, when the check valve is forced to its seat by the check-valve spring, preventing the pressure in the cylinders from escaping back into the brake pipe again. The emergency valve, being held open by the emergency piston, will consequently return to its seat when the auxiliary-reservoir and brake-cylinder pressures have nearly equalized. At the same time, port *s* in the slide valve registers with port *r* in the slide-valve seat and allows air from the auxiliary reservoir to flow to the brake cylinder. But the size of ports *s* and *r* is such that comparatively little air gets through them before the brake pipe has stopped venting air into the brake cylinder. This sudden discharge of brake-pipe air into the brake cylinder has the same effect on the next triple valve as would be caused by a similar discharge of brake-pipe air to the atmosphere. In this way each triple valve applies the next.

The release after an emergency is effected in exactly the same manner as after a service application, but requires longer time, owing to the high brake-cylinder and auxiliary pressures and lower brake-pipe pressures.

Fig. 57 illustrates two different types of freight-brake equipment in which the type "K" triple valve is used. The lower figure represents the equipment usually found installed on steel hopper-bottom coal and coke cars, while the upper figure shows that usually found on wood box and gondola cars.

Type "L" Triple Valve. The type "L" triple valve is the outcome of a demand for a brake capable of handling heavy fast passenger trains with a greater degree of safety, flexibility, and comfort of passengers than the standard quick-action triple valve could give. It is used in connection with what is known as the L. N. Passenger Car equipment.

In order that trains may be controlled easily and smoothly when running at either high or low speeds, and that stops may

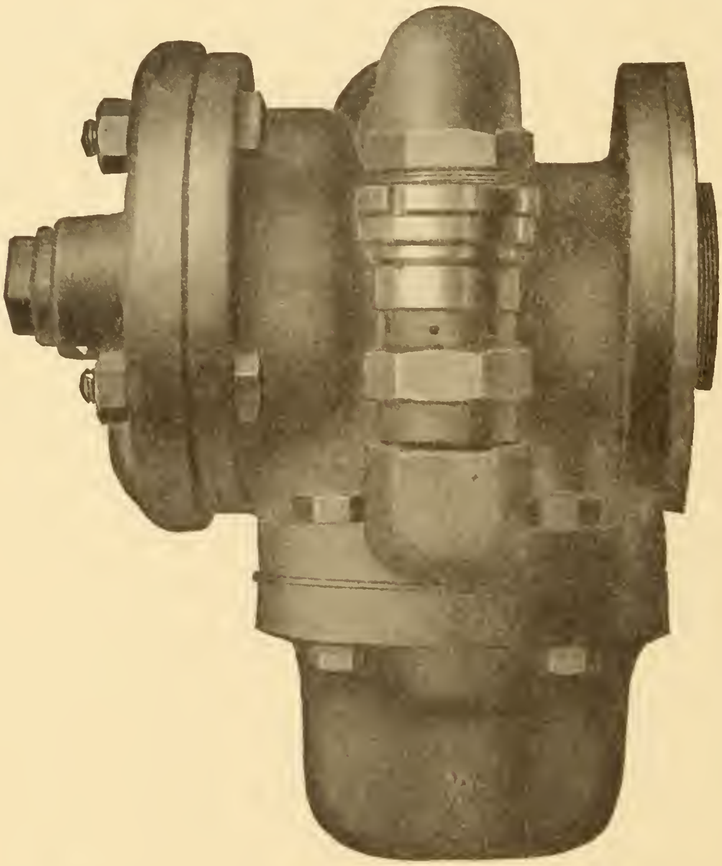


Fig. 58. Type "L" Triple Valve, Showing Safety Valve in Place
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

be made quickly and with the least liability of wheel sliding, the brake apparatus must provide the following essential features of operation:

(a) A small brake-pipe reduction must give a moderate brake-cylinder pressure and a moderate but uniform retardation on the train as a whole.

(b) It must be possible to make a heavy-service reduction quickly but without liability of quick action.

(c) It must be possible to graduate the release as well as the application of the brakes.

(d) To insure the ability to obtain brake applications in rapid succession and to full power, a quick recharging of the auxiliary reservoirs is necessary. This feature also enables the engineer to handle long trains in heavy grade work with a much greater factor of safety than heretofore and eliminates the need for pressure-retaining valves.

For high-speed trains a high brake-cylinder pressure available

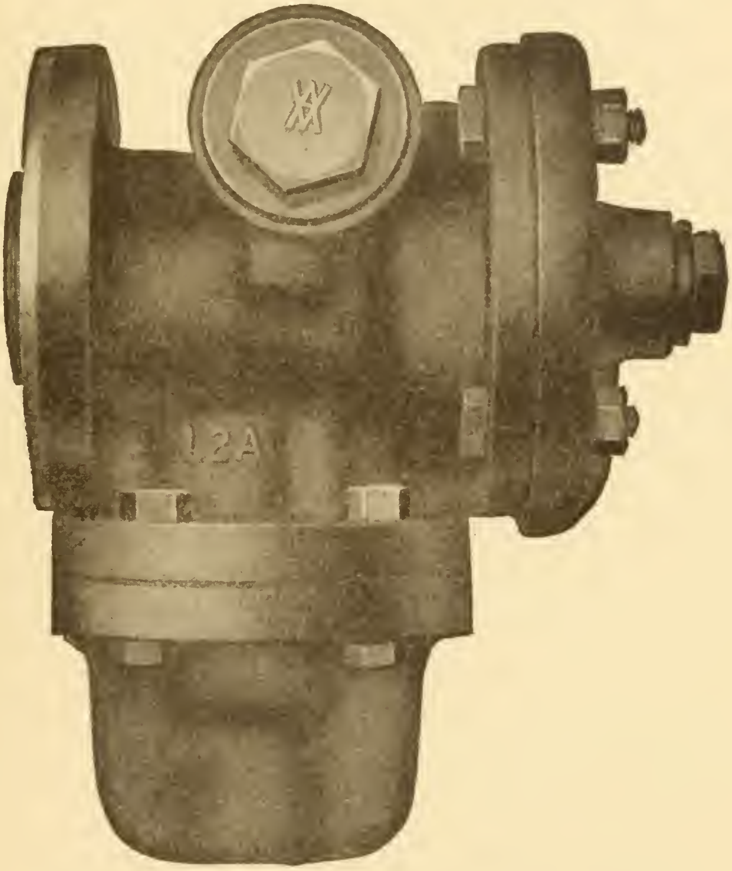


Fig. 59. Type "L" Triple Valve, Showing By-Pass Piston Cap
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

for emergency application is imperative, in order to provide a maximum braking power when the shortest possible stop is required.

New Features in "L" Type. The following new features are incorporated in the new Type "L" triple valve:

(1) *Quick recharge* (of auxiliary reservoirs), making it possible to obtain full braking power almost immediately after a release has been made.

(2) *Quick service*, by which a very quick serial *service* action of the brakes throughout the train is obtained, similar to that in emergency applications but less in degree.

(3) *Graduated release*, which permits of partly or entirely releasing the brakes on the entire train at will. This permits of the best method of braking,

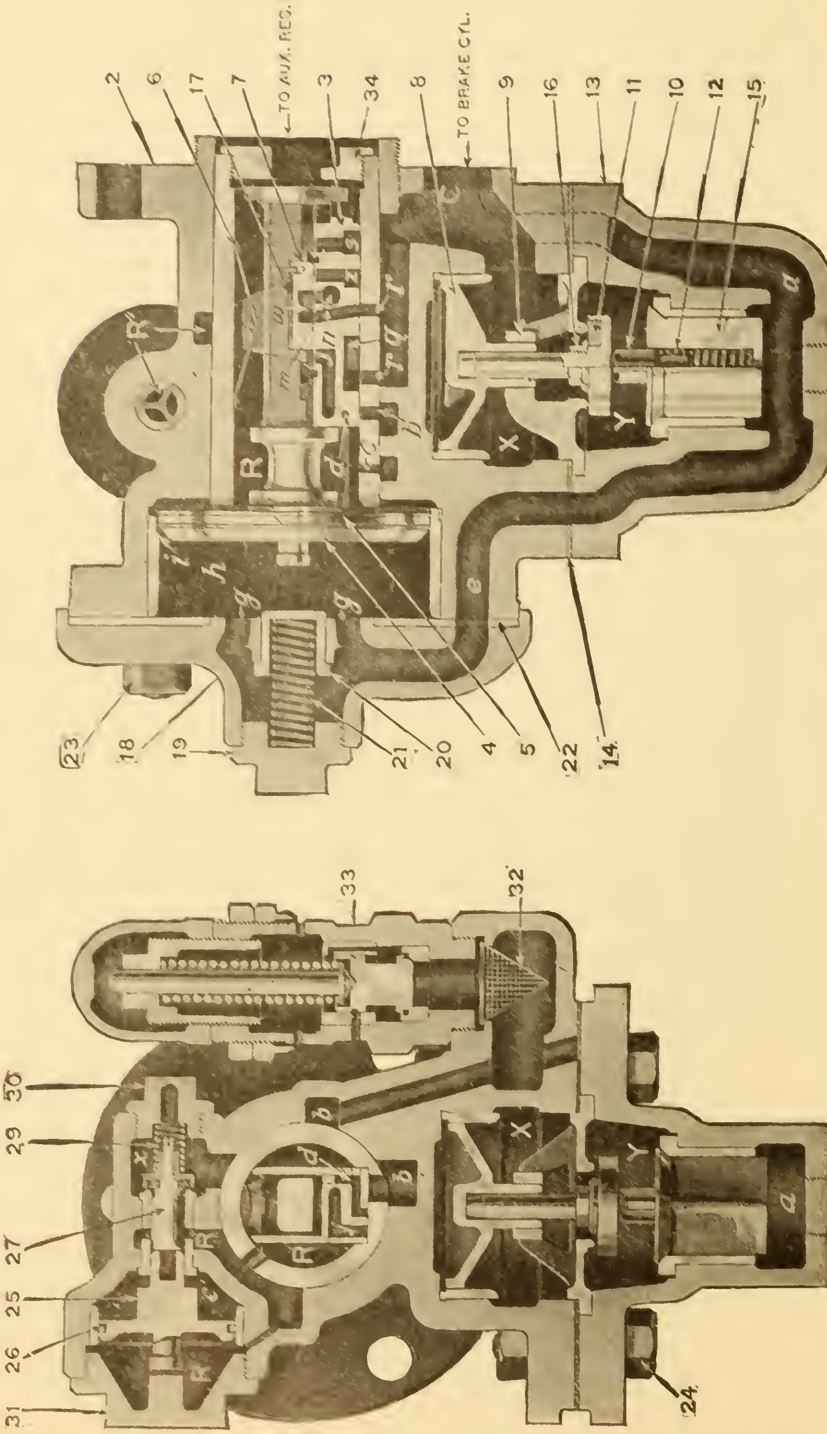


Fig. 60. Vertical Sections through Westinghouse Type "L" Triple Valve—Left, Section at Right Angles to Main Piston; Right, Section along Axis of Main Piston

namely, a heavy application at high speed, gradually reduced as the speed becomes moderate, with just enough brake-cylinder pressure left to complete the stop.

(4) *High emergency-cylinder pressure*, which greatly increases the available braking power over that obtained with a full-service reduction. As with the quick-action triple valve, the brake-pipe air is vented into the brake cylinder. The high emergency-cylinder pressure is made possible by using air from a supplementary reservoir, a reservoir about $2\frac{1}{2}$ times the capacity of the auxiliary reservoir in addition to that from the auxiliary reservoir. The use of the supplementary reservoir also makes possible the graduated-release feature.

Two illustrations of the Type "L" triple valve are given in Figs. 58 and 59. Fig. 58 is a side view showing the safety valve in place. Fig. 59 is the opposite side of the valve showing the by-pass piston cap.

Fig. 60 shows two vertical cross sections of the Type "L" triple valve with all parts numbered, the names of the parts being as follows: *2* valve body; *3* slide valve; *4* piston; *5* piston ring; *6* slide-valve spring; *7* graduating valve; *8* emergency-valve piston; *9* emergency-valve seat; *10* emergency valve; *11* rubber seat for emergency valve; *12* check valve spring; *13* check-valve case; *14* check-valve case gasket; *15* check-valve; *16* emergency-valve nut; *17* graduating-valve spring; *18* cylinder cap; *19* graduating-spring nut; *20* graduating sleeve; *21* graduating spring; *22* cylinder-cap gasket; *23* bolt and nut for cylinder cap; *24* bolt and nut for check-valve case; *25* by-pass piston; *26* by-pass piston ring; *27* by-pass valve; *28* by-pass-valve seat; *29* by-pass-valve spring; *30* by-pass-valve cap; *31* by-pass-piston cap; *32* strainer; *33* safety valve; *34* end cap.

The Type "L" triple valve is built in three sizes for use in connection with brake cylinders of different sizes as follows: Triple valve "L-1" for 8- and 10-inch cylinders; "L-2" for 12- and 14-inch cylinders; "L-3" for 16- and 18-inch cylinders.

The "L" triple valve has several recognized positions quite similar to those mentioned for other triple valves already described. In explanation of the operation of the valve, reference will be made for the sake of clearness to the diagrammatic views shown in Figs. 61 to 64. In these figures certain parts are referred to by the use of abbreviations as follows: B.P. (brake pipe); S.R. (supplementary reservoir); B.C. (brake cylinder); A.R. (auxiliary reservoir); S.V. (safety valve); EX. (exhaust).

Release and Charging Position. The valve is illustrated in release and charging position in Fig. 61.

Air from the brake pipe enters through the passages *a, e, g,* and *h,* to the face of the triple-valve piston, forcing it to release position, thence through feed groove *i* to chamber *R* and the auxiliary reservoir. Brake-pipe air in passage *a* also raises the check valve *15*, and entering chamber *Y* flows thence through the ports

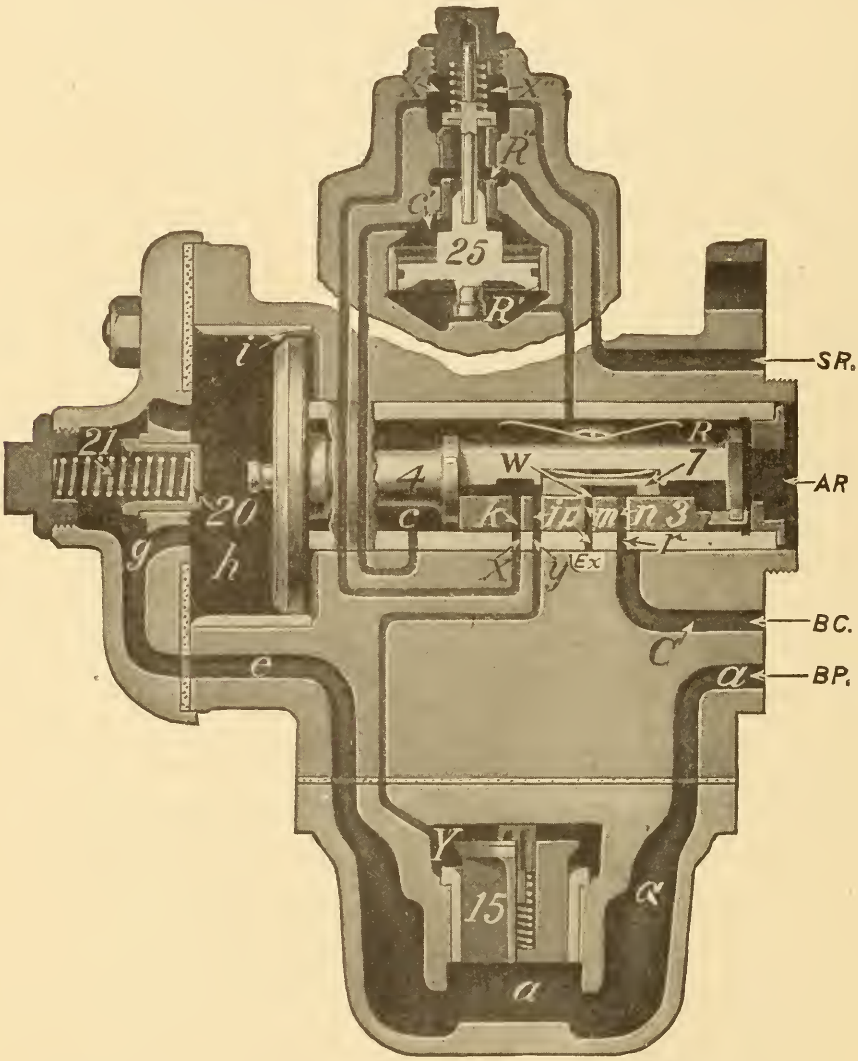


Fig. 61. Type "L" Triple Valve, Showing Release and Charging Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

y and *j* into chamber *R* and the auxiliary reservoir. This check valve then prevents any back flow of air from the auxiliary reservoir to the brake pipe. At the same time, port *k* registers with port *x*, and the air in chamber *R* also flows through these ports and x' and x'' into the supplementary reservoir. Both the auxiliary and supplementary reservoirs are thus charged at the same time and to the same pressure from the brake pipe through the two different channels already mentioned.

With the parts in the above-mentioned position, air from the brake cylinder, entering the triple valve at *C*, flows through passage *r*, port *n*, large cavity *w* in the graduating valve, and ports *m* and *p* to the atmosphere, thus releasing the brake.

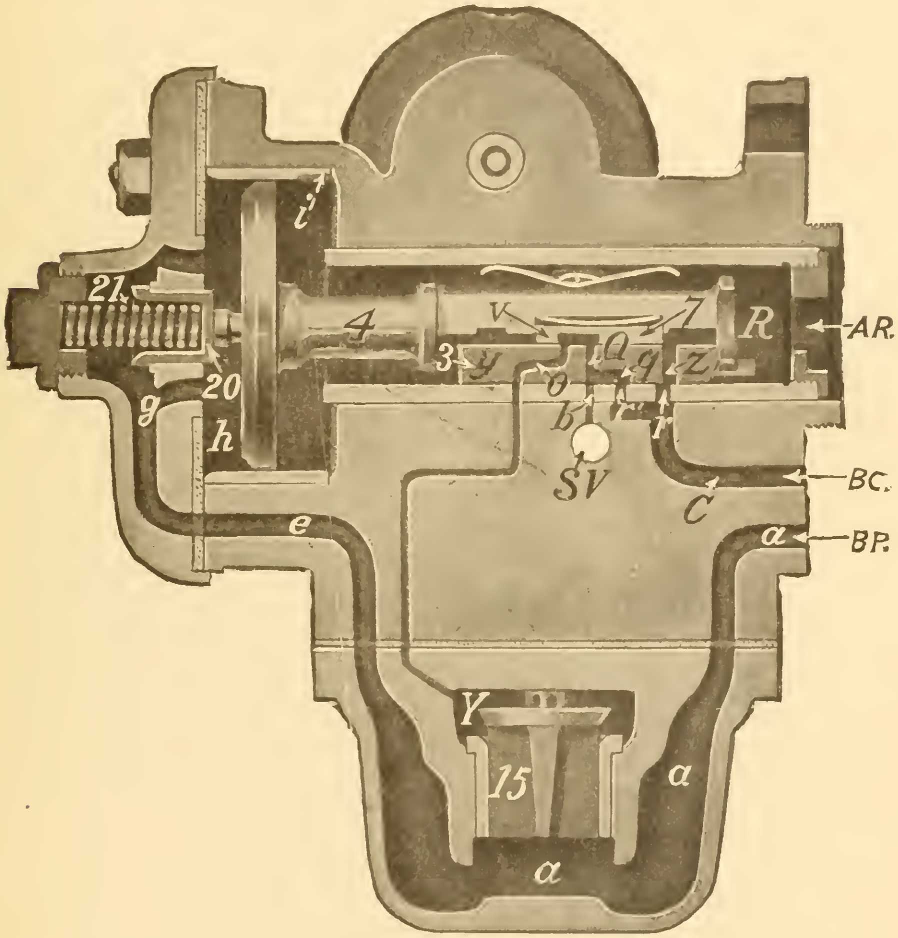


Fig. 62. Type "L" Triple Valve, Showing Quick-Service Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

Service Application. A service reduction in brake-pipe pressure reduces the pressure in chamber *h* and on the face of the triple-valve piston below that in the auxiliary reservoir on the opposite side of the piston. The higher auxiliary reservoir pressure, therefore, forces the piston in the direction of the lower brake-pipe pressure, carrying with it the attached graduating valve. The first movement of the piston closes the ports *j*, *m*, and *k*, Fig. 61, thus shutting off communication between the brake pipe and the auxiliary and supplementary reservoirs and closing the exhaust passage from the brake cylinder to the atmosphere. The same movement opens port *z* and connects ports *Q* and *o* in the main slide valve through the small cavity in the graduating valve, Fig. 62. The spider, or lugs, on the end of the main slide valve, which is carried along with the piston and graduating valve as the reduc-

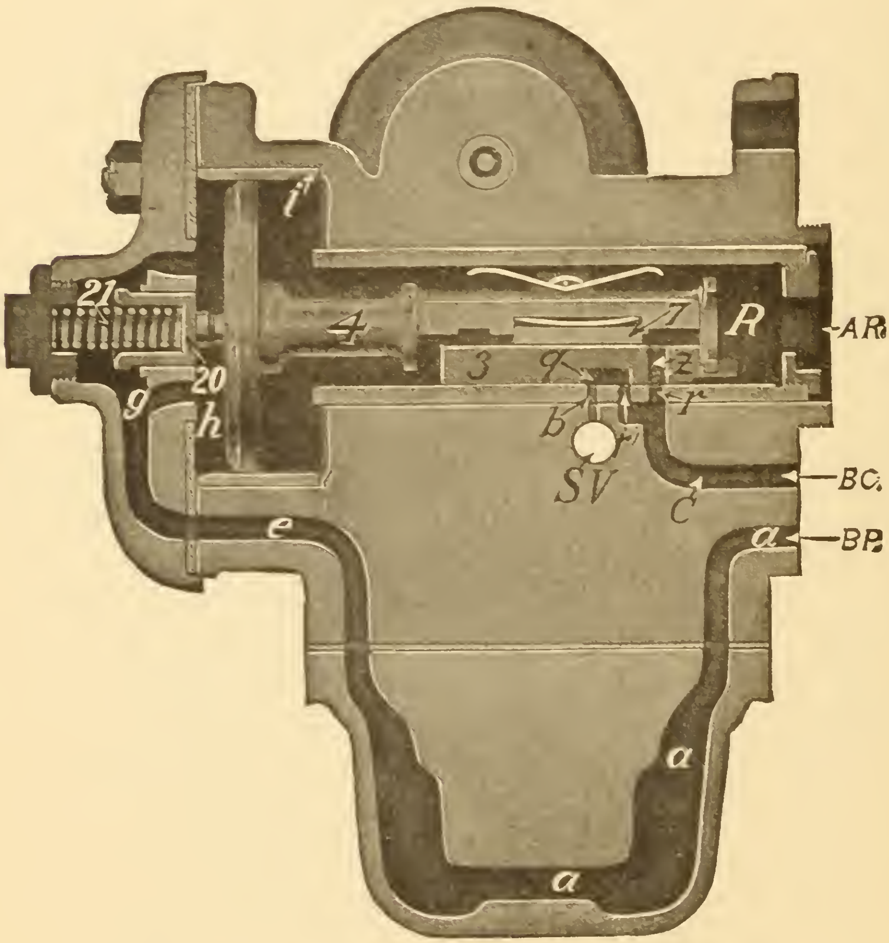


Fig. 63. Type "L" Triple Valve, Showing Full-Service Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

tion continues, finally brings the parts to *quick-service* position. Service port *z* in the slide valve registers with the brake-cylinder port *r* in the seat, permitting the air in the auxiliary reservoir to flow to the brake cylinder and apply the brakes. At the same time, the quick-service ports *o* and *Q*, cavity *q* in the slide valve, and the small cavity *v* in the graduating valve connect passage *y*, leading from the chamber *Y* in the check-valve case, with passage *r′* leading to the brake cylinder. This allows air from the brake pipe to lift the check valve and flow through the above-named ports to the brake cylinder. This constitutes the *quick-service* action of the triple valve, in that it causes a slight but definite reduction in break-pipe pressure locally at each valve. The amount of air vented from the brake pipe to the cylinder through the quick-service ports is not great in amount: first, because the ports and passages are small; and, second, because in the movement of slide valve *3* to full-service position the quick-service port *y* is restricted as it approaches this position and is completely closed just before the service port *z* is fully open. The amount by which the service port is opened depends in any given case upon the rate of reduction in break-pipe pressure as compared with that of the auxiliary reservoir. If the former is at first rapid as compared with the latter, which would be the case with short trains, the higher auxiliary-reservoir pressure moves the piston at once to *full-service* position, shown in Fig. 63, thus automatically cutting out the quick-service feature where it is not needed.

When in *full-service* position, the service port *z* is fully open and the quick-service port *o* is closed. This stops the flow of air from the brake pipe to the brake cylinder and the quick-service action ceases. The graduating spring is slightly compressed in the full-service position. In any case where the brake-pipe reduction is so rapid that the quick-service feature is of no advantage, the difference of pressure on the two sides of the triple-valve piston becomes at the same time sufficient to compress the graduating spring and automatically close the quick-service port. But if the brake-pipe reduction is less rapid or slow, as in the case of long trains or moderate-service reductions, a partial opening only of the service port is sufficient to preserve a balance between the pressure on the two sides of the triple-valve piston. The service port connecting the auxiliary reservoir to the brake cylinder is much larger than the quick-service port connecting the brake pipe to the brake cylinder. This serves to effectually prevent an emergency application being obtained when only a service application is desired.

During the time the slide valve *3* remains in quick- or full-service position the cavity *q* connects the brake-cylinder port *r′*

with port *b* leading to the safety valve, which is ordinarily set for 62 pounds. In event of the brake-cylinder pressure rising to 62 pounds, the safety valve acts and prevents further pressure increase in the brake cylinder.

Lap Position. After sufficient reduction of brake-pipe pressure has taken place to apply the brake to the desired amount, the flow of air from the auxiliary reservoir to the brake cylinder will reduce the pressure on the reservoir side of the triple-valve piston slightly below the brake-pipe pressure. The slightly excess pressure, together with the slightly compressed graduating spring, will move the piston and graduating valve to *lap* position. In this position all ports are blanked by the graduating valve, and the air flowing to the brake cylinder will be stopped. The slight difference in pressure which caused the piston to move is not sufficient to move the slide valve *3* when the piston-stem shoulder comes in contact with the slide valve. Therefore, there is no further movement of triple-valve parts until conditions are changed.

The *lap* position of the slide valve *3* is determined by the position previous to lap. The graduating valve is the only valve moved in obtaining *lap* position; so if the slide valve is in quick-service or full-service position, the lap position obtained will be quick-service lap or full-service lap.

Release and Recharge. When the brake-pipe pressure is increased to release the brake, the pressure on the brake-pipe side of the piston causes the piston to move, and with it the slide valve and graduating valve, to the extreme right, as shown in Fig. 61.

In this position the air in the brake cylinder is exhausted through ports *r* and *n*, the large cavity *w* in the graduating valve and port *m* to the exhaust passage *p* and atmosphere, as previously described. Meanwhile, the auxiliary reservoir is being recharged from the brake pipe through the ports *y* and *j* and feed groove *i*. At the same time, port *x*, leading from the supplementary reservoir, is open through port *k* to the auxiliary reservoir. The air, which was prevented from leaving the supplementary reservoir by movement of the slide valve to service position, now flows into the auxiliary reservoir and helps to recharge it.

During the time the slide valve is in release position, the pressures on the brake pipe and auxiliary reservoir sides of the triple-valve piston are always balanced. This is of importance, as it insures a quick response of the brakes to any reduction or increase in brake-pipe pressure irrespective of what operation may have occurred immediately preceding. The supplementary reservoir is at the same time being re-charged, as has been previously explained.

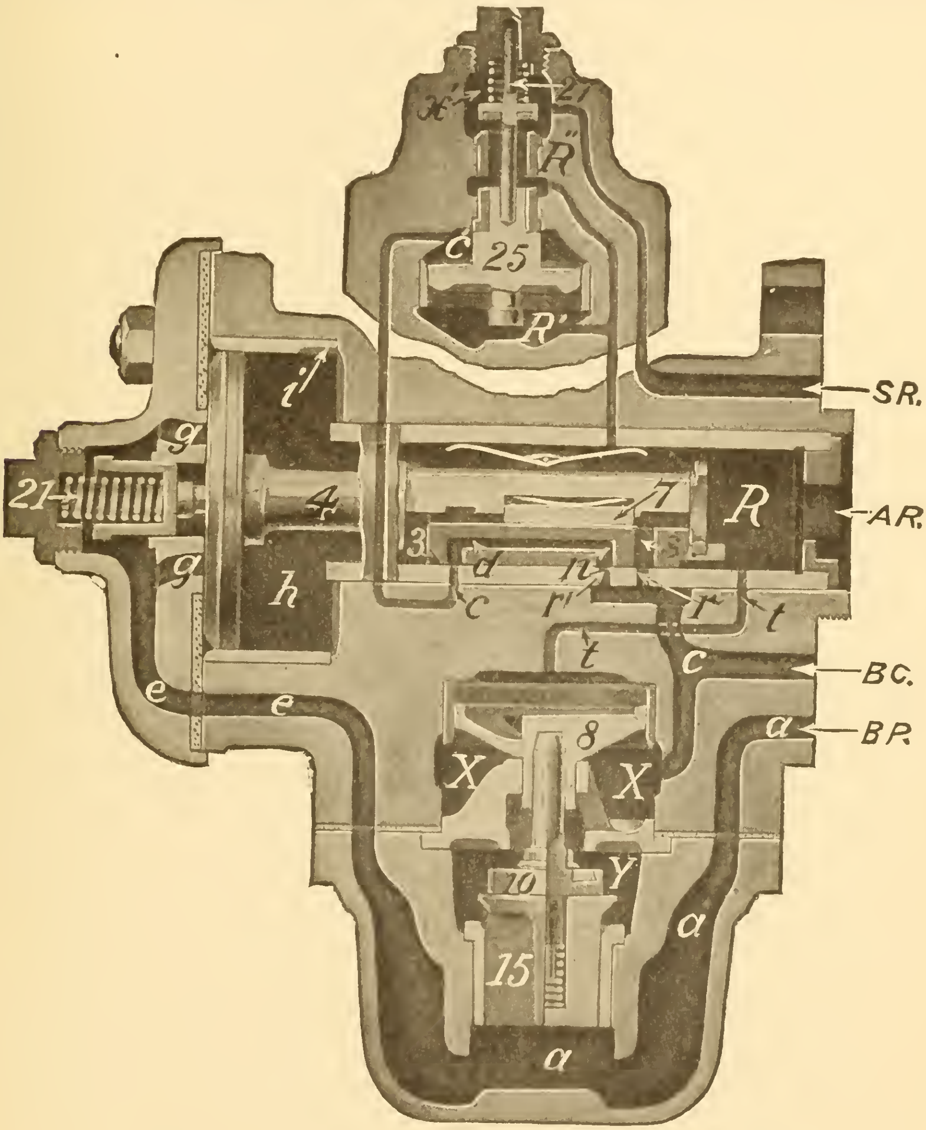


Fig. 64. Type "L" Triple Valve, Showing Emergency Position
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

Graduated Release. Suppose that, after the brakes have been applied, only sufficient air is permitted to flow into the brake pipe to move piston *4* with the slide and graduating valve to release position, and the engineer's brake-valve handle is then returned to lap position. Then the flow of air from the supplementary reservoir through ports x and k to the auxiliary reservoir continuing after the rise in break-pipe pressure has ceased will raise the pressure on the auxiliary-reservoir side of the triple-valve piston slightly above that on the break-pipe side and cause the piston and its attached graduating valve to move to the left to graduated release-lap position.

In this position the graduating valve closes the exhaust port m, Fig. 61, thus preventing further flow of air from the brake cylinder to the atmosphere. It also closes port k—which prevents further recharging of the auxiliary reservoir from the supplementary reservoir—and port j and feed groove i, which cuts off the supply of air from the brake pipe to the auxiliary reservoir. Thus the brake is only partly released and a portion of the air pressure originally in the brake cylinder still remains there. In this way the brake may be released in a series of steps or graduations.

Emergency Position. When the brake-pipe pressure is reduced suddenly, or its reduction continues to be more rapid than that of the auxiliary-reservoir pressure, the piston is forced to the extreme left and compresses the graduating spring. The parts are then in emergency position, as shown in Fig. 64. In this position air from the auxiliary reservoir enters the brake-cylinder passage r through the port s in the main slide valve, instead of port z as in service application. Port t in the seat is also uncovered by the end of the main slide valve, thus admitting air from the auxiliary reservoir through port t to the top of the emergency piston. The air pressure thus admitted to the top of this piston pushes it down and forces the rubber-seated emergency valve from its seat. This allows the brake-pipe air in passage a to lift the emergency check valve and flow through chambers Y and X to the brake cylinder C in the ordinary way. At the same time, port d in the main slide valve registers with port c in the seat. This allows air from behind the by-pass piston to flow through ports c, d, and n to r' and the brake cylinder. As there is no pressure in the brake cylinder at this instant, the by-pass piston with its attached by-pass valve is forced upward, diagrammatically (or inward, actually) by the auxiliary-reservoir pressure acting on the lower (or outer) side of the piston. The air in the supplementary reservoir then flows past this valve into the passageway leading to the auxiliary reservoir. It thereby adds to the latter the volume of the supplementary reservoir. This gives, in effect, an auxiliary-reservoir volume approximately three and one-half times the size of the one which supplies air to the brake cylinder in service applications. Air from the supplementary reservoir continues to flow to the auxiliary reservoir until the pressure in the latter and that in the brake cylinder have risen nearly to that remaining in the supplementary reservoir. Communication

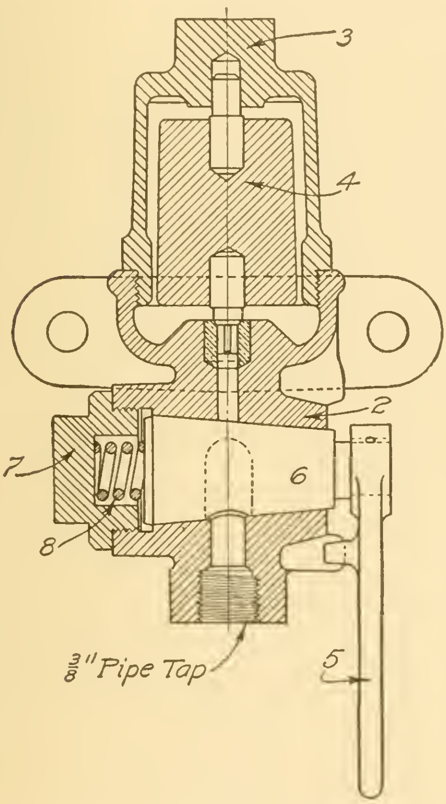


Fig. 65. Single-Pressure Retaining Valve, Open

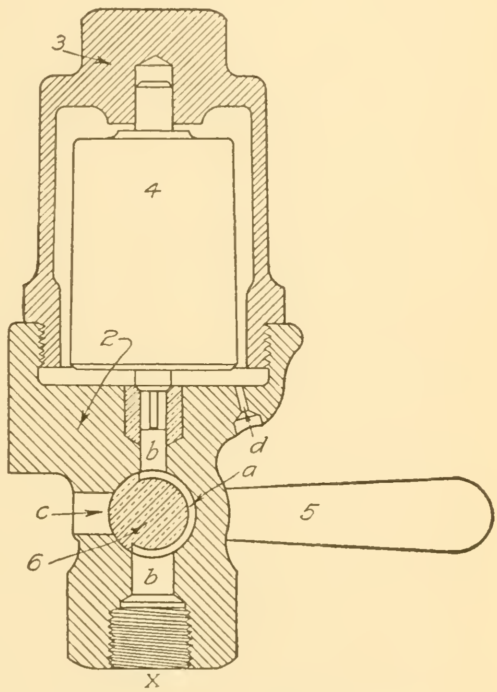


Fig. 66. Single-Pressure Retaining Valve, Closed

is then closed between the two reservoirs by means of the by-pass valve spring and valve.

In emergency position the communication with the safety valve is cut off and the pressure is held until the brake is released.

MISCELLANEOUS TYPES OF VALVES

Pressure Retaining Valve. The pressure retaining valve is a regular part of all freight car equipment and is furnished with passenger car equipments only on special order. It is usually fastened on the end of the car, by means of lag screws, in a convenient position, and is connected to the triple-valve exhaust port by the retaining-valve pipe. Pressure retaining valves are built in two types: namely, plain, or single-pressure; and combined high- and low-pressure.

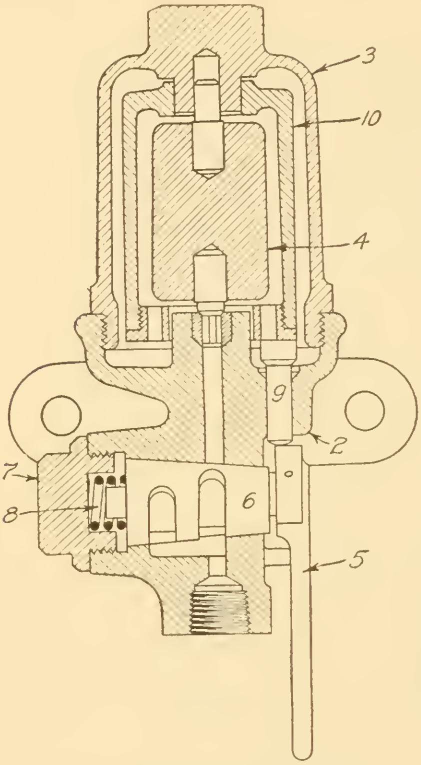


Fig. 67. High- and Low-Pressure Retaining Valve Section

The plain, or single-pressure, retaining valve, Figs. 65 and 66, consists of a plug cock *6* connected to the retaining valve pipe at *X* and having two outlets, one to the atmosphere and the other to the retaining valve proper. This latter consists of a weighted valve *4* normally resting on a seat *2* and holding port *b* closed. When the handle *5* of the retaining valve is turned down, the groove *a* in the cock key connects port *b* and the outlet *c* to the atmosphere. Consequently, when "turned down" the triple-valve exhaust is open through tne retaining-valve pipe, port *b*, groove *a*, and exhaust port *c* to the atmosphere. When the retaining-valve handle is "turned up" to the horizontal position, Fig. 66, groove *a* connects port *b* below the cock key with port *b* above it, so that when a release is made, the air exhausting from the brake cylinder flows to the retaining valve and through port *b*, cavity *a*, and upper port *b* to the weighted valve *4*, which it must lift in order to flow past valve *4* to the atmosphere through the small port *d*. The weight *4* is capable of retaining a pressure of 15 pounds in the brake cylinder. As long as the pressure of the air from the brake cylinder is greater than this, it holds the valve *4* from its seat and the air exhausts to the atmosphere through port *d*, which, being

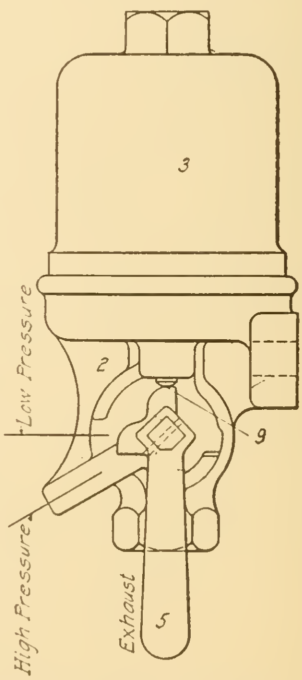


Fig. 68. High- and Low-Pressure Retaining Valve, Showing Three Positions

small, makes the release of the brake much slower than when the retaining valve is not used. When the pressure has been reduced to 15 pounds, it is no longer able to hold the weighted valve *4* off its seat and the valve then closes and the remaining 15 pounds is retained in the brake cylinder until the handle *5* is turned down. When used on vestibuled passenger cars, the valve is provided with an extension handle to permit of its being conveniently operated from the platform.

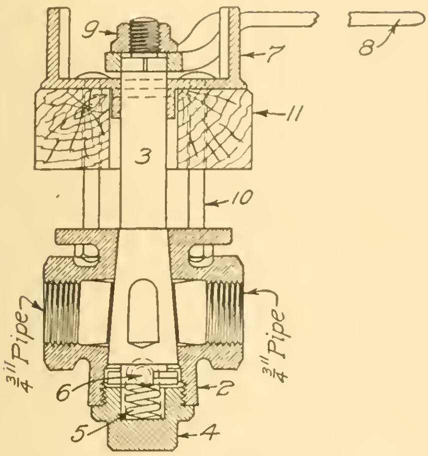


Fig. 69. Simple Conductor's Valve

High- and Low-Pressure Retaining Valve. Under extreme conditions of heavily loaded trains on grades, it is often necessary to provide for retaining more than 15 pounds in the brake cylinder. The high- and low-pressure retaining valve, Fig. 67, is used for this purpose. This is similar to the valve just described except that a cylindrical weight *10*, surrounding the usual weighted valve *4*, is added. When the handle *5* is "turned down", air from the brake cylinder passes freely to the atmosphere, as explained, and a lug on handle *5* raises the lifting pin *9* and the outer weight *10* so that the smaller weight *4* alone rests on the valve seat and the wear is reduced to a minimum. When the handle is "turned up" to a horizontal position, as in the case of the plain, or single-pressure, retaining valve, another lug on the handle raises lifting pin *9* and the outer weight *10* so that the smaller weight *4* alone acts to retain 15 pounds pressure in the brake cylinder in the manner already described.

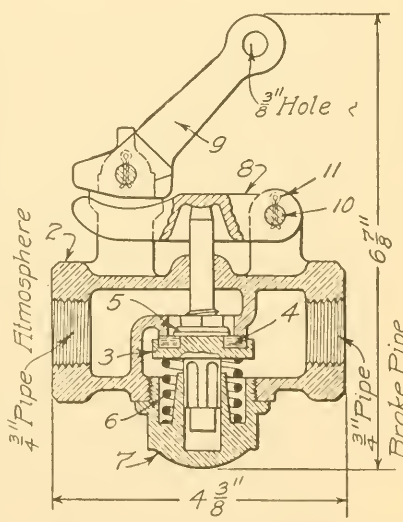


Fig. 70. "B-3-A" Conductor's Valve

When it is desired to retain a higher pressure in the brake cylinder, the handle is placed in the intermediate position marked "High Pressure", Fig. 68. This permits the lifting pin *9* to drop away from the outer weight *10*, Fig. 67, which then rests on the inner weight *4* and the air pressure must then lift both weights, the combined weight of which is capable of retaining 30 pounds in the brake cylinder before it can escape to the atmosphere. Conditions in some sections of the country require relatively lower pressures to be retained. To meet this demand, retaining valves are built to retain

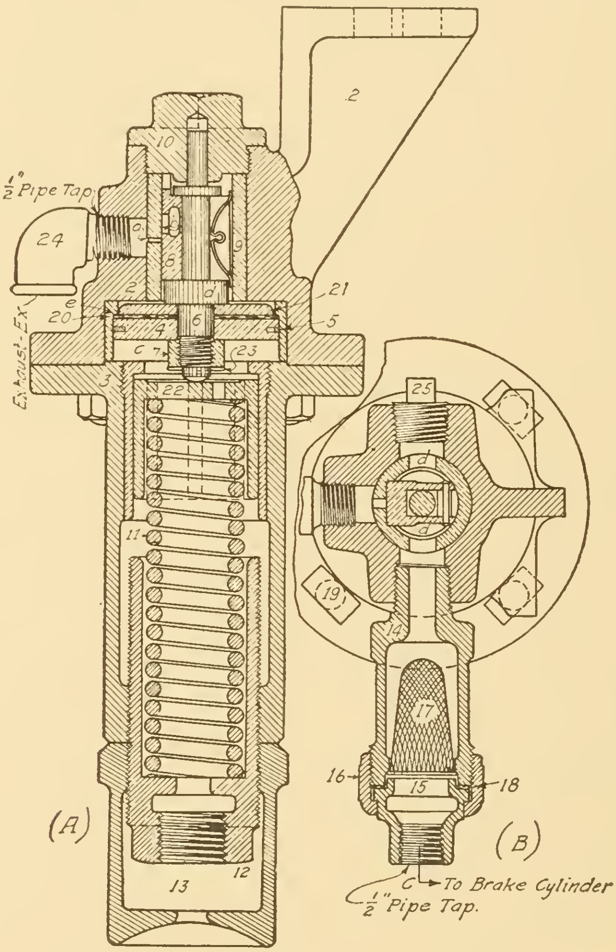


Fig. 71. Westinghouse High-Speed Reducing Valve

pressures from 10 to 25 pounds. Where it is desired to retain higher pressures, they are built as high as 50 pounds.

Conductor's Valve. The conductor's valve, Fig. 69, is a part of all passenger car equipments and is now in common use. Fig. 70 illustrates the type of valve now being furnished. It is connected to a branch pipe leading from the brake pipe and is conveniently located inside of the car, so that in case of an emergency or necessity it can be reached. Frequently a cord is attached to the handle which runs the entire length of the car and permits of the opening of the valve with the least possible delay. The valve most commonly used is of the non-self-closing plug-cock type. When the valve is opened, it permits air from the brake pipe to escape freely to the atmosphere, causing a quick-action application of all brakes in the train. After making a stop in this manner, the valve must be closed before the brake pipe and system can be re-charged and the brakes released.

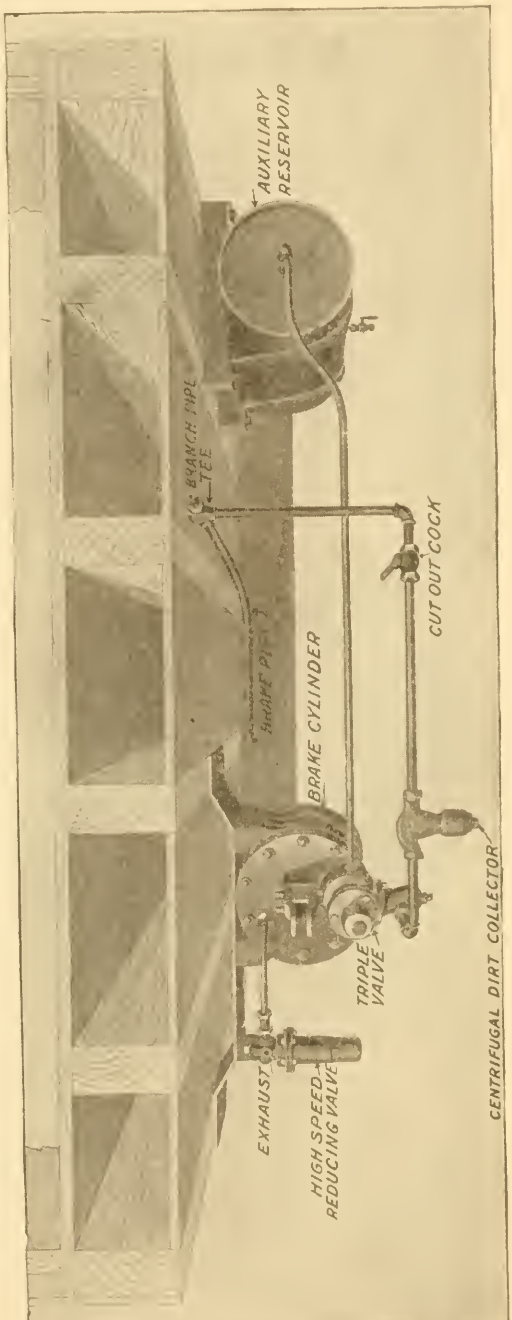


Fig. 72. Westinghouse High-Speed Reducing Valve Applied to Car

High-Speed Reducing Valve. It has been known for a good many years that as the speed of the train is increased, the maximum brake-shoe pressure may also be increased without danger of skidding the wheels. That is, a train going at a speed of 80 miles an hour would require a much greater brake-shoe pressure to skid the wheels than a train going 5 miles an hour. This fact has been taken advantage of in the design of the high-speed brake equipment. Instead of carrying a brake-pipe pressure of 70 pounds, a much higher pressure is used, the usual pressure being 110 pounds. When a full-service application is made, about 85 pounds pressure is obtained in the brake cylinder. If this pressure were allowed to continue in the brake cylinder until the train stopped, there would be danger of skidding the wheels. In order to prevent this, a valve known as the automatic high-speed reducing valve is used. The construction of this valve is shown in Fig. 71 and Fig. 72 illustrates the application of the valve to a car.

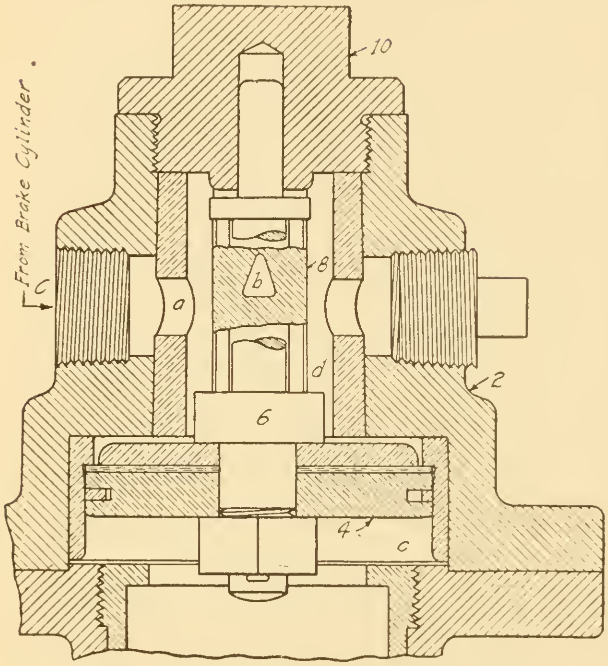


Fig. 73. Position of Ports for Release Position

Method of Action. When air enters the brake cylinder from the auxiliary reservoir, it has free access to the reducing valve through a pipe at *C* in section *B*, Fig. 71, so that chamber *d* above piston *4* is always subject to brake-cylinder pressures. Regulating spring *11*, adjusted by nut *12*, provides a resistance to the downward movement of piston *4*, which is finally stopped by spring box *3*. Connected to piston *4* is its stem *6*, fitted with two collars which control the movements of slide valve *8*. Slide valve *8* is provided with a triangular port *b* in its face, which is always in communication with chamber *d*. Port *a* in the slide valve seat leads directly to the atmosphere through exhaust opening *Ex*.

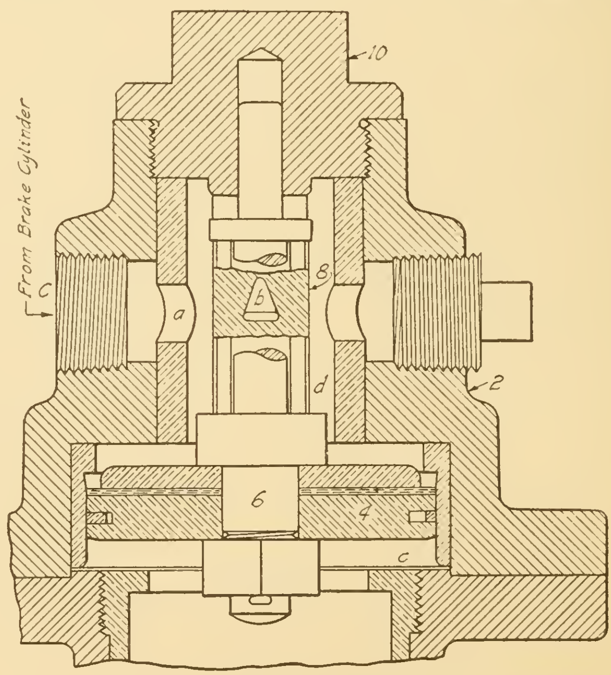


Fig. 74. Position of Ports, Service Stop, Pressure Exceeding 60 Pounds in Brake Cylinder

Normal Position. Fig. 71*A* shows slide valve *8* and its piston *4* in normal positions, which are held if brake-cylinder pressure does not exceed 60 pounds.

Release Position. In release position, Fig. 73, it will be noted that port *b* of slide valve *8* does not register with port *a* of its seat, so that when the brakes are applied they will remain so until released in the usual way, unless the brake-cylinder pressure becomes sufficiently great to overcome the tension of spring *11* and force piston *4* downward.

Heavy-Service Application. When the brake-cylinder pressure begins to exceed 60 pounds, in a heavy-service application, the pressure upon piston *4* moves it downward until port *b* in the slide valve registers with port *a* in its seat, as shown in Fig. 74, in which position any surplus brake-cylinder pressure is promptly discharged to the atmosphere. The spring then raises the piston and slide valve to their normal positions, closing the exhaust port and retaining 60 pounds pressure in the brake cylinder. In the operation just described, the greatest width of port *b* is exposed to port *a*, and these ports are so proportioned that, in this particular position, the surplus air is discharged from the cylinder fully as rapidly as it is admitted through the service-application port of the triple valve.

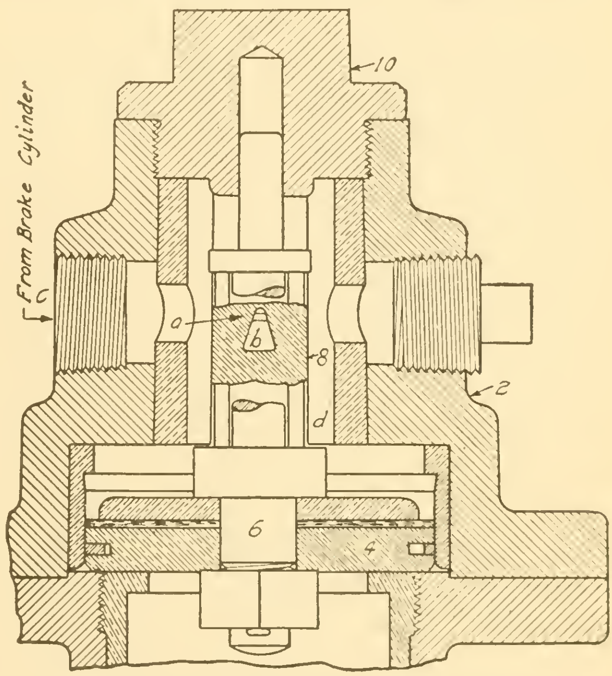


Fig. 75. Position of Ports, Emergency Stop for Westinghouse High-Speed Reducing Valve

Emergency Application. In an emergency application of the brakes, the rapid admission of a large volume of air to the brake cylinder raises the pressure more quickly than it can be discharged through the service port of the pressure-reducing valve. Under these conditions, piston *4* of the high-speed reducing valve, Fig. 75, is forced to the lower end of its stroke, in which position the apex of triangular port *b* in the slide valve is brought to register with port *a*, thus restricting the discharge of air from the brake cylinder in such a manner that the pressure in the brake cylinder does not become reduced to 60 pounds until the speed of the train has been very materially decreased; but the area of the opening of port *b* gradually increases as the reducing pressure above piston *4* permits the spring to raise the piston and slide valve slowly. The rate of the discharge thus increases as the speed of the train decreases, until finally, when the brake-cylinder pressure has become reduced to 60 pounds, port *a* is closed, and the remainder of the brake-cylinder pressure is retained until released in the usual way through the triple valve.

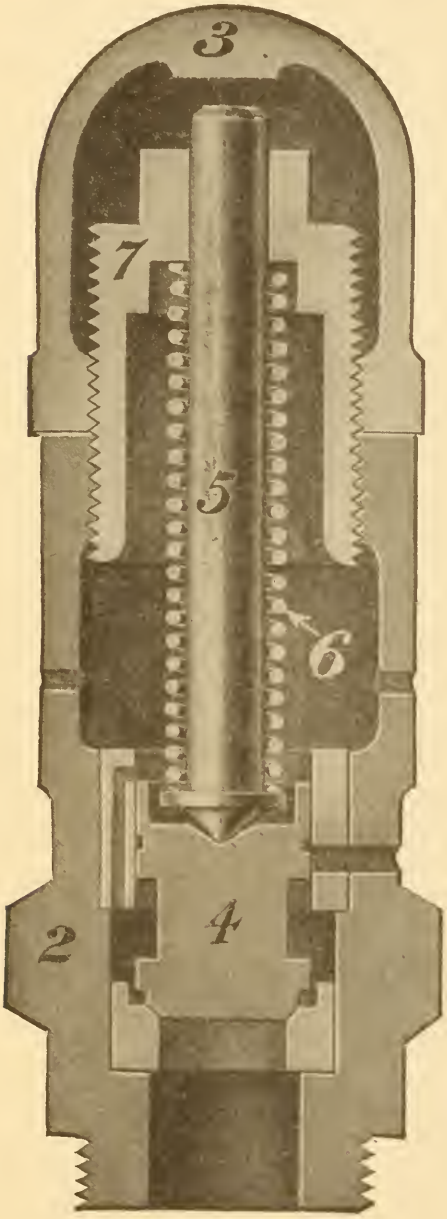


Fig. 76. "E-6" Safety Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

When an emergency application of the brakes occurs at high speeds, there is little danger of wheel sliding, and it will be observed that port *b* is so shaped that brake-cylinder pressure escapes slowly at such time, as already explained; while, at lower speeds, where a heavy-service application is more likely to occur and there is a greater tendency toward wheel sliding, the base of triangular port *b* is exposed, allowing brake-cylinder pressure to reduce quickly.

Cars not equipped with the reducing valve should not be attached to trains employing the high-speed brake equipment unless the brake cylinders are equipped with a safety valve provided for temporary use in such cases.

"E=6" Safety Valve. The "E-6" safety valve forms an important part of several different air-brake equipments. This is especially true of the "ET" locomotive brake equipment. Its form of construction and operation is clearly shown in Fig. 76, which is a vertical section of the valve. Its construction is such as to cause it to close quickly with a *pop* action, which insures a firm seating. Valve *4* is held to its seat by the compression of spring *6*. When the pressure

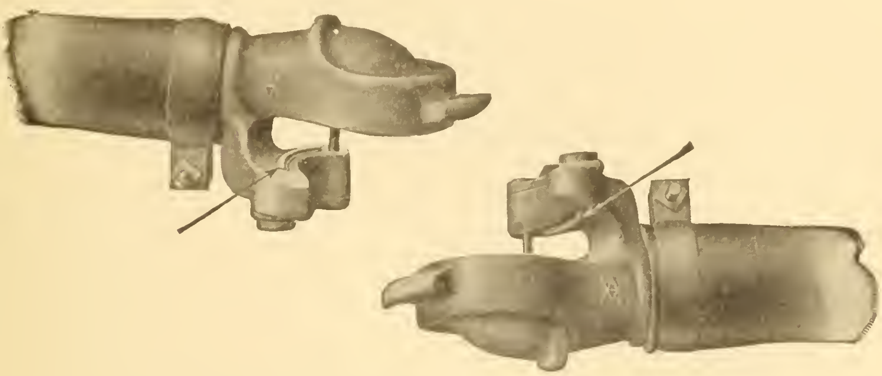


Fig. 77. Hose Protecting Coupling, Showing Flexible Head
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

below valve *4* overcomes the spring pressure above, it rises until valve stem *5* is stopped by cap nut *3*. The air in discharging passes around valve *4* and out at ports in the body *2*, one of which is shown. As the pressure drops, valve *4* moves downward slightly and partly closes the discharge ports in the body *2*. Air then flows to the spring chamber and assists the spring in closing the valve, thus assisting in the "pop" action referred to above.

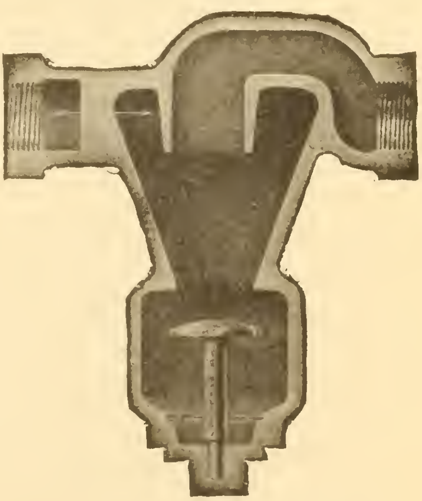


Fig. 78. Centrifugal Dirt Collector
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

Two of the important brake-pipe fittings are shown in Figs. 77 and 78, Fig. 77 showing the scheme used in joining the flexible hose between cars. When uncoupled, the hose should always be attached to the dummy coupling to keep the hose from being injured by swinging and to prevent cinders and dirt from getting into the brake pipe. The hose should always be parted by hand and not pulled apart by the separation of the cars. Fig. 78 illustrates the type of centrifugal dirt collector. It is placed in the branch pipe leading to the triple valve. The centrifugal dirt collector replaces the older form of strainer which has been common for a number of years. It can be cleaned by removing the plug at the bottom.

BRAKES AND FOUNDATION BRAKE GEAR

General Requirements. The foundation brake gear includes all levers, rods, beams, pins, etc., which serve to transmit the braking force from the piston of the brake cylinder to the brake shoes. It is important that all longitudinal rods should be parallel with the center line of the car, when the brakes are fully applied. The brake beams should be hung in such a manner that they will always be the

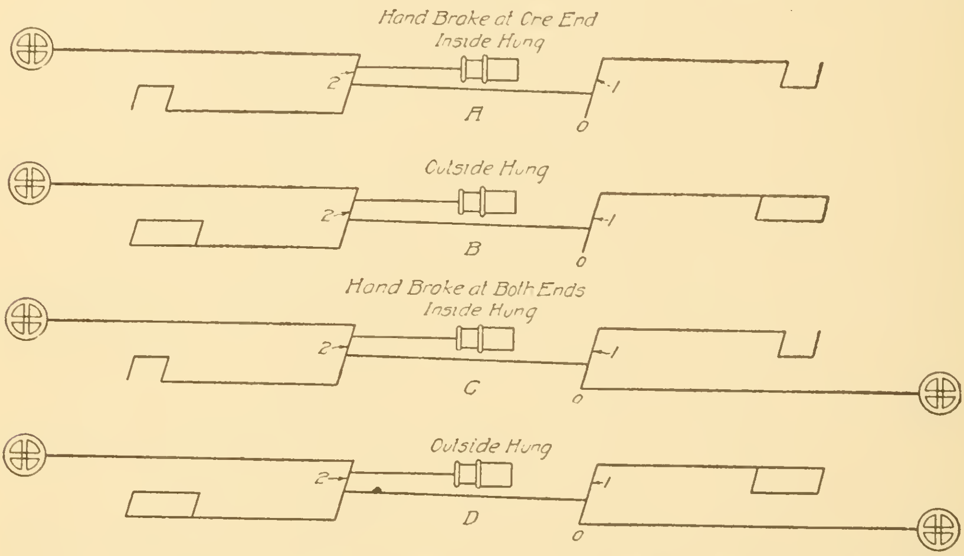


Fig. 79. Foundation Brake-Gear Systems Adopted by Master Car Builders' Association

same distance above the rail, the reason being that this practice reduces the chance for flat wheels, since the piston travel is not affected by the loading or unloading of the car. The rods and levers should be designed so that they will move in the same direction when the brakes are applied by hand as when by air. The levers should stand approximately at right angles to the rods, when the brakes are set.

A number of different systems of rods and levers have been used by different railroad companies, with varying degrees of success. The systems adopted by the Master Car Builders' Association are diagrammatically shown in Fig. 79. The four cases shown represent two general systems—those where the brake shoes are hung inside, between the truck wheels; and those where they are hung outside. Freight cars are generally fitted with the brake shoes hung inside, while the passenger cars usually have the brake shoes hung outside. In the first two cases (*A* and *B*), the brake can be applied by hand from only one end of the car; while in the other two cases (*C* and *D*), the brake can be operated by hand from either end. In applying the brake by hand in any case, the coil spring in the brake cylinder offers no resistance, since the push rod has no pin connection to the piston rod. The piston rod of the brake cylinder is hollow. When the brake is operated by hand, the push rod slides outward in the hollow rod without moving the piston. A detailed description of the operation of the four cases shown is not thought necessary. One or two points, however, might assist to a clearer understanding of them. The lower end of the lever *1* in *A* and *B* is fixed at *O*. The lower end of the lever *1* in *C* and *D* is held by a stop at *O* and cannot move to the left, but is free to move to the right when the brake is operated by hand from the right-hand end of the car. The lever *2* in all four cases has no fixed points. In all cases, the arrangement is such that no brake shoe will

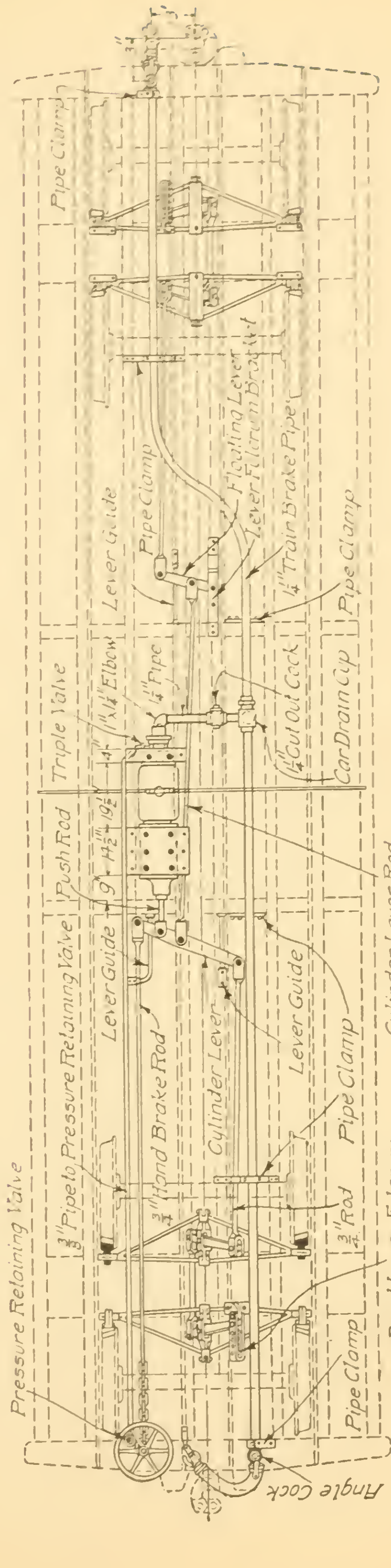
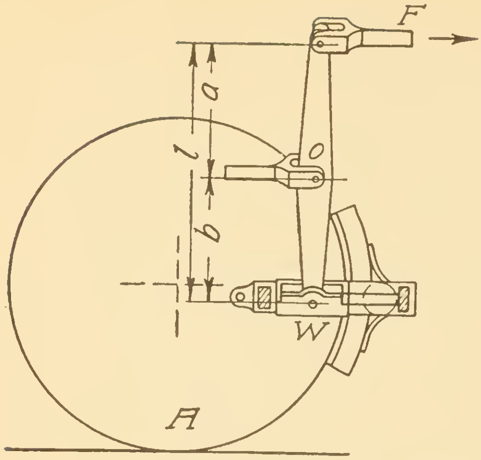


Fig. 80. Application, to a Freight Car, of Inside-Hung Brake-Gear System Shown at *A* in Fig. 79



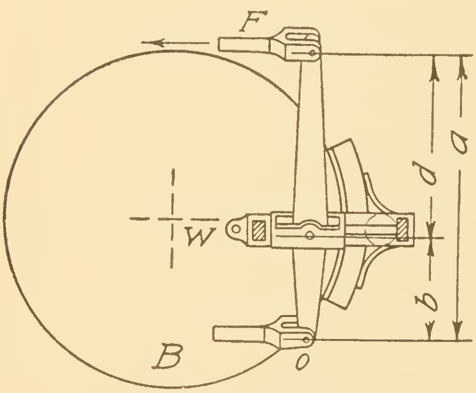
$$W = \frac{F \times a}{b};$$

$$F = \frac{W \times b}{a}; \quad l = a + b;$$

$$a = \frac{W \times b}{F}; \text{ or, } a = \frac{W \times l}{F + W};$$

$$b = \frac{F \times a}{W}; \text{ or, } b = \frac{F \times l}{F + W}.$$

FULCRUM BETWEEN APPLIED AND DELIVERED FORCES



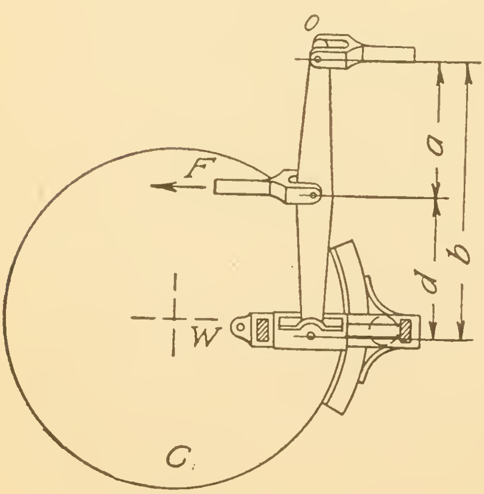
$$W = \frac{F \times a}{b};$$

$$F = \frac{W \times b}{a}; \quad a = b + d;$$

$$a = \frac{W \times b}{F}; \text{ or, } a = \frac{W \times d}{W - F};$$

$$b = \frac{F \times a}{W}; \text{ or, } b = \frac{F \times d}{W - F}.$$

DELIVERED FORCE BETWEEN FULCRUM AND APPLIED FORCE



$$W = \frac{F \times a}{b};$$

$$F = \frac{W \times b}{a}; \quad b = a + d;$$

$$a = \frac{W \times b}{F}; \text{ or, } a = \frac{W - d}{F - W};$$

$$b = \frac{F \times a}{W}; \text{ or, } b = \frac{F \times d}{F - W}.$$

APPLIED FORCE BETWEEN FULCRUM AND DELIVERED FORCE

Fig. 81. Illustrating Application of Principle of Moments to Levers in Brake Systems

press against its wheel with any great force until all brake shoes are held firmly against their respective wheels, and all shoes press against the wheels with an equal force. Fig. 80, with the various parts named, shows the application of case *A* of Fig. 79 to a freight car.

Leverage. It is a well-known principle in Mechanics, that the greater the weight on a car wheel, the greater the brake-shoe pressure necessary to cause it to slide or skid on the track. For this reason, in designing the brake levers, rods, etc., for a freight car, the light or unloaded weight of the car is the basis of all calculations. If the loaded weight of the car were used in the calculations, the proportions would be such that if the brakes were applied when the car was unloaded the wheels would slide. In order to prevent as far as possible chances arising of having flat spots worn on the wheels, due to wheels sliding on the track, the following percentages of light weights on the wheels are usually, but not always, employed in determining the brake-shoe pressure:

Passenger cars.........	90 per cent
Freight cars...........	70 per cent
Tenders................	100 per cent
Locomotive drivers	75 per cent (of weight on drivers)
Locomotive truck......	75 per cent (of weight on truck)

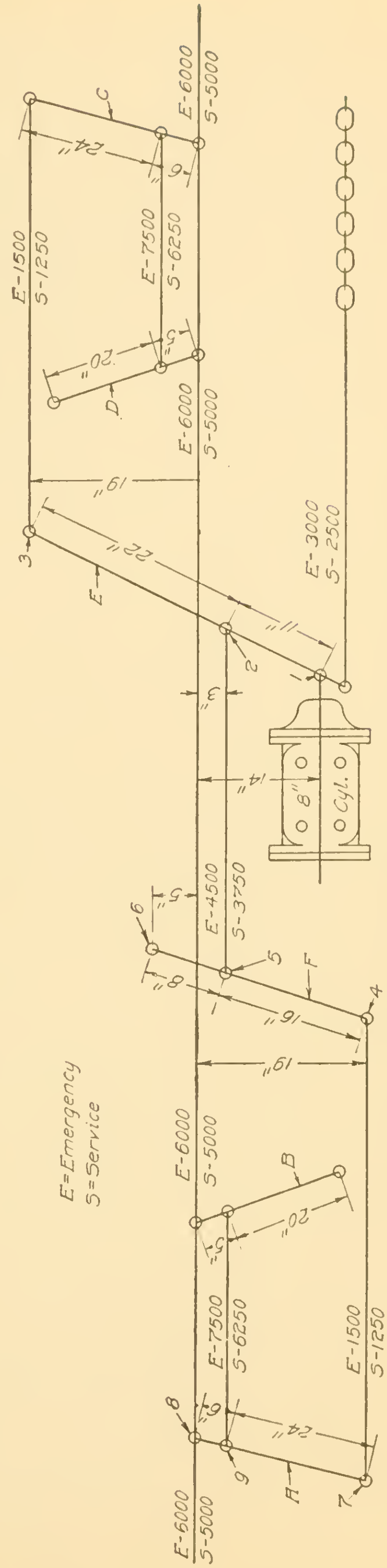


Fig. 82. Scheme of Levers and Rods Commonly Used on Freight Cars

It is frequently found necessary to change these percentages in order to meet special conditions which arise.

In calculating the brake-shoe pressure of any car the following three things must be known: *First,* the diameter of the brake cylinder and its maximum pressure; *second,* the sizes and positions of all levers in the system; and *third,* a working knowledge of the theorem of moments as used in Mechanics.

The principle or theorem of moments may briefly be stated as follows: *The product of the force applied at one pin and its perpendicular distance from the fulcrum pin is equal to the product of the force delivered at the other pin and its perpendicular distance from the fulcrum pin.* This principle has been applied to the three different classes of levers, and the forces and distances worked out, Fig. 81. The chief difficulty the amateur experiences is in locating the fulcrum pin. In *A, B,* and *C,* Fig. 81, the fulcrum pin is located at *O,* the force applied is *F,* and the force delivered is *W.* In any case, if the pull *F* on the lever is known, the brake-shoe pressure *W* can be determined.

Fig. 82 represents diagrammatically the scheme of levers and rods commonly used on freight cars. All distances of rods from the center line of the car are taken when the levers are at right angles to it. The brake cylinder on a certain freight car, taken as an illustration, is 8 inches in diameter, and has an area of about 50 square inches. If the maximum brake-cylinder pressure in emergency applications is 60 pounds, the total pressure delivered to the push rod would be 50×60, or 3000 pounds. This 3000 pounds is transmitted to the lever *E* at the pin *1.* The lever *E* is of the class shown in *B,* Fig. 81, and its fulcrum is at the pin *3.* Applying the formula gives 4500 pounds delivered at the pin *2.* This 4500 pounds is transmitted to the lever *F,* which is of the class shown in *C,* Fig. 81, and its fulcrum is at the pin *6.* Applying the formula gives 1500 pounds delivered at the pin *4.* This 1500 pounds is transmitted to the lever *A,* which is of the class shown in *A,* Fig. 81, and its fulcrum is at the pin *9.* Applying the formula gives 6000 pounds delivered to the brake beam at the pin *8.* In a similar manner the other brake-beam pressures can be determined. In the figure, the calculation has been carried through for both service and emergency applications.

It is seen that 6000 pounds is transmitted to the middle of each of the four brake beams. Each brake shoe will then receive a pressure of 3000 pounds. Since there are eight wheels, the total braking pressure will be 8×3000, or 24,000 pounds. This total braking pressure must not exceed 70 per cent of the unloaded weight of the car.

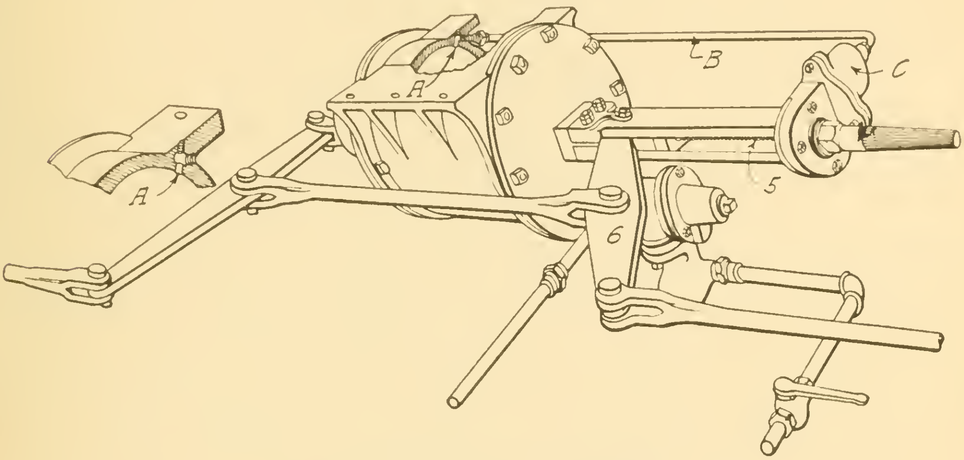


Fig. 83. Automatic Slack-Adjuster

Automatic Slack=Adjuster. Full braking pressure will be secured as long as the maximum allowable brake-cylinder pressure can be maintained. Since the brake-cylinder pressure depends upon the length of stroke of the piston, it follows that the stroke of

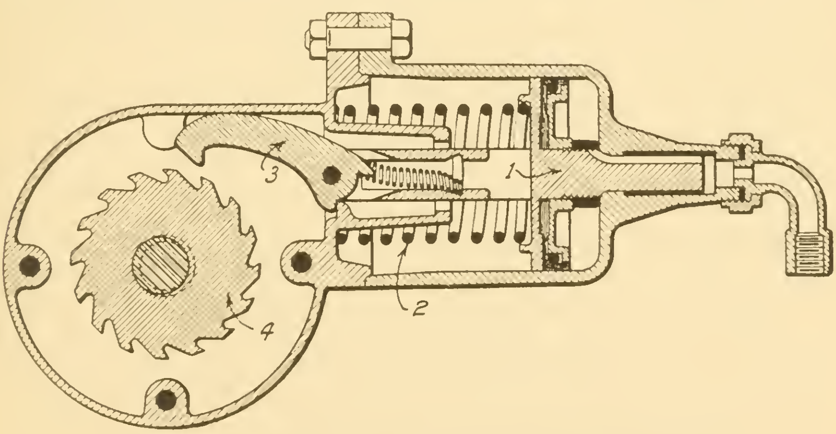


Fig. 84. Part Sectional View of Automatic Slack-Adjuster

the piston should be kept as nearly constant as possible. The greater the stroke, the less the pressure. The stroke of the piston should be kept at about 8 inches. As the brake shoes and various connections wear, the stroke of the piston is increased, and the pres-

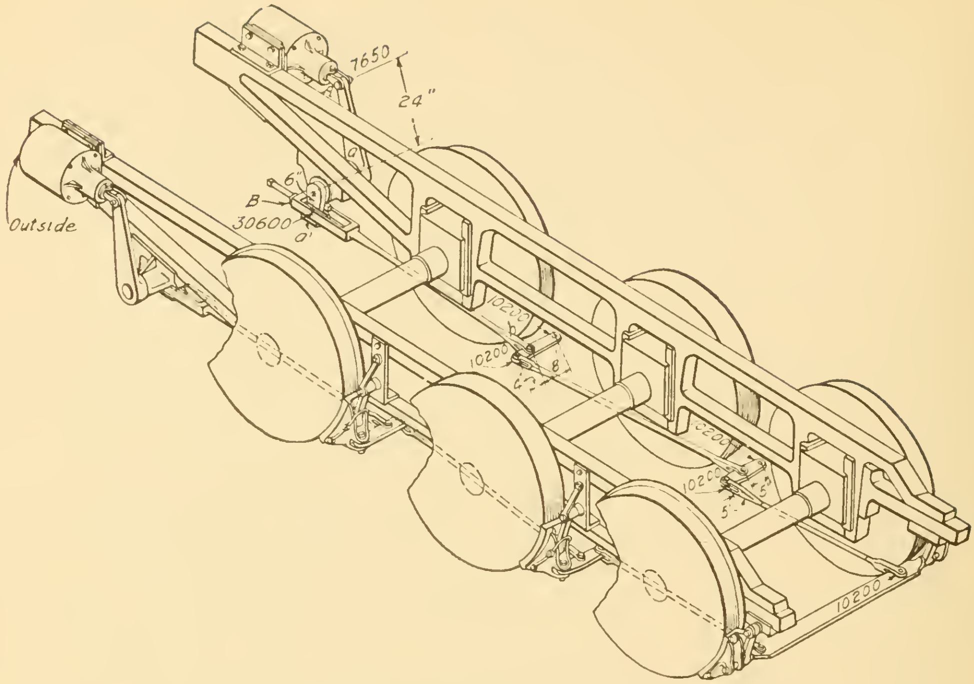


Fig. 85. Outside Equalized Driver-Brake for Locomotives

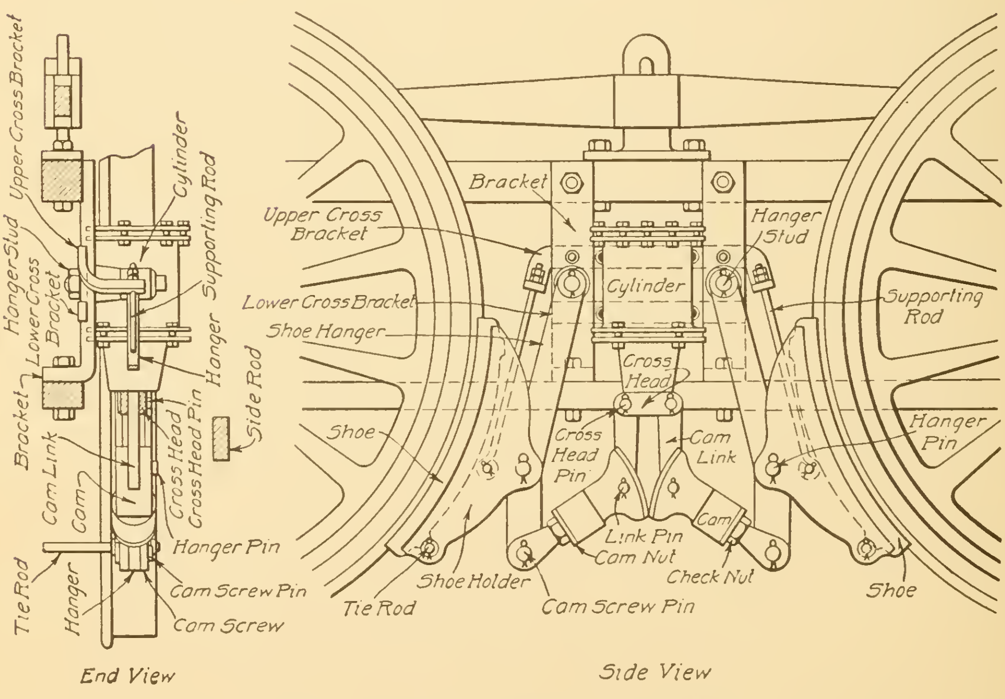


Fig. 86. Cam Driver-Brake for Locomotives

sure with which the shoes are forced against the wheels is decreased. In order to compensate for this wear, some means must be provided for taking up the slack. This is done in one of two ways—by changing the fulcrum pin of the dead lever (see Fig. 80) or by using the automatic slack-adjuster. The first method of adjustment is the one most commonly used and is necessarily very coarsely graded. The automatic slack-adjuster, when used at all, is usually fitted to the passenger car equipment.

The automatic slack-adjuster, Figs. 83 and 84, is manufactured by the Westinghouse Air Brake Company. The purpose of the

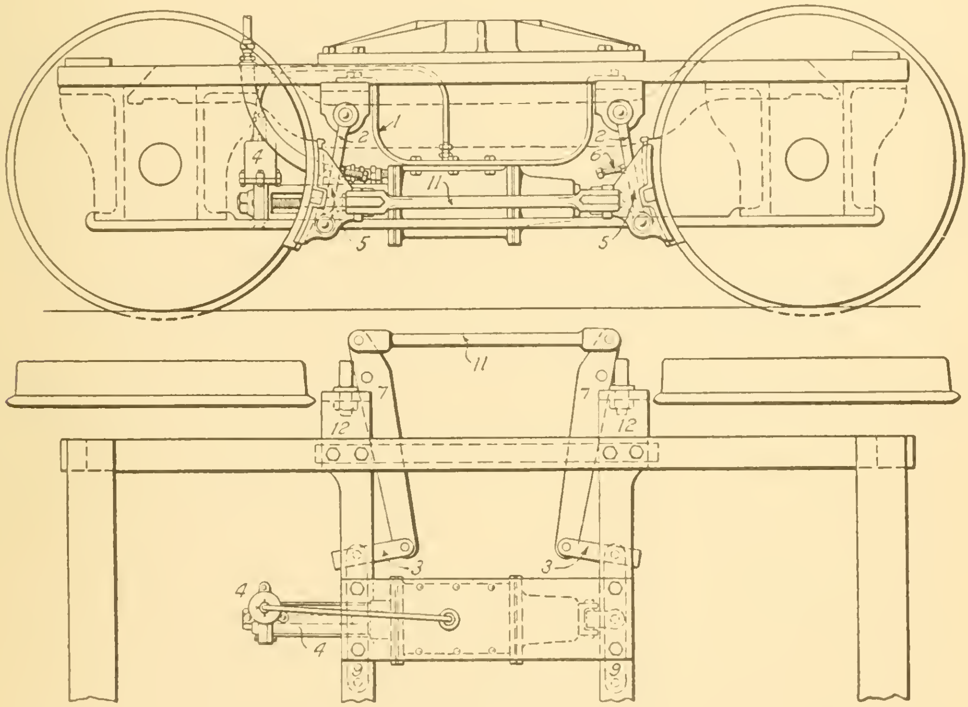


Fig. 87. Locomotive Truck Brake

apparatus is to maintain a constant, predetermined piston travel. The brake-cylinder piston acts as a valve to control the admission and release of air to pipe *B* through port *A*. Whenever the stroke of the brake-cylinder piston is so great that port *A* is passed by the piston, air from the cylinder enters port *A* into pipe *B* and enters cylinder *C*, which is shown in section in Fig. 84. The air entering the small cylinder acts on piston *1*, forcing it to the left, compressing spring *2*, and causing the small pawl *3* to engage the ratchet wheel *4*. When the brake is released, the brake-cylinder piston returns, and air in the small cylinder *C* escapes to the atmosphere through pipe *B* and port *A*, thus permitting spring *2* to force piston *1* to its normal position. In so doing, pawl *3* turns the ratchet wheel *4* on screw *5*, and thereby draws the fulcrum end of lever *6* slightly nearer the slack-adjuster cylinder *C*. Each operation of piston *1*, as just described, reduces the brake-cylinder piston travel about $\frac{1}{32}$ of an inch. When piston *1* is in its normal position, the outer end of pawl *3* is lifted, permitting screw *5* to be turned by hand.

Locomotive Driver Brakes. The brakes are applied to the drivers of a locomotive in two general ways—by the outside equalized system, Fig. 85, and by cams, Fig. 86. The former scheme has practically replaced the latter, because of its simple design and adjustment. In the system, Fig. 85, the levers are proportioned so that each wheel receives the same braking pressure. If the brake cylinders are each 14 inches in diameter and the cylinder pressure is 50 pounds, the pressure delivered at pin *A* is about 7650 pounds, while that on each wheel is 10,200 pounds. These values vary for different locomotives. The stroke of the piston is regulated by the adjustment mechanism at *B*.

The action of the cam-driver brake is shown in Fig. 86. When air is admitted to the brake cylinder, the piston is forced downward. This action pushes down the crosshead cams, which force the brake shoes against the drivers. The piston travel is controlled by adjusting the cam nut on each cam.

Locomotive Truck Brakes. In certain types of locomotives, a considerable proportion of the weight of the locomotive is carried on the truck. It follows, that in order to develop the full braking power of the locomotive, a well-designed truck brake should be provided. The type of brake shown in Fig. 87 is now quite common. It is fitted with an automatic slack-adjuster, but this feature is not so important here as on the car equipment.

MULTIPLE-UNIT CONTROL ELECTRIC TRAIN ON LONG ISLAND RAILROAD, EQUIPPED WITH WESTINGHOUSE MOTORS AND CONTROL APPARATUS

Courtesy of Westinghouse Electric and Manufacturing Company

AIR BRAKES

PART II

MODERN BRAKE EQUIPMENT

FUNDAMENTAL TYPES

High=Speed Brake Equipment. The high-speed brake equipment, Fig. 88, is a modification of the quick-action brake and can be used in passenger service. The parts not found on the ordinary equipment are as follows: Type "E" safety valve, high-speed reducing valve, reversing cock, feed-valve bracket, and an additional feed valve.

Action of Reversing Cock. The locomotive equipment may be changed from the quick-action to the high-speed brake by simply turning the reversing-cock handle. When this handle is in the position opposite to that shown in Fig. 88, the 70-pound feed valve is in service, so that the locomotive is ready to operate the ordinary quick-action brake; when the brake-valve handle is in running position, 70 pounds pressure is carried in the brake pipe, and the compressor will slow down when main-reservoir pressure reaches 90 pounds. If, however, the brake-valve handle is in lap, service, or emergency-application position, main-reservoir pressure is cut off from the excess-pressure head, and the compressor will continue to operate until the main-reservoir pressure reaches the limit set by the maximum pressure head, to insure available pressure promptly to release and re-charge the brakes on long and heavy trains.

If the reversing-cock handle be turned to the position shown, the 110-pound feed valve will become operative, giving 110 pounds brake-pipe pressure, which results in a corresponding increase in main-reservoir pressure depending upon the adjustment of the maximum pressure head of the governor.

Principles Involved. The principles involved in the high-speed brake are (a) the friction between the brake shoe and the wheel,

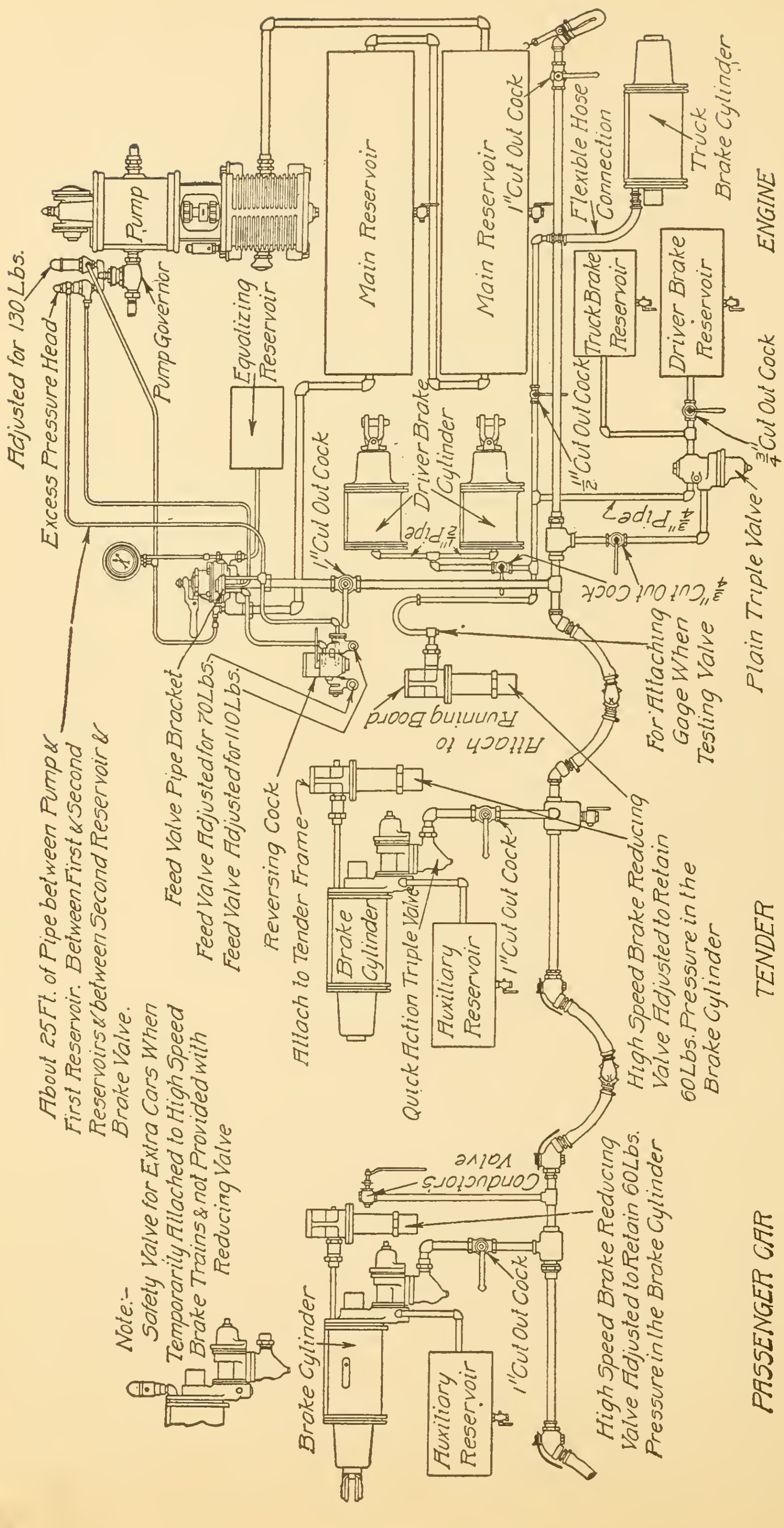


Fig. 88. Diagrammatic Illustration of Westinghouse High-Speed Brake Equipment

that tends to stop the rotation, becomes less as the rapidity of rotation of the wheel increases, and (b) the adhesion between the wheel and rail remains practically constant regardless of the speed. It will thus be seen that, at high speeds, a greater brake-cylinder pressure, with corresponding increase of the brake-shoe pressure, can be used without danger of sliding wheels; but, in such a case, it is necessary to provide means for reducing this high-cylinder pressure as the speed of the train is decreased. This is accomplished by the automatic reducing valve, which has previously been explained.

Cars not fitted with reducing valves should not be attached to trains using the high-speed brake unless the brake cylinders are

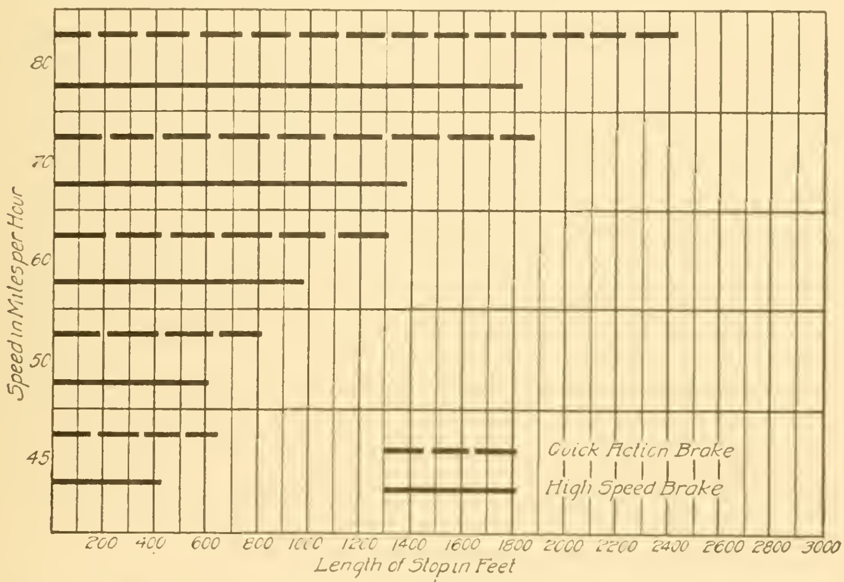


Fig. 89. Diagram Showing Minimum Length of Stop for Train of Engine and Six Coaches with Quick-Action and High-Speed Brakes

fitted with the Type "E" safety valve provided for temporary use. Fig. 89 illustrates graphically the saving in distance in stopping a train fitted with the high-speed brake equipment.

Double=Pressure Control or Schedule "U". The differences between Schedule "U" and high-speed equipments are that no additional parts are used on cars with Schedule "U". The Type "E" safety valve takes the place of the high-speed reducing valve in the locomotive and tender equipment, and plain triple valves are used on both the locomotive and tender. The equipment is shown in Fig. 90. The few simple appliances afford the means whereby the engineer can change the brake-pipe and main-reservoir pressure from one predetermined standard to another at will.

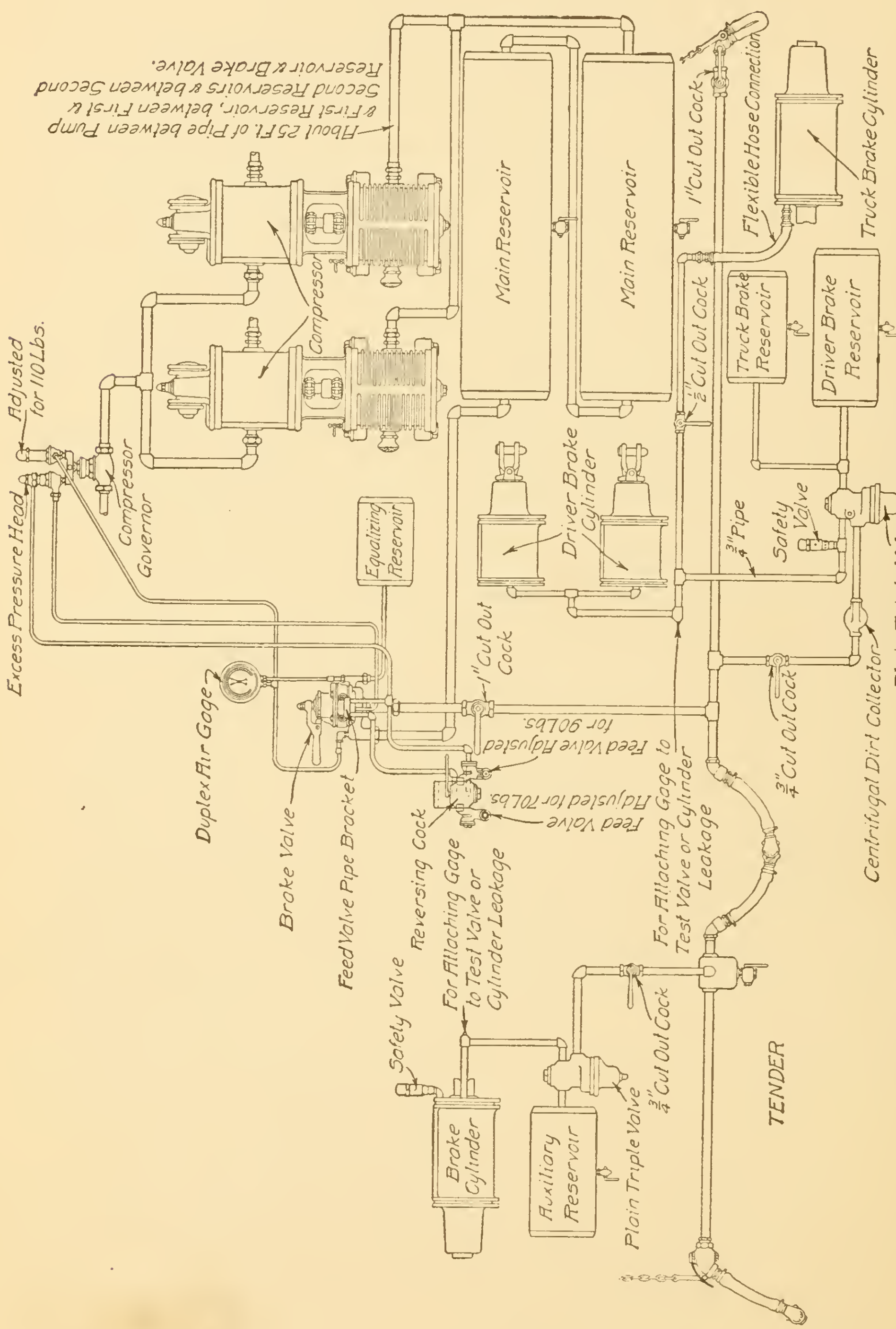


Fig. 90. Diagrammatic Illustration of Double-Pressure Control Apparatus, or Schedule U

The equipment is particularly adapted for use upon heavy grades where "empties" are hauled up the grade and "loads" down.

The 70-pound brake-pipe pressure provides for a proper control of the empty cars, and requires less work from the compressor, while the 90-pound pressure makes it possible to obtain higher brake-cylinder pressures to compensate for the increased weight to be controlled when the cars are loaded. The loaded weight of the car is still, however, sufficiently in excess of the maximum braking power obtainable to insure an ample margin against wheel sliding.

"LN" Passenger-Car Brake Equipment. The demand for a more efficient brake equipment for passenger service, to meet the new conditions of heavier trains, faster speeds, and more frequent service, resulted in the development of the "LN" equipment. A diagram illustrating the arrangement of piping and location and

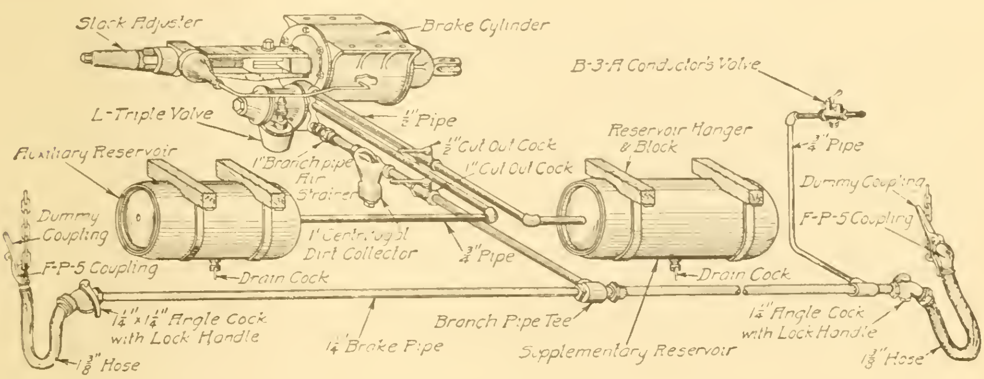


Fig. 91. Westinghouse Piping Diagram for "LN" Passenger Brake Equipment

names of all parts is shown in Fig. 91. The principles underlying the action of the parts have already been presented under the discussion of the Type "L" triple valve.

Specifications. The equipment is made up of the following parts:

(1) A *triple valve*, Type "L", which has connections through the brake-cylinder head to the brake-pipe branch pipe, the auxiliary reservoir, and the supplementary reservoir. It operates automatically in response to an increase or decrease in brake-pipe pressure, as previously described.

(2) The *Type "E" safety valve* is attached directly to the Type "L" triple valve and thus becomes an important feature of the "LN" equipment, since in service applications it prevents any excess brake-cylinder pressure and in emergency applications it is cut out entirely.

(3) A *brake cylinder*, with a piston and rod which operates in the usual way.

(4) *Reservoirs*, of which there is one auxiliary and usually one supplementary, for the purpose of storing air for use in applying the brakes. When

desirable or more convenient, however, two supplementary reservoirs of the proper size may be used.

(5) A *centrifugal dirt collector* is connected in the branch pipe between the brake pipe and triple valve as near the triple valve as circumstances will permit.

(6) A *branch-pipe air strainer* is inserted in the branch pipe close to the triple-valve connection on the brake-cylinder head for further protection to the triple valve.

(7) A *conductor's valve* placed inside each car by means of which the brakes may be applied by the conductor in case of accident or emergency.

(8) A *branch-pipe tee*, various *cut-out cocks, angle cocks, hose couplings, dummy couplings*, etc., the location and uses of which will be readily understood by reference to Fig. 91.

(9) An *automatic slack-adjuster*, which is not a fundamental part of the equipment, but recommended for use.

The high emergency-cylinder pressure with the graduated release feature, as explained under the discussion of the "L" triple valve, makes it possible to use the equipment as a high-speed brake when carrying 90 pounds brake-pipe pressure, and obtain better results than when using 110 pounds pressure with the old standard equipment in steam-road service. If, then, a more powerful brake is desired, it can be obtained by simply increasing the brake-pipe pressure.

No. 6 "ET" LOCOMOTIVE BRAKE EQUIPMENT

It has been shown that a single modern locomotive possessed a possible braking power of one-tenth of a 50-car freight train, one-eighth of a 12-car Pullman train, one-fourth of a 10-car passenger train, and one-third of a 6-car passenger train. These figures would indicate that the locomotive brake equipment should be developed to the highest degree. The first step taken in this direction was the development of the combined automatic and straight-air equipment for locomotives. This system was greatly simplified and improved by the more recent development of the so-called "ET" locomotive brake equipment.

Functions and Advantages. The No. 6 "ET" (engine and tender) equipment possesses all the functions which are now required in locomotive brake service; it can be applied to any locomotive without change or modification of any of its parts. The locomotive so equipped may be used in any kind of service, such as high-speed passenger, double-pressure control, ordinary passenger or freight, or switching service, without change or adjustment of the brake apparatus. Its important advantages are as follows:

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

They 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 leakage from them and of variation in piston travel, undesirable though these defects are, until released by the brake valve.

They can be graduated on or off with either the automatic or the 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 with greater ease than was heretofore possible.

Arrangement of Piping, Etc. The general arrangement of piping, etc., is shown diagrammatically in Fig. 92. The names of the various parts composing the equipment are:

(a) The *air compressor* to compress the air. The *main reservoirs* in which to store and cool the air and collect water and dirt.

(b) A *duplex compressor governor* to control the compressor when the pressures for which it is regulated are obtained.

(c) A *distributing valve*, and small double-chamber reservoir to which it is attached, placed on the locomotive to perform the functions of triple valves, auxiliary reservoirs, double check valves, high-speed reducing valves, etc.

(d) Two *brake valves*—the *automatic* to operate the locomotive and train brakes, and the *independent* to operate the locomotive brakes only.

(e) A *feed valve* to regulate the brake-pipe pressure.

(f) A *reducing valve* to reduce the pressure for the independent brake valve and for the air-signal system when used.

(g) Two *duplex air gages*—one, to indicate equalizing-reservoir and main-reservoir pressures; the other, to indicate brake-pipe and locomotive brake-cylinder pressures.

(h) *Driver*, *tender*, and *truck brake cylinders*, *cut-out cocks*, *air strainers*, *hose couplings*, *fittings*, etc., incidental to the piping, for purposes readily understood.

Names of Pipes. In order to simplify the description of the different parts of the equipment, the following names of pipes are given which are shown in Fig. 92:

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

Connecting Pipe: Connects the two main reservoirs.

Main Reservoir Pipe: Connects the second main reservoir to the automatic brake valve, distributing valve, feed valve, reducing valve, and compressor governor.

Feed Valve Pipe: Connects the feed valve to the automatic brake valve.

Excess-Pressure Pipe: Connects the feed-valve pipe to the upper connection of the excess-pressure head of the compressor governor.

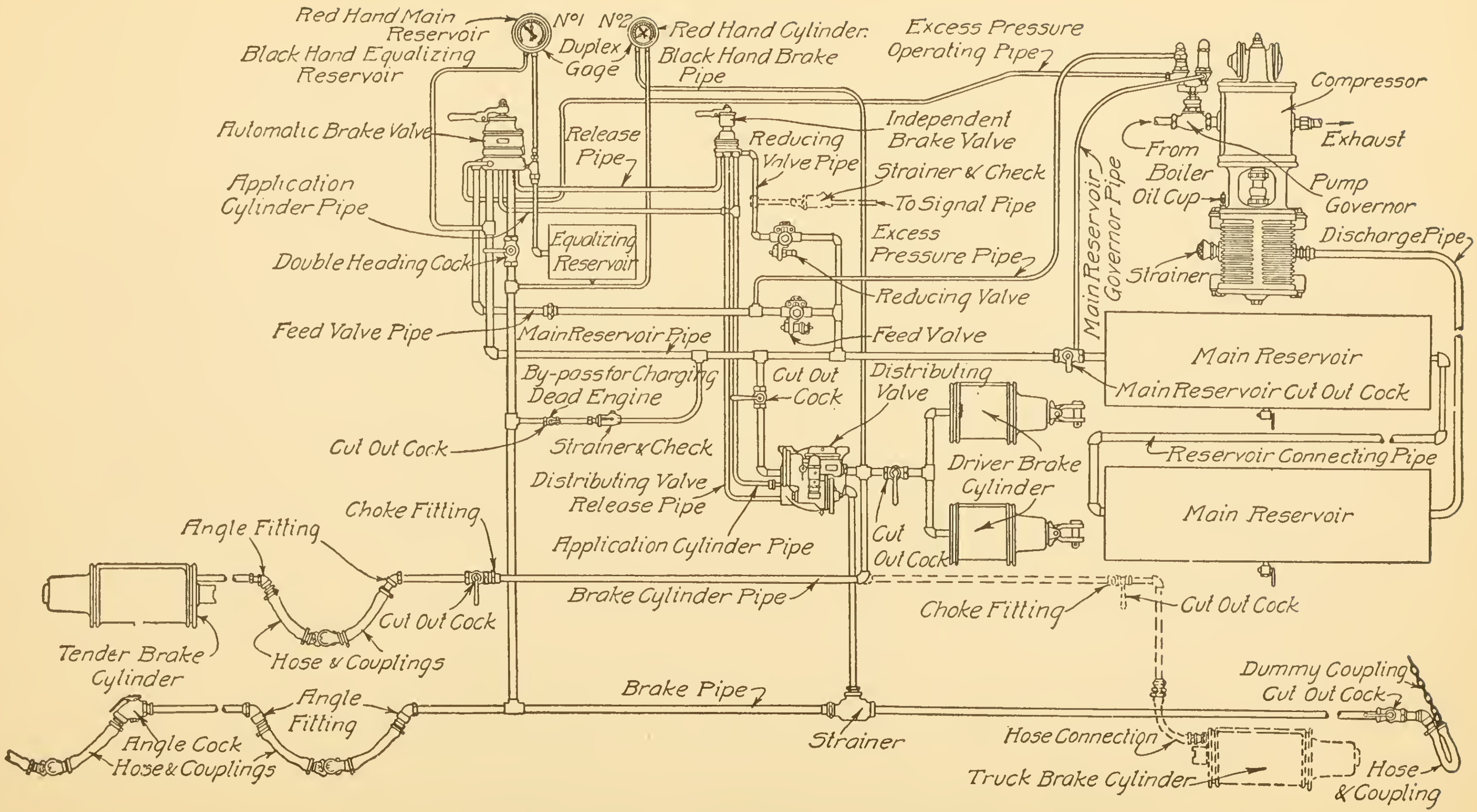


Fig. 92. Diagram of Westinghouse "ET-6" Equipment

Excess-Pressure Operating Pipe: Connects the automatic brake valve to the lower connection of the excess-pressure head of the compressor governor.

Reducing Valve Pipe: Connects the reducing valve to the independent brake valve, and to the signal system, when used.

Brake Pipe: Connects the automatic brake valve with the distributing valve and all triple valves on the cars in the train.

Brake-Cylinder Pipe: Connects the distributing valve with the driver, tender, and truck-brake cylinders.

Application Cylinder Pipe: Connects the application cylinder of the distributing valve to the independent and automatic brake valves.

Distributing Valve Release Pipe: Connects the application-cylinder exhaust port of the distributing valve to the automatic brake valve through the independent brake valve.

In some installations the automatic brake valve is provided with a pipe bracket to which the feed valve is directly attached, thus eliminating the feed-valve pipe and the excess-pressure pipe.

Manipulation of Equipment. *Positions of Automatic and Independent Brake Valves.* The automatic brake valve has six fixed positions for its handle—*release, running, holding, lap, service,* and *emergency;* while the independent brake valve has but five—*release, running, lap, slow-application,* and *quick-application.*

General Directions. The following directions for the manipulation of the equipment are abbreviated from that furnished by the manufacturers and applies to modern equipment. They are not intended to apply rigidly to all individual cases or conditions:

When not in use, carry the handles of both brake valves in *running* position.

To apply the brakes in service, move the handle of the automatic brake valve to the *service* position, making the required brake-pipe reduction, then back to *lap* position, which is the one for holding all the brakes applied.

To make a smooth and accurate two-application passenger stop, make the first application sufficiently heavy to bring the speed of the train down to about 15 miles per hour at a convenient distance from the stopping point, then release as explained in the following paragraph and re-apply as required to make the desired stop, the final release being made as explained below.

Passenger Service. In making the first release of a two-application stop, the brake-valve handle should be moved to *release* position and then quickly back to *running* position, where it should be allowed to remain for an instant—*first,* to permit the pressures in the equalizing reservoir and brake pipe to equalize; and *second,* to release part of the driver brake-cylinder pressure—then moved to *lap* position and from there to *service* position, as required. In passenger service, the time the handle is in *release* position should be only momentary; but the time in *running* position should be governed by the conditions existing for each particular case, such as the length of train, kind of reduction made, time available, and so on.

In making the final release of a two-application stop, with short trains, release shortly before coming to a standstill by moving the handle to *release* position and immediately back to *running* position, and leave it there. With long trains, the brakes should, as a rule, be held applied until the train stops.

The release after a one-application stop should be made in the same manner as the final release of a two-application stop.

Freight Service. Under present conditions it is, as a rule, safest to come to a stop before releasing the brakes on a freight train, especially a long one, rather than attempt to release at low speed. However, if conditions—for example, a short train, or a train equipped with Type "K" triple valves—permit of the release while in motion, the brake-valve handle should be moved to *release* position and held there long enough to move as many of the triple valves to release position as possible without unduly overcharging the head end of the train—the time in *release* position should be governed by the length of train, amount of reduction made, etc.—then returned to *running* position to release the locomotive brakes and complete the recharging of the auxiliary reservoirs. A few seconds after such a release, particularly on long trains, it is necessary to again move the handle to *release* position and quickly back to *running* position to "kick off" any brakes at the head end of the train that may have re-applied due to their auxiliary reservoirs having been slightly overcharged.

Holding Locomotive Brakes Applied. If, when releasing, it is desired to hold the locomotive brakes applied after the other brakes release, move the handle from *release* back to *holding* instead of *running* position, then release the locomotive brakes fully by moving the handle to *running* position and leaving it there, or graduate them off, as circumstances require, by short, successive movements between *holding* and *running* positions.

Emergency Application. To apply the brakes in emergency, move the handle of the automatic brake valve quickly to *emergency* position and leave it there until the train stops and the danger is past.

When using the independent brake only, the handle of the automatic brake valve should be carried in *running* position. The independent application may be released by moving the independent brake-valve handle to *running* position. Release position is for use only when the automatic brake-valve handle is not in *running* position.

While handling long trains of cars, in road or switching service, the independent brake should be operated with care to prevent damage to cars and lading, caused by running the slack in or out too hard. In cases of emergency arising while the independent brake is applied, apply the automatic brake instantly. The safety valve will restrict the brake-cylinder pressure to the proper maximum.

Heavy Grade Service. The brakes on the locomotive and on the train may be alternated in heavy grade service where conditions—such as short, steep grades or where grade is heavy and straight for short distance—require, to prevent overheating of driving-wheel tires and to assist the pressure-retaining valves in holding the train while the auxiliary reservoirs are being re-charged. This is done by keeping the locomotive brakes released by use of the independent brake valve when the train brakes are applied, and applying the locomotive brakes just before the train brakes are released, and then releasing the locomotive brakes after the train brakes are re-applied. Care and judgment should be exercised in the use of driver brakes on grades to prevent overheating of tires.

Release Position of Independent Brake Valve. When all brakes are applied automatically, to graduate off or entirely release the locomotive brakes only, use *release* position of the independent brake valve.

The red hand of gage No. 2, Fig. 92, will show at all times the pressure in the locomotive brake cylinders, and this hand should be watched in brake manipulation.

Release position of the independent brake valve will release the locomotive brakes under any and all conditions.

Use of Automatic Brake Valve for Holding and Grade Work. The automatic brakes should never be used to hold a locomotive or a train while standing even where the locomotive is not detached, for longer than ten minutes, and not for such time if the grade is very steep or the condition of the brakes is not good. The safest method is to hold with hand brakes only and keep the auxiliary reservoirs fully charged so as to guard against a start from brakes leaking off and to be ready to obtain any part of full braking power immediately on starting.

The independent brake is a very important safety feature in this connection, as it will hold a locomotive with a leaky throttle or quite a heavy train on a fairly steep grade if, as the automatic brakes are released, the slack is prevented from running in or out—depending on the tendency of the grade—and giving the locomotive a start. To illustrate: The best method to make a stop on a descending grade is to apply the independent brake heavily as the stop is being completed, thus bunching the train solidly; then, when stopped, place and leave the handle of the independent brake valve in *application* position; then release the automatic brakes and keep them charged. Should the independent brake be unable to prevent the train from starting, the automatic brakes will become sufficiently recharged to make an immediate stop; in such an event enough hand brakes should at once be applied as are necessary to hold the train. Many runaways and some serious wrecks have resulted through failure to comply with the foregoing instructions.

When leaving the engine, while doing work about it, or when it is standing at a coal chute or water plug, always leave the independent brake-valve handle in *application* position.

After Emergency Application not Controlled by Engineer. After an emergency application of the brakes, while running over the road, due to any cause other than intended by the operating engineer himself:

(1) In passenger service, move the brake-valve handle to *emergency* position at once and leave it there until the train stops.

(2) In freight service, move the brake-valve handle to lap position and let it remain there until the train stops.

This is to prevent loss of main-reservoir pressure and insure the brakes remaining applied until released by the engineer in charge of the train. After the train stops, the cause of the application should be located and remedied before proceeding.

More than One Locomotive on Train. Where there are two or more locomotives in a train, the instructions already given remain unchanged so far as the leading locomotive, or the locomotive from which the brakes are being operated, is concerned. On all other locomotives in the train, however, the double-heading cock under the automatic brake valve must be closed and the automatic and independent brake-valve handles carried in *running* position.

Many of the parts composing the No. 6 "ET" equipment are the same as used in connection with other equipments and have already been explained. These parts include the following: the "H-6" automatic brake valve, the "S-6" independent brake valve, the "B-6" feed valve, the "C-6" reducing valve, the "E-6" safety valve, the Type "SF" compressor governor, the air compressor, etc. The new features are the different pipes and connections, and the distributing valve and double-chamber reservoir.

DISTRIBUTING VALVE AND DOUBLE-CHAMBER RESERVOIR

General Method of Operation. Fig. 93 illustrates diagrammatically the essential features of the distributing valve and the double-chamber reservoir. Instead of a triple valve and auxiliary reservoir for each of the engine and tender equipments, the distributing valve is made to supply all brake cylinders. The distributing valve is made up of two portions called the "equalizing portion" and the "application portion". The valve is connected to a double-chamber reservoir, the two chambers being called, respectively, the "pressure chamber" and the "application chamber". For various reasons the distributing valve and double-chamber reservoir are combined in one device, Figs. 94 and 95.

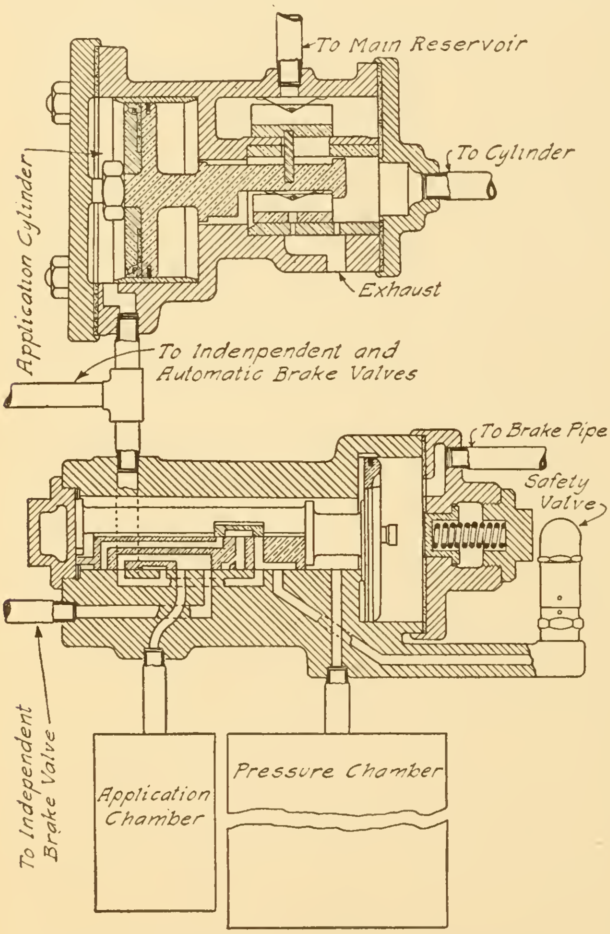


Fig. 93. Diagrammatic View of Essential Parts of Westinghouse Distributing Valve and Double-Chamber Reservoir

The distributing valve is the most important feature of the "ET" equipment. As shown by Figs. 94, 95, and 96, it has five

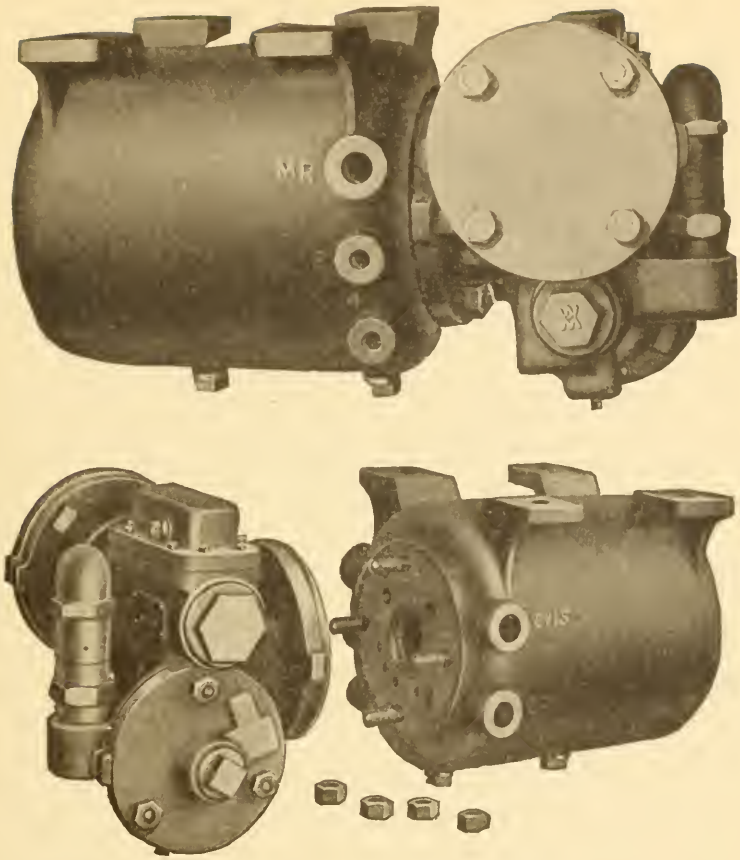


Fig. 94. No. 6 Distributing Valve and Double-Chamber Reservoir. *MR*, Main-Reservoir Pipe; *4*, Distributor Valve Release Pipe; *2*, Application-Cylinder Pipe; *CYLS*, Brake-Cylinder Pipe; *BP*, Brake Pipe

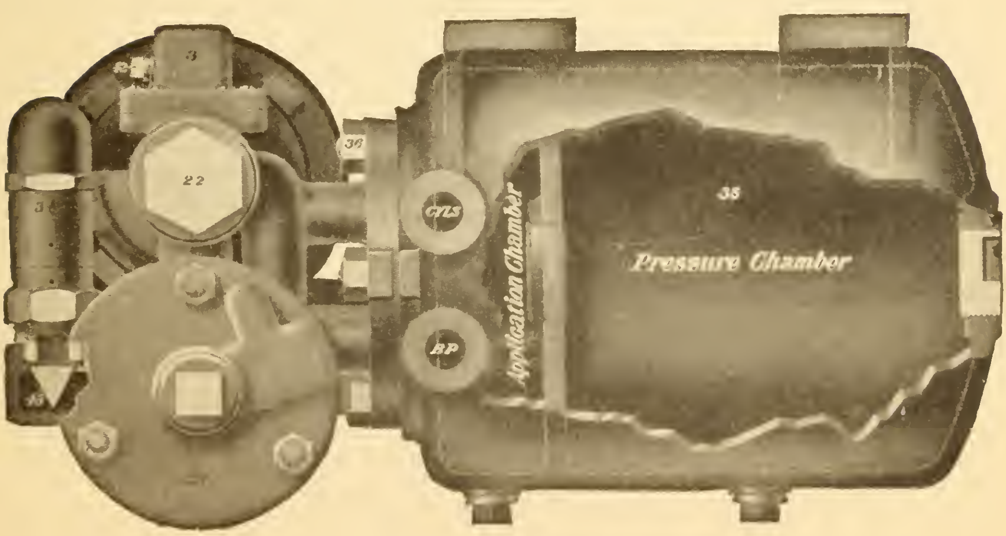


Fig. 95. No. 6 Distributing Valve and Double-Chamber Reservoir, with Pressure Chamber Cut Away

Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania pipe connections. Fig. 96 is a vertical section of the actual valve. For the sake of clearness, the distributing valve together with the double-pressure chamber may be considered as a miniature brake set, consisting of the equalizing portion representing the triple valve; the pressure chamber, the auxiliary reservoir; and the application portion always having practically the same pressure in its

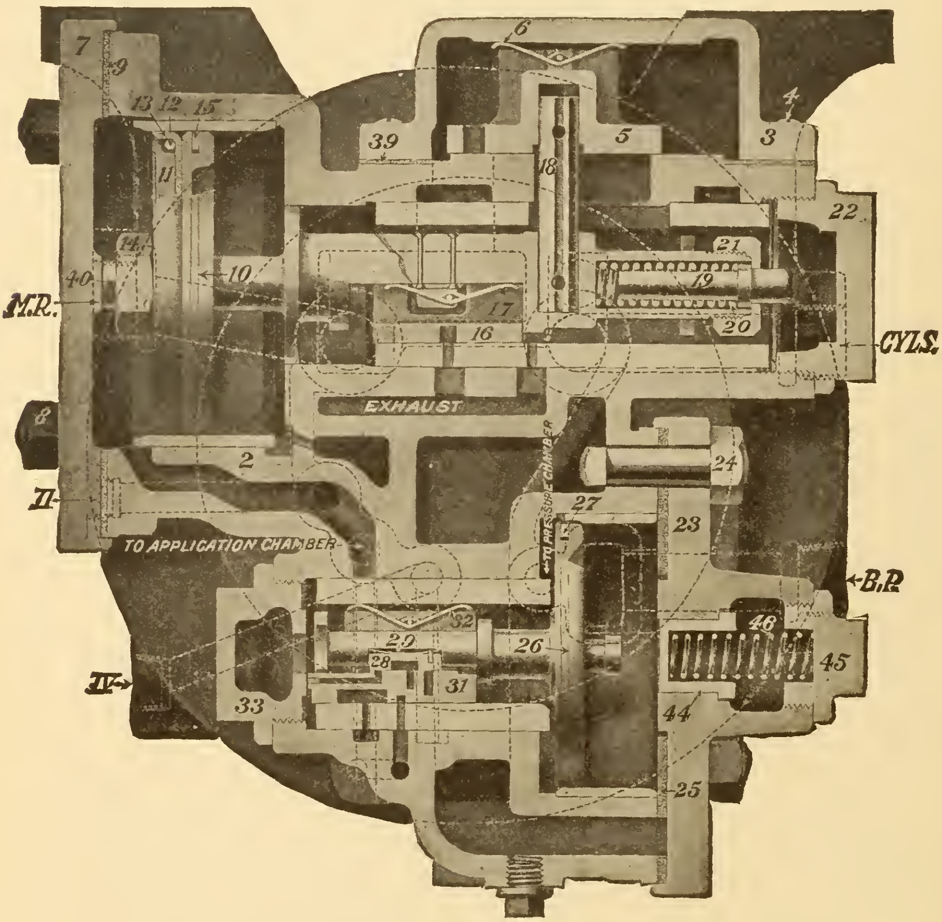


Fig. 96. Section of No. 6 Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

cylinder as that in the brake cylinders. The equalizing portion and pressure chamber are used in automatic applications only; reductions of brake-pipe pressure cause the equalizing valve to connect the pressure chamber to the application chamber and cylinder, allowing air to flow from the former to the latter. The upper slide valve, connected to the piston rod of the application portion, admits air to the brake cylinders and is called the "application valve", while the lower one releases the air from the brake cylinders and is called the "exhaust valve". As the air admitted to the brake cylinders comes directly 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

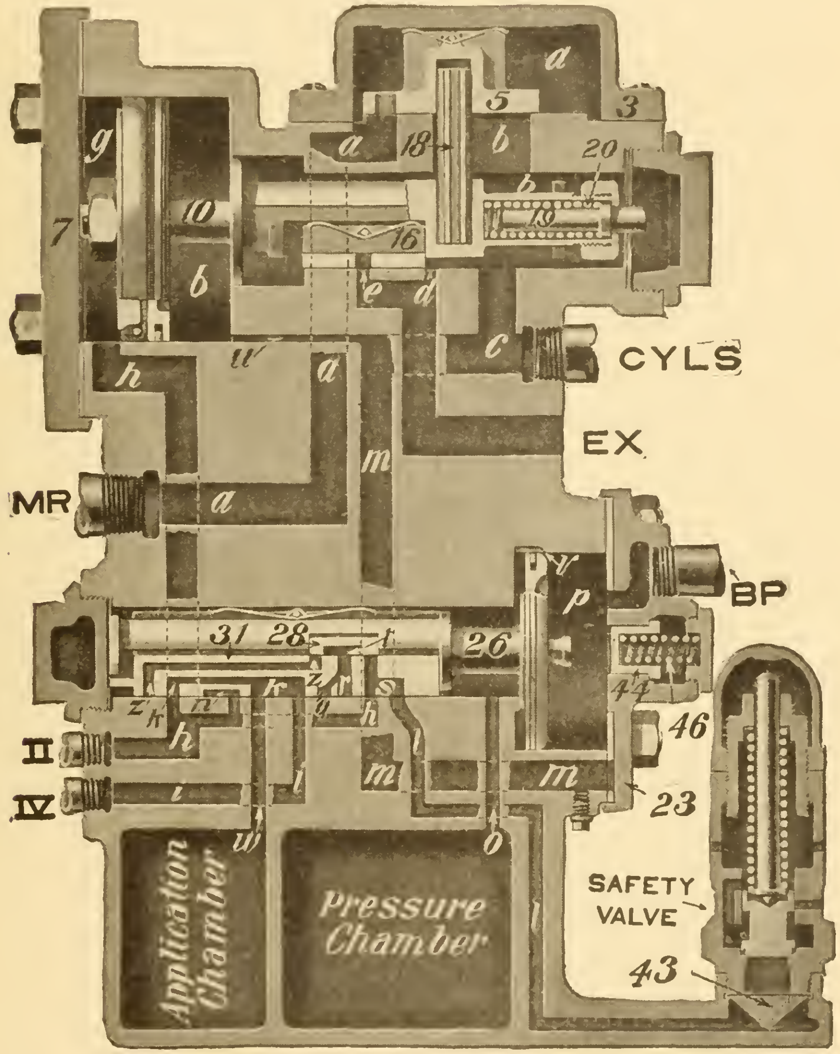


Fig. 97. Release Position, Automatic or Independent Connections for Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

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 any brake-cylinder leakage. The operation of this locomotive brake, therefore, depends upon the admitting of air to and the releasing of air from the application cylinder—in independent applications, directly by means of the independent brake valve; in automatic applications, by means of the equalizing portion and the air pressure stored in the pressure chamber.

The well-known principle embodied in the quick-action triple valve, by which it gives a high braking power in emergency applications and a sufficiently lower one in full-service applications to provide a desired protection against wheel sliding, is embodied in the "No. 6" distributing valve. In describing the operation of the valve, reference will be made to the nine diagrammatic views shown in Figs. 97 to 106. For convenience, the chambers of the reservoir are indicated at the bottom as being a part of the valve.

Automatic Brake Operation

Charging. Referring to Fig. 97, which shows the parts in the release position, it will be seen that as chamber *p* is connected to the brake pipe, brake-pipe air flows through the feed groove *v* over the top of piston *26* into the chamber above equalizing valve *31*, and through port *o* to the pressure chamber, until the pressures on both sides of the piston are equal.

Service. When the engineer wishes to make a service application by the use of the automatic brake valve, the brake-pipe pressure in chamber *p* is reduced, the amount of this reduction depending on the degree with which it is desired to set the brakes. This action causes a difference in pressure on the two sides of piston *26*, which causes the piston to move toward the right until it occupies the position shown in Fig. 98. The first movement of piston *26* closes the feed groove *v*, and at the same time moves the graduating valve *28* until it uncovers the upper end of the port *z* in the equalizing valve *31*. As piston *26* continues its movement toward the right, the shoulder on the end of its stem comes in contact with the left end of equalizing valve *31*, which is then also moved to the right until the projecting piece on the right of the piston strikes the equalizing piston graduating sleeve *44*. The initial tension of the graduating spring *46* prevents further movement of the piston and attached parts, unless an emergency application has been made, as explained later, instead of a service application. With the parts in this position, port *z* in the equalizing valve registers with port *h* in its seat, and cavity *n* in the equalizing valve connects ports *h* and *w* in the seat. As the equalizing valve chamber is always in communication with the pressure chamber, and with the parts in the position illustrated in

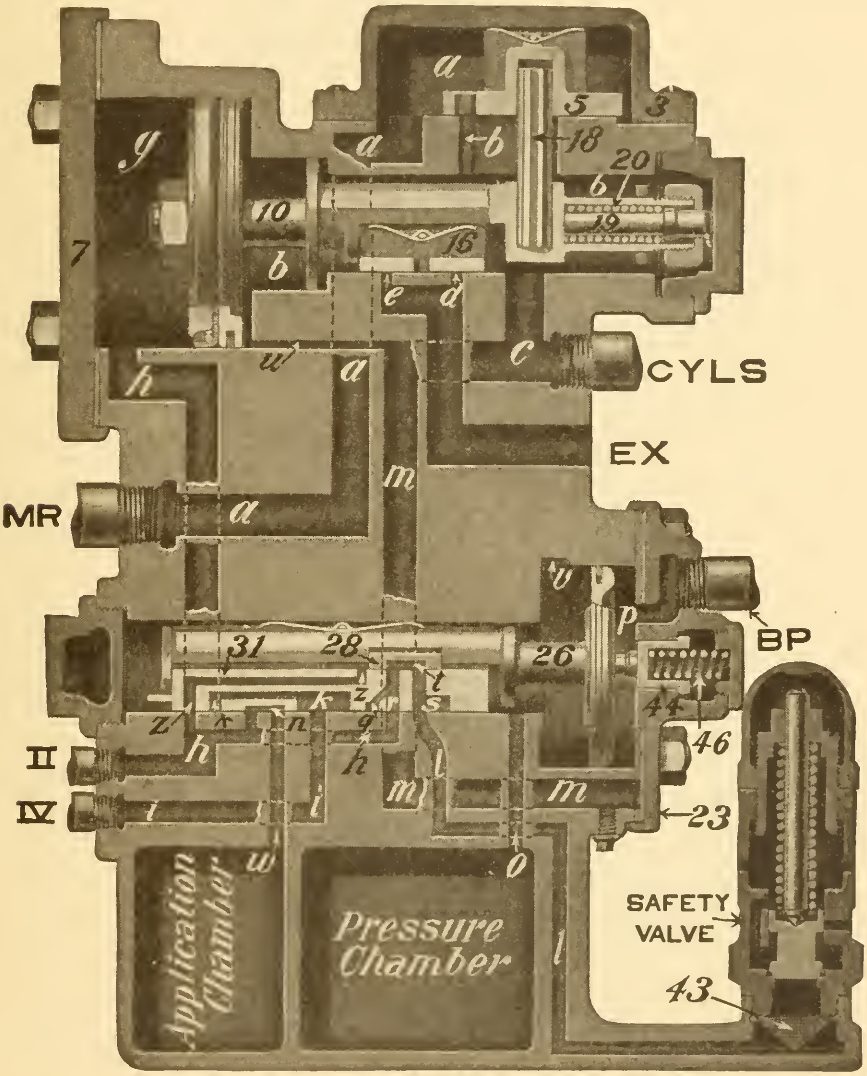


Fig. 98. Automatic Service Position of Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

Fig. 98, air can flow from the pressure chamber to both the application cylinder and the application chamber. This air pressure from the pressure chamber acting on piston *10* moves it to the right, as shown, causing exhaust valve *16* to close exhaust ports *e* and *d*, and acts with sufficient force to compress application piston graduating spring *20*. As piston *10* is moved to the right, it carries with it application valve 5, by means of its connection with the piston stem through the pin *18*. With the application valve in the position shown, its only port is fully opened and air is permitted to flow from the main reservoirs into chambers *bb* and through passage *c* to the brake cylinders. Air from the main reservoirs will continue

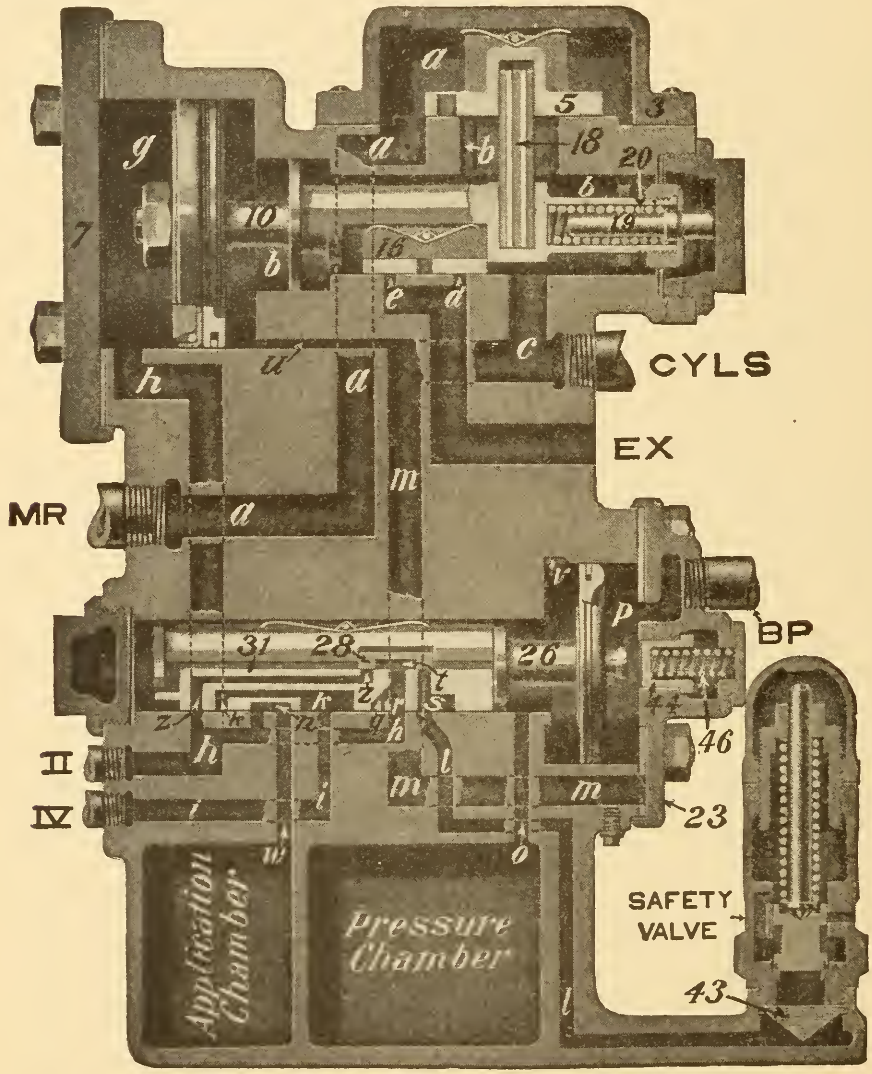


Fig. 99. Service-Lap Position for Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

to flow, through the path indicated above, into the brake cylinders until full equalization occurs.

During the movement just described, cavity *t* in the graduating valve *28* connects ports *r* and *s* in the equalizing valve, and by the same movement ports *r* and *s* are brought to register with ports *h* and *l* in the seat. This establishes communication between the application cylinder and the safety valve, which, being set at 68 pounds (three pounds above the maximum obtained in an emergency application from 70 pounds brake-pipe pressure), limits the brake-cylinder pressure to this amount.

The amount of pressure resulting in the application cylinder for a certain brake-pipe service reduction depends on the comparative volumes of the pressure chamber, application cylinder, and its chamber. These volumes are such that with 70 pounds in the pressure chamber they will equalize at about 50 pounds.

Service Lap. When the brake-pipe reduction is not sufficient to cause a full-service application, the conditions described above continue until the pressure in the pressure chamber is reduced enough below that in the brake pipe to cause piston *26* to force graduating valve *28* to the left until stopped by the shoulder on the piston stem striking the right-hand end of equalizing valve *31*, the position indicated in Fig. 99 and known as service lap. In this position, graduating valve *28* has closed port *z* so that no more air can flow from the pressure chamber to the application cylinder and chamber. It also has closed port *s*, cutting off communication to the safety valve, so that any possible leak in the latter cannot reduce the application-cylinder pressure, and thus similarly affect the pressure in the brake cylinders. The flow of air past application valve *5* to the brake cylinders continues until their pressure slightly exceeds that in the application cylinder, when the higher pressure and application-piston graduating spring together force piston *10* to the left, Fig. 99, thereby closing port *b*. Further movement is prevented by the resistance of exhaust valve *16* and the application-piston graduating spring having expanded to normal position.

From the above description it will be seen that application piston *10* has application-cylinder pressure on one side *g* and brake-cylinder pressure on the other. When either pressure varies, the piston will move toward the lower. Consequently, if pressure in chamber *b* is reduced by brake-cylinder leakage, the pressure maintained in the application cylinder *g* will force piston *10* to the right, opening application valve *5* and again admitting air from the main reservoirs to the brake cylinders until the pressure in chamber *b* is again slightly above that in the application cylinder *g*, when the piston again moves back to lap position.

Automatic Release. When the automatic brake-valve handle is placed in release position, and the brake-pipe pressure in chamber *p* is thereby increased above that in the pressure chamber, equalizing piston *26* moves to the left, carrying with it equalizing valve *31* and graduating valve *28* to the position shown in Fig. 97. The feed groove *v* now being open permits the pressure in the pressure chamber to feed up until it is equal to that in the brake pipe, as before described. This action does not release the locomotive brakes because it does not discharge application-cylinder pressure. The release pipe is closed by the rotary valve of the automatic brake valve, and the application-cylinder pipe is closed by the rotary valves of both brake valves. To release the locomotive brakes, the automatic brake valve must be moved to running position. The release pipe is then connected by the rotary valve to the atmosphere and, as exhaust cavity *k* in the equalizing valve *31* connects ports *i*, *w*, and *h* in the valve seat, the air in the application cylinder and chamber will escape. As this pressure reduces, the brake-cylinder pressure will force application piston *10* to the left until exhaust valve *16* uncovers exhaust ports *d* and *e*, allowing brake-cylinder pressure to escape, Fig. 97, or in case of graduated release, to reduce in like amount to the reduction in the application-cylinder pressure.

Emergency. When a sudden and heavy brake-pipe reduction is made, as in an emergency application, the air pressure in the pressure chamber forces equalization piston *26*, Fig. 100, to the right with sufficient force to compress equalizing-piston graduating spring *46*, and to seat against the leather gasket beneath cap *23*. This movement causes equalizing valve *31* to uncover port *h* in the seat without opening port *w*, making a direct opening from the pressure chamber to the application cylinder only, so that they quickly become equalized. This cylinder volume, being small and connected with that of the pressure chamber at 70 pounds pressure, equalizes at about 65 pounds. Also, in this position of the automatic brake valve, a small port in the rotary valve allows air from the main reservoirs to feed into the application-cylinder pipe, and thus to the application cylinder. The application cylinder is now connected to the safety valve through port *h* in the seat, cavity *q* and port *r* in the equalizing valve, and port *l* in the seat. Cavity *q* and port *r* in the equalizing valve are connected by a small port, the size of which permits the air in the application cylinder to escape through the safety valve at the same rate that the air from the main reservoirs, feeding through the rotary valve of the automatic brake valve, can supply it, preventing the pressure from rising above the adjustment of the safety valve.

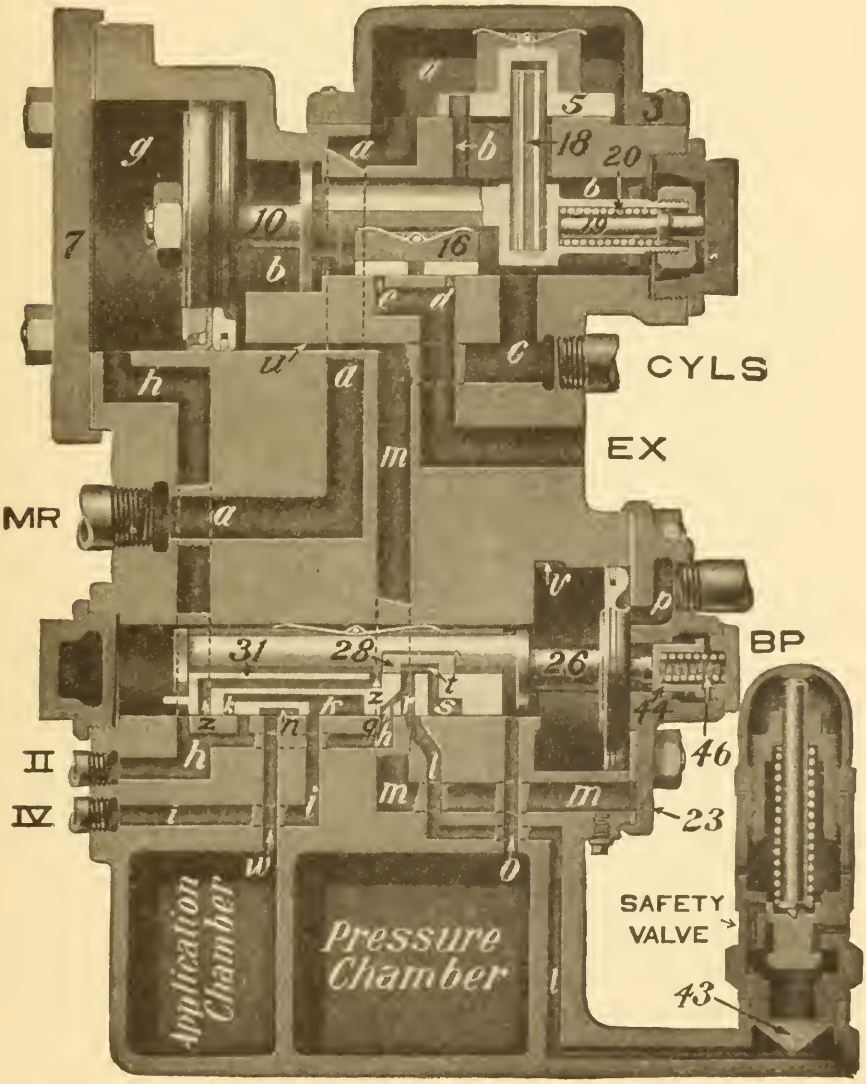


Fig. 100. Emergency Position for Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

In high-speed brake service, the feed valve is regulated for 110 pounds brake-pipe pressure instead of 70, and main-reservoir pressure is 130 or 140 pounds. Under these conditions an emergency application raises the application-cylinder pressure to about 93 pounds; but the passage between cavity *q* and port *r* is so small that the flow of application-cylinder pressure to the safety valve is just enough greater than the supply through the brake valve to decrease that pressure in practically the same time and manner as is done by the high-speed reducing valve, until it is approximately 75 pounds. The reason why the pressure in the application cylinder, pressure

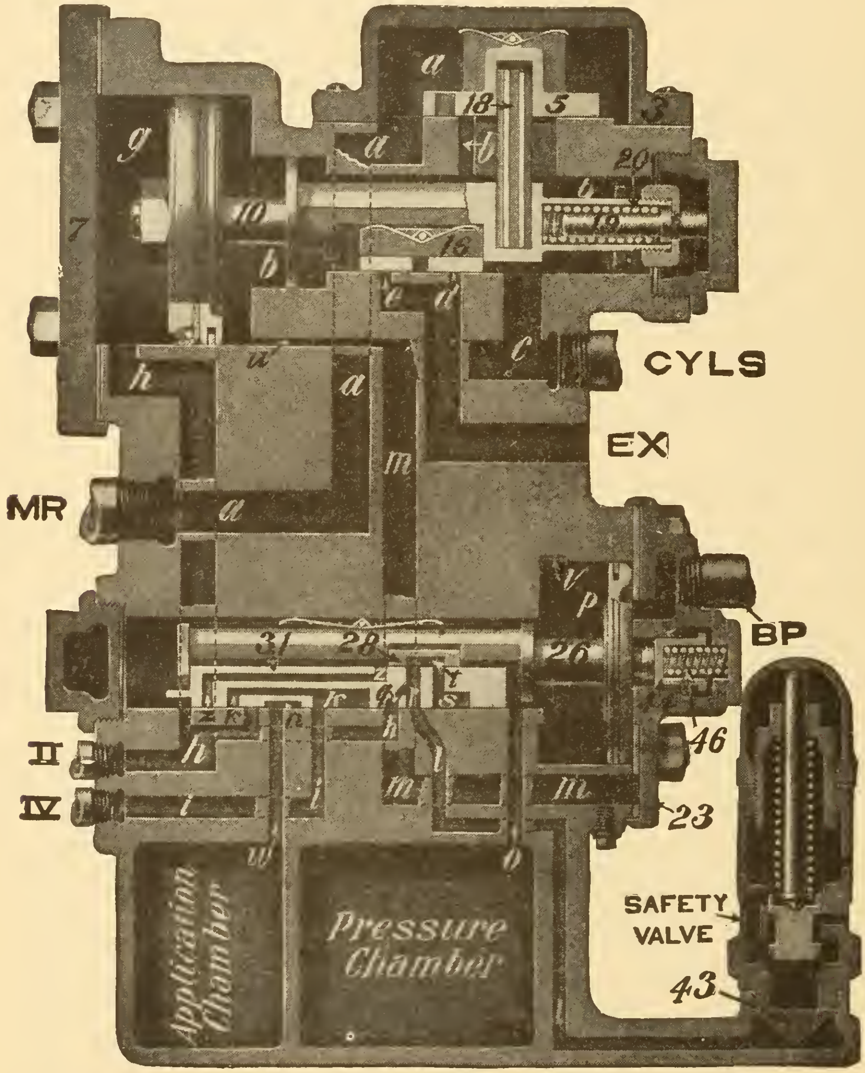


Fig. 101. Emergency Lap Position for Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

chamber, and brake cylinders does not fall to 68 pounds, to which pressure the safety-valve is adjusted, is because the inflow of air through the brake valve with the high main-reservoir pressure used in high-speed service is equal, at 75 pounds, to the outflow through the small opening to the safety valve. This is done to get a shorter stop in emergency. The application portion of the distributing valve operates similarly, but more quickly than in service application.

Emergency Lap. The movable parts of the valve remain in the position shown in Fig. 100 until the brake-cylinder pressure slightly exceeds the application-cylinder pressure, when the application piston and application valve move back to the position known as "emergency lap" as shown in Fig. 101.

The release after an emergency is brought about by the same manipulation of the automatic brake valve as that following service application, but the effect on the distributing valve is somewhat different. When the equalizing piston, equalizing valve, and graduating valve are forced to the release position by the increased brake-pipe pressure in chamber *p*, the application chamber—pressure in which is zero—is connected to the application cylinder, having emergency pressure therein through port *w*, cavity *k*, and port *h*. The pressure in the application cylinder at once expands into the application chamber until these pressures are equal, which results in the release of brake-cylinder pressure until it is slightly less than that in the application cylinder and chamber. Consequently, in releasing after an emergency (using the release position of the automatic brake valve), the brake-cylinder pressure will automatically reduce to about 15 pounds, where it will remain until the automatic brake-valve handle is moved to running position.

If the brakes are applied by a conductor's valve, a burst hose, or parting of train, the movement of equalizing valve *31* breaks the connection between ports *h* and *i* through cavity *k*, so that the brakes will apply and remain applied until the brake-pipe pressure is restored. The handle of the automatic brake valve should be immediately moved to emergency position to prevent a loss of main-reservoir pressure.

Independent Brake Operation

Independent Application. When the handle of the independent brake valve is moved to either slow- or quick-application position, air from the main reservoir, limited by the reducing valve to a maximum of 45 pounds, is allowed to flow to the application cylinder, forcing application piston *10* to the right as shown in Fig. 102. This movement causes application valve *5* to open its port and allow air from the main reservoirs to flow into chambers *bb* and through passage *c* to the brake cylinders, as in an automatic application, until the pressure slightly exceeds that in the application cylinder. The application-piston graduating spring *20* and higher pressure then force application piston *10* to the left until application valve *5* closes its port. Further movement is prevented by the resistance of exhaust valve *16* and the application-piston graduating

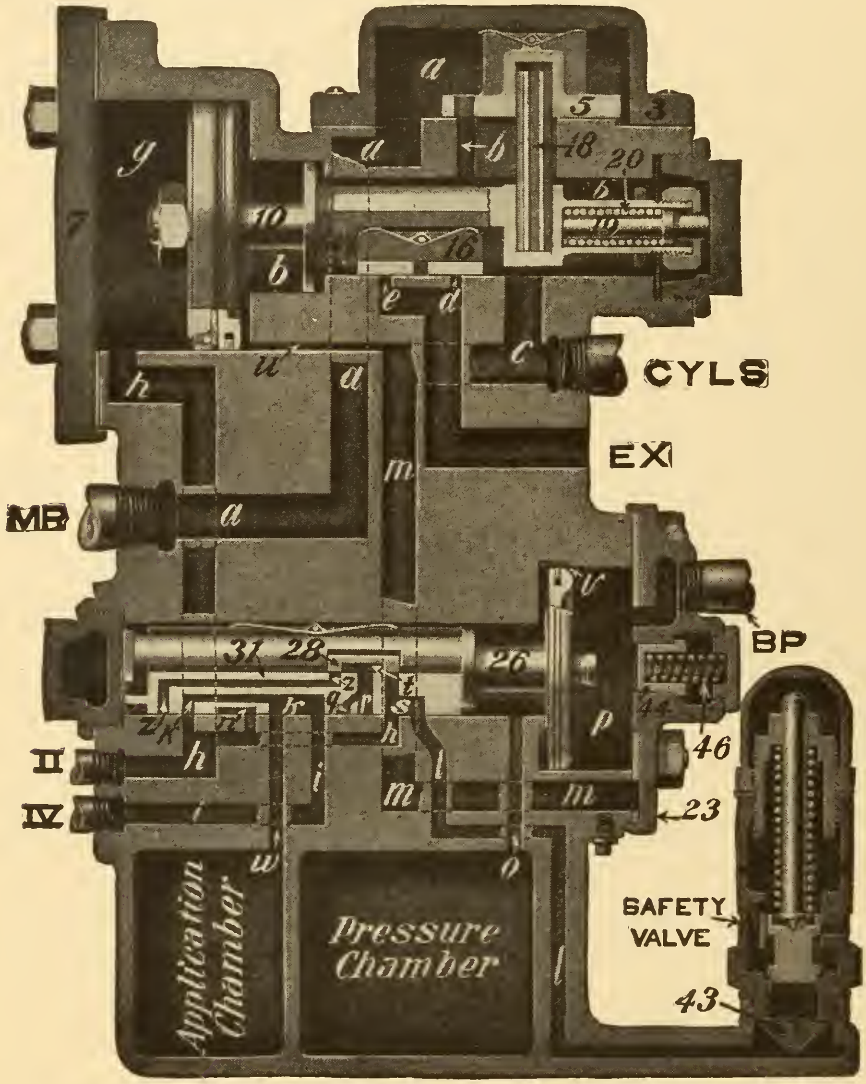


Fig. 102. Independent Application Position for Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

spring having expanded to its normal position. This position, shown in Fig. 103, is known as "independent lap".

Independent Release. When the handle of the independent brake valve is moved to release position, a direct opening is made from the application cylinder to the atmosphere. As the application-cylinder pressure escapes, brake-cylinder pressure in chamber *b* moves application piston *10* to the left, causing exhaust valve *16* to open exhaust ports *e* and *d* as shown in Fig. 97, thereby allowing brake-cylinder pressure to discharge to the atmosphere.

If the independent brake valve is returned to lap before all the application-cylinder pressure has escaped, the application piston *10*

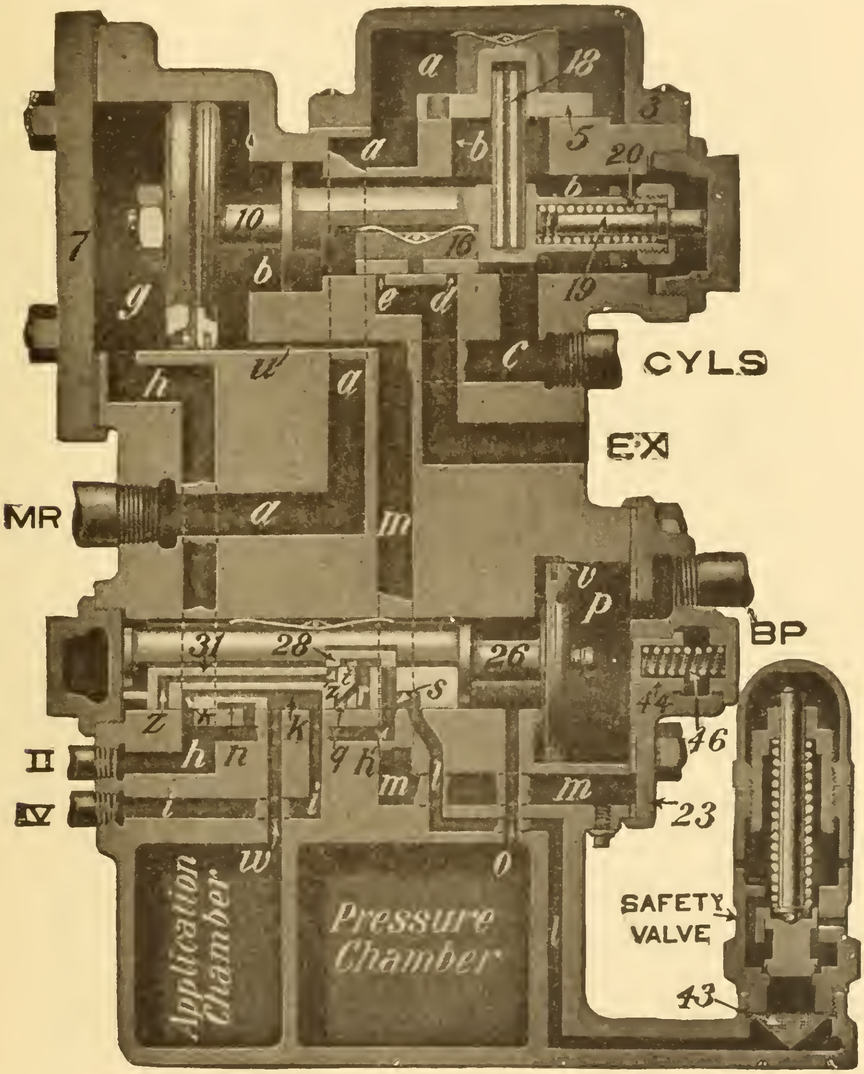


Fig. 103. Independent Lap Position for Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

will return to independent lap position, Fig. 103, as soon as the brake-cylinder pressure is reduced a little below that remaining in the application cylinder, thus closing exhaust ports *e* and *d* and holding the remaining pressure in the brake cylinders. In this way the independent release may be graduated as desired.

Fig. 104 shows the position the distributing valve parts will assume if the locomotive brakes are released by the independent brake valve after an automatic application has been made. This results in the application portion going to release position without changing the conditions in either the pressure chamber or brake

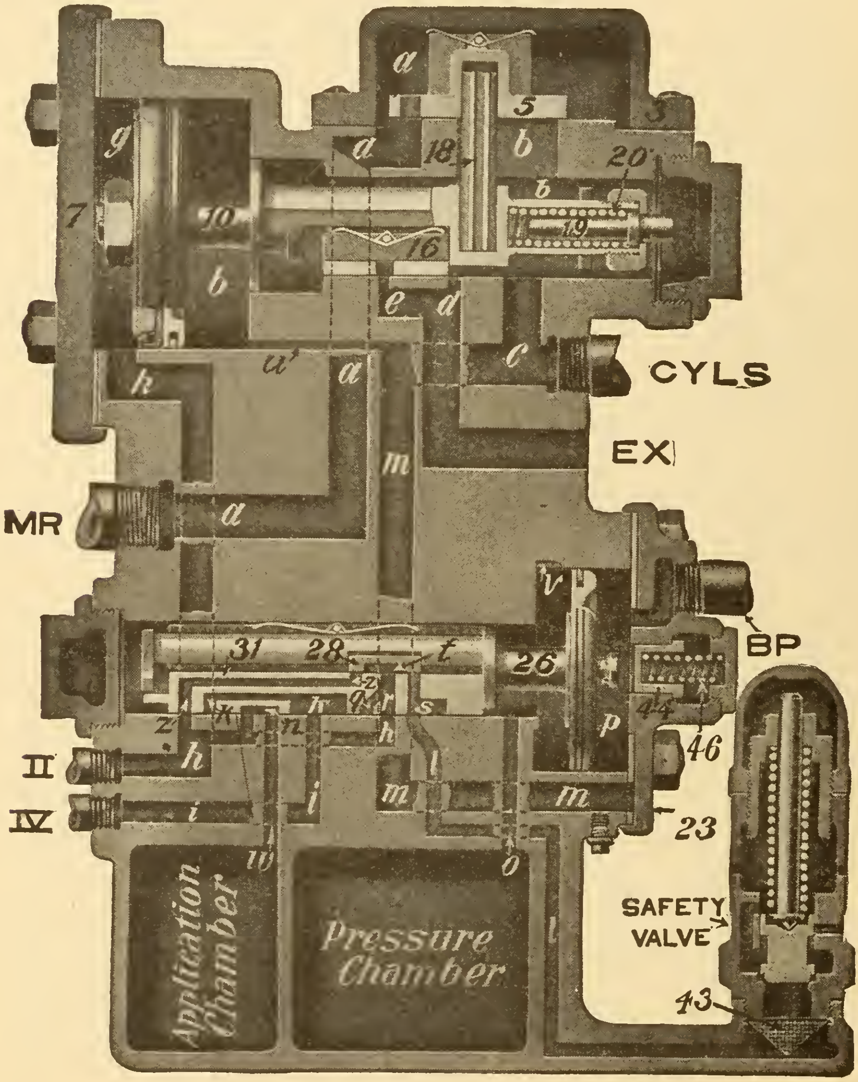


Fig. 104. Release Position for Distributing Valve
Courtesy of Westinghouse Air-Brake Company, Wilmerding, Pennsylvania

pipe; consequently, the equalizing portion does not move until release is made by the automatic brake valve.

An independent release of locomotive brakes may also be made in the same manner, after an emergency application by the automatic brake valve. However, owing to the fact that, in this position, the automatic brake valve will be supplying the application cylinder through the maintaining port in the rotary valve, the handle of the independent brake valve must be held in release position to prevent the locomotive brakes from re-applying so long as the handle of the automatic brake valve remains in emergency position. The equalizing portion of the distributing valve will remain in the position shown in Figs. 100 and 101.

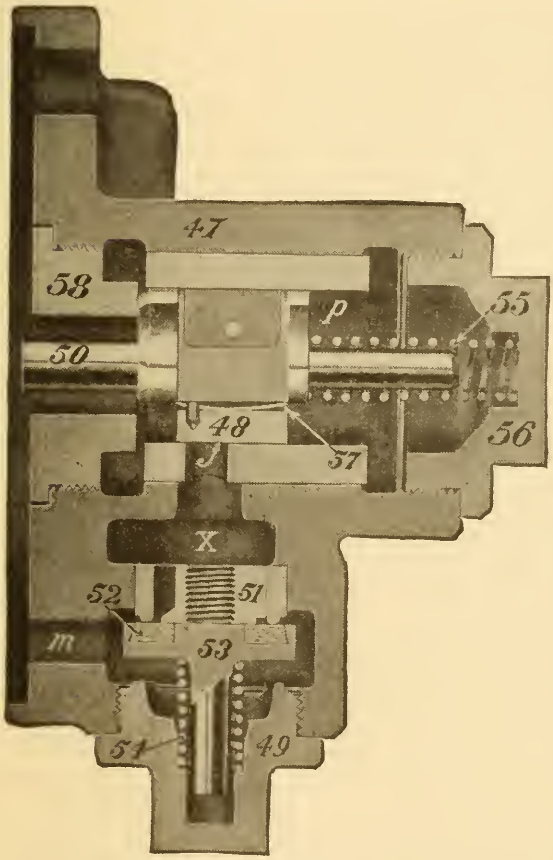


Fig. 105. Section Showing Quick-Action Cylinder Cap for No. 6 Distributing Valve
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

Double=Heading. When there are two or more locomotives in a train, the instructions already given remain unchanged so far as the leading locomotive, or the locomotive from which the brakes are being operated, is concerned. On all other locomotives in the train, however, the double-heading cock under the automatic brake valve must be closed and the automatic and independent brake-valve handles carried in running position. The release pipe is then open to the atmosphere at the automatic brake valve, and the operation of the distributing valve is the same as that described during automatic brake applications. In double heading, therefore, the application and the release of the distributing valve on each helper locomotive is similar to that of the triple valves on the train. Port *u* drains the application cylinder of any moisture precipitated from the air in chamber *b*, such moisture passing to the lower part of the distributing valve through port *m*, where it may be drawn off by removing the pipe plug.

Quick=Action Cylinder Cap. The equalizing portion of the distributing valve corresponds to the plain triple valve of the old standard locomotive brake equipments. There are, however, conditions under which it is advisable to have it correspond to a quick-action triple valve; that is, vent brake-pipe air into the brake cylinders in an emergency application. To obtain this, the cylinder cap *23,* Fig. 96, is replaced by the quick-action cylinder cap, Fig. 105.

In an emergency application, as equalizing piston *26* moves to the right and seals against the gasket, Fig. 106, the knob on the

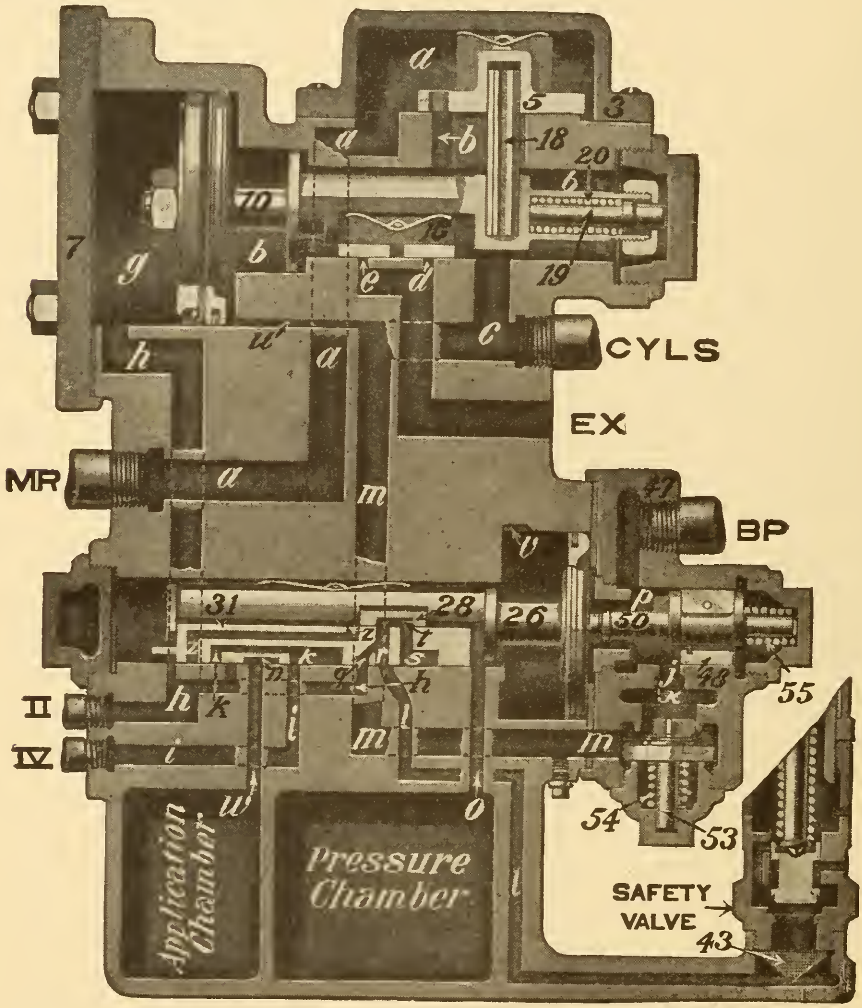


Fig. 106. Emergency Position of No. 6 Distributing Valve with Quick-Action Cap
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

piston strikes the graduating stem *50,* causing it to compress equalizing-piston graduating spring *55,* and move emergency valve *48* to the right, opening port *j.* Brake-pipe pressure in chamber *p* flows to chamber *X,* pushes down check valve *53,* and passes to the brake cylinders through port *m* in the cap and distributing valve body. When the brake cylinders and brake pipe equalize, check valve *53* is forced to its seat by spring *54*, thus preventing air in the brake cylinders from flowing back into the brake pipe. When a release of the brakes occurs and piston *26* is moved back to its normal position, Fig. 97, spring *55* forces graduating stem *50* and emergency valve *48* back to the position shown in Fig. 105.

"PC" PASSENGER BRAKE EQUIPMENT

Characteristics. The "PC" passenger brake equipment was designed for fast passenger service and for cars weighing as high as 150,000 pounds. Briefly stated, the requirements recognized as essential in a satisfactory brake for this modern service are as follows:

(a) Automatic in action.
(b) Efficiency not materially affected by unequal piston travel or brake-cylinder leakage.
(c) Certainty and uniformity of service action.
(d) Graduated release.
(e) Quick re-charge and consequent ready response of brakes to any brake-pipe reduction made at any time.
(f) Maximum possible rate of re-charging the brake pipe alone.
(g) Predetermined and fixed flexibility of service operation.
(h) Maximum sensitiveness to release, consistent with stability, combined with minimum sensitiveness to the inevitable fluctuations in brake-pipe pressure tending to cause undesired light-service applications, brakes creeping on, etc., and yet guard against the attainment of too high a difference of pressure between the brake pipe and the pressure chamber (auxiliary reservoir).
(i) Full emergency pressure obtainable at any time after a service application.
(j) Full emergency pressure applied automatically after any predetermined brake-pipe reduction has been made after equalization.
(k) Emergency braking power approximately 100 per cent greater than the maximum obtainable in service applications.
(l) Maximum brake-cylinder pressure obtained in the least possible time.
(m) Maximum brake-cylinder pressure maintained throughout the stop.
(n) Brake rigging designed for maximum efficiency.
(o) Adaptability to all classes and conditions of service.

Special Features of "PC" Equipment. The construction and principle of operation of the "PC" brake equipment is such as to permit of the fulfillment of all of the above requirements. The features which may be mentioned as being peculiar to the equipment are as follows:

(1) Graduated release and quick re-charge obtained as with previous improved types of triple valves.
(2) Certainty and uniformity of service action.
(3) Quick rise in brake-cylinder pressure.

(4) Uniformity and maintenance of service brake-cylinder pressure during the stop.
(5) Predetermined limiting of service braking power.
(6) Automatic emergency application on depletion of brake-pipe pressure.
(7) Full emergency braking power at any time.
(8) The service and emergency features being separated permits the necessary flexibility for service applications to be obtained without impairing in the slightest the emergency features of the equipment.
(9) A low total leverage ratio, with corresponding over-all efficiency.
(10) Less sensitiveness to the inevitable fluctuations in brake-pipe pressure, which tend to cause undesired light applications of the brake.
(11) Maximum rate of rise of brake-pipe pressure possible with given length of brake pipe, with consequently greater certainty of brakes releasing when a release is made.
(12) Greatly increased sensitiveness to release in long trains, when it becomes necessary to have the maximum sensitiveness to an increase in brake-pipe pressure to insure all valves in the train responding as intended.
(13) The elimination of the graduated release feature is specially provided for in the construction of the valve. This is provided for to permit the use of cars not equipped with a graduated release brake.

All of the functions mentioned above have been combined in such a way that they will interchange with existing equipments in an entirely satisfactory manner.

Names of Various Parts and Their Identification. Fig. 107 shows all of the parts making up the equipment, together with their names. It also illustrates the two methods of installation. The following is a list of the names of the various parts, a number of which have previously been described in connection with other brake equipments:

(1) The "No. 3-E" control valve, corresponding in a general way to the triple valve of the old-style passenger equipment, and more closely to the distributing valve of the "ET" equipment.
(2) Two brake cylinders—one for service and both for emergency applications.
(3) Two supply reservoirs, called the service and emergency reservoirs, respectively.
(4) A centrifugal dirt collector.
(5) A branch-pipe air strainer.
(6) A conductor's valve.
(7) A branch-pipe tee, cut-out cocks, angle cocks, hose couplings, dummy couplings, etc., similar to those found on other equipments.
(8) An automatic slack-adjuster, which is not an essential part of the equipment, but which is strongly recommended.

Of all the parts making up the equipment, the control valve illustrated in Figs. 108, 109, and 110, is the most important. As can be seen, the valve portions are supported upon the compartment reser-

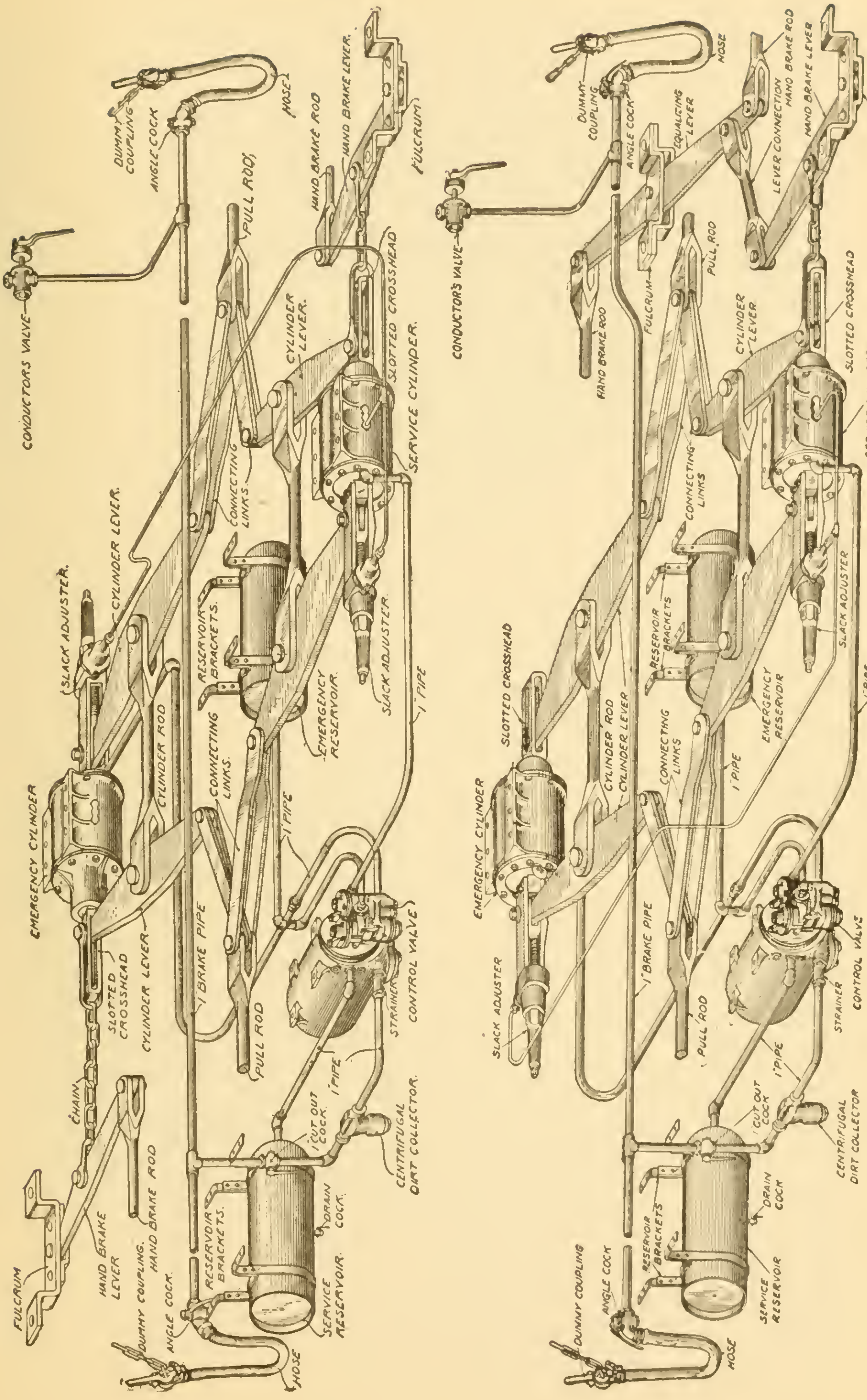


Fig. 107. Westinghouse "PC" Brake Equipment. Upper, Cylinders Pointing in Opposite Directions; Lower, Cylinders Pointing in Same Direction

voir, which is bolted to the underframing of the car. The compartment reservoir is made up of the pressure chamber, application chamber, and the reduction-limiting chamber. The equalizing and

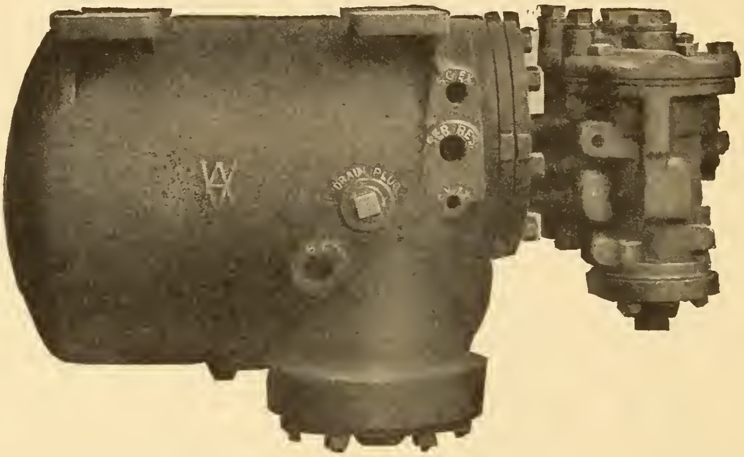


Fig. 108. Westinghouse "3-E" Control Valve, Showing Side View

application portions of the compartment reservoir correspond to those of the "ET" equipment. The location and size of the pipe connections are more clearly shown in the outline drawings, Figs. 111 and 112. Actual sections of the control valve and compartment reservoir are shown in Figs. 113, 114, and 115, having all of the parts numbered. The following five paragraphs are arranged to assist in identifying the various parts:

Fig. 109. Westinghouse "3-E" Control Valve, Showing Front View

Equalizing Portion: *2* Equalizing body; *3* Release piston; *4* Release slide valve; *5* Release slide-valve spring; *6* Release graduating valve; *7* Release graduating-valve spring; *8* Release piston-cap nut; *9* Release piston ring; *10* Release cylinder cap; *11* Release cylinder-cap gasket; *12* Square-head cap screw; *13* Release piston graduating sleeve; *14* Release piston graduating spring; *15* Release piston graduating nut; *16* Check valve; *17* Check-valve cap nut; *18* Direct and graduated release cap; *19* Stud and nut for direct and graduated release cap; *20* Equalizing piston; *21* Equalizing piston ring (large); *22* Equalizing slide valve; *23* Equalizing slide-valve spring; *24* Equalizing graduating valve; *25* Equalizing graduating-valve spring; *26* Large equalizing cylinder cap; *27* Large equalizing cylinder-cap gasket; *28* Square-head cap screw; *29* Equalizing piston-stop sleeve; *30* Equalizing piston-stop spring; *31* Equalizing graduating nut; *32* Equalizing piston ring (small); *33* Small equalizing cylinder cap; *34* Gasket for small equalizing cylinder cap; *35* Square-head cap screw; *36* Cap nut for small equalizing cylinder cap; *37* Small equalizing pis-

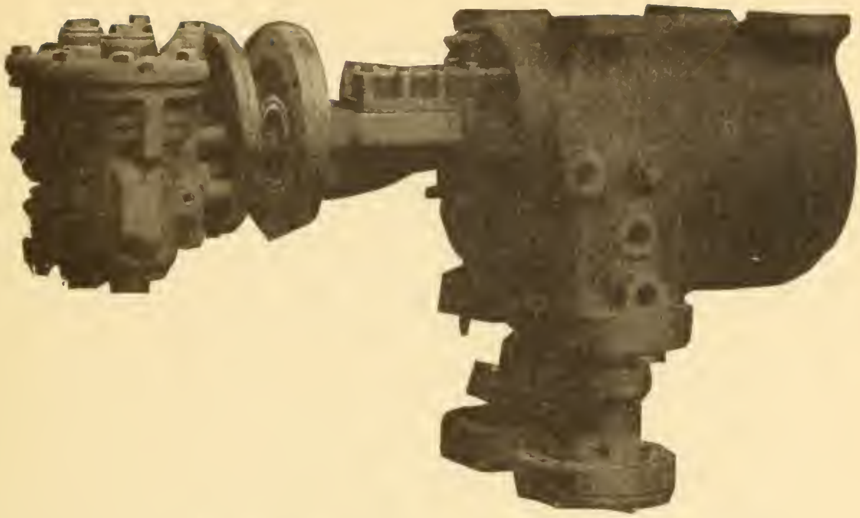


Fig. 110. Westinghouse "3-E" Control Valve, Showing Different Portions of Valve

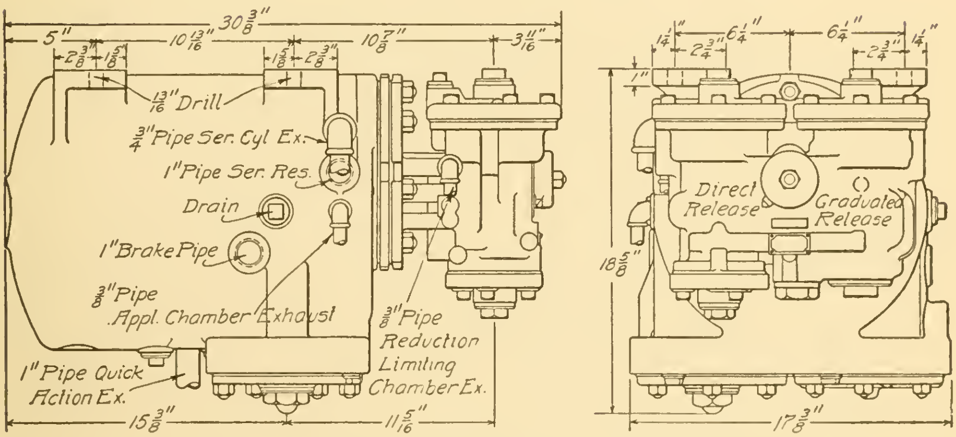


Fig. 111. Outline of Westinghouse "3-E" Control Valve

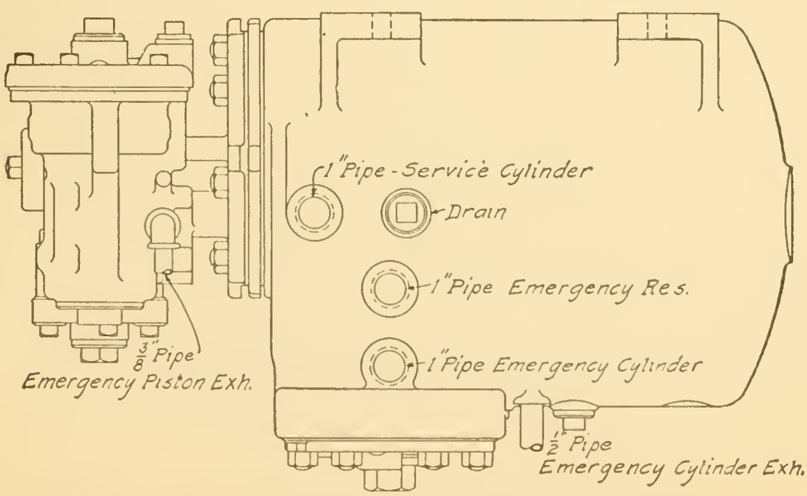


Fig. 112. Outline of Westinghouse "3-E" Control Valve, Showing Side Opposite to That of Fig. 111

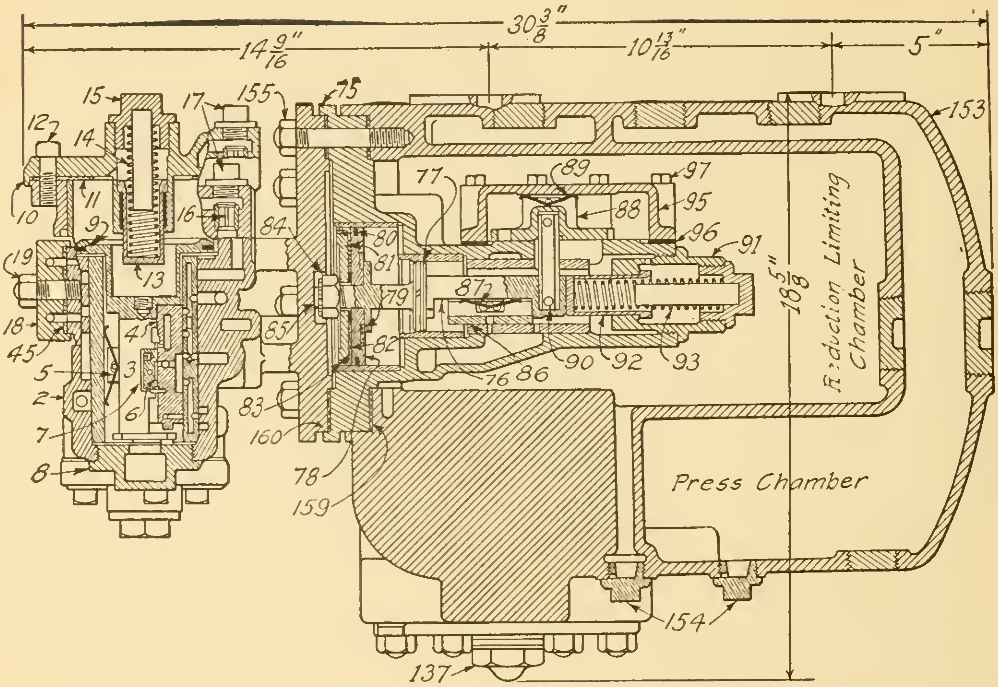


Fig. 113. Actual Longitudinal Section of Westinghouse "3-E" Control Valve

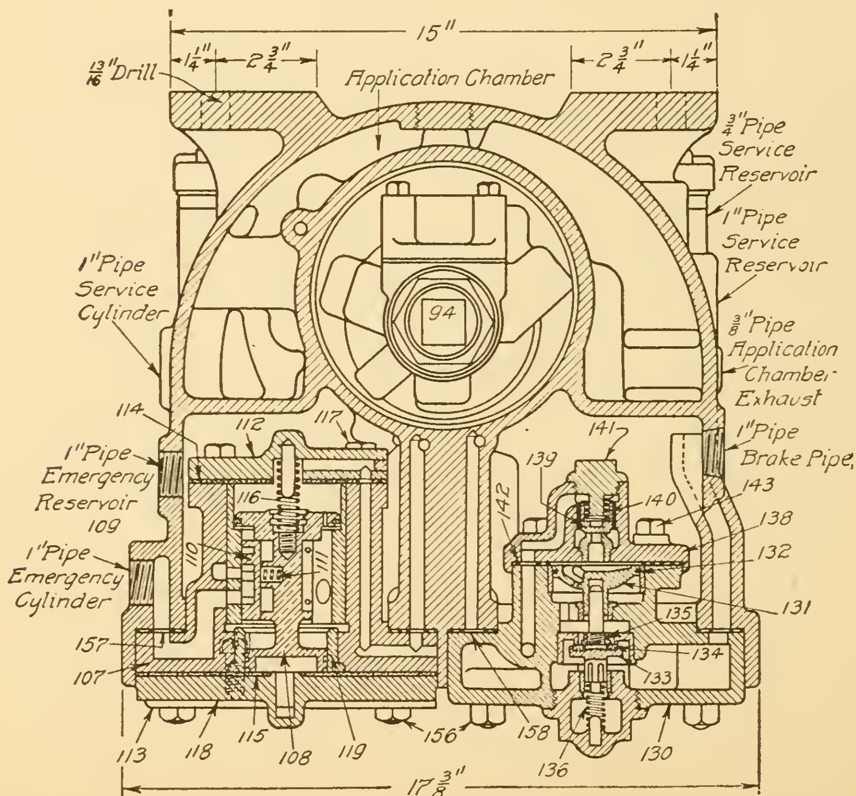


Fig. 114. Actual Cross Section of Westinghouse "3-E" Control Valve

ton bush; *38* Service-reservoir charging valve; *39* Charging-valve piston ring; *40* Charging-valve piston ring; *41* Charging-valve seat; *42* Charging-valve washer; *43* Internal charging-valve nut; *44* External charging-valve nut; *45* Gasket for direct and graduated release cap.

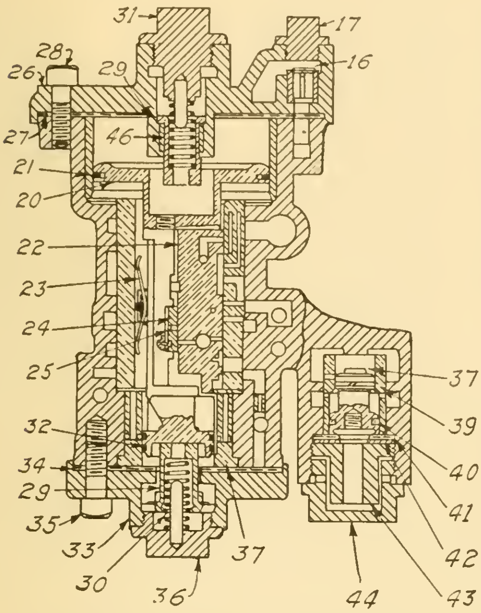


Fig. 115. Section through Equalizing Portion of Westinghouse "3-E" Control Valve

Application Portion: 75 Body; *76* Piston stem; *77* Piston ring (small); *78* Piston head; *79* Piston seal; *80* Piston ring (large); *81* Piston follower; *82* Piston-packing leather; *83* Piston-packing leather expander; *84* Piston nut; *85* Piston cotter; *86* Exhaust valve; *87* Exhaust-valve spring; *88* Application valve; *89* Application-valve spring; *90* Application-piston bolt; *91* Spring box; *92* Piston-spring sleeve; *93* Piston spring; *94* Graduating nut; *95* Application-valve cover; *96* Application-valve cover gasket; *97* Square-head screw for application-valve cover.

Emergency Portion: 107 Body; *108* Piston complete! *109* Piston ring; *110* Slide valve; *111* Slide-valve spring; *112* Small cylinder cap; *113* Large cylinder cap; *114* Small cylinder-cap gasket; *115* Large cylinder cap gasket; *116* Piston spring; *117* Square-head cap screw for small cylinder cap; *118* Oval fillister head cap screw; *119* Emergency-piston bush.

Quick-Action Portion: 130 Body; *131* Piston complete; *132* Piston ring; *133* Quick-action valve; *134* Quick-action valve seat; *135* Quick-action valve nut; *136* Quick-action valve spring; *137* Quick-action valve cap nut; *138* Quick-action valve cover; *139* Quick-action closing valve; *140* Quick-action closing valve spring; *141* Cover cap nut; *142* Cover gasket; *143* Square-head cap screw for cover.

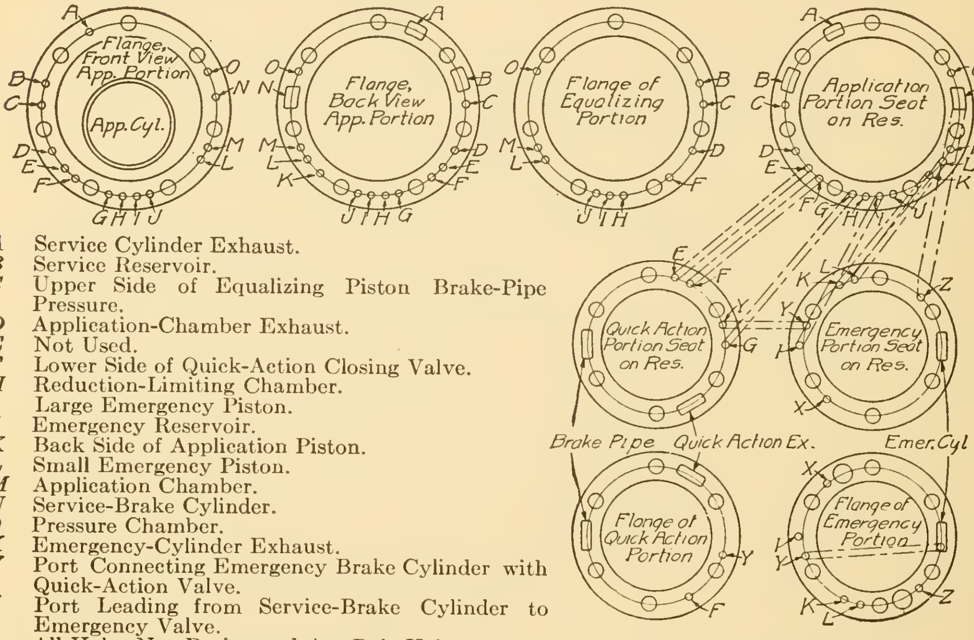
Reservoir: 153 Triple-compartment reservoir; *154* Cap nut; *155* Stud with hex. nut; *156* Stud with hex. nut; *157* Emergency-cylinder gasket; *158* Quick-action cylinder gasket; *159* Large reservoir gasket; *160* Equalizing-cylinder gasket.

CONTROL VALVE

Fig. 116 is presented to assist in gaining a clearer idea of the location of the parts in the different portions of the control valve. On account of the complicated construction of the "No. 3-E" control valve, reference will be made to the diagrammatic views shown in Figs. 117 to 131, in explaining its action.

Fig. 117 shows all of the ports and operative parts of the control valve in *normal* position. This is the position which the various parts of the valve would occupy with all parts properly assembled, but before any air has been admitted to the brake pipe.

It will be noted that the direct- and graduated-release cap is shown in its *graduated-release* position. Just below it is shown the position which the cap occupies when adjusted for direct instead of graduated release. In all the succeeding views, except Fig. 129, the cap is considered to be adjusted for graduated release. Fig.



A Service Cylinder Exhaust.
B Service Reservoir.
C Upper Side of Equalizing Piston Brake-Pipe Pressure.
D Application-Chamber Exhaust.
E Not Used.
F Lower Side of Quick-Action Closing Valve.
H Reduction-Limiting Chamber.
I Large Emergency Piston.
J Emergency Reservoir.
K Back Side of Application Piston.
L Small Emergency Piston.
M Application Chamber.
N Service-Brake Cylinder.
O Pressure Chamber.
X Emergency-Cylinder Exhaust.
Y Port Connecting Emergency Brake Cylinder with Quick-Action Valve.
Z Port Leading from Service-Brake Cylinder to Emergency Valve.
All Holes Not Designated Are Bolt Holes.

Fig. 116. Diagrams of Flanges and Seats for Westinghouse "3-E" Control-Valve Portions

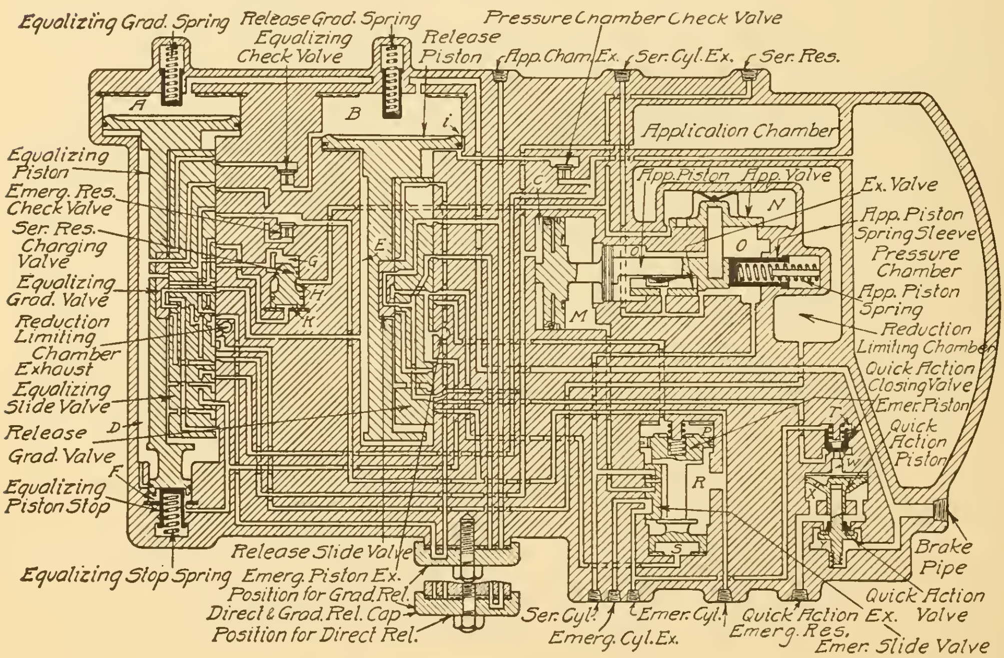


Fig. 117. Normal Position of Westinghouse "3-E" Control Valve

129 with the accompanying explanation refers to the operation of the valve with the cap adjusted for direct release.

Release and Charging Position

Fig. 118 shows only those parts and ports which are operative while the brake is being released and the pressure chamber and emergency and service reservoirs are being charged.

Charging Empty Equipment. In charging the empty equipment, air from the brake pipe entering the control valve at the point indicated passes to chambers *B* and *A* and forces the equalizing and release pistons of the equalizing portion, with their attached valves, to *release* position. Brake-pipe air then passes from chamber *B*, lifting the equalizing check valve, and by way of the equalizing slide

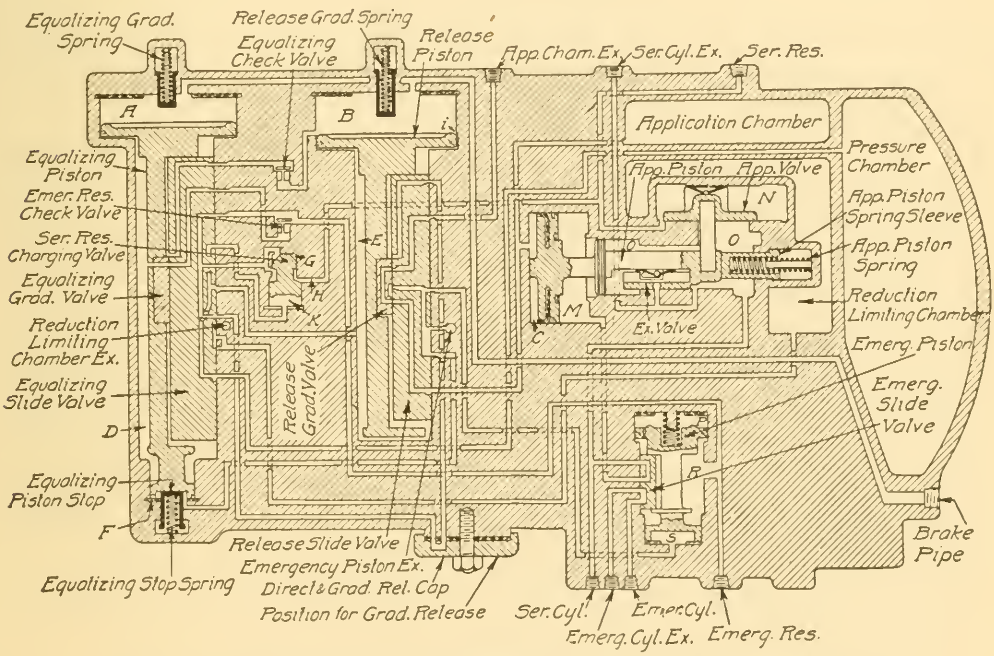


Fig. 118. Release Position, Charging-Pressure Chamber, Emergency and Service Reservoirs for Westinghouse "3-E" Control Valve

valve into chamber *D*. Air from chamber *D* then flows through the equalizing graduating and slide valve—so shown in the diagrammatic drawing for the sake of clearness. In this and a number of instances following, this port in actual valves opens past the end of instead of through the graduating valve, past the emergency-reservoir check valve, and thence in two directions: (1) to chamber *R* and to the emergency reservoir, and (2) through the equalizing slide valve to two different ports, one connecting to the service-reservoir charging valve and thence to the service reservoir; the other by way of the direct- and graduated-release cap and through the release slide valve and past the end of the release graduating valve to chamber *E*.

Air from the brake pipe and chamber *B* also flows through feed groove *i* and charges chamber *E*. From chamber *E*, the air flows by way of the equalizing slide valve in two directions: (1) to the pressure chamber direct (which is thus charged to brake-pipe pressure), and (2) to chamber *K*. With substantially the same pressures (brake-pipe pressure as explained) in chambers *G* and *K*, and a lower pressure (service-reservoir pressure) in chamber *H*, the service-reservoir charging valve remains in the position shown in Fig. 117, being held in this position until the re-charging is completed, since chamber *K* is relatively small and the ports leading to it of ample capacity to charge it more quickly than the pressure can be built up in chambers *G* and *H*.

Release Connections. Referring to Fig. 117, it will be noted that the pressure-chamber check valve prevents the air in chamber *E* from flowing directly to the pressure chamber, but allows a free passage of air in the opposite direction.

Chamber *F* at the small end of the equalizing piston is connected through the release slide valve to the emergency-piston exhaust and atmosphere, thus holding the equalizing piston and its valves positively in release position. Chamber *S* at the small end of the emergency piston is connected through the release slide valve to the emergency-piston exhaust and the atmosphere in release position, thus holding the emergency piston and its valve positively in the proper position.

The reduction-limiting chamber is connected through the equalizing slide valve to the reduction-limiting chamber exhaust and atmosphere. The application chamber and chamber *C* are connected through the release slide valve and graduating valve to the application-chamber exhaust port leading to the atmosphere.

The service brake cylinder is connected through the exhaust slide valve of the application portion to the service brake-cylinder exhaust port leading to the atmosphere. The emergency brake cylinder is connected through the emergency slide valve to the emergency-cylinder exhaust port leading to the atmosphere.

It will be noted that Fig. 117 and some that follow show a small cavity in the release graduating valve. This cavity is connected to the emergency-piston exhaust in all positions of the valve, but has no other connection. The purpose of this cavity is merely to insure that, under all conditions, there will be sufficient differential pressure acting on the graduating valve to hold it to its seat.

Service Application

(a) **Preliminary Service Position.** With the equipment fully charged as explained above, the result of a service reduction in brake-pipe pressure will be to lower the pressure in chambers *A* and *B* below that in chambers *D* and *E*, thus creating a differential pres-

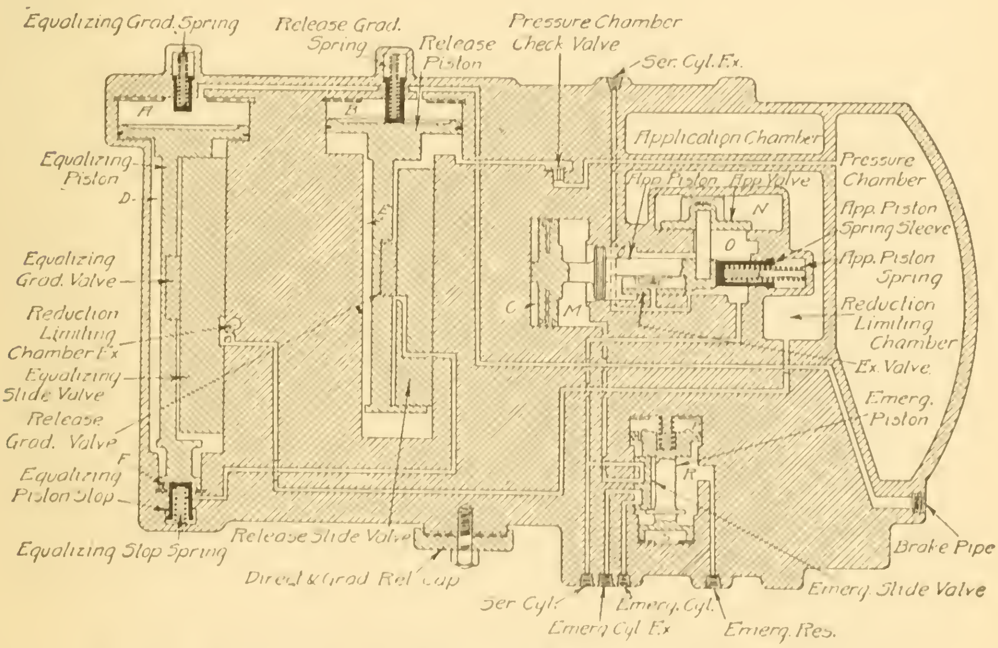


Fig. 119. Preliminary Service Position of Westinghouse "3-E" Control Valve

sure on the equalizing and release pistons. Since chamber *F* is open to the atmosphere, Fig. 118, the release piston will move on a much less differential than the equalizing piston. There is a small amount of lost motion between release piston and release graduating valve, and somewhat more between release piston and release slide valve so that during the first movement of the release piston, the release slide valve still remains in its release position, thus keeping chamber *F* open through the emergency-piston exhaust port to the atmosphere. The release piston, therefore, is the first to move when a brake-pipe reduction is made and it carries with it the release graduating valve and finally moves the release slide valve to the position shown in Fig. 119, called *preliminary service* position. In this position the piston has closed the feed groove *i* (which is therefore not shown in Fig. 119) and just touches the release graduating-piston sleeve.

The function of the valve in this position is to close the port leading from the application chamber to the atmosphere (which is therefore not shown in Fig. 119), to close the port connecting chamber *F* to the emergency-piston exhaust, and to open this latter port, connecting chamber *E* past the end of the release graduating valve and through the release slide valve to chamber *F*. Pressure-chamber air is, therefore, free to flow past the pressure-chamber check

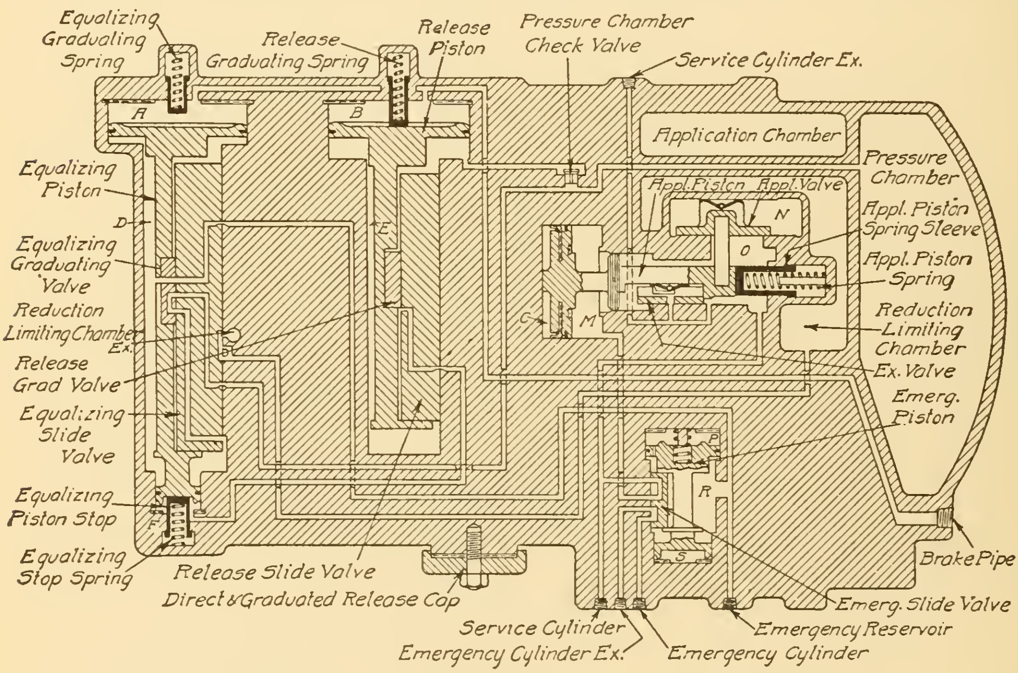


Fig. 120. Secondary Service Position of Westinghouse "3-E" Control Valve

valve to chamber *F*, thus balancing the pressures in chambers *F* and *D* on the opposite sides of the small end of the equalizing piston.

This position, it should be understood, is assumed only momentarily and should be regarded as the first stage only of the complete movement of the parts from *release* and *charging* to the *service* position of the parts.

(b) **Secondary Service Position.** The balancing of the pressures in chambers *F* and *D*, as explained, permits the equalizing piston to move in accordance with the difference of pressure already existing between chambers *D* and *A*. When the shoulder on the end of the piston stem comes in contact with the equalizing slide valve, as shown in Fig. 120, a connection is momentarily made from the emergency reservoir through the equalizing slide valve and past the end of (although shown as through in the view) the graduating valve to chamber *D*. The purpose of this connection is to prevent a drop in pressure in chamber *D* which would otherwise take place on account of the movement (displacement) of the equalizing piston. The displacement of the equalizing piston is sufficiently great, compared with the volume of chamber *D*, to require the provision just explained.

At the same time, the pressure chamber is connected through the equalizing slide valve and graduating valve to chamber *D*, thus

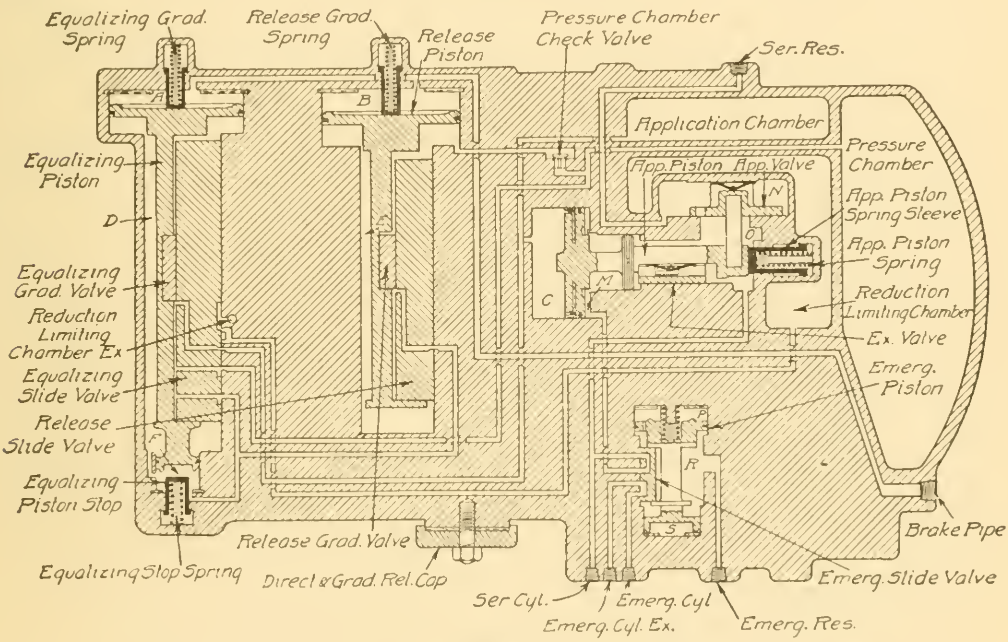


Fig. 121. Service Position of Westinghouse "3-E" Control Valve

keeping the pressures in these two chambers equal. The other connections remain as explained under the heading "Preliminary Service Position".

(c) **Service Position.** The differential between the brake-pipe pressure in chamber *A* and the pressure in chamber *D* (pressure-chamber pressure as explained) is sufficient to move the equalizing piston and its valves past the intermediate secondary service position into service position, Fig. 121, in which the equalizing piston just touches the equalizing graduating-spring sleeve.

Chambers *F* and *D* are in communication by way of a feed port around the small end of the equalizing piston. The pressure chamber is connected to chamber *D* through two channels, *first,* by way of the pressure-chamber check valve to chamber *E* and thence past the end of the release graduating valve through the release slide valve to chamber *D* by way of a port past the end of (shown as through in diagram) the equalizing slide valve, as well as through chamber *F;* and *second,* the pressure chamber is also connected directly to the seat of the equalizing slide valve and past the end of (shown as through in diagram) the slide valve direct to chamber *D.*

From chamber *D,* air from the pressure chamber can flow past the end of the equalizing graduating valve and through the equalizing

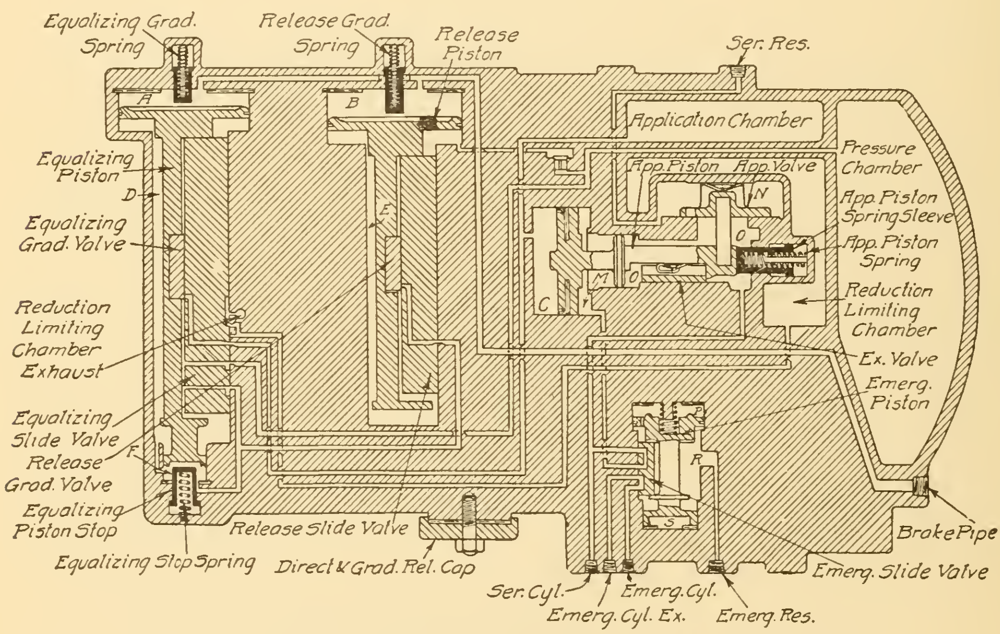


Fig. 122. Service Lap Position for Westinghouse "3-E" Control Valve

slide valve to the application chamber and chamber *C* on the face of the application piston. The pressure of the compressed air thus admitted to chamber *C* causes the application piston to move to its application position, compressing the application-piston spring in so doing.

In this position the brake-cylinder exhaust slide valve closes the brake-cylinder exhaust ports (which, therefore, are not shown in Fig. 121), and the application slide valve opens the application port, permitting air from the service reservoir (chamber *N*) to flow to chamber *O* and the service brake cylinder, thus applying the brakes. The air flowing thus to the service brake cylinder also flows by way of the emergency slide valve to chamber *M*, in which the pressure is increased equally with that of the service brake cylinder. The flow of air from the service reservoir to the service cylinder continues, therefore, until the pressure in the service brake cylinder and in chamber *M* becomes substantially equal to that in the application chamber on the opposite side of the application piston. The application-piston spring then returns the piston and the application slide valve back to *lap* position, Fig. 122, thus holding the brakes applied with a service brake-cylinder pressure substantially equal to that put into the application chamber, as before mentioned.

It will be noted that in *service* position, the reduction limiting chamber and emergency brake cylinder still remain connected to the atmosphere, as explained under the heading "Release Position".

(d) **Service Lap Position.** In case that less than a full-service reduction is made, that is to say that the brake-pipe pressure is not

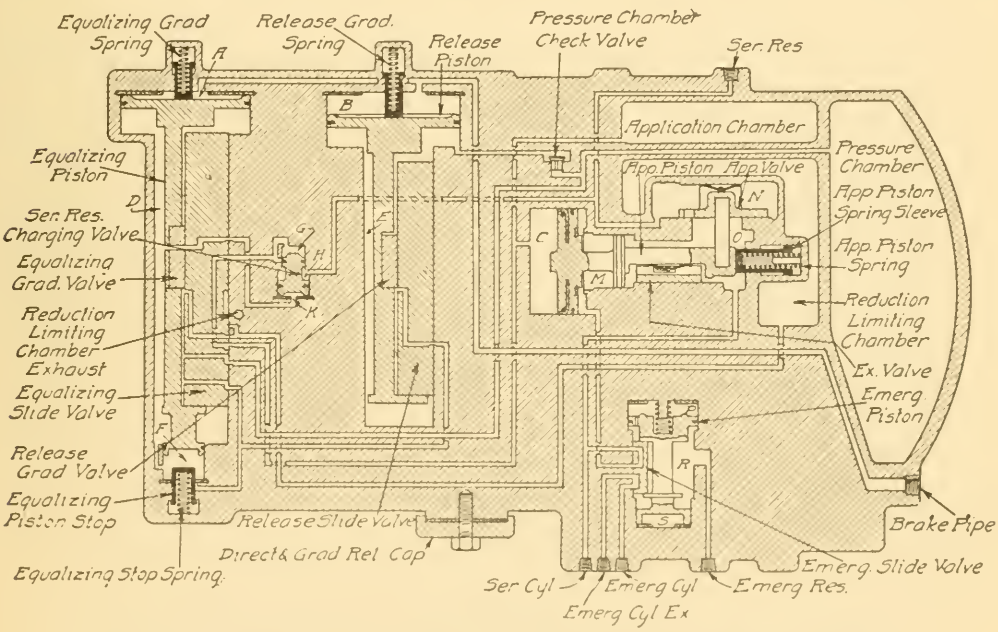


Fig. 123. Over-Reduction Position for Westinghouse "3-E" Control Valve

reduced below the point at which the pressure-chamber and application-chamber pressures equalize, the flow of air from the pressure chamber to the application chamber as explained under the heading "Service Position" will finally reduce the pressure in chamber *D* to slightly below that to which the brake-pipe pressure is reduced. The slightly higher brake-pipe pressure in chamber *A* then causes the equalizing piston and graduating valve to return to their *service lap* positions, Fig. 122, and close communication from the pressure to the application chamber, holding whatever pressure was built up in chamber *C* and the application chamber.

It will be plain that any decrease in brake-cylinder pressure, due to leakage, will now reduce the pressure in chamber *M* below that which is bottled up in the application chamber (chamber *C*). The differential pressure thus established on the application piston will cause it to move again toward its *service* position and open the application valve port, as shown in Fig. 123, just enough to supply a sufficient amount of air from the service reservoir to the service brake cylinder to restore the depleted brake-cylinder pressure to its original amount, following which the application valve will be again lapped as already explained. In this way, the brake-cylinder pressure will be maintained constant, regardless of leakage, up to the capacity of the service reservoir.

The release piston and graduating valve may or may not return to their lap positions at the same time as, and in a manner similar to the movement of, the application piston and valves, but they perform no function in either case. Otherwise the parts remain the same as in service position.

(e) **Over-Reduction Position.** If the brake-pipe reduction is carried below the point at which the pressure and application chambers equalize—86 pounds when using 110 pounds brake-pipe pressure and 54 pounds with 70 pounds brake-pipe pressure—such an over-reduction results in lowering the pressure in chamber *A* below that in chamber *D* (pressure-chamber pressure). The equalizing piston consequently moves beyond its *service* position, Fig. 121, carrying with it the equalizing slide valve and graduating valve to what is called the *over-reduction* position.

The relative resistances of the release and equalizing graduating springs is such that the release piston and its valves still remain as in *service,* although for the moment the same differential between pressure-chamber and brake-pipe pressure is acting upon the release piston as was sufficient to move the equalizing piston and its valves to the *over-reduction* position.

The result is that air from the pressure chamber—which is still connected to chamber *D* in substantially the same manner as explained under "Service Position"—now flows past the end of the equalizing graduating valve and through the equalizing slide valve to the reduction-limiting chamber instead of to the application chamber as in *service* position.

The reduction-limiting chamber being at atmospheric pressure permits the pressure in the pressure chamber (and chambers *E* and *D*) to drop, in accordance with the continued over-reduction of brake-pipe pressure, to the point of equalization of the reduced pressure-chamber pressure and the reduction-limiting chamber pressure. Otherwise the condition of the pressures in the reservoirs and brake cylinders controlled by the control valve is unchanged, except that in the movement of the equalizing slide valve to *over-reduction* position, Fig. 123, a connection is made from the application chamber and chamber *C* by way of the equalizing slide valve to the top (chamber *G*) of the service-reservoir charging valve, and from chamber *D* (pressure-chamber pressure) past the end of the equalizing graduating valve and through the equalizing slide valve to chamber *K*. Since the pressure in the pressure chamber is being reduced, while that in the application chamber and service reservoir is equalized, or practically so, at about 86 pounds pressure, the service-reservoir charging valve is not lifted, but is held down to its seat.

With the parts in this position, it will be noted that the service reservoir and the application chamber are separated only by the ring in the small end of the service-reservoir charging valve. If there is any slight leakage which tends to cause a drop in application-chamber pressure—which is relatively small compared with the service-reservoir volume—the air in the service reservoir will gradually find its way around the ring in the small end of the service-reservoir charging valve and prevent any material drop in application-chamber pressure, thus practically eliminating the possibility of the brakes gradually leaking off, due to application-chamber leakage. The application valve port is shown partly open, supplying brake-cylinder leakage, as already explained.

(f) **Over=Reduction Lap Position.** Provided the brake-pipe reduction is not carried below the equalizing point of the pressure chamber and reduction-limiting chamber, a slight reduction of the pressure in the pressure chamber (and chambers *D* and *E*) below that held in the brake pipe, resulting from the continued flow of air from the pressure chamber to the reduction-limiting chamber, will cause the equalizing piston and graduating valve to be returned to *over-reduction lap* position, Fig. 124. This closes the port from the pressure chamber to the reduction-limiting chamber and prevents further flow of air in this direction, but otherwise all parts and pressures are as explained under "Over-Reduction Position", except that the port connecting chamber *D* past the end of the equalizing graduating valve and through slide valve to chamber *K* is blanked by the movement of the equalizing graduating valve.

Should the brakes be held applied in *over-reduction lap* position for a sufficient length of time, with an application-chamber leakage

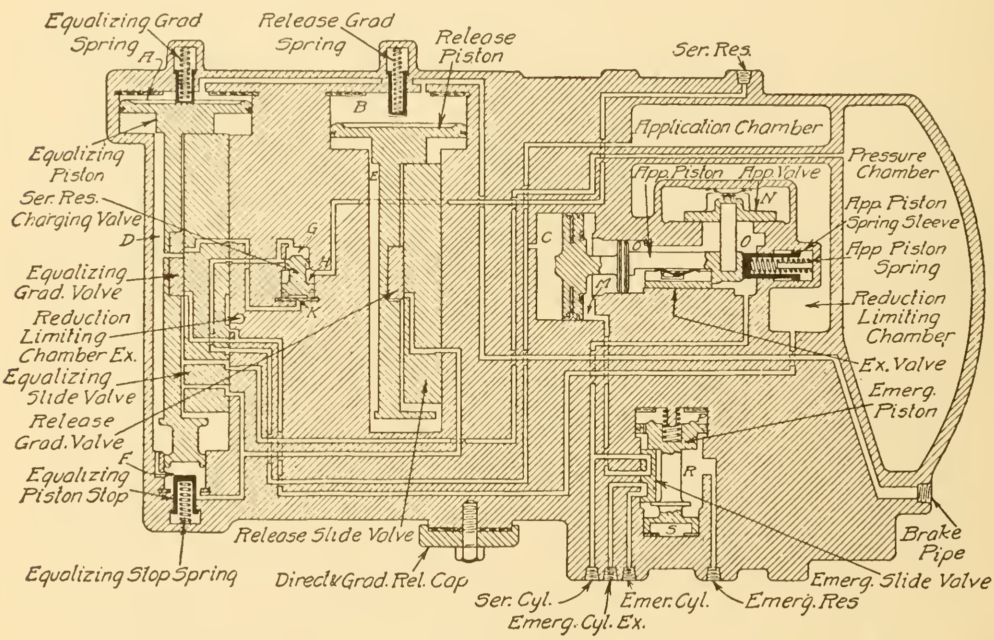


Fig. 124. Over-Reduction Lap Position for Westinghouse "3-E" Control Valve

so great that the air from the service reservoir could not get past the ring in the small end of the service-reservoir charging valve fast enough to supply such leakage (in the manner explained in connection with Fig. 123), the service-reservoir charging valve will finally be lifted, making wide open connection from the service reservoir to the application chamber.

From what has been said, it will be plain that if the brake-pipe reduction is continued below the point at which the pressure and the reduction-limiting chambers equalize, the pressure in the pressure chamber can no longer continue to reduce in accordance with the still falling brake-pipe pressure. This results in a differential being established between the pressure in the pressure chamber (and chambers *D* and *E*) and the brake-pipe pressure which, when the brake-pipe pressure is reduced below 60 pounds when carrying 110 pounds brake-pipe pressure or below 35 pounds with 70 pounds brake-pipe pressure, is sufficient to cause the release piston to travel to its extreme (emergency) position and produce quick action and an emergency application of the brakes as will be explained under "Emergency Position".

Releasing Action

(a) **Preliminary Release Position.** Whether the parts are in service lap or over-reduction lap position, after an application has been made, an increase in brake-pipe pressure above that in the

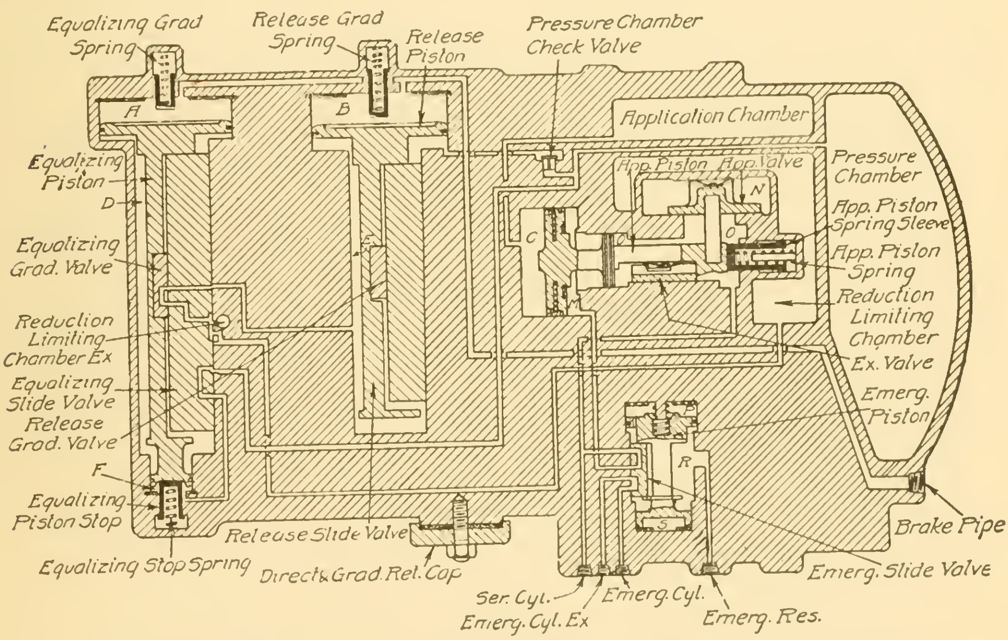


Fig. 125 Preliminary Release Position for Westinghouse "3-E" Control Valve

pressure chamber (chambers *D* and *E*) will cause the equalizing piston and its valves to return to the release positions described below.

The equalizing piston moves before the release piston, the parts being designed to require a somewhat higher differential to move the release piston and its attached valves than is sufficient to move the equalizing piston.

In preliminary release position, Fig. 125, it will be noted that chamber *E* behind the release piston is connected by way of the equalizing slide valve and graduating valve to the reduction-limiting chamber exhaust. This connection is made but momentarily, in what may be considered the first stage of the movement of the parts to release position. It plays a very important part, however, in the release operation of the valve, since, by thus insuring a momentary but material drop in the pressure in chamber *E* below that in the brake pipe and in chamber *B*, the release piston is forced to return positively to its release position shown in Fig. 126—*secondary release* position.

In *preliminary release* position, the pressure chamber is connected by way of the equalizing slide valve to chamber *F*. The

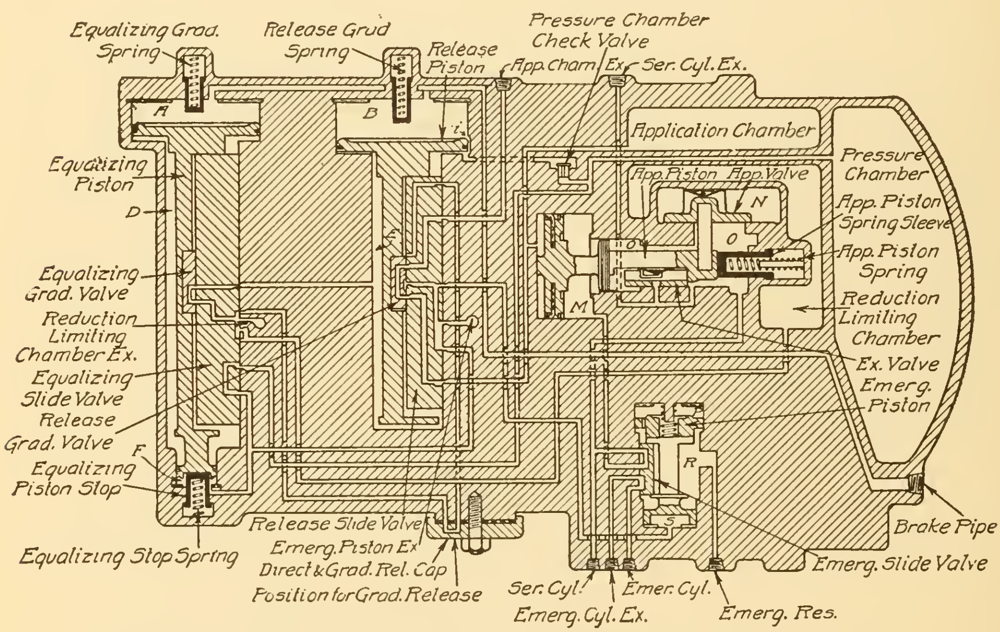


Fig. 126. Secondary Release Position for Westinghouse "3-E" Control Valve

pressure thus acting in chamber *F*, in addition to the force of the equalizing stop spring, serves to insure that the equalizing piston and its valves hesitate in preliminary release position for a sufficient length of time to reduce the pressure in chamber *E*, as already explained.

It will be observed that the application piston is still in its lap position, holding the pressure in the service brake cylinder. This continues until the release of air from the application chamber and chamber C, which does not take place until the parts move to the next stage in the release movement—*secondary release* position, Fig. 126.

In the movement of the equalizing slide valve to preliminary release position, the reduction chamber is connected to the reduction-chamber exhaust port and the atmosphere, and so remains until the parts again move to over-reduction position or beyond.

Although there are other connections made in the preliminary release position as shown in Fig. 125, they perform no particular function other than has already been described, and consequently do not need to be again referred to.

(b) **Secondary Release Position.** In the movement of the parts to release position, the next stage, following the preliminary release position is called the *secondary release* position, Fig. 126. It will be seen from the illustration that the venting of the air from chamber E through the equalizing slide valve and graduating valve to the reduction-limiting chamber exhaust has resulted in the relatively higher brake-pipe pressure moving the release piston and its valves to their release positions, although for an instant the equalizing piston and its valves still remain as shown in Fig. 125—*preliminary release* position.

With the release piston and its valves in the position shown in Fig. 126, a connection is made from chamber F through the release slide valve to the emergency-piston exhaust. At the same time the pressure chamber is connected by way of the equalizing slide valve to the same port which connects chamber F to the atmosphere. This tends to maintain the pressure in chamber F temporarily so as to insure the connection from chamber E to the atmosphere being held open, as explained above, until the release piston and its valves are entirely back in their release positions. In so moving, however, the release slide valve is gradually increasing the size of the opening from chamber F to the atmosphere, until a point is reached where the pressure in chamber F is lowered sufficiently to permit the differential pressure already acting on the equalizing piston to start this piston toward its release position. The resulting movement of the equalizing slide valve restricts and finally stops entirely the flow of air from the pressure chamber to chamber F, the pressure in which is, therefore, rapidly exhausted to the atmosphere through the ports already mentioned and the equalizing piston and its valves are then held positively in their release position as shown in Fig. 127.

Comparing Fig. 125 and Fig. 126, it will be noted that the movement of the release piston, slide valve, and graduating valve from the position shown in Fig. 125 to that shown in Fig. 126, opens communication from chamber *E* past the end of the release graduating valve, through the release slide valve and direct- and graduated-release cap and through the equalizing slide valve to the reduction-limiting chamber exhaust and atmosphere. This outlet from chamber *E* to the atmosphere is simply additional, it will be noted, to

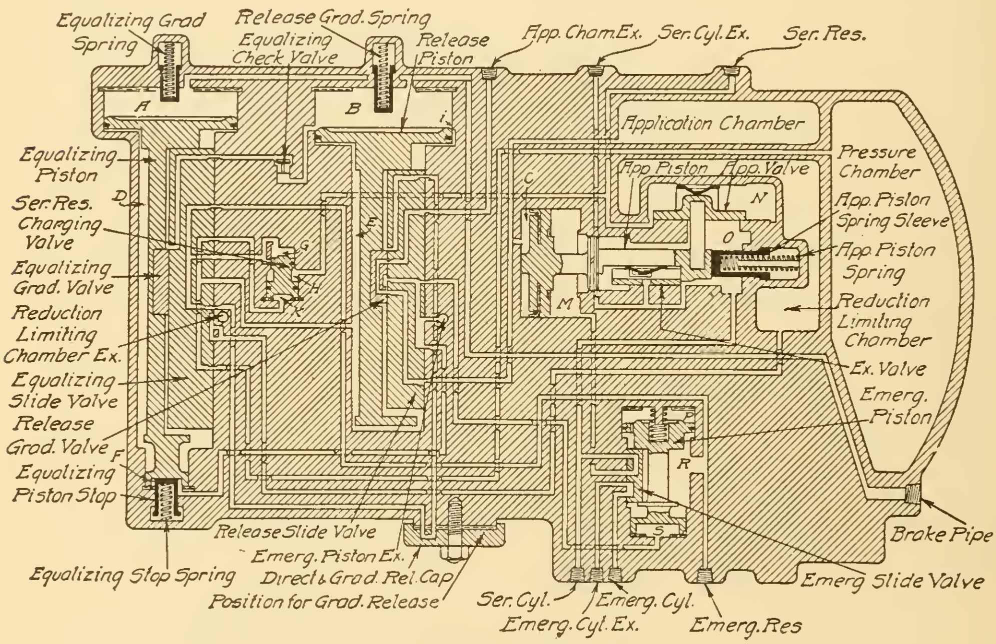


Fig. 127. Graduated Release and Release, Charging-Pressure Chamber Only, for Westinghouse "3-E" Control Valve

that already existing as explained in connection with Fig. 125, and, like it, is but momentary. In the succeeding position, Fig. 127, both these connections from chamber *E* to the atmosphere are cut off.

The movement of the release graduating and slide valves to their release positions opens the application chamber and chamber *C* by way of the valves mentioned to the application-chamber exhaust and atmosphere. The resulting reduction of pressure in chamber *C* below that exerted by the application-piston spring and the air pressure in chamber *M* causes the application piston, with its attached valves, to move back to release position, Fig. 126, opening the service brake cylinder through the exhaust valve to the service-cylinder exhaust and atmosphere. The release of the brake is, therefore, commenced as soon as the release piston and its valves are returned to their release positions.

While there are other connections shown in Fig. 126 besides those just explained, they perform no particular function, so far as the momentary position of the parts in secondary release position, Fig. 126, is concerned, and will, therefore, not be referred to until all can be explained together under "Graduated Release Position", Fig. 127.

(c) **Graduated Release Position.** As already stated, the movement of the release slide valve to its release position connects chamber *F* to the emergency-piston exhaust and atmosphere, causing the equalizing piston and its valves to be moved to and held positively in their release positions, Fig. 127.

It should be clearly understood that a very slight increase in brake-pipe pressure (about $1\frac{1}{2}$ to 2 pounds) above that remaining in the pressure chamber is sufficient to move the parts through the successive momentary positions of preliminary and secondary release as just explained, until they reach their final positions shown in Fig. 127—*graduated release* position.

In this position (graduated release being assumed to be cut in), the application chamber and chamber *C* are open through the release slide valve and graduating valve to the application-chamber exhaust and atmosphere. So far as this connection is concerned, the release would be complete provided the parts did not move, but it will be noted that in this position also the emergency reservoir is connected by way of the equalizing slide valve, and the direct- and graduated-release cap (which is adjusted to give graduated release) through the release slide valve and past the end of the release graduating valve to chamber *E*. The pressure in the emergency reservoir is substantially that to which it was originally charged, namely, normal brake-pipe pressure. The pressure in chamber *E*, it will be remembered, was reduced equally with the pressure-chamber pressure when the brake application was made. Air from the emergency reservoir, at the higher pressure, will therefore flow into chamber *E* and, from chamber *E* by way of the equalizing slide valve, to the pressure chamber, at the lower pressure, and tend to increase the pressure in chamber *E* and the pressure chamber at the same time that the brake-pipe pressure in chamber B is being increased. If the pressure in chamber E rises faster than that in chamber B, the higher pressure which will soon be built up in chamber E will tend to move the release piston and graduating valve over toward graduated-release lap position, Fig. 128, and either partially restrict or wholly stop the flow of air from the application chamber to the atmosphere, and from the emergency reservoir to chamber E. If the brake-pipe pressure is increased very slowly, the relatively rapid increase of pressure in chamber E may cause the release piston and graduating valve to graduate the release as explained in connection with

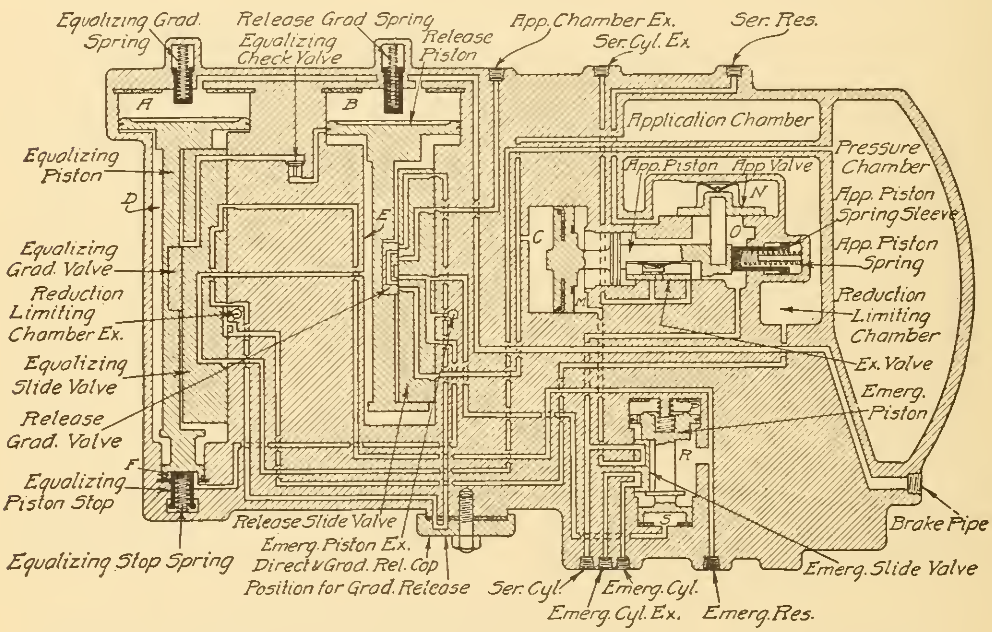


Fig. 128. Graduated-Release Lap Position for Westinghouse "3-E" Control Valve

Fig. 128. If the rate of rise of brake-pipe pressure is not slow enough to permit this action, the parts will move toward the position shown in Fig. 128 sufficiently to so restrict the flow of air from the emergency reservoir to chamber E as to adjust the rate of rise of pressure in chamber E to correspond to that of the brake pipe and chamber B, in which case the release of air from the application chamber will be correspondingly prolonged.

The escape of air from the application chamber and chamber C to the atmosphere, as already explained in connection with Fig. 126, results in the application-piston spring and brake-cylinder pressure acting in chamber M moving the application piston with its valve back from their lap position, as shown in Fig. 125, to their release position, as shown in Figs. 125 and 127, in which position air from the brake cylinder is exhausted to the atmosphere by way of the exhaust valve and service-cylinder exhaust port. Whether the brake-cylinder pressure is entirely or only partially released depends upon whether the exhaust air from the application chamber and chamber *C* is partial or complete. This has already been referred to and will be further mentioned in connection with Fig. 128. It will be noted that in Figs. 125, 126, and 127, the reduction-limiting chamber is connected to the reduction-limiting chamber exhaust and atmosphere through the equalizing slide valve, and that in Figs. 126 and 127 chamber *S* is connected through the release slide valve to the emergency-piston exhaust and atmosphere, so that the air in these chambers is completely exhausted to the atmosphere when either a graduated or direct release is made.

Referring to Fig. 127, it will be noted that chamber *E* is connected to chamber *K* and that air from the emergency reservoir has access to chamber *G*. These connections being opened by the movement of the equalizing slide valve to its release position, whether or not the service-reservoir charging valve will be opened and permit the re-charging of the service reservoir to begin at once will depend on the relative pressures in the pressure chamber and emergency and service reservoirs.. With the ordinary manipulation of the brake, the service-reservoir charging valve will remain closed, Fig. 127, preventing the air from the emergency reservoir reaching the service reservoir, and the pressure chamber only will be re-charged until its pressure has been increased to within about 5 pounds of that in the emergency reservoir.

As already indicated, if the brake pipe is fully re-charged without a graduation of the release being made, the parts will remain in the positions shown in Fig. 127 and the release will be complete and without graduations. The only change which takes place while such a release is being made is the movement of the service-reservoir charging valve from the position shown in Fig. 127 to that shown in Fig. 118, which should properly be regarded as illustrating the final stage in the re-charging of the equipment of which Fig. 127 illustrates the initial stage. That is to say, at first the pressure chamber alone is re-charged and this re-charge is accomplished from the emergency reservoir only, without any air being drawn for this purpose from the brake pipe. The air which is supplied through the brake valve to the brake pipe is, therefore, given every possible advantage and opportunity to accomplish what is intended when the brake-valve handle is moved to release position, namely, to release the brakes by causing an increase of pressure sufficient to accomplish this, throughout the entire length of the brake pipe. After the release has been thoroughly established in this manner, the re-charging of the reservoirs to their original pressure takes place as explained in connection with Fig. 118.

(d) **Release Lap Position.** If, however, the brake-pipe pressure is not fully restored, a graduation of release being made, that is, if the brake pipe is partially re-charged and the brake-valve handle then returned to lap position, the continued flow of air from the emergency reservoir to pressure chamber and chamber *E* will tend to increase the pressure in the pressure chamber and chamber *E* above that of chamber *B* which is now stationary, causing the release piston and graduating valve to move over until the shoulder on the end of the release piston stem comes in contact with the release slide valve, Fig. 128. This closes the exhaust from the application chamber to the atmosphere and prevents further flow of air from the emergency reservoir to the pressure chamber and chamber *E*.

The flow of air from the service brake cylinder to the atmosphere (continuing as explained in connection with Fig. 127), will at once reduce the pressure in chamber *M* below that now retained in chamber *C* by the small amount which is sufficient to cause the application piston to move over to the position shown in Fig. 128, in which the exhaust valve is closed, thus preventing further release of air from the service brake cylinder. The other connections remain as already explained

(e) **Release and Charging Pressure Chamber and Emergency and Service Reservoirs.** The gradual release of brake-cylinder pressure may be continued as explained above, Fig. 128, until the pressures in the emergency reservoir and pressure chamber have become equal. On account of the relatively large volume of the emergency reservoir compared with that of the pressure chamber, this equalization will not take place until the pressure chamber has been re-charged to within about 5 pounds of the brake-pipe pressure carried.

Beyond this point, whatever small amount of pressure may remain in the service brake cylinder is released entirely and the emergency and service reservoirs, as well as the pressure chamber, are re-charged from the brake pipe as described in connection with Fig. 128.

(f) **Direct Release and Charging Position.** Up to this point, the direct- and graduated-release cap has been assumed to be in the position for graduated release. Fig. 129 corresponds to Fig. 127, except that the direct- and graduated-release cap is adjusted for direct release. It will be noted that there is now no connection from the emergency reservoir to the pressure chamber or chamber *E*. Consequently the pressure chamber is being re-charged only by air

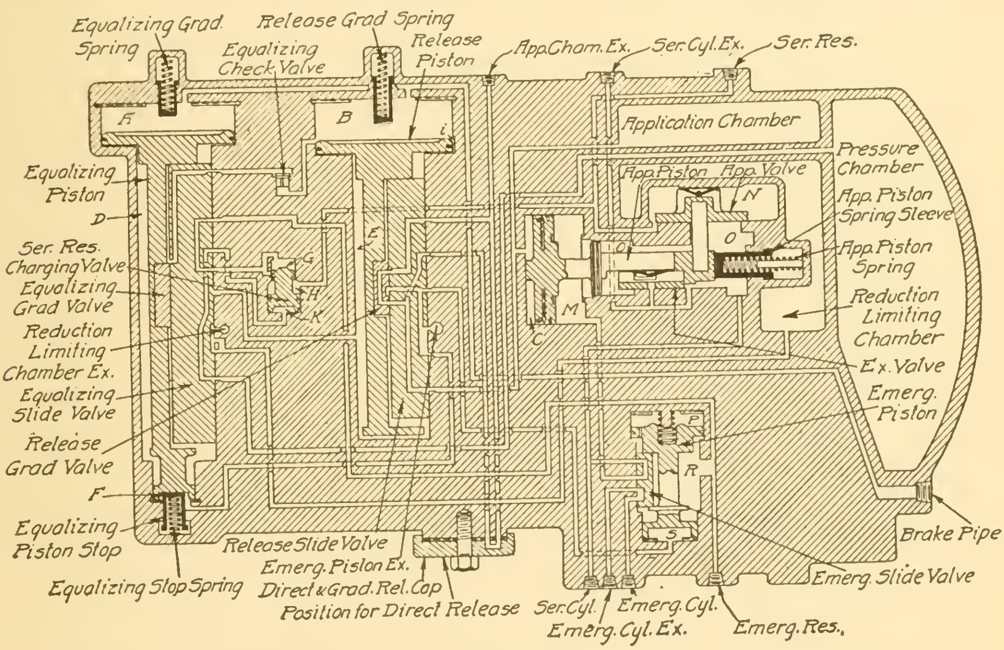


Fig. 129. Direct Release, Charging Pressure Chamber Only, for Westinghouse "3-W" Control Valve

from the brake pipe going through feed groove *i* to chamber *E*, and thence by way of the equalizing slide valve to the pressure chamber. The pressure in chamber *E* cannot, therefore, increase above that in chamber *B*, and the release piston, graduating valve, and slide valve remain in the position shown in Fig. 129.

With the direct- and graduated-release cap adjusted for direct release, it will be noted from Fig. 129 that the application chamber and chamber *C* are open through the release slide valve to a port connecting through the direct- and graduated-release cap to the application-chamber exhaust and atmosphere. This affords an outlet from the application chamber to the atmosphere which cannot be closed as long as the release slide valve remains in the position shown, even though the release piston and graduating valve should, from any cause, be moved back so that the release graduating valve would partially or entirely restrict the application-chamber release port, which is also shown to be open through the release graduating valve in Fig. 129. Moreover, it will be noted that there are two outlets from the application chamber to the atmosphere when the valve is adjusted for direct release as compared with one when graduated release is cut in.

Emergency Position

(a) **Quick-Action Valve Venting.** When the brake-pipe pressure is reduced faster than at the predetermined rate for service

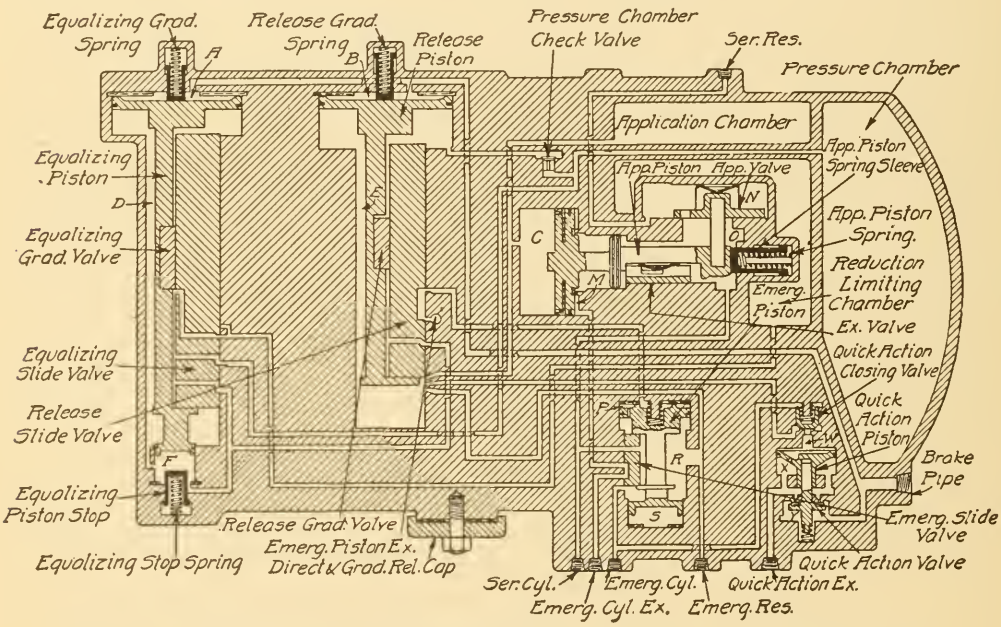


Fig. 130. Emergency Position, Quick-Action Valve Venting, for Westinghouse "3-E Control Valve

applications, or if the brake-pipe reduction should be continued below the point at which the pressure and reduction-limiting chambers equalize (as explained under "Over-Reduction Position"), the differential pressure acting on the release and equalizing pistons becomes sufficient to move them to their extreme or emergency positions, Fig. 130.

In this position, air from the emergency reservoir flows directly to chamber E and from chamber E to the under side of the quick-action closing valve. Chamber *T*, above the quick-action closing valve, is connected to the emergency brake-cylinder port in which there is no pressure, even though a full-service application of the brakes may have just preceded the emergency application.

The higher pressure on the under side of the quick-action closing valve, therefore, raises this valve and air flows to chamber *W* above the quick-action piston, forcing the latter down and opening the quick-action valve against brake-pipe pressure in chamber *Y*. As soon as the quick-action valve is unseated in this manner, air from the brake pipe flows past the quick-action valve to the quick-action exhaust and atmosphere, causing a local venting of brake-pipe air and transmitting the quick application serially throughout the train.

Air from the emergency reservoir flowing to chamber *E* also flows directly to the application chamber and chamber *C*, which forces the application piston and its valve over into their extreme positions, opening the service reservoir through the application slide valve and chamber *O* to the service brake cylinder, thus permitting the pressures in the service reservoir and service brake cylinder to equalize.

At the same time chamber *P*, above the large emergency piston, is connected through the release slide valve to the emergency-piston exhaust and atmosphere, permitting the emergency-reservoir pressure in chamber *R* to force the emergency piston and its slide valve upward to their emergency positions.

In this position of the emergency parts, the emergency reservoir is connected past the end of the emergency slide valve to the emergency brake cylinder, thus permitting the pressures in the emergency reservoir and brake cylinder to equalize. Chamber *R* is also connected through the emergency slide valve to the service cylinder port, which permits equalization of the service and emergency reservoirs and brake cylinders.

It will be noted that in this position the emergency slide valve opens a port which connects chamber *M*, behind the application piston, through the emergency slide valve to emergency cylinder exhaust. This, in connection with the admission of air from the emergency reservoir to the application chamber and chamber *C*, as already explained, still further insures a quick and positive movement of the application piston and its valves to emergency position.

In this position the pressure chamber is connected through the equalizing slide valve to chamber *D*. The pressure chamber is also connected past the pressure-chamber check valve to chamber *E*, and chamber *D* is connected past the end of the equalizing graduating valve through the equalizing slide valve to the reduction-limiting chamber.

(b) **Quick=Action Valve Closed.** The emergency brake-cylinder pressure and the pressure in chamber *T* above the quick-action closing valve continue to rise and the pressure in the emergency reservoir and in chamber *W* below the quick-action closing valve falls, as explained above, until these pressures become substantially

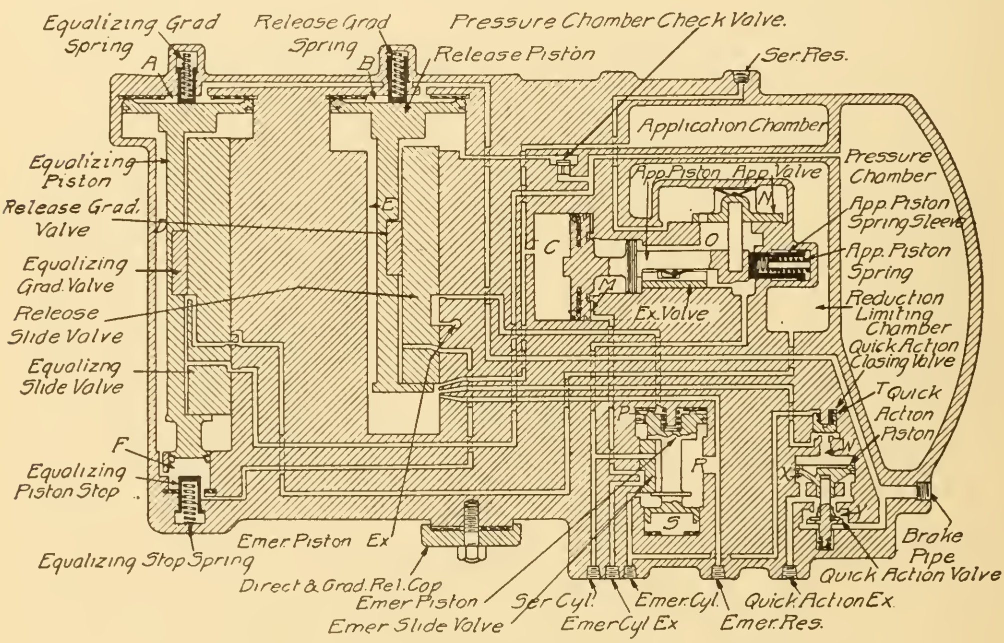


Fig. 131. Emergency Position, Quick-Action Valve Closed, for Westinghouse "3-E" Control Valve

equal. This equalization of the pressures on the opposite sides of the quick-action closing valve permits its spring to return the valve to its seat, cutting off further flow of air to chamber *W*. Chamber *W* is connected through the leakage hole in the quick-action piston to chamber *X* so that as soon as the quick-action closing valve is seated, the pressure in chamber *W* expands through this leakage hole to chamber *X* and the atmosphere through the quick-action exhaust opening. The balancing of the pressures in chambers *X* and *W* thus permits the quick-action valve spring to return the quick-action valve to its seat, closing the outlet from the brake pipe to the atmosphere, Fig. 131. This insures against an escape of air from the brake pipe to the atmosphere when a release is made following the operation of the quick-action parts.

Except for the closing of the quick-action valve and return of the quick-action parts to normal position, the positions of the other parts of the valve and connections between the various reservoirs and cylinders, etc., remain as already explained in connection with Fig. 130.

When releasing after an emergency application, as soon as the brake-pipe pressure in chambers *A* and *B* is increased above that which remains in chambers *D* and *E*, the parts will move to their release positions, exhausting the air from the brake cylinders and re-charging the reservoirs and pressure chamber as explained under "Release and Re-Charging", Figs. 125, 126, 127.

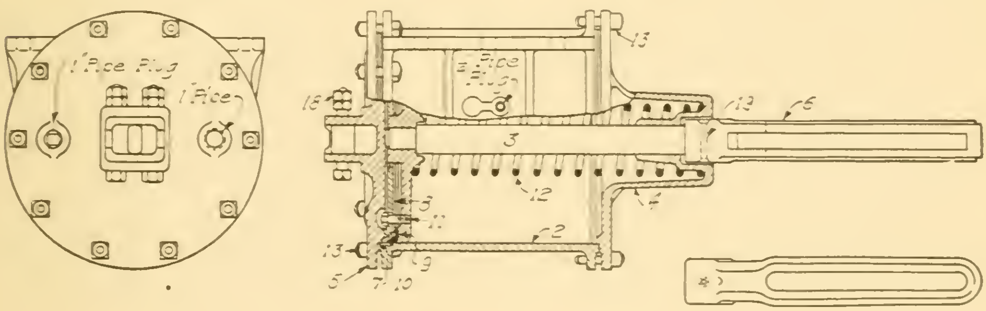


Fig. 132. Diagrammatic Section of Brake Cylinder

Fig. 132 illustrates the type of brake cylinder employed, two of which are used on each car. As previously explained, one brake cylinder is used during service application and both in emergency applications.

INSTRUCTIONS FOR OPERATING "PC" PASSENGER BRAKE EQUIPMENT

The following suggestions are given by the builders for the general handling of the "PC" Passenger Brake Equipment.

The brake should be handled by the engineers in the same manner as with cars equipped with quick-action triples, the only difference being that an emergency application will be obtained should a service reduction of the brake-pipe pressure be continued below 60 pounds when carrying 110 pounds pressure or below 35 pounds with 70 pounds brake-pipe pressure.

When it is found necessary to cut out the brake, close the cut-out cock in the crossover pipe and bleed both the service and emergency reservoirs.

Should it become necessary to bleed the brake when the engine is detached, or air connection is not made, first bleed the brake pipe and then bleed both the service and the emergency reservoirs.

The two sets of cylinder levers are connected to the same truck pull rods as stated above. Therefore, when a service application of the brake is made, the push-rod end of the emergency-cylinder lever will move the same distance as the push-rod end of the service-cylinder lever, but the crosshead being slotted, the piston of the emergency cylinder will not move. Consequently, the fact that the emergency-cylinder crosshead is in release position does not indicate that the air brakes are released. To determine this, look at the ends of either the service- or emergency-cylinder levers.

Whenever it is necessary to change the adjustment of the automatic slack-adjuster, it is imperative that the crossheads of the two adjusters be left at the same distance from their respective brake-cylinder heads, in order that the piston travel of the two cylinders in emergency application will be the same.

The various exhaust openings referred to in the following are plainly marked on the outline drawings.

The quick-action exhaust is the one-inch opening in the bottom of the control-valve reservoir. Should there be a continual blow at this opening, make an emergency application and then release; if the blow continues, remove the quick-action portion and substitute a new or repaired portion or repair the quick-action valve seat, which will be found defective. The quick-action portion is at the left hand when facing the equalizing portion.

There are three control-valve exhaust openings—two on the equalizing portion and one on the side of the control-valve reservoir, all tapped for $\frac{3}{8}$-inch pipe.

Should there be a blow at the application-chamber exhaust ($\frac{3}{8}$-inch exhaust opening on side of the control-valve reservoir) with the brakes applied or released, it indicates a defective equalizing portion, and a new one, or one that has been repaired, should be substituted.

Should there be a blow at the reduction-limiting chamber exhaust ($\frac{3}{8}$-inch exhaust on left side of equalizing portion) in release or service position, it indicates a defective application portion, and a new one, or one that has been repaired, should be substituted. This portion is located back of the equalizing portion inside the reservoir. If the blow occurs only after 30 pounds brake-pipe reduction, it indicates a defective emergency-reservoir check valve (the middle check valve in the equalizing portion) and a new one, or one that has been repaired should be substituted. If the blow does not cease, it indicates a defective equalizing portion, and a new one, or one that has been repaired, should be substituted.

Should there be a blow at the emergency-piston exhaust ($\frac{3}{8}$-inch exhaust on the right-hand side of the equalizing portion), make a 15-pound brake-pipe reduction and lap the brake valve. If the blow ceases, it indicates that the emergency piston is defective, and a new portion or one that has been repaired, should be substituted. If the blow does not cease, it indicates that the equalizing portion is defective, and a new one, or one that has been repaired, should be substituted.

A hard blow at the service brake-cylinder exhaust (tapped for $\frac{3}{4}$-inch pipe and located at the left side of the control-valve reservoir) with the brakes applied indicates that the application portion is defective, and a new one, or one that has been repaired, should be substituted. This portion is located back of the equalizing portion inside the reservoir. If this blow occurs when the brakes are released, it indicates either a defective application or emergency portion, and a new one or a repaired portion, as found to be required on investigation, should be substituted.

A hard blow at the emergency-cylinder exhaust (tapped for ½-inch pipe and located on the bottom of the control-valve reservoir) with the brakes either applied or released indicates a defective emergency portion, and a new one, or one that has been repaired, should be substituted.

If the trouble described in the five paragraphs immediately preceding is not overcome by the remedies therein suggested, remove the application portion and examine its gasket, as a defect in same may be the cause of the difficulty.

When removing the application, emergency, and quick-action portions, their respective gaskets should remain on the reservoir. On removing the equalizing portion, its gasket should remain on the application portion, except when the application portion is shipped to and from points where triple valves are cared for.

When applying the different portions, the gaskets should be carefully examined to see that no ports are restricted, and that the gasket is not defective between ports. See also that all nuts are drawn up evenly to prevent uneven seating of the parts.

On the front and at the center of the equalizing portion is located the direct- and graduated-release cap (held by a single stud) on which is the pointer. The position of this pointer indicates whether the valve is adjusted for direct release or graduated release. This cap should be adjusted for either direct or graduated release according to the instructions issued by the railroad.

Recent Improvements in Brake Equipment. In addition to the different brake equipments described, mention might be made of two other equipments which have just recently been tried out. One of these is the Westinghouse Electro-Pneumatic Brake Equipment with the Type "U" standard universal valve, for use in passenger service. The other is the Empty and Load Freight Brake Equipment. The results of tests conducted on each of these equipments has been satisfactory in every way, but the apparatus has not at the present time been very widely used.

WESTINGHOUSE TRAIN AIR-SIGNAL SYSTEM

Essentials of Air-Signal System. A train signal system is very essential in maintaining fast schedules with passenger trains, its object being to furnish a means of communication between the trainmen and enginemen. The most common form used is the pneumatic, and is made up of the following principal parts:

(1) A ¾-inch signal pipe, which extends throughout the length of the train, being connected between cars by flexible hose and suitable couplings.

(2) A reducing valve, which is located on the engine, and which

feeds air from the main reservoir into the signal pipe at 40 pounds pressure.

(3) A signal valve and whistle, located in the cab and connected to the signal pipe.

(4) A car discharge valve, located on each car and connected to the signal pipe.

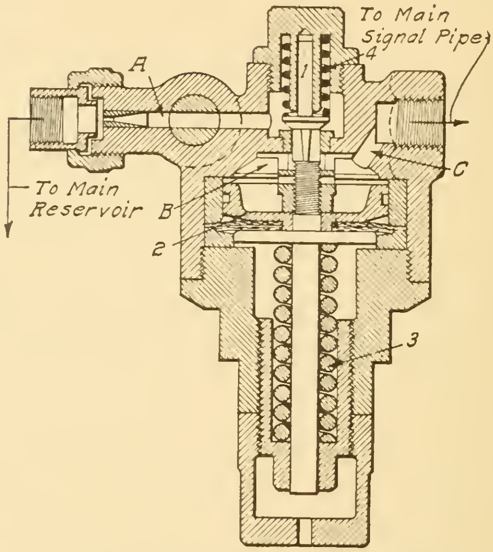


Fig. 133. Section through Reducing Valve in Westinghouse Air-Signal System

The action of the signal system is automatic. If an accident happens to the train which breaks the signal pipe, the pressure in the signal pipe is reduced and the whistle in the cab blows a blast. The trainmen may also signal the enginemen by opening the car discharge valve, which reduces the pressure in the signal

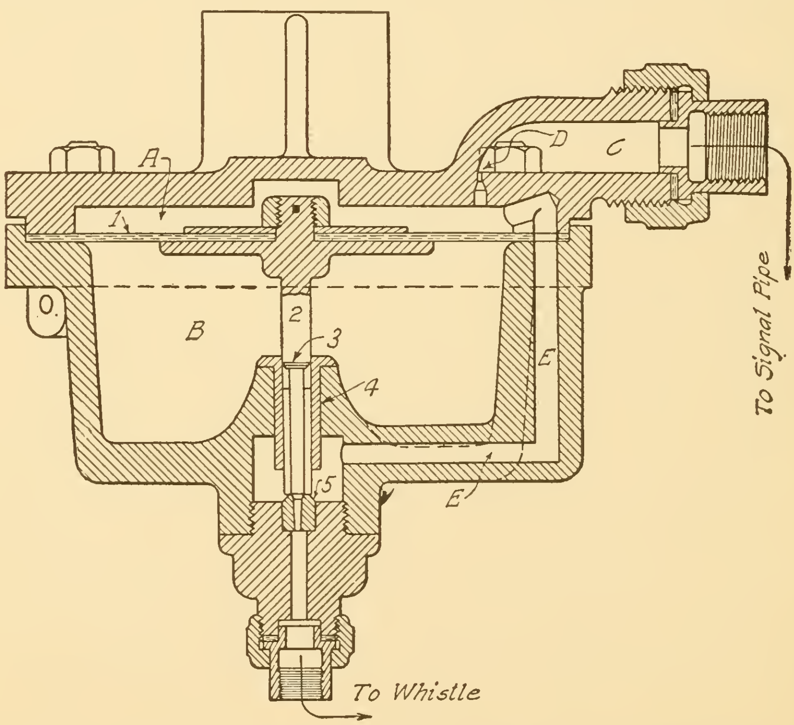


Fig. 134. Section through Signal Valve in Westinghouse Air-Signal System

pipe, thus operating the signal valve in the cab and blowing the whistle as before. The operation of the various parts is as follows:

Reducing Valve. The reducing valve, a section through which is shown in Fig. 133, is located in a suitable place on the locomotive. Its purpose is to receive air from the main reservoir and feed it into the signal pipe, maintaining a pressure of 40 pounds. When no air is in the system, the parts occupy the position shown, but when air is admitted from the main reservoir, it flows through the passage *A* and the supply valve *1*, into the chamber *B* and out through the port *C* into the main signal pipe. When the air in the main signal pipe attains a pressure of 40 pounds, the pressure in the chamber *B*, acting on the piston *2*, forces it downward and compresses the spring *3*. This permits the spring *4* to close the supply valve *1*. No more air can then enter the signal pipe until its pressure becomes reduced so that the spring *3* will force the piston *2* upward and lift the supply valve *1*. Type "C-6" reducing valve, Fig. 36, is also used.

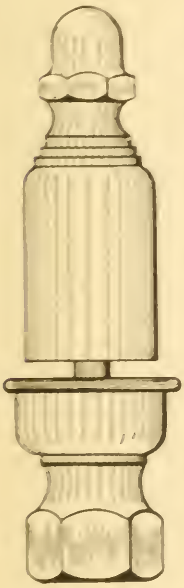


Fig. 135. Signal Whistle in Westinghouse Air-Signal System

Signal Valve. The signal valve, Fig. 134, controls the supply of air to the whistle, a reduction of air pressure in the signal pipe admitting air to the whistle through the signal valve. The two compartments *A* and *B* are divided by the diaphragm *1* to which is attached the stem *2*. This stem is milled triangular in section from the lower end to the peripheral groove *3* but above the groove *3* it fits the bushing *4* snugly. The lower end of the stem *2* acts as a valve on the seat *5*. Air enters the signal valve from the signal pipe, through the passage *C*, passing through the small port *D* into the chamber *A*, and through the passage *E*, around the triangular portion of the stem *2*, into the chamber *B*. This charges the chambers *A* and *B* to the signal-pipe pressure. A sudden reduction in signal-pipe pressure reduces the pressure in the chamber *A*; and the diaphragm *1*, acted on by the pressure in the chamber *B*, rises, lifting the stem *2* and momentarily permitting air to pass from the signal pipe to the whistle, Fig. 135. The resulting blast of the whistle is a signal to the enginemen. This same reduction of pressure in the signal pipe causes the reducing valve to re-charge the system. The pressures in the chambers *A* and *B* equalize quickly, and the lower end of the stem *2* returns to its seat.

Car Discharge Valve. The car discharge valve, Fig. 136, is usually located outside the car above the door or under the roof of the vestibule, in such a position that the signal cord passing through the car can easily be fastened to the small lever of the valve. The valve is connected to a branch pipe which extends from the signal pipe. The signal cord is connected to the eye in lever *1*. Each pull in the signal cord causes the lever *1* to open the check valve *2*, permitting air to escape from the signal pipe. This causes a reduction in the signal pipe, which, in turn, causes the whistle to blow as previously described. The spring *3* closes the valve *2* when the signal cord is not held.

For the successful operation of the signal system, the signal pipe must be perfectly tight. Care must be exercised in using the car discharge valve so that sufficient time is permitted to elapse between successive discharges.

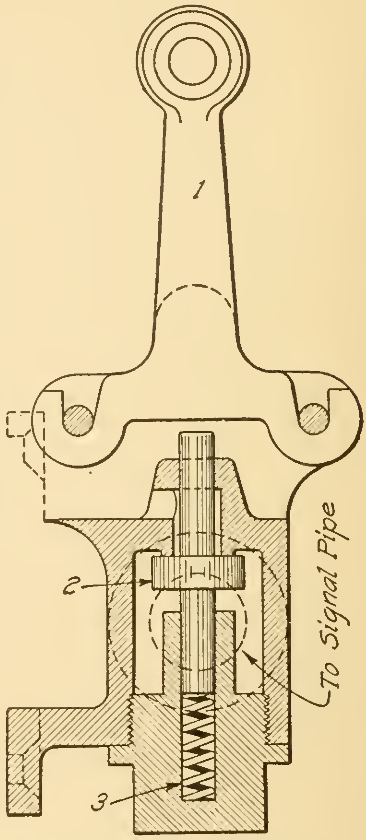


Fig. 136. Section through Car Discharge Valve in Westinghouse Air-Signal System

BRIEF INSTRUCTIONS FOR THE USE AND CARE OF AIR-BRAKE EQUIPMENT

The following instructions apply more directly to the old types of passenger and freight brake equipments, applying only in a general way to the later improved types.

Train Inspection. When a train is made up at a terminal, the air hose should all be coupled and the angle cocks all opened except the one at the rear end of the last car. The brake pipe should then be charged to about 40 pounds, in order that the inspector may examine for leaks. When the brake pipe has been fully charged, the engineer should apply the brake by making a light reduction in the brake pipe, which should then be followed by a full-service application. He should note the time required in making these reductions, in order to be assured that all pistons are moved past the leakage groove when the train is out upon the road. The engineer, after making the full reduction, should leave his brake valve in lap position until the inspector has examined the brake under every car. It should be the duty of the engineer to see that the brake equipment on the locomotive is in proper working order.

Running Test. In passenger service, when a locomotive has been changed or a train made up, the engineer should make a running test within a mile of the station, as follows: A brake-pipe reduction of about 5 pounds should be made. If the brakes are felt to be applying and the time of the discharge is proportional to the number of cars in the train, the engineer will conclude that the brake is in proper working order. It is well, also, to make this test on approaching hazardous places.

Service Applications. In making a service application of the brakes, the first reduction should be about 5 pounds on a train of cars 30 or less, and about 7 pounds on a train exceeding 30 cars. This will insure the travel of all pistons beyond the leakage groove. Subsequent reductions of from two to three pounds can be made to increase the braking power, if desired. A reduction of 25 to 30 pounds will make a full-service application.

In stopping a passenger train, at least two applications should be used; the first should reduce the speed of the train to about 8 miles an hour, when the train is within two or three car lengths of the point at which the train is to be stopped. Moving the brake-valve handle to release position for only sufficient time to release all brakes, then returning it to lap position, will make it possible for a second light application to stop the train. Just before all stops of passenger trains, except exact-position stops at water stations and coal chutes, the brakes should be released to avoid shocks to passengers. This release should be made on the last revolution of the drivers. If it should be made too soon and the train keep on moving, the engineer's brake valve should be moved to service position until the train stops.

In making stops of freight trains, the best practice is to shut off the steam and allow the slack to run in before applying the brakes. The stop should be made with one application of the brakes. After the first reduction is made, if there are any leaks in the brake pipe, the braking force will be increased, and any subsequent reduction should be made less, in order to make up for these leaks. In stopping a long freight train at water stations and coal chutes, it is best to stop short of the place, cut off, and run up with the locomotive alone.

On a freight train, where the locomotive is not equipped with the straight air brake or the "ET" equipment, the brakes should not be released when the speed of the train is 10 miles per hour or less. If this is done, the brakes in the front of the train may release, and, as the slack runs out, the train may part. If the locomotive is equipped with straight air or "ET" equipment, the train brakes can be released after the locomotive brakes are set, without danger of parting the train.

Emergency Applications. The emergency application should never be used, except in case of an emergency. If the necessity arises, an emergency application may be made after a service reduction of about 15 pounds. In case an emergency is caused by the train parting, hose bursting, or the conductor's valve being opened, the engineer should place his valve on lap, in order to save the main-reservoir air.

Use of Sand. The use of sand increases the braking power of a train and should be made in emergency stops. If sand is used in service stops, it should be supplied some time before the brakes are applied in order to have sand under the entire train. If, for any reason, the wheels should skid, do not apply the sand as it will produce flat spots on the wheels.

Pressure Retaining Valve. In holding trains on grades, a part or all of the retaining valves are set to maintain air pressure in the brake cylinder. If only part are set, those in the front of the train should be used.

Backing Up Trains. In backing up long freight trains, the train should be stopped by the hand brakes on the leading end of the train, for the reason that if air were used, the brakes would apply on the cars near the engine and the leading cars might cause a break-in-two.

In backing up a passenger train, where the train is controlled by a man on the leading car by means of an angle cock, the engineer's valve should be in running position. This gives the man on the rear of the train full control of the brakes. As soon as the engineer feels the brake apply, he should place his valve on lap.

Double-Heading. When two or more locomotives are coupled in the same train, the brakes are operated by the leading locomotive. The cut-out cocks in the brake pipe just below the engineer's valve on all locomotives but the first should be closed. The pumps on all engines should be kept running.

Conductor's Brake Valve. A conductor's brake valve is located on each passenger car. The purpose of this valve is that the conductor may stop the train in case of emergency; if the engineer's brake valve should fail to operate, he may signal the conductor to apply the brakes by opening the valve.

Use of Angle Cocks. In setting a car out of a train, first release the brakes, then close the angle cock on both sides of the hose to be disconnected, and finally disconnect the hose by hand. Before leaving a car on the side track, the air brakes should first be released by opening the release valve on the auxiliary reservoir; and if the car is on a grade, the hand brake should be set.

The angle cock should not be opened on the head end of a train while the locomotive is detached. When connecting a locomotive to the train that is already charged with air, the angle cock at the rear of the tender should be opened first to allow the hose to become charged and thus prevent a slight reduction in the brake pipe, which might set the brakes. All angle cocks upon charged brake pipes should be opened slowly.

Cutting Out Brakes. If the brake equipment on any car is defective, it may be cut out by closing the cut-out cock in the branch pipe leading from the brake pipe to the triple valve. The release valve on the auxiliary reservoir should be opened to discharge the air. Never more than three cars with their brakes cut out should be placed together in a train on account of the emergency feature being unable to skip more than this number.

Air Pump. The air pump should be run slowly with the drain-cocks open until the steam cylinder becomes warm and sufficient air-pressure has been attained to cushion the air, after which time the throttle may be fully opened. The lubricator should be in operation as soon as possible after starting, and the swab on the piston rod should be kept well oiled. The air cylinder should receive oil each trip. Valve oil should be used, and it should be inserted through the oil cup provided for that purpose, and not through the air strainer.

Engineer's Brake Valve. With the handle in running position, the main-reservoir pressure should be maintained at 90 pounds or as high as needed, and the brake pipe at 70 or 110 pounds, depending on the system. This requires that the springs in the pump governor and feed valve must be carefully adjusted and that no leaks exist between ports in the rotary valve. The rotary valve should be cleaned and oiled when necessary; and if leaks exist, the valve should be scraped to a fit.

Triple Valve and Brake Cylinders. The triple valve and brake cylinders should receive an occasional cleaning and oiling in order that they may be relied upon to fulfill their function. In cleaning the cylinder, special attention should be given to removing any deposit in the leakage groove. The walls of the cylinder should be coated with suitable oil or grease, and all bolts in the cylinder head and follower should be kept tight.

In cleaning the triple valve, a common practice is to place the removable parts in kerosene until the other parts and the brake cylinder have been cleaned. The parts are then removed, cleaned, oiled, and replaced. Special care should be given to the slide valve and its seat, and to the graduating valve. All lint should be removed before replacing the parts. The piston packing ring should never be removed, except for renewing. A few drops of oil is all that is necessary for lubricating the entire triple valve. No oil should be permitted to get upon the gaskets or rubber-seated valve. The graduating-valve and check-valve springs should be examined and, if necessary, renewed.

AIR BRAKES AS APPLIED TO ELECTRIC CARS

GENERAL SURVEY OF SYSTEMS DEVELOPED

That electric street cars and interurban cars should be equipped with reliable and efficient braking apparatus is a well-established fact, which is emphasized by the frequency of accidents on roads where poorly constructed braking appliances are used. The modern electric car is several times heavier than cars used a decade ago and speeds have increased remarkably, yet we frequently find cars fitted with braking apparatus but little better than that used in the days of the horse car. Of recent years, the most progressive roads have given much attention to the construction of their equipment in order to insure the safety of their passengers and, as a result, braking appliances have been greatly improved.

Hand Brakes. The hand brake was the first form of brake used on electric cars and is still used in many of the smaller cities. It is also found today on many cars fitted with air brakes, to be used in case of necessity. The early forms of hand brakes consisted of a brake staff located at either end of the car, having a chain connected to the lower end of the staff. As the handle turned, the chain was wound up on the staff, and the resulting motion actuated the rods and levers which brought the brake shoes in contact with the wheels.

An improved form of brake staff is shown in Fig. 137. Here the winding drum takes the form of a spiral cam. In operation, the slack in the chain is quickly taken up and a very great braking pressure can be obtained.

Early Forms of Air Brake. The first form of air brake installed on electric cars was known as the *straight air-brake system.* It is largely used today, as is also the *automatic air-brake system.* The straight air-brake system is usually found on trains of not more than one or two cars in length. Since electric roads do not, at this time, interchange cars to any great extent, there is no very great necessity of interchangeable air-brake apparatus. As a result, there are a number of different types and makes of air-brake apparatus found in use on electric cars. All operate upon practically the same general principles.

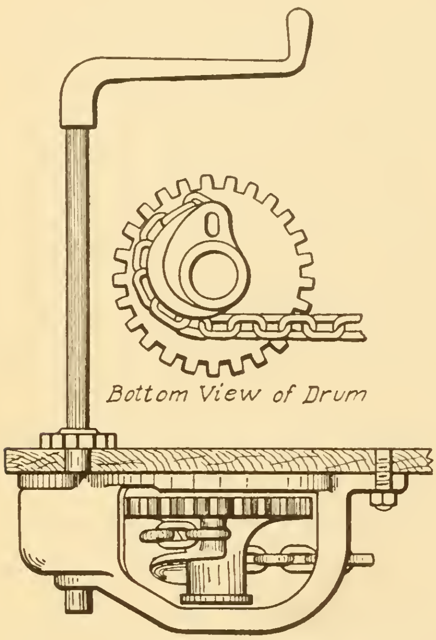


Fig. 137. Hand Brake for Electric Cars

Characteristics of Modern Systems. The Westinghouse Company, in order to meet the requirements of the different classes of electric car service, has developed the following different brake equipments: (a) The "SM-1" Brake Equipment; (b) the "SM-3" Brake Equipment; (c) the "SME" Brake Equipment; (d) the "AMS" Brake Equipment; (e) the "AMM" Brake Equipment; (f) the "AMR" Brake Equipment; and (g) the "EL" Locomotive Brake Equipment.

"SM-1" and "SM-3" Brake Equipments. Both the "SM-1" and "SM-3" brake equipments are straight air equipments, designed only for use on cars operated as single units. The two systems cover the air brake in its simplest form and are not considered satisfactory or safe for use on trains of more than one car in length.

"SME" Brake Equipment. This is a straight air-brake equipment having an automatic emergency feature by means of which the simplicity of the straight air brake is retained for service operation, but it also has the additional protection afforded by the automatic

application of the brake in case of a break-in-two or the bursting of a hose. It is designed for use on trains of not more than two cars in length.

"AMS" Brake Equipment. The "AMS" equipment is designed for use on cars running either singly or in not more than two-car trains, in city or slow-speed service. It combines the safety features of an automatic brake with the ease and flexibility of manipulation of the straight air system. A simple form of plain triple valve is used, having a quick re-charging feature.

"AMM" Brake Equipment. The "AMM" equipment is constructed for use on cars operated in trains of not more than three cars in length. It is especially well adapted for both city and high-speed interurban service. It is designed to provide for quick and flexible operation of the brakes on a single car unit by the straight air-brake system with the added feature of an immediate change to automatic brake operation whenever two or three cars make up the train.

"AMR" Brake Equipment. The "AMR" equipment is designed for use on trains of not more than five cars in length. It is designed for either city or high-speed interurban service and is strictly an automatic brake system. This equipment possesses such advantages as quick service, emergency, graduated release, and quick re-charging features.

"EL" Locomotive Brake Equipment. The development of the modern high-power electric locomotive for handling both freight and passenger traffic at terminals and for service on electrified steam railroads created a demand for a thoroughly reliable and efficient brake which would embody the desirable features of the Westinghouse No. 6 "ET" equipment. Accordingly the No. 14 "EL" locomotive brake equipment was developed, which is an adaptation of the No. 6 "ET" equipment to the conditions of electric service. The important and general features of this equipment may be obtained by reference to the description of the "ET" equipment, pages 110 to 132, Part II.

As the space allotted to this subject is limited, only one electric car system will be described—the Westinghouse "SME" brake equipment. This system is chosen because it represents in a general way many systems now in common use.

DETAILS OF "SME" BRAKE EQUIPMENT

Features of "SME" System. As previously mentioned, this equipment is essentially a straight air-brake equipment having an automatic emergency feature. The simplicity of the straight air brake is available for ordinary service operation, while the additional safety features of the automatic application of the brake is provided in case of a break-in-two, bursting of a hose, etc. The system is designed for use on trains of not more than two cars in length. The chief features of the equipment when using the Type "D" emergency valve, as set forth in the manufacturer's pamphlets are as follows:

(a) Straight air operation for service stops.
(b) Brake cylinder release operates locally, i.e., through the emergency valve on each car.
(c) Prompt service application and release operations due to design of the emergency valve.
(d) Automatic maintenance of brake cylinder leakage.
(e) Uniform brake cylinder pressure, independent of variations in piston travel or leakage.
(f) Practically uniform compressor labor insured without the necessity of a governor synchronizing system.
(g) Automatic application of the brakes in case of ruptured piping, burst hose, or parting of the train.
(h) Retarded release after an emergency application, as a penalty to discourage the unnecessary use of this feature.
(i) One size of emergency valve for any size of brake cylinder.
(j) Possibility of conductor setting the brakes in emergency by means of conductor's valve.

Principal Working Parts. The system is composed of the following principal parts, which are located on the motor car:

(a) A motor-driven air compressor which furnishes the compressed air for use in the brake system.
(b) An electric compressor governor which automatically controls the operation of the compressor between predetermined minimum and maximum pressures.
(c) A fuse box, fuse, and two snap switches in the line from the trolley to the governor and air compressor, protecting the latter from any excessive flow of current and enabling the current supply to the compressor to be entirely cut off when desired.
(d) Two main reservoirs to which the compressed air is delivered from the air compressor, where it is cooled and stored for use in the brake system. Where the climatic conditions render it necessary, a radiating pipe should be installed between the compressor and the first reservoir and between the two reservoirs to assist in the cooling process.

(e) A check valve installed between the main reservoirs and the emergency valve, to prevent a back flow of air into the main reservoirs when two motor cars are operated together. This being the case, each compressor is required to supply the air used for braking purposes on its own car.

(f) A safety valve connected to the first main reservoir, which protects against excessive main-reservoir pressure should the compressor governor, for any reason, become inoperative.

(g) Two brake valves, one at each end of the car, through which (1) air is allowed to charge the emergency pipe and to exhaust from the straight air application and release pipe when releasing the brakes; (2) air enters the straight air application and release pipe when applying the brakes; (3) the flow of air to or from the brake system may be prevented, as when the brakes are being held applied; and (4) the air in the emergency pipe is allowed to escape to the atmosphere in emergency applications.

(h) An exhaust muffler placed under the platform to deaden the brake valve exhaust.

(i) Just below the brake valve a pipe leads from the emergency pipe to the black hand connection of the duplex air gage, which hand shows main-reservoir pressure, as the emergency pipe is always charged to main-reservoir pressure, except when an emergency application of the brakes is made, as explained later.

The red hand of the duplex air gage is connected either to the brake cylinder direct or to the piping so as to show brake cylinder pressure.

(j) An emergency valve, connected to the brake cylinder head (or pipe bracket if used) which (1) controls the flow of air from the reservoirs to the brake cylinder when applying the brakes; (2) controls the flow of air from the brake cylinder to the atmosphere when releasing the brakes; and (3) automatically maintains brake cylinder pressure against leakage, keeping it constant when holding the brakes applied.

(k) A brake cylinder, with a piston and rod so connected through the brake levers and rods to the brake shoes that, when the piston is forced outward by air pressure, this force is transmitted through said rods and levers to the brake shoes and applies them to the wheels.

(l) A conductor's valve (furnished when ordered) located inside each car, enabling the conductor to apply the brakes if necessary.

(m) Various cut-out cocks, air strainers, hose couplings, dummy couplings, etc., the location and uses of which will be readily understood from the explanations which follow.

(n) While not a part of the air-brake apparatus proper, the car is usually equipped with two air alarm whistles, one at each end of the car, to be used as a warning of approach, with the necessary whistle valves and cut-out cocks.

Two lines of pipe—the emergency pipe and the straight air application and release pipe—extend the entire length of the car and train, when two or more cars are coupled together, being provided with suitable hose and couplings at the ends of the cars. The cut-out cocks in these pipes, located just back of the hose connections, should always be enclosed at each end of a single car or train and always open between cars which are being operated together as a train.

Equipment on Non-Motor Trailers. The equipment of a non-motor trailer car consists of a brake cylinder, auxiliary reservoir, emergency valve, straight air application and release pipe, and emergency pipe, all of which, except the auxiliary reservoir, have been described above.

In addition, an auxiliary reservoir is used on a non-motor trailer car to furnish an independent supply of air for applying the brakes on that car when an application is made. The auxiliary reservoir pipe is connected to the emergency valve in the same manner as is the main reservoir supply pipe on a motor car. The auxiliary reservoir is charged from the emergency pipe by way of the emergency valve.

OPERATION RULES FOR "SME" BRAKE EQUIPMENT

The following rules furnished by the Westinghouse Company for operating the "SME" brake equipment are intended to cover in a condensed form the important instructions to be observed in handling this equipment in service.

Charging. Before starting the air compressor, see that the following cocks are closed: the drain cocks in the reservoirs; the cut-out cocks (if used) under the non-operative brake valves, also under the whistles not to be operated; and the cut-out cocks in the emergency and straight air pipes at the head and rear end of the car, or of the trains when two cars are coupled together.

See that the following cocks are open: the cut-out cock, if any is used, in the emergency pipe under the brake valve to be operated; governor cut-out cock; the cut-out cock under the whistles to be operated; and all the emergency pipe and straight air pipe cut-out cocks between cars.

See that all hand brakes are fully released. The fuse in the compressor circuit must be in place and must be "live".

Place the handle of the brake valve to be operated—all other brake valves being in *lap* position—in *release* position and start the compressor by closing the switches in the compressor circuit on each motor car.

Do not attempt to move the car until the gage shows full main-reservoir pressure.

Running. Keep the brake valve handle in *release* position when not being used. In event of sudden danger, move the brake-valve handle quickly to *emergency* position, at the extreme right, and leave it there until the car has stopped and the danger is past.

If the brakes apply while running over the road, due to bursting of hose, etc., move the brake-valve handle to *emergency* position at once, to prevent loss of main-reservoir pressure, and leave it there until the car or train stops and the danger is past. The cause of the application should be located and remedied before proceeding.

Service Application. To apply brakes for an ordinary stop, move the brake-valve handle to either *one-car service* position or *two-car service* position depending upon the conditions existing and results desired. When the desired brake-cylinder pressure has been obtained, as shown by the red hand of the air gage, the brake-valve handle should be placed in *lap* position, where it should remain until it is desired either to release the brakes or to make a heavier application.

How heavy an application should be made, and whether a full application should be made at once or the brakes graduated on, depends upon the circumstances in each particular case—such as the speed and weight of the train, condition of the rails, grade, kind of stop desired, and regard for the comfort of the passengers.

Because the retarding effect of a given brake-cylinder pressure is greater at low speeds, this fact will result in an abrupt stop, with perhaps danger to lading, discomfort to passengers, or slid flat wheels. With high speeds, however, a heavy initial application should be made in order to obtain the most effective retardation possible when the momentum of the car is greatest. If the brakes are applied lightly at first and the braking pressure increased as the speed of the car diminishes, it not only makes a longer stop, but the high brake-cylinder pressure at the end of the stop will be likely to produce a rough stop, slid wheels, and to result in loss of time.

The best possible stop will be made when the brakes are applied as hard, at the very start, as the speed, the conditions of the rails, and the comfort of the passengers will permit, and then graduated off as the speed of the car is reduced, so that at the end of the stop little or no pressure remains in the brake cylinder.

To properly weigh all these varying factors in every stop becomes, after a little practice, an act of unconscious judgment. Careful attention to cause and effect at the very start and a real desire to improve are the most necessary qualifications in order to become expert in handling this or any other form of brake equipment.

Holding Brakes Applied. The brake-valve handle should be left in *lap* position until it is desired either to release the brakes or to apply them with greater force. If the car is to be left standing with the brakes applied for any length of time, the air brakes should be released and the hand brakes set.

Release. The brakes are released, as with any straight air brake, by placing the brake-valve handle in *release* position and leaving it there, if it is desired to fully release the brakes; or, if it is desired to graduate or partially release the brakes, by moving the handle to *release* position for a moment, then back to *lap* position, repeating this operation until the car is brought to rest, only enough pressure being retained in the brake cylinder at the end of the stop to prevent the wheels from rolling.

Emergency. Should it become imperative to stop in the shortest possible time and distance, to save life or avoid accident, move the handle quickly from whatever position it may be in to *emergency* position, which is at the extreme right, and allow it to remain there until the car stops and the danger is past.

When releasing after an emergency application, it will be observed that the release takes place slowly. This is intentional, the equipment being so designed that when such a release is made, a fixed period of time must elapse from the movement of the handle to *release* position until the brake releases. This is not only to secure an additional protection but to discourage the unnecessary use of the *emergency* position of the brake-valve handle.

Changing Ends. When changing from one end of the train or car to the other, place the brake-valve handle in *lap* position; close the cut-out cock (if used) in the emergency pipe under the brake valve; then remove the handle, after placing it on the brake valve at the other end, move it to *release* position and open the cut-out cock (if used) in the emergency pipe under this brake valve.

GRAPHICAL REPRESENTATIONS OF PROPER BRAKING METHODS

Much time can be saved by a proper use of the brake in making service stops, in adapting the brake cylinder pressure to the speed at which the car or train is moving. For example, for high speeds

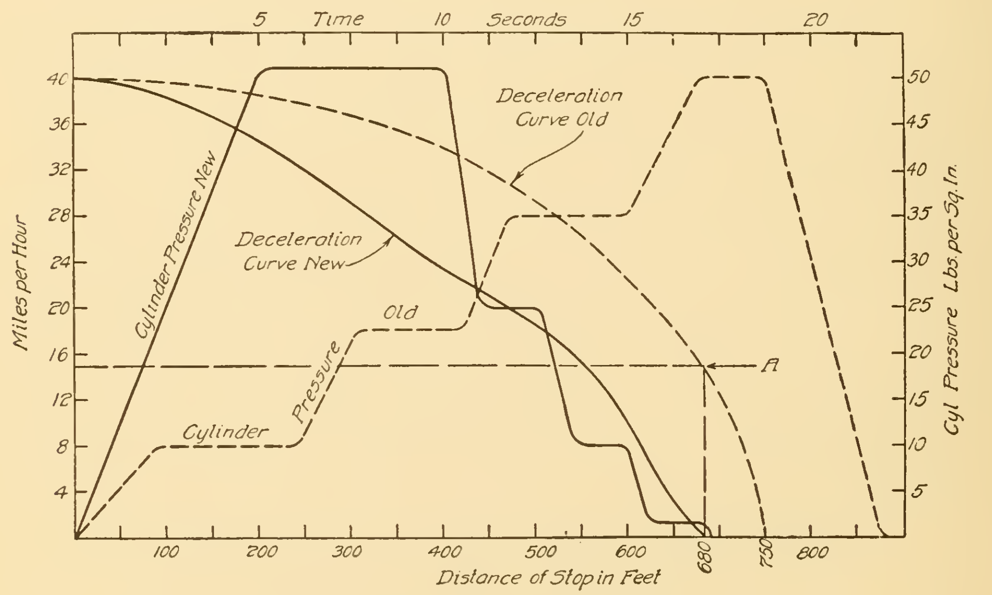


Fig. 138. Diagram Showing Distance of Stop for Electric Car in Feet

make a full application and graduate the pressure off as the speed reduces. To handle the train smoothly, make a heavy application and soon enough so that if held on, the train would stop short of the mark. Then as the stopping point is approached, graduate the pressure off of the brake cylinder so that little remains when the stop is completed. If on the level track, complete the release; if on a grade, hold until the signal to start is given, then release.

Proper and Improper Manipulation. A clear idea of proper and improper methods of brake manipulation is shown graphically in Fig. 138. The dotted lines show the usual method of operation and the results obtained with the old-style brake apparatus. Assume

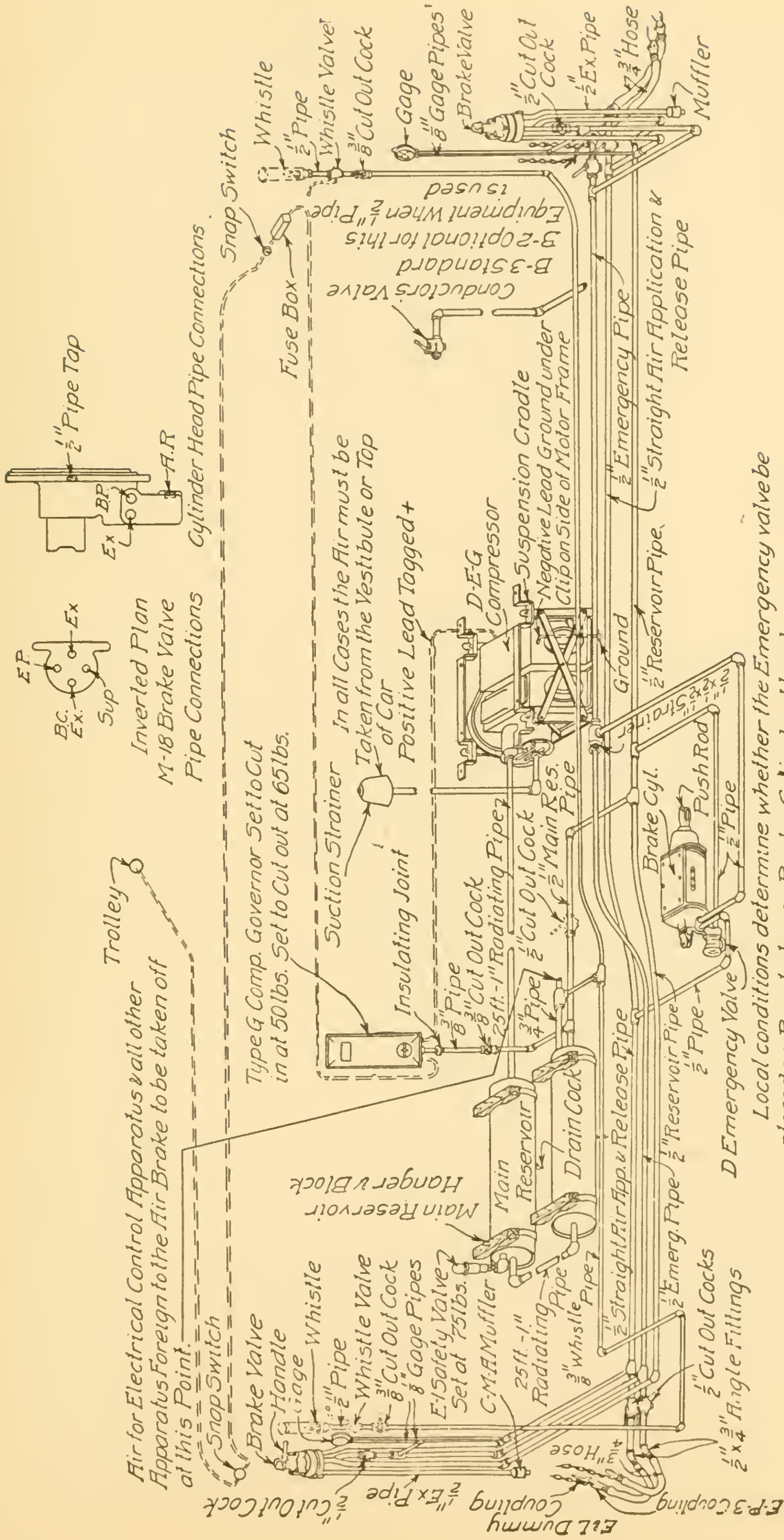


Fig. 139. Piping Diagram for Westinghouse "SME" Brake Equipment (with Type "D" Emergency Valve), for Motor Car

the speed to be 40 m. p. h. when the application is begun. The brake is applied in a series of steps or graduations so that in about 16 to 17 seconds, maximum cylinder pressure has been reached; but meanwhile the train has been brought nearly to a standstill with the highest brake-cylinder pressure being developed at the time the speed is lowest and, consequently, with great tendency on the part of the wheels to slide, making it necessary to get rid of this high-cylinder pressure at once or come to a stop with an unpleasant jerk. A stop by this method is made in say 750 feet.

The full lines illustrate the proper method and show what is possible in the way of smoothness of stop, accuracy of stop, saving of time, and freedom from tendency to wheel sliding. The maxi-

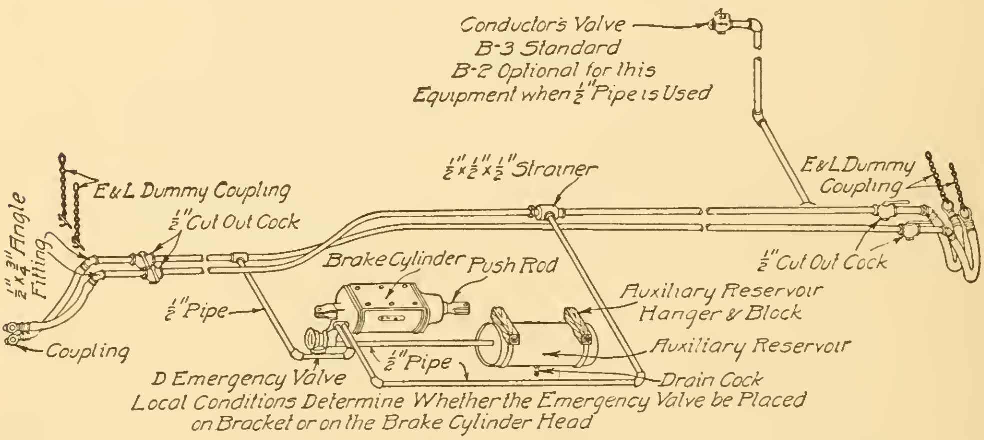


Fig. 140. Piping Diagram for Westinghouse "SME" Brake Equipment (with Type "D" Emergency Valve) for Trailer Car

mum cylinder pressure is obtained at once when the speed of the train is highest and the holding power of the brakes least effective. At the end of about ten seconds, when the speed has been reduced to say 20 m.p.h. and the brakes are "taking hold" more powerfully, a part of the cylinder pressure is released—enough (25 pounds) being retained in the cylinder to maintain as high a rate of deceleration as possible without danger of sliding of wheels. This operation is repeated as may be necessary to keep the retarding force (brake-cylinder pressure) in its proper relation to the decreasing speed of the train. A stop by this method is made in say 680 feet—70 feet shorter than by the improper method—and plainly with much greater smoothness, less tendency to wheel sliding, in shorter time, and with the brake-cylinder pressure nearly or completely exhausted and the system practically fully re-charged.

The point *A* in the diagram shows that during the stop by the first method the train was running at a speed of over 15 m.p.h. when passing the point at which it would have come to a stop, if the second and correct method of brake operation had been followed. Assuming a weight of 160,000 pounds for the train, it therefore possessed at the point *A* about 1,200,000 foot-pounds or 600 foot-tons of energy, which would have been harmlessly dissipated had the brakes been manipulated properly. Such a comparison as this shows clearly that the question of which method of operation to pursue is not of theoretical but of vital and practical importance.

DESCRIPTION OF EQUIPMENT

Figs. 139 and 140, illustrate diagrammatically the "SME' brake equipment, including piping and relative location and names of all parts.

Type "D-EG" Motor-Driven Air Compressor. Type "D-EG" air compressor is manufactured for use with 110-, 220-, and 600-volt direct-current operation, also two- and three-phase alternating current at 110, 220, 440, and 550 volts, and for 25, 40, or 60 cycles. It can also be furnished to operate on single-phase 100-volt current, and 15 or 25 cycles.

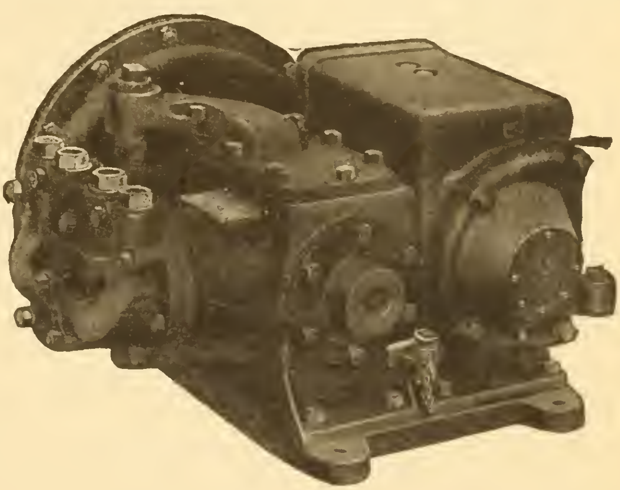


Fig. 141. Type "D-EG" Motor-Driven Air Compressor
Courtesy of Westinghouse Air Brake Company, Wilmerding, Pennsylvania

Fig. 141 illustrates the general appearance of the air compressor and Fig. 142, shows the method of cradle suspension under the car when in service. Figs. 143 and 144 illustrate its form of construction, Fig. 143 being a horizontal section and side elevation, and Fig. 144 an end elevation with a vertical section of the cylinder.

Type of Compressor. The compressor is of the duplex type, having pistons moving in opposite directions. Its action in compressing air is as follows: Air is drawn through suction screen *4* (which is now usually replaced by a cylinder cover with a piped suction to any convenient place for securing pure air) in the cylinder cover *25* to chamber *J* through chamber *H* (which is filled with curled hair), thence by raising either one of the two steel inlet valves *1*, through ports *C* or C^1 into cylinders *A* or *B* (depending upon which piston is moving away from the cylinder cover). On the return stroke the air is forced through either port *K* or K^1, past one of the discharge valves *2*, then into chamber *E*, from which it goes into discharge pipe *D*. Both the inlet and discharge valves are made of pressed steel tubing and are, therefore, light and easily removable. The inlet valves are accessible by removing caps *3*, the discharge valves by removing caps *26*. Inasmuch as all the valves close by gravity, there are no springs to break, corrode, or lose their temper.

Pistons. The pistons *5* are accurately fitted with rings *6*. For the best results, it is essential that the packing ring be installed with the square segment of the ring nearest the wrist pin. When this is done, the angle portion is next the pressure end of the piston, which is necessary in order that the ring joints may lap in such a way as to prevent leakage.

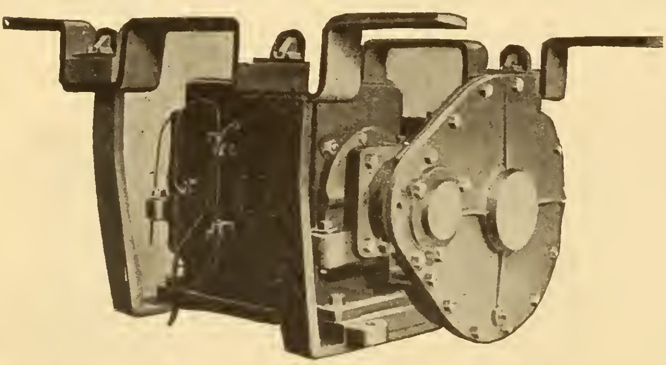


Fig. 142. Westinghouse Type "D-EG" Motor-Driven Air Compressor Suspended in Cradle under Car

To insure correct replacement of pistons and rings, a letter is stamped at the top of the outside flange of each cylinder, on the outside face of each piston, and on the inside face of the joint of each packing ring segment. In addition to this letter, each packing ring segment is also stamped.

Connecting Rod Construction. The wrist pins *7* are of steel, hardened, ground, and secured in place by a set screw *30*; a bronze bushing *8* in the connecting rod *9* works on them. The crank end of the connecting rod is lined, and has a strap *10* hinged at its lower end and secured by an eyebolt *11* at the upper end. On this bolt between the two parts are thin steel washers *12*, which may be removed as the bearing wears, and the strap then tightened down on the remaining ones and locked with the jam nut.

The center line of the cylinder is a little above the center line of

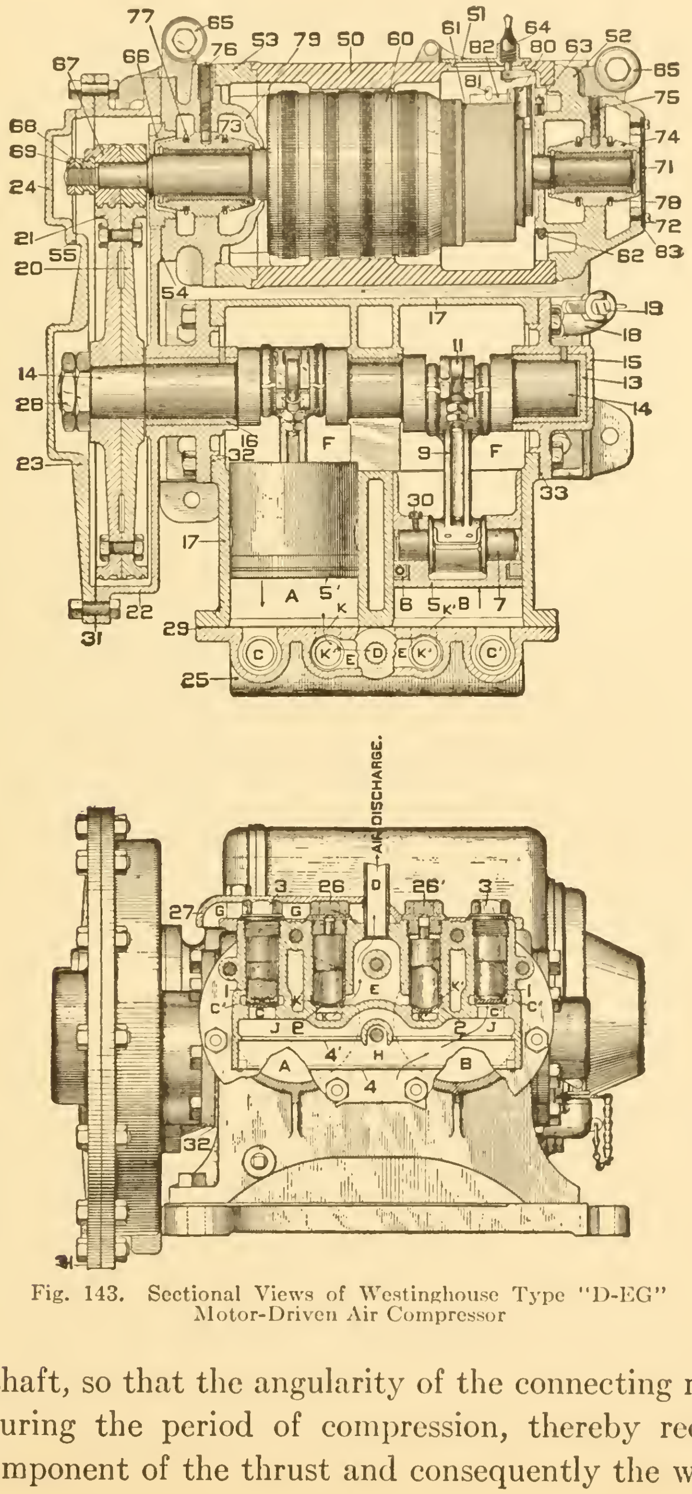


Fig. 143. Sectional Views of Westinghouse Type "D-EG" Motor-Driven Air Compressor

the crankshaft, so that the angularity of the connecting rod may be reduced during the period of compression, thereby reducing the vertical component of the thrust and consequently the wear on the cylinders. The shaft must, however, always run with the compression part of the stroke on the upper half revolution, i.e., clockwise when viewed from the gear end. The crankshaft *14* is made of heavy forged steel and, besides having ample end bearings *13* and *16* of bronze, is provided with a large babbitt-lined center bearing which is a part of the crankcase cylinder casting *17*.

Lubrication. The parts mentioned above are all lubricated from a bath of oil, poured into the dust-proof crankcase through a special fitting *18*, which acts as a gage of the oil level; the fitting is

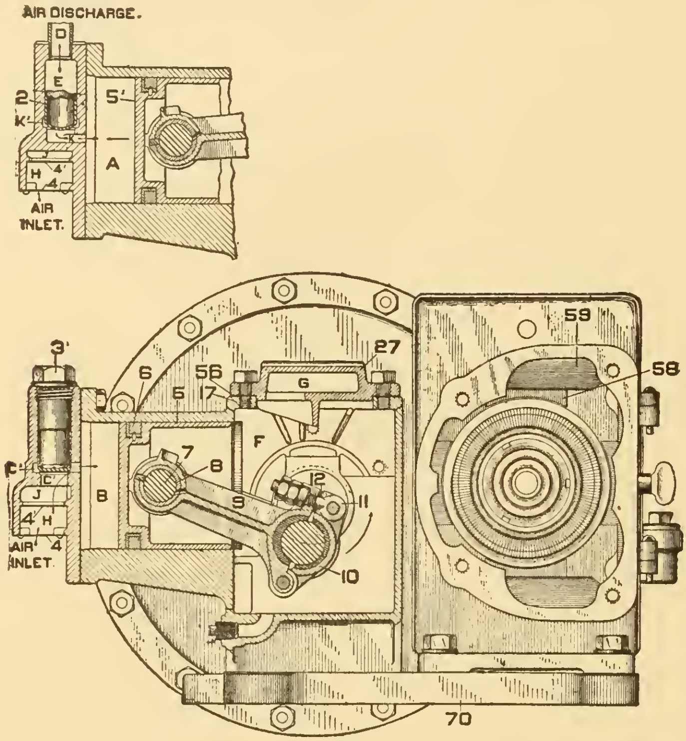


Fig. 144. Part Section of Westinghouse Type "D-EG" Motor-Driven Air Compressor

closed by a suitable screw plug *19* which is secured to it by means of a chain. On the overhanging end of the crankshaft is the gear wheel *20*, made of semi-steel mixture in two halves and bolted together to form the well-known "herringbone" type of gear. It is forced onto the shaft over a square key and secured by the nuts *28*.

Motor. The motor is of the series type with a cast-steel magnet frame *50*, having a prolongation on the commutator end, provided with an opening to permit of ready access to the brushes and commutator. This opening has a door *51* hinged to the frame and tight-fitting so as to exclude rain and dust. In the ends of the frame are centered housings *52*, *53*, and *79*, which carry the armature bearing at the ends of the motor; *52* and *79* are provided with an oil well with filling hole so located that it is impossible to flood the interior of the motor with oil. Cast-iron bearing shells *73* and *74*, of ample proportions, with babbitt inserts, are centered in the housings and secured by means of set screws *75* and *76*. Each bearing has two oil rings *77* and *78*, which insure the proper lubrication of the shaft as long as any oil remains in the wells. An overflow passage, below the opening into the motor at the pinion end, leads to the bottom of the gearcase in the earlier forms of the compressor and to the crankcase in the latter forms, effectively preventing any of the gear lubricating oil, which might work through the pinion bearing into its oil well, from flooding the motor.

Two of the four field poles are a part of the frame *50*, the other two, *58*, being made up of laminations of soft sheet steel riveted together and bolted to the frame, thereby also securing in place the field coils *59*. The armature *60* is built up of electric soft sheet-steel punchings. The commutator *61* is of liberal length, with deep segments insulated with the best grade of mica.

Fig. 145. Westinghouse Type "J" Electric Compressor Governor

Type "J" Electric Compressor Governor. The location of the compressor governor is shown in Fig. 139. That shown is a type used in connection with the smaller class of compressors and differs from the type under discussion. Its purpose is to start and stop the compressor, in order to maintain a predetermined pressure, by alternately making and breaking the circuit leading to the motor. The general appearance of the governor is shown in Figs. 145 and 146, while Fig. 147 is a vertical diagrammatic section.

As may be seen, the governor is made up of two distinct portions, one being a switch and the other a pneumatic regulator. Current from the trolley to the compressor is made or broken by the switch spider *43*, attached to the switch piston and rod *16* and making connection between finger contacts *5* when the governor is in "cut in" position. The governor operates equally well with either direct or alternating current. It is thoroughly insulated and is covered by an iron casing held in place by the thumb nuts *13*. The admission of air to and exhaust air from the cylinder *W* is controlled by the regulating portion of the governor and takes place through port *g* which, when the governor is in the "cut-in" position, is connected by cavity *h* in the slide valve *76* with the exhaust port *f* leading to the atmosphere.

Referring to Fig. 147, main-reservoir air enters the governor at the pipe connection marked "To Main Reservoir", and flows through the passage *a* to the space *B* between the double pistons *25*. From *B* it flows through ports *e* and *j* to space *K* on the face of the diaphragm *60*, on the opposite side of which is a spindle *61* held against the diaphragm by the regulating spring *62*. The stem of spindle *61* projects through the regulating nut *63* to the end of the "cutting-out" regulating valve *28*, which is held firmly against the end of the spindle or its seat, as the case may be, by the regulating valve spring *27*. So long as the main-reservoir pressure is less than that for which regulating spring *62* is adjusted, the latter holds the spindle *61* over so that the "cutting-out" regulating valve *28* remains seated. If the main-reservoir pressure is increased so that its pressure on diaphragm *60* is able to overcome the pressure on the regulating spring *62* on its opposite side, the spindle *61* will be forced back toward regulating valve *28*, which it lifts slightly and permits the air in chamber *C* to flow through port *l* and space *M* past the regulating valve to the atmosphere.

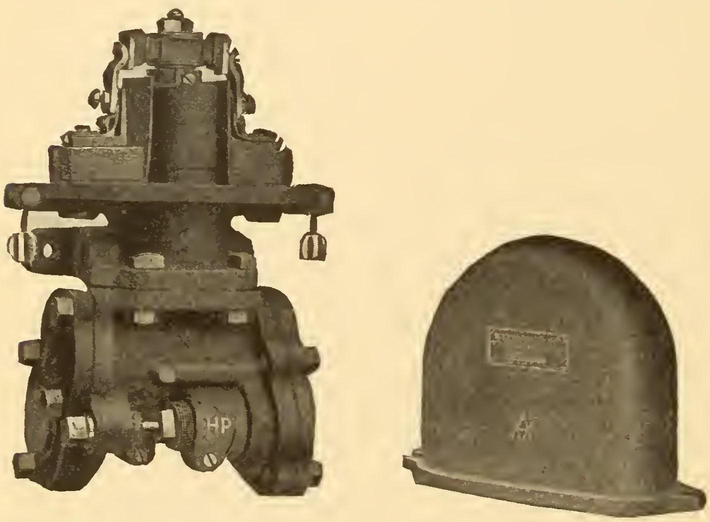


Fig. 146. Westinghouse Type "J" Electric Compressor Governor in Cut-in Position—Cover Removed

As the pressures on the smaller end of the double piston are balanced at this time and the pressure in chamber *B* on the right-hand side of the larger end of the double piston is now much higher than that in chamber *C*, the pistons and attached slide valve are moved to the left to "cut-out" position, as shown in detail at the right, Fig. 147. It will be seen that the first movement of the slide

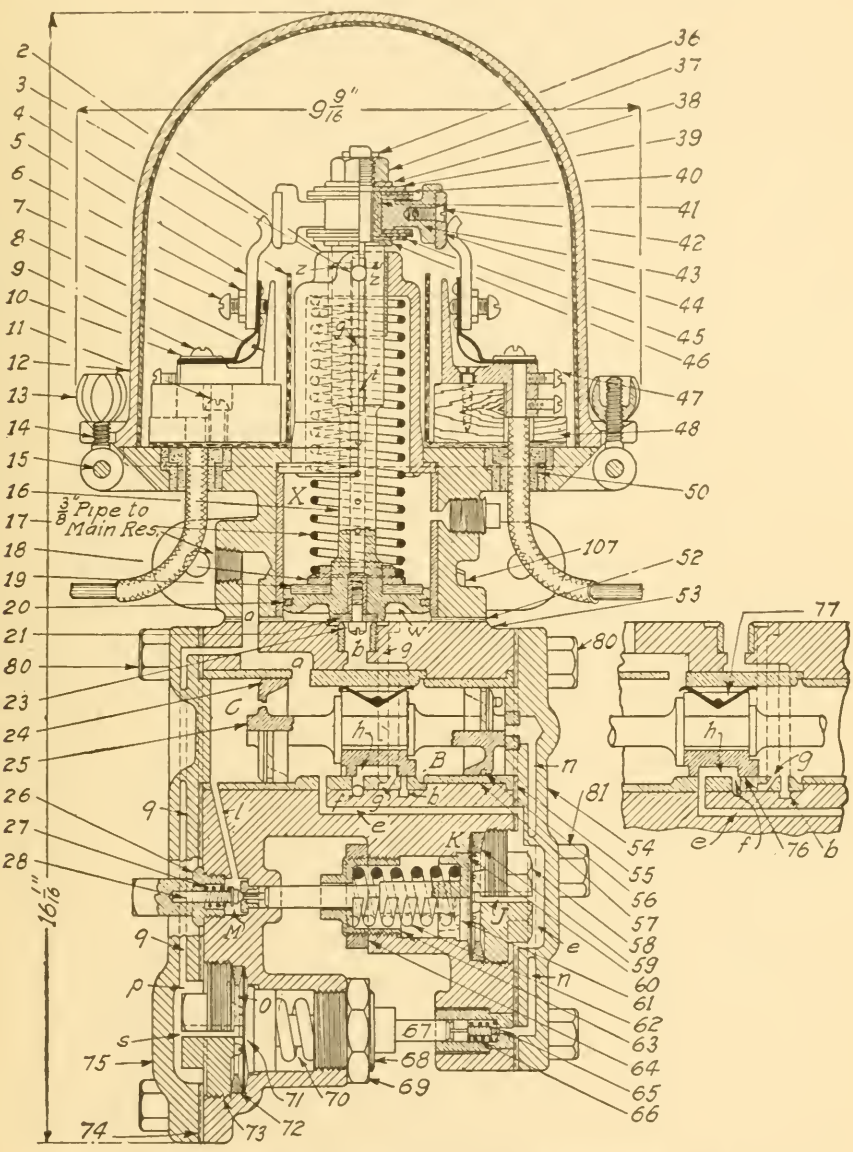


Fig. 147. Diagrammatic Sectional View of Westinghouse Type "J" Electric Compressor in Cut-in Position

valve *76* opens port *b* to chamber *B*, permitting air at main-reservoir pressure to flow through port *b* to the piston "seal" *21*. The area of port *b*, however, is so small that the main-reservoir pressure acting therein is not able to overcome the pressure of spring *17*, which holds the switch piston to its seat. But a further travel of the slide valve opens port *g*, which allows air at main-reservoir pressure to flow to the air cylinder *W*, thus breaking the "seal" of the piston and the main-reservoir pressure then acts on the entire area of the piston, causing it to move outward very rapidly and break the circuit. By having port *b* open before port *g*, a free flow of high-pressure air to the space *W* below the switch piston is insured and a "quick-break" obtained, which eliminates any tendency to cut out slowly. During this movement the air above the switch piston is compressed, and forced through ports *y* and *z* in the hollow rod to the atmosphere. The ports *z* are so placed that they pass the ends of the contact fingers just when the circuit is broken and the quick piston movement causes the air in *X* to be expelled with such force as to make an effective and complete pneumatic blow-out.

In this position of the slide valve *76* it will also be seen that cavity *h* connects port *e* to the exhaust port *f* and atmosphere, thus relieving diaphragm *60* of pressure and permitting the regulating valve *28* to seat. Air from chamber *C* can then no longer escape to the atmosphere and it rapidly becomes equal in pressure to that in chamber *B* (due to flow of air through the small leakage port shown in the large double piston). Both ends of the double piston are then balanced and the parts remain in "cut-out" position until the governor is "cut-in" as follows: A branch from port *a* permits air at main-reservoir pressure to flow through port *q* to *p* and the space *O* on the face of diaphragm *71*, on the opposite side of which is a spindle *67* held against the diaphragm by the "cutting-in" regulating spring *70*. The stem of the spindle projects through the regulating nut *68* and the "cutting-in" regulating valve *65* is held against the end of the stem by the regulating valve spring *66*. So long, therefore, as the main-reservoir pressure on the face of the diaphragm *71* is greater than the pressure of the regulating spring *70* on its opposite side, the regulating valve *65* will be held to its seat by the stem of spindle *67* and the port *n* is then closed.

After the governor has been "cut-out" as explained above and the main-reservoir pressure falls to such a point that the air pressure on diaphragm *71* is no longer able to overcome the pressure of the regulating spring *70* on its opposite side, the latter moves the spindle over so as to permit the regulating valve spring *66* to raise the regulating valve *65* slightly from its seat. This permits the air in chamber *D*, back of the smaller end of the double piston, to escape through port *n* and past the regulating valve *65* to the atmosphere. The larger end of the double piston is balanced at this time and the pressure in chamber *B*, therefore, forces the smaller piston back to the position shown in Fig. 147, carrying with it the large piston and slide valve, exhausting the air from the air cylinder *W* through ports *g* and *h* and exhaust port *f* to the atmosphere, and allowing the piston spring *17* to force the piston *16* and the circuit closer *43* back to "cut-in" position. It will be seen from the illustration that when the double piston moves to "cut-in" position, as explained, a projection boss on the outside face of the small piston closes the connection between chamber *D* and port *n*, so that the pressure in *D* has no escape when the governor is cut in. Chamber *D* is very small and as the small piston and its packing ring, when fitted as tight as is practicable, are still not absolutely air-tight, the slight leakage past the small piston soon equalizes the pressures in *D* and *B*, and, as the pressures in *C* and *B* are also equal, both double pistons are again balanced and the parts remain in "cut-in" position until the governor is "cut-out" as already explained.

The governor is adjusted for a cutting-in pressure of 50 pounds and a cutting-out pressure of 65 pounds.

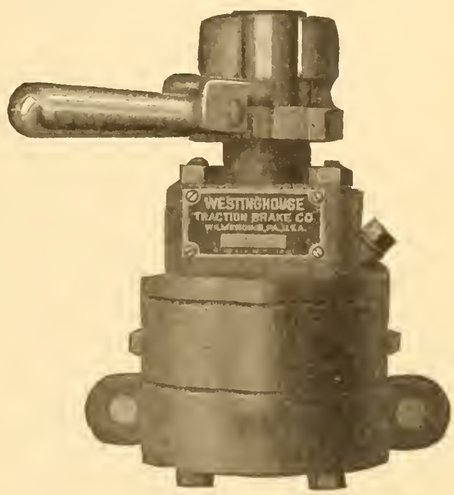


Fig. 148. Westinghouse "M-18" Brake Valve

Type "M-18" Brake Valve. The "M-18" brake valve, Fig. 148, is of the rotary type and it is fitted with a removable handle. A top view of the valve, Fig. 149, shows the different position of the handle, while a vertical section illustrates the arrangement of the ports, etc. The positions of the handle, named from left to right are, *release, lap, one-car service, two-car service,* and *emergency position.* The pipe connections are as follows:

(a) Straight air application and release pipe, leading to the emergency valve.
(b) Emergency pipe, which also leads to the emergency valve.
(c) Brake valve exhaust pipe, leading to the exhaust muffler under the platform.
(d) Reservoir pipe, leading to the emergency valve and to which the reservoir is connected through the check valve.

Duplex Air Gage. The duplex air gage, Fig. 150, is installed in the direct line of vision of the motorman, when operating the brake valve. The pipe connection for the brake-pipe gage hand is taken off from the brake pipe just below the cut-out cock. The

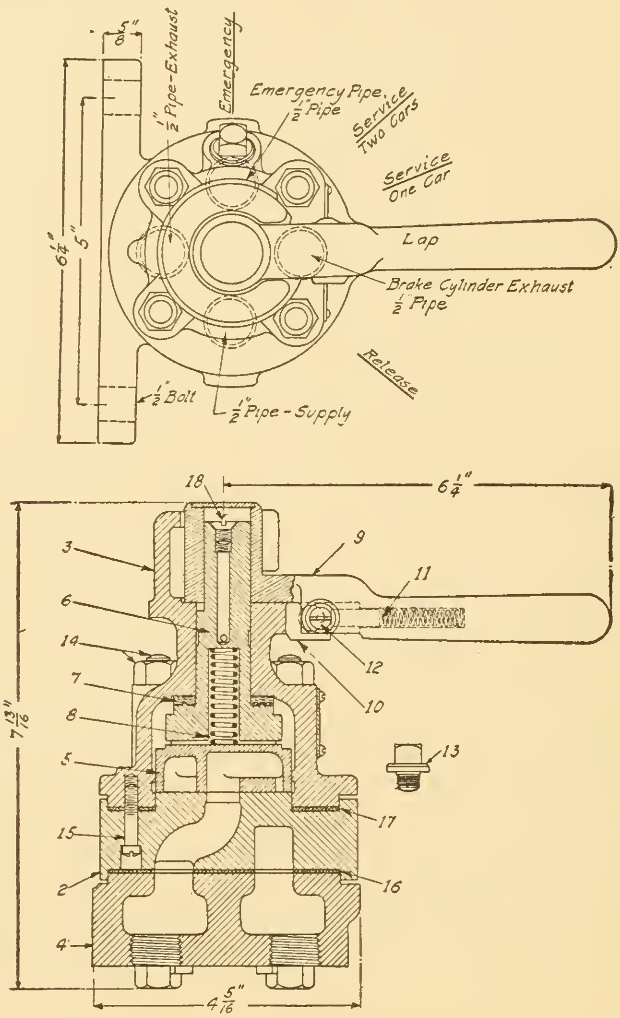


Fig. 149. Westinghouse "M-18" Brake Valve in Plan and Actual Section

connection for the main-reservoir gage hand is taken out from the emergency pipe.

Type "D" Emergency Valve. The Type "D" emergency valve is illustrated in Figs. 151 and 152. It contains an equalizing piston *11*, a slide valve *13* (which serves as a means of exhaust only), an emergency piston *24* and slide valve *25*. Communication between the reservoir and brake cylinder is controlled by the poppet valve *17*. The valve may be attached to the cylinder head or to a bracket under the car floor or on a stand inside of the car. The emergency reservoir and straight air and release pipes are connected directly to the cylinder head.

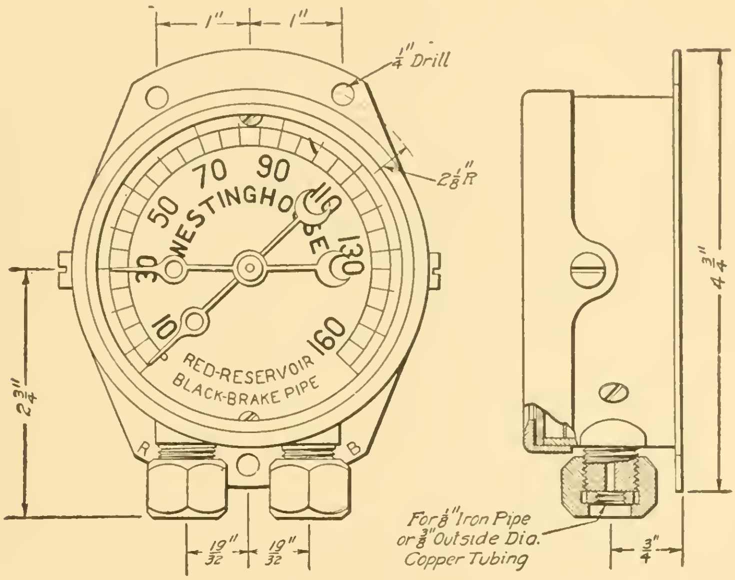


Fig. 150. Westinghouse Duplex Air Gage

Brake Cylinder. The brake cylinder employed is illustrated in Fig. 153. The piston *3* is connected to the brake rigging in such a manner that it moves only when the power brake is used. When the hand brake (if provided) is used, no movement of the piston occurs. The piston rod is made hollow to receive the push rod *14*, which is attached to the levers of the foundation brake gear. The release spring *9* forces the piston to *release* position when the air pressure is exhausted from the brake cylinder. The packing leather *7* is held against the cylinder wall by the expander *8* which insures an air-tight piston.

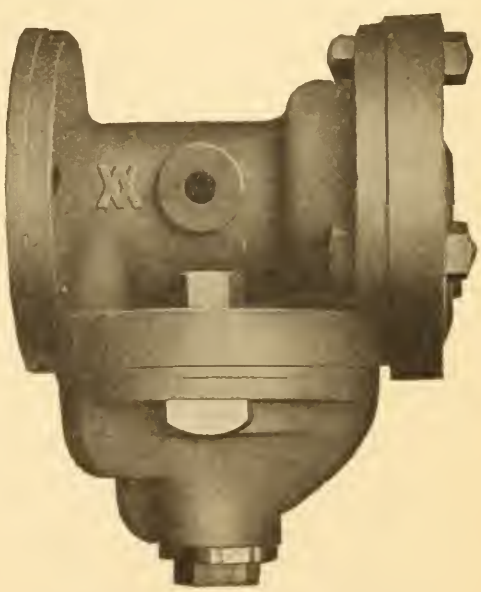


Fig. 151. Westinghouse Type "D" Emergency Valve

Conductor's Valve. This valve is located in a convenient position in the car and is preferably fitted with a cord attached to its handle and running the entire length of the car. It is to be used only in cases of necessity or emergency. It is connected to

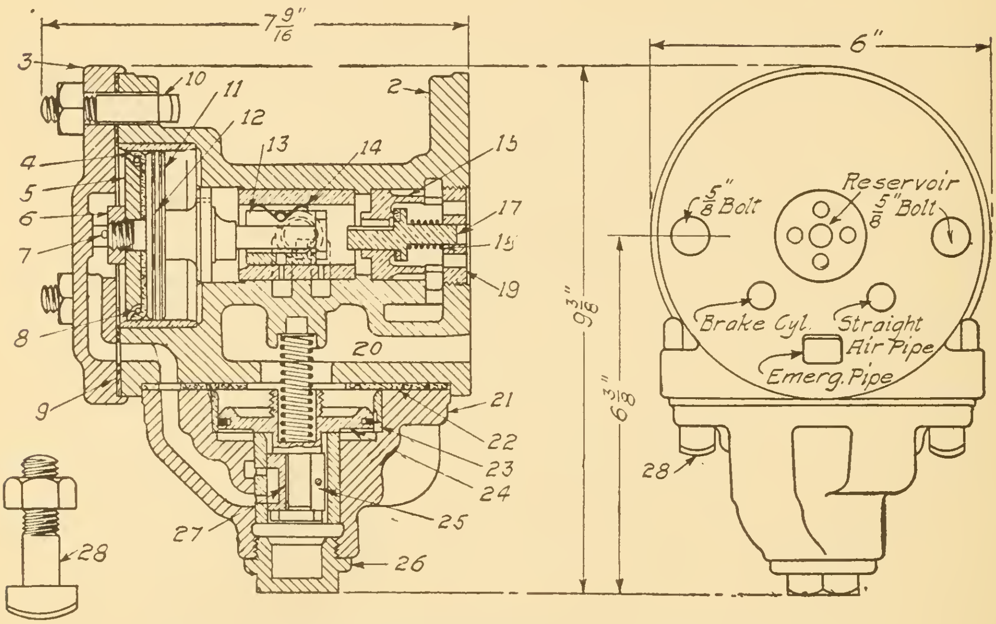


Fig. 152. Actual Section and End View of Westinghouse Type "D" Emergency Valve

the emergency pipe by a branch pipe and permits air to flow directly from the emergency pipe to the atmosphere, setting the brakes in

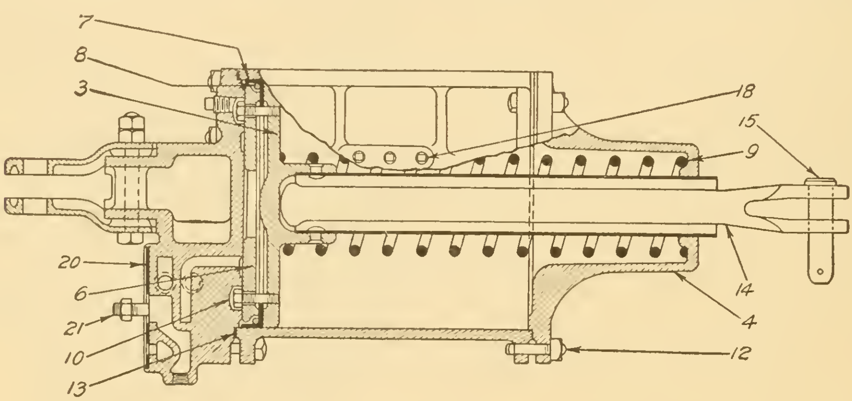


Fig. 153. Diagram of Brake Cylinder

emergency. The style of the valve is of the non-self-closing type and must be closed by hand after being used.

METHOD OF OPERATING "SME" BRAKE EQUIPMENT

In giving an explanation of the operation of the "SME" equipment, reference will be made to the diagrammatic views shown in

Figs. 154 to 158. In this discussion it is assumed that the non-operative brake valve on the rear of the car is in *lap* position.

Charging. With the reservoirs charged and the brake-valve handle in release position, air flows from the main reservoirs through the check valve to the brake valve and into the emergency pipe. A feed groove *i* around the emergency piston *24* permits an equalization of pressure in the emergency pipe with main reservoir pressure, which is assisted by a small port through the rotary valve *5* of the brake valve in all positions except emergency.

Service Application. To apply the brakes, move the brake-valve handle to either one-car service position or two-car service

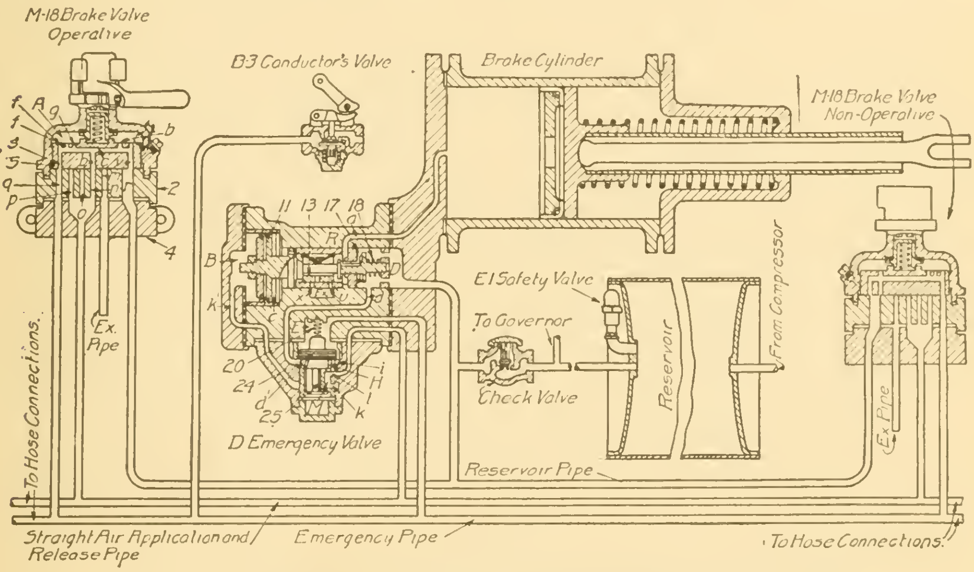


Fig. 154. Diagram of One-Car Service, "SME" Equipment with Type "D" Emergency Valve (*Westinghouse*)

position, depending upon the length of train, speed, condition of rail, kind of stop desired, etc. In one-car service position a relatively small opening (see port *b*, Fig. 154) is made from the reservoir pipe to the straight air application and release pipe and this position is, therefore, used with a single car or when running at slow speeds, and so on. In two-car service position the opening from the reservoir pipe to the straight air pipe is larger (see port *b*, Fig. 155), and this position is, therefore, used with trains of greater length, when running at higher speeds, or, in general, when a heavier application of the brakes is desired.

In response to this movement of the brake-valve handle, air is admitted from the reservoir pipe to the straight air application and release pipe and emergency valve through port *r*, cavity *c*, and ports *b*, *n*, and *o* of the brake valve, thence through port *l*, cavity *M* of emergency slide valve *25*, ports *k* and *k′* to chamber *B* and the face of equalizing piston *11*, forcing it inward. The first movement of the emergency valve piston takes up the lost motion between the collar on the stem and the exhaust valve *13*, and after closing the exhaust ports *x* and *u*, cutting off the brake cylinder from the atmosphere unseats check valve *17*. Communication is thus established between chambers *D* and *R* and the brake cylinder so that air is admitted direct from the main reservoirs to the brake cylinder. When the pressure in the brake cylinder

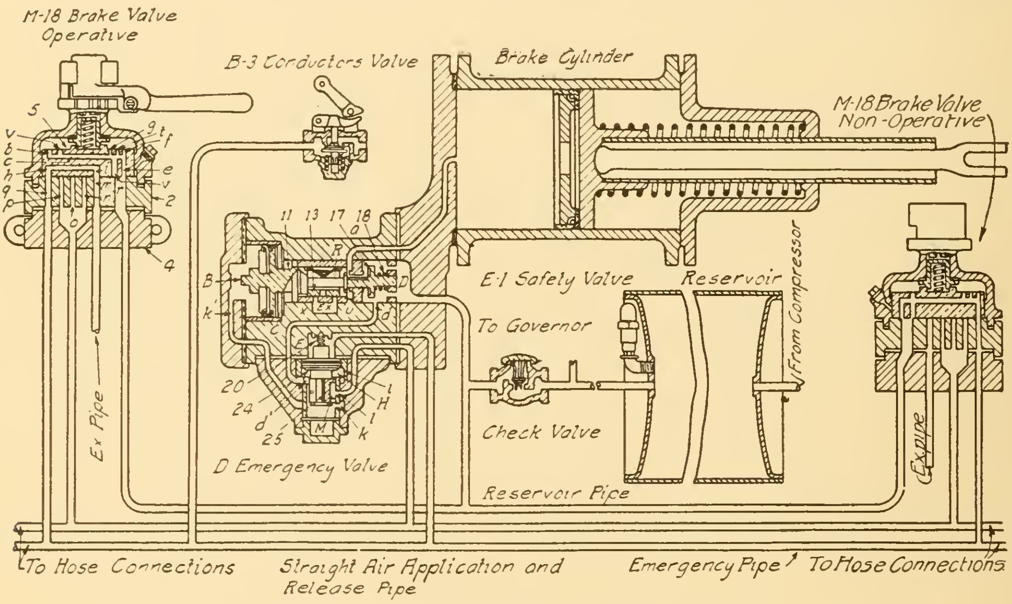


Fig. 155. Diagram of Two-Car Service, "SME" Equipment with Type "D" Emergency Valve (*Westinghouse*)

almost equals that in chamber *B*, spring *18* will drive the equalizing piston outward until the check valve *17* seats. A further rise of pressure in chamber *B* will move the equalizing piston inward, unseating the check valve and causing an equal rise in brake-cylinder pressure.

Holding Brakes Applied. When the desired brake-cylinder pressure has been obtained, the brake-valve handle should be placed in *lap* position. This causes the parts of the emergency valve to assume lap position, Fig. 156, and holds the brakes applied. In this position communication is cut off between the reservoir pipe and the straight air application and release pipe so that no further supply of air is admitted to chamber *B* of the emergency valve, and check valve *17* is seated so that no air is admitted to

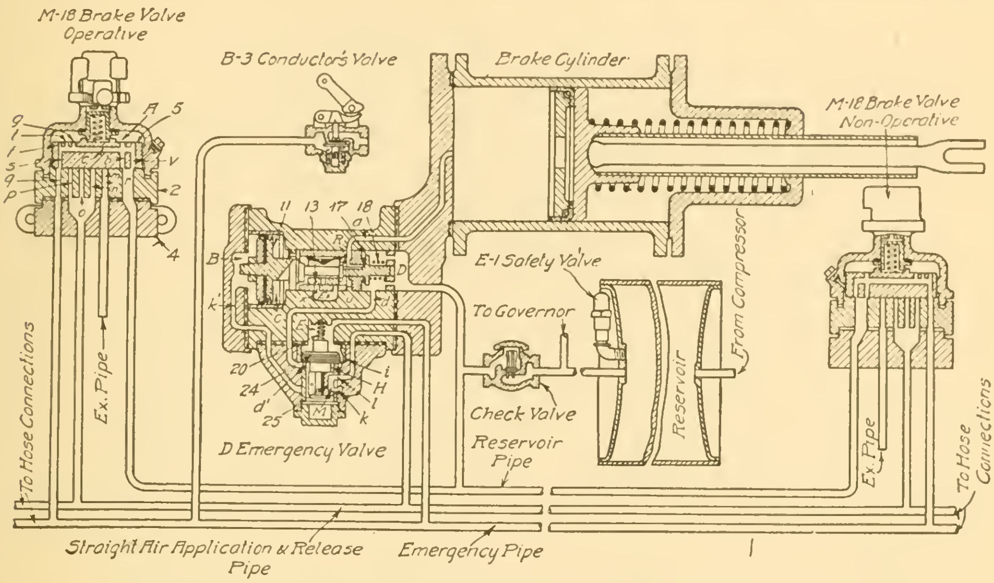


Fig. 156. Diagram of Service Lap Position, "SME" Equipment with Type "D" Emergency Valve (*Westinghouse*)

the brake cylinder. However, should leakage occur in the brake cylinder, it will be automatically maintained, for a decrease of

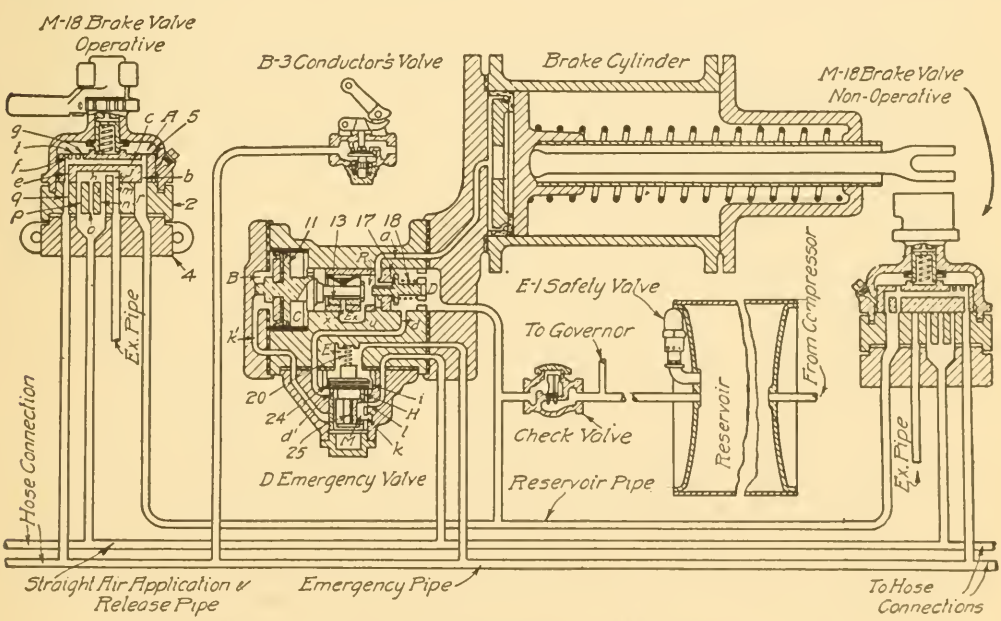


Fig. 157. Diagram of Release Position, "SME" Equipment with Type "D" Emergency Valve (*Westinghouse*)

pressure in chamber *R*, which is always open to the brake cylinder, below that in chamber *B* on the opposite side of the piston will cause piston *11* to move inward again, unseating check valve *17* and admitting more air to the brake cylinder to replace that lost by leakage.

Releasing. In releasing the brakes after an application, Fig. 157, the air in chamber *B* of the emergency valve is exhausted through ports *k'* and *k*, cavity *M* of slide valve *25*, and port *I* to the straight air pipe, thence through ports *n*, *o*, and *p* in the rotary valve seat *2*, cavity *h* and port *j* in the rotary valve, and port *m* to the atmosphere through the exhaust pipe. The greater pressure in chamber *R* then forces the equalizing piston to *release* position, uncovering the exhaust ports *x* and *u* and allowing the air from the brake cylinder to escape to the atmosphere.

Emergency Application. The *emergency* position of the brake valve should be used only when it is necessary to stop the car within

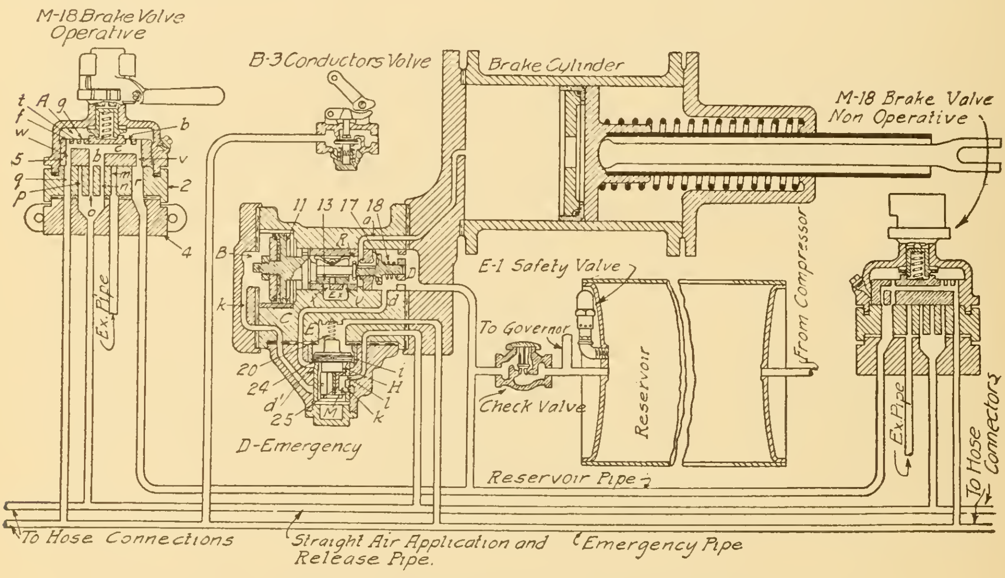


Fig. 158. Diagram of Emergency Position, "SME" Equipment with Type "D" Emergency Valve (*Westinghouse*)

the shortest possible distance to save life or avoid accident. In this position, Fig. 158, the straight air application and release-pipe connection is blanked in the brake valve, while the emergency-pipe air is exhausted to the atmosphere through port *q* in the rotary valve seat, ports *h* and *j* in the rotary valve, and port *m* in the seat, thus reducing the pressure on the upper side of the emergency piston *24*, which is forced to the upper end of its stroke by the main-reservoir pressure on the under side, carrying with it slide valve *25*. This cuts off the straight-air pipe connection and admits air from the main reservoirs through ports *d* and *d′*, *k* and *k′*, to chamber *B*, forcing piston *11* to its extreme inner position. This action opens the check valve *17* wide and permits the air from the main reservoir to flow rapidly into the brake cylinder until the pressures equalize. In the same way also, should a hose burst or uncouple, or pipe break, the resulting rapid drop in emergency pipe pressure will insure an emergency application of the brakes as described.

Upon restoring the pressure in the emergency pipe by placing the brake-valve handle in *release* position, the equalized pressure on either side of the emergency piston *24* permits spring *20* to return the piston to its normal position, thus releasing the pressure back of the equalizing piston through the straight air pipe and brake valve to the atmosphere, at the same time allowing brake-cylinder air to escape through the exhaust ports *x* and *u* in the emergency valve.

Axle=Driven Compressor Equipment. Axle-driven compressors are now practically extinct. When used, a slight change in the piping is necessary from that above described. Since the compressor is mounted on the truck and has some movement relative to the car frame which carries the reservoir, flexible hose connections are necessary to make connections to the reservoir and also to the compressor regulator. A small reservoir is also used which receives air from the compressor. This small reservoir is connected to the main reservoir by a pipe containing a regulating valve. The air attains a pressure of about 35 pounds in the small reservoir before any air passes into the main reservoir. This 35-pound pressure in the small reservoir is attained while the car runs about 100 yards and is available for applying the brakes. This always insures air for operating the brakes, if the car previously runs a short distance. With this exception, the piping would be the same, and no further description is thought necessary.

Storage Air=Brake Equipment. If a car is fitted with a storage air-brake equipment, no compressor is installed on the car. The compressed air which is used for braking is carried on the car in large reservoirs. The general scheme of a storage equipment is shown in Fig. 159, which illustrates an obsolete type of the straight air-brake system as applied to a single car. Two large reservoirs connected by a one-inch pipe carry air at high pressure. These reservoirs

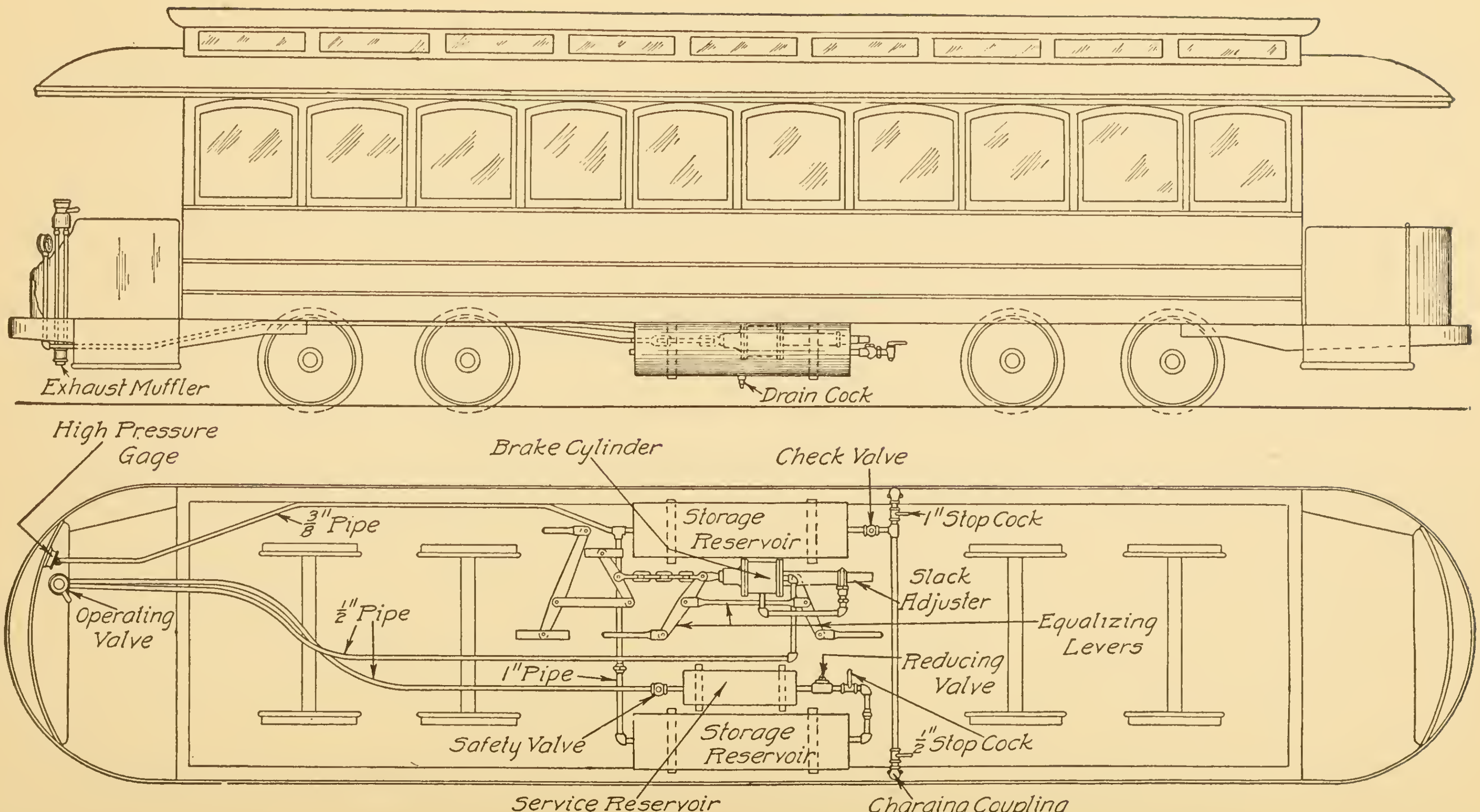


Fig. 159. General Layout of Storage Air-Brake Equipment on a Street Car

deliver air through a reducing valve to a service reservoir. The pressure in the service reservoir corresponds to that in the reservoir previously described. Other than these parts just mentioned, the straight air-brake system and the storage air-brake system are the same.

Train Air Signal. As the size of electric cars and the length of trains increase, a reliable signal system becomes more and more a necessity. The systems now used are quite similar to those employed on steam roads, one of which has already been explained.

Stopping a Car. The brake equipment of all electric cars is calculated with reference to the unloaded weight of the car, that is, the parts are so designed that there will be no danger of slipping the wheels when the car is unloaded. In stopping a car, the forces which act to retard its motion are: (a) the resistance of the atmosphere; (b) the frictional resistance of the journals and track; and (c) the resistance of the brake shoes on the wheels.

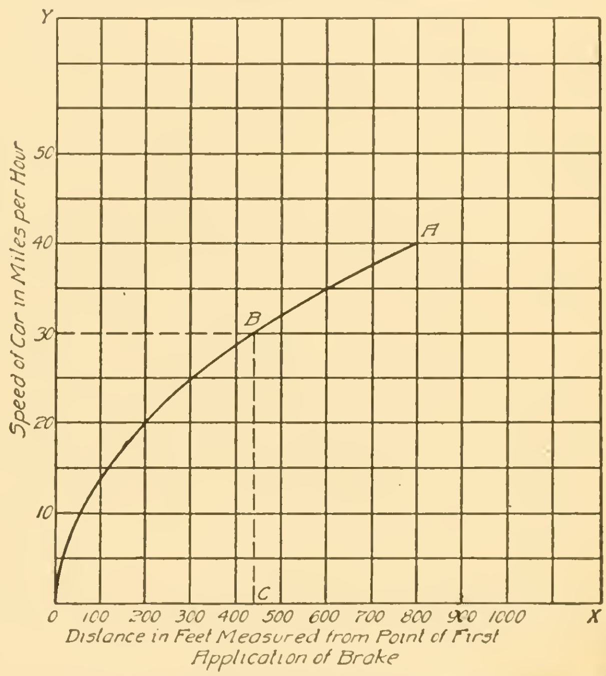


Fig. 160. Diagram Showing Relation between Speed of Car and Distance in Which Stop Can Be Made after Application of Brake

When the brake is applied, the car pitches forward on the front truck, and the weight of the rear truck is thereby decreased. If proper allowances have not been made in proportioning the brake levers, the rear wheels will probably slip on the track. If the wheels should slip, the distance required in which to bring the car to rest would probably be greater than that required had the wheels not slipped. In bringing a car to rest, the energy of translation of the entire car and the energy of rotation of all the wheels and motors must be absorbed by friction. To do this efficiently and safely in the shortest possible time is the purpose of the modern brake system.

The average person who rides on street and interurban cars knows nothing as to the distance in which these cars can be stopped. "In what distance can a modern double-truck electric car be stopped?" is a question which is frequently asked. In answer to this question, Fig. 160 has been prepared. A great many experiments have been made in stopping cars, with varying results. The chief factors which affect the results of such tests are the condition of the rails and the character of the material composing the brake shoes. Fig. 160 shows graphically the relation between the distance required to stop a car and the speed (in miles per hour) at the instant the brake was applied. It represents the average result of a large number of experiments with a double-truck car fitted with brake equipment as described in the preceding pages. With perfect conditions, the curve *ABO* would fall above that shown, while with very poor conditions, it would fall lower. The value of the diagram is made apparent by the following application:

Example. Find the distance in which a double-truck electric car may be stopped, if power is shut off and the brake applied while running at a speed of 30 miles per hour.

Solution. Starting on the vertical line *OY* at 30 miles per hour, follow the horizontal line to the right until the curve *ABO* is reached at the point *B*. From point *B*, follow the vertical line downward until the horizontal line *OX* is reached at the point *C*. This point *C* indicates the distance in feet in which the car may be stopped, which in this instance is 440 feet. In the same way, the stopping distances may be determined for cars running at any speeds.

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