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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

AIR-BRAKE PUMPS
TRIPLE VALVES AND BRAKE VALVES
AIR-BRAKE TROUBLES
OPERATING AND TESTING TRAINS
FOUNDATION BRAKE GEAR
AIR-SIGNAL SYSTEM
HIGH-SPEED BRAKE

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one to select the proper formula, method, or process and in teaching him how and when it should be used.

This volume is devoted to the Westinghouse air-brake and air-signal systems. It treats of the automatic brake system with all its improvements, the combined straight-air and automatic brake for engines and tenders, the schedule **U**, or high-pressure, control apparatus for the control of heavy freight trains on grades, the high-speed brake and the air-signal system. Great pains have been taken to treat the subject from the standpoint of the men who handle the brakes, and everything that will affect the operation of the air or air-signal systems has been carefully considered. The defects and their remedies are treated in such a manner as to cover every case likely to arise. This work should prove invaluable to all persons interested either directly or indirectly in the operation, care, or maintenance of the Westinghouse air-brake system.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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RED.	*Main-Reservoir Pressure.*
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KEY TO THE COLOR PLATES.

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NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 1, which was its former title.

AIR-BRAKE PUMPS

HISTORICAL

THE STRAIGHT-AIR BRAKE

1. The forms of brake in general use before the adoption of the air brake were the hand and the spring brake; most trains, however, were controlled by hand power.

Both of these brakes were ineffective, even for the slower speed of trains in those days, and a field of invention was open for the production of a brake that would permit of a higher safe speed for trains. Mr. George Westinghouse, Jr., in 1869, brought out the first form of brake operated by air, called the **straight-air brake.**

2. General Equipment.—The engine equipment that was employed in connection with this kind of brake consisted of a pump, a main reservoir, an engineer's valve, a gauge, and a train pipe. A pipe connection between the pump and main reservoir allowed the pump to compress air directly into this reservoir, and the air thus compressed was stored in the reservoir for braking purposes. A pipe led from the main reservoir to the engineer's valve, which at that time was a three-way cock. This valve had three positions, namely, *lap*, *service*, and *release*. The improved three-way cocks had a *running position* and an *excess-pressure valve*.

With the valve on lap, all ports were closed, and there could be no passage of air through the valve; in service position, a port was opened between the main reservoir and the train pipe, and in release position, a port connection was established between the train pipe and the atmosphere.

On each car, and on the tender, were placed a brake cylinder and a train pipe, a hose being provided at each end of the train pipe to enable the train pipe to be coupled up throughout the train. The train pipe on the car was directly connected with the brake cylinder, so that, if any pressure was in the train pipe, the same pressure was in the brake cylinder.

3. Operation.—While the brakes were off, and before they could be operated, the pump compressed the desired pressure into the main reservoir. If the engineer wished to apply the brakes, he placed the three-way cock in service position. This position of the valve allowed main-reservoir air to pass through the three-way cock into the train pipe, and thence into the brake cylinders, since the brake cylinders were directly connected with the train pipe. When the desired pressure had been admitted to the train pipe and brake cylinders, the three-way cock was placed on lap, in which position all ports were blanked. The pump would continue compressing air into the main reservoir, to be put into the train pipe when the valve was again placed in service position.

To release the brakes, the engineer placed the valve in release position, which allowed air coming from the train pipe and brake cylinders to pass to the atmosphere through the three-way cock.

4. Defects.—With this form of brake, the brakes on the entire train were rendered useless if a hose burst or if the train broke in two, as then the air admitted into the train pipe to set the brakes would pass to the atmosphere through the burst hose instead of into the brake cylinder. Aside from this, there were several other serious defects in this brake. On a long train, the main reservoir, when connected with the train pipe and brake cylinders through the three-way cock, would equalize at a low and comparatively ineffective braking pressure, as a consequence of which considerable time was required to stop a train. Again, air entering at the head of the train had a tendency to apply the brakes at the head end first, and, when a sudden application of the brakes was made, the slack, running ahead from the rear, would often do serious damage to the cars and their contents. The effect of friction on the flow of air through the train pipe also hindered the free passage of air through the train pipe, causing the brake to be slow in its action, both in application and release.

THE AUTOMATIC AIR BRAKE

5. The many defects of the straight-air brake led to further study, invention, and experiment, the result being the introduction of the **automatic air brake** by Westinghouse in 1873. This brake derived its power from compressed air carried on the engine and each car for braking purposes.

The adoption of the automatic brake necessitated the addition of an auxiliary reservoir and plain triple valve under each car and tender, but did not, for the time being, affect the engine equipment—the brake valve, reservoir, etc.

With the automatic brake the necessary braking power, regardless of the length of the train, was stored in the auxiliary reservoir under each car, for use on that particular car; and, if a hose burst or the train parted, the triple valves would automatically apply the brakes on the whole train—something that could not result on a train equipped with the straight-air brake. Thus, a safer and quicker brake was obtained. The brake is operated by changing the pressure of the air in the train pipe; decreasing train-pipe pressure applies the brakes, and increasing train-pipe pressure releases the brakes. The plain automatic brake was found to be too slow in its action on a long train in cases of emergency, the brakes not setting in succession with sufficient rapidity to avoid damage when the slack in the train ran ahead. When a quick reduction of train-pipe pressure was made, the head-brakes would be set in full before the reduction reached the rear of the train, this retardation being due to the friction of the air in the long train pipe. In order to have a brake that would operate quicker in succession throughout a long train, the Westinghouse *quick-action triple valve* was brought out in 1887. This valve could be substituted for the plain triple valve on trains already equipped by using a larger train pipe, a cut-out cock in the cross-over pipe, and changing the brake levers.

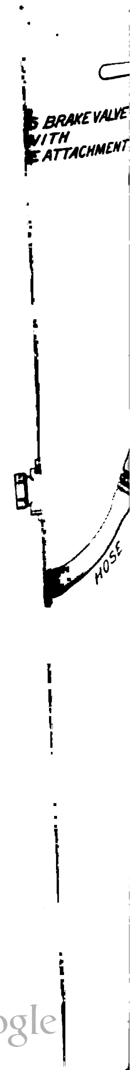
6. High-Speed Brake.—The straight-air brake on cars is now practically a thing of the past; the plain automatic brake is used only on engines, tenders, and a few old-style car equipments put on years ago. The **quick-action automatic brake** is in general use on both freight and passenger cars throughout the country.

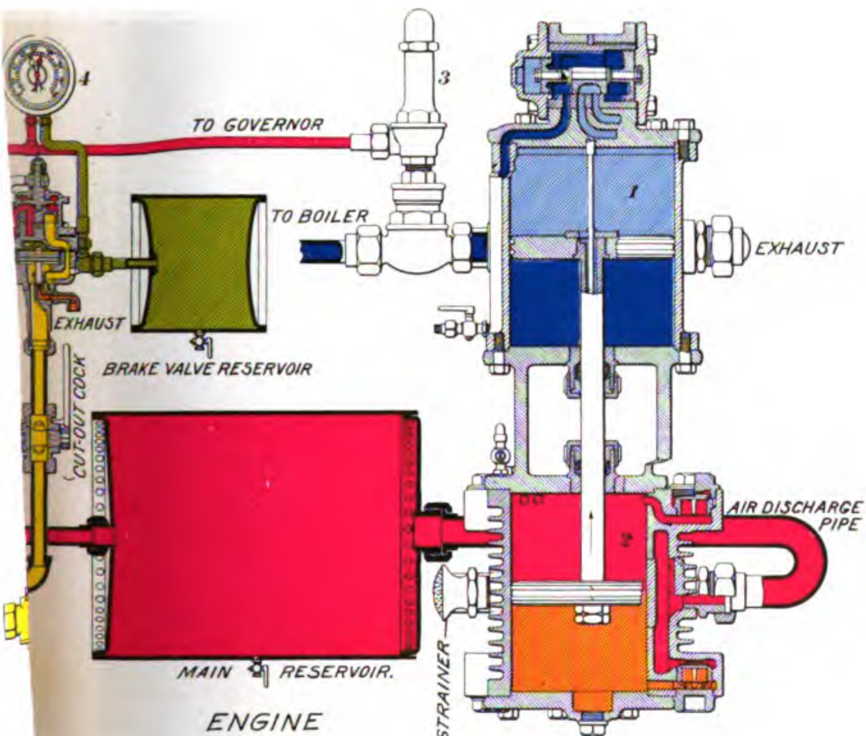
The demand for trains having a schedule speed of more than 50 miles an hour has made necessary a brake even more powerful than the quick-action automatic brake. Such a one is the **high-speed brake,** now used on fast-timed trains like the Empire State, the Black Diamond, the Congressional Limited, etc.

WESTINGHOUSE AUTOMATIC AIR BRAKE

GENERAL ARRANGEMENT OF BRAKE

7. Air Pump.—The essential parts of the Westinghouse automatic air brake, and their arrangement on the engine, tender, and passenger car, are shown in Fig. 1. The air pump, generally placed above the right running board in front of the cab, consists of a steam cylinder *1* and an air cylinder *2*. The two pistons working in these cylinders (one in each) are attached to the same piston rod, as seen in the figure. Therefore, the air piston moves up and down exactly as the steam piston does, and thus compresses the air to be used in the brake system. When the compressed air leaves the pump, it goes to the main reservoir and to the engineer's brake valve; thence, in certain positions of this


BRAKE VALVE
ATTACHMENT
HOSE



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3
TO GOVERNOR
TO BOILER
EXHAUST
EXHAUST
BRAKE VALVE RESERVOIR
CUT-OUT COCK
AIR DISCHARGE PIPE
STRAINER
MAIN RESERVOIR.
ENGINE

valve, it passes through the same into the train pipe, and thence through the triple valves into the auxiliary reservoirs. A pressure usually of 90 pounds is stored in the main reservoir on the engine for the purpose of releasing brakes and recharging the auxiliaries and train pipe.

8. Pump Governor.—The pump governor *3* is placed in the steam pipe leading to the pump, being located between it and the lubricator. It acts as an automatic throttle valve that stops the pump when the desired air pressure is obtained in the main reservoir or train pipe (to whichever it may be connected), and starts it again when, for any reason, this pressure falls below the desired amount.

9. Main Reservoir.—This reservoir, which usually is placed under the engine, just back of the cylinders, is a store chamber in which a large supply of compressed air is maintained. This supply of air is used to charge the train pipe and auxiliaries; to release brakes, if set, by charging the train pipe to a higher pressure than that in the auxiliaries; and to feed any train-pipe leaks while the brakes are released. Also, it often provides air for operating sand blowers, bell ringers, blow-off cock, water scoop, and other devices with which the engine is equipped. The usual main-reservoir pressure is 90 pounds, but this is exceeded in mountainous districts when handling very long trains, when the train is equipped with the high-speed brake, or when the Westinghouse special attachment for controlling heavy trains on long down grades is used.

10. Engineer's Brake Valve.—This valve is located in the cab of the engine in a position convenient to the engineer. Its function is to regulate the flow of air from the main reservoir to the train pipe, and through chamber *D* in the brake valve to the small *equalizing reservoir* under the right running board, sometimes called the *brake-valve reservoir*, or "little drum"; from the train pipe through the engineer's valve to the atmosphere; and from chamber *D*, the equalizing reservoir, and train pipe to the atmosphere; also, if desired, it prevents any flow of air whatsoever. The equalizing reservoir is connected to chamber *D* of the brake valve, with the object of increasing the volume of that chamber. Air passes through chamber *D* when going either into or out of the brake-valve reservoir.

11. Air Gauge.—The air gauge *4* is placed in the cab in such a position that it may be easily seen and read by the engineer. It is generally a duplex pattern, and really consists of two gauges. It has two hands or pointers—one colored red and the other black. The red hand indicates the main-reservoir pressure; the black one shows the pressure in chamber *D* (of brake valve) and the equalizing reservoir, this pressure being generally the same as that in the train pipe. Although the gauge pipe leading to the black gauge hand is connected with the equalizing reservoir, the black hand, for reasons that will be explained in the study of the engineer's valve, is generally spoken of as indicating train-pipe pressure.

12. Cut-Out Cock.—A cut-out cock *5* is placed in the train pipe just below the brake valve. This allows the brake valve to be "cut out" from the train pipe for the purpose of testing, or when this particular engine is the "following" one of a "double-header," and the brakes are to be controlled by the leading engineer.

13. Train Pipe and Attachments.—Mention has already been made of the train pipe. This pipe leads from the brake valve back through the train, and is connected to the triple valves by means of branch pipes, usually called cross-over pipes. It is through the train pipe that air, after leaving the brake valve, is conducted to the triple valves, through which valves it passes into the auxiliary reservoirs. The pressure usually carried in the train pipe is 70 pounds, except in mountainous districts and on trains equipped with the high-speed brake. The sections of train pipe under adjacent cars are connected by means of flexible rubber hose and suitable couplings.

Angle cocks, for the purpose of closing the train pipe, are placed at each end of cars and locomotives, in case it should be necessary to switch a car, or if for any reason it is necessary to disconnect the hose, as well as to close the rear end of the train pipe. Angle cocks, in all modern equipments, are open when the handle stands parallel with the train pipe, as shown in Fig. 1, and closed when at right angles to it.

The handle of the cut-out cock *6*, Fig. 1, stands at right angles to the branch pipe when the cock is open, and parallel with it when closed. In very old equipments, however, the older form of cut-out cock is used, their handles standing crosswise of the pipe when closed. If there is any doubt as to whether a cock is open or closed, glance at the crease in the top of the plug valve. This crease should be parallel with the pipe when the cock is open. If the brake on any car is defective, it may be cut out by closing the cut-out cock *6*, without affecting the operation of the brakes ahead of, or behind, that car.

14. Auxiliary Reservoir.—An auxiliary reservoir should be placed on each engine, tender, and car; the old custom of using one auxiliary for both engine and tender is now considered very poor practice, and is seldom met with. The function of the auxiliary reservoir is to receive and store air for use in applying the brake on the car on which it is placed. Auxiliary pressure, when fully charged, is equal to train-pipe pressure.

15. Brake Cylinder.—A brake cylinder, in which a piston operates, is placed under each car of the train. The brake levers are connected to the crosshead *7*, Fig. 1, in such a way that, when air pressure is admitted to the brake cylinder and forces the piston out, the brake shoes are forced up to the wheels. Brake cylinders on engines and tenders are constructed differently from that shown.

16. Triple Valve.—This valve is so called because it consists of three valves: the triple piston, which opens and closes the feed port; the slide valve, which opens and closes the ports between the auxiliary and brake cylinder, and between the brake cylinder and the atmosphere; and the graduating valve, which controls the flow of air to the brake cylinder in a graduated application of the brakes. This valve connects the train pipe, auxiliary reservoir, and brake cylinder. It has three duties to perform: to charge the auxiliary by connecting it with the train pipe; to apply the brake by connecting the auxiliary with the brake cylinder; and to release the brake by connecting the brake cylinder with the atmosphere.

17. Conductor's Valve.—This valve is used on passenger equipment and cabooses. It is placed inside the car within easy reach of the trainmen and enables them to stop the train in the event of an emergency of which the engineer is unaware. It is connected with the train pipe by a branch pipe so that when the valve is opened it allows air to escape from the train pipe and applies the brakes.

18. Drain Cups.—Drain cups are placed on all tenders, and air strainers on all cars. Each contains a screen to keep dirt and other foreign matter from the triple. The drain cup on the tender is made large, as it collects considerable moisture, which should be drawn off through the drain cock after each trip, especially in cold weather.

MAIN RESERVOIR

SIZE

19. The **main reservoir**, Fig. 1, is an air-tight cylinder having a pipe connection with the pump, one with the engineer's brake valve, and usually one with the air-signal pipe. It varies in size according to the kind of service—freight or passenger—in which the engine is employed. In the best practice, a main reservoir of not less than 16,000 cubic inches capacity for passenger, and from 20,000 to 50,000 cubic inches for freight, service is used.

A larger main reservoir is necessary on freight than on passenger engines because of the greater number of air cars handled in a train in freight service; because there is a longer train pipe and more auxiliaries to recharge after the brakes are released; and because of the greater volume of the long train pipe a greater volume of air must be had in the main reservoir to insure a prompt release of the brakes.

If the train is long and the main reservoir small, a high pressure must be carried in the latter in order that it may equalize with the train pipe at a sufficiently high pressure to promptly release the brakes and recharge the auxiliaries. When the main reservoir is large, a much lower reservoir pressure can be carried, and the pump can also store a greater quantity of air while the brakes are applied. When, therefore, the main reservoir is small, the pump must work both faster (or stronger) and against a higher pressure, either of which tends to cause overheating. A much higher pressure is required in the main reservoir than in the train pipe, not only to release brakes, but also to force the air through the train pipe in the shortest time possible and thus release all brakes on a long train promptly and as nearly simultaneous as possible. About 20 pounds more pressure in the reservoir than in the train pipe is usually needed with a large reservoir; with a small reservoir, more than 20 pounds is necessary. The difference in pressure between the reservoir and the train pipe is called *excess pressure*. *Main-reservoir pressure* begins at the discharge valves of the air pump and ends at the rotary valve of the brake valve. *Train-pipe pressure* begins at the rotary valve and ends at the triple piston of the triple valves.

LOCATION

20. The main reservoir is usually located between the frames back of the cylinder saddle, or along the side of the boiler under the running board. The latter location permits of a larger capacity than any other place, as a long reservoir of moderate diameter can be used on each side of the boiler. The main reservoir is sometimes placed under the deck of the engine or on the back end of the tender. It should, if possible, be located lower than the air pump in order that all oil or moisture will drain into and remain in it. It should be drained after each trip, a drain cock being placed in the bottom of the reservoir for this purpose.

When water is allowed to accumulate in the main reservoir, it not only reduces the space available for storing air, but, if the pipes of the brake system are not properly arranged on the engine, the water will work into the brake system, carrying dirt and oil with it, which gums up the brake valve and triples and prevents the brakes from working properly. In cold weather, water in the pipes will freeze and stop them up. The water that collects in the main reservoir is drawn in with the air as vapor. When the air is compressed it cannot contain all this vapor. As soon as the compressed air cools off to the normal temperature, the vapor condenses and is deposited as water in the reservoir. If the air is cooled off before it leaves the reservoir, all the water will be deposited in the reservoir; otherwise, some of the water will be deposited in the train pipe and triple valves.

DUPLEX AIR GAUGE

21. A **duplex air gauge,** which indicates both train-pipe and main-reservoir pressures, is located in the engine cab, in a position convenient for the engineer. This gauge, shown in Fig. 2 (*a*) and (*b*), consists of two gauges combined in one, the same dial serving for both hands. The left-hand gauge, which, as seen, connects with *M*, operates the black hand. This hand is said to represent train-pipe pressure, although *M* really has a pipe connection to chamber *D* and the equalizing reservoir; but the study of the engineer's valve will develop the fact that there is direct connection between the equalizing reservoir and train pipe in release and running positions, but not in service, lap, or emergency positions. The other gauge connection *T*, a part of the right-hand gauge, is piped to the connection *R* of the brake valve, so that this hand, colored red, indicates main-reservoir pressure.

22. Principle of Working.—An inside view of the air gauge is shown in Fig. 2 (*b*), in which *A* and *B* are two

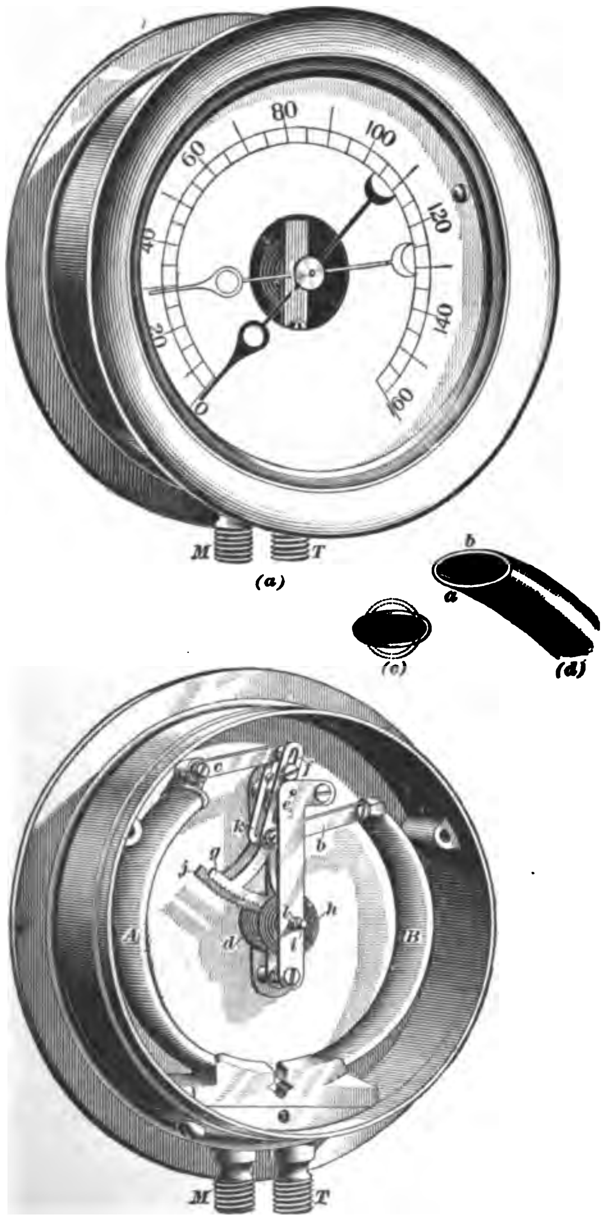

FIG. 2

bent tubes of elliptical shape, as shown in (*d*). The tube *A* is connected to the fitting *M*, and the tube *B* to the fitting *T*. The bottom ends of the tubes are held fast and the top ends are closed and free. The action of the gauge may be thus explained: If a tube of elliptical section is bent as shown in view (*b*), and then subjected to an internal pressure (of either a gas or a liquid) the force exerted will tend to straighten the tube. This is due to the fact that the force exerted within the tube tends to make it assume the circular form shown dotted in view (*c*). In assuming the circular form, the concave side *a* of the bent tube tends to lengthen, while the convex side *b* tends to shorten. These combined efforts tend to straighten the tube out, and therefore impart a movement to its free end.

Tube *A* is connected to one end of the lever *k j* by means of the link *c*. This lever is pivoted at *e*, and the end *j* forms a toothed sector that meshes with a pinion on the spindle *l*. The spindle *l* carries the black hand, or pointer, of the gauge, is hollow, and rotates about the spindle *i*, which carries the red hand. Tube *B* is connected by link *b* to the lever *fg* at a point below the fulcrum, or pivot, so that the red hand will be turned in the same direction as the black one. The lower end of the lever *fg* takes the form of a toothed sector that meshes with a pinion on the spindle *i* and operates the black hand.

23. Operation of Gauge.—Since train-pipe pressure connects with *M*, air under pressure enters tube *A* and tends to straighten it out. This causes the free end of *A* to move to the left, drawing the link *c* with it, thus moving the toothed sector *j* to the right. As this sector engages with the spindle *l*, the latter is made to move clockwise, that is, to have a motion in the same direction as the hands of a clock. The black hand is thus given a similar motion.

Main-reservoir pressure acts within the tube *B* to straighten it, and the free end is moved to the right. As the bar *b* is connected below the fulcrum of the lever *fg*, the movement of the free end of *B* will cause the toothed sector *g* to move to the right and turn the red hand clockwise also. The

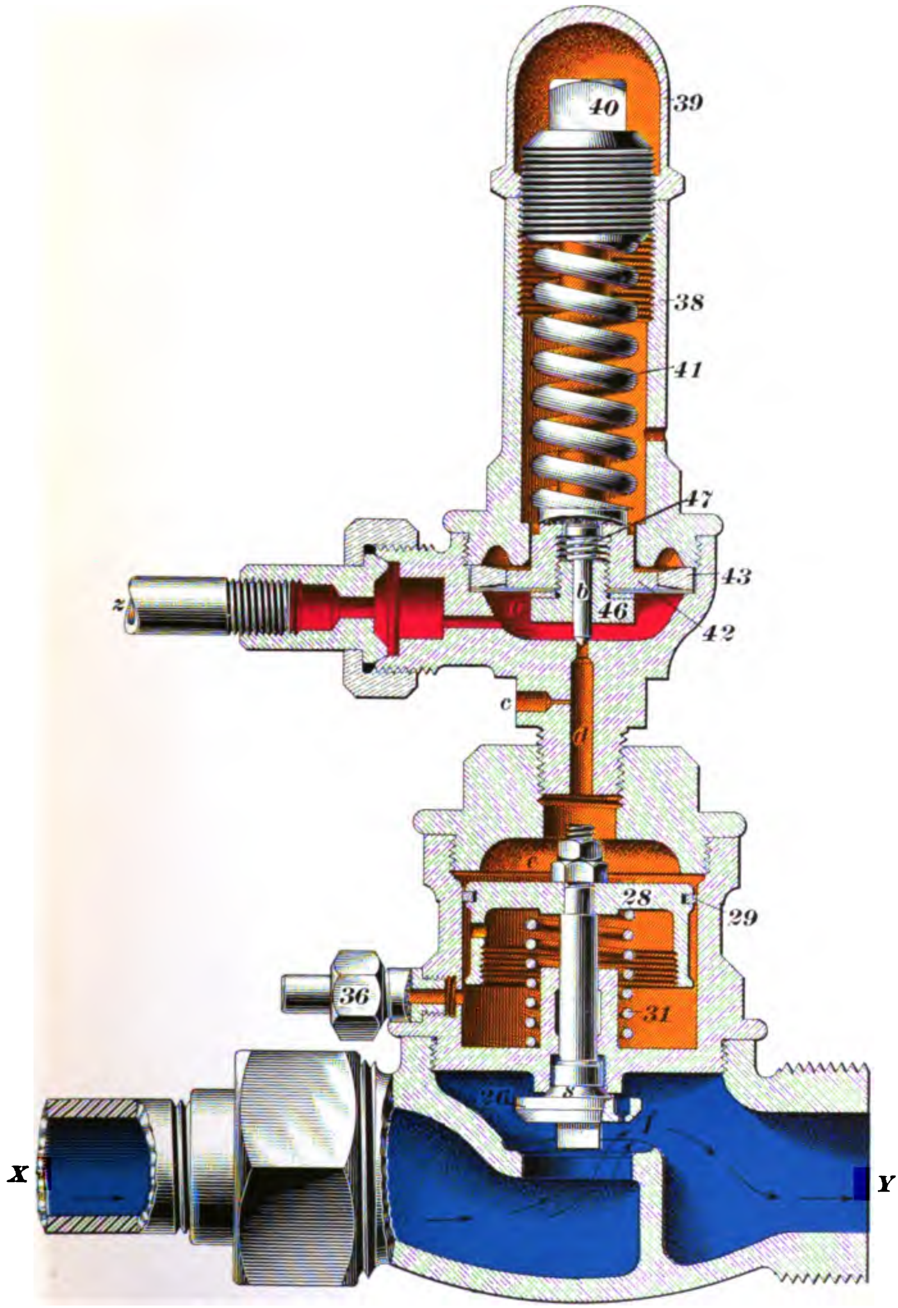

FIG. 3

greater the pressure within the tubes, the greater will be the tendency for them to straighten out, and the higher will be the pressure registered by the gauge; *d* and *h* are small coil springs to take up the play or backlash in the teeth of the sector and pinion.

PUMP GOVERNORS

DESCRIPTION

24. The operation of the old style of **pump governor,** Fig. 4, is so nearly similar to that of the improved type, Fig. 3, that a description of the latter will suffice for both.

The steam-supply pipe to the air pump leads from the top of the dome to a throttle, usually conveniently situated in the cab. From the throttle, the pipe leads to the steam connection *X*, Figs. 3 and 4, of the pump governor, the other connection *Y* of which is piped to the pump, as shown in Fig. 1. All steam must pass through the governor, whose function is to shut off steam from the pump when the desired air pressure is obtained, and to admit steam when the pressure falls below the amount desired.

When used in connection with a D-8 brake valve having an excess-pressure valve, the governor is operated by train-pipe pressure. When used with the F-6 brake valve having the feed-valve attachment, the governor is operated by main-reservoir pressure; the air-pipe connection to the governor is in each case made at *z*.

25. Referring to Fig. 3, it will be seen that chamber *a* is in direct communication with the pipe connection *z* that leads to the main-reservoir pressure when used with the F-6 brake valve. *42* is a brass diaphragm that, in moving, operates the pin valve *b*. Spring *47* holds up pin valve *b* so that it raises with diaphragm *42*, and yet allows the valve sufficient freedom of movement sidewise. *11* is a regulating spring that tends to hold down the diaphragm *42* with a force just a trifle less than the pressure in *a* at which the governor is intended to operate. *28* is the governor piston, to which the steam valve *26* is attached by means of its stem and the locknuts. The piston spring *31* holds the steam valve *26* to its upper seat *s* to prevent steam passing the stem; it does this by forcing the piston upwards, carrying the valve *26* along. *29* is a packing ring, made a sufficiently good fit to prevent any serious leakage of air from chamber *e* past the piston. In the old style governor, Fig. 4, the packing ring *24* was made loose so that air would leak past piston *5*. *36* is the drip-pipe connection. The position of the drip pipe on the old governor is shown by dotted circles. The object of a drip pipe is to permit the escape to the atmosphere of any air that leaks past the ring *29* or of any steam that leaks up by the stem of the steam valve *26*, instead of allowing it to accumulate under piston *28*.

A small port *f* is drilled in the new governor steam valve *26*. Its purpose is to maintain a circulation of steam in the supply pipe, and to keep the pump working slowly, thereby keeping the latter warmed up and preventing, to a great extent, the condensation of steam when the pump is started. If the pump were inactive for some time after full main-reservoir pressure had been attained, steam would condense, and the condensation would be thrown out of the stack, on the engine jacket, when the pump next started to work.

In the following explanation, it will be assumed that the governor is to be used with the F-6 brake valve, and, therefore, is operated by main-reservoir pressure.

OPERATION OF GOVERNOR

26. The regulating spring *41* is, as a general practice, adjusted so that it will just withstand a main-reservoir pressure of 90 pounds pushing upwards on the diaphragm *42*, Fig. 3. When the pump is in operation, the pressure in the main reservoir, and consequently in chamber *a* of the governor, increases until a pressure of 90 pounds is reached. When the pressure in chamber *a* just slightly exceeds the pressure exerted by the regulating spring *41*, the diaphragm *42* is raised, carrying the pin valve *b* with it. The

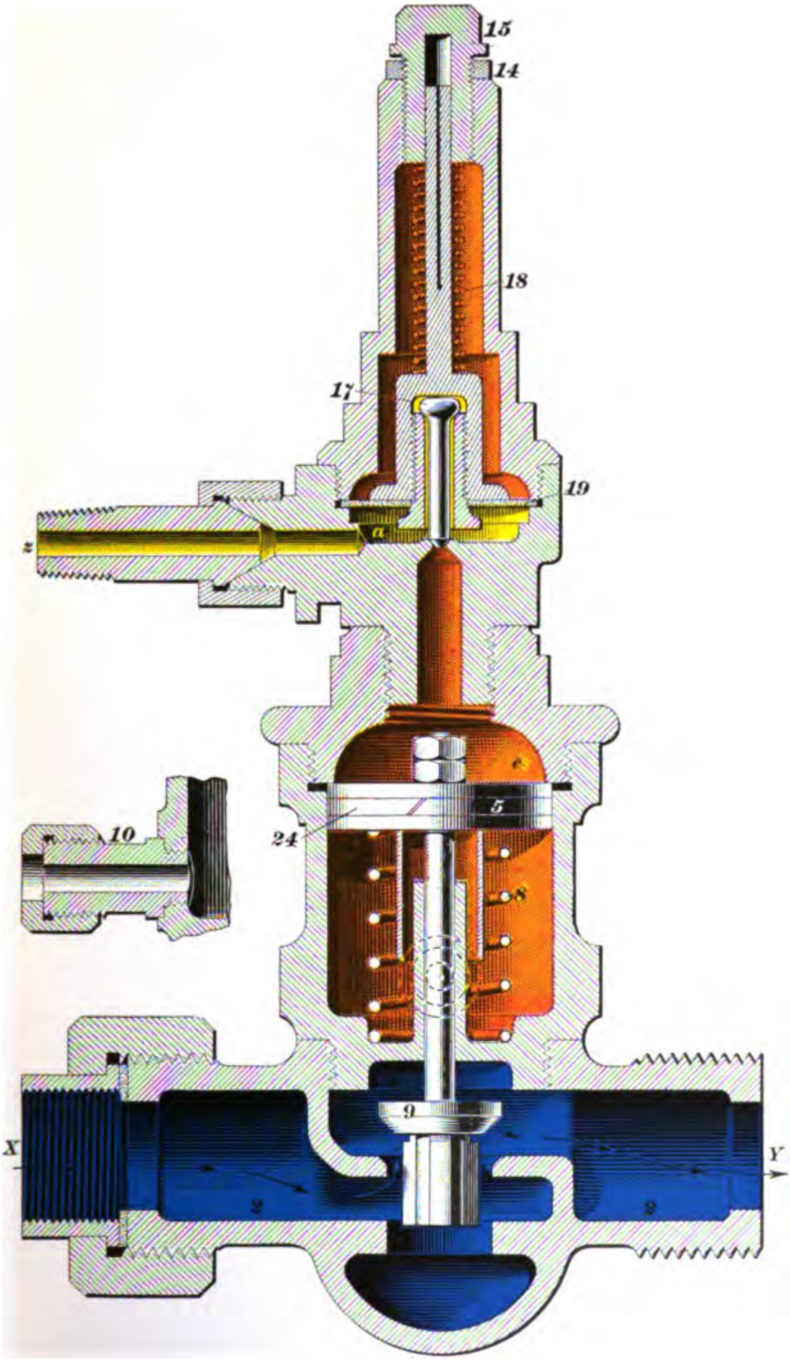

Fig. 4

air in chamber *a* passes by the unseated pin valve *b*, down through port *d*, and into chamber *e* on top of the piston *28*, forcing it down and thus seating the steam valve *26*. As long as main-reservoir pressure remains at 90 pounds, the diaphragm *42* will hold the pin valve *b* from its seat, and the pressure in chamber *e* will hold the steam valve *26* to its seat. If the main-reservoir pressure falls below 90 pounds, the thrust of the spring tending to force down the diaphragm *42* will overcome that of the air in chamber *a* tending to force it up; consequently, the diaphragm will move downwards and thus seat the pin valve *b*. This shuts off the air supply from chamber *e*, and the air confined therein by the pin valve closing will escape to the atmosphere through the relief port *c*. The pressure now being removed from above the piston *28*, the spring *31*, aided by the steam under valve *26*, forces the piston upwards, unseating valve *26*, and allowing steam to pass through the governor to the pump. The piston *28* is made enough larger than the steam valve *26* to enable a moderate air pressure to easily hold valve *26* to its seat against the combined upward force of the steam pressure under the valve and the push of spring *31*.

27. The operation of the governor is the same, whether used with the F-6 or with the D-8 brake valve. In the former case, the governor is operated by main-reservoir pressure; in the latter case, it is operated by train-pipe pressure. In this governor, the spring *41* must be adjusted to just withstand an upward pressure on the diaphragm *42* equal to train-pipe pressure.

In the old-style governor, when the pin valve *17* closes, the air above piston *5* leaks by the packing ring *24* (purposely made a loose fit), and escapes through the waste-pipe stud *10*, indicated by the dotted circles. The rapidity with which the air above piston *5* will escape and permit the governor to operate, depends on the condition of the governor and fit of packing ring *24*. In some cases, the leakage is so slow that fully half a minute elapses after the pin valve is closed before the governor starts the pump. If the stem of valve *9* does not make a good fit there will be a leakage of steam into the chamber below piston *5*.

It is necessary that a governor be sensitive so that it will start and stop the pump promptly and maintain practically a constant main-reservoir pressure; as the old governor did not fulfil these conditions, it had to be improved on.

The improved governor is provided with a relief port *c*, Fig. 3, the object of which is to enable the governor to start the pump promptly when the pressure in chamber *a* allows the pin valve *b* to close. The relief port communicates with chamber *e*, and is of such a size as will, in 2 seconds after the pin valve closes, release sufficient air from above piston *28* to enable the governor to start the pump. This port permits a constant leakage of air from chamber *a* as long as the pin valve is open. On account of this leakage the pump will make an occasional stroke or two.

The small port *f* drilled through the steam valve *26* in the improved governor is provided, as has already been stated, to allow sufficient steam to pass to the pump when the steam valve is closed, to make the pump take a stroke or two occasionally, thus keeping it warmed up. In the old governor, the pump ceases to work after full pressure is attained, except so far as may be required to supply any leaks in the brake system that would otherwise reduce the train-pipe pressure below 70 pounds.

28. Duplex Pump Governor.—A sectional view of a duplex pump governor is shown in Fig. 5. By comparing this figure with Fig. 3, it will be seen that both the diaphragm bodies and the steam-valve body of the duplex governor are exactly the same as the corresponding parts of the ordinary improved governor. The only difference in the two valves is that the duplex governor is provided with the Siamese fitting *S* and an extra diaphragm case. This valve is nothing more nor less than a combination of two ordinary governors, and it operates in exactly the same way as the ordinary governor, since one or the other of the diaphragm

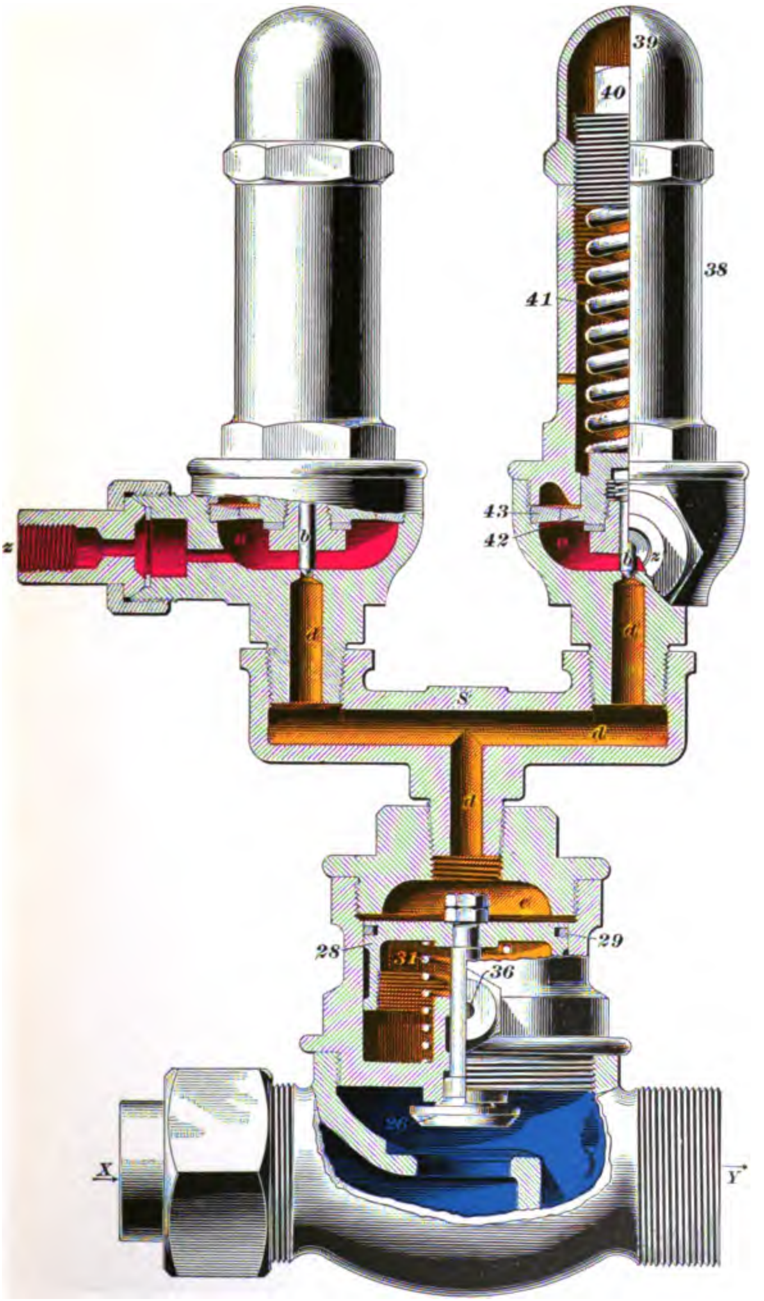

Fig. 5

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bodies is always cut out. The description of the improved governor applies to this governor also; therefore, no further description is necessary. It will be observed that in breaking away the steam-valve case in the illustration of this governor, a sufficient portion has been retained to allow of the drip-pipe connection *36* being shown; also, in breaking away the right-hand diaphragm case, part of the union fitting *z* has been retained. The parts of the valve are lettered and numbered the same as the corresponding parts of the valve shown in Fig. 3.

THE 8-INCH AIR PUMP

29. Fig. 6 shows a cross-sectional view of the Westinghouse 8-inch air pump as used at the present time. In the illustration, *3* is the steam cylinder, and *2* its head; *4* is the centerpiece that forms the bottom head of the steam cylinder and also the top head of the air cylinder, *6* being the lower head of the latter cylinder.

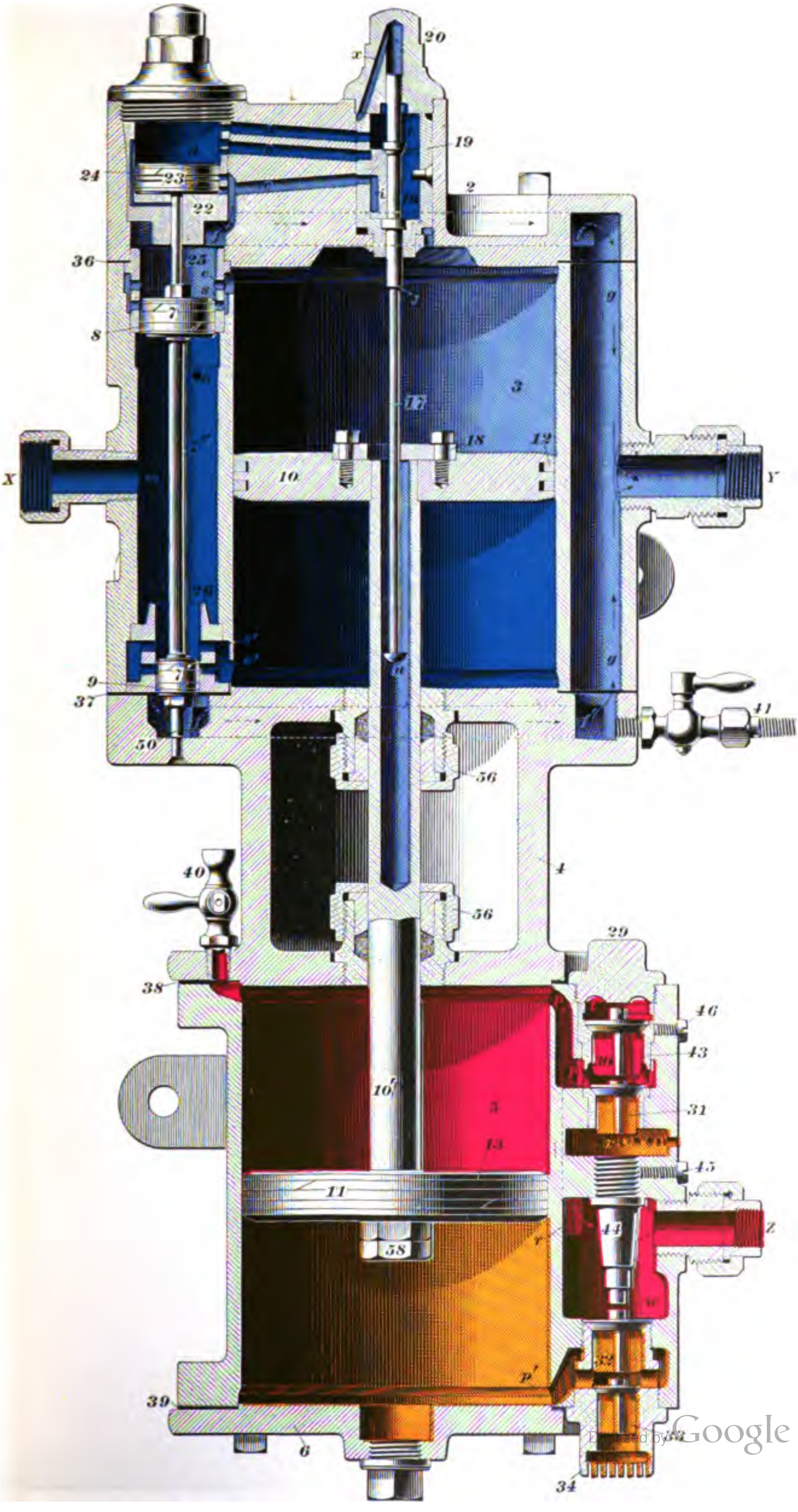
THE STEAM CYLINDER

30. Description.—On referring to Fig. 6, two pistons *7* and *7′* of unequal diameters will be observed, connected together by the stem *7″*, the whole forming what is known as the main steam valve; *8* and *9* are the upper and lower main-valve packing rings, respectively; *10* is the steam piston and *10′* the piston rod, to the lower end of which is connected the air piston *11*. The steam end of the piston rod *10′* is made hollow to receive the reversing rod *17*, which works up and down inside it. *12* and *13* are piston packing rings; *23* is the reversing piston, which is $\frac{1}{8}$ inch larger in diameter than piston *7*; *24* is the reversing-piston packing ring; and *16* is the reversing slide valve, which is brought into play to reverse the movement of the steam piston *10*.

31. The main valve *7*, which is also called a differential valve, controls the admission to, and the exhaust of steam from, cylinder *3*. It works inside the bushings *25* and *26*, contained inside chamber *m*, one at each end. Each bushing has two rows of ports (circular holes) *s*, *e* and *s'*, *e'*, respectively. The ports *s* and *s'* are the admission ports, and *e* and *e'* are the exhaust ports. The stop-pin *50* prevents the main valve from dropping below the bushings *25* and *26* far enough for the packing rings *8* and *9* to expand and so prevent the valve from moving upwards. The steam-supply pipe from the pump governor is connected to the pump at *X*; while the pump is operating, chamber *m* is full of steam and acts as a steam chest for the steam cylinder *3*. Port *h* in chamber *m* leads to chamber *l* in the reversing-valve bushing *19*, which serves as a steam chest to furnish steam to the space above the reversing piston in chamber *d*. The reversing valve *16*, which works inside the reversing-valve bushing *19*, moves up and down with the reversing rod *17*, any movement of the rod causing a corresponding one in the reversing valve. The reversing piston *23* works in the bushing *22*, and has a stem that passes through the bushing and bears on the main valve stem *7''*.

32. The upper end of the reversing rod works freely inside the cap nut *20*. One end of port *x* opens into the top of the cap nut, and the other end connects with a passage that runs down alongside the reversing-valve bushing *19* and thence into top of steam cylinder *3*. This port, in conjunction with the passage, is for the purpose of balancing the steam pressure on the ends of the reversing rod *17*, by connecting the top end of the cylinder *3* with the space above this end of the rod, so that the rod will not move in either direction except when moved by the reversing plate. *36*, *37*, *38*, and *39* are copper gaskets, forming the joints between the cylinders, heads, and centerpiece, as shown. *41* is a drip cock that should be opened when the pump is first started, to get rid of any condensation. *56*, *56* are the gland nuts.

33. Operation of Steam Cylinder.—When the pump is not working, there is a tendency for the steam and air pistons and also the main valve and reversing valve to


20
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19
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23
22
36
25
7
8
3
17
18
12
10
X
Y
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37
50
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40
29
38
46
43
31
10'
5
13
11
45
44
Z
58
39
6
34

settle down to their lowest positions. When the pump throttle is first opened, steam enters chamber *m* and exerts an upward pressure on piston 7, and a downward pressure on piston 7′. Since the area of piston 7 is greater than that of piston 7′, the steam pressure would force the main valve upwards, were it not for the fact that steam from chamber *m* passes through port *h* into chamber *l* in the valve bushing *19*, and thence through port *a* into chamber *d* above the reversing piston *23*. The downward pressure of the steam on piston *23* is transmitted (through the stem) to the main valve 7″, and it thus overcomes the upward push of the steam in chamber *m* on piston 7, as piston *23* is $\frac{1}{8}$ inch larger in diameter, and both are acted on by the same pressure. The pistons *23* and *7* being thus nearly balanced, the downward pressure acting on the small piston *7′* suffices to hold down the main valve in the position shown. While in this position, steam from chamber *m* passes through the lower admission ports *s′* into the steam cylinder underneath piston *10*, forcing it up. Any steam that is above the piston *10* passes through the exhaust port *e* of bushing *25*, thence into the exhaust passage *f f* across the top head of the pump, as shown by the dotted lines, into the chamber *g* and out to the exhaust at *Y*. Just before piston *10* reaches the end of its upward stroke, the reversing plate *18* strikes the shoulder *j* on the reversing rod *17*, and the rod and reversing valve *16* are moved upwards until the valve *16* closes port *a*, and, by means of the cavity *i*, connects the exhaust port *b* with port *c*. The steam above the reversing piston *23* now exhausts through port *b*, exhaust cavity *i*, and port *c*, thence through the exhaust passage *f f* into chamber *g*, and out at *Y*. This removes the pressure from above piston *23*, and, as the upward force exerted by piston 7 of the main valve is greater than the downward force exerted by piston 7′, the main valve moves upwards, closing ports *s′* and *e*, and opening ports *s* and *e′*. Steam from chamber *m* then passes through the steam ports *s* into the steam cylinder above piston *10*, which, consequently, is forced downwards. The steam below piston *10* passes out through the exhaust ports *e′* in bushing

26, through the passage *f' f'* into *g*, and thence out of the exhaust at *Y*.

Just before piston *10* reaches the end of its downward stroke, the under side of the reversing plate *18* strikes the button *u* on the end of the reversing rod *17*, and the reversing valve *16* is moved down to the position shown. This closes the exhaust port *b*, and opens the steam port *a*, admitting steam once more from chamber *l*, through port *a* into chamber *d*. The combined downward pressure on the reversing piston *23* and the piston 7' is now greater than the upward force acting on piston 7, and the main valve moves down, so that steam from chamber *m* is again admitted through ports *s'* into the cylinder below piston *10*, forcing it upwards once more, the ports *e* exhausting the steam from above the piston. This completes a full stroke in the steam end of the pump.

THE AIR CYLINDER

34. Description.—In the air cylinder, as shown in Fig. 6, *31* and *33* are the receiving valves; *30* and *32* the discharge valves. The port *p'* leads from the bottom end of the air cylinder to the space between the valves *32* and *33*, and port *p* leads from the top end of the air cylinder to the air space between valves *30* and *31*. The space *t* above the top discharge valve *30* is in direct connection with chamber *w*, by means of a passage in the body of the cylinder, which enters this chamber at *r*. Air enters the lower end of the cylinder through the air inlets in the lower valve-chamber cap *34*, and air for the upper end of the cylinder enters through the air inlets *v*, just below the receiving valve *31*.

35. The receiving valves should have a lift of $\frac{1}{8}$ inch, and the discharge valves one of $\frac{3}{32}$ inch. The lift of the valve *30* is regulated by the distance between it and the cap nut *29*; the lift of valve *31* is regulated by the distance between the top of itself and the bottom of valve *30*; the discharge-valve stop *44* regulates the lift of valve *32*, and is itself held in position by the setscrew *45*. The lift of valve *33* is regulated by the distance between itself and the bottom of valve *32*; *40* is the oil cup through which the air cylinder may be oiled. If the cup is filled and the cock opened while piston *11* is descending, the oil will be drawn in; or, oil may be poured in when the pump is idle.

36. Operation of Air Cylinder.—As the steam piston is forced up and down, the air piston *11* is carried with it. When the air piston *11* is on its up stroke, the air above the piston is compressed and the tendency is to form a partial vacuum below the piston. The air compressed above the piston passes through port *pp* and in between the valves *30* and *31*, forcing the latter on its seat and, as soon as the pressure beneath valve *30* is greater than the main-reservoir pressure on top of it, forcing this valve from its seat, and flowing into space *t*, thence into port *r* and down into chamber *w*, from whence it passes out at *Z* into a pipe leading to the main reservoir. Main-reservoir pressure in chamber *w* is holding the lower discharge valve *32* on its seat, and just as soon as the partial vacuum under piston *11* (due to its upward movement) is sufficiently great, the pressure of the atmosphere forces the lower receiving valve *33* from its seat and passes through port *p'* into the cylinder, filling the space beneath piston *11* with air at atmospheric pressure.

By the time the air piston has reached the top of its cylinder, the main valve will have made its upward stroke and cut off steam from the bottom side of steam piston and admitted it to the top, thus reversing the motion of the steam piston and, therefore, of the air piston also. As the air piston moves downwards, it tends to form a partial vacuum behind it, and to compress the air in front of (i. e., beneath) it. The air that is being compressed below the piston passes through port *p'*, holds the receiving valve *33* to its seat, and, as soon as the pressure beneath the lower discharge valve *32* is greater than the (main-reservoir) pressure in chamber *w* above it, forcing this valve from its seat and flowing into chamber *w* and out to the main reservoir at *Z*. As already mentioned, a partial vacuum has been formed in the space above piston *11* and in port *pp*, and atmospheric pressure forces air in to fill this space, entering the holes at *v*, and raising the top receiving valve *31* from its seat, thence passing through port *pp* and filling the upper part of the air cylinder with air at atmospheric pressure. The motion of the pump is again reversed as the piston nears the bottom of the cylinder, and in moving upwards it compresses the air that has just been taken in above the piston and forces it into the main reservoir. A complete cycle of the movements of the pump has now been traced.

THE 9½-INCH AIR PUMP

37. As the custom of equipping freight cars with the air brake became more and more general, an engineer often found himself called on to handle sixty or more air-brake cars in a single train; it therefore became imperative that a pump of greater capacity than the old 8-inch pump should be employed. To meet this demand, the 9½-inch air pump was brought out.

38. Six views of the Westinghouse **9½-inch air pump** are given in Fig. 7. (*a*) and (*b*) are cross-sectional views, showing the pump on an up and a down stroke, the front half of the pump removed; an additional portion of the centerpiece and air cylinder *x y z* is also shown broken away, so that a view of the discharge air valves, valve cases, and air passages may be presented. (*c*) is a side view, showing a section through the valve gear in the upper steam-cylinder head; a portion of the steam cylinder also is shown broken away. (*d*) is a back view, in which portions of the steam and air passages and of the air-valve cases are broken away to give a clearer idea of the location of the valves, ports, and passages. (*e*) is a view of the outside of the bushing *75*, while (*f*) is a cross-sectional view of the upper steam head taken from the side. The steam-supply pipe is connected to the pump at *X*, the exhaust pipe at *Y*, and the air-discharge pipe to the main reservoir at *Z*.

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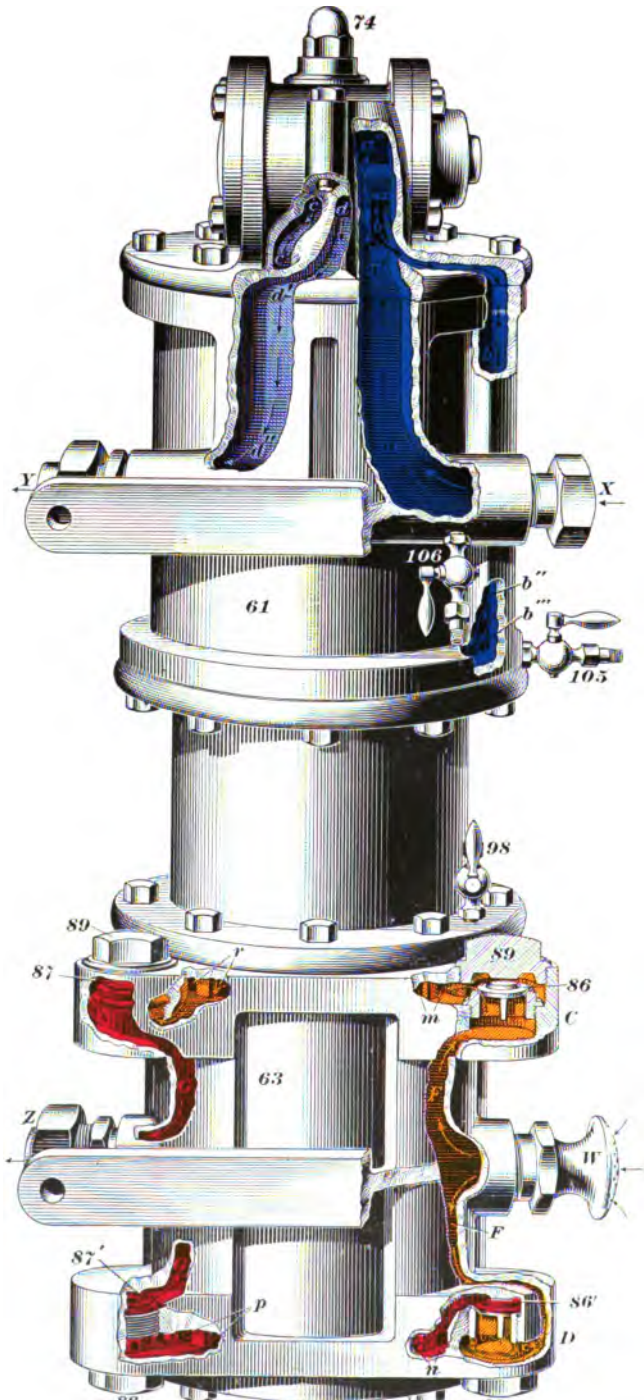
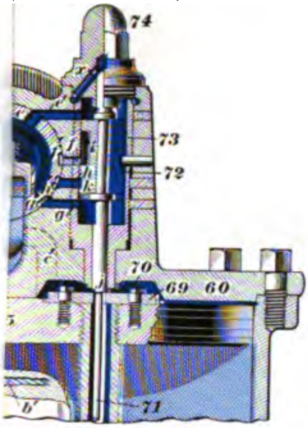


(d)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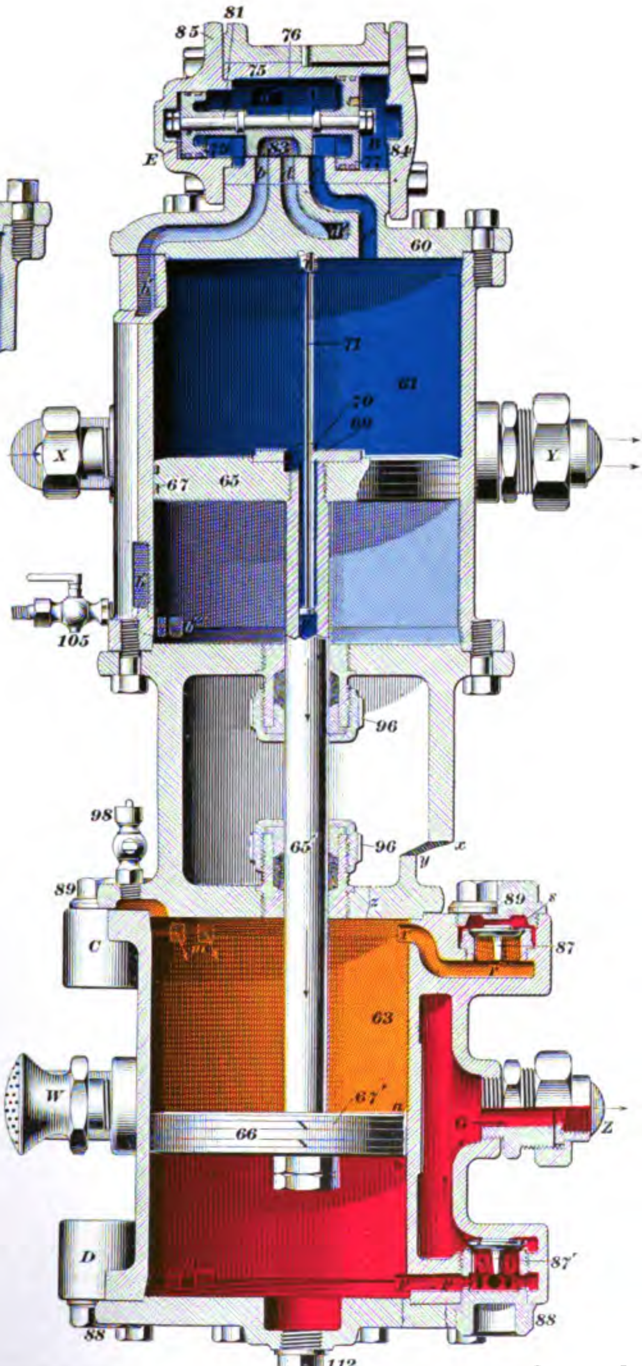
73
72
70
69
60
71
b'
(f)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85
76
75
E
84
60
71
61
70
69
X
Y
67
65
105
96
98
65'
96
x
y
89
89
C
87
63
W
67'
66
Z
D
87'
88
88
112
(b)

THE STEAM CYLINDER

39. Description.—In Fig. 7, *61* is the steam cylinder and *63* the air cylinder. The steam piston *65* and air piston *66* are connected by piston rod *65'*, the upper part of which is hollow, as in the 8-inch pump. In the $9\frac{1}{2}$-inch pump, all the steam valve gear, except reversing rod *71*, is contained within the upper steam-cylinder head *60*. This is a great convenience, for, should the valve gear get out of order, a new head can in a few minutes be substituted for the defective one.

Three views of the main-valve bushing *75* are given, namely, a longitudinal section in views (*a*) and (*b*), a transverse section in view (*c*), and an outside elevation in view (*e*), showing the bushing removed from the steam-cylinder head. In this latter view is also shown the main-valve head *85*. The ports *b* and *c* pass through the bushing, and are the steam ports for the steam cylinder, views (*a*) and (*d*). The port *d* also passes through the bushing, and is the exhaust port for the steam cylinder. The groove *f'* connects with the exhaust port *d*. Grooves *h'* and *g'* connect with the ports *h''* and *g''*, which open into chamber *B*, the space between piston *77* and the cylinder head *84*. A passageway *t* in the bush and *t'* in the main-valve head *85* (represented by dotted lines) establishes communication between chamber *E* in the main-valve head and the exhaust groove *f'*; chamber *E*, therefore, is in constant communication with the atmosphere through passages *t'* and *t*, groove *f'*, and exhaust port *d*. Any steam that may leak past the piston *79* is thus prevented from accumulating in chamber *E*, where it would prevent the main valve *76* from taking a stroke to the left. The port *a''* connects chamber *A*—the space within the bushing *75*—with the steam-supply passage *a' a*, views (*c*) and (*d*); consequently, this chamber, which acts as a steam chest for the slide valve *83*, is always filled with steam as long as steam is turned on to the pump. Port *e* connects with the passage *e'*, which leads into the reversing-valve bushing *73*; therefore, this bushing, which acts as a steam chest for the reversing valve *72*, is also filled with steam as long as the pump is supplied with it.

The steam port *b* in bushing *75* connects with the steam passage *b′ b″*, which opens into the lower end of the steam cylinder below the piston at *b‴*, views (*a*), (*c*), and (*d*). The other steam port *c* connects directly with the upper end of the steam cylinder through the passage *c′*. The exhaust port *d* connects with the passage *d′ d″*, views (*a*) and (*d*), which leads to the atmosphere through the exhaust connection *Y*.

40. Steam enters the pump at *X*, flows through the passage at *a a′*, views (*c*) and (*d*), and enters the main-valve bushing through the port *a″*. Three ports, *f*, *h*, and *g*, in the reversing-valve bushing *73*, connect directly with the grooves *f′*, *h′*, and *g′*, in the main-valve bushing *75*, views (*c*) and (*e*). A reversing valve *72*, having a cavity *i* in its face, operates inside the bushing *73*. The duty of this valve is to admit steam to, and exhaust steam from, the space *B* between the piston *77* and head *84*, immediately before the piston valve *76* takes its stroke toward the left or right, respectively. The reversing valve *72* is held between two shoulders on the reversing rod *71*, so that if the rod is moved up or down it moves the valve with it, as in the 8-inch pump. When the reversing valve is in the position shown in view (*c*), it closes port *g*, and the cavity *i* connects port *f* with port *h*; hence, chamber *B* is open to the atmosphere, and any steam therein can exhaust through port *h″*, groove *h′*, port *h*, cavity *i* in slide valve, port *f*, groove *f′*, and exhaust port *d*. When the reversing valve is moved to its highest position, port *g* is open and the part *k* of the valve separates ports *f* and *h*. Steam can now flow through port *g*, groove *g′*, and port *g″* into chamber *B*, whence it cannot escape into the exhaust, owing to the ports *f* and *h* being closed.

41. The main valve *76* consists of two pistons *77* and *79* of unequal diameter, connected by the valve stem *81*. The small piston *79* works to and fro in the main-valve head *85*, piston *77* working in the main-valve bushing *75*. The slide valve fits between two shoulders on the main-valve stem *81*, and, therefore, whenever the piston valve moves, it carries the slide valve with it.

42. It is thus seen that this pump contains three steam valves: the main slide valve *83*; the main valve *76*, called a differential piston valve; and the reversing valve *72*. The duty of the slide valve *83* is to regulate the admission of steam to, and the exhaust of steam from, the upper and lower sides of the piston *65*, as required. It is a valve of the ordinary **D** type, and is similar to the slide valve of a locomotive; however, as in the case of the latter valve, some means must be provided for moving it back and forth as required. This is the duty of the main valve *76*.

The duty of the reversing valve *72* is to admit steam to chamber *B* when the main valve is to make a stroke to the left (as viewed in the illustration) and to exhaust the steam therefrom when the main valve is to make a stroke to the right. If the steam is exhausted from chamber *B*, the main valve will naturally take a stroke to the right, since the steam in chamber *A*, which acts on both pistons, exerts a greater total force on the larger piston *77*. To make the main valve take a stroke to the left, it is necessary to admit steam into chamber *B*; this acts against, and balances, the pressure exerted on piston *77* by the steam in chamber *A*, and the pressure of the steam on the small piston *79* will then move the main valve to the left.

The reversing cap nut *74* fits steam-tight around the rod *71*. Passage *x* connects with another passage outside the bushing leading into the upper end of the steam cylinder. As in the 8-inch pump, this passage allows the steam in the top end of the cylinder (whether live or exhaust steam) to equalize through *x*, so that there is the same pressure on both ends of rod *71*. This prevents the rod being moved either way by the pressure of the steam in bushing *73*. Two drain cocks *105* and *106*, located in the steam passages b'' and *a*, are provided for the purpose of removing condensed water. They should be opened when the pump is first started and kept open until it is thoroughly warm, after which they should be closed to prevent the escape of the oil. *96, 96* are the gland nuts by means of which the piston-rod packing is adjusted.

43. Operation of Steam Cylinder.—When the pump is at rest, the pistons *65* and *66* generally settle to the bottom of their cylinders, and the reversing plate *69* strikes against the button *u* on the reversing rod *71* and pulls the reversing valve *72* down into the position shown in view (*c*). As soon as steam is admitted to the pump, it enters chamber *A* in the main-valve bushing, and, owing to the area of piston *77* being greater than that of *79*, forces the main valve to the right, as shown in view (*a*), passes down through port *b* and passage *b′ b″*, views (*a*) and (*d*), and enters the cylinder below piston *65* through the ports *b‴*, forcing the piston upwards. Any steam that may be above the piston *65* will exhaust through the passage *c′*, port *c*, the cavity in the slide valve, port *d*, passage *d′ d″*, and out at *Y*. As the steam piston *65* nears the end of its upward stroke, the top of the reversing plate *69* strikes the shoulder *j* on the reversing rod *71*, and forces reversing valve *72* upwards until it opens port *g*, view (*f*), and the part *k* of the valve separates ports *h* and *f*. This permits steam to enter chamber *B* and balance the pressure on piston *77* of the main valve, and the pressure on piston *79* then forces the main valve, and with it the slide valve *83*, to the left until the cavity of the slide valve *83* connects port *b* with exhaust port *d*, view (*b*). When the slide valve is in this position, the steam port *c* is uncovered and steam from chamber *A* flows down through the passage *c c′* into the steam cylinder, above the steam piston, forcing the piston downwards. The steam below the piston then flows through the ports *b‴*, up through passage *b″ b′* and port *b*, views (*a*) and (*d*), through the cavity in the slide valve, down through port *d* and passage *d′ d″*, and out of the exhaust at *Y*. As the piston nears the end of its downward stroke, the bottom of the reversing plate *69* strikes the button *u* on the reversing rod *71* and pulls the rod and reversing valve downwards to the position shown in view (*c*). This movement of the valve exhausts the steam from chamber *B* and allows the piston valve *76* to move the slide valve to the right into the position shown, thus permitting steam to pass underneath piston *65* and force it upwards. What occurs during the upward stroke has been explained.

THE AIR CYLINDER

44. Description.—A side view of the air cylinder *63* is shown in Fig. 7, view (*c*); a rear view will be seen in (*d*); while views (*a*) and (*b*) show the cylinder with the front half removed and a portion of the rear half broken away, so as to show the discharge air valves and passages. The piston *66* is broken away at *a b* so that port *p*—where passage *p'* enters the air cylinder—may be seen. The receiving air valves are contained within the valve cases *C* and *D*. The lift of both the receiving and discharge valves of this pump should be $\frac{3}{32}$ inch. Air enters the upper end of the cylinder through ports *m*, and the lower end through ports *n*. The air leaves the upper end of the cylinder through ports *r*, and the lower end through ports *p*, passing in each case into chamber *G*, and thence out through *Z* to the main reservoir. An oil cup *98* is provided, through which oil may be supplied to the air cylinder. Oil may be poured through this cup while the pump is standing still, or it may be filled and the cock opened when the air piston is on its downward stroke; the partial vacuum in the upper end of the air cylinder will then cause the oil to be forced into the cylinder by the atmospheric pressure.

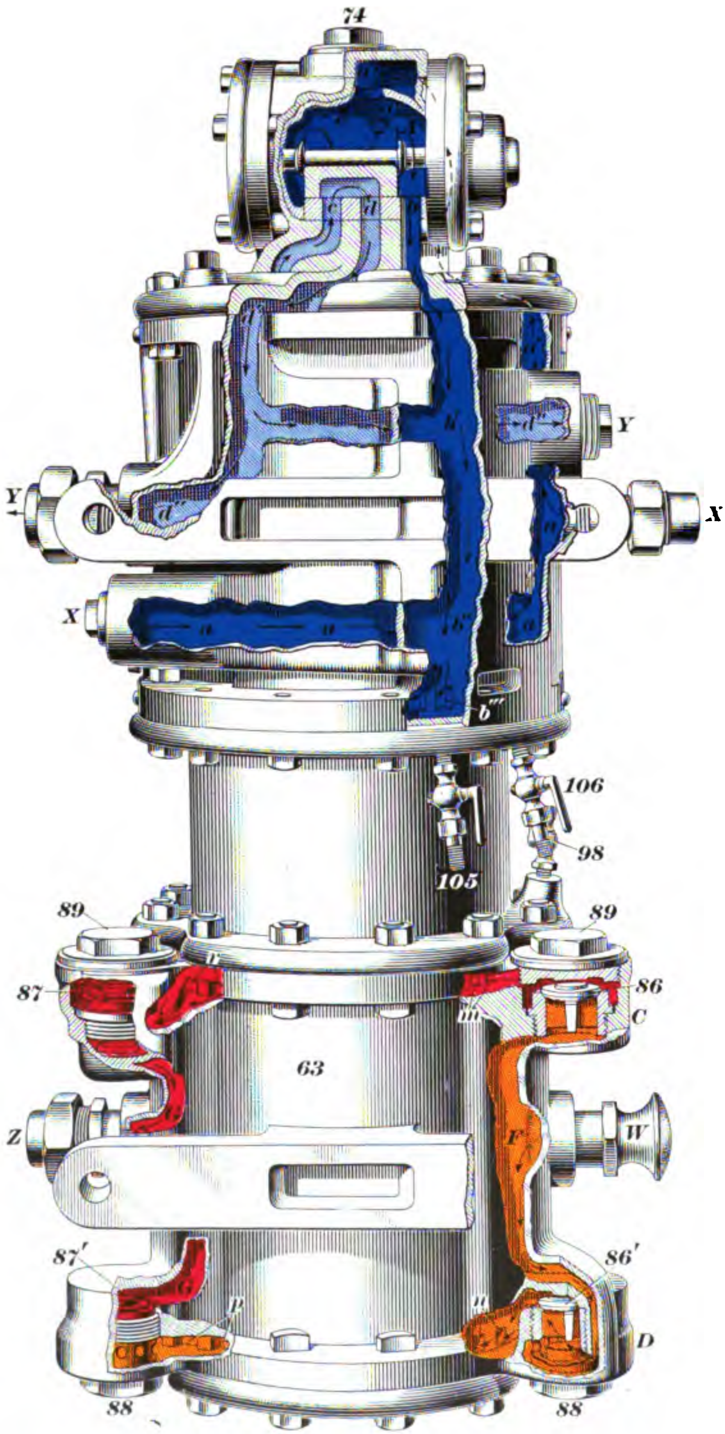
45. To remove the top steam-cylinder head *60*, it is necessary to raise the steam piston *65* in its cylinder until the reversing rod *71* can be disengaged from the piston and reversing plate. In order that the pistons may be easily raised, the plug *112* in air-cylinder head is provided. A bar can be used through this opening, and the pistons raised very readily. This plug opening is useful in other ways also, as it enables the lower end of the air cylinder to be cleaned and the piston-rod nuts to be inspected. The pipe to the main reservoir is connected at *Z*, and main-reservoir pressure, therefore, is always acting to hold valves *87* and *87'* on their seats; to unseat them, the pressure below the valves must be greater than main-reservoir pressure.

46. Operation of Air Cylinder.—When the air piston *66* makes an upward stroke, it causes a partial vacuum to be formed below it, while the air above is compressed. Air then flows in through the screened inlet *W*, view (*d*), and passes downwards through the passage *F*, view (*d*), then through the receiving valve *86'* and ports *n*, as shown by the arrows, into the lower end of the air cylinder, filling it with air at atmospheric pressure. In the meantime, the air that is compressed above the piston holds receiving valve *86* on its seat, and passes out through ports *r* and the passage *r'* to the under side of discharge valve *87*, and, as soon as its pressure exceeds that in the main reservoir, raises valve *87* and flows through the passages *s* and *G* and out at *Z* to the main reservoir, as shown by the arrows. On the downward stroke of the air piston, a partial vacuum is formed above, and the air is compressed below it. Air then flows in through *W*, view (*d*), and passes up the passage *F*, through receiving valve *86* and ports *m*, and fills the upper part of the cylinder with air at atmospheric pressure.

As the air is compressed below the piston, it holds receiving valve *86'* on its seat, and passes out through ports *p* and passage *p'* to the under side of discharge valve *87'*, and, as soon as it exerts a pressure slightly greater than main-reservoir pressure, opens valve *87'* and passes up through passage *G* and out at *Z* to the main reservoir.

THE 11-INCH AIR PUMP

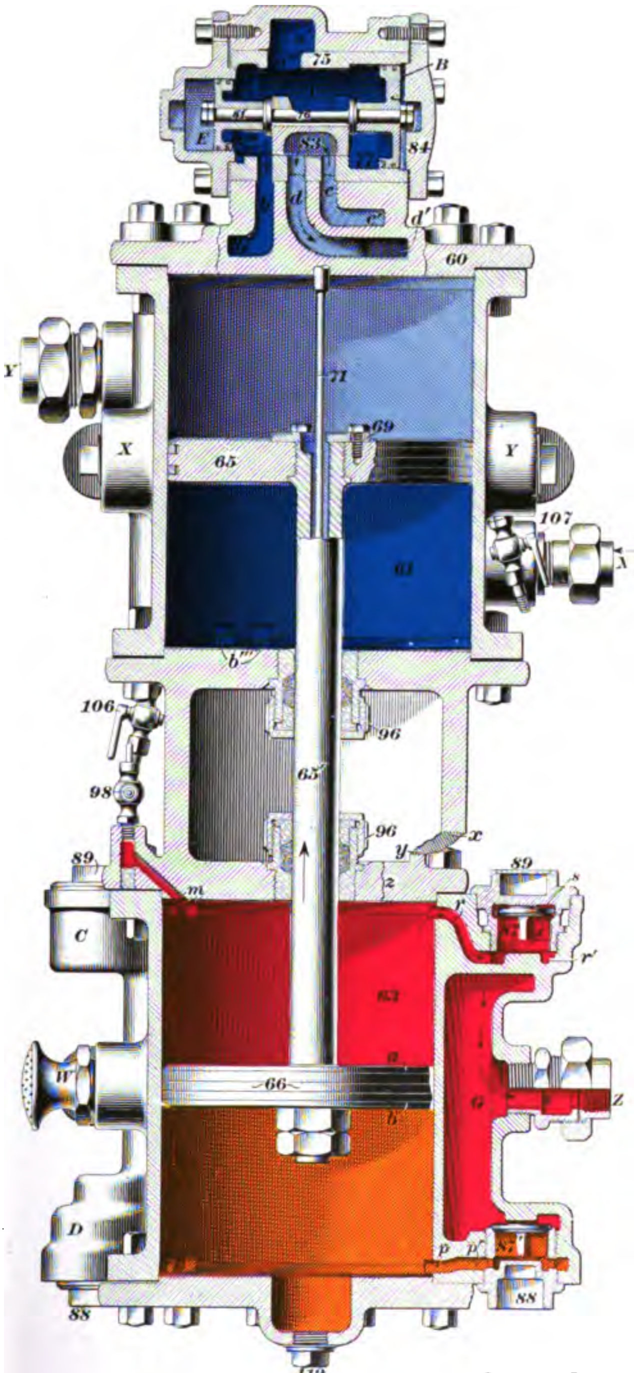
47. At the time of the introduction of the 9½-inch air pump it was supposed that this pump would supply all the air needed, but as a larger pump is a ready means for furnishing more air to supply leaks, etc., there was a demand for a pump of still greater capacity. To meet this demand the **11-inch air pump** was designed.


74
Y
X
Y
X
b'''
106
98
105
89
89
87
86
C
63
Z
W
F
87'
86'
D
88
88


83
c
d'
105
106
89
C
D

(c)


74
x
73
72
60
71
69
X
61
96
63
112
(b)


75
B
E
83
84
d
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c'
d'
60
Y
71
69
X
65
Y
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107
106
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65'
98
96
x
y
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89
r
r'
C
62
W
66
G
Z
D
p
88
112
a

It will be noted, in Fig. 8, that the air cylinder and arrangement of the valves are exactly like that of the 9½-inch pump, with the exception of their size. The 9½-inch pump has a cylinder of 9½-inch bore and 10-inch stroke, while the 11-inch pump has cylinders of 11-inch bore and 12-inch stroke. All the ports, passages, and valves of this pump are made sufficiently larger than those of the 9½-inch pump to do the work properly for the larger capacity. The reversing slide valve *72* has a flat seat instead of a curved one, in order to facilitate repairs.

There are some radical differences in the position and arrangement of the steam passage in the walls of the steam cylinder and in the top head, so that the steam enters the valve bushing in front of the main steam chest instead of at the back. This allows of a better design and arrangement of the bolts that hold the top head on the steam cylinder; instead of tap bolts holding the heads and centerpiece to the cylinders, T head-bolts are used, with nuts on the outside similar to those that hold the heads on the brake cylinders. At the back of the steam cylinders, where the pump brackets come, there are five tap bolts.

Referring to Fig. 8 (*a*), (*b*), and (*c*), view (*a*) is a cross-section, showing the front half of the pump removed; an additional portion of the centerpiece and air cylinder *x y z* is also shown broken away, so that a view of the discharge air valves, valve cases, and air passages may be presented (*b*) is a side view, showing a section through the valve gear in the upper steam-cylinder head; a portion of the steam cylinder, also, is shown broken away. (*c*) is a back view, in which portions of the steam and air passages and of the air-valve cases are broken away to give a clearer idea of the location of the valves, ports, and passages. The steam-supply pipe is connected to the pump at *X*; as this pump has right- and left-hand connections, the steam and exhaust passages are double; view (*c*) shows these passages. Steam enters the pump at the right-hand connection *X*, if the pump is located on the engineer's side of the engine, or at the left-hand connection *X*, if on the fireman's side, passes up through *a*, *a'* across the top of the steam-cylinder head, up beside the reversing-valve bushing and in front of main-valve bushing, entering through the port *a''* between the two pistons *77* and *79* and around the main slide valve *83*. Steam also passes through port *e* and *e'* into the reversing-valve bushing *73* as in the 9½-inch pump.

The operation of the 11-inch pump, both steam and air ends, is precisely like that of the 9½-inch pump. There are four drain cocks in the steam and exhaust passages in the walls of the cylinder, in order to drain all the water out of the pockets formed by the passages that are not used.

As to the relative capacities of the 9½- and 11-inch pumps, the 9½-inch pump will compress 36 cubic feet of free air at 100 strokes per minute. The 11-inch pump will compress 48 cubic feet of free air with the same number of strokes, so the 11-inch pump running at the same speed has one-third greater capacity.

NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 2, which was its former title.

TRIPLE VALVES AND BRAKE VALVES

WESTINGHOUSE AUTOMATIC AIR BRAKE
(Continued)

THE PLAIN TRIPLE VALVE

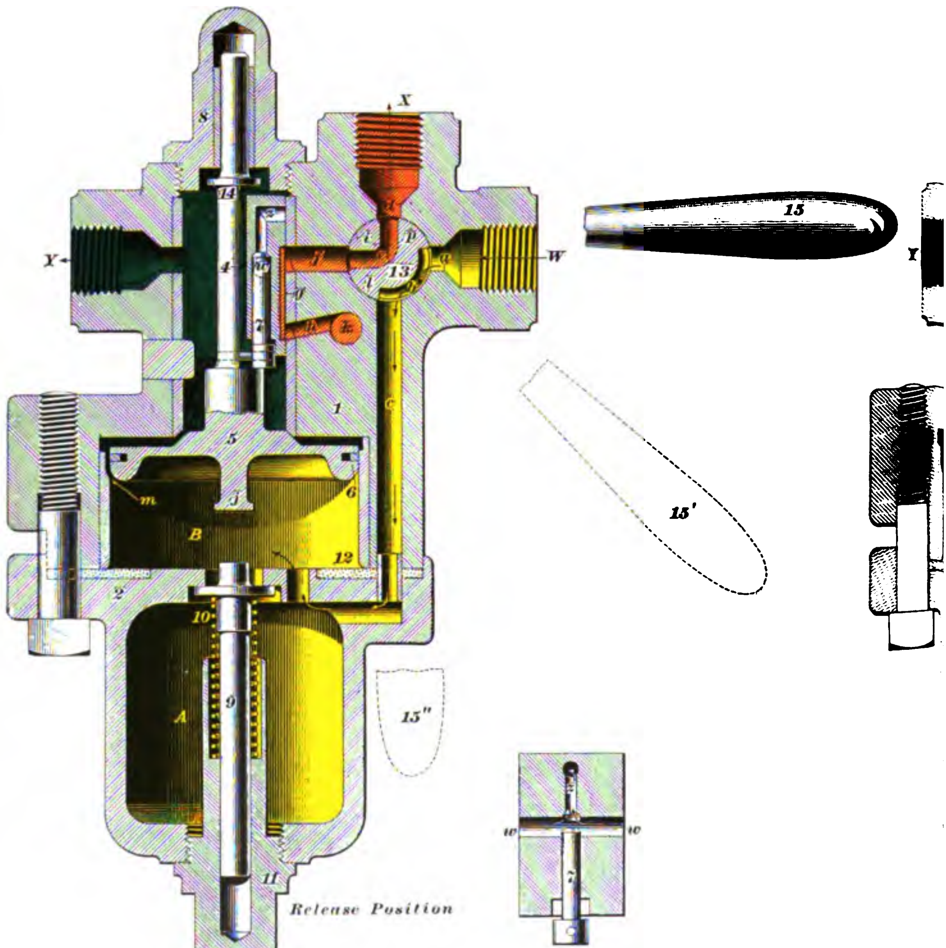
GENERAL REMARKS

1. As mentioned in the *Westinghouse Air Brake*, Part 1, the straight-air brake was in due time supplanted by the automatic brake. The essential part of the new style of brake was the triple valve, now known as the **plain triple valve,** to distinguish it from a later form known as the quick-action triple valve. The plain triple is still in use on engines and tenders, and also on some of the very early car equipments. It is practically the same as the service part of the present quick-action triple, that is, the part of the latter that is used in making a service application of the brakes. These two kinds of triples are somewhat differently constructed, but the results, actions, and parts employed in making a service application of the brakes are practically identical in each case. When the plain automatic triple was introduced, it was necessary to so construct a triple valve that, if put in a train with a number of straight-air cars, the automatic feature of the triple could be cut out, and the brakes on that car used "straight air," as on the other cars.

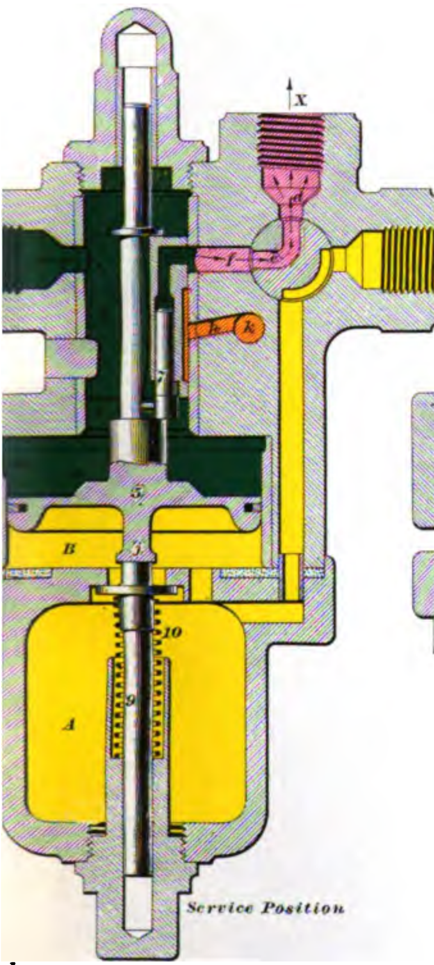
DESCRIPTION

2. In Fig. 1 are shown cross-sectional views of the old-style plain triple valve. The plug valve *13*, which effects the required changes, is actuated by the handle *15*. This handle may be placed in any of the positions *15*, *15'*, or *15''*. In position *15*, the triple can be used with the automatic brake. In position *15'*, the portions *p*, *l*, and *i* of the plug cover the ports *a*, *f*, and *d*, and the brake is cut out entirely on that car. In position *15''*, the passage *e* in valve *13* connects port *a* with port *d*, thus enabling the triple to be used in the straight-air system. A lug, not shown in the figure, was later cast on the handle *15*, to prevent the handle from being turned to position *15''*. In modern types, Fig. 2 (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*), the plug cock *13* is omitted, being replaced by a cut-out cock in the branch pipe.

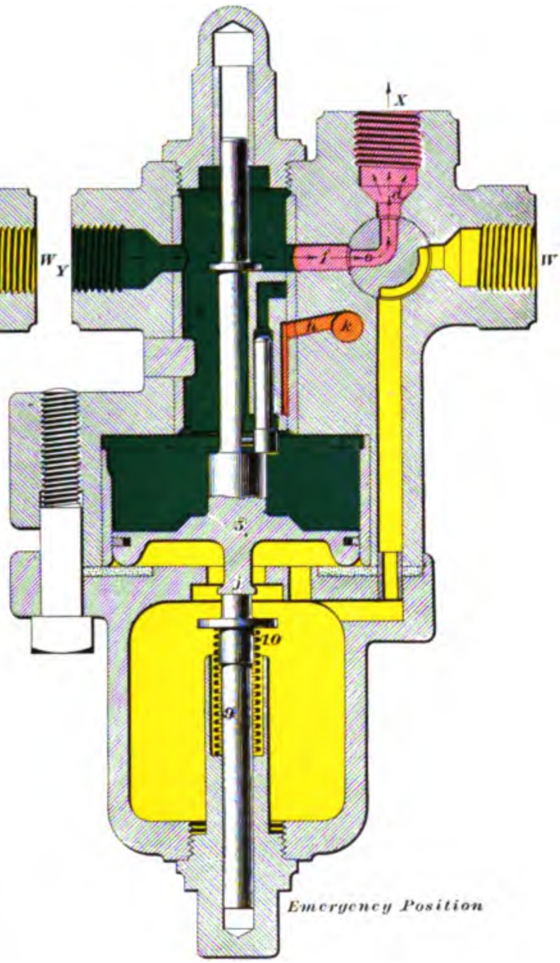
3. The other parts of the triple valve are: *1*, the triple body; *2*, the drain cup; *3*, the triple slide valve; *4*, the slide-valve spring; *5*, the triple piston; *6*, the triple piston packing ring; *7*, the graduating valve; *8*, the upper cap nut; *9*, the graduating stem, *10*, the graduating spring; *11*, the graduating-stem nut; *12*, the cylinder-cap gasket. The space *C* is called the slide-valve chamber; *g* the exhaust cavity in the face of the slide valve *3*; *k* the triple exhaust port; *m* is a small feed groove in the piston bushing; and *n* is a groove in the shoulder of the triple piston itself. These grooves *m* and *n* allow air from the train pipe to feed into the auxiliary reservoir when the triple piston is in release position. The piston *5* is acted on by pressure on both sides, moving away from the greater pressure when the two pressures are unequal, or remaining stationary when these pressures are equal. The branch pipe from the train pipe connects with the triple at *W*; the pipe leading from the brake cylinder connects at *X*, while the connection to the auxiliary reservoir is made at *Y*. In the tender equipment, Fig. 1, *Westinghouse Air Brake*, Part 1, is shown a plain triple valve connected to the auxiliary reservoir, brake



(a) (b)



(c)



(d)

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cylinder, and train pipe. Chamber *C*, Fig. 2, is always charged with auxiliary pressure, and chamber *B* with train-pipe pressure, the piston *5* marking the line of separation between the two. The piston *5* may be moved up or down by increasing or decreasing the pressure in chamber *B* above or below that in chamber *C*. The packing ring *6* is made a good fit in the bushing, so that when the piston has moved down far enough to cover the groove *m*, air cannot readily pass by it in either direction.

In release position, view (*a*), the shoulder of piston *5* makes an air-tight joint with the valve bushing at *s* except at the groove *n*; hence, all air must pass through groove *n* to enter the auxiliary. Groove *n*, therefore, regulates the rate of charging and prevents leakage past the packing ring increasing the rate.

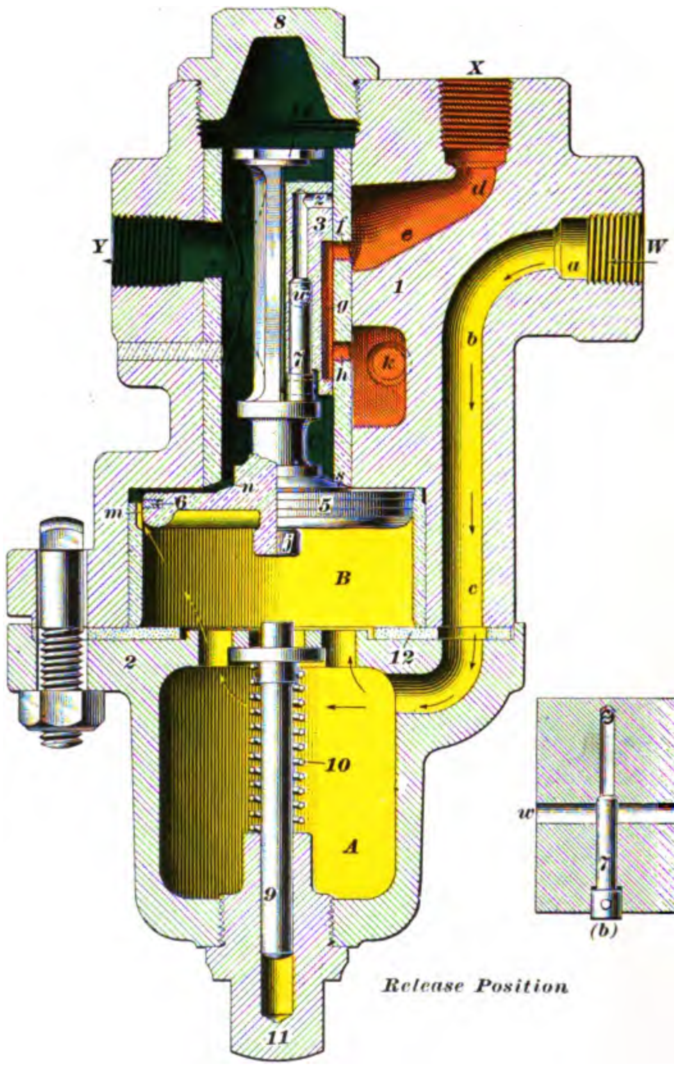
ACTION OF PARTS

4. The automatic portion of the mechanism consists of the slide valve *3*, graduating valve 7, piston *5*, and graduating stem *9*. A sectional view of the slide valve *3*, showing the graduating valve and ports, is given in views (*b*) and (*d*). The port *w* passes through the slide valve from one side to the other. When the graduating valve 7 is off its seat, auxiliary air can flow through port *w* past the valve and out at *z*, but when the valve is on its seat, no air can escape through port *z*. Besides ports *w* and *z*, there is an exhaust cavity *g* in the face of the valve, as in view (*a*). The slide valve is surrounded by air at auxiliary pressure, which holds the valve to its seat. The spring *4* holds the valve to its seat when there is no auxiliary pressure to perform this duty, thus preventing dirt from collecting on the valve seat and affecting the working of the triple.

The piston *5* controls the movements of the slide valve and the graduating valve, and acts as a valve to open and close the feed port *m*. The slide valve fits loosely between shoulders on the piston stem, and, when the piston moves far enough, it carries the slide valve with it. The duty of the slide valve is to control the flow of air between the auxiliary and the brake cylinder, and between the brake cylinder and the atmosphere. The graduating valve *7* is connected to the stem of piston *5* by means of a small pin, the place where it enters the valve and stem being shown; thus, the graduating valve is fixed with respect to the piston *5* and moves along with it. The duty of the graduating valve is to graduate the air admitted into the brake cylinder during a service application of the brakes. The length of the slide valve *3* is purposely made less than the distance between the shoulders on the piston stem, so that the piston in moving downwards will open, or, in moving upwards will close, the graduating valve *7*, before it moves the slide valve *3*. When the slide valve is in service position, the piston *5* can move up and down far enough (about $\frac{5}{32}$ inch) to operate the graduating valve without disturbing the slide valve. Hence, the piston may move a limited distance without moving the slide valve; whereas, the graduating valve, being secured to the piston stem by the small pin referred to, must move with the piston.

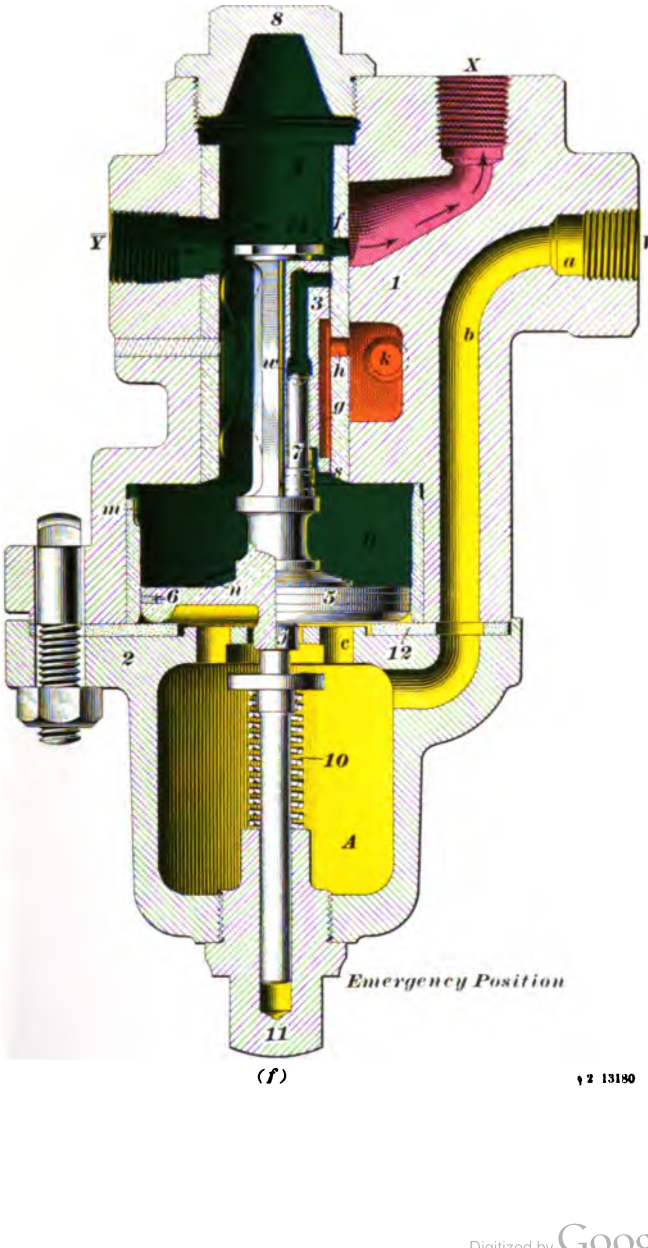
5. The graduating stem *9* is held in position by the graduating spring *10*. When a gradual, or service, reduction of train-pipe pressure is made, the pressure in chamber *B* is reduced below that in chamber *C*, and auxiliary pressure then moves piston *5* down until its knob *j* touches the graduating stem *9*, when the spring *10* prevents its moving farther. When a sudden and heavy reduction of train-pipe pressure is made, as in emergencies, a sufficient difference of pressures is established in *B* and *C* to cause piston *5* to move down quickly and compress spring *10*, the piston traveling the whole length of chamber *B* until it bottoms on the lower end. The duty of the graduating stem and spring is to prevent the triple piston moving past service position during a service application on a short train. It also aids in starting the piston from emergency position.

The graduating nut can be removed when it is desired to drain the triple or to examine the graduating stem and spring. *w* and *z* form one continuous port through the slide valve *3*, as



Release Position

(a)



Emergency Position

(f)

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explained in connection with view (*b*); this port is opened and closed by the graduating valve 7, and is called the service, or graduating, port. When the triple is in service position, air from the reservoir flows through the slide valve by means of this port, thence through ports *f* and *d* into the cylinder.

DUTIES OF THE TRIPLE VALVE

6. The triple valve has three duties to perform: to charge the auxiliary; to apply the brakes; and to release the brakes.

When an engine is coupled to a car, air from the main reservoir flows into the train pipe, thence through the branch pipe, entering the triple at *W*. When the triple is "cut in," the air can flow in at *W*, and on through ports *a*, *b*, *c* into chamber *A*, whence it passes into chamber *B*. If piston *5* were down, the air entering chamber *B* would force it up into release position, view (*a*). This movement of the piston opens the feed groove *m*, and air therefore feeds from chamber *B* past piston *5*, through the grooves *m* and *n* into the slide-valve chamber *C*, which communicates through *Y* with the auxiliary reservoir. The air continues to feed past piston *5* as long as train-pipe pressure in chamber *B* is greater than the auxiliary pressure in chamber *C*. The usual train-pipe pressure is 70 pounds, and, when the auxiliary pressure has reached this amount, the pressures in chambers *B* and *C* are equal, and the auxiliary is said to be fully charged. The lower side of piston *5* is generally referred to as the "train-pipe side" and the upper as the "auxiliary side," or the "slide-valve side."

7. Charging Auxiliary Reservoir.—A modern triple valve should charge an auxiliary from zero up to 70 pounds in about 70 seconds, with a constant train-pipe pressure of 70 pounds. With the triple in release position and the auxiliary charged, there will be 70 pounds in the train pipe, 70 in the auxiliary, and atmospheric pressure in the brake cylinder, since the slide-valve cavity *g* connects the brake cylinder with the atmosphere, the communication being through the ports and passages *d*, *e*, *f*, *g*, *h*, and *k*.

8. Applying Brakes.—To apply brakes, it is necessary that the train-pipe pressure be reduced below auxiliary pressure. This may be made: in the usual way by the engineer, by the use of the conductor's valve, or by a break-in-two, a burst hose, or a heavy leak in the train pipe.

If the engineer makes a reduction of 7 pounds in the train pipe, only 63 pounds will remain in chamber *B*, whereas at the beginning of the reduction, there will be 70 pounds in chamber *C*, or the auxiliary side of piston *5*. The greater auxiliary pressure will force piston *5* downwards. While being forced down, this piston closes the feed groove *m* and unseats the graduating valve 7, allowing auxiliary air to enter the slide valve at *w* and pass through to the end of port *z*. The air, however, cannot pass out of port *z* until the slide valve is moved to service position. By the time the graduating valve is unseated and the feed groove *m* closed, the shoulder *14* on the upper end of the piston stem has engaged the slide valve and begun to move it down. As the slide valve moves down, the exhaust cavity *g* is first closed to the ports *f*, *e*, and *d*, preventing the escape of brake-cylinder air. When the knob *j* touches the graduating stem *9*, the piston *5* is prevented from making any further downward movement. With the triple piston in this position, the service port *z* of the slide valve is directly in front of port *f*. This position of the valve, view (*c*), is called the service position. The graduating valve being off its seat, there is now an open communication between the auxiliary and the brake cylinder, and air flows from the auxiliary through the ports *w* and *z* in the slide valve; thence through the ports *f*, *e*, *d*, and out at *X* into the brake cylinder, where the pressure will force out the brake piston and set the brakes. Just so long as the auxiliary pressure is greater than that in the train pipe, so long will piston *5* be held down and the graduating valve remain unseated; but the auxiliary pressure gradually expands into the brake cylinder, until the pressure in chamber *B* is sufficiently greater than that in chamber *C* to overcome the small friction of the packing ring *6* and cause piston *5* to move upwards and seat the graduating valve, thereby closing port *w*. The pressure on the train-pipe side of the piston *5* still slightly exceeds that in the auxiliary, but not to such an extent as to overcome the additional friction encountered in moving the slide valve *3*; the piston therefore stops as soon as the graduating valve has been seated. This is called the lap position of the triple valve, view (*e*); in this position all ports are blanked. The brakes are now partially set; a further train-pipe reduction will be necessary to apply them harder.

If another 5-pound train-pipe reduction is made, the greater auxiliary pressure again forces down the piston, but in this case the slide valve was already in service position, and it is only necessary to move the piston sufficiently to unseat the graduating valve. This is accomplished by the time the knob *j* touches the graduating stem *9*; and once more, by means of the service port of the slide valve, communication is established between the auxiliary and the brake cylinder. The graduating valve is again seated automatically by the piston *5* when the auxiliary pressure becomes a little less than that in the train pipe.

After the slide valve has once been moved down, it remains in service position until the brakes are released. Each reduction of train-pipe pressure causes the brake to set harder, and these reductions may be continued just as long as the pressure in the auxiliary is greater than that in the brake cylinder. When these pressures become equalized, the brake is fully set, and a further train-pipe reduction will be a waste of train-pipe air. Ordinarily, a train-pipe reduction of about 20 pounds will cause a full application of the brakes.

9. Releasing Brakes.—To release brakes, the train-pipe pressure must be increased above auxiliary pressure, or auxiliary pressure reduced below train-pipe pressure. The usual method is for the engineer to allow the air stored in the main reservoir to feed quickly into the train pipe. When the pressure on the train-pipe side of piston *5* is sufficient to overcome auxiliary pressure and the friction of the working parts, the piston is forced upwards to release position, carrying the graduating and slide valves with it. In this position, view (*a*), the feed groove *m* is opened, and air from the train pipe feeds through *m* and *n* to recharge the auxiliary. At the same time, the pressure in the brake cylinder escapes through *X* and ports *d*, *e*, *f*, *g*, *h*, and *k* into the atmosphere.

10. Emergency Application.—To apply brakes in an emergency, it is necessary to make a sudden and heavy train-pipe reduction. This sudden reduction causes piston *5* to move down very quickly and, compressing the graduating spring *10*, to traverse the full length of chamber *B*. In this position, a direct connection is established between the auxiliary and brake cylinder across the upper end of the slide valve *3*, as shown in view (*f*). Auxiliary air passes direct into ports *f*, *e*, *d* and out into the brake cylinder at *X*, without having first to pass through the service ports of the slide valve. As only the large ports are used in emergency position, they allow the pressure in the auxiliary and brake cylinder to equalize more quickly than do the smaller ports used in the service position. With a plain triple, the brake sets more quickly in emergency than in service, but not with greater force.

To get the full emergency action of the brakes with plain triple valves, it is necessary to make a sudden reduction of about 20 pounds in train-pipe pressure. After an emergency application, the release of the brakes is accomplished in the same way as after a service application.

THE QUICK-ACTION TRIPLE VALVE

GENERAL REMARKS

11. Besides the plain triple, there is another, the *quick-action triple valve*, thus making two kinds of triple in use. The **quick-action triple valve** is automatic in its action and can be used on a train of which some of the cars are fitted with the plain triple, but it cannot be worked "straight

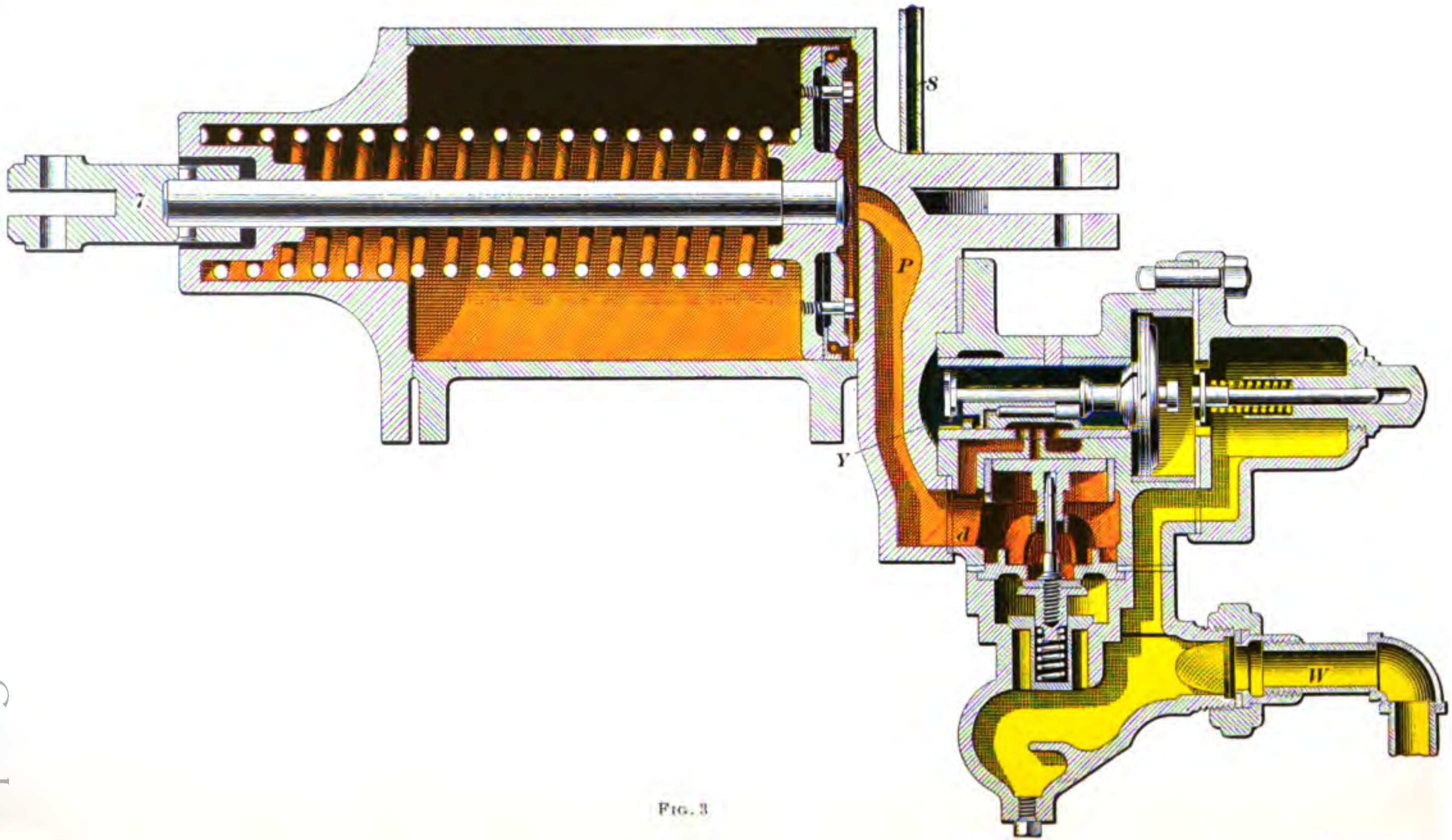


Fig. 3

air," as can the old-style plain triple, for when the triple valve is cut out the communication from the train pipe to the brake cylinder is also cut off.

In *Westinghouse Air Brake*, Part 1, is shown the arrangement (on a passenger car) of the quick-action triple, auxiliary reservoir, brake cylinder, and connections. A **T** drain cup is inserted in the train pipe; a branch pipe extending from this **T** piece connects with the triple, as shown.

In this branch pipe is a stop-cock *6*, by means of which the brake on that particular car can be cut out or in, as desired, without interfering with the brakes on the rest of the train. When the handle of this cock stands at right angles, or crosswise, to the branch pipe, the brake on that car is cut in; that is, it can be operated from the engine in the ordinary manner. When the handle is turned so as to be parallel to, or in line with, the pipe, the brake on that car is cut out, or is inoperative.

Fig. 3 shows the triple connected to the brake cylinder, this illustration being on a larger scale than in *Westinghouse Air Brake*, Part 1. The branch pipe from the **T** piece connects with the triple at *W*. The opening *d* of the triple valve communicates with the passage *P* in the cylinder head, through which passage air is conducted to and from the brake cylinder. The opening *Y* connects with a pipe *8* leading to the auxiliary reservoir, through which pipe the air is conducted between the auxiliary and the triple.

DESCRIPTION

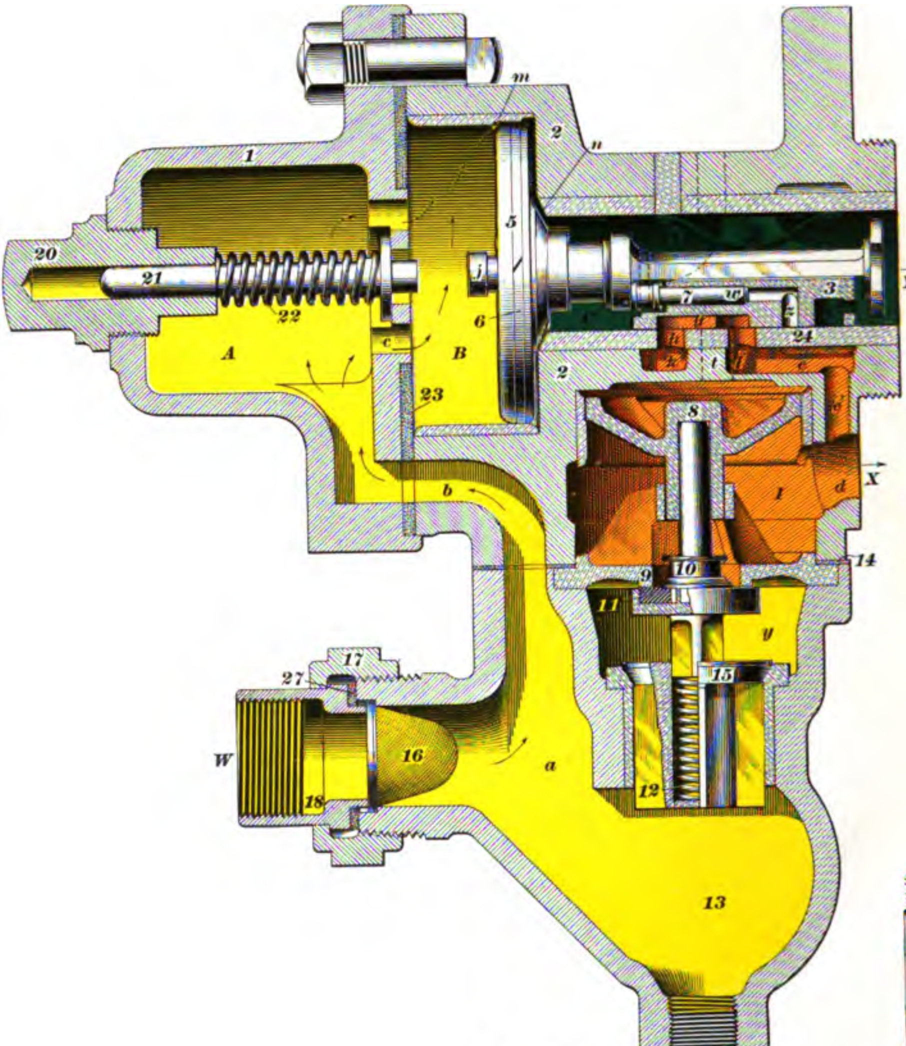
12. The parts of a quick-action freight triple as numbered and lettered in Fig. 4 (*a*) are: *1*, the cylinder cap; *2*, the triple body; *3*, the slide valve; *4*, the slide-valve spring; *5*, the triple piston, and *6*, its packing ring; *7*, the graduating valve; *8*, the emergency-valve piston; *9*, the emergency-valve seat; *10*, the emergency valve, also commonly known as the rubber-seated valve; *11*, the rubber seating; *12*, the check-valve spring; *13*, the check-valve case; *14*, the check-valve case gasket; *15*, the check-valve; *16*, the train-pipe strainer; *17–18–27*, a union joint; *20*, the graduating-stem nut; *21*, the graduating stem; *22*, the graduating spring; *23*, a leather gasket, and *24*, the slide-valve bushing. The branch pipe from the train pipe connects at *W*, the pipe to the cylinder at *X*, and the auxiliary connection at *Y*. *m* and *n* are the feed grooves; *t*, a port, shown in view (*f*), through which auxiliary air passes to the space above piston *8* to operate valve *10*.

The F-27 passenger triple has a packing ring in the emergency piston *8* to limit leakage past the piston to a desired amount. A small hole is drilled through the web of the piston *8* so that in the event of air leaking by the slide valve into the chamber above piston *8* it can escape without operating the piston and setting the triple in emergency.

13. The quick-action triple contains two distinct sets of mechanism. One of these, consisting of the triple piston *5* with stem, slide valve *3*, and graduating valve *7* with stem *21* and spring *22*, is used in making service stops and in releasing brakes; it is often called the service part of the triple. The other set, consisting of the emergency piston *8*, emergency valve *10*, and train-pipe check-valve *15*, is only brought into use in an emergency application of the brakes; it is hence often called the emergency or quick-action part of the triple.

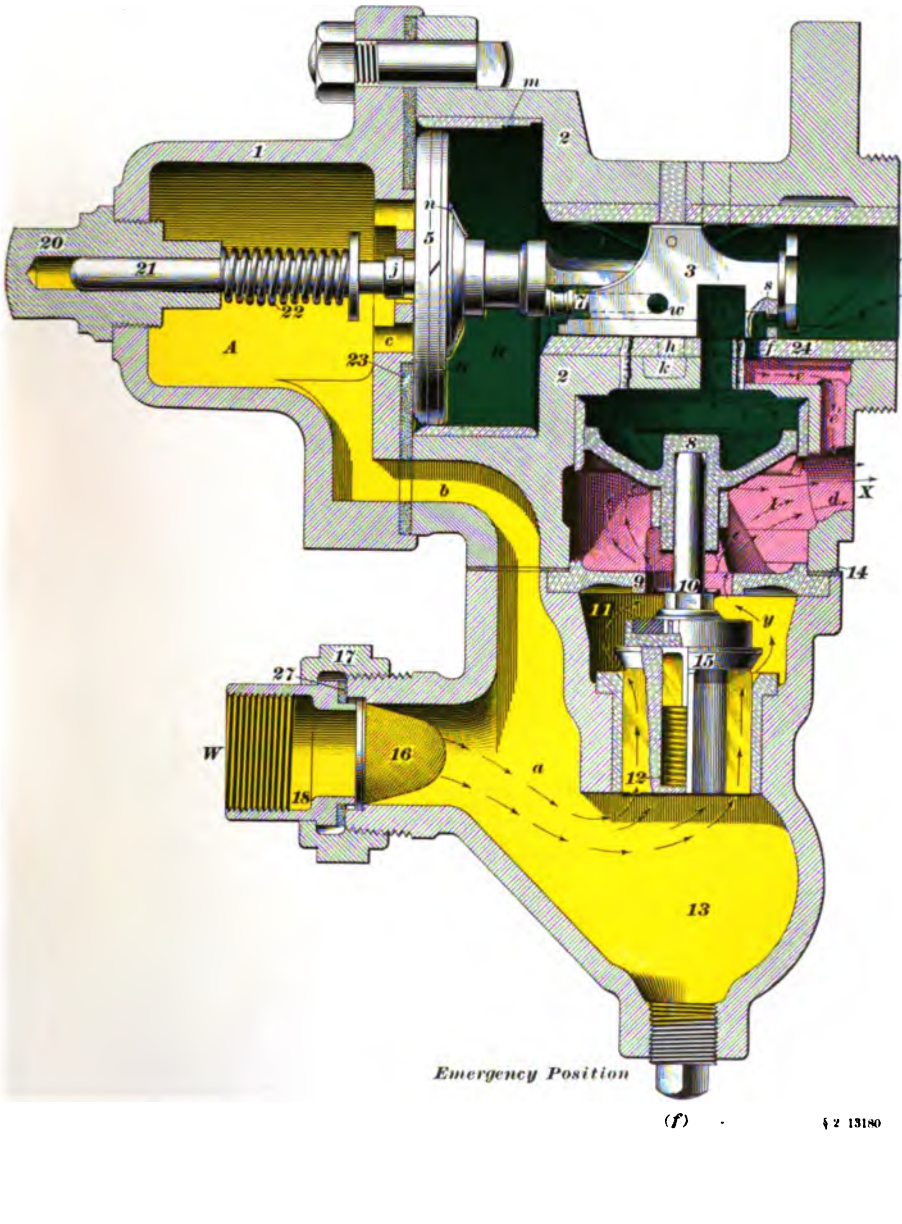
SERVICE PART OF TRIPLE

14. Description.—The description and mode of action of the service part of the plain triple applies also to that of the quick-action triple, except in so far as the slide valves *3* differ somewhat in detail. As in the case of the plain triple, the stem of piston *5* engages with slide valve *3*, and also operates the graduating valve *7*. The service ports *w* and *z* in the valve *3* are the same as in the plain triple, but this valve contains, in addition, an emergency port *s* that extends from the face of the valve to the end, as shown in section in view (*a*), also, the valve is longer, and one of its edges, or corners, is cut away, as shown at *q*, view (*b*). This latter view represents the valve as transparent, so as to show the ports better, and it is turned upwards so as



Release Position

(a)



Emergency Position

(f)

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to show the exhaust cavity *g* in its face; *w* and *z* are the service ports controlled by the graduating valve *7*; *s* is the emergency port, the small end of which is smaller than port *z*; *q* is referred to either as the removed corner or the diagonal slot of the valve. Cavity *g* and ports *w*, *z*, and *s* are shown also in view (*a*). The port *f*, with passages *e*, *e'*, and *d*, leads to the brake cylinder; port *t* extends from the face of the valve seat into the chamber above emergency piston *8*; and exhaust ports *h* and *k* lead to the atmosphere. The ports *f*, *t*, *h*, and *k* are also shown in view (*c*), which is a view of the valve seat *24*.

When the slide valve is in emergency position, the removed corner *q* allows auxiliary air to pass down through port *t* and force piston *8* downwards. This unseats emergency valve *10*, and opens communication between chamber *y* and the brake cylinder; the check-valve *15* is then raised by train-pipe pressure and allows train-pipe air to pass to the brake cylinder.

15. Rubber-Seated Valve.—The duty of the emergency, or rubber-seated, valve *10* is to prevent the train-pipe air from passing into the brake cylinder through chamber *I* and port *d*, except when required to do so in emergency applications. Were it not for this valve, the brakes would apply as soon as air was turned into the train pipe, and, the triple exhaust port *k* being open, there would be a constant blow through to the atmosphere.

16. Train-Pipe Check.—The train-pipe check-valve *15* prevents the brake-cylinder pressure from flowing back into the train pipe, in the event of a hose bursting or the train pipe breaking, or at any time when the train-pipe pressure is less than the brake-cylinder pressure. If a hose were to burst, all the air would leave the train pipe, and the brakes on the entire train would set in full. If the train-pipe check *15* were not in the triple, there would be nothing to prevent air passing from the cylinder to the train pipe and out to the atmosphere, in case the train parted or a hose burst; this would release that brake.

Spring *12* holds valve *10* to its seat when there is no air pressure present to perform this duty, and also when the pressures above and below piston *8* become equalized after an emergency application of the brake. It performs the same duty for train-pipe check *15*.

17. Train-pipe air entering the triple at *W* flows through the passage *a b* and port *c*, and on through the feed grooves *m* and *n* into chamber *C*, thence through *Y* into the auxiliary. If, when air enters the triple, there is no pressure on top of the train-pipe check *15*, the air underneath will raise it from its seat against the force of the spring *12* and fill chamber *y*, forcing the rubber-seated valve *10* more firmly on its seat. When the pressure in chamber *y* and the force exerted by the spring *12* are together slightly greater than the train-pipe pressure underneath the check-valve *15*, this valve is forced to its seat and thenceforth plays no further part unless an emergency application is made.

18. Release Position.—The slide valve of the quick-action triple is shown in release position in Fig. 4 (*a*). In this position, any air that may be in the brake cylinder can pass through passages *d* and *e' e*, port *f*, cavity *g* of the slide valve, and the port *h*, out through exhaust port *k* to the atmosphere. Port *k* is also shown in view (*c*), as is also the port *f* leading through the passage *e e'* to the brake cylinder and port *t* leading to the top of the emergency piston *8*.

19. Service Position.—The operation of this triple in service application is the same as that of the plain triple. When a service application of the brakes is made, the triple piston *5* moves out until the knob *j* touches the graduating stem *21*, Fig. 4 (*d*), after which any further movement is prevented. The exhaust port closes first, and the service port *w* and port *z* of the slide valve connect with the brake cylinder by way of port *f* and passages *e e'* and *d*. As the graduating valve *7* opens before the slide valve moves forwards, air passes from the auxiliary reservoir through ports *w*, *z*, *f* and passages *e e'*, *d* to the brake cylinder until auxiliary pressure is reduced just a trifle below train-pipe pressure, when the triple piston moves to lap position, view (*e*), and the graduating valve 7 is closed. During succeeding reductions, the graduating valve simply opens and closes without moving the slide valve, as in the plain triple.

EMERGENCY PART OF TRIPLE

20. When, in cases of danger, etc., a sudden reduction of train-pipe pressure is made, what is termed the emergency part of the triple valve is called into play; the triple piston *5* moves out quickly, the graduating spring *22* is compressed, and the triple piston travels the full length of chamber *B*. The emergency position of the triple is shown in Fig. 4 (*f*). In this position, port *s* in the slide valve connects with port *f* in its seat, and auxiliary pressure can pass through the ports *s*, *f* and passages *e e'*, *d* out at *X* into the brake cylinder. The removed corner *q* of the slide valve, view (*b*), has reached a position directly above port *t*, view (*f*), thus allowing auxiliary air to pass down through port *t* on to the top of the emergency piston *8*, forcing it downwards. This downward movement unseats the emergency valve *10*, and allows the air in chamber *y* above the emergency check *15* to escape. Train-pipe pressure beneath this check-valve now forces the latter from its seat and air from the train pipe passes up by it, on through chamber *y* and the unseated emergency valve *10*, into chamber *I*, and out at *X* to the brake cylinder. The emergency valve remains unseated until the pressures above and below piston *8* are nearly equalized, when the spring *12* forces the emergency valve and check-valve to their seats.

The position of the removed corner *q* on the slide valve is such that, as the valve moves forwards to emergency position, it connects port *t* of the valve seat with auxiliary pressure before port *s* connects with port *f*. The emergency valves therefore open before port *s*, and consequently train-pipe air—which passes like a flash through the large openings of the emergency valves—is admitted in sufficient quantity to give a pressure in an 8-inch brake cylinder of about

$24\frac{1}{2}$ pounds, when check-valve *15* closes. As soon as port *s* connects with port *f*, auxiliary pressure discharges into, and equalizes with, the brake cylinder; but, since the cylinder already contains about $24\frac{1}{2}$ pounds pressure, they equalize at about 60 pounds pressure instead of at 50 pounds, as in a service application.

The opening through the emergency port *s* of the slide valve is made smaller than the service port *z*, to retard the flow of air somewhat from the auxiliary reservoir to the brake cylinder during an emergency application of the brakes, so as to allow as much air as possible to enter the brake cylinder from the train pipe, and thus increase the final brake-cylinder pressure.

21. Plain and Quick-Action Triples Compared. Plain and the quick-action triples work exactly the same in a service application, but in emergency the quick-action triple sets the brake quicker and gives a greater brake-cylinder pressure. Also, the quick-action triple sets its brake harder in emergency than it does in service application, owing to the emergency valve, piston, and check-valve operating so as to allow train-pipe pressure to enter the brake cylinder and aid the auxiliary pressure in applying the brake.

The plain triple sets its brake quicker in emergency than it does in service, owing to the use of larger ports; but the brake does not set any harder, since it simply has auxiliary pressure to use in applying the brakes in either service or emergency.

When a quick-action triple goes into emergency position, a sudden train-pipe reduction is made near it when the emergency valve opens. This sudden reduction starts the next quick-action triple, and that starts the next, and so on throughout the train. If from any defect one triple goes into quick action, all will follow.

Ordinarily, a gradual train-pipe reduction of about 20 pounds will cause a plain or a quick-action triple valve to equalize the pressures between the auxiliary and brake cylinders at about 50 pounds. In emergency, with a quick-action triple, the pressures are equalized at about 60 pounds, while with a plain triple, the same pressure is obtained in the cylinder in emergency as in a full-service application, namely, 50 pounds. With quick-action triples, a sudden train-pipe reduction of 10 or 12 pounds will produce a full emergency action of the brakes; while, with a plain triple, a reduction of about 20 pounds is necessary. The reason for this is that a 12-pound reduction will cause the emergency valves of the first triples to open and produce a further train-pipe reduction. Train-pipe pressure is not affected in this way when a plain triple goes into emergency, and, therefore, while a sudden 12-pound reduction would force the triple to emergency position, it would not stay there, as it would be forced back to lap or perhaps to release, as soon as auxiliary pressure had reduced the 12 pounds. It is necessary, therefore, to reduce train-pipe pressure below that at which the auxiliary and brake cylinders equalize, to obtain a full emergency application with plain triples.

FREIGHT AND PASSENGER EQUIPMENTS

22. Equipments Compared.—An illustration of the freight-car equipment now used is given in Fig. 5. It consists of auxiliary reservoir *10*, brake cylinder *2*, and triple valve *18*. This equipment has to be made very compact on account of the limited space on freight cars; but, while it appears to be different from that used on passenger cars, it is exactly the same in principle and operation.

In the passenger-car equipment, Fig. 3, there is a pipe *8* leading from chamber *Y* of the triple valve to the auxiliary reservoir; in the freight-car equipment, Fig. 5, the air passing from the train pipe through the triple goes direct to the auxiliary.

In freight equipment, auxiliary tube *b* connects the triple valve *18* with the brake cylinder. In passenger equipment, the triple is fastened directly to the cylinder. When a freight brake is released, brake-cylinder air flows through tube *b* and out through the triple exhaust to the atmosphere. Freight triples have no packing ring in the emergency piston *8*.

In the passenger equipment, Fig. 3, the piston rod is fastened to the crosshead *7*, and the brake levers, also connected to the crosshead *7*, are controlled by the cylinder piston, the levers being moved every time the piston moves. In a freight equipment, Fig. 5, this is not the case, as a push rod, bottoming on the piston, is inserted in the sleeve *3*. The outer end of the push rod (not shown in figure) is connected to the brake levers, and, when the hand-brakes are applied, the push rod may be drawn out without moving the piston. When the air brake is applied, piston *3* is forced out, carrying the push rod with it.

There are practically no points of difference in the freight and passenger equipments other than those already described, and a description of the parts in the one will apply equally to those of the other. The various parts of the triple valve have already been described and the mode of working explained.

23. Description.—The auxiliary reservoir *10*, Fig. 5, is a storage reservoir. The air stored there is for use in the cylinder *2*, and its use is confined entirely to the car on which it is placed.

The release valve *17*, or bleed cock, as it is sometimes called, provides a means of reducing auxiliary pressure. If the brake on any particular car should "stick," it can be released by opening the bleed cock of the auxiliary on that car until air begins to exhaust from the triple valve, when the bleed cock should immediately be closed. Bleeding the auxiliary reduces its pressure below that in the train pipe, which consequently forces the triple piston to release position and releases the brake.

The brake cylinder can be oiled by means of the oil plug *16*; there is a similar plug on the other side of the cylinder. The later equipments do not have oiling plugs.

The piston *3* is operated by the air pressure in applying the brakes. In the top of the brake cylinder will be noticed a small groove *a*, known as the leakage groove. The triple exhaust port takes care of any air that enters the brake cylinder while brakes are released; the leakage groove is provided so that any air that enters the brake cylinder while the triple is in service position due to a very light application, such as would result from train-pipe leaks, etc., will pass by piston *3* and out to the atmosphere through the open end of the cylinder. In past practice, the groove was placed in the top of the cylinder (in which position it is least likely to become clogged with dirt), and is of such a length that the brake piston must move out about 3 inches before the groove is covered. Leakage grooves are now cut in the side of brake cylinders instead of at the top. Leakage grooves are found in the brake cylinders of freight and passenger cars, and also on most tenders; they were not used in driver-brake cylinders until recently, when grooves $2\frac{5}{8}''$ long and half the size of the car grooves were employed. *9* is the release spring; when, in applying the brakes, air enters the cylinder and forces piston *3* out, the

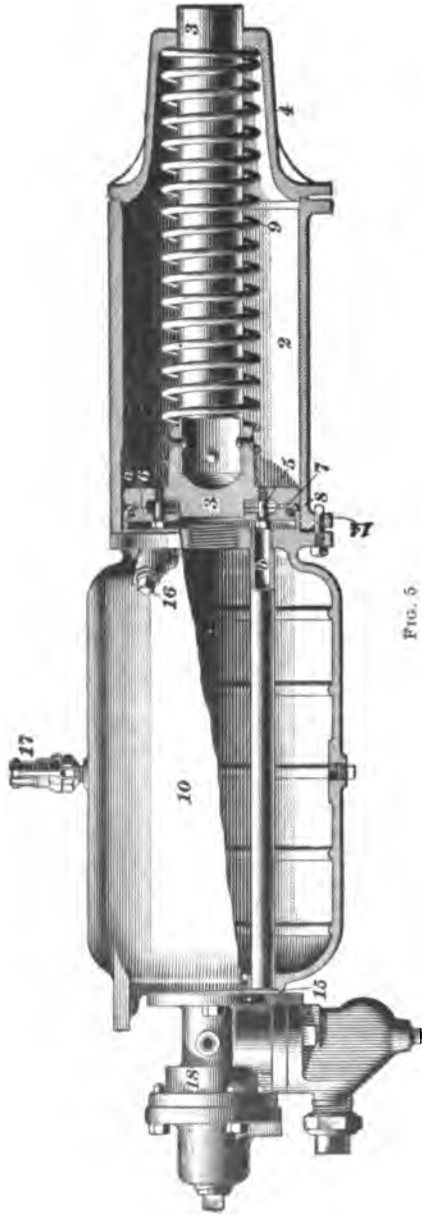


Fig. 5

release spring is compressed; in releasing the brake, air leaves the cylinder and the release spring forces piston *3* back to release position, as shown in Fig. 5. *4* is the front cylinder head; it acts as a guide for the sleeve *3*.

The cup leather packing *7* is to keep the air that enters the cylinder from passing by the piston; it takes the place of the ordinary iron packing rings used in steam cylinders. *6* is the follower plate, which holds the leather packing in place. *8* is the expander ring, which forces out the leather against the walls of the brake cylinder, and so prevents air from passing the piston. As the air enters the cylinder, it strikes the flanges of the leather, forcing them against the walls of the cylinder, and forming an air-tight joint.

TRAIN-PIPE COUPLINGS

24. In Fig. 6 (*a*) is shown an air-brake hose *H* with the nipple *N* and coupling *C* attached; they are fastened to the hose by means of the clamps *c, c*. (*b*) is an enlarged view of the coupling *C* shown in (*a*); this is a device for coupling together the hose on two adjacent cars. (*d*) is an angle cock, one of which is attached to each end of the train pipe on each car. Connection is made between hose and angle cock by means of the hose nipple *N*, shown in (*a*), which is screwed into the angle cock at *1*, the other end *6* of the cock being screwed on to the train pipe. *2* is a plug valve operated by the handle *4*. *3* is the liner, or bushing, in which the plug *2* works; it constitutes the valve body. As the valve now stands, air can pass through it. To stop the flow of air, the handle must be placed at right angles to the position here shown. The spring *5* holds the plug tight to its seat. In views (*a*) and (*b*), *2* is a rubber gasket, by means of which a tight joint is made when the couplings are united between two cars. (*c*) is called a coupling hook. The coupling *C* when not in use is hung in the coupling hook, instead of allowing the hose to hang down and collect dirt, snow, and cinders, which would gradually work into the triples and impair their action.

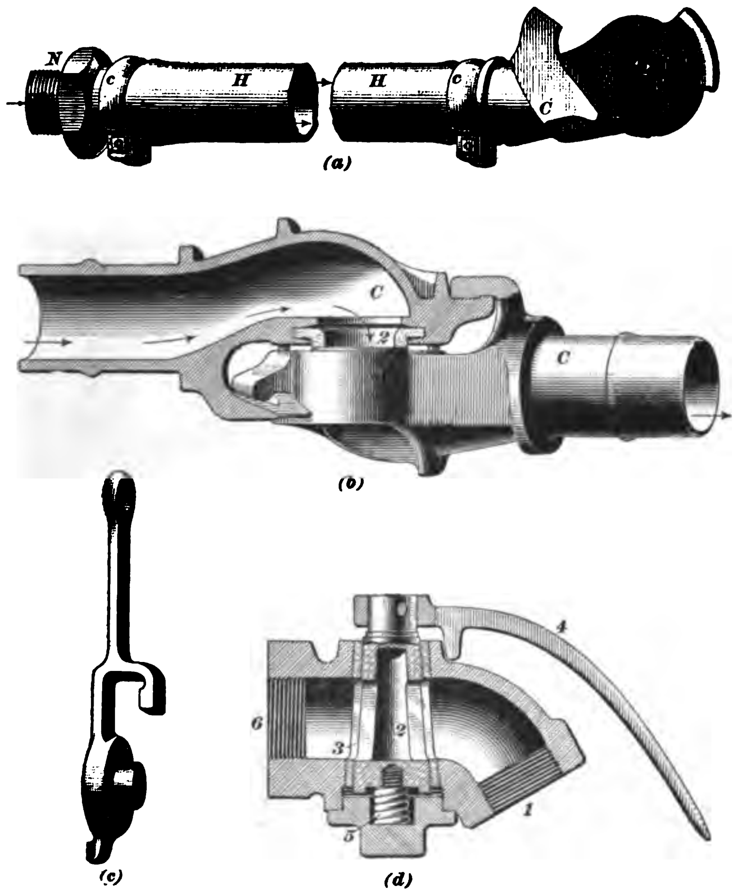


Fig. 6

RETAINING VALVE

25. Duty.—The **retaining valve,** Fig. 7, is part of the air-brake equipment on all freight cars used in interchange service, all sleepers and official cars, and on passenger cars, engines, and tenders in mountainous districts. It is located at the end of the car, within easy reach of the

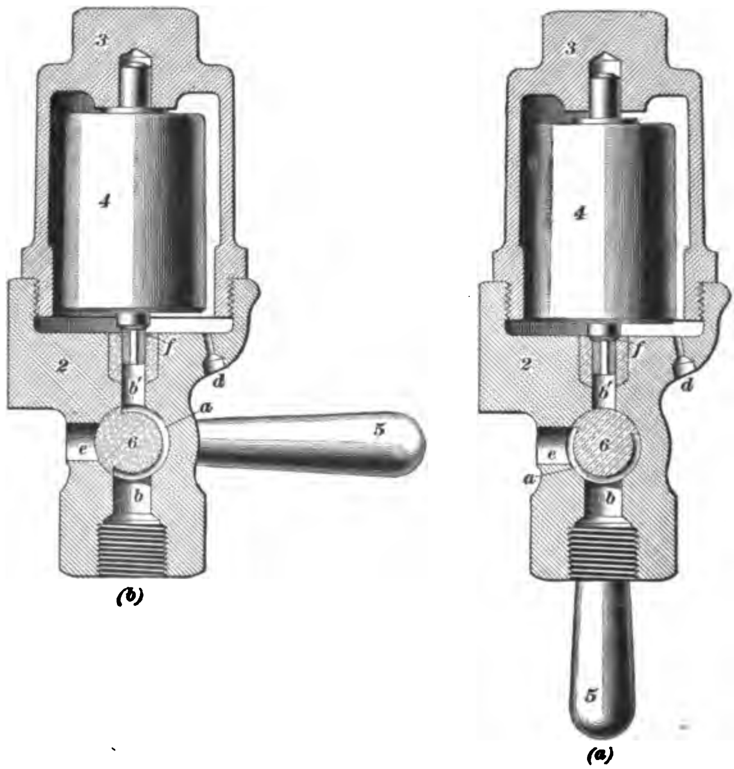


Fig. 7

trainmen when the train is in motion, and is connected by a pipe with the exhaust port of the triple valve. Its purpose is to retard the discharge of air from, and retain a pressure of 15 pounds in, the brake cylinder while the triple valve is in release position and the engineer is recharging the auxiliaries after a release on a grade, to be ready for another application of the brakes.

26. Operation.—With the retaining valve in release position, Fig. 7 (*a*), the air that escapes from the exhaust port of the triple valve passes through the retainer pipe into port *b* and thence around groove *a* in the plug *6* of the cock and out through port *e*, giving a free exhaust for the air from the brake cylinder. If the handle *5* is turned up to the horizontal or retaining position, view (*b*), the free exhaust opening *e* is closed and the air from the cylinder must then pass around the plug *6* and up against the valve *f*. This valve is held on its seat by the weight *4*, which is heavy enough to hold the valve down against a pressure of 15 pounds. If the air coming from the brake cylinder has a pressure exceeding 15 pounds, it will raise the valve and pass up into the retainer cap *3*. It must then pass out through the small port *d*, the diameter of which at its smallest part is $\frac{1}{16}$ inch. This retards the flow of air so that it takes about 20 to 25 seconds for the air to pass out of an 8-inch cylinder with 8 inches travel and reduce the pressure from 50 to 15 pounds; thus, sufficient time is given for the auxiliaries to recharge from 50 to 70 pounds before the pressure is reduced to 15 pounds. The brake-cylinder pressure reduces gradually during the recharging, and the retainer finally keeps 15 pounds until the handle *5* is turned down to the vertical position, and opens the exhaust port *e*. With larger cylinders, the use of this size retainer makes the time for reducing the pressure from 50 to 15 pounds proportionately longer. The small port *d* chokes the discharge of air so that the weight *4* closes the valve *f* at short intervals during the reduction. The restricted opening *d* is a valuable feature of this valve.

Two sets of retaining valves are now in use: one with port *d* $\frac{1}{16}$ inch in diameter, used with 6-, 8-, and 10-inch brake cylinders; the other with port *d* of $\frac{1}{8}$ inch diameter for use with 12-, 14-, and 16-inch cylinders. The latter differs slightly in form from the ordinary retainer, but the operation of the two is precisely the same.

When retaining valves were first used, they had two ¼-inch openings, which reduced the pressure so rapidly that the retainer was not very effective on heavy grades.

27. Special Driver-Brake Retaining Valve.—Fig. 8 shows this valve, which has three positions of the handle *5*. When the handle is turned down to position *1*, it permits a free exhaust of brake-cylinder air to the atmosphere. When the handle is horizontal, position *2*, it closes all ports, so that no air can escape, thus retaining all the air in the brake cylinder. When the handle is turned perpendicularly upwards to retaining position *3*, it allows air to pass out under the valve *f* and through port *d* slowly, finally retaining 15 pounds in the cylinder.

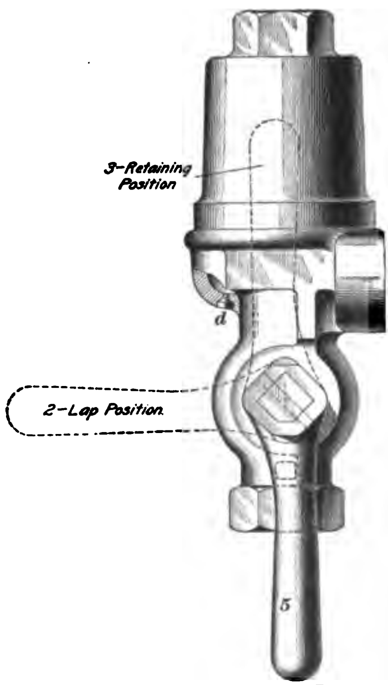
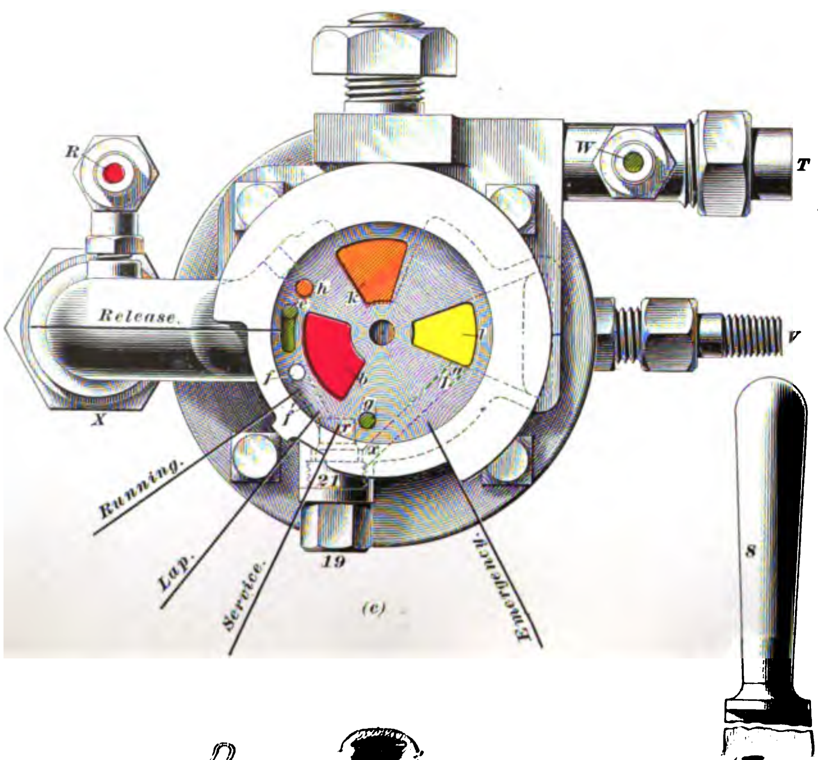
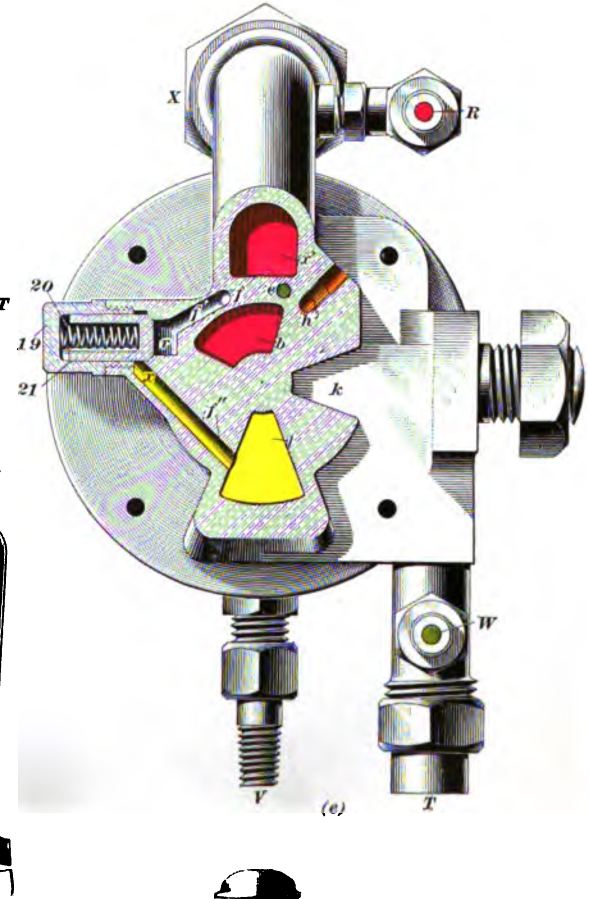


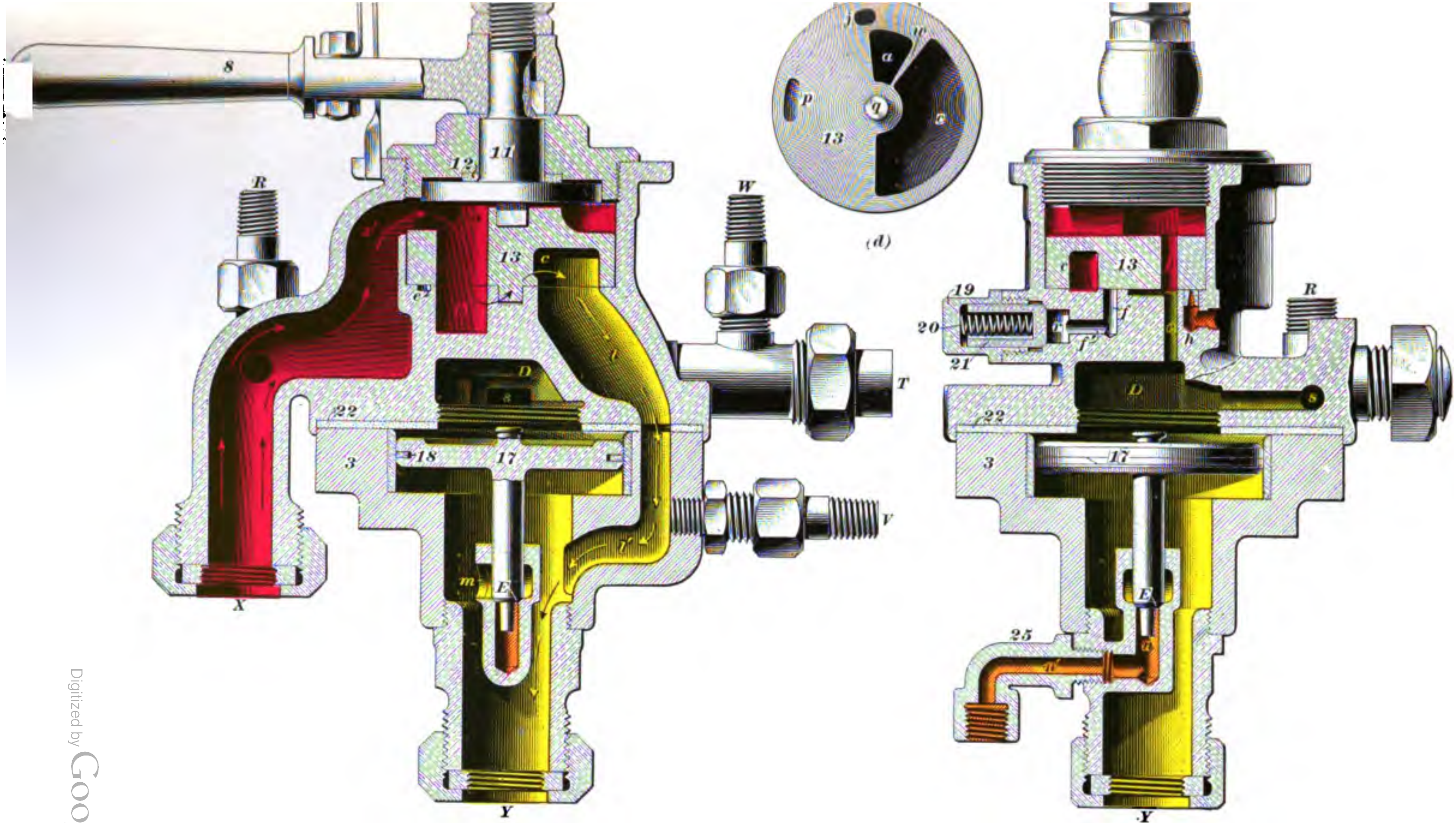
FIG. 8

The pipe connection and groove *a* of the plug cock are made somewhat larger in this retainer than in the standard freight-car retainer, so as to discharge the air from 14- and 16-inch cylinders in the same number of seconds as the ordinary retainer does the 8-inch cylinder.

A retaining valve has nothing to do with the operation of the triple valve, either in service or emergency applications. Its duty is to reduce brake-cylinder pressure slowly until it reaches 15 pounds, after the triple goes to release position, and to retain that amount while the auxiliaries are being recharged.


R
Release.
X
W
T
V
Running.
Lap.
Service.
Emergency.
21
19
(e)
8


X
R
20
19
21
k
W
V
T
(e)



(a) FIG. 9 (b)

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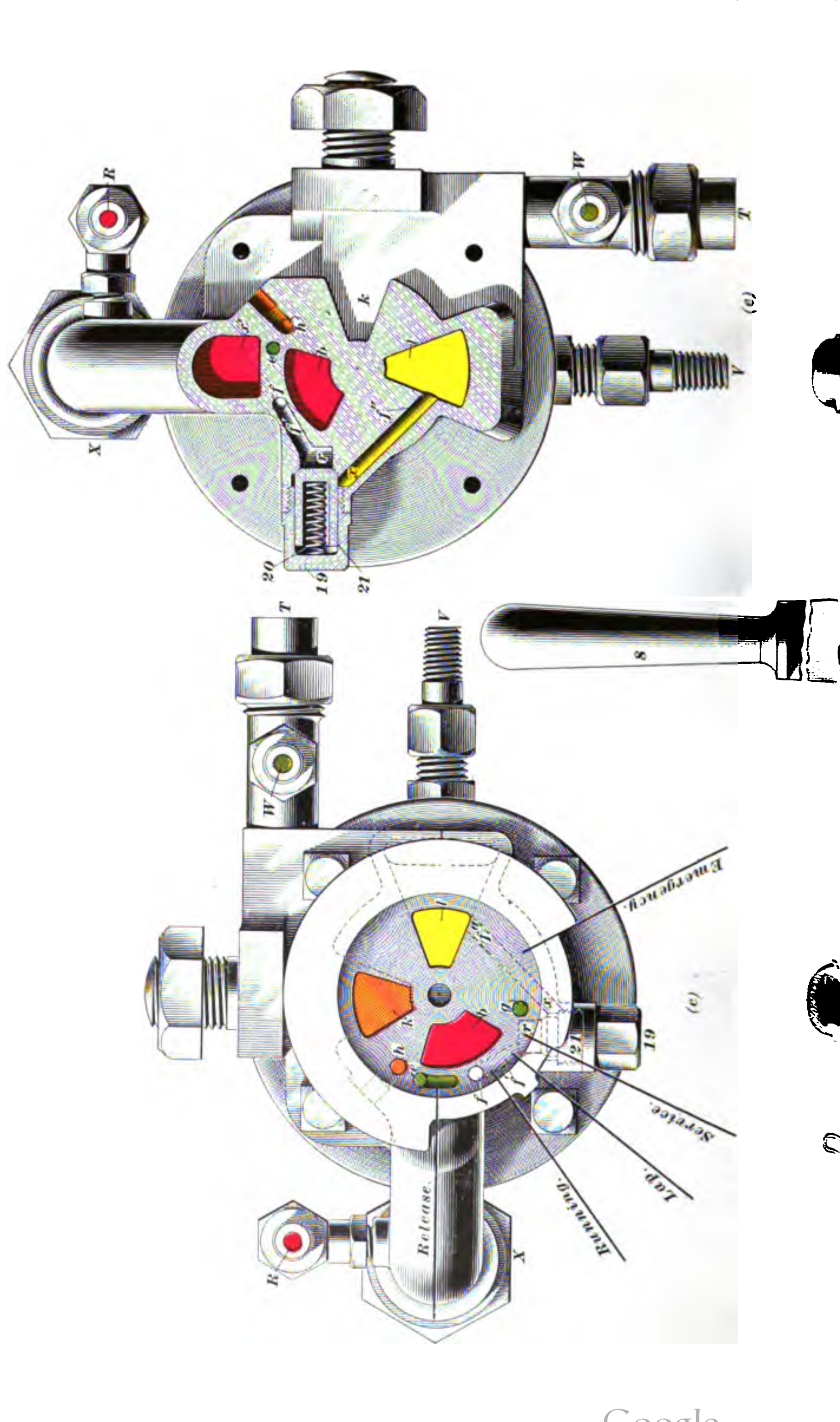
Emergency.
Service.
Lap.
Running.
Release.
(e)
(c)

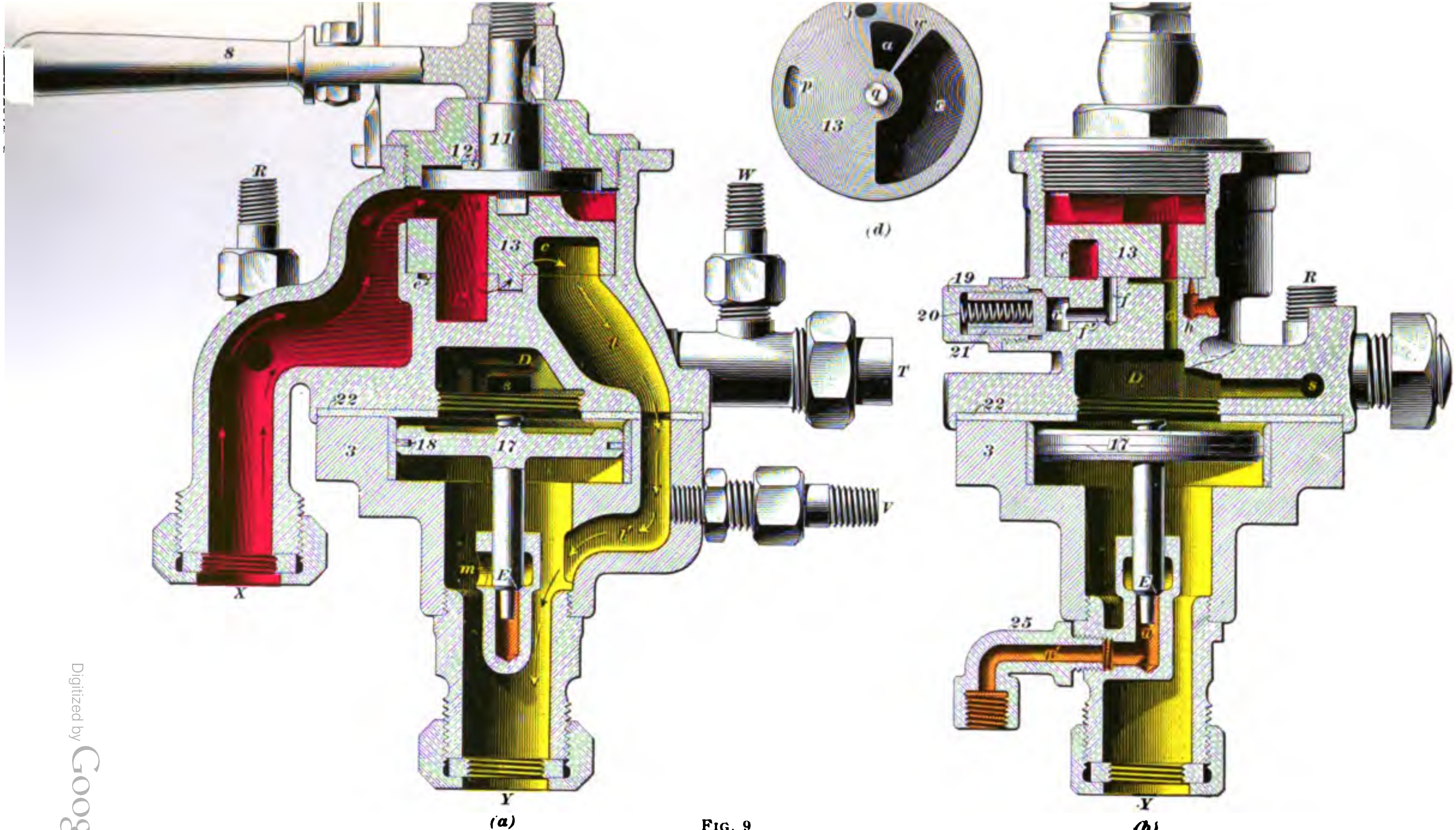
8
R
11
12
13
c
e
D
s
22
3
18
17
m
E
X
Y
(a)
W
T
V
p
q
13
a
(d)
19
20
21
13
f
D
s
R
22
3
17
E
25
Y
(b)

FIG. 9

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ENGINEER'S D-8 BRAKE VALVE

28. The engineer's brake valve is that part of the air-brake equipment by means of which the engineer can control the action of the brakes. The two kinds of brake valves now in use are the D-8 or 1889 brake valve and the D-5, E-6, or F-6, the latter three terms denoting one and the same valve, the letter and number being changed as each new catalog is issued. The D-8 is gradually being supplanted by the F-6, but there are still a large number of the former in use.

29. Description.—The **D-8 brake valve** is shown in Fig. 9, views (*a*) and (*b*) being cross-sections, and (*c*) a plan view with the rotary valve and handle removed so as to show the rotary seat. View (*d*) shows the face of the rotary valve and the ports and cavities in it. View (*e*) is a horizontal section through the excess-pressure valve *21* in view (*b*). In view (*e*) is shown the passage *f′* leading from the feed-port *f* to chamber *r* on one side of the excess-pressure valve, and the passage *x f″*, which leads from the other side of the excess-pressure valve to the direct-application-and-supply port *l*.

Fig. 9 (*a*) and (*b*) and also Fig. 10 show the rotary valve *13* in release position, with cavity *b* of the rotary seat connecting port *a* of the rotary with cavity *c*, which latter connects with port *l*.

In view (*d*), which shows the face of rotary valve *13*, *q* is a pin that fits into a hole in the rotary seat; it acts as a guide for the rotary. The supply port *a* and also port *j* pass entirely through the rotary, while *c* is a cavity in the face of the rotary, but not extending through it; *p* is a small groove in the face of the rotary. When the valve is in service position this groove connects port *e* with port *h*, view (*c*), and thus establishes a connection between the equalizing reservoir and the atmosphere; *w*, in view (*d*), is a partition separating port *a* from cavity *c*.

The direct-application-and-supply port *l* leads to the train pipe through the passage *l′*, as shown in view (*a*), the train pipe being connected at *Y*. The direct-application-and-exhaust port *k*, view (*c*), leads direct to the atmosphere.

The preliminary-exhaust port *h* leads down and out to the atmosphere, as shown in view (*b*). A bushing with a $\frac{5}{64}$-inch hole through it is put in port *h* to limit the rate of discharge from chamber *D*. In this view, also, is seen how the preliminary-exhaust port *e* leads through the rotary-valve seat into chamber *D*, the cavity or space above the equalizing piston *17*, which is connected directly with the equalizing reservoir

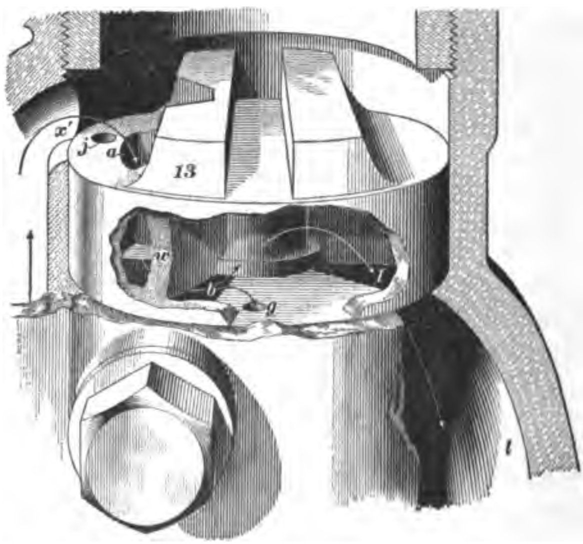


FIG. 10

through passages and the pipe connection *T*. The small groove connecting with port *e* is of such a length as will keep port *j* of the rotary valve in communication with port *e* (as the brake-valve handle is moved from release to running position) as long as there is communication between the main reservoir and the train pipe by way of port *a*, cavity *b* in rotary-valve seat, cavity *c* in rotary valve and port *l*, thereby maintaining sufficient pressure in chamber *D*, during the time the brake valve is being moved to running position, to prevent the train-pipe exhaust valve *E* opening.

The supply port *b*, Fig. 9 (*a*) and (*c*), is simply a cavity in the rotary seat, and is only used in full-release position to establish communication between port *a* and cavity *c* of the rotary. Fig. 10 shows the rotary valve in release position, with cavity *b* establishing communication between port *a* and cavity *c*, the passage of the air from port *a* through cavity *b*, into cavity *c*, and from thence to port *l* and the train pipe, being indicated by arrows.

The equalizing port *g*, Fig. 9 (*c*), leads into chamber *D*. In running and full-release positions, this port serves to establish a connection between both sides of the equalizing piston *17*, that is, between chamber *D* (or equalizing-reservoir pressure) and train pipe. Pipe connection is made between *z* on the pump governor and *V* in Fig. 9 (*a*) and (*c*); the pump governor, therefore, is operated by train-pipe pressure when used with this valve.

EQUALIZING RESERVOIR

30. The small equalizing reservoir, or brake-valve reservoir, sometimes called the little drum, is generally placed under the cab foot-board. A pipe leads from this small drum to the engineer's valve, where it connects at *T*, Fig. 9, and thence through passage *s* with chamber *D*. Passage *s* is contracted at the union joint *T* so that chamber *D* will charge up quicker than the reservoir and thus insure seating piston *17* when the brake valve is placed in full-release position. Also, it restricts the flow of air from the equalizing reservoir into chamber *D*, and thus makes the equalizing piston respond more promptly to a service reduction. The equalizing reservoir serves to increase the capacity of chamber *D* without enlarging the engineer's valve. Were chamber *D* of small capacity, it would be impossible to make a gradual service application of the brakes, for the reason that a gradual reduction of pressure could not be made in chamber *D*; the least opening from this chamber would cause a great reduction of pressure and would set the brakes harder than desired.

Until recently, the equalizing reservoir was 10 inches by 12 inches, with a capacity of 621 cubic inches. The reservoir now used, however, is 10 inches by 14½ inches and has a capacity of 812 cubic inches.

The black gauge hand is connected at *W* and indicates chamber *D* and equalizing-reservoir pressure. The red gauge hand is connected at *R*, and so indicates main-reservoir pressure, this reservoir being piped to the brake valve at *X*.

The equalizing piston *17* separates chamber *D* from the train-pipe pressure, chamber *D* pressure always acting to hold it down, and train-pipe pressure to force it up. As long as these two pressures remain equal, the piston remains stationary, but if the equalizing-reservoir pressure is reduced below that in the train pipe, the piston will be raised by train-pipe pressure, which will then escape to the atmosphere through port *m*, train-pipe exhaust valve *E*, and port *n n'*, Fig. 9 (*a*) and (*b*). As soon as the train-pipe pressure under piston *17* is reduced below that in chamber *D*, the piston is forced down by the pressure above it, and closes the train-pipe exhaust valve *E*.

It is essential that a thorough knowledge be acquired of the ports and cavities of the brake valve, and their connections in the different positions of the rotary, in order to obtain a clear conception of the various brake-valve operations.

BRAKE-VALVE POSITIONS

31. There are five positions of the brake valve; namely: release, running, lap, service, and emergency.

1. *Release Position*.—This position, Fig. 9 (*a*) and (*b*), is used in releasing the brakes, and in charging the equalizing reservoir, train pipe, and auxiliary reservoirs.

2. *Running Position*.—This is the position used while the brakes are off, as when running along the road. This is the position in which the valve must be carried in order to have excess pressure.

3. *Lap Position*.—In this position, the rotary valve closes and separates all the brake-valve ports, thus preventing the passage of any air through the brake valve. The

brake-valve handle is carried on lap position between reductions in a service stop.

4. *Service Position.*—This is the position used in making a gradual application of the brakes, such as at stations, water cranes, slow-ups, and the like.

5. *Emergency Position.*—This position is used when it is desired to stop a train in the shortest possible time, as in cases of imminent danger.

OPERATION OF D-8 BRAKE VALVE

32. It must be remembered that main-reservoir pressure is always free to enter the brake valve at *X*, and, unless otherwise stated, 70 pounds will be considered as standard train-pipe, and 90 pounds as standard main-reservoir, pressure.

33. Release Position.—To release brakes, the brake-valve handle is placed in full-release position, namely, that shown in Fig. 9 (*a*) and (*b*). This brings the supply port *a* of the rotary valve *13* in such a position over cavity *b* in its seat that the partition *w* between port *a* and cavity *c* of the rotary is directly over the center of cavity *b* in the seat (see Fig. 10). The supply port *a* is thus directly connected with cavity *c* by means of cavity *b*, and air passes from port *a* into cavity *c*, as shown by the arrows in Fig. 10, cavity *c* being then in direct connection with port *l*. A direct connection is thus had with the main-reservoir pressure (which is always on top of the rotary valve) by way of the supply port *a* down into cavity *b* of the rotary seat, past the partition *w* of the rotary valve, up into cavity *c* of the rotary, and then down through the direct-application-and-supply port *l* and the passage *l'*, Fig. 9, into the train pipe at *Y*, raising the pressure in the train pipe and charging the auxiliaries through the triples. At the same time that air is passing through cavity *c* into the train pipe, it also passes into chamber *D* through port *g*, which port is exposed to cavity *c*; in this way the pressures above and below the equalizing piston *17* are kept equal.

In full-release position, port *j* is directly over port *e* leading to chamber *D*, and this furnishes another port connection between the main reservoir and this chamber, views (*b*) and (*d*). Thus, when the rotary is in full-release position, it is seen that there are two small port connections between the main reservoir and chamber *D*, and one large connection between the main reservoir and train pipe.

The pump is stopped by the governor when the train-pipe pressure has reached 70 pounds, so that if the rotary is left in full-release position, 70 pounds is all that will be obtained in the main reservoir, train pipe, and equalizing reservoir, since a direct connection is established between these three places in this position.

The brake-valve handle, therefore, should be moved to running position just before 70 pounds has been reached, in order to have the proper excess pressure.

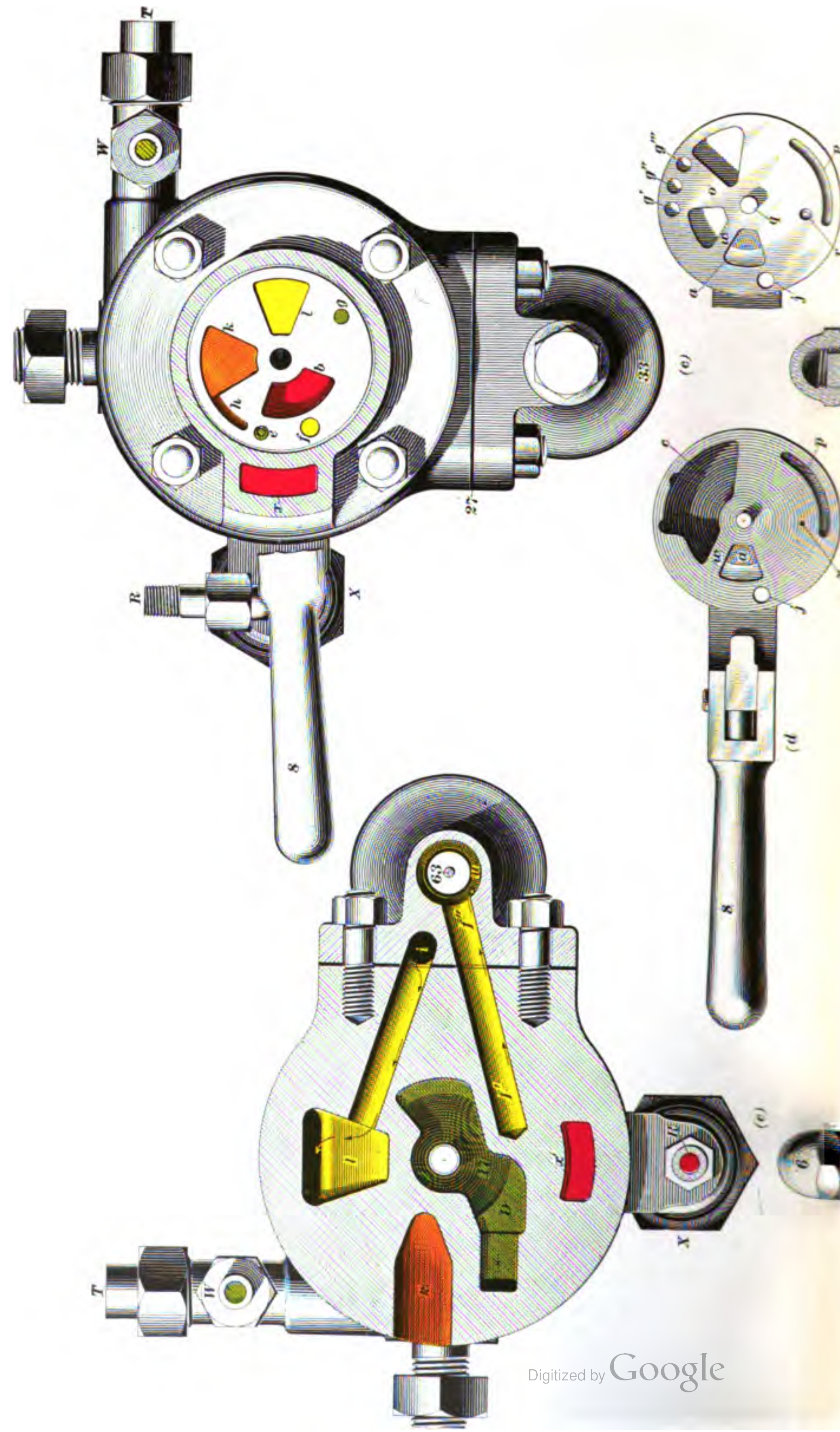
34. Running Position.—In this position, the partition *w* in the rotary valve has been moved around so as to break the connection between port *a* and cavity *c*. Air may now pass from port *a* into cavity *b*, but cannot get out. Port *j* of the rotary is directly over the feed-port *f*, and port *e* is blanked. The main-reservoir air reaches the train pipe by passing down through port *j* of the rotary into port *f* and passage f', and so on into chamber *r*, where it moves the excess-pressure valve *21* from its seat and passes on through passage $x f''$ into port *l* leading to the train pipe. Cavity *c* still establishes communication between port *l* and equalizing port *g*, so that, as air enters the train pipe, it is also free to pass up into cavity *c* of the rotary and down through port *g* into chamber *D*. A direct connection is thus obtained in running position between the train pipe and chamber *D*, the pressures above and below the equalizing piston *17* are equal, and the black gauge hand, which usually indicates chamber *D* pressure only, now shows train-pipe pressure also, due to the above direct connection.

In running position, air can only get from the main reservoir into the train pipe by passing the excess-pressure valve *21*, which is held on its seat by a spring having a resistance of 20 pounds. After the air begins to pass the excess-pressure valve the train-pipe pressure will rise, but the two pressures will keep 20 pounds apart for the train-pipe pressure and the 20-pound spring on one side will balance the main-reservoir pressure on the other side of the valve. If the pump is started with the brake valve in running position, the red hand will show 20 pounds pressure before the black hand moves at all. The hands will then rise 20 pounds apart until 90 pounds is obtained in the main reservoir, and 70 in the train pipe, when the pump will stop, since the governor, which is operated by, and regulates, the train-pipe pressure, is adjusted to 70 pounds. With the D-8 brake valve, therefore, the excess pressure is regulated by the excess-pressure spring. **Excess pressure** is the amount that main-reservoir pressure exceeds train-pipe pressure.

35. Lap Position.—With the valve handle in this position, all ports are closed. Port *j* of the rotary, Fig. 9 (*b*) and (*d*), has been moved around past port *f*, and the rotary now covers port *g*. The main reservoir, chamber *D*, and train pipe are entirely separated from one another, and the black hand indicates only chamber *D* or equalizing-reservoir pressure, as there is no port connection between the upper and lower sides of the equalizing piston *17*.

36. Service Position.—When in this position, the valve handle will have been moved so that the groove *p* of the rotary *13*, Fig. 9 (*d*), connects the preliminary-exhaust port *e*, views (*b*) and (*c*), with port *h* leading to the atmosphere. The engineer leaves the rotary in service position until the black hand shows that the desired reduction of chamber *D* pressure above piston *17* has been made, when the rotary is moved to lap position. In service position, the only port connection through the rotary is between chamber *D* and the atmosphere, through ports *e*, *p*, and *h*. Chamber *D* pressure, on top of the equalizing piston *17*, now being reduced below train-pipe pressure underneath it, the piston is raised, opening the train-pipe exhaust valve *E* and permitting train-pipe air to escape through ports *m* and *n n'* to the atmosphere at the train-pipe exhaust *25*. Train-pipe air continues to escape at the train-pipe exhaust until the pressure below piston *17* is a trifle less than that in chamber *D* above it, when the piston is forced down, closing the train-pipe exhaust valve *E*. If the rotary is again placed in service position, the events just described will again occur, the amount of train-pipe reduction corresponding to the reduction of equalizing-reservoir pressure. When the engineer makes a service application of the brakes, he simply makes a reduction of chamber *D* pressure, and then piston *17* automatically reduces the train-pipe pressure; while piston *17* is reducing the train-pipe pressure, the triple-valve pistons are automatically reducing the pressure in the auxiliaries by allowing it to escape into the brake cylinders.

37. Emergency Position.—In this position, the cavity *c* of the rotary valve is so placed that it connects the direct-application-and-supply port *l*, which leads to the train pipe, with the direct-application-and-exhaust port *k* leading to the atmosphere. This port *k*, the cavity *c*, and the port *l* being large, cause a large opening to be made between the train pipe and atmosphere, and a sudden heavy train-pipe reduction is the result. This sudden reduction causes the triples near the engine to go to emergency position. It was seen in the study of the quick-action triple that when one quick-action triple went into emergency position, a sudden reduction of train-pipe pressure near it was made through the quick-action part of the triple; this started the next one, and so on to the end of the train, each triple helping to keep this sudden reduction traveling quickly backwards throughout the train. In the service application of the brake, all train-pipe reductions escape to the atmosphere through the train-pipe exhaust; while in emergency position, a sudden reduction is made to start the first quick-action triples into emergency, and these triples make sudden reductions of train-pipe pressure; but, instead of wasting the air by passing it to the atmosphere, they put it into the brake cylinders, where it is used to increase the braking power.



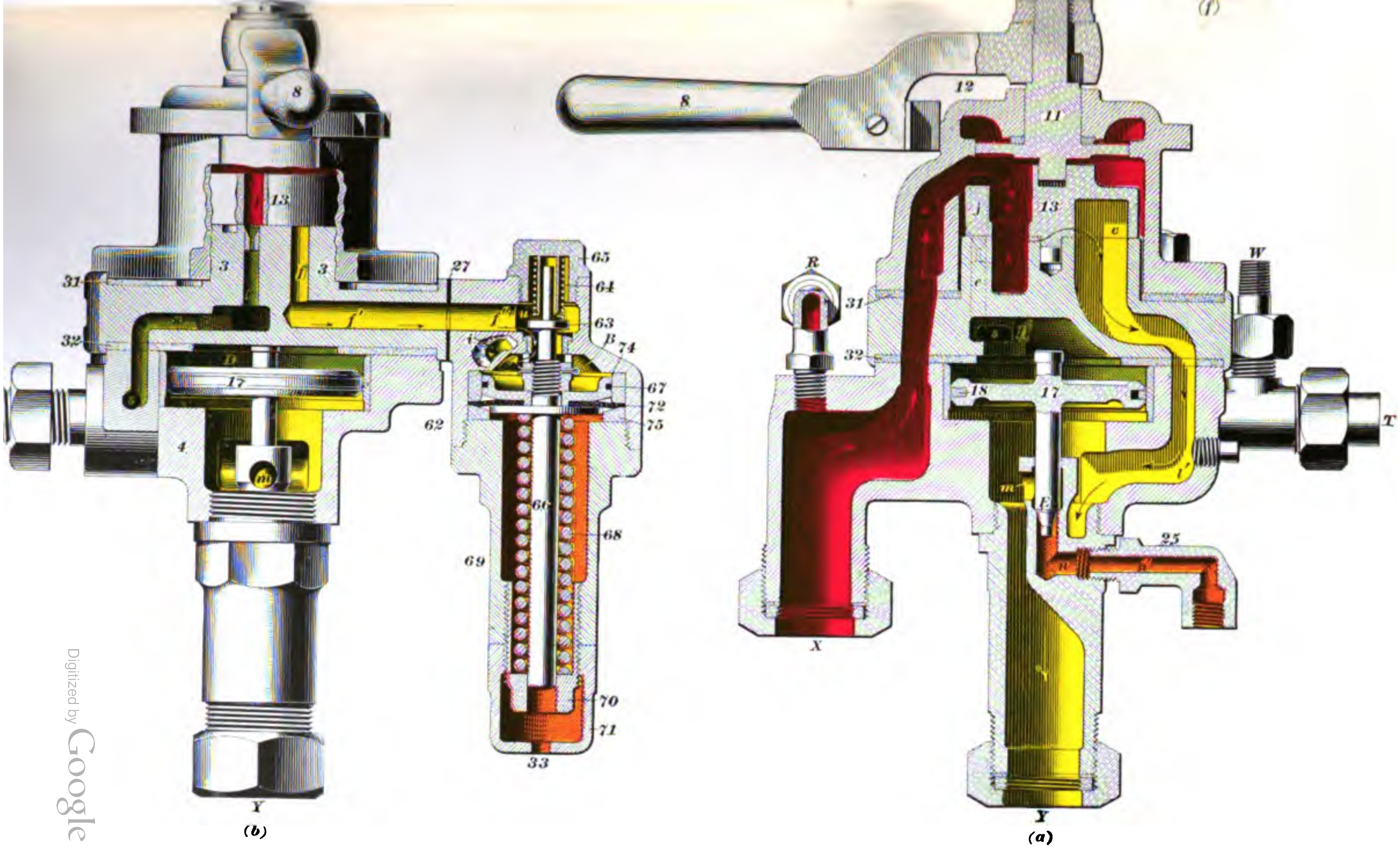


FIG. 11

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ENGINEER'S D-5, F-6, OR 1892 MODEL BRAKE VALVE

38. The **D-5, F-6, G-6** or **1892 model brake valves** are practically the same only the D-5 and F-6 (1892 model) valves have the feed-valve attachment while the G-6 model has the slide-valve feed-valve. The F-6 model is illustrated in Fig. 11, wherein (*a*) and (*b*) are cross-sectional views, while (*c*) is a plan view with the top part of the valve body and the rotary valve *13* removed, so as to show the ports and cavities in the rotary-valve seat *3*. In (*d*) is shown a plan view of the under side, or face, of the rotary *13*, showing the ports and cavities in it. View (*e*) represents a section of the valve taken through the passage *f*, *f'* to show the passages to and from the feed-valve attachment.

Comparing Fig. 11 (*c*) and Fig. 9 (*c*), it will be seen that both the form and location of ports *l* and *k* and cavity *b* are practically the same; port *f* is in about the same location, but in the D-8 valve it is $\frac{1}{4}$ inch in diameter, whereas in the F-6 valve it is $\frac{9}{32}$ inch; port *h* of the D-8 valve is replaced in the F-6 valve by the groove *h* that leads into the exhaust port *k*; the preliminary-exhaust port *e* is located as in the D-8 valve, and the bushing for limiting the discharge of air from chamber *D* is placed in this port. [See Fig. 11 (*b*).] Port *g* in the F-6 valve is $\frac{1}{4}$ inch in diameter and is placed nearer to port *l*, and is in such a position that it will not register with port *j* of the rotary valve when the brake valve is being moved to emergency position. Port *g* in the D-8 valve is only $\frac{3}{16}$ inch in diameter.

Comparing Fig. 11 (*d*) with the plan of the D-8 rotary valve shown in Fig. 9 (*d*), it will be seen that cavity *c* is in about the same position in each case, but that the two differ slightly in form, the projection in cavity *c* of the F-6 brake valve being for the purpose of covering port *g* in lap position. The partition *w* is made wider in this valve to reduce the wear at that point. Port *j* is made round, whereas in the D-8 valve it is lengthened so as to connect main-reservoir pressure with feed-port *f* before the partition *w* cuts off communication between the supply port *a* and cavity *c* as the brake valve is being moved to running position. Also, the groove *p* is lengthened in the F-6 valve so as to keep the preliminary-exhaust port *e* in communication with groove *h* and exhaust port *k* in all positions of the brake valve between service and emergency positions. This allows chamber *D* to empty in emergency position. In emergency position, port *f* of D-8 valve registers with port *g* and charges chamber *D* to main-reservoir pressure; these ports never register with F-6 valve. View (*f*) shows the face of the latest form of rotary valve in which cavity *c* is partly covered so as to reduce the wear of the valve and make it wear more evenly.

39. The excess-pressure valve *21* of the D-8 valve is replaced in the F-6 valve by the feed-valve attachment *33*, views (*b*) and (*c*). The excess-pressure valve in the D-8 valve maintains a predetermined difference of pressure between the main reservoir and the train pipe; the feed-valve attachment can be regulated to give any desired train-pipe pressure up to that of the main reservoir. With the F-6 valve the pump governor controls the pump and determines the excess pressure; hence, excess pressure is adjusted by regulating the pump governor.

The pump governor is connected at *z* by a pipe to *R*, Fig. 11, and therefore is operated by main-reservoir air.

The equalizing reservoir is connected at *T*, the black gauge hand at *W*, and the red one at *R*. The pipe connections to the train pipe and the main reservoir are the same in this as in the D-8 valve. The various operating positions of the brake-valve handle (release, running, lap, service, and emergency) are also the same as for the D-8 valve, as shown in Fig. 9 (*c*).

OPERATION OF F-6 BRAKE VALVE

40. The feed-valve attachment, shown in Fig. 11 (*b*), consists of a spring box *69*, within which is contained a regulating spring *68* that exerts an upward pressure on the feed-valve piston *74* above it, and within the feed-valve body is a supply valve *63*, the lower stem of which is of such a length that it rests on the upper stem of the feed-valve piston. When this piston is up in its normal position it holds the valve *63* from its seat against the resistance of the spring *64*, which tends to hold down the valve. When the brâke valve is in running position, chamber *u*, above the supply valve *63*, is in connection with main-reservoir air through the passage *f″ f′*, port *f* in the rotary seat, and port *j* in the rotary valve. Chamber *B*, just above piston *74*, is in direct communication with the train pipe at all times through port and passage *i* and direct-application-and-supply port *l*, Fig. 11 (*e*). Chamber *B* is therefore always filled with train-pipe air, which exerts a downward pressure on piston *74*, while chamber *u* is always filled with main-reservoir air. The downward pressure of the air in chamber *B* on piston *74* is resisted by the spring *68*, which is adjusted to resist a downward pressure of 70 pounds per square inch. Just so long as the train-pipe pressure in chamber *B* is less than 70 pounds, the spring *68* will hold up piston *74* sufficiently to keep the supply valve *63* unseated, and main-reservoir air will flow by valve *63* into chamber *B* and on into the train pipe, views (*e*) and (*b*). When the pressure in the train pipe and in chamber *B* reaches 70 pounds, the piston *74* is forced down, compressing the spring *68*. As piston *74* descends, the supply valve *63* is forced to its seat by the spring *64*, and no more air can pass from the main reservoir into the train pipe through the feed-valve attachment (or train-pipe governor, as it is sometimes called) until a reduction of train-pipe pressure has occurred.

If leaks reduce the train-pipe pressure below 70 pounds, the spring *68* raises piston *74* and supply valve *63*, and allows main-reservoir pressure to restore the loss due to leakage, after which the supply valve *63* is again closed. The tension of the spring *68* is regulated by means of the regulating nut and screw *70*. Screwing up increases the tension of spring, and consequently the train-pipe pressure, and unscrewing reduces train-pipe pressure. In Fig. 11 (*b*) the feed-valve attachment is shown in section; a small portion of the body is further broken away so as to show the port *i* by which the air, after passing from *u* through the feed-valve into *B*, makes its way along the passage shown into port *l*; this passage runs along behind the passage *f'' f'*, exactly on the same level with it, so that it cannot be seen in view (*b*); its position, however, is shown in view (*e*).

41. Release Position.—When the brake valve is in this position, Fig. 11, views (*a*) and (*b*), the supply port *a* of the rotary stands directly over cavity *b* of the rotary seat, and port *j* of the rotary stands directly over the preliminary-exhaust port *e*, view (*b*). Main-reservoir air is free to pass into port *a* of the rotary, and down into cavity *b* of the rotary seat. The partition *w* between cavity *c* and port *a* of the rotary, view (*d*), now stands across the middle of cavity *b*, so that the air entering cavity *b* from port *a* passes under this partition and up into cavity *c*, as shown in Fig. 10. The air passes from cavity *c* into the supply port *l* and out into the train pipe at *Y*. Train-pipe pressure increasing, the triple pistons are forced to release position and the auxiliaries are charged. While the air is passing through cavity *c* to port *l*, it is free to pass down through the equalizing port *g* into chamber *D*, and thence out to the equalizing reservoir through port *s*. During the time air is feeding into the chamber *D* through port *g*, main-reservoir air is feeding through port *j* of the rotary and the preliminary-exhaust port *e* of its seat into the chamber *D*. In release position, one large port leads from the main reservoir to the train pipe, and two small ports lead to the equalizing reservoir (through chamber *D*). In view (*d*) is seen a very small port *r*, called the engineer's warning port, drilled through the rotary valve in such a position that, when the latter is in full-release position, this warning port is directly over the exhaust port *k* in the rotary seat, view (*c*). Main-reservoir air on top of the rotary blows through this small warning port into the exhaust port *k*, and the sound of the escaping air is heard by the engineer. This is to warn him that he must not leave the valve in full-release position too long, for the following reasons: With this valve the pump is not stopped until 90 pounds pressure is obtained in the main reservoir, as main-reservoir pressure operates the pump governor, which is adjusted to 90 pounds. There is a direct connection between the main reservoir and train pipe in full-release position, and if the rotary is left there, 90 pounds pressure will be obtained in both the main reservoir and train pipe; this high pressure in the auxiliaries will be apt to slide wheels when the brakes are applied, and there will also be a lack of excess pressure for releasing brakes. Besides this, if the valve is now placed in running position, the feed-valve attachment will be held closed until train-pipe pressure is reduced to 70 pounds, consequently, train-pipe leaks will tend to cause the brakes to "creep on" until both train-pipe and auxiliary pressures are reduced to 70 pounds, when the feed-valve will begin operating again and supply the air lost through these leaks.

42. Running Position.—In this position, port *j* of the rotary is in communication with port *f* of the rotary seat, and air from the main reservoir passes down through ports *i*, *f*, through the passage *f′ f″*, and on through the feed-valve attachment and into the train pipe by way of passage *i* and port *l*, as explained in the description of the feed-valve attachment. The air continues to flow thus until the train-pipe pressure reaches 70 pounds, when the feed-valve attachment closes. As air passes through the feed-valve attachment through port *i* and on into port *l* and the train pipe, some of it passes up into cavity *c* in the rotary and down through port *g* into chamber *D*. Connection is thus maintained between the train pipe and chamber *D*, that is, between both sides of the equalizing piston *17*. The black gauge hand is piped to the equalizing-reservoir connection at *T*, and, as there is in running position a port connection between the train pipe and chamber *D* through the cavity *c* in the rotary and port *g*, the black hand must in this position indicate both chamber *D* and train-pipe pressures. The same movement that changes the rotary *13* from full-release to running position, closes the warning port *r* and moves the partition *w* of the rotary until it prevents the passage of air from cavity *b* of the rotary seat into cavity *c* of the rotary. The feed-valve attachment keeps the train-pipe pressure at 70 pounds, and the pump governor stops the pump when main-reservoir pressure has reached 90 pounds, so that, when everything is fully charged and the valve is in running position, the black hand should register 70 pounds and the red hand 90 pounds.

43. Lap Position.—In this position, the rotary has been moved around so as to close all connections. Port *j* is closed to port *f*; the equalizing port *g* is covered so that it is shut off from cavity *c*; and connection between the top and bottom of the equalizing piston *17* is cut off.

44. Service Position.—In this position, the rotary has been moved so that groove *p* in the face of the rotary valve, Fig. 11 (*d*), connects the preliminary-exhaust port *e* in the rotary seat with the port *h*, which leads into the direct-application-and-exhaust port *k*. A direct connection is thus established between chamber *D* and the atmosphere, and air from chamber *D* can pass through port *e*, groove *p*, and ports *h* and *k* to the atmosphere. The reduction of the pressure in chamber *D* causes the equalizing piston to rise and open the train-pipe exhaust valve *E*, as described in the operation of the D-8 valve.

45. Emergency Position.—In this position, the rotary has been moved around so that cavity *c* connects port *l* (leading to the train pipe) with the exhaust port *k* (leading to the atmosphere). The opening of these large ports causes a sudden train-pipe reduction, which gives an emergency application of the brakes, as described in the case of the D-8 valve.

Also, groove *p* in the rotary valve connects port *e* with groove *h*, thus exhausting the air from chamber *D* and allowing the black hand of the gauge to drop to zero.

SLIDE-VALVE FEED-VALVE

46. Introductory.—All engineer's brake valves prior to the 1892 brake valve were provided with an excess-pressure valve the duty of which was to maintain a fixed difference of pressure between the train pipe and main reservoir when the brake valve was in running position. While the excess-pressure valve performed that duty, yet several faults were to be found with it, which finally led to its being abandoned for the feed-valve attachment. The strength of the spring in the excess-pressure valve fixed the amount of excess pressure carried, and this amount could not be changed without adding washers to increase the tension of the spring, or substituting a spring of different strength. Moreover, it did not regulate the amount of pressure carried in the train pipe, but simply maintained a fixed difference in pressure between the train pipe and main reservoir; hence, if the main reservoir were overcharged (as could happen when the brakes were held on for some time), the train pipe also became overcharged when the brake valve was moved to running position. Again, if the main reservoir equalized with the train pipe when the brakes were being released, and the brake valve was then moved to running position, the brake valve would practically be lapped until 20 pounds excess pressure was obtained, during which time the brakes were very apt to creep on. If the main reservoir equalized with the train pipe at a pressure greater than 70 pounds, the governor would not start the pump until the train-pipe leaks reduced train-pipe pressure below 70 pounds, and the 20 pounds excess had then to be pumped. It was due to these faults of the excess-pressure valve that the feed-valve attachment was introduced with the 1892 brake valve.

47. The feed-valve attachment is simply a form of pressure-reducing valve; its duty is to regulate the train-pipe pressure to a standard pressure—usually 70 pounds—just as the signal-reducing valve regulates the signal-pipe pressure to 40 pounds. The feed-valve attachment overcame all the objectionable features of the excess-pressure valve and proved very successful on trains of short and medium length. However, when used with long freight trains it developed a serious fault that finally led to the adoption of the **slide-valve feed-valve,** brought out with the G-6 brake valve in 1900.

The feed-valve attachment is operated by train-pipe pressure acting on a diaphragm against the force of a regulating spring. This spring begins to be compressed when the train-pipe pressure reaches about 45 pounds, and as the pressure is increased to 70 pounds, the spring is compressed sufficiently to permit the feed-valve to close and cut off communication between the train pipe and the main reservoir. On account of this action, the feed-valve begins to close gradually from the time train-pipe pressure reaches 45 pounds or thereabouts, thus gradually reducing the flow of main-reservoir air into the train pipe. The result is that on a long train where the feed-valve is adjusted for 70 pounds and there is considerable train-pipe leakage, train-pipe pressure cannot be raised to 70 pounds with the brake valve in running position. By the time train-pipe pressure reaches, say, 65 pounds or thereabouts, the feed-valve has closed to such an extent that just sufficient air can pass it to make up for the loss through train-pipe leakage; consequently, it is impossible to increase the pressure in the train pipe above that amount. This defect has been overcome in the slide-valve feed-valve. No modification is necessary in existing brake valves in order to use the slide-valve feed-valve, as the method of attachment is exactly the same as that of the feed-valve attachment of the 1892 brake valve.

48. External Construction.—A very good idea of the external construction of the slide-valve feed-valve can be obtained from Figs. 12 and 13, the first of which is a view from the front, while the second is a view from the rear. As its name implies, the slide-valve feed-valve consists of two parts *X* and *Y*, Fig. 12. Part *X* contains the slide-valve arrangement, and governs the train-pipe supply, while the

FIG. 12

FIG. 13

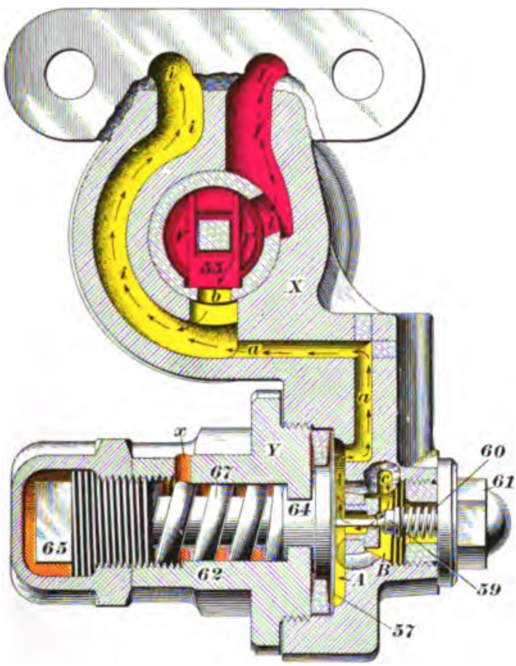

FIG. 14

regulating arrangement in part *Y* [which is practically the same in construction (see Fig. 11) and identically the same in operation as the feed-valve attachment of the 1892 brake valve] is used to operate the slide-valve part *X*. It is due to the adoption of a slide valve instead of a poppet valve for regulating the supply of air to the train pipe that a wide-open communication between main reservoir and train pipe is maintained until the standard pressure is obtained. Since the starting friction of the slide valve is greater than the sliding friction, it follows that once the slide valve is started it will move its full stroke and so totally open or totally close the supply port; hence, there can be no gradual closing of the supply port as in the old feed-valve attachment.

49. Passages *a*, *f*, and *i*.—Fig. 14 shows a back view of the slide-valve feed-valve with part of the valve so broken away as to show the passages *a*, *f*, and *i*, and their relations to ports *b* and *l*. When the feed-valve is in position on the brake valve, the passage *f* connects with the passage *f'* in the brake valve, Fig. 11, so that it is charged with air at main-reservoir pressure when the brake valve is in running position. Since port *l* in the supply-valve bushing connects passage *f* with chamber *F*—the space surrounding the supply valve *55*—it follows that chamber *F* is charged with main-reservoir pressure whenever passage *f* is so charged.

Passage *i* in the feed-valve connects with passage *i* in the brake valve, Fig. 11; hence, it is always in direct communication with the train pipe and charged with train-pipe air. Furthermore, passage *i* is connected with chamber *F* through the supply port *b* in the supply-valve bushing. Passage *a* connects passage *i* with chamber *A*—the space between the diaphragm *57* and the regulating valve *59*—hence, chamber *A* is always charged with train-pipe air, since it is in direct communication with it.

The arrows indicate the flow of air through the feed-valve when it is open and supplying air to the train pipe. It will be observed that a portion of the feed-valve has been broken away in such a manner as to show the regulating valve *59*;

also, it shows how the end of the passage *c* opens into chamber *B*—the space surrounding the regulating valve.

50. Passage *c*.—Fig. 15 is a perspective view of the feed-valve with the cap nut *53* removed and part of the valve broken away to show the course of the passage *c* and its relation to the regulating valve *59* and to passage *a*. Passage *c* connects chamber *B* with chamber *E*—the space between the supply-valve piston *54* and the cap nut *53*—thus maintaining equal pressures in the two chambers. The regulating valve *59* controls communication between chambers *A* and *B*, so that when it is open chamber *E* is in direct communication with the train pipe through the passage *c*, chamber *B*, valve *59*, chamber *A*, and passages *a* and *i*. A portion of the feed-valve in Fig. 15 is broken away so as to show how the end of passage *a* opens into chamber *A*.

51. Slide-Valve Arrangement.—Fig. 16 is a side view of the feed-valve attachment, with the upper part *X* sectioned through the center to show the arrangement of the supply valve *55*, and the lower part *Y* below the line *A B* sectioned in such a way as to show the passages *a* and *c* and chamber *B*. A portion of the upper part *X* of the valve is broken away to show the end of the passage *i*.

The supply valve *55* controls port *b* leading from chamber *F* into the passage *i*. This slide valve is operated by means of the supply-valve piston *54* and the supply-valve piston spring *58*. Although piston *54* makes a snug fit in its bushing it is not provided with a packing ring for the reason that a certain amount of leakage from chamber *F* into chamber *E* is necessary in order that the feed-valve may work properly. The spring *58* is made sufficiently strong to force piston *54* and supply valve *55* back against the flush nut *52* (which acts as a stop for the piston) whenever the difference in pressures in chambers *F* and *E* allow the spring to move the piston against main-reservoir pressure. Port *b*, therefore, is closed when the pressure in chamber *E* equals that in chamber *F*. When the pressure in chamber *E* is less than that in chamber *F*, the greater pressure on the chamber *F* face of piston *54*

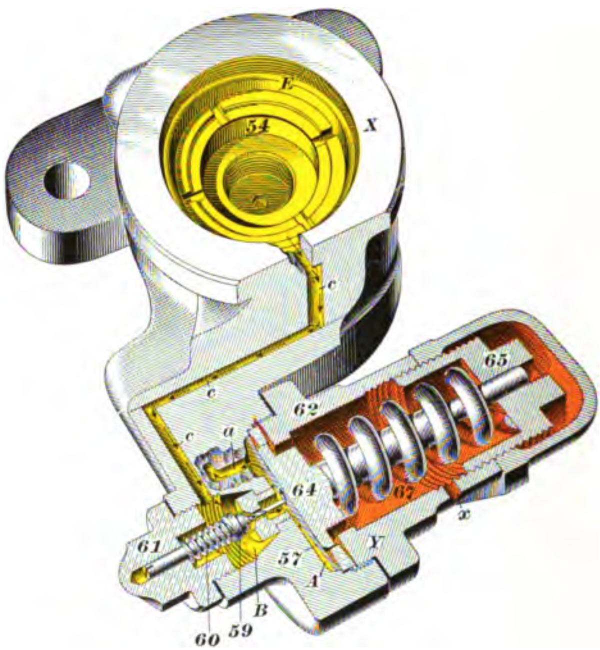

Fig. 15

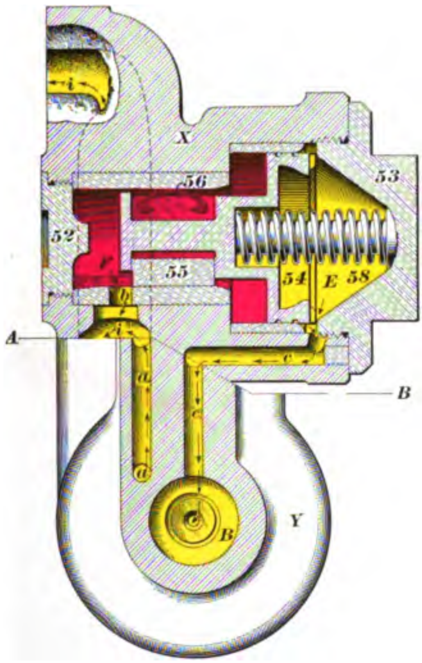

FIG. 16

forces the piston forwards, moving valve *55* with it, and thus opening port *b*. Therefore, port *b* is always open when the pressure in chamber *E* is less than that in chamber *F*. The supply-valve spring *56* is intended to hold supply valve *55* on its seat when that valve is relieved of pressure, in order to prevent dirt from getting between the valve and its seat. In Fig. 16, chamber *B* is shown with the regulating valve *59* removed.

52. Regulating Arrangement.—As already remarked, the regulating valve, part *Y* of this valve, is practically the same in construction as the old feed-valve attachment. This will be more readily seen by comparing part *Y* of Fig. 15 with the feed-valve in Fig. 11 (*b*). Passage *c* of Fig. 15 corresponds to passage *f'* of Fig. 11, and the passage *a* to passage *i*. The operation of these valves is identically the same. The vent hole *x* is to prevent air (due to leakage past the diaphragm *57*) accumulating in the spring box and thus rendering the feed-valve inoperative.

53. Operation of Slide-Valve Feed-Valve.—On account of the parts *X* and *Y* being at right angles to each other, it is difficult to illustrate the operation of the valve by means of true sectional views. For that reason, two conventional views, Figs. 17 and 18, have been prepared for use in explaining the operation of the slide-valve feed-valve.

At such times as the feed-valve is not under pressure, port *b* is closed while the regulating valve *59* is open. The spring *58* forces the supply valve *55* back until it covers port *b* (as in Fig. 18), while the regulating spring *67* forces the diaphragm to unseat the regulating valve *59* (as in Fig. 17).

Fig. 17 shows the position of the parts of the feed-valve when the train pipe is charged to less than 70 pounds and air is feeding through the feed-valve into it. Under those conditions, main-reservoir air enters passage *f* and chamber *F*, forcing piston *54* forwards until it uncovers port *b*. The air then flows from chamber *F* through port *b* into passage *i* and thence into the train pipe, increasing the pressure there.

While train-pipe pressure is less than 70 pounds, the regulating valve *59* is held off its seat by the regulating spring *67* and there is direct communication between chamber *E* and the train pipe through passage *c*, valve *59*, and passages *a* and *i*. The leakage that takes place past the piston *54* therefore passes directly to the train pipe, as indicated by the arrows, so that chambers *E* and *A* are maintained at train-pipe pressure. When 70 pounds is obtained in the train pipe, the pressure on the diaphragm *57* is sufficient to compress the regulating spring *67* enough to allow the regulating valve *59* to close. This cuts off communication between chamber *E* and the train pipe, and the leakage occurring past piston *54* then quickly charges chamber *E* to the same pressure as chamber *F*, which allows the spring *58* to move the supply valve *55* to "closed" position, as shown in Fig. 18. In this position no air can feed into the train pipe, since port *b* is closed.

The parts of the feed-valve remain in the positions shown as long as the train-pipe pressure remains at 70 pounds. Any reduction of train-pipe pressure, however, allows the spring *67* to expand and unseat the regulating valve *59*; pressure in chamber *E* is then immediately reduced to train-pipe pressure, so that the greater pressure of the air in chamber *F* forces the piston *54* to "open" position, as shown in Fig. 17.

54. Regulation.—If the slide-valve feed-valve does not regulate train-pipe pressure to the proper amount, it can be made to do so by adjusting the regulating nut *65*.

If it maintains a pressure below the standard, turn the regulating nut *65* slowly until the tension of the spring *67* is sufficiently increased to give proper regulation.

If it maintains too high a pressure, place the brake valve in service position and reduce the train-pipe pressure several pounds below standard; then turn the regulating nut *65* so as to relieve the spring *67* of a little of its tension, place the brake valve in running position, and note the pressure that is then maintained. If still too high, proceed again as above, and continue to so regulate until the feed-valve is properly adjusted.

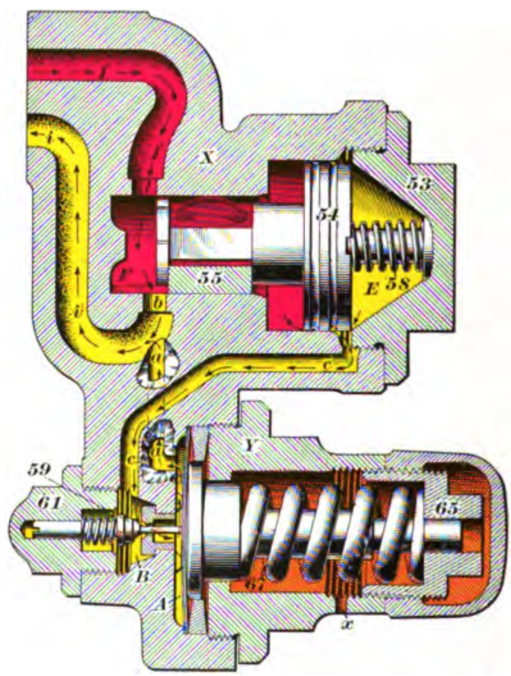

FIG. 17

§ 2 13180

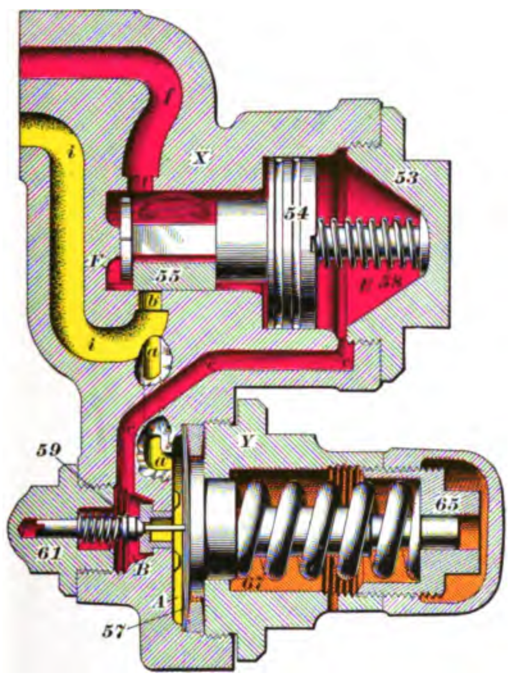

FIG. 18

55. Care.—In order that the feed-valve may perform its functions properly, it is necessary that it be cleaned and oiled occasionally. If the feed-valve is to be cleaned when the air-brake system is charged with air, it must be relieved of all pressure before it can be taken apart. To do this, close the cut-out cock in the train pipe underneath the brake valve, so as to save the air in the train pipe, and place the brake valve in service or emergency position to empty the feed-valve and the short piece of train pipe above the cut-out cock; the feed-valve may then be taken apart and cleaned. Clean both the piston *54* and its cylinder, and the slide valve *55* and its bushing, very carefully, leaving no lint on the parts, for it will cause trouble; clean, also, the regulating valve and its seat and the hole in the cap nut *61* into which the valve *59* extends.

In oiling the supply valve *55*, only a small amount of valve oil, vaseline, mutton tallow, or some similar lubricant should be used, the oil being applied with the finger. Only a very small amount of some light lubricating oil (engine oil will do) should be used on the supply-valve piston *54* and its cylinder, and that should be well rubbed on with the fingers. If too much or too heavy oil is used on these parts, it will get into the grooves of the piston and act as an oil packing and will interfere very materially with the action of the feed-valve. The regulating valve *59* should not be oiled, but should be replaced dry.

PIPE ARRANGEMENT FOR DUPLEX GOVERNOR

56. The duplex pump governor is necessary on engines equipped with the high-speed brake and the high-pressure control or special apparatus, for loaded freight trains, and it is also necessary on many engines not used in this special service. It provides a means for carrying two pressures in the main reservoir; a moderate one while running with brake released and a much higher one while the brake is applied, so as to provide a high excess pressure for the prompt release of the brake. This is done by piping the low-pressure side of the governor to port *f'* in the F-6 brake valve, a hole being drilled through the bottom case *4* of the valve near the figures *62*, in Fig. 11 (*b*), through gasket *32*, and into port *f'*. A pipe is connected to this opening, by a suitable union, and to the low-pressure side of the governor, which usually is set at 90 pounds. When the brake valve is in running position, the air in port *f'* is at main-reservoir pressure; when this pressure reaches 90 pounds it operates the governor, which shuts off steam from the pump. During an application of the brake or while the brake valve is on lap, the pressure in port *f'* is shut off from the main reservoir and is much lower than 90 pounds. Usually it is the same as that in the train pipe, and cannot be raised to 90 pounds; consequently, the low-pressure side of the governor being cut out by the brake valve, does not operate, and the pump continues to work and raises main-reservoir pressure until the high-pressure side of the governor (usually set at 110 pounds and operated by main-reservoir air) stops it.

When a duplex governor is used with the high-speed brake, one side is adjusted for a pressure of 90 pounds (to be used in the event of the engine being coupled to an ordinary quick-action brake using 70 pounds train-pipe and auxiliary pressure) and the other side is adjusted for the higher pressure used with the high-speed brake. A cut-out cock is placed in the pipe that leads to the low-pressure side of the governor, which must be closed when the engine is used with a high-speed brake.

With the high-pressure control apparatus for loaded freight trains, the low-pressure side of the duplex governor is piped to the low-pressure side of the reversing cock, so that when the lower train-pipe pressure is being used the side of the governor that is adjusted to 90 pounds will control the pump. When the low-pressure side is cut out and does not operate, the high-pressure side, which is always connected to main-reservoir air, controls the pump.

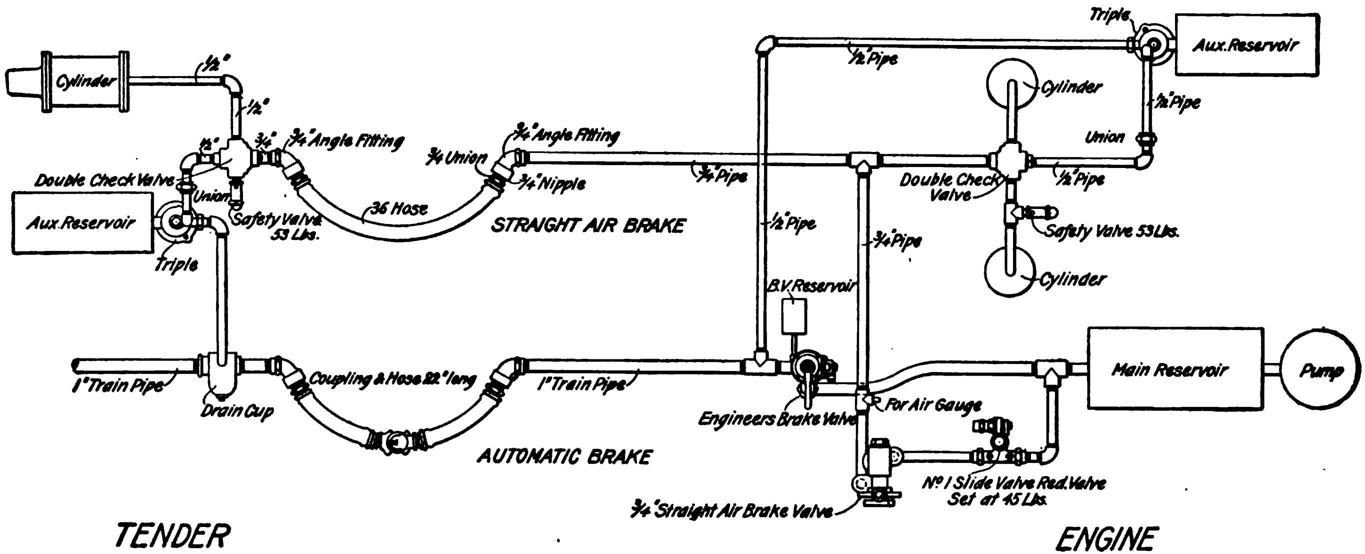
Cylinder
1/2"
1/2"
1/2"
3/4"
3/4" Angle Fitting
Double Check Valve
Union
Aux. Reservoir
Triple
Safety Valve 53 Lbs.
36 Hose
3/4 Union
3/4" Angle Fitting
3/4" Nipple
STRAIGHT AIR BRAKE
3/4" Pipe
1/2" Pipe
1/2" Pipe
3/4" Pipe
B.V. Reservoir
Triple
Aux. Reservoir
Cylinder
1/2" Pipe
Union
Double Check Valve
1/2" Pipe
Safety Valve 53 Lbs.
Cylinder
1" Train Pipe
Drain Cup
Coupling & Hose 22" long
AUTOMATIC BRAKE
1" Train Pipe
Engineers Brake Valve
For Air Gauge
Main Reservoir
Pump
No 1 Slide Valve Red. Valve
Set at 45 Lbs.
3/4" Straight Air Brake Valve
TENDER
ENGINE

FIG. 19

COMBINED STRAIGHT-AIR AND AUTOMATIC BRAKE FOR ENGINES AND TENDERS

GENERAL ARRANGEMENT

57. The Westinghouse Air Brake Company has recently put into service some additional equipment for locomotives already equipped with the automatic brake, which consists of an additional brake valve, a slide-valve feed-valve, a double check-valve for each triple valve, and the necessary piping to convey the air from the main reservoir through the feed-valve to the straight-air brake valve, and from the brake valve to the double check-valves and brake cylinders.

It is so arranged that either the automatic or the straight-air brake can be operated separately from the other, and while the most service can be gotten from it on switch engines, it is a very valuable adjunct on road engines.

A view of the general arrangement of this equipment is shown in Fig. 19. In addition to the automatic brake with its 1-inch train pipe, there is also a straight-air brake valve that is supplied with air from the main reservoir through a $\frac{3}{4}$-inch pipe; in this pipe is located a slide-valve feed-valve that is used as a reducing valve and is set at 45 pounds so that the air pressure at this brake valve is not allowed to get above 45 pounds. A $\frac{3}{4}$-inch pipe leads from the brake valve to the brakes on the engine and tender and is connected to the double check-valve of each. These double check-valves are placed between the triple valve and brake cylinder, and are designed to automatically connect the brake cylinder to either the triple valve of the automatic brake or to the straight-air brake valve and at the same time prevent air passing out of the exhaust port of one system while the other is being operated.

STRAIGHT-AIR BRAKE VALVE

58. Construction.—A good idea of the external construction of the straight-air brake valve can be obtained from Figs. 20 and 21; the former shows the valve in an upright position, and the latter shows it lying down so as to give a view of its bottom.

The pipe from the main reservoir connects with the valve at *X*; the pipe leading from the brake cylinder, through the double check-valves, connects with the brake valve *Y*; while *Z*

Fig. 20

is the exhaust port. *U* and *V* are the cap nuts for the check-valves *8* and *9*, respectively.

The interior construction of this brake valve can be readily seen from Figs. 22 and 23, which represent the brake valve so sectioned and broken away as to show all the ports, passages, and valves to the best advantage, and from opposite sides of the valve.

The shaft *2* extends through the partition *P* and the brake-valve case and is connected to the handle *4*, so that moving the handle rotates the shaft. To prevent leakage along the shaft past the partition *P* when the brake is applied, a specially prepared leather washer *6* is placed between the shoulder of the shaft and the partition. The shaft is then held against the washer by air pressure acting on the end of the shaft assisted by the spring *7*; when the brake is released, the spring *7* holds the shaft against the washer.

FIG. 21

The shaft *2* is used as a means of operating the check-valves *8* and *9*. A slot is cut in the shaft directly above each check-valve, as shown, and a piece of steel having a rounded flange along one edge is riveted in each slot. The flanges are directly above the stems of the check-valves and come in contact with the stems when opening the valves. The flanges are so placed in the shaft that with the handle *4* in its mid, or lap, position, they do not touch the stems and both check-valves *8* and *9* are closed. As the handle *4* is moved to application position, Figs. 22 and 23, the shaft is so rotated as to cause the flange above valve *8* to force the valve from its seat while the other valve *9* remains closed.

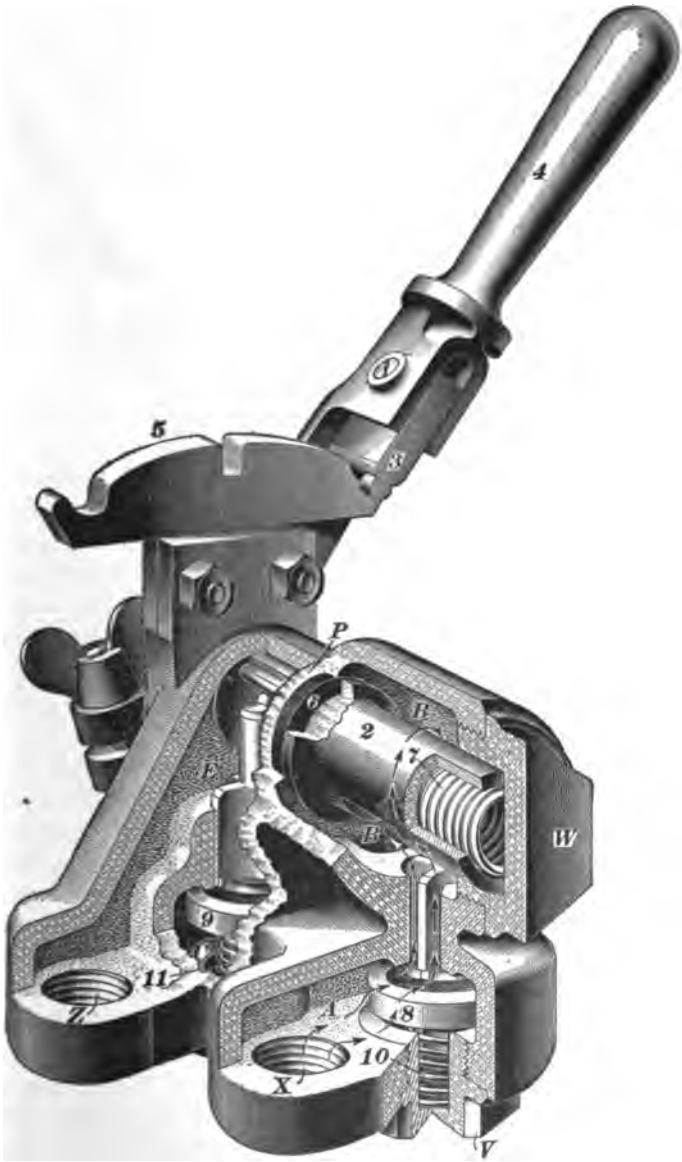

FIG. 22

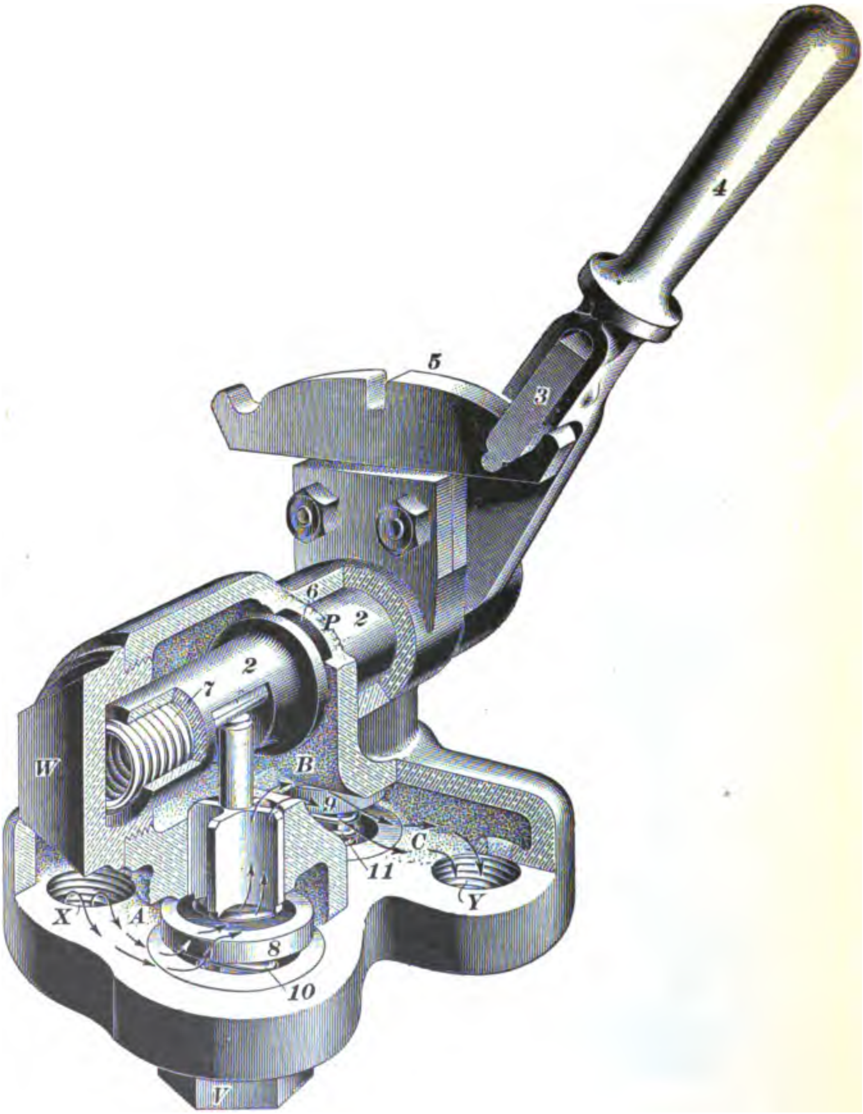

FIG. 23

When the handle is moved to release position, Fig. 25, valve *8* is closed, and the other flange strikes valve *9* and forces it open.

The check-valves *8* and *9* are made interchangeable and are provided with seats of specially prepared leather to better prevent leakage. The tips of the valve stems are made of steel to resist wear. The normal position of these valves is closed; they are held up against their seats by the springs *10* and *11;* the valves must be forced downwards to be opened.

Chamber *A* is the space beneath valve *8*; it is directly connected with the main reservoir connection *X*, and a pressure of 45 pounds is maintained in it.

Chamber *B* is the space above valve *8* surrounding the shaft *2*. It is directly connected with chamber *C*, as shown, and both chambers are always charged to the same pressure.

Chamber *C* is the space beneath valve *9* into which the brake-cylinder connection *Y* opens.

Chamber *E* is the space between the top of valve *9* and the exhaust port *Z*, which opens into it. This chamber is always open to the atmosphere.

59. Operation.—To apply the brake, the handle *4* is moved to application position, Figs. 22 and 23. This movement causes valve *8* to be unseated, and allows air to flow from chamber *A* past valve *8*, into chamber *B* and thence through chamber *C* and connection *Y* into the pipe leading to the brake cylinder, as indicated by the arrows. In this position, valve *9* is closed so that no air can escape from chamber *C* to the exhaust. If the handle is left in this position, the brake-cylinder pressure will equalize with chamber *A* pressure at 45 pounds—that being the pressure at which the slide-valve feed-valve is set to reduce to—and no higher brake-cylinder pressure can be obtained with the straight air.

To make a partial application of the brake, the handle *4* is moved to application position until the desired brake-cylinder pressure is obtained, when it is moved to lap. To

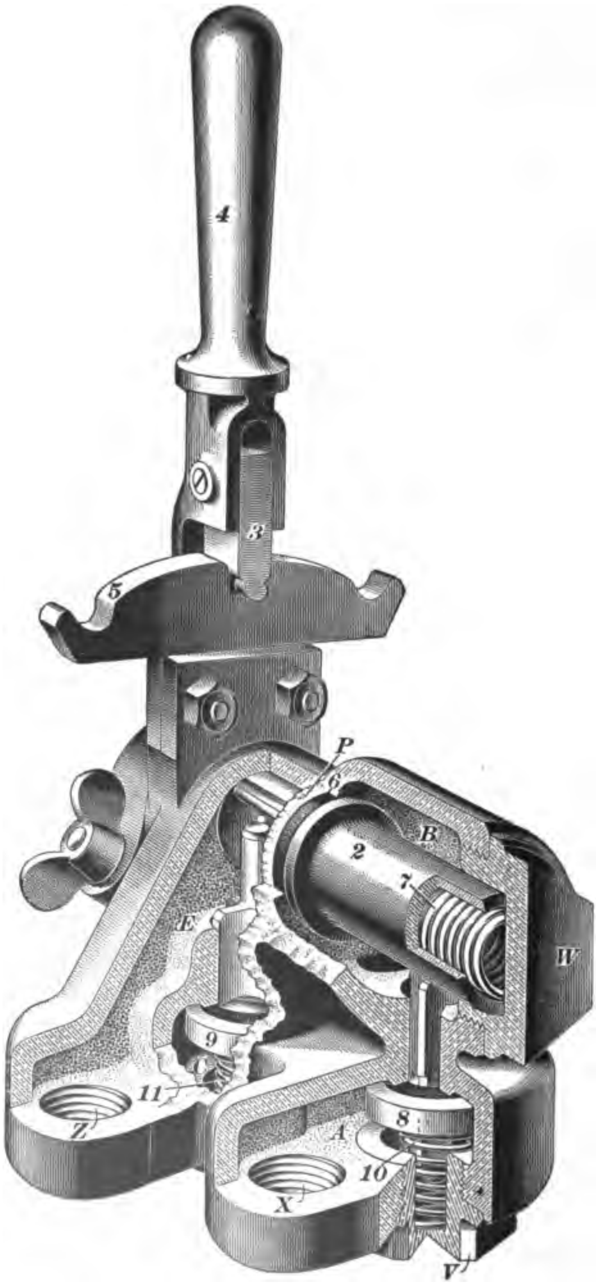

FIG. 24

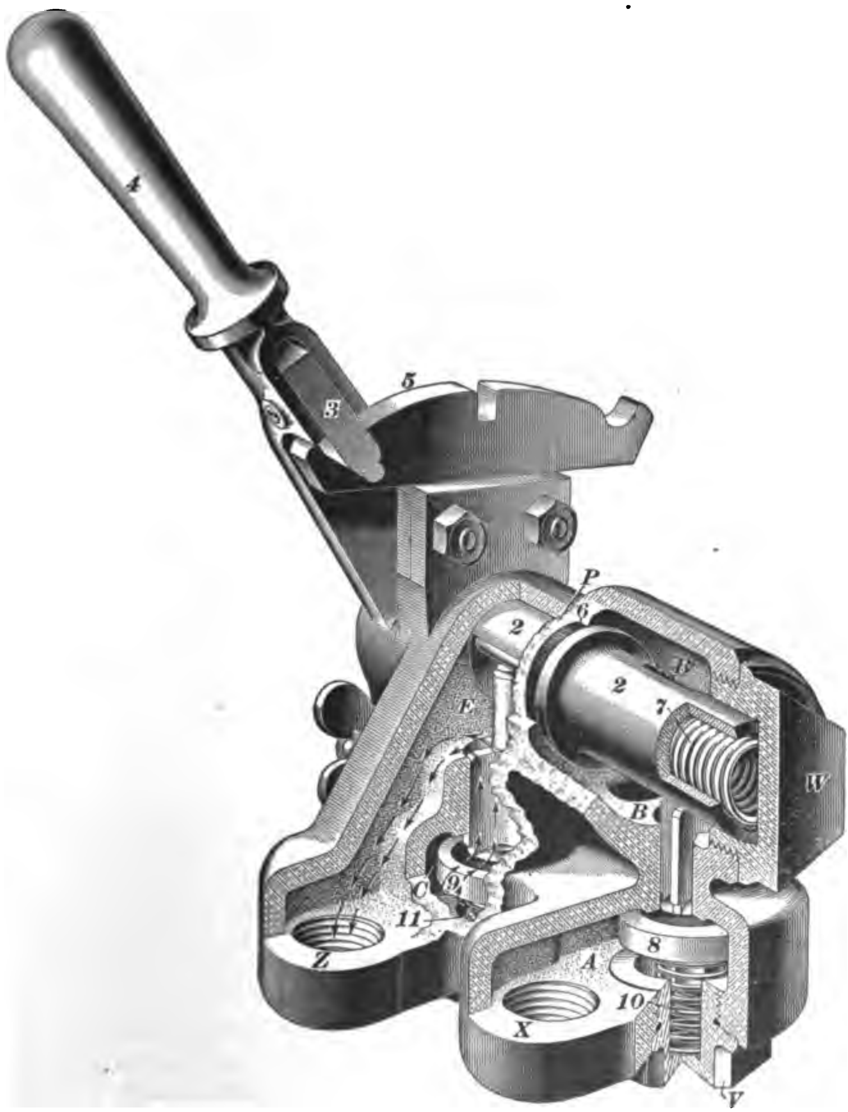

Fig. 25

increase the application, move the handle to application position for the proper increase, and then back to lap.

In lap position, Fig. 24, valves *8* and *9* are both closed; no air can pass from chamber *A* into the brake cylinder, or from the brake cylinder to the atmosphere through valve *9*. Valve *8* is held up against its seat by the combined efforts of spring *10* and chamber *A* pressure; valve *9* is held up against its seat by spring *11* and chamber *C* pressure.

To release the brake, move the handle *4* to release position, Fig. 25. This allows valve *8* to close and cut off the supply of air to the brake cylinder, and the valve *9* is opened and allows brake-cylinder air to escape to the atmosphere through chamber *C*, valve *9*, chamber *E*, and the exhaust port *Z*, as indicated by the arrows.

A graduated release can be made with this brake valve when desired. To partly release the brakes, move the handle to release position until the desired reduction of brake-cylinder pressure is made, and then move it to lap.

The notches at the ends of the quadrant *5* that the latch *3* fits into, are intended to hold the handle in position against the tension of the springs *10* and *11*. If these notches become worn, the force of the spring *11* is liable to return the handle to lap position from release position.

DOUBLE CHECK-VALVE

60. Construction.—The double check-valve shown in Fig. 26 is located in the pipe between the triple valve and its brake cylinder. It is connected to the triple valve at one end, to the straight-air brake valve at the other, and to the brake cylinder at the side opening. It consists of a valve body *2* with a brass bushing *4* pressed into it, inside of which a valve *5* moves easily. On each end of this double check are leather gaskets *7*, which can make air-tight joints at *a* and *b*, according to which end of the bushing *4* the valve has been moved.

In this description of the action of the double check-valve it is to be understood that the automatic brake is to be released when the straight air is applied, and vice versa.

When straight air is used, air coming in from the brake valve at *W* will push the valve *5* into the position shown. Gasket *7* will then make a tight joint at *b* and prevent the escape of air at the exhaust port of the triple valve. The air will then pass through ports *c* to the cylinders.

When the automatic brake is applied, valve *5* moves to the other end of its travel, makes a joint at *a* and prevents any escape of air at the straight-air brake-valve exhaust opening; the air then passes through ports *c'* to the cylinders.

These double check-valves should always be in a horizontal position, so that they will not be moved by gravity. A double

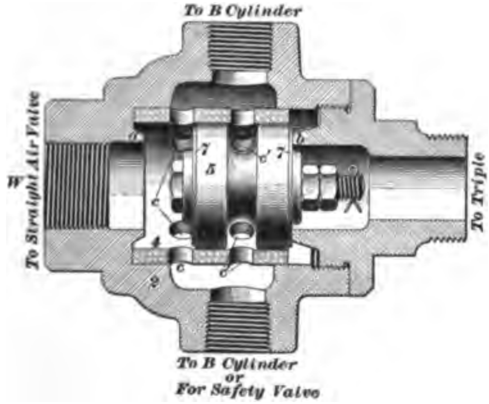

FIG. 26

check-valve is required for each triple valve on the locomotive, one for the tender brake and one for the driver brake.

A safety valve, Fig. 27, is attached to the pipe leading from each double check-valve to the brake cylinder for the purpose of preventing any overpressure in the cylinders. These safety valves are set at 53 pounds.

61. Operation.—To operate the automatic brake, the straight-air brake valve should be in release position. If left on lap and the double check-valve leaks at the seat *a*, or valve *8* leaks, air will gradually charge up the pipe leading to the straight-air brake valve, and when the automatic brake is released the double check-valve may be reversed and stick the brake. Also, if the automatic brake is applied when the straight-air brake is set, it will raise the brake-cylinder pressure above the safe limit and possibly skid the wheels.

The engineman can feel the resistance of the air against the movement of the check-valve *8*, and after a little practice can thus judge the amount of air he admits to the brake cylinder, so that a gradual application can be made and not cause shocks to the cars coupled to the engine. A partial release of the brake can be controlled in the same manner as the gradual or partial application.

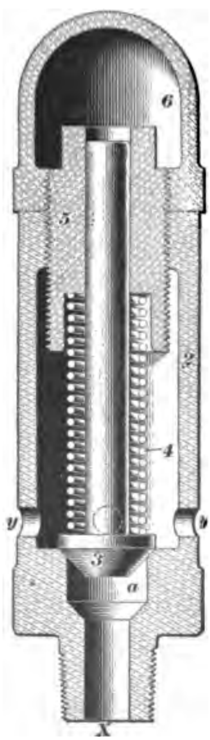

FIG. 27

The size of the ports in the reducing valve in a measure restricts the flow of air from the main reservoir to the brake valve. With an engine having large brake cylinders this helps to make the application gradual. Standard pressures for the automatic brake should be carried in the train pipe and main reservoir, which will insure the triple valve remaining in release position when so desired.

62. The Westinghouse Air Brake Company gives the following instructions for operating the combined straight-air and automatic driver and tender brakes:

Always keep both brakes cut in and ready for operation, unless failure of some part requires cutting out.

Carry an excess pressure of 10 pounds or more in the main reservoir, as this is necessary to insure a uniformly satisfactory operation.

When using the automatic brake, keep the straight-air brake valve in release position, and when using or releasing the straight-air brake, keep the automatic brake valve in running position; this to avoid driver and tender brakes sticking.

Automatic brakes must not be used while the straight-air brake is applied; first release the straight-air brake.

Though the use of the straight-air brake while the automatic brake is applied will not increase the driver and tender brake-cylinder pressure above 45 pounds, yet the release of either brake cannot be assured while the other brake is on lap or application position.

Bear in mind that the straight air on the driver and tender brakes is almost as powerful as the automatic brakes on same, and that each should be used with care to avoid rough handling of the train, or loosening of tires on drivers, in holding down a long grade.

The straight-air reducing valve should be kept adjusted at 45 pounds, and the driver and tender safety valves at 53 pounds. Where a full application of the straight-air brake causes either or both safety valves to operate, it indicates too high adjustment of the reducing valve or too low adjustment of safety valves. Have them tested and adjusted.

63. Advantages.—It is a difficult matter to release the automatic brake on a long train at slow speeds and avoid breaking the train in two or more parts. By the use of the combined equipment, the straight-air brake can be applied on the engine and tender just before releasing the automatic brake. This will hold the engine back solid against the train and prevent the slack running out before the rear brakes release, which is the main cause of break-in-twos when releasing at slow speed.

On switching locomotives the use of the straight-air brake will enable the brake to be applied and released as rapidly as necessary for fast work without the delay between successive applications caused by recharging the auxiliary. The release from the cylinders is almost instantaneous, as the ports through which the air passes from the cylinders are much larger in the straight-air equipment than in the triple valves so the air can exhaust to the atmosphere rapidly. Any leaks that reduce the cylinder pressure with the automatic brake are not felt with the straight-air brake, as the air from the main reservoir maintains the standard pressure of 45 pounds in the brake cylinder while the brake valve is in application position.

NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 3, which was its former title.

AIR-BRAKE TROUBLES

(PART 1)

DEFECTS AND THEIR REMEDIES

THE PUMP GOVERNOR

1. The duty of the **air pump** is to supply compressed air, without which the brakes cannot be operated. Anything that renders the pump inoperative, cuts off the supply of air and makes the air-brake system useless.

The **pump governor** is a throttle valve whose duty it is to automatically control the air pump; hence, any disorder in the governor will affect the working of the pump and make the brake system less reliable and effective, or it may render the system entirely useless until cut out.

IMPROVED GOVERNOR

2. Causes of Failure to Operate.—It is necessary that the governor be sensitive so that it will start and stop the pump promptly and thus maintain a constant main-reservoir pressure. If the governor does not operate the pump properly, and cannot be made to do so by adjusting the tension of the regulating spring, the trouble may be due to any of the following causes: (1) Leaky pin valve; (2) steam valve held open by solid matter on its seat; (3) relief port stopped up; (4) drip pipe frozen or stopped up; (5) pin valve held on its seat by the spring box; and (6) governor piston stuck in bushing.

1. *Leaky Pin Valve.*—This, the most common cause of the governor failing, may be due to the pin valve *b*, Fig. 3,* Part 1, not seating properly; or to solid matter, such as dirt, gum, or scale, holding the valve from its seat. A leaky pin valve allows air at main-reservoir pressure (or train-pipe pressure, as the case may be) to pass from chamber *a* past valve *b* and through passage *d* into chamber *e* above the piston *28*. If the air leaks past the valve faster than it escapes through the relief port *c*, pressure will accumulate in chamber *e* and force the piston downwards, so as to wholly or partially close the steam valve *26*. If the steam valve is closed, the pump will stop; if partially closed, the steam supply will be throttled and the pump will work slower than usual. A slight leak past the pin valve will make the governor less prompt in starting the pump after the pin valve closes, and will be indicated by a discharge of air from the relief port *c* during the time the pump is working.

The pin valve may be removed for cleaning by unscrewing the spring box from the diaphragm body.

2. *Steam Valve Held Open by Dirt or Solid Matter.*—If steam valve *26* is held off its seat, the pump will work slowly until main-reservoir pressure stops it. The pin valve *b* will remain closed while the pressure is below the standard amount and will open at the proper pressure, but the pump will move slowly. A leaky steam valve will also keep the pump moving slowly. When steam valve *26* is partly open, it does not make a tight joint at the upper seat *s*, and steam will pass up around the stem (which is not a steam-tight fit) and blow out at the drip pipe if the pipe is open. Therefore, a blow at this pipe shows that valve *26* is partly open.

3. *Relief Port c Stopped Up.*—The duty of the relief port *c* is to allow the air to escape from chamber *e* when the pin valve *b* closes, so the pump will start promptly. If port *c* is stopped up, this means of escape is cut off, and the air will have to leak past the packing ring *29* and out of the drip pipe. The rapidity with which it will do this depends on the

*All figure numbers used in Sections 3 and 4 refer to the illustrations in *Westinghouse Air Brake*, Parts 1 and 2.

fit of the packing ring; if it fits snug, the steam valve *26* may not open until some time after the pin valve closes. In this case, it is possible for leaks to reduce main-reservoir pressure several pounds before the pump begins to work again.

4. *Drip Pipe Stopped Up.*—If the drip pipe is frozen or stopped up and the stem of the steam valve *26* is worn, steam will feed up into the chamber under the piston and prevent its being forced downwards to close valve *26*. The pump, therefore, will continue to work until sufficient pressure is accumulated in the main reservoir to stop it. A worn steam-valve stem is indicated by steam escaping from the drip pipe—if the latter is not stopped up. If the stem does not leak sufficiently to prevent the steam valve being closed, the pump will continue to work, for air will leak down past the piston packing ring as soon as the pin valve opens, and accumulate under the piston and balance the pressure on both sides. Spring *31* soon raises the piston, and thus opens the steam valve. The pump then starts, and works until stopped by the pressure in the main reservoir, acting in opposition to the steam pressure. Steam valve *26*, when open, is supposed to make a steam-tight joint on the beveled seat of the steam-valve cylinder and thus prevent steam blowing by it into the space beneath piston *28*. If this leak occurs in cold weather, the steam will condense and cause the drip pipe to be frozen up.

5. *Pin Valve Held on Its Seat by Spring Box or Spring 47 Missing.*—If the pin valve is too long, or the edge of the diaphragm body so reduced that the pin valve is held on its seat when the spring box is screwed down tight, the governor will not operate. To test for this defect, slack off the spring box.

If spring *47* is missing, the pin valve will not rise with the diaphragm.

6. *Governor Piston Stuck in Bushing.*—If the governor-piston bushing becomes badly worn, or the cylinder is so damaged that the piston gets jammed in the bushing, the piston will stick at the lower end of its stroke, and the pump will not start. A light tap on the governor or on the steam pipe near it is sufficient to start it operating again.

7. *Diaphragm 42 Cracked.*—A cracked diaphragm will cause the governor to fail to stop the pump when the required pressure is obtained; and if badly cracked, it will render the governor entirely inoperative. It is indicated by a blow at the vent port in the spring box *38*. A new diaphragm must be inserted to remedy this defect.

OLD-STYLE GOVERNOR

3. Defects.—All that has been said about the causes of trouble with the improved governor is equally applicable to the **old-style governor,** with the exception of that part which refers to the relief port *c*. This governor has no steam-tight joint at the top of the steam valve *9*, so a worn steam-valve stem will be indicated by steam blowing out of the drip pipe, if it is not stopped up.

CUTTING OUT A GOVERNOR

4. In case a governor becomes disabled, it may be cut out by placing a blind gasket in the air pipe leading to it, as, for instance, in the union at *z*, or by plugging the small opening that leads into chamber *a*. In either case, pressure will be excluded from chamber *a*, and the steam valve will remain open, thus providing a free passage for the steam through the governor. When the governor becomes disabled, and, for any reason, cannot be repaired on the road, it should be cut out of service, and the pump operated by hand—by means of the pump throttle.

PUMPS

PACKING THE PUMP

5. The life and efficiency of an air-brake pump depends, to a great extent, on the care it receives. With metallic packing, when a spring holds the packing rings in place, the gland nuts should be screwed down solid so they will not work off and let the packing rings shift. The rings must break joints to prevent steam passing by them. When metallic packing is not used, vulcabeston or cord asbestos will give satisfaction. Fibrous packing should be so put in as to fill the stuffingbox evenly and thus give an even pressure on all sides of the rod. Also, care should be exercised not to screw the packing gland nuts too tight, as the rubbing friction between the piston rod and packing, when the latter is pressed too hard against the former, may produce sufficient heat to burn out the packing and cause unnecessary trouble on the road. If the gland nuts can be screwed up sufficiently by hand to prevent a blow, no wrench should be used. A blow should be stopped as soon after it occurs as is possible, as the steam, in escaping, tends to cut a channel through the packing along the piston rod, and thus spoil it.

A **swab** saturated with oil should always be used on the piston rod. This not only serves to keep the rod and packing, but also the air cylinder, in good condition, as some of its oil works down into the latter and helps to lubricate it. If the swab is made to fill the space between the gland nuts it will prevent their working off.

OILING THE PUMP

6. Steam Cylinder.—A sufficient quantity of good valve oil should be used in the steam cylinder to keep the parts well lubricated and prevent groaning. The quantity of oil necessary will depend on the kind of oil used, and also on the pump itself, as some pumps require more than others. If the pump groans constantly, and the pump exhaust or the drain cocks show that considerable water is being worked through the steam cylinder, its dry pipe should be examined for leaks that might allow water to reach the pump and wash out the oil.

7. Air Cylinder.—The quantity of oil to be used in the air cylinder depends to a great extent on the pump, but in any case it should be used very sparingly. The amount should only be sufficient to keep the packing rings free and prevent the cylinder walls from cutting. If too much is used, a gummy deposit is formed in the air cylinder and air passages, and on the air valves, which tends to cause heating; also, oil works back into the brake valve and triples, and causes them to work poorly. Good valve oil is considered best for use in the air cylinder. The oil may be fed to the cylinder by means of a swab on the piston rod, or through the air-cylinder oil cups, *but it should never be fed through the air inlets*, as it will close the air passages, gum up the valves, reduce their lift, and sooner or later result in overheating. Animal or vegetable oils should not be used in the air cylinder, as they gum very readily; also, mineral oils that have a low flashing point, as, for instance, kerosene, should not be used in a hot cylinder, as they generate an explosive gas that ignites at a comparatively low temperature, and may, therefore, cause trouble.

CLEANING OUT THE PUMP

8. Occasionally, the air cylinder of an air pump groans. If oiling the piston-rod packing does not stop it, on arrival at the shop the lower air-cylinder head should be removed, the piston pushed up to the top end of the cylinder, and the cylinder thoroughly cleaned by means of a piece of waste saturated with kerosene. The cylinder should then be wiped out thoroughly with clean waste, and oiled lightly with a good grade of mineral oil or vaseline, after which the head may be replaced.

If the air passages of a pump become gummed up, they may be cleaned out by working a potash solution through the air cylinder. To do this, disconnect the air-discharge pipe at the main reservoir, and make provision for catching the solution as it is discharged through this outlet. Run the pump very slowly, and allow the potash to be drawn in through the air-inlet ports, and thus worked through the pump. Pass the same solution through four or five times, or until the passages are clean. Sufficient clean hot water must then be worked through the pump to thoroughly cleanse it of all potash, since, if any is allowed to remain, it will gradually work back into the brake system, destroy the gaskets, and work mischief in general. If a potash solution cannot be had, use hot soapy water, or even clear hot water alone.

RUNNING THE PUMP

9. Starting.—When first starting the pump, the drain cocks should be opened, and left so until the pump is thoroughly warm; it should be started slowly to allow the water of condensation to escape gradually, and to prevent pounding. No provision is made in the steam end of an air pump for bringing the piston to rest easily by means of cushioning, since, when the pump is working against pressure, the air in the air cylinder acts as a cushion. When the pump is first started, however, there is little or no pressure in the main reservoir, and consequently there is nothing to prevent the pistons from striking the cylinder heads violently if the pump throttle is opened very wide. For this reason, the pump should be run slowly until sufficient pressure is accumulated to cushion the pistons—about 25 or 30 pounds.

After the pump is warm, the drain cocks should be closed, and the throttle may be opened wide enough to run the pump at the required speed. The air-pump lubricator should be started as soon as the pump, since, by oiling the cylinder well at the start, less oil will be necessary afterwards to keep it working smoothly. If a pump groans badly in the top end, the reversing piston probably needs oil; in this case, close the pump throttle, remove the reversing-chamber cap, and pour in a small quantity of good valve oil. See that the oil does not escape through leaky governor connections or through the drain cocks working open.

10. Speed of Pump.—A pump should not be run at a slower speed than 40 strokes a minute. The speed may be increased as occasion demands, but racing should be avoided, as it causes overheating. To get the best results, the speed should not exceed 140 strokes per minute. At that speed a 9½-inch pump will charge 50,000 cubic inches reservoir capacity at the rate of 20 pounds per minute.

If a pump is run too slowly, some of the air, being compressed, will pass by the packing rings, and expand and fill the other end of the cylinder, and thus less fresh air will be drawn in through the suction valve at each stroke; in consequence of this, the pump heats up and its efficiency is greatly reduced. When the pump is run at its proper speed, however, the air has less time in which to pass by the piston packing rings; consequently, the pump heats less and its efficiency is greater.

LIFT OF AIR VALVES

11. The **lift** of the receiving air valves in the 8-inch pump should be $\frac{1}{8}$ inch, and that of the discharge valves, $\frac{3}{32}$ inch. The lift of both the receiving and the discharge valves of the $9\frac{1}{2}$-inch and 11-inch pumps should be $\frac{3}{32}$ inch. All the air valves in the $9\frac{1}{2}$-inch and 11-inch pumps are of the same size; in the 8-inch pump, the receiving valves are smaller than the discharge valves, hence, they must have a higher lift to accommodate the passage of the air.

WORKING TEMPERATURE OF PUMP

12. Conditions Affecting the Temperature.—The **normal temperature** of a pump depends on: (1) the quantity of air it compresses; (2) the rate at which the air is compressed; (3) the pressure against which the pump works; and (4) the temperature of the air before compression.

1. *Quantity of Air Compressed.*—The greater the quantity of air compressed in a given time, the more continuously, or else the faster, the pump will have to work in order to compress it; hence, the greater will be the normal temperature of the pump.

2. *Rate of Compression.*—Experiment shows that the faster the air is compressed, the higher will be its final temperature; also, the faster the pump is run, the less time there is for the radiation of heat between strokes. Hence, since more heat is generated, and less heat radiated at each stroke

of the pump, it is evident that the temperature of the pump must increase with its speed.

3. *Resisting Pressure.*—More power is employed when working against a higher than when working against a lower pressure; therefore, heat is generated at a greater rate. Also, experiment shows that the final temperature of air under compression increases with the pressure.

4. *Temperature of Air Before Compression.*—Experiment shows that air at 0° F. will have a final temperature of about 360° F. when compressed to 90 pounds pressure, while air at 100° F. will have a temperature of about 530° F., the speed of the compressor being the same in both cases.

EXCESSIVE HEATING OF PUMP

13. Causes.—The **overheating** of a pump may be due to one of the following causes: (1) Continuous high speed; (2) excessive pressure to work against; (3) air-piston rings badly worn; (4) air cylinder leaking; (5) main reservoir leaking back into air cylinder; (6) air passages in pump or air-discharge pipe partially stopped up; (7) air valves stuck shut; or (8) too small a main reservoir.

1, 2. *Continuous High Speed, or Excessive Pressure.*—It has already been shown (see preceding article) how either of these causes will result in excessive heating.

3. *Leaky Piston Packing Rings.*—This defect will cause a pump to overheat more quickly and to a higher degree than any of the other causes; consequently, the air-piston packing rings should receive frequent attention.

When the packing rings are badly worn, air can pass by them in either direction; consequently, less air is taken into the cylinder and less forced into the main reservoir at each stroke than if the rings were tight. As the piston moves forwards, it compresses, and therefore raises the temperature of the air in front of it; some of this air then escapes past the piston, and raises the temperature of the incoming air considerably before it is compressed. This results in a still higher final temperature of the air when compressed, and that portion that in its turn escapes past the piston is at a higher temperature, and hence heats the incoming air to a higher degree than in the previous stroke. At each stroke of the piston, the air that leaks by is hotter than in the previous stroke, and raises the temperature of the incoming air still more, until finally the pump is badly overheated.

There is also another effect due to leaky packing rings: Since the pump neither takes in nor discharges as much air as it would if in normal condition, it follows that a greater number of strokes will have to be made to pump up main-reservoir pressure; consequently, the pump will have to work faster or for a longer time than usual, either of which contingencies will help to overheat it.

To test for worn air-piston packing rings, run the pump at about 45 strokes per minute, against full main-reservoir pressure, and place the hand over the air-inlet ports. If on both strokes of the pump air is drawn in during the first part of the stroke only, the suction ceasing during the latter part, it indicates that the packing rings are leaking. The reason the suction ceases before the end of the stroke is that as the piston moves forwards at the beginning of its stroke, a vacuum is created and air is drawn into the cylinder behind it, but, as the piston continues to advance, the air in front is gradually compressed until, finally, it is forced past the packing rings in sufficient quantities to destroy the vacuum and thus the suction.

Another method is to run the pump slowly against full main-reservoir pressure and open the oil cup on the air cylinder; leakage by the packing rings will be indicated by air blowing out of the oil cup as the piston makes its down strokes.

4. *Leakage From the Air Cylinder.*—Any such leakage, either through a leaky or broken receiving valve, or a blow in the piston-rod packing, reduces the amount of air pumped per stroke, and the pump must either be run faster or for a longer time to compress a given amount. A leaky receiving valve is indicated by air blowing back through the valve as the piston moves toward it. Also, it causes the piston to take a quicker stroke when traveling in that direction.

To test for a leaky receiving valve in an 8-inch pump, hold the hand over the air-inlet ports; air will be forced out as the piston moves toward the leaky valve. In the 9½-inch and 11-inch pumps, the air for both ends of the air cylinder enters through the same inlet; consequently, air will be taken in on both the up and the down strokes. Suppose the lower receiving valve *86'* to leak; then, as the piston moves toward the valve, it compresses the air in that end of the cylinder and forces some through the leak. This air, instead of being forced out of the air inlet *W*, Fig. 7, Part 1, passes up through the passage *F*, past the upper receiving valve *86*, and through port *m*, into the other end of the cylinder; consequently, less air is drawn in through the air inlet, to fill this end of the cylinder. Therefore, to test for a leaky receiving valve in the 9½-inch pump, run the pump slowly and place the hand over the air inlet; the suction will be less on the stroke toward the leaky valve. Also, the stroke toward the leaky valve will be quicker than the one from it.

5. *Back Leakage From Main Reservoir.*—This may be due to a broken discharge valve, to a defective valve seat, or to the valve being held from its seat by dirt or gum. Any of these causes will allow air to be compressed into the main reservoir, but, when the pump is reversed, the air will flow back through the defective valve and hold the receiving valve for that end of the cylinder to its seat; consequently, there will be no suction for that end of the cylinder. Also, the strokes of the pump will be uneven, the one toward the defective valve being the slower.

To test for leaky discharge valve, proceed as follows: Pump up full main-reservoir pressure and stop the pump. Open the air-cylinder oil cup and if air discharges from it the upper discharge valve is leaking. If the lower discharge valve leaks, it will be indicated by a continuous discharge of air from the plug hole in lower cylinder head when the plug is removed.

6. *Air Passages or Discharge Pipe Stopped Up.*—Occasionally the air passages or the air-discharge pipe become partly closed with gum and dirt. This increases the back pressure on the pump. It has also another effect: when the air-inlet

passages are choked, the pump does not draw in as much air at a stroke as it should; while a choked discharge pipe requires more power to force air into the main reservoir and increases the leakage past the piston rings. These effects cause the pump to run slower than usual and heat up.

If the air valves have too little lift, the effect will be the same as though the air passages were choked. If only one valve has too little lift, the strokes of the pump will be uneven—the faster stroke being toward the defective valve, if a receiving valve, or from it, if a discharge valve.

7. *Air Valves Stuck Shut*.—If it is a receiving valve, there will be no suction as the piston moves from it; the strokes of the pump will be uneven, the one toward the defective valve being the faster. The pump will probably pound on the fast stroke, and it will also become heated. The reason why the strokes are uneven is that the vacuum, formed in the end of the cylinder in which the stuck valve is, works against the steam pressure on the stroke away from the stuck valve, and with it on the return stroke. If both receiving valves are stuck, there will be no suction on either stroke of the pump; the pump will pound and heat, and the red hand of the gauge will not move forwards. The strokes, however, will be even, but the pump will run faster than usual. If the air-inlet ports become frozen or stopped up, the effect will be the same as though both receiving valves were stuck shut.

If a discharge valve is stuck shut, the strokes of the pump will be uneven, the slow stroke being toward the defective valve; there will be less suction as the piston moves from it, and the pump will heat. The reason why the strokes are uneven is as follows: The cylinder is full of air as the piston starts toward the stuck valve, and, since the valve is closed and the air cannot escape, it is compressed and offers a steadily increasing resistance to the movement of the piston. The stroke from the stuck valve is assisted by this compressed air, which acts like a compressed spring to force the piston along. As the force exerted by the air acts against the steam pressure in the first instance, and with it in the second, it is evident that one stroke will be faster than the other.

Should both discharge valves stick, the pump will run slower than usual and heat badly, and there will be no suction on either stroke, the piston simply churning back and forth in the cylinder. In this case, also, the red hand of the gauge will not move forwards. If the discharge pipe is frozen or stopped up, it will have the same effect as if both discharge valves were stuck shut. When the strokes of the pump are uneven, the pump is generally referred to as being "lame."

8. *Main Reservoir Too Small.*—The use of a small main reservoir in heavy freight service is very often the cause of the pump overheating, since it does not hold sufficient air to release the brakes and recharge the auxiliaries promptly; the pump, consequently, must be worked faster when the brakes are released. A pump is not as efficient when hot as when cold, since air, on entering a hot cylinder, expands, and less is required to fill it at atmospheric pressure; hence, the pump, when hot, must make a greater number of strokes, to do a given amount of work, than when cold.

Of the eight causes of a pump heating, the engineer on the road practically has control over only the first two. Therefore, if the pump runs hot its speed should be reduced as much as possible and yet maintain sufficient air to safely control the train. Also, the piston swab and the air cylinder should be oiled with good valve oil. At the end of the trip, test the pump to determine the cause of overheating and report properly on the work book.

POUNDING IN PUMP

14. Usual Causes.—Pounding in an air pump may be due: to water in the cylinder; to the pump being loose on the brackets that hold it, or the brackets being loose on the boiler; to the main piston striking against cylinder heads; to the nuts *58* of the 8-inch pump, or corresponding nuts on the 9½-inch and 11-inch pumps, working loose and striking the air-cylinder head; or to the air valves pounding on their seats, due to too much lift. The 8-inch pump may pound if the main valve strikes the stop-pin, or if the reversing piston strikes either the reversing-chamber cap, or the bottom of the reversing chamber itself.

Clearance in Pump.—The **clearance** in an air pump is purposely made as small as possible, the air as it is compressed in the air cylinder being relied on to act as a cushion for the pistons, to prevent their striking the cylinder heads. Packing rings that are badly worn, or receiving valves that are stuck, broken, or leaky, will destroy this cushioning effect of the air, and hence will allow the pump to pound. Also, the reversing plate, or the button on the reversing rod, may be worn, or the reversing plate bolts loose, so that the pump is not reversed in time to prevent the piston striking the heads and causing a pound.

Parts Too Long.—If either the stop-pin *50*, the main valve *7''*, or the stem of the reversing piston *23* is too long, it may make the main valve strike the stop-pin and cause a pound. The stop-pin is intended to prevent the main valve dropping down far enough (when steam is shut off) to allow the piston packing rings to expand below the bushings and prevent the main valve rising.

The combined length of the main-valve spindle, reversing-piston stem, and stop-pin should be such that, when the reversing piston is bottomed on its bushing and the valve spindle is tight up against it, there will be about $\frac{5}{64}$ inch space between the bottom of the main-valve spindle and the stop-pin. When this space is provided, there will be no pounding of the main valve.

Reversing Piston Striking.—Before the reversing piston *23* can commence its upward stroke, the reversing valve *16* must close the steam port *a* in the upper steam-cylinder head and connect port *b* with the exhaust passage *c*. Therefore, as soon as the reversing piston, in moving upwards, closes the exhaust port *b*, the steam caught above it is compressed and forms a cushion that stops the reversing piston and main valve quietly.

The small ports near the bottom of the reversing-piston bushing *22* connect the lower end of this bushing with the exhaust passage *f*. When reversing piston *23*, on its downward stroke, closes the lower of these ports, it compresses the exhaust steam caught below it, and provides a cushion for this stroke. If the packing rings are badly worn, the steam, instead of being compressed, will leak by them, reducing or totally destroying the cushion, and allowing the reversing piston to strike the cap, or the bottom of the bushing. Leakage past the packing rings in piston *77* and *79* of the 9½-inch and 11-inch pumps will cause a pound.

9½-INCH PUMP BLOWING

15. Usual Causes.—A **blow** in the steam end of the 9½-inch pump may be due to: (1) a leak past the seat of the reversing valve *72*; (2) the reversing rod worn, and loose in the reversing-valve chamber cap; (3) a leak past slide valve *83*; (4) worn packing rings in either piston of the main valve *76*; (5) worn packing rings in steam piston *65*; or, (6) the gasket between the top cylinder head and the cylinder not making a tight joint.

1. *Reversing Valve Leaking.*—If the reversing valve *72* leaks into port *f*, Fig. 7 (*f*), Part 1, there will be a blow, since steam from the reversing-valve bushing will pass through ports *f* and *f'* and exhaust port *d* out into the atmosphere. This probably will be a light blow, however, and will be continuous, since port *f* connects directly with the exhaust port *d*.

2. *Worn Reversing Rod.*—If the top of the reversing rod were worn so as to be loose in the cap nut *74*, steam could pass by the stem into the cap nut, and thence through port *x* and the passage that runs down alongside the reversing-valve bushing, into the top of the steam cylinder *61*. On the up stroke of the piston, this end of the cylinder is connected with the exhaust; consequently, the leak described will cause a constant, though light, blow during the up stroke.

3. *Slide Valve Leaking.*—If there is a leak past the slide valve *83*, it will cause a constant blow through the exhaust port *d* while the pump is working.

4. *Main-Valve Rings Blowing.*—Worn packing rings in piston *79* of the main piston valve *76* will also cause a constant blow at the exhaust during the time the pump is working, since chamber *E* is always connected with the atmosphere through the passage *t' t*, view (*e*). Chamber *B* (to the right of piston 77) is connected with the exhaust only during the up stroke of the pump; hence, worn packing rings on piston 77 will cause a blow on the up stroke only.

5. *Steam-Piston Rings Blowing.*—Worn packing rings in piston *65* will cause a constant blow at the exhaust while the pump is working, since one end of the cylinder is always full of steam while the other end is connected to the exhaust, and steam can readily pass the packing rings. A leak past the steam-piston packing rings will produce the strongest blow of all.

6. *Leaky Gasket.*—The gasket between the top head and the cylinder may permit steam to escape from the cylinder into the exhaust passage *d' d''*, or into the steam passage *b' b''*. In the first case it will blow on the down stroke only, since the upper end of the cylinder is connected to the steam supply on that stroke only. In the second case, the steam will escape from the upper end of the cylinder through the passage *b'*, port *b*, and out at the exhaust *d* to the atmosphere, on the down stroke. On the up stroke, steam will escape from the passage *b'*, through the leak in the gasket, into the upper end of the cylinder, and thence out the exhaust. In the second case, the leak will cause a constant blow. A leak from passage *a* into the cylinder will blow.on the up stroke only.

8-INCH PUMP BLOWING

16. Usual Causes.—A blow will be produced in the steam end of the 8-inch air pump: (1) if the reversing valve *16* is worn so that steam can escape into the exhaust passage; (2) if the end of the reversing rod in the cap nut *20* is worn and allows steam to escape past it; (3) if the packing rings or the pistons of the main valve *7*, or of the reversing piston *23*, are worn or broken; or (4) if the packing rings of the steam piston *10* are worn or broken.

1. *Reversing Valve Leaking.*—A constant blow will occur if the reversing valve is so worn that steam escapes through the ports *c*, *f f*, and *g* to the exhaust.

2. *Worn Reversing Rod.*—If the end of the reversing rod *17* in the cap nut *20* is worn, steam can escape by it and pass through the passage *x* into the upper end of the steam cylinder *3*. This will cause a blow on the up stroke, since the upper end of the cylinder is open to the exhaust on that stroke.

3. *Main-Valve Rings Blowing.*—If the packing rings in either piston of the main valve are worn or broken, there will be a constant blow at the exhaust, since ports *f f* and *f′ f′* are always in connection with port *g*, which leads to the exhaust at *Y*.

Reversing-Piston Rings Blowing.—If the packing rings in the reversing piston *23* leak, there will be a blow on the up stroke, the steam escaping past the packing rings *24*, thence through the small ports at the bottom of the reversing chamber, and on through the passages *f f* and *g* to the exhaust at *Y*. The blow will occur only during the up stroke, since there is no steam in chamber *d* above the reversing piston during the down stroke.

4. *Steam-Piston Rings Blowing.*—If the packing rings of the steam piston allow steam to escape past them, a constant blow will be produced, as explained in connection with the 9½-inch pump.

9½-INCH OR 11-INCH PUMP STOPS

17. Usual Causes.—It should be remembered that certain defects in the pump governor will cause the pump to **stop**. To determine whether or not the governor is at fault, open the drain cock *106*; if steam escapes freely, the trouble is not in the governor.

If the cause of the pump stopping is not in the governor, it may be due to lack of lubrication or to the failure of some of the parts that reverse the motion of the pump. This may be due to a loose or badly worn reversing plate, or a bent or broken reversing rod, either of which may prevent the movement of the reversing valve. If the air-piston rod nuts work loose or one of them comes off and gets under the air piston, or if an air valve breaks and a piece works into the cylinder so as to stop the downward movement of the piston before it has moved the reversing valve, the pump will stop. To locate these troubles, shut off the steam, wait a few seconds for the steam pressure on the valve to decrease so that this valve will drop down, then turn on the steam again. If it makes an up-and-down stroke and stops, look for the above defects.

The pump exhaust may be stopped by a frozen elbow or some gum and cinders. To test for this, uncouple the exhaust pipe at the union. If pump works all right with exhaust pipe uncoupled, the trouble is due to stoppage in the exhaust pipe.

Bad leaks between the steam passages and the upper end of the steam cylinder, due to defects in the copper gasket that is between the head and the cylinder, will allow live steam to pass to the exhaust through the upper end of the cylinder at each upward stroke. A blow may occur direct into the exhaust port *d* from steam port *a*; this would blow on both strokes. If the pump is not in good condition otherwise, this will so interfere with the steam pressure that the pump will not pump against a high main-reservoir pressure, but will stop.

8-INCH PUMP STOPS

18. Locating the Cause.—Since, in the 8-inch pump, there is no drain cock similar to *106*, Fig. 7, Part 1, a different test must be made to determine whether the governor is responsible for the pump stopping.

If the governor is operated by train-pipe pressure, close the cut-out cock *5* in the train pipe just below the brake valve, Fig. 1, Part 1, and place the brake-valve handle in service position; this gradually reduces the pressure in the chamber *a* of the governor, Fig. 3, Part 1; hence, the force exerted by the regulating spring *41* to close the pin valve *b* gradually increases. If the pump does not start by the time the train-pipe pressure is fully discharged, the probability is that the pump, and not the governor, is at fault. Of course, if the governor has a relief port *c*, a constant blow from this port will indicate that the fault is in the governor.

If the governor is operated by main-reservoir pressure, close the cut-out cock as before, to prevent brakes setting, and disconnect the air pipe from the governor at the union *z*. If the pump then starts, it indicates that the fault lies with the governor.

Another method that may be used when the governor is connected to either main-reservoir or train-pipe pressure, is to remove the cap nut *20* of the reversing-valve chamber or disconnect the steam-supply pipe to the pump at the union *X*, and note whether steam passes the governor freely. If so, the fault is not in the governor.

19. Usual Causes of Pump Stopping.—If the trouble is in the pump, it may be that: (1) the stop-pin *50* is broken or is too short; (2) the main-valve or reversing-piston packing rings are broken; (3) the reversing rod is bent or broken; (4) the reversing plate is loose or worn out; (5) the main piston-rod nuts are loose or broken; (6) the pump is very dry from lack of lubrication; or, (7) the exhaust pipe may be stopped up.

1. *Defective Stop-Pin.*—A stop-pin that is broken or is too short will allow the main valve to drop down sufficiently for the packing rings to expand below the bushings *25* and *26*. This will prevent the valve from taking an up stroke, and the motion of the pump cannot be reversed. In this case, steam will be admitted below piston *10* through the lower steam ports, and the pump will always stop on the upper end of the stroke.

Sometimes, in a case of this kind, the pump can be started by giving it steam and tapping lightly near the bushings. If this does not start it, and circumstances are such that the upper steam-cylinder head can be removed, it may be possible to forcibly raise the valve, although there is danger of breaking the packing rings or spiders in the effort.

If the valve cannot be raised in this way, the only remedy will be to remove the cylinder from the centerpiece and get at it from below. This, of course, would not be attempted on the road.

If the main valve can be raised and the pump started, the governor should be cut out of service by means of a blind gasket, as explained in Art. 4, and care should be taken that steam is not again entirely shut off during the remainder of the run, as, otherwise, the trouble might occur again, especially if the main-valve rings are much worn.

2. *Main-Valve or Reversing-Piston Rings Defective.*—There have been cases in which broken main-valve rings have blocked the valve and prevented its movement, thereby stopping the pump. A bad leak past the reversing piston, due to broken packing rings, will allow so much steam to escape that the pressure in chamber *d* will be reduced considerably, and a sufficient back pressure may be exerted on the under side of this piston to prevent the pump reversing its motion.

3, 4. *Defective Reversing Rod or Plate.*—A broken reversing rod, or a loose or worn-out reversing plate, will also prevent the pump from being reversed.

If every time the pump throttle is closed for a few minutes and then reopened the pump takes an up-and-down stroke and then stops, it is an indication that for some reason the reversing valve *16* has not moved to its lower position, and the pump should be examined for the cause.

5. *Loose Air-Piston Nuts.*—If the trouble is due to none of the above causes, remove the lower air-cylinder head and examine for loose or broken nuts *58* on piston rod, for pieces of broken air valve, or for dirt between piston and cylinder head, which prevents the pump completing its stroke and operating the reversing valve.

6. *Pump Run Dry.*—The part that is most affected when a pump is allowed to become very dry is the reversing piston; and this is consequently liable to stick and stop the pump for want of lubrication. A light tap will frequently start it again, in which case oil should be used freely to protect the pump against the possibility of cutting.

7. *The Exhaust Stopped Up.*—The exhaust of pump may be stopped up due to a frozen elbow or to an obstruction of gum and cinders. To test for this, uncouple the exhaust pipe at the pump union. If pump works all right with exhaust pipe uncoupled, the trouble is due to stoppage in the exhaust pipe.

If either an 8-inch or a 9½-inch pump stops, it can, in some cases, be started again by first closing the pump throttle until all the steam in the pump has condensed, and then opening it quickly. If this is not effective, tap the steam pipe near the governor, also the steam-cylinder head; a little jar will often start the pump, especially if it stopped from lack of lubrication.

An air pump will compress air in but one direction if either a receiving or discharge valve is stuck (open or shut), or if the air-cylinder piston-rod packing blows out.

NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 4, which was its former title.

AIR-BRAKE TROUBLES

(PART 2)

DEFECTS AND THEIR REMEDIES
(Continued)

QUICK-ACTION TRIPLE VALVE

TIME REQUIRED TO CHARGE AUXILIARIES

1. Effect of Size of Feed Groove.—The triple valve, like any other mechanism that is used under varying conditions and is subject to rough treatment, is liable to certain disorders, the cause and remedy of which should be thoroughly understood.

As soon as an engine is coupled to a train, the engineer charges the latter, by forcing air from the main reservoir through the train pipe, thence through the feed grooves of the triples, and into the auxiliary reservoirs. The feed grooves are made of such a size that, with a constant train-pipe pressure of 70 pounds, they will charge an auxiliary from 0 to 70 pounds in about 70 seconds. A train with fifty auxiliaries would charge as quickly as a single auxiliary, if the pump could keep the train-pipe pressure constant at 70 pounds; but, as it cannot do this, more than 70 seconds is required to charge the train. On a train of only four or five cars, the auxiliaries will charge in about the same length of time as a single auxiliary; but, with longer trains, the time of charging depends on the size and condition of

NOTE.—All figure numbers used in this Section refer to the illustrations in *Westinghouse Air Brake*, Parts 1 and 2.

the pump, the number of auxiliaries to be charged, and the extent of leaks in the train pipe and auxiliaries, etc.

Although feed grooves *m* and *n* are of the same size, groove *n* really is the one that limits the rate of charging the auxiliary. Air can leak past the triple packing ring and increase the amount that passes through groove *m*, but all the air entering the auxiliary must pass through groove *n*, because the beveled shoulder of the triple piston makes an air-tight joint with the bushing at all points except at the groove *n*.

The feed grooves vary in size according to the service and the size of auxiliary reservoir they are to charge. In F-27 quick-action passenger triple, and the old F-24 plain triple valve, the feed groove is one-half a circle of $\frac{128}{1000}$ inch diameter. In F-36 quick-action triple, and the new F-24 plain triple valves, the feed groove is one-half a circle of $\frac{88}{1000}$ inch diameter. In F-25 special driver-brake plain triple, used in connection with 12-inch, 14-inch, and 16-inch driver-brake cylinders, and F-46 high-speed plain triples, used for operating driver and engine truck brakes, and F-29 quick-action triple, used in connection with 12-inch and 14-inch cylinders on passenger cars, the feed groove is one-half a circle of $\frac{173}{1000}$ inch diameter. The old F-24 plain triple valve had a larger feed groove than the new F-24 (1900 Catalog G-24) triple on account of the fact that it was originally designed for passenger service with 10-inch cylinders. The new valve is designed for use with 8-inch and 10-inch driver and tender cylinders and is intended to avoid too quickly charging the cylinders located on this portion of the train. The old triple valve fed too fast when located on engine with small cylinders.

The feed grooves in some of the first quick-action triples were made smaller than the present ones; consequently, one of these triples required about 2½ minutes to charge an auxiliary with a constant train-pipe pressure of 70 pounds. Many of the plain triples, on the other hand, had feed grooves that were too large for the volume of the auxiliaries they controlled; consequently, these auxiliaries could be charged in about 40 seconds under the same conditions. The time required to charge auxiliaries should particularly be borne in mind when picking up uncharged cars or when recharging on a grade preparatory to making another application.

2. Auxiliary Charging Too Slowly.—As already stated, the feed groove is of such a size that, with everything in good condition, it will charge an auxiliary from 0 up to 70 pounds in about 70 seconds from a train-pipe pressure of 70 pounds. The time of charging, however, does not depend entirely on the feed groove; the auxiliaries may charge more slowly from any of the following causes: The strainer of the drain cup, at the junction of the cross-over pipe and the train pipe, or the strainer in the triple valve, may be partially stopped up, so as to restrict the flow of air to the triple valve; the feed groove may be partially closed with gum or dirt; or the auxiliary reservoir may leak.

3. Effect of Cinders in the Train Pipe.—If oil, cinders, scale, pipe fins, etc. get into the train pipe, they may clog the strainers and feed grooves, get under the graduating valve and hold it from its seat, unseat the slide valve, cause wear of slide-valve seat and piston packing ring and its bushing, and so increase friction that the triple is not sensitive. Dirt and cinders will work into the train pipe if the brake hose is not hung up properly when not in use; scale may come from the inside of the pipes, or pipe fins, and if not removed by the pipemen may work loose and cause trouble.

4. Effect of Working Conditions.—It will thus be seen that the conditions of strainers and triples may not be the same on any two cars of a train; hence, the time required to charge the different auxiliaries may vary considerably, and, when possible, sufficient time should be allowed for all the auxiliaries to become fully charged before the brake valve is placed on lap, or the brakes applied again. If the valve is lapped while some of the auxiliaries are undercharged, they will continue to take air from the train pipe until they equalize with it, and thus may reduce train-pipe pressure sufficiently to apply the brakes on the cars on which the auxiliaries were fully charged. On the other hand, if a service reduction is made while some of the auxiliaries are undercharged, the latter may not apply the brakes on their cars at the first reduction, and they will continue to take air from the train pipe until they equalize with it; in this case, the other brakes will set harder than is intended.

EFFECT OF TRAIN-PIPE AND AUXILIARY LEAKS

5. Train-Pipe Leaks.—Leaks in the train pipe not only increase the time required to charge the auxiliaries, but, after the brakes are applied, they cause the triples to gradually apply the brakes harder, or, as is usually said, the brakes "creep on." A leak at any part of the train pipe affects all the triples, since the train pipe is continuous throughout the train.

6. Auxiliary-Reservoir Leaks.—As long as the brakes are off and the triples are in release position, the pump will make good any leakage of auxiliary pressure, and no harm will be done, aside from keeping the pump at work to supply the leak. When the brakes are applied, however, and the triple slide valves are in service position, a reduction of pressure in any auxiliary will allow train-pipe pressure to force its triple piston to release position, and release the brake on that car. Then, since the feed groove is open in this position, air from the train pipe will feed into the auxiliary to supply the leakage and to charge the auxiliary to train-pipe pressure; hence, a reduction will be made in train-pipe pressure that will tend to apply the other brakes harder. It is possible, however, for the auxiliary reservoir to leak, and still not cause the brake to "leak off" or release. If the train-pipe leaks reduce train-pipe pressure at the same rate that the leakage from the auxiliary reduces auxiliary pressure, the brake will not leak off; or, if the packing ring *6* is much worn, sufficient air may leak past into the auxiliary reservoir to supply the leakage and thus prevent the brake releasing.

Leakage of auxiliary air at the triple exhaust is generally due to dirt on the seat of the slide valve, a worn slide-valve seat, a leak in the gasket that is between the triple valve and the brake cylinder (see passenger equipment, Fig. 3, Part 2) or in the gasket *15* that is between the triple valve and the auxiliary reservoir or in the auxiliary tube (*b*) of the freight equipment, Fig. 5, Part 2. Leakage from the auxiliary reservoir that does not appear at the triple exhaust may occur through the bleed cock, past the triple-valve gasket *15*, the pipe leading from auxiliary to brake cylinder in the passenger equipment, or through a sand hole in the casting.

IMPORTANCE OF GRADUATING VALVE

7. The graduating valve 7, Fig. 4, Part 2, is the part of the triple that makes it most sensitive. If the triple were made without a graduating valve, but simply had the service or graduating port *z*, and the slide valve were fastened firmly to the stem of the piston, the brakes could still be applied and released, but the triple valve would not be nearly so sensitive, and greater reductions would be necessary to move the parts. For instance, when a reduction of train-pipe pressure was made, the triple would assume service position; but it would not assume lap position again until a sufficient difference of pressure existed between the auxiliary and the train pipe to allow the latter pressure to overcome the friction, not only of the triple piston packing ring, but also of the slide valve, in which case the latter would be forced back far enough to close the service port *z* (lap position). Then, when it was desired to apply the brake harder, a much greater train-pipe reduction than usual would be necessary to move the triple piston to service position again, since the auxiliary pressure would have to overcome the friction of the slide valve as well as of the triple piston.

TRIPLE-VALVE LEAKS AND DEFECTS

8. Blow at Triple Exhaust.—If a blow occurs at the exhaust port of the triple, it may be due to any of the following causes: (1) A leaky slide valve; (2) dirt on the seat of the emergency valve *10*, Fig. 4, Part 2, or a worn-out rubber seat *11*; (3) a leak in gasket *14* or a sand hole between the passage *a* and the chamber *I*; (4) a leak of auxiliary air from chamber *Y* to the passage *d*, owing to defective gasket between brake cylinder head and triple valve of passenger equipment; (5) a leak from the auxiliary through gasket *15* in the freight equipment; (6) auxiliary tube *b*, which leads from the triple through the auxiliary to the brake cylinder, might be leaking; or, (7) there may-be a sand hole through the casting.

1. *Leaky Slide Valve.*—This will generally cause a blow at the exhaust port of the triple, regardless of whether the slide valve is in service or in release position, since, in either position, auxiliary air can feed across the face of the valve into the exhaust cavity *g*, and out to the atmosphere through ports *h* and *k* (see Fig. 4). With a leaking slide valve, the tendency for the brake, when set, is to release itself, since auxiliary pressure is, in that case, being reduced.

Dirt on the seat of this valve will cause a constant leak at the triple exhaust; it will also cause the brake to be erratic in its action; sometimes the slide valve will seat properly and the brake remain set; at others, the dirt will allow auxiliary air to escape to the atmosphere across the face of the slide valve, and release the brake after being applied. A thorough cleaning of the triple is the proper remedy.

2. *Emergency Valve Leaking.*—If the emergency valve leaks, the blow at the exhaust port will cease, as explained above, if the exhaust port is closed by applying the brake.

If a strong, heavy blow exists at the triple exhaust, and the brake will not release on that car, the emergency piston *8* is, perhaps, being held down so as to keep the emergency valve *10* unseated. In this position, the train-pipe pressure raises check *15*, air passes into the brake cylinder through the large ports faster than it can escape to the atmosphere through the slide valve and exhaust ports, and the brake remains applied, because air is entering the brake cylinder faster than it can escape. A light tap on the outside of the triple will loosen piston *8* and allow the emergency valve to seat. If the exhaust valve is held from its seat by some foreign matter, making an emergency application will remedy the trouble, as the dirt will be carried from the seat when the emergency valve opens.

When the emergency valve leaks, air passes from the train pipe into the brake cylinder. If the triple is in release position, the air feeding into the cylinder escapes to the atmosphere through the triple exhaust; if the brake is set, the air cannot escape, and the train-pipe and brake-cylinder pressures equalize and apply this brake hard. If the leaky triple is in a long train, in which the volume of train-pipe air is comparatively great, the brake cylinder will equalize at such a high pressure, on the first light service reduction, that the wheels on that car will probably be slid. Also, this brake may stick when the others release.

3, 4, 5, 6. *The Other Causes.*—When the triple is in release position, the leak will, in these cases, and also in case 2, allow air to reach the brake-cylinder cavity *l*, and pass through the slide-valve exhaust cavity to the atmosphere; but, when the brake is applied, the exhaust cavity of the slide valve no longer connects port *l* with the exhaust port *h*, and so the blow does not occur at the exhaust. In this case, the air continuing to leak into the brake cylinder will apply the brake harder. If auxiliary air leaks into the brake cylinder, the tendency will be to release the brake; while, if the train pipe feeds the leak, the brake will be set tighter, and the leakage will also tend to set the other brakes tighter by reducing train-pipe pressure.

9. Locating Cause of Blow at Triple Exhaust. First charge the brake and close the cut-out cock in the cross-over pipe. If the brake applies, it indicates that the leak is causing a train-pipe reduction, and is due to a leak past the emergency valve, a leak in gasket *11*, or a sand hole between passage *a* and chamber *I*. If the blow is due to dirt on the seat of the emergency valve, it usually can be remedied by making an emergency application of the brakes, as the dirt is thus blown off the valve seat.

If, instead of applying, the brake releases, the leak is an auxiliary leak. Open the cut-out cock in the cross-over pipe and apply the brake lightly. If the blow continues, it indicates a leaky slide valve; if it ceases, the trouble is due to a split auxiliary tube, defective gasket *15*, or a sand hole through the casting in the freight equipment, or defective gasket between triple and brake-cylinder head in passenger equipment. Which of these is causing the blow can only be determined by inspection.

10. Other Common Defects.—The most common causes of trouble in the quick-action triple valve are: (1) strainers stopped up; (2) dirt on the seat of the graduating valve; (3) defective graduating spring; (4) triple gummed up; (5) broken graduating pin; and (6) triple freezing up.

1. *Strainers Stopped Up.*—Sometimes a triple valve will not set the brake on a car in response to either a light or a heavy train-pipe reduction. This may be due to the strainers being partly stopped up; or the triple may be so gummed up and dirty that the triple piston cannot move.

When a quick-action triple in a train applies a brake in emergency, the quick-action part of the triple takes air from the train pipe suddenly. This sudden reduction is sufficient to start the next quick-action triple into emergency, the next one following, and so on throughout the entire train. If two or three cars with dirty strainers, or with plain triples, are placed together in a train, the sudden reduction made by the quick-action triple ahead of these will not be sufficient to work the next quick-action triple immediately behind them, owing to the effect of friction on the flow of air through the train pipe destroying the suddenness of the reduction; hence, the quick-action effect cannot be obtained on these cars or on the ones back of them. Or, if the engineer makes an emergency application with this train, and laps the brake valve too quickly, the air from the rear cars will flow ahead and kick off the head-end brakes, and only a light service application will be obtained on the brakes back of the ones causing the trouble. If the brake-valve handle is left in emergency position a sufficient length of time, full emergency action will be had on the cars ahead, and full service on those back of the ones causing the trouble.

2. *Dirt on the Seat of the Graduating Valve.*—This will not affect the triple in release position, as port *z* is then closed by the slide-valve seat, and it will make no difference whether the graduating valve is open or closed. In lap position, this will cause a leak that allows auxiliary air to escape through the graduating valve and ports *z* and *f* into the brake cylinder, thus applying the brake harder and reducing auxiliary pressure. Whether or not this reduction of auxiliary-reservoir pressure will allow the brake to release depends on the condition of the triple piston packing ring. If it is tight, auxiliary air will continue to leak into the brake cylinder until a sufficient difference of pressure exists between the train pipe and the auxiliary to start the slide valve moving, when it may move to release position and release the brake. If air can leak by the piston packing ring into the auxiliary as fast as it leaks by the graduating valve into the cylinder, the brake will continue to set harder instead of releasing. With a full application of the brakes, the auxiliary and brake-cylinder pressures are equal; therefore, under such conditions, a leaky graduating valve cannot release the brake unless the brake cylinder also leaks and reduces the auxiliary pressure at the same time.

3. *Defective Graduating Spring.*—The effect produced by a weak or broken graduating spring *22* depends on the length of the train. The duty of this spring is to prevent the parts of the triple valve from moving past service position, Fig. 4 (*d*), Part 2, during a service application of the brakes. If the spring is broken or is too weak to stop the parts at service position, and if the train is a short one of five cars or less, these parts will move to emergency position and apply the brake quick action, the other brakes, of course, following suit. With a long train, on the other hand, the graduating spring can be removed entirely and not cause the brake to apply quick action.

This is explained as follows: Since the graduating valve is open, auxiliary air begins to discharge into the cylinder as soon as port *z* of the slide valve arrives above port *f* in the seat. Whether the parts will move beyond this position and cause an emergency application depends on whether the train pipe or the auxiliary pressure reduces the more quickly. A short train pipe contains a comparatively small volume of air; this discharging through the brake valve has its pressure reduced at a much greater rate than the auxiliary pressure that reduces through the graduating valve; as soon as a sufficient difference in pressure is formed, the parts of the triple valve are moved forwards, and the brakes are applied in emergency. With a long train, the volume of air in the train pipe and the frictional resistance to its movement are so much greater that train-pipe pressure cannot be reduced through the train-pipe exhaust of the brake valve as fast as auxiliary pressure is reduced through the graduating valve. As a result, train-pipe and auxiliary pressures remain about equal, and a sufficient difference of pressure is not formed after service position is reached to move the parts of the triples to emergency position.

4. *"Sticky" Triples.*—A sticky triple is frequently the cause of the brakes applying quick action during a service reduction. Generally, when a triple sticks, it does not respond to the first service reduction, nor, in some cases, to the second, and the brake on that car does not set; usually, with the next reduction, the difference in pressure between the auxiliary and the train pipe is such that the piston is torn loose and moves quickly forwards, compressing the graduating spring *22*, and moving the slide valve to emergency position. The sudden reduction caused by the quick-action part of the faulty triple coming into play, starts the next triple into quick action, which affects the one following, and so on throughout the train. If the packing ring is so tight in its bushing as to require a considerable difference of pressure on the piston to move it, it may allow such a reduction of auxiliary pressure that when the piston does move it goes to release position. On a long train, a leaky

packing ring will prevent release of its brake. The air feeds by it and equalizes train-pipe and auxiliary pressures without moving the triple to release position.

5. *Broken Graduating Pin.*—If the pin that fastens the graduating valve 7 to the stem of the triple piston is broken, the graduating valve will be held on its seat by auxiliary pressure, and the brake on that car will not apply until a sufficient reduction is made to move the triple slide valve to emergency position, when it will set quick action. With a light service reduction, the triple assumes service position, but the graduating valve being on its seat, no air can pass from the auxiliary to the brake cylinder, and the brake does not apply on this car. With only a light reduction, the auxiliary pressure acting on the triple piston is not sufficient to compress the graduating spring, but, when a second train-pipe reduction is made, the auxiliary pressure is sufficiently greater than that in the train pipe to force the triple piston out and compress the graduating spring, and the triple then assumes emergency position. If the graduating valve is so badly gummed up that air can only escape very slowly through it, the effect will be the same as though the graduating pin were broken.

6. *Triple Freezing Up.*—Water may collect in the check-valve case of the triple valves; in cold weather, this water may freeze and cause trouble. In thawing out a triple, always remove the drain plug and drain off the water to avoid a recurrence of the trouble. The water found in the brake system comes mostly from the moisture drawn into the pump with the air; as the compressed air cools this moisture is given up, and some of it is deposited in the brake system.

11. Locating the Cause of Trouble.—To locate a sticky triple, or one with a broken or badly gummed-up graduating valve, make a service reduction that is not quite sufficient to cause the defective triple to operate quick action, and then look for the brake that has not set. Cut this one out, and repeat the test to make sure the trouble has been properly located. If all brakes go into emergency with the first light service reduction, the only way to locate the faulty triple will be to first close an angle cock in the middle of the train, and try to locate the trouble in one half first; then proceed in the same manner with the half that is known to contain the faulty triple, and so on until the search has been narrowed down to four or five cars. The brakes may then be applied and the piston of these cars watched to see which one jumps first, or the cars may be cut out one at a time until the trouble is located.

PLAIN TRIPLE VALVE

WHERE USED

12. The plain triple valve is usually found only on engine, tender, and old passenger-car equipments. The parts of this triple correspond to the service parts of the quick-action triple, and they are liable to the same disorders. The graduating spring *10* in the plain triple serves the same purpose as the one in the quick-action triple, but it is comparatively of little importance, since, when a plain triple goes into emergency, it does not affect the other triples, as it does not take air from the train pipe.

LEAKS AND OTHER DEFECTS

13. Leaks.—Among the most common sources of trouble in the plain triple are leaky slide and graduating valves, or a blow at the exhaust port.

Leaky Valves.—A leaky slide valve or graduating valve will affect the brake in the same manner as would the same defect in a quick-action triple.

Triple Exhaust Blowing.—A blow at the exhaust port *k* may be caused by a leaky slide valve *3* or plug cock *13*. As in the case of the quick-action triple, there will be a continuous blow at the exhaust port if the slide valve leaks, regardless of whether the brake is applied or released. If the plug cock *13* leaks and the slide valve is in release position, air from the train pipe entering at *W* will leak by the plug valve into port *e*, thence through port *f*, cavity *g* of the slide valve, and ports *h* and *k*, to the atmosphere. If the brake is set, the slide valve will be in such a position that cavity *g* will be closed to port *f*, and the blow at the exhaust will cease; but the air leaking by the plug cock will pass out to the brake cylinder at *X* and set this brake tighter. With the plug cock leaking, the train-pipe and brake-cylinder pressures will gradually equalize, and, on a long train having a large volume of air in the train pipe, the train-pipe and brake-cylinder pressures might equalize sufficiently high to slide the wheels.

14. Other Defects.—Under this heading may be mentioned defective rings and the freezing up of the triple.

Defective Rings.—A worn piston packing ring *6* will allow air to feed by the piston without moving the piston to release. On a long train, a slow train-pipe reduction might allow auxiliary pressure to feed back through the feed grooves *m* and *n*, and past the packing ring sufficiently fast to keep equal with train-pipe pressure, in which case the triple piston would not be forced out, and the brake would not apply; or in releasing brakes, if train-pipe pressure is increased slowly, as when brakes are released with the brake valve in running position, it might feed by the packing ring sufficiently fast to charge the auxiliary and leave the brake set, thus causing the wheels to slide.

Triple Freezing Up.—Water may collect in chamber *A*; in cold weather, therefore, the latter should be drained frequently by partially unscrewing the lower cap nut *11*.

CARE OF TRIPLES

15. Triple valves should be inspected and thoroughly cleaned and oiled at least once every 6 months. In cleaning the triple, it is a good idea to immerse the triple piston in kerosene while cleaning the other parts. The emergency parts of the quick-action triple should be removed, examined, and cleaned, and then replaced without oiling, as these particular parts are seldom used, and oil would only serve to collect dirt. The slide valve and the chamber in which it works should be thoroughly cleaned, and great care should be exercised to remove any lint from the valve or its seat. The graduating valve and all small ports should be carefully cleaned. After everything else has been attended to, the triple piston packing ring should be cleaned carefully, without being removed from the piston, as in so removing it there is great danger of springing the ring out of true. Before replacing the piston, the ring should move freely to the touch, and in entering the piston into its bushing, care should be taken not to bruise the packing ring.

The graduating stem should be forced in with the thumb to make sure that the graduating spring is doing its work properly. The only parts of the triple that need oiling are the triple piston packing ring, the bushing in which it works, and the face of the slide valve; sufficient oil can be held on the end of the finger to oil these parts. Too much oil is a detriment rather than a benefit, since it collects scale and dirt. The strainer in the triple, and the one in the train-pipe **T**, where the branch pipe couples on, should always be kept clean.

FREIGHT EQUIPMENT

LEAKS AND OTHER DEFECTS

16. Leaks.—In addition to the causes of trouble already given as occurring in the triple itself, the freight equipment shown in Fig. 5, Part 2, is liable to various leaks, as follows:

Defective Gasket.—The gasket *15* between the triple valve and the auxiliary may leak, allowing air to pass from the auxiliary into pipe *b*, and thence to the brake cylinder; or, from the auxiliary to the atmosphere. The leak between the auxiliary and the brake cylinder will cause a blow at the triple exhaust port when the triple is in release position. After the brake is applied and the triple is in service position, however, the leakage of auxiliary air across the gasket, either to the brake cylinder or the atmosphere, will tend to release the brake.

Pipe Leaking in Auxiliary.—If pipe *b* leaks inside of the auxiliary, the same effect will be noticed as if the gasket *15* leaked between the auxiliary and pipe *b*.

Leaky Valves.—A leaky release valve *17* will allow a constant escape of auxiliary air to the atmosphere. With the triple valve in release position, the pump will supply this leak and no ill effect will be noticed aside from the extra work put on the pump; when the brake is applied, however, the escape of air reducing the auxiliary pressure will tend to release it.

17. Other Defects.—There are also certain other defects of the various parts that may give trouble.

Split Sleeve.—The sleeve *3* sometimes splits, owing to the side motion of the push rod that works inside it. When this occurs, the release spring cannot force the brake piston to release position when brakes are released, as it binds in the non-pressure head of the cylinder; consequently, the brake shoes tend to drag on the wheels.

Defective Spring.—If the release spring *9* is weak, it will not force the brake piston to release position properly, especially if the cylinder is somewhat dirty; as a result of this, the piston may stay out after the triple has moved to release position and allowed the air to escape from the cylinder. In such a case, the sleeve and piston will gradually work in when the car is moving, since the jar of the wheels against the shoes will work them away, and cause the rods and levers to assume their normal release positions.

Defective Packing.—If the packing leather *7* is cracked or worn through on the bend of the flange, or if there is any leakage from the cylinder or piping, it will be impossible to set that brake and keep it on, for, as the air enters the cylinder, it will escape past the piston and the brake will gradually leak off. Sometimes a brake in this condition will not apply with a service application, but will do so with an emergency application, after which it gradually leaks off.

A brake with this defect should not be cut out, because in the event of an emergency every bit of available braking power is needed and this brake would then be valuable.

Leakage Groove Stopped Up.—If the leakage groove *a* becomes stopped up with dirt or gum, and the piston travel happens to have been taken up short enough, the pressure on the brake piston may get so high that the wheels on this car may slide when the brakes are applied. If such a car were near the rear of a long train, the train pipe of which leaked, the reduction due to the leak might work the triple piston out far enough to close the exhaust port and allow some of the auxiliary-reservoir air to reach the brake cylinder. The air feeding in slowly would blow through the leakage groove were it open; but, being closed, the brake of this car would gradually apply and might stall the train.

Expander Ring Out of Place.—The duty of the expander ring *8* is to hold the flange of the packing leather against the walls of the cylinder. If the expander ring worked out, due to its not being put in properly, the flange of the leather would drop down, and all air entering the cylinder would probably escape past the piston to the atmosphere.

CARE OF EQUIPMENT

18. Cleaning and Oiling the Cylinder.—When the cylinder head and piston are removed, the walls of the cylinder should be thoroughly cleaned with waste saturated with kerosene, and special care should be exercised to free the leakage groove of all dirt or gum; the cylinder should then be wiped dry.

The expander ring should be removed, and both that and also the groove in which it rests thoroughly cleaned; then, before the ring is replaced, a small amount of oil should be put into the groove. Before replacing the piston, the cylinder walls should be thoroughly oiled or greased, by covering the hand with the oil or grease and then rubbing the walls with the hand. When the cylinder is oiled through the oil plug *16*, care should be taken not to put in so much that, when the piston is moved to release position, the oil will be forced through pipe *b* into the triple, as this will decay the rubber-seated valve and render the triple useless until repaired.

19. Cleaning and Oiling Triples.—In cleaning and oiling triples, all parts should be thoroughly cleaned, as explained under Care of Triples. It is not necessary to oil the emergency parts, and sufficient oil can be held on the end of the finger to oil the slide valve, its bushing, the triple piston packing ring, and the bushing in which it works. The strainer, where the branch pipe couples to the triple, should also be cleaned, as well as the one where the branch pipe joins the main train pipe.

RETAINING VALVE

ITS DUTY AND OPERATION

20. Duty.—The primary object of the retaining valve is to retain a pressure of 15 pounds in the brake cylinder, during the time the triple is in release position, while the engineer is recharging the auxiliaries in descending a grade. It has no effect whatever on any brake except that of the car on which it is placed, and it only affects the releasing of that brake, since it merely retains 15 pounds pressure in the brake cylinder.

The retainers, however, often perform another duty, namely, to keep the slack of a freight train bunched after brakes have been released, and the train is drifting preparatory to making a stop. Two or three of the head-end retainers judiciously used in such a case will often prevent a bad jar at the rear of a train.

The retainer is used on almost all cars in freight service, and, in mountainous districts, on passenger cars also. A retainer, when in service, holds 15 pounds pressure in the brake cylinder, while the brake is released, regardless of whether the piston travel is long or short.

21. Testing.—To test a retaining valve, the handle should be turned up and the engineer signaled to apply and release the brakes. About $\frac{1}{2}$ minute after air ceases to discharge from the retainer, the handle should be turned down, and, if the discharge through port *e* is about normal, the retainer may be considered to be all right.

22. Use on Grades.—In using the retaining valves on a grade, it is best not to raise the handles until the train is rounding the summit of the hill. If the retaining handles are turned up before the summit is reached, and the leakage groove in any of the brake cylinders should happen to be stopped up, any leak that would allow air pressure to reach that cylinder would set the brake, and perhaps stall the train.

GAINS DUE TO USE OF RETAINING VALVE

23. The following remarks will give an idea of the gain effected by using the retaining valve in handling trains on grades: With train pipe and auxiliary fully charged, and the piston travel adjusted to 8 inches, a 5-pound train-pipe reduction will give a brake-cylinder pressure of about 10 pounds; with this brake full-set, a pressure of about 50½ pounds is developed in the brake cylinder. If the retainer handle is now raised, and train-pipe pressure is increased so as to force the triple-valve piston to release position, the auxiliary will be recharged to 70 pounds, while the brake cylinder will retain 15 pounds. This will cause the brake cylinder and auxiliary to equalize on succeeding applications at about 58 pounds, instead of 50, as long as the retaining valve is cut in. This not only gives a greater braking power, but also saves air, since a reduction of only about 15 pounds is necessary to make a full application of the brakes. Then again, with 15 pounds already in the brake cylinder, a 5-pound reduction will give a brake-cylinder pressure of about 33 pounds. It is thus seen that by using retainers, a large gain in braking power is made with the first 5-pound reduction, a gain is made when the brake is full-set, less air need be used to apply the brake in full, and less time is required to recharge after a release is made.

With the piston travel adjusted to 8 inches, an emergency application without a retaining valve develops about 57½ pounds in the brake cylinder, while, with a retaining valve, a brake-cylinder pressure of about 62 pounds is developed. This also shows a slight gain in favor of the retaining valve.

The gain made with a 5-pound train-pipe reduction, after the retaining valve is cut in, appears, at first glance, to be out of proportion, but it should be remembered that, when the retaining valve is not in use and a train-pipe reduction is made, part of the first auxiliary air that enters the brake cylinder escapes through the leakage groove to the atmosphere, before the piston has moved out far enough to close it. Some air also blows past the packing leather before the flanges are forced tightly against the cylinder walls. This does not occur when the retainer is in use, as the 15 pounds retained holds the piston out to cover the leakage groove; it also holds the packing leather against the cylinder walls. The gain therefore is due first to the prevention of loss of air when the air first enters the cylinder, and second to the fact that the cylinder already contains air to a pressure of 15 pounds above atmospheric pressure. When the retainer is not used, the piston must be pushed out each application and the space filled with air to the 15 pounds.

It will thus be seen that a retaining valve is not only an aid in controlling the speed of the train while on a down grade, during the time the pump is recharging the auxiliaries, but it is also an adjunct that causes a more powerful braking force to be developed while it is in use. Also, by using less air at each application, while the retainer is holding 15 pounds, it reduces the amount the pump has to supply.

The figures given are for a retaining valve that holds the full 15 pounds in the brake cylinder. This amount has been found by repeated tests to be the standard pressure for cars in interchange service and gives good results in braking on long grades, without excessive heating of wheels.

LEAKS AND DEFECTS

24. The retaining valve, Figs. 7 and 8, Part 2, will be rendered useless by any of the following defects: A leak at the union in the retainer pipe near the triple valve. A leaky plug cock *6* that allows the air that should be retained in the brake cylinder to leak by the plug valve into port *e*, and thence to the atmosphere. Dirt on the seat of the weighted valve *4*, which will hold the valve from its seat and allow the air to pass by the valve and out to the atmosphere at port *d*. A leak at the joint where the retainer screws on to the retainer pipe, which also allows the brake-cylinder air to escape to the atmosphere. A split in the pipe leading to the retaining valve, or a leaky packing leather in the brake cylinder, will produce the same effect as an imperfect retaining valve. Port *d* being stopped up and retainer cut in; for all the air will be retained in the brake cylinder when the triple moves to release position and the brake will remain set with full force. If the retaining valve is not placed perpendicularly on the car, it will retard the exhaust of air but will not retain the final 15 pounds in the brake cylinder.

A constant blow at the retaining valve, or at the retainer pipe if the retainer is broken off, does not denote a defective retainer. The trouble is in the triple valve, and the retainer or pipe must not be plugged to stop the blow, as all the air will then be held in the brake cylinder, which probably would cause wheels to slide.

D-8 BRAKE VALVE

DEFECTS

25. Testing Excess-Pressure Spring.—If the pump is started with the brake valve in full release, both red and black gauge hands should move up together, as, in this position, main-reservoir, equalizing-reservoir, and train-pipe pressures are all directly connected. If the gauge hands do not stay together, the gauge is incorrect, and should be reported for adjustment. With this valve, the pump governor is operated by train-pipe pressure; consequently, when properly adjusted, it stops the pump when train-pipe pressure reaches 70 pounds, and, with the brake valve in release position, both hands of the gauge should register this amount when the pump stops.

If the pump is started with the valve handle in running position, the red hand should be 20 pounds in advance of the black one; and, when the pump stops, the black hand should register 70 pounds and the red hand 90. If the black hand indicates 70 pounds, but the red hand indicates less than 90, the excess-pressure spring *20*, Fig. 9, Part 2, is either too short or too weak. If the black hand stands at 70 pounds and the red above 90, the excess-pressure spring is too stiff, or the valve *21* needs cleaning, to make it work more freely.

Should the spring *20* break, temporary repairs can be made by lengthening the longer piece by stretching until it will hold the excess-pressure valve to its seat with sufficient force to maintain, as nearly as possible, the proper excess pressure. If the spring breaks near the middle, it may be necessary to force a small piece of wood into the valve *21*, so as to partially fill it and thus compensate for the short spring. The broken spring should be replaced by a new one at the first opportunity.

If the spring is too weak, it should be removed and lengthened by stretching until of the proper strength. If too stiff, it should be shortened by cutting off a piece. If, when the governor stops the pump, the black hand registers either more or less than 70 pounds, and the gauge is correct, the pump governor needs adjusting. To do this, remove the cap nut *39*, Fig. 3, Part 1, and unscrew the nut *40* to adjust for a lower train-pipe pressure, or screw it down for a higher pressure.

26. Brake Valve Fails to Maintain Excess Pressure.—If, with the valve in running position, both hands remain together all the time, and no excess pressure is maintained, the trouble is caused by a leaky rotary valve or by dirt on the seat of the excess-pressure valve *21*. Sometimes this leak from the main reservoir into the train pipe is so slight that it does not affect the excess pressure when the engine is coupled to a train; but, when the engine is alone, no excess pressure can be maintained, as the train pipe equalizes with the main reservoir. In the former case, leaks out of the train pipe compensate for the slight leak into it; while, in the latter, the train pipe is so short that practically no air leaks out, in which case the leak into it soon causes the train pipe and main reservoir to equalize.

27. Testing for Leaky Rotary.—To test for a leaky rotary, close the cut-out cock below the brake valve, and start the pump with the valve handle on lap position. In this position all ports are blocked, and any leak into the train pipe will cause a blow at the train-pipe exhaust, or will be indicated by the black hand of the gauge.

A method that can be used when the brake system is charged is to make a service reduction of 30 or 40 pounds, lap the valve and then close the cut-out cock *5* in the train pipe under the brake valve; any leakage of main-reservoir air into the train pipe will be indicated by a blow at the train-pipe exhaust or by the black hand of the gauge.

Still another method is to fully charge the main reservoir and place the brake valve on lap; drain all air from the equalizing reservoir, the engine and tender auxiliaries, and the train pipe, and see that all bleed cocks are closed; then open the angle cock at the back of tender, and place the end of the hose in a pail of water. Any leakage of main-reservoir air into train pipe will be indicated by bubbles rising to the surface of the water. Although this method will detect a smaller leak, the others are sufficiently accurate, and can be tried more easily.

EXCESS-PRESSURE VALVE FAULTS

28. Dirt on Valve Seat.—If the rotary does not leak, the trouble must be in the excess-pressure valve. In fact, dirt on the seat of the excess-pressure valve is generally found to be the source of trouble when excess pressure cannot be maintained.

29. Removing the Valve.—If necessary to remove the excess-pressure valve *21*, for cleaning or otherwise, close the cut-out cock under the brake valve, and place the valve in service position before attempting to remove it. Closing the cut-out cock retains the air in the train pipe and auxiliaries; while placing the brake valve in service position closes port *f* to main-reservoir pressure, and empties chamber *D* and the train pipe above the cut-out cock *5*, thus removing all pressure from the excess-pressure valve. The valve may then be removed by unscrewing the cap nut *19*. Clean both the valve and its seat thoroughly, being careful not to scrape the face or seat of the valve with any hard material. Before replacing, place the brake-valve handle in running position for a second or two, to blow out any loose dirt or scale that may be in the ports leading to the valve.

30. Valve Stuck Shut.—Occasionally, the excess-pressure valve becomes stuck shut, so that air cannot pass through it into the train pipe when the brake valve is placed in running position. This results usually from the use of too much or poor oil in the air end of the pump; the oil forms a gum that gradually blocks the excess-pressure valve and may also cause trouble in other parts of the air-brake system. With the excess-pressure valve stuck, the engineer very often goes over the road with the brake-valve handle in full release, and with no excess pressure. This is a very bad practice and one that should be avoided. If the excess-pressure valve sticks, take it out and clean it. This can be done in a few minutes, and will cause very much less delay than if it were allowed to remain stuck and the valve carried in full release, as in the latter case the brakes are liable to stick after each application. If the excess-pressure valve *21* works stiffly in the cap nut *19*, the valve will be less sensitive than usual and the excess pressure will fluctuate; that is, when the valve works stiffly, more than 20 pounds excess pressure must be obtained before it will open, while, on the other hand, it will not close until the excess pressure is less than 20 pounds.

31. Leaks.—If the brake valve is left in lap position until a high main-reservoir pressure is pumped up, and is then moved to running position, the train pipe will be overcharged. Under these conditions a leak in the rotary valve or past the excess-pressure valve will allow train-pipe and main-reservoir pressures to equalize, and maintain them equal; and, since with this brake valve the governor is set to stop the pump as soon as a train-pipe pressure of 70 pounds is obtained, the pump will not start again until the pressure in both train pipe and main reservoir is reduced to that amount. Thus, a considerable reduction in train-pipe pressure must take place, which is very liable to cause the brakes to "creep on."

32. High Excess Pressure.—If this brake valve is lapped before train-pipe pressure is obtained, the governor will not stop the pump, which will continue to operate until sufficient main-reservoir pressure is accumulated to stop it. With a high excess pressure, as in this case, care must be exercised in releasing the brakes; that is, do not leave the valve too long in release, for, if the main reservoir is allowed to equalize with the train pipe and auxiliaries, they will be charged to such a pressure—especially with a short train—that it will be liable to burst some of the hose or else slide the wheels when the brakes are applied. On some roads, a duplex pump governor is used to prevent overcharging—one side being set at 70 pounds and operated by train-pipe pressure, the other being set at 90 pounds and operated by main-reservoir pressure. In this way, the pump is stopped as soon as either the main reservoir or the train pipe is charged to the desired pressure. This practice gives very good results.

33. Rotary Valve Turns Hard.—When the rotary valve is hard to turn, it does not necessarily indicate that the valve needs oiling. The nut that holds the handle *8* on may be screwed down so tight that the gasket *12* binds.

34. Peculiarity of D-8 Valve.—A peculiarity of this brake valve is that, if placed in a position midway between the service and the emergency positions—in which position the direct-application-and-supply port *l* is connected by cavity *c* of the rotary valve with the exhaust port *k*—the black hand of the air gauge, instead of dropping back to zero, will indicate the amount of pressure in the main reservoir.

The reason for this is that, in this position, port *j* of the rotary valve is directly above port *g* in its seat; consequently, the equalizing reservoir equalizes with the main reservoir, and, since the black hand indicates the pressure in the equalizing reservoir, it must, in this position, indicate main-reservoir pressure, the same as in full-release position.

PORT *h* AND PORT-AND-GROOVE *e*

35. Size of Port *h*.—The hole through the plug in port *h*, Fig. 9, Part 2, is made of such a size that equalizing-reservoir pressure will be reduced from 70 to 50 pounds, in service position, in from 5 to 6 seconds. If it takes longer than this, the packing ring in the equalizing piston is probably so loose that the train-pipe air leaks into chamber *D* above the equalizing piston, or else the preliminary-exhaust port *e*, Fig. 9, is partially closed with dirt or gum. If port *e* is closed entirely, a service application cannot be made with the brake valve.

36. Small Groove in the Rotary Seat.—This groove, which connects with port *e*, is made of such a length as to connect chamber *D* with the main reservoir (through port *j* and the groove-and-port *e*) from the instant the train pipe is connected with main reservoir through port *a*, cavity *c*, and the supply port *l*, Fig. 9. The combined area of the ports *e* and *g*, which lead to chamber *D*, is such that, ordinarily, chamber *D* will charge as fast or faster than the train pipe. Without the groove, however, the train pipe would be connected with the main reservoir—through port *a* and cavity *c*—both before port *j* made connection with port *e*, in moving the valve to release position, and also after it had broken connection with this port in moving from release position. At such times, therefore, train-pipe pressure would generally increase faster than the pressure in chamber *D*; consequently, a discharge would probably occur at the train-pipe exhaust valve for an instant or two, while moving the brake valve into release position.

RECHARGING SHORT TRAIN

37. When the train pipe is short, as, for instance, on a lone engine and tender, a discharge generally occurs at the train-pipe exhaust valve for a second or two when the brakes are released. The reason for this is that the capacity of the train pipe is small, while the ports through which it is charged are large compared with the area of the ports through which chamber *D* is charged; hence, the pressure in the train pipe increases faster than that in chamber *D*, and therefore raises the equalizing piston. This opens the train-pipe exhaust valve *E*, and a discharge takes place until train-pipe pressure is reduced below the pressure of chamber *D*, after which the valve is closed. This will occur with either a D-8 or an F-6 brake valve.

With a long train pipe, this discharge does not take place, for the reason that the volume to be filled is so much greater that the pressure in chamber *D* increases faster than train-pipe pressure; consequently, the equalizing piston is held on its seat.

F-6 BRAKE VALVE

TESTING

38. Testing the Gauge.—If the pump is started with the brake valve in full release, the hands of the air gauge will move up together until they both register full main-reservoir pressure. The pump governor, when used with this valve, is operated by main-reservoir pressure, and does not stop the pump until main-reservoir pressure is obtained; consequently, the gauge hands will move up together and register the same pressure when the pump stops, since, in release position, there is a direct connection between the train pipe and the main reservoir. If the hands do not move up together, the gauge is incorrect and should be reported.

If the pump is started with the brake valve in running position, the hands of the gauge will move up together until full train-pipe pressure is obtained; the feed-valve attachment then closes and the black hand consequently remains stationary, but the red hand continues to move up until full main-reservoir pressure is obtained.

39. Testing the Pump Governor.—If, with a correct gauge, the red hand indicates either more or less than proper main-reservoir pressure when the pump governor stops, the pump governor needs regulating. This is accomplished by removing the cap nut *39*, Fig. 3, Part 1, and slacking the regulating nut *40* to regulate for a lower, or screwing it tighter for a higher, main-reservoir pressure.

40. Testing the Feed-Valve Attachment.—With the brake valve in running position, and the red hand indicating more than standard train-pipe pressure, if the black hand indicates either more or less than 70 pounds, the feed-valve attachment needs regulating. This is accomplished by removing the cap nut *71*, Fig. 11 (*b*), Part 2, and slacking the regulating nut *70* to reduce, or screwing it up to increase, the train-pipe pressure.

LEAKS AND OTHER DEFECTS

41. Brake Valve Fails to Maintain Proper Train-Pipe Pressure.—If, in running position, the brake valve fails to maintain excess pressure and the black hand gradually moves up until it indicates the same as the red hand, the trouble is due to a leak from the main reservoir into the train pipe, either through the rotary valve, the gasket *32*, the supply valve *63*, or feed-valve case gasket *27* in the feed-valve attachment, or a leaky supply valve or regulating valve in the slide-valve feed-valve.

42. Leaky Rotary Valve.—A leak in the rotary valve generally occurs past the partition *w*, so that main-reservoir air can pass down port *a* and leak into cavity *c* of the valve, thence passing to the train pipe through port *l*. If the rotary valve wears out of true, however, main-reservoir air may leak under the edge of the valve into cavity *c*. Any leak from the main reservoir into the train pipe, therefore, tends to release the brakes when they are applied. The test for a leaky rotary of an F-6 valve is the same as with the D-8.

43. Leaky Gasket *32*.—A leak in the gasket *32* generally allows main-reservoir air to pass from the passage *Xx'* into chamber *D* above the piston *17*, view (*a*). Since the capacity of the equalizing reservoir is small, such a leak will cause the black hand to quickly move up to the position of the red hand when the brake valve is lapped. It will also make the service reductions slower than usual, since the air feeding into chamber *D* tends to maintain the pressure there, and, if the leak is a very bad one, it will prevent any service reduction being made at all. With chamber *D* pressure greater than train-pipe pressure, as in the above case, air will leak past the equalizing piston packing ring *18* into the train pipe.

Gasket *32* may leak between port *l* and chamber *D*. This leak will necessitate more time in making a reduction from chamber *D*, and if the leak is a bad one or the train pipe long so that train-pipe capacity is great, the piston *17* will not raise.

Testing for Leaky Gasket.—A leak in gasket *32* may be detected by placing the brake valve on lap and watching the gauge; if the gasket leaks, the black hand will move up rapidly toward the red hand. A leak through the rotary valve or the gasket *32* can be readily distinguished from a leak in gasket *27* or supply valve *63*, since the former are constant while the two latter occur only when the brake valve is in running position.

To distinguish between a leaky gasket *32* or a leaky rotary, lap the valve, close the cut-out cock, and the black hand will instantly move up even with the red one. Then make a reduction of chamber *D* pressure and note whether the black hand drops the proper amount of 20 pounds in 5 to

6 seconds. If gasket *32* leaks, the black hand will fall very slowly, or not at all, and piston *17* will not raise. If the rotary leaks, the black hand will fall, and piston *17* will raise quickly.

If gasket *32* leaks air from port *l* into chamber *D*, the leak will not show on the black hand of the gauge except during a service reduction, when train-pipe air will pass into chamber *D* and retard the reduction, and if the leak is a large one piston *17* will not raise. To test for this leak from train pipe into chamber *D*, make sure the leak is not a main-reservoir leak. Then close cut-out cock under the brake valve, make a heavy service reduction, and note how rapidly the black hand of the gauge falls. Recharge again, open the cut-out cock, and make a reduction the same in amount as the first and note how the black hand falls. The increase of time for the second reduction will be a measure of the extent of the leak from train pipe with chamber *D*.

44. Leak Past the Supply Valve.—A leak past the supply valve may be due to a leaky valve, to the valve being held from its seat by dirt or gum, or to a defective diaphragm *72*, view (*b*). To determine which of these is causing the trouble, the supply valve must be removed and inspected.

To remove the valve, close the cut-out cock *5* under the brake valve, and place the brake valve in service position, so as to remove all pressure from the feed-valve attachment. Unscrew the cap nut *65*, and remove the supply valve *63*.

To clean the valve, soak it in kerosene, or heat it in steam, and then wipe dry with clean cloth or waste. The valve seat may be cleaned with a piece of wood.

The face of the supply valve is made of soft metal, and, therefore, should never be scraped with any hard tool, as the valve may thus be ruined. In case of a leaky supply valve, grind it to a tight fit by placing carefully on its seat and turning with the fingers while applying a light pressure. The spring box *69* must be taken out and the piston *74* pulled down so as to allow the supply valve to rest firmly on its seat. Do not use emery, as it is unnecessary and will cause trouble if it gets into the brake system. The supply valve cannot stand much grinding. Before replacing the supply valve, put the brake valve in running position for a second or two, to blow out any loose dirt there may be around the supply-valve seat.

45. Defective Diaphragm.—The edges of the diaphragm *72* will be so crushed and squeezed out, if the spring box *69* is screwed up too tight, that the diaphragm will fill the space in diaphragm ring *75* and thus prevent the feed-valve piston *74* moving to the bottom of its travel; consequently, the supply valve will be held from its seat. The spring box *69* should only be screwed up until a firm joint is made with the diaphragm, and not until it makes a tight joint with the feed-valve case *62*.

If the trouble in the feed-valve attachment is in the gasket *27* or the supply valve *63*, it may be readily repaired while on the road, but if in the diaphragm *72*, repairs had better not be attempted until the end of the run. In this case, no excess pressure can be carried, and train-pipe pressure will have to be regulated by means of the pump throttle.

46. Feed-Valve Piston Sticking.—Trouble is sometimes experienced in removing piston *74*, on account of the diaphragm ring sticking in the valve body. In such a case, proceed as follows: Remove the supply valve *63* as described, and replace the cap nut *65*; unscrew the spring case *69*, grasp the stem *66* of the piston in the right hand, and move the brake-valve handle carefully to running position. Main-reservoir pressure acting on top of piston *74* will blow it and the ring *75* out. When replacing the piston, be sure that packing ring *67* works freely, and do not bruise it by pounding in getting the piston back.

47. Leaky Feed-Valve Case Gasket *27*.—A leak sometimes occurs in the gasket *27*, between the feed ports *f' f''* and *i*, which allows main-reservoir air to pass directly into the train pipe when the brake valve is in running position. This can sometimes be stopped by simply tightening the nuts of the feed-valve studs. If it cannot, then close the cut-out cock under the brake valve, place the valve in service position, remove the feed-valve case from the brake-valve body, and replace the blown-out gasket with a temporary one made of pasteboard, part of an old felt hat, or of anything similar that is at hand.

48. Leaky Train-Pipe Exhaust Valve.—Sometimes the train-pipe exhaust valve *E* is held from its seat by dirt or gum; this causes a continual blow at the exhaust valve, and when the brake valve is on lap the brakes will gradually set harder. It may be possible to clean off the seat by closing the cut-off cock *5* and quickly moving the brake valve from full release to emergency and back again a couple of times. Or, it may be possible to blow the dirt off the seat by closing the cut-out cock, making a heavy service reduction, and moving the brake valve quickly to release position. This will instantly overcharge the short piece of train pipe and raise the equalizing piston, causing a strong blow at the train-pipe exhaust that will blow the obstruction off the valve seat. If neither method is successful, the equalizing piston will have to be removed and cleaned.

49. Preliminary-Exhaust Port Plug.—The size of the passage through the plug in preliminary-exhaust port *e* is such that, during a service reduction with the 10″ × 12″ equalizing reservoir, the pressure should be reduced from 70 to 50 pounds, in about 5 seconds. With the 10″ × 14½″ reservoir, it would take about 6½ seconds to make the same reduction. If the pressure does not reduce at this rate, the trouble is due to one of the following causes: Either the size of this passage is reduced owing to the presence of gum and dirt; or, the piston packing ring *18* is so worn that train-pipe air can pass by it into chamber *D*; or, the gasket *32* is leaking. If the opening in this plug has been enlarged it will permit so rapid a discharge from chamber *D* as to cause piston *17* to reduce train-pipe pressure fast enough to give an emergency application on a short train.

50. Defects of Slide-Valve Feed-Valve.—Like any other piece of mechanism, the slide-valve feed-valve is liable to develop defects, which, while they may not be common to it, yet may occur occasionally; hence, it is well to understand the effects of possible defects on the operation of the feed-valve. The possible defects are: (1) leaks past the cap nut *53* or *61*, (2) leaky supply valve *55*, (3) leaky regulating valve *59*, (4) piston *54* too loose a fit, (5) piston *54* too tight a fit, (6) spring *58* broken, (7) regulating valve *59* gummed up, (8) ruptured diaphragm *57*.

1. *Leaky Cap Nuts 53 or 61*.—Leakage past either cap nut will produce the same effect. As long as the leakage is less than the leakage past the piston *54* into chamber *E*, it will simply increase the interval of time between the closing of the regulating valve *59* and the closing of port *b* by the slide valve *55*; the train pipe may thereby be somewhat overcharged each time the feed-valve acts.

If the leakage is greater than that occurring past piston *54*, the pressure in chamber *E*, instead of being increased to chamber *F* pressure when the regulating valve *59* closes, will be reduced still further; the supply valve *55*, therefore, will remain open all the time, and the feed-valve will be inoperative. To overcome this defect temporarily, use a rubber washer if at hand, or, if not, one of leather or pasteboard or some similar substance.

2. *Leaky Supply Valve 55*.—A leaky supply valve *55* will allow main-reservoir air to leak into the train pipe after the supply valve has covered port *b*. If this leakage is greater than the train-pipe leakage, train-pipe pressure will be increased above standard pressure.

3. *Leaky Regulating Valve 59*.—A leak past this valve may be due either to a defect in the valve or its seat, or to dirt between the valve and its seat. If the leakage is less than that occurring past the piston *54*, no especial harm will result, since the pressure in chamber *E* will be maintained. If, however, the leakage is greater than that past piston *54*, chamber *E* pressure will be reduced thereby and maintained about equal to train-pipe pressure, and the supply valve *55* will be held open by chamber *F* pressure. The feed-valve, therefore, will be inoperative, and train-pipe and

main-reservoir pressures will equalize. If the trouble is due to dirt, cleaning will overcome it; otherwise, the valve must be reseated.

To test for a leaky supply valve *55*, or regulating valve *59*, proceed as follows: First make sure that there is no leakage past the cap nuts *53* and *61*, as a leak past either cap nut will tend to produce the same effect as a leak past the supply valve *55*, or the regulating valve *59*. If the cap nuts are tight, close the cut-out cock below the brake valve and move the brake-valve handle to service or emergency position so as to remove all pressure from the feed-valve attachment. Next unscrew the spring box and take out the diaphragm spindle and diaphragm and move the brake valve to running position. There will be a severe blow from port *a* for a second or two, and then, if everything is in good condition, the blow will stop and not occur again. If, however, the blow continues, test for leakage past the regulating valve by holding a light or finger in front of it. If the regulating valve is tight and air escapes continually from port *a*, the supply valve *55* is leaking.

4. *Piston 54 Too Loose a Fit.*—If the fit of the supply-valve piston *54* should be made so loose that the leakage past it is more than the regulating valve *59* can accommodate, the pressure in chamber *E* will remain equal to that in chamber *F* and the supply valve *55*, consequently, will remain closed after the regulating valve *59* has opened. This will make the slide-valve feed-valve inoperative, since the only way air can get through the slide-valve feed-valve into the train pipe will be past the regulating valve *59*.

5. *Piston 54 Too Tight a Fit.*—If this piston is fitted too tightly, or if it becomes too tight fitting through grease, oil, or gum, the proper leakage past the piston will be interfered with and the interval between the closing of valve *59* and valve *55* will be increased, thereby tending to overcharge the train pipe.

The piston is made slightly less in diameter than its cylinder, and it is provided with two grooves that are intended to prevent undue leakage. If too much oil is used in the feed-valve, it will collect in these grooves and form an oil packing that may so limit the leakage past the piston as to very seriously interfere with the proper working of the feed-valve, and the train pipe may become overcharged every time the regulating valve closes.

6. *Spring 58 Broken.*—If spring *58* is broken or too weak to force piston *54* and slide valve *55* back to closed position, the feed-valve will be inoperative. The port *b* will remain uncovered, and main-reservoir pressure will equalize with the train pipe. If this spring is too weak, the difficulty may be temporarily overcome by stretching the spring or using washers between it and the cap nut.

7. *Regulating Valve 59 Gummed Up.*—If the regulating valve is so gummed up that air from chamber *E* cannot escape past it as quickly as air from chamber *F* leaks into chamber *E*, supply valve *55* will be periodically closed and opened as long as regulating valve *59* is open. If valve *59* should become entirely closed, the pressure in chamber *E* and *F* will soon equalize and the valve *55* will move to closed position and remain there, thus rendering the feed-valve inoperative. Cleaning, of course, will overcome this difficulty.

CARE OF ENGINEER'S VALVES

51. General Remarks.—There is a wide range of variation in the time a rotary valve will continue working satisfactorily in general service. Some valves will run 3, 4, or 6 months, while others will not run as many weeks.

Tallow or vaseline are good lubricants for the rotary, but oil of any kind should be used sparingly on any part of the brake apparatus, except the steam end of the pump. Oil that has a tendency to gum should never be used.

Whenever the rotary valve works hard, the brake valve should be taken apart and the rotary cleaned and oiled, to prevent cutting. At the same time, the packing ring *18* should be cleaned, but without removing it, since, if removed, it is liable to be sprung out of true, which will necessitate refitting to the bushing in which it works. Also clean the stem and seat of the valve *E* thoroughly, but leave no oil on either, as it will catch particles of dirt and scale and cause trouble.

52. Rotary Working Hard.—The chief causes of a rotary working hard are: too free use of oil in the air end of the pump, or the use of poor oil; constant use of the emergency position of the valve, which tends to draw dirt and scale from the train pipe on the rotary seat; a hot pump, the heat from which will cake the oil on the rotary seat; the nut *7*, Fig. 11 (*b*), Part 2, or the corresponding nut in Fig. 9 (*a*), being screwed down so tight as to cause gasket *12* to bind on the top casing of the engineer's valve, or the gasket may be worn so thin that the rotary key *11* rubs against the valve body.

53. Cleaning the Feed-Valve Attachment.—In cleaning the feed-valve attachment of the F-6 valve, or the excess-pressure valve of the D-8 valve, remove all dirt and gum and clean the valve chambers thoroughly; then blow out, by turning the brake valve to running position. Any gum present should be softened, if possible, and wiped out instead of being scraped out with a tool, which is liable to scratch the valve seat. The packing ring *67* of the feed-valve piston *74* should be cleaned without removing, and then oiled a little. In putting the parts together, do not screw the nuts that fasten the rotary-valve handle too tight; and, in screwing the lower casing *69* of the feed-valve attachment on the F-6 valve, be sure that there is an opening of about $\frac{1}{32}$ inch between the upper and lower parts of governor body, since screwing the lower part up tight crushes the gasket *72*.

THE EQUALIZING RESERVOIR

ITS IMPORTANCE

54. The equalizing reservoir plays a very important part in the handling of the brakes in service applications. Its duty, as explained in *Westinghouse Air Brake*, Part 2, is to increase the capacity of chamber *D* in the brake valve an amount sufficient to enable small service reductions to be made, so as to apply the brakes gradually.

EFFECTS OF LEAKS

55. Slight Leaks.—A slight leak in the equalizing reservoir or its connections constantly tends to reduce the pressure in chamber *D*; the effect of such a leak depends on the position of the brake-valve handle.

In full-release and running positions there will practically be no effect, aside from the fact that a little extra air will have to be supplied by the pump.

When the valve is moved to service position, the leak acts to help the reduction made by the engineer, and consequently a harder application of the brakes than is intended will be made.

When the valve is moved to lap position, the leak continues to reduce the pressure in chamber *D*; train-pipe pressure then raises the equalizing piston and air escapes to the atmosphere, setting the brakes harder. A slight leak from the equalizing reservoir, therefore, causes a blow from the train-pipe exhaust valve when the brake valve is in lap position, and the longer the train pipe, the stronger the blow will be.

56. Bad Leaks.—A bad leak, such as would be produced by a split or broken pipe to the equalizing reservoir or air gauge, will allow chamber *D* pressure to escape entirely, and the train-pipe exhaust valve will be held open by train-pipe pressure until it has all escaped. This will result in a full application, or, in some cases, an emergency application of the brakes. Such a leak, therefore, will render the brake system useless until it is stopped.

Leak in Equalizing Reservoir.—If the leak occurs in the equalizing reservoir, or in the pipe leading to it, place a blind gasket in the union at *T* of the brake valve, Figs. 9 and 11, Part 2, plug the train-pipe exhaust elbow *25* or take it out and plug the opening. The plug in the equalizing reservoir can be used for this purpose. Use the brake valve carefully in emergency position (like the old three-way cock) in making service stops. In all other respects, the brake valve should be operated as usual, since placing the gasket and plug in the places mentioned does not affect its working in release, lap, running, or emergency positions.

Defective Gauge Pipe.—If the leak is due to a split or break in the pipe leading to the air gauge, the trouble may be remedied by putting a blind gasket in the union *W* of the brake valve. This will cut out the black hand of the gauge, but will not in any way affect the working of the brake valve.

MAKING SERVICE STOPS FROM EMERGENCY POSITION

57. Considerable care and judgment must be exercised in making service stops from emergency position. If the exhaust port is opened too wide, or opened or closed too rapidly, trouble is almost sure to follow. The exhaust port should be opened very gradually and just sufficiently wide to make, as nearly as possible, the usual train-pipe reduction; if opened wider, too great a reduction will be made and rough handling of passengers or freight will probably result.

Opening Exhaust Port Too Rapidly.—If the exhaust port is opened too wide or too rapidly, a quick reduction is made in the forward end of the train pipe, which may operate the emergency part of the triple—if it does not, it sets the front-end brakes before the back-end ones; and the longer the train pipe, the greater this effect will be. This tends to retard the front cars, and the rear ones, which are not retarded, crash into them with great force if the train is very long, and damaged draft rigging or freight is the result.

Closing Exhaust Port Too Rapidly.—If the exhaust port is closed too quickly, the forward brakes may be "kicked off." When once in motion, the long column of air in the train pipe cannot be stopped instantly; consequently, if the exhaust port is closed very rapidly, the air will continue to flow forwards after it is closed and may raise the pressure in the front end of the train pipe sufficiently to release or kick off the forward brakes. If the exhaust port is closed so quickly that the train-pipe pressure is not equalized the whole length, the triple valves on the front end will equalize the auxiliaries and train pipe at a lower pressure than on the rear cars, and, when the train-pipe pressure finally equalizes the whole length, the pressure in the train pipe on the head cars will be greater than in the auxiliaries on those cars, thus causing the triples to move to release position and release some of the head brakes.

NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 5, which was its former title.

OPERATING AND TESTING TRAINS

OPERATING AND TESTING

THE MAKE-UP OF A TRAIN

1. The smoothness and ease with which a freight train can be handled, as well as the facility with which it can be stopped by means of the air brake, depends, to a considerable extent, on the way the train is made up. The make-up of a passenger train, on the other hand, affects the handling of the train so very slightly that, so far as the braking is concerned, no particular attention need be paid to it.

GENERAL CONSIDERATIONS

2. The conditions of braking on passenger and freight trains differ greatly. On a passenger train there is no free **slack** between cars to bother; both the load and the braking power are distributed quite uniformly throughout the length of the train; the brakes are kept in good condition and the piston travel maintained within proper limits; train-pipe, auxiliary, and brake-cylinder leakage is very slight; and the length of the train pipe is such that, practically, the brakes set simultaneously on all parts of the train.

With a freight train, on the other hand, there is a great deal of slack, which must be handled properly to avoid severe shocks; the load is generally distributed unevenly throughout the train; the brakes generally do not receive

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sufficient attention to keep them in as good condition as those on a passenger train; and the brake-piston travel is seldom uniform. Consequently, the braking force, even on an all-air train, is not uniform throughout its length; the leakage in the brake system is greater in freight than in passenger service; and, lastly, the train pipe on a freight train is generally so long that the retarding effect of friction on the flow of air through it is sufficient to cause an appreciable interval of time to elapse between the operation of the first and last brakes. The increased diameter of the freight-car train pipe helps this last trouble in a measure.

3. Effects of Slack.—There is always free slack in a freight train that must be handled with great care to prevent severe shocks, which injure both drawbars and freight. The slack gives less trouble on all-air than on part-air trains, as each car has an air brake, which permits of the retarding force being applied to, or removed from, each car at nearly the same instant; the slack, therefore, cannot gather or run out quickly, and shocks when they occur are less severe.

The engineer has some direct control over the slack that is between the air cars, but he has no control over that between the non-air cars; consequently, the free slack back of the air cars must be taken up every time the brakes are applied, and be run out at every release. Whether a shock will occur either in "bunching" or "stretching" a train, depends on how quickly it is accomplished. In bunching a train, if the first service reduction is made sufficiently heavy to bunch the train quickly, the last cars will run up against the others with great force; and the heavier the last cars are loaded, the greater will be the shock and consequent damage. On the other hand, the lighter the rear cars, the less the shock will be; hence, a part-air train can be handled more easily and with less chance of damage to freight if the heavily loaded cars are placed next to the air cars, and the less heavily loaded ones and empties next to the way car. In stretching a train after the slack has been bunched, the head end must be started gradually until all the slack has run out. If started too rapidly, by the time the rear-end cars are started the slack between cars will run out so quickly that the draft shaft rigging may be injured. The compression and expansion of drawbar springs cause shocks when brakes are released. Unequal braking power and unequal loads on the cars tend to compress some springs more than others; these kick out the slack in expanding and produce shocks that are most serious at slow speeds.

4. Effects of Unevenly Distributed Load.—When a freight train is made up of both loaded and empty cars, and the loaded cars are distributed haphazard throughout the train, the load is said to be *distributed unevenly*. Since it is harder both to start and stop loaded cars, shocks of a more or less serious nature occur at different points of the train every time it is started, stopped, or has its speed retarded suddenly. This trouble can be avoided by placing all loaded cars together at the head end of the train.

5. Effects of Unequal Piston Travel.—To handle freight trains smoothly by means of the air brake, it is essential that the travel of the brake-cylinder pistons be kept within the proper limits. If the piston travel on some of the cars in a train is too short, while on others it is too long, shocks will occur at a number of points in the train every time the brakes are applied or released. This is due to the fact that the brake cylinders having a short piston travel apply their brakes harder at each reduction and equalize with their auxiliaries sooner, and at a higher pressure, than those having a long piston travel; also, when fully applied the triples move to release position later than the long-travel brakes. This causes the slack to be gathered at some parts of the train, and to run out at others, every time the brakes are applied or released, producing a surging of the cars that results in shocks, which make smooth handling of the train difficult.

6. Effects of Length of Train Pipe.—The length of train pipe also has considerable influence on the ease with which the train can be handled. Frictional resistance tends to retard the flow of air through the train pipe, and the longer the train pipe the more troublesome this retarding effect becomes. When conditions are normal, the retarding effect is such that in making an ordinary service reduction on a fifty-car air freight train, the pressure in the head end of the train pipe is reduced about 3 pounds before the reduction begins to be felt at the rear end; while, on releasing brakes on such a train, there may be a difference of pressure of about 10 or 12 pounds between the two ends, the pressure at the head end being the higher. This difference of pressure causes the head-end brakes to both apply and release sooner than the rear-end ones, with the result that, on a long train, some severe shocks will be produced if the brakes are not handled with skill and judgment.

MAKING UP FREIGHT TRAINS

ALL-AIR TRAIN

7. **All-air trains** can be handled much more smoothly and satisfactorily if properly made up. When the cars are mostly equipped with quick-action triples, care should be taken not to place together two or three cars that either have plain triples or have their brakes cut out, or are merely piped, since, in cases of emergency, it will be impossible to obtain the quick action of the triples back of them. Besides, the cars without brakes operating will crowd against the others, compressing the drawbar springs and causing a severe surge when the brakes are released.

PART-AIR TRAIN

8. In making up a **part-air train,** all the air cars, whether loaded or empty, should be placed together at the head end of the train and cut into service. Every air brake possible should be employed in braking, since the more in use the more smoothly the train can be handled; besides, they may be needed to make a quick stop in an emergency. Do not place together three or four cars with plain triples, or with brakes cut out, if most of the cars have quick-action triples, but distribute them among the quick-action cars. As to the non-air cars, the best results will be obtained if they can be so arranged that the loaded ones are next to the air cars and ahead of the empties. Empty non-air flat cars are liable to be damaged if placed ahead of loads next to the air cars; they should come next to rear end.

TESTING BRAKES

ENGINE EQUIPMENT

9. The Air Pump.—Any defects in the engine air-brake or signal apparatus should be reported at the end of the trip, so that the necessary repairs can be made before the engine is again called into service. If necessary, tests should be made to locate the defects.

The air pump should be tested under its usual head of steam as follows: With the pump running at normal speed, note the time at intervals of 10 pounds, while the main-reservoir pressure is being raised from 40 to 90 pounds. If the pressure is pumped in the usual time, during which the pump shows no sign of disorder, the presumption is that it is in good condition and no further tests will be necessary. If the test shows that the pump is not in normal condition, it may be due to leaky packing rings, leaky receiving valves, back leakage from main reservoir, air valves being stuck, or the strainer at air inlet stopped up. Tests, as in *Westinghouse Air Brake*, Part 3, should be made to locate the cause.

10. The Pump Governor.—The governor should be tested to see whether standard pressure is obtained when it stops the pump; also, to see whether it will start the pump promptly when a light reduction of not more than 2 pounds is made in the pressure that operates the governor. If the pump stops either before or after standard pressure is obtained, the governor should be adjusted, by means of the regulating nut *40*, until it regulates the pump properly.

If the governor does not start the pump promptly when a slight reduction is made, it may be due to a leaky pin valve, to the relief port *c* being stopped up, or (in governors not having this relief port) to the governor piston packing ring being too tight.

11. The Brake Valve.—The brake valve should first be tested for leaks from main reservoir into the train pipe. In the D-8 valve this will occur past the rotary valve, so that a test for a leaky rotary should be made by one of the methods given in *Westinghouse Air Brake*, Part 4; in the F-6 valve, the leak may occur either past the rotary valve or the gasket *32*. Tests for these defects are given in *Westinghouse Air Brake*, Part 4. Next, if the valve is of the D-8 type, the excess-pressure spring should be tested to ascertain if it is of the proper resistance, as in *Westinghouse Air Brake*, Part 4; or, if the valve is of the F-6 type, test the tension of the regulating spring *68* in the feed-valve, as in *Westinghouse Air Brake*, Part 4. Then, if a D-8 valve, test for a leak past the excess-pressure valve, *Westinghouse Air Brake*, Part 4; or, if an F-6 valve, test for a leaky supply valve and leaky feed-valve case gasket, *Westinghouse Air Brake*, Part 4.

Next make a service reduction of 20 pounds in chamber *D*, and note the time required. If longer than 5 seconds, the size of the passage in the preliminary-exhaust port is reduced; the piston packing ring is worn so that air passes it, and the top of the piston does not make a tight joint with the gasket *22* or *32* above it, allowing train-pipe air to leak into chamber *D*; or, in the F-6 valve, the gasket *32* is leaking (see *Westinghouse Air Brake*, Part 4). If the reduction is made in less than 5 seconds, either the equalizing reservoir leaks or there is water in it; for test, see *Westinghouse Air Brake*, Part 4.

12. Driver and Tender Brakes.—It is important that the engine brakes be kept in good order because the braking power of the engine is a large part of the entire braking power of the train and it should be fully utilized. An air gauge should be attached to the driver- and tender-brake cylinders at least once a month, to ascertain the condition of the piston packing leathers. After the auxiliaries are fully charged, make a 35- or 40-pound service reduction, lap the valve, and note the pressure at which the auxiliary and cylinders equalize. Also, note the pressure at the end of 5 minutes; if it does not decrease more than 5 or 6 pounds, the brake cylinder is in good condition. If the gauge shows that the brake-cylinder pressure decreases at a considerably greater rate, examine the packing leathers and look for leaks in the cylinder connections, the gasket between the cylinder and head, and the piston-rod packing.

If the driver-brake cylinder is in such a position that it is subjected to considerable heat, it should be oiled sufficiently often to keep the packing leather soft and pliable. It is poor practice to use water to soften the packing leather, since it dries out very quickly and the leather then becomes harder and is much more liable to crack.

Driver Brake Fails to Apply.—If the driver brake fails to apply, first see if the brake is cut in. If it is, open the release cock on the auxiliary to see whether it is charged. If the auxiliary is charged, the triple piston may be badly gummed and stuck in release position, or its packing ring is badly worn. In either case, when a reduction is made, the auxiliary may equalize with the train pipe through the feed groove and past the packing ring so fast that the piston is not moved out. In case the triple piston is stuck, one or two sudden heavy reductions should loosen it. If the cause cannot be located, take down the triple and examine it; the graduating stem *21* may be so put in that the piston and slide valve cannot move far enough to admit air to the cylinder. Also, examine the brake-cylinder packing leathers, as a leak there is a cause for failure to apply.

Driver Brake Fails to Release.—This may be due to a worn piston packing ring in the triple valve, aided by dirt and gum, the leakage past the packing ring allowing auxiliary pressure to equalize with the train pipe without moving the triple piston; or the triple exhaust port may be stopped up; or the release spring in the brake cylinder may be weak or broken; or, in the cam brake, the piston travel may be so long that the brakes lock against the drivers. In the latter event, the cams must be pried until the brake releases. In the event of the brake being stuck, try to release it by making a heavy reduction and then quickly placing the brake valve in full-release position.

Driver Brake Releases.—If the driver brakes release soon after being applied, it may be due to a leak in the auxiliary reservoir or its connections, a leaky graduating valve in the triple valve, or a leaky rotary. A leaky packing leather or piston-rod packing will allow the brake to leak off.

13. Triple Valves.—Plain triples are used on the engine and tender; therefore, if a blow occurs at the exhaust port of either triple, look for a leaky slide valve *3*, or, in the old-style triple valve, for a leak past the plug cock *13* into port *f*, *Westinghouse Air Brake*, Part 2. To determine which of these is causing the blow, apply the brake lightly; this causes the slide valve to close communication between port *f* and the exhaust port *k*; and if the trouble is due to a leaky plug cock, the blow will cease, while if due to a leaky slide valve, it will continue.

The method of testing the air-signal system for defects will be given after the signal system has been explained.

TERMINAL TEST OF TRAIN

14. When Test Should Be Made.—A thorough terminal test of the brakes should be made at the point where a crew takes charge of the train, whether it is at a terminal or elsewhere, and just before starting down a steep grade. The object of this is to find the number of brakes that can be depended on, so that the engineer will know just how much braking power is available for holding the train; also, to locate any defects that there may be, so that they can be repaired before beginning the trip. This test should be made with both passenger and freight trains.

A full terminal test is not necessary when a train breaks in two, or when it is cut in two at crossings or in order to set out cars. After coupling up, all that is necessary is to have a service application and release made from the engine in order to make sure that the last brakes on the train apply and release. This shows that the train pipe is open to the rear, which is the important point, since it is known that the brakes were holding all right before the train was cut in two.

Where cars are picked up, a regular terminal test of the brakes on the cars picked up should be made, but it is not necessary to extend the test to cars that were already in the train. However, when applying and releasing the brake, note whether the last brakes apply and release, thus making sure that the train pipe is open to the end of the train.

15. Making the Test.—If possible, all the air cars should be coupled up and the brakes cut in before the engine is connected to the train, as both time and air are thus saved.

On taking his engine, the engineer should start his pump and run it slowly until sufficient pressure is accumulated in the main reservoir to cushion the pump; he should then increase its speed and pump up the proper main-reservoir pressure. Also, he should carefully inspect the air-brake apparatus on both the engine and tender, to assure himself that all necessary repairs have been made, and that everything is in perfect working order. The train pipe on the engine should be blown out, to get rid of any dirt and water that may be in it, before the engine is coupled to the train. The brake valve should be carried in lap position* while the engine is being coupled to the train, thus keeping train-pipe and auxiliary pressures below the standard, and a high main-reservoir pressure. After coupling the hose between engine and train, the tender angle cock should be opened first, so that the hose will be charged when the car angle cock is opened. If the car angle cock is opened first and the train

*There is considerable difference of opinion as to the position in which the valve should be carried when coupling to the train, but the consensus of opinion seems to favor lap position.

is equipped with quick-action triples, the brakes are liable to apply quick action, due to the sudden reduction caused by train-pipe air expanding to fill the empty hose. The angle cocks should always be opened slowly, since, if the handle is turned quickly, emergency action may result.

During the time the train is being charged, the inspector or trainman should pass along and examine each car for leaks and other defects. It should be observed whether all angle cocks are open, except the last one on the rear air-braked car; whether the cock in each branch pipe is open so that all cars, except those that are not in good condition, are cut in; whether the hand-brakes are fully released; and, if the retainers are to be used, whether the retainer handles are turned up.

After the train has been fully charged to standard pressure, the brake system should be tested. If time will permit, 70 pounds pressure should always be obtained before this test is made; but in no case should it be made with less than 60 pounds for passenger trains or 50 pounds for freight trains. When the train is fully charged, it will be indicated by the pump slowing up.

To make the test, a service reduction of from 5 to 7 pounds, or one just sufficient to move the brake pistons out past the leakage grooves, should be made, and the brake valve lapped. The engineer should then watch the air gauge to ascertain the extent of train-pipe leaks, since they will be indicated by the black hand falling. A sufficient number of moderate service reductions should then be made to produce a 20-pound train-pipe reduction, and the brakes should be held on while the train is inspected to see whether all brakes set or whether any of them leak off after being set; also, the length of the piston travel on each car should be examined. After the entire train has been inspected, the engineer should be signaled to release brakes, and, if the train is equipped with the air-signal system, the signal should be given from the rear car to make sure that the air signal is connected up and working properly. The engineer should then release the brakes, and, if the retainers were not in use, the train should be inspected to see whether all brakes release properly and whether there is a blow at the exhaust port of any of the triple valves. If the retainer handles were turned up during the test, the inspector or brakeman should go over the train after the engineer has released, and turn down the retainer handles, noting, as he turns down each one, whether the brake releases, and whether a blow occurs at retainer after brake has released. If a good volume of air discharges from the retainer as the handle is turned down, the retainer is working properly. After the test, a report should be made to both the engineer and conductor, showing the total number of air and non-air cars in the train; the number of air cars in good working order and the number cut out; the condition of the piston travel; the number of retainers, if they are to be used, that are working properly; and also, the general condition of the train.

In testing the brakes, the engineer should always make the same initial reduction in chamber *D* pressure and note the length of time the train-pipe exhaust blows, as by making a practice of so doing he soon will be able to judge of the length of train pipe that is cut in, and thus, in many instances, can detect an angle cock that has been left closed. He cannot tell by the sound of the exhaust the number of brakes that set, but he can judge of the length of train pipe cut in. He should also note if the sound of the train-pipe exhaust is full and continuous, or strong at first and then stringing out weaker for some seconds, indicating that an angle cock is partly closed or that there is a stoppage in the train pipe. Also, if when making a reduction the exhaust from the train-pipe exhaust valve ceases suddenly before it should, it denotes that a triple in the train has gone into emergency which must be located and given proper care.

16. Brake Fails to Apply.—If, during the inspection, a brake is found that will not set, first make sure that it is cut in, and then try the bleed cock on the auxiliary reservoir, to ascertain whether the reservoir has been charged. If the auxiliary is not charged, and there is sufficient time at disposal, take down the triple and look for a stopped-up feed groove. If air issues freely from the bleed cock, it may be that the feed groove was only partly stopped up, resulting in the auxiliary being charged insufficiently to set the brake when the test was made. If not, the trouble may be due to a badly worn triple piston packing ring, or a bad leak from the brake cylinder. If the trouble cannot be remedied at the time, cut out the brake by closing the cut-out cock in the branch pipe leading to the triple.

17. Brake Releases.—If a certain brake will not stay on, but releases as soon as it is set, the trouble is due to a heavy leak either from the brake cylinder or from the auxiliary reservoir. If the leak is from the auxiliary, the triple valve will move to release position, and air from the brake cylinder will come out of the exhaust. If the leak is in the brake cylinder only, the triple valve will not move. The leak from the brake cylinder may occur through the leakage groove or past the piston in the brake cylinder. The hand-brake may be partly set, or the slack in the brake may be taken up so short that the brake-cylinder piston cannot move out far enough to cover the leakage groove, in which case the brake will either not set, or will release at once. The leak past the brake-cylinder piston may be due to a dried-out packing leather, or to the expander ring being out of place.

Leaks from the auxiliary reservoir may occur through a defect in the release valve or through the triple exhaust port. If at the release valve, look for a bent valve rod or for dirt on the valve seat. A leak due to the former may be remedied by straightening the valve rod; that due to the latter can in some cases be remedied by quickly jerking open the release valve two or three times. If the leak cannot be stopped, the brake must be cut out.

18. Brake Fails to Release.—If a brake fails to release, and there is a strong blow at the exhaust port of the triple valve, the trouble is caused by a bad leak past the rubber seat of the emergency valve, or else the valve is stuck open. In either case, train-pipe air enters the brake cylinder at a faster rate than brake-cylinder air can escape through the exhaust port, and consequently pressure accumulates in the cylinder and holds the brake on. If the trouble does not cease when the triple is jarred lightly with a piece of wood, make a quick, heavy reduction, and then release; if this does not prove effective, cut out the brake by closing the cut-out cock, drain the auxiliary reservoir by means of the release valve, and then suddenly cut in the brake; if the blow still continues, cut the brake out of service.

If, when the brake refuses to release, there is no blow at the triple exhaust, first see if the handle of the retainer on that car is turned down, and, if so, whether the retainer exhaust port is stopped up. A certain kind of wasp has been known, in some localities, to build its nest in the retainer and thus plug it up. The retainer being all right, see whether the hand-brake is fully released; whether the slack has been taken up too tight; or whether the brake has released, but the spring in the brake cylinder is unable to move the brake piston to release position. If the trouble is not in any of these places, it is pretty sure to be due to a badly worn packing ring in the triple piston.

Testing Piston Packing Ring.—The condition of the triple piston packing ring can be determined as follows: Apply the brake by making a 10- or 12-pound reduction, and then gradually open the release valve on the auxiliary of the defective brake a very small amount, so that a slight discharge takes place through it. If the brake does not release within 10 or 15 seconds, gradually open the release valve a little wider, so as to increase the rate of discharge. Continue to increase the discharge every 10 or 15 seconds until the brake releases; then the rate at which air is escaping through the release valve at the moment of release will be a measure of the rate at which train-pipe air escapes past the triple piston packing ring. The escape of air through the release valve, however, must be slightly greater than that past the packing ring, as otherwise a sufficient auxiliary reduction cannot be obtained to release the brake. When the packing ring is worn, train-pipe pressure must be increased quite rapidly to move the triple to release position; in such a case, therefore, the brakes are more liable to stick on a long, than on a short, train.

If the engineer finds that some of the brakes have a tendency to stick, he should carry the full amount of excess pressure all the time, and, at places where a heavy application must be made, he should have a high main-reservoir pressure to insure a prompt release.

19. Train-Pipe Leaks.—In inspecting a train for leaks, the parts to be inspected may be divided into: (1) the train pipe and its branch pipes; (2) the hose and couplings; (3) the triple valves; (4) the auxiliary reservoir; and (5) the brake cylinder.

1. *The Train Pipe and Branch Pipes.*—Leaks in the train pipe may occur at any of the joints. If at the union joint at the car drain cup, it can sometimes be stopped by tightening that joint; if not, a new gasket must be used. When the leak occurs at the joint where the branch pipe screws into the car drain cup, or in the joints at the stop-cock in the branch pipe, it can sometimes be stopped by disconnecting the branch pipe at the triple valve and turning the pipe until the leak ceases. If the leak occurs in the union at the triple, it may be stopped by tightening the union joint or by replacing the union gasket.

The leak may be due to a split or break in the train pipe. In that case, switch the car behind all the air cars and couple its hose to that of the last air car; then close the front angle cock on the defective car and open the rear one on the car ahead, so that the hose will be included in the train pipe. Then, should the train part between the defective car and the last air car, the brakes will be applied.

2. *The Hose and Couplings.*—In looking for leaks in an air-brake hose, not only the hose but also the couplings and nipples should be examined. The hose itself may be porous, in which case the air escapes so silently and in such finely divided streams that it is very liable to be overlooked,

especially as the hose may have the appearance of being perfectly sound. In some cases, such a hose can be detected by bringing a lighted torch near it, or by wetting the hand and moving it over the hose, the escaping air making the hand feel cooler. The best method, however, is to apply a little soap and water by means of a sponge or piece of waste; the escaping air will be indicated by the formation of bubbles. Such a hose, when located, should be removed and marked "defective," a sound hose being put in to replace it.

Leakage at the hose coupling may occur past the gaskets 2, or under the hose clamps *c*, Fig. 6, *Westinghouse Air Brake*, Part 2. If in the gaskets, close the angle cocks on either side of the hose, separate it, and if the gaskets have been distorted out of shape, straighten them and try them again. If they still leak, new gaskets should be used. If none are at hand, separate the couplings and put a match or small sliver of wood back of each lug and again unite the couplings; this will force the gaskets closer together, and will probably stop the leak, but is liable to tear off the hose if they are not parted by hand. The manner in which frozen couplings are parted is a cause of trouble with coupling gaskets. Frozen couplings must be thawed out before parting, otherwise the gaskets will be ruined. Paper should never be used between the hose gaskets to stop a leak, as it will work into the brake system and cause trouble. If the leak is under the hose clamp *c* tighten the clamp or use a new hose.

Leakage at the hose nipple may be due to the nipple not being screwed tight enough into the angle cock, or the leak may occur under the nipple hose clamp. If the former, screw up the nipple until it makes a tight joint; if the latter, tighten the clamp, and if this does not stop the leak, change the hose. Pulling the hose apart puts a severe strain on the train pipe and hose and produces more train-pipe leaks than any other cause.

3. *The Triple Valves.*—A blow at the triple exhaust port may be due to a leak either from the train pipe or from the auxiliary reservoir. To test for the source of the blow, close the stop-cock in the branch pipe so as to cut out the brake;

if the leak is from the train pipe, the brake will set; if from the auxiliary reservoir, it will not. The exhaust port of the triple valve or of the pressure retainer must never be plugged up on account of a blowing occurring at either place, for the reason that it would then be impossible to release the brake on that car.

4. *The Auxiliary Reservoir.*—Leakage from the auxiliary reservoir may occur through either the release valve, the triple exhaust port, or direct to the atmosphere, as mentioned in *Westinghouse Air Brake*, Part 4.

5. *The Brake Cylinder.*—Brake-cylinder leakage might occur past the piston packing leather, the cylinder-head gasket, or in piping between triple and brake cylinder where a plain triple is used.

20. Cutting Out a Brake.—When, on account of some defect in the apparatus, it becomes absolutely necessary to cut a brake out of service, proceed as follows: Close the cut-out cock in the branch pipe to the triple valve; if an old-style plain triple is used, first release the brake so that the brake piston moves back and uncovers the leakage groove, turn the handle to the position that is midway between the horizontal and vertical. The release valve of the auxiliary reservoir must then be opened and secured in that position, if a freight car, so that the reservoir will be relieved of all pressure; otherwise, the brake is liable to set and cause trouble. Never attempt to cut out a brake by closing the angle cocks at the ends of the car, as that will not only cut out the brake on that car but on all others back of it, since closing an angle cock cuts off the train pipe back of it.

21. Cutting Out a Car.—A brake is cut out by closing the stop-cock in the branch pipe. A car is cut out by closing the angle cocks at each end of the car, the release valve being opened and auxiliary drained the same as when a brake is cut out. After a car has been cut out, it should be switched to the rear of the air cars, and its front hose coupled into the train pipe so that, if the train should part between the defective car and the last air car, the brakes will apply.

RUNNING TEST

22. It is desirable, when practicable, that a **running test** of the brakes be made on all passenger trains when leaving the terminal station and just previous to meeting points, drawbridges, railway crossings, etc. to make sure that the brakes hold properly. A running test should also be made when, for any reason, a train is parted during the run or when it has stood for some time at a station where there is the possibility of some one having closed an angle cock.

It would not be practicable to require the running test for all trains in freight service; but it is desirable that fast freights make the test on approaching a point of possible danger at high speed, when the brakes might be called on to make a short stop. The conditions of braking in freight service are very different from those of passenger service, so the general use of the running test would cause trouble.

The engine throttle is kept open while this test is being made, the engineer simply making a light service reduction to see whether, and how well, the brakes take hold. As soon as he feels them take hold properly, he releases. While making the reduction, the engineer should note the length of time the train pipe exhausts, since by so doing he can judge of the length of the train pipe that is cut into service. For best results in judging length of train pipe, this train-pipe reduction should always be made about the same amount.

TEMPERATURE TEST

23. The holding power of brakes varies greatly on different cars, due to the difference in braking power on light and heavy cars or to defects in the brake system If a brake is applied to a revolving wheel for any length of time, the wheel becomes heated; and the longer the brake is held on, or the greater the retarding force exerted by it, the greater will be the resulting temperature of the wheel. Of course, the brakes on a train are all applied at the same time, so that if they held equally well the wheels would be of a uniform temperature throughout the train, and no information could result from a test of the wheel temperature. It will be found, however, that the wheels heat unequally, some being much hotter and others much cooler than the average. If the brakes on the wheels of average temperature are assumed to be doing their proper share of work, those on the wheels of higher temperature must, for some reason, be doing more than their share, while those on the wheels of lower temperature must be doing less than their share; hence, a test and record of the temperature of the wheels of a train, after the brakes have been applied for some time—as in descending a long grade—will give some very interesting and useful information as to the condition and relative holding power of the brakes on different cars. The record should be such that it will show clearly which brakes require attention, and therefore should contain a statement of the number of each car on which the temperature of the wheels is very much above or below the average, and whether the wheels are too hot or too cold.

24. Locating Defects.—Having, then, a record of the defective brakes, stating the comparative temperatures of the wheels, it remains to locate and remedy the defect that causes the trouble.

If the wheels on a certain car are too hot, it indicates either that the brake on that car holds better than the other brakes or else that it did not fully release with the others, and consequently had been dragging. Hence, the piston travel on that car should be measured to see whether it is too short, and the hand-brake inspected to see whether it is fully released. Also, inspect the pressure retainer to see whether it is working properly, and the brake cylinder to see whether the piston is stuck out, due to a defect in the cylinder or brake rigging. The brake may have been held on, due to a leak from the train pipe into the cylinder past the emergency valve, but this would be at once detected by a blow at the triple exhaust port.

If the wheels are too cold, it indicates either that the brake, for some reason, did not hold as well as the others, or did not apply with the others, or else that it released soon after it was set. The brake-piston travel, therefore, should be measured to see whether it is too long—in which case the force exerted by the brake would be considerably less than with the proper piston travel; or whether it is too short—in which case it is possible that the brake piston does not cover the leakage groove, the brake leaking off as a result. Also, the brake may not have applied at all, as the cut-out cock may not have been opened; or else it may have released again, due to leakage in the brake cylinder, auxiliary reservoir, triple valve, or—when the brakes have been released and the retainer is supposed to be holding 15 pounds in the brake cylinder—in the pipe leading to the retaining valve.

On roads where there are long down grades on which the retainers must be used, the wheel-temperature test is especially essential. When the brakes are held on for a considerable length of time, some of the wheels are liable to become very hot, and since the heating takes place at the rim, the wheel is subjected to stresses that are liable to cause it to break.

HANDLING TRAINS

SERVICE STOPS

25. Reduction and Application Defined.—Before taking up the question of train handling, it is well to get a clear idea of the meaning of the terms reduction and application. By **reduction** is meant a reduction in train-pipe pressure; by **application** is meant an application or applying of the brakes, whether they are fully or only partly set. A reduction of train-pipe pressure will cause an application of the brakes. Every time the brakes are applied and released, it is referred to as an application of the brakes.

An application of the brakes may be either a service or an emergency application. When several reductions are made in producing an application, the application is said to be a *service*, or *graduated*, *application* of the brakes; such applications are referred to as full-service or partial-service. In a full-service application, the brake cylinder and auxiliary pressures equalize, and the brake is set with all the force of the air contained in the auxiliary reservoir; this application may be made either with one or more service reductions. In a partial application, equalization does not take place and the brake is set with only a part of its full force.

When a sufficiently sudden train-pipe reduction is made to operate the triples quick action, the application is said to be an emergency application and the brakes are set with their greatest force.

26. General Considerations.—In making a service application of the brakes, the first reduction will depend somewhat on the length of the train and its speed. Whatever the length of the train pipe, the first reduction must be sufficient to cause the brake-cylinder pistons to move out far enough to cover the leakage grooves; otherwise, the brake will not set, and the air that should have been used in setting it will pass out through the leakage groove and be wasted. If too heavy a reduction is made, the slack of the train (if a freight) will run in so quickly that a severe shock will result.

The amount of reduction necessary to cover the leakage grooves can readily be determined when testing the train or when making the first stops. In passenger service, from 5 to 7 pounds is generally sufficient for the first reduction. With a freight train consisting of, or controlled by, ten air cars, a reduction of from 5 to 7 pounds will give good results. When the train contains more than this number of air cars, the reduction must be increased accordingly. For example, a train containing twenty-five air cars will probably require an 8-pound initial reduction, while a train of fifty or sixty air cars may require a 10-pound reduction.

27. The First Reduction.—There are several reasons why a heavier first reduction is necessary with a long train than with a short one. Of course, since the volume of air contained in the equalizing reservoir is constant, regardless of the length of the train line, a reduction of chamber *D* pressure (of any given amount) can always be made in practically the same time. The volume of air in the train pipe, on the other hand, increases directly with its length, so that the longer it is, the more time is required to make a given reduction in the train-pipe pressure. Since train-pipe pressure reduces more slowly on a long train than on a short one, there is a greater chance for auxiliary pressure to feed back into the train pipe through the feed groove before it is closed by the triple piston. This reduces auxiliary air and has the same effect as though the first reduction had been lighter. Again, the more slowly train-pipe pressure is reduced, the more slowly will auxiliary pressure feed into the cylinder and the more air will pass out of the leakage groove and past the packing leather.

The amount of the reduction depends, also, on the fit of the equalizing piston packing ring and the joint made by piston *17* with the gasket above it. The piston is supposed to make an air-tight joint with the gasket, but if the latter is not in good condition leakage can occur from the train pipe into chamber *D* at such times as chamber *D* pressure is less than train-pipe pressure. The packing ring never makes an air-tight fit, and in some cases considerable air can leak by it. When the train is long, a reduction can be made several seconds sooner in chamber *D* and the equalizing reservoir than in the train pipe; hence, chamber *D* pressure may be less than train-pipe pressure for several seconds during a service reduction. If piston *17* does not make a tight joint with the gasket when it raises, air will leak from the train pipe into chamber *D* and raise chamber *D* pressure, and the longer it takes for the train-pipe pressure to reduce, or the greater the leakage into chamber *D*, the more will chamber *D* pressure be raised. Thus, a 6- or 7-pound chamber *D* reduction may result in only a 4- or 5-pound train-pipe reduction, and to reduce the train pipe 6 or 7 pounds, a reduction of 8 or 9 pounds may be necessary in chamber *D*.

The speed of the train has considerable to do with the amount of the first reduction. With a slow or moderate speed a moderate reduction is necessary in order that the slack of the train will not run in too quickly. At a fast speed the reduction should be much heavier in order to control the train; it will not give any shock at high speeds.

28. Reductions Following.—The amount of the reductions after the first depends on the length of the train pipe, the condition of the brake, and the distance in which the stop must be made. With the brake in good condition, the reductions should not, as a rule, be more than from 2 to 6 pounds, being small when the train pipe is short, and increasing as the length of the train pipe increases.

Experiment has shown that a brake grips the wheel better, and consequently retards the train more, at slow than at fast speeds for the same train-pipe reduction; therefore, the danger of producing shocks is greatest at slow speeds, and the reductions should be made accordingly. Also, sufficient time must elapse between reductions to allow all the brakes to set and the slack to equalize throughout the train. If the reductions are made too close together, the effect will be the same as though one heavy reduction had been made. For example, if one 3-pound reduction is followed by another before the train-pipe exhaust ceases, the brakes will set as though a continuous 6-pound reduction had been made. It must be remembered that the graduating valve in the triple valve does not close until the train-pipe exhaust ceases, regardless of when the preliminary exhaust stops, and any reduction made before it closes will prevent that event taking place until auxiliary pressure is reduced an amount equal to the sum of the reductions.

29. Number of Reductions.—The number of reductions to be made in a service application depends on circumstances. It is not good practice to wait so long before applying the brakes that a sufficient number of heavy reductions must be made to cause a full application, in order to make the stop at the proper spot. It is better to make the first reduction at such a distance from the stopping point that a full application of the brakes will not be necessary.

The reductions should be moderate and sufficient in number to make not more than a 15-pound train-pipe reduction in bringing the train to a standstill. The engineer then has at his command a reserve braking force that will be of the greatest value in case of emergency while running into a station.

30. Passenger-Train Stops.—An ordinary station stop with a passenger train is generally made with one application of the brakes, and in no case should more than two applications be necessary. With one application a 7- or 10-pound reduction should be made at the proper distance from the stopping point, and this should be followed by a sufficient number of 2- or 3-pound reductions to bring the train to rest gradually at the proper point. On account of the resistance of the brake-beam springs used with passenger equipment, it takes a greater brake-cylinder pressure to move the piston past the leakage groove; for this reason a heavier initial reduction is needed than with a freight train where no brake-beam springs are used. The brakes should be released just before the train stops, unless the train is very long, so that the car trucks can right themselves while it is still in motion. If this precaution is not taken, there will be an unpleasant lurch backwards just as the train stops, in case the brake beams are hung to the truck outside of the wheels. With inside-hung brake beams on four-wheel trucks there is no lurch from this cause. Six-wheel trucks have the beams hung from the ends of the truck.

Two-Application Stops.—Such stops are made with so heavy a first reduction, while the speed is high, as to stop the train a few car lengths short of the proper place. With this heavy reduction the brakes are applied with more force at a high speed, and therefore the stop can be made quicker than with a one-application stop. When speed is reduced so that the train can be stopped with a light application—say to 15 or 18 miles per hour—release all brakes and at once come to lap. The second application can then be made so as to stop at the exact point smoothly. With a very long passenger train, over ten cars, do not finally release the brakes after the second application until the train stops. Unless there is a straight-air equipment in service on the engine a full release at slow speed is sure to cause serious shocks and usually breaks the train in two parts. In all releases handle a long passenger train the same as a long freight train, as a passenger train of fifteen coaches is about as long as a freight train of twenty-eight cars. The pressure should be sufficiently low so the trucks will not tilt and cause a surge that is annoying to the passengers. In making stops on grades where the brakes must be held on, it is best to use two applications. On some roads, all service stops with passenger trains are made with two applications of the brakes with good results, especially where the track is slippery.

Overcharging Train Pipe.—In releasing the first application preparatory to making the second, when stopping a train, the brake valve should be thrown to full release long enough to release all triples and then immediately moved to lap position, as otherwise the train pipe will be overcharged. The aim should be to suddenly raise the train-pipe pressure sufficiently to release all brakes without trying to recharge the auxiliaries. The feed groove in the triples is small, and if the brake valve is left in release position so long that the train pipe is charged 15 or 20 pounds higher than the auxiliaries, the latter may not have time to equalize with the train pipe before the second application has to be made. Suppose that the train-pipe pressure is 6 or 7 pounds higher than the auxiliary pressure when the second application is about to be made, the engineer, to set the brake with the first reduction, must make a 12- or 13-pound reduction—6 or 7 pounds to make the train pipe equal to the auxiliary pressure, and a further reduction of 5 or 6 pounds to apply the brakes. If the engineer makes the ordinary reduction, the brake will not apply, and the train will either run past the stopping point or else the engineer will have to make an emergency application, which will, when the train is running slowly, cause a very disagreeable lurch. The easiest way to avoid this is not to overcharge the train pipe when releasing the brakes.

Number of Applications.—It is not good practice to make more than two applications of the brake in stopping a train. Every time the brakes are applied and released, the amount of air taken into the brake cylinder from the auxiliary is discharged into the atmosphere. This reduces the auxiliary pressure, so that on the second application it equalizes with the brake cylinder at a much lower pressure than on the first, while on the third application it equalizes at a very greatly reduced pressure. For example, if a brake is adjusted so that it will equalize with the auxiliary at about 50 pounds on the first application, and the valve is lapped so the auxiliaries will not recharge between the applications, it will equalize at about 30 pounds on the second, 20 pounds on the third, and at only about 10 or 12 pounds on the fourth application. It will thus be seen that the power of the brake falls away very rapidly with each application; hence, the advisability of making but two applications at the most.

As already stated, two applications are advisable when making a stop on a grade. It will be found advisable, also, to make two applications whenever a close accurate stop is to be made, such as at water tanks or coal chutes. In each instance the stop should be made according to the instructions just given for a stop on a grade, and the brakes should be held on until the water or coal has been taken.

Holding Brakes On.—When the brakes are held on for any length of time, with the D-8 valve, it will be necessary to stop the pump when main-reservoir pressure is obtained; otherwise, it will overcharge the main reservoir. This in turn will overcharge the train pipe when the brake valve is placed in release or running position, wheels will skid, and any weak hose may burst. A duplex governor corrects this defect.

Stopping by Means of Tail-Hose.—When a train is backing up and is to be stopped by the train hands with the **tail-hose**, the engineer should carry his brake valve in running position until he is given a signal or feels the first application, when he should place the valve on lap until he gets the signal to release. During the run backwards the brake valve must be carried in running position to supply any train-pipe leaks, but it should be lapped in time so that the man making the stop will have complete control of the train, since he is responsible for making the stop. On many roads, the rule is to keep the brake valve in running position while backing up and trainmen are controlling the speed of the train. A very good rule is to carry the valve in running position as usual when backing up, and to put it on lap at a point where the engineer would make an application if he were doing the braking.

31. Part-Air Freight Trains.—The amount of free slack in a part-air train makes such a train difficult to handle without producing shocks. This free slack must either be gathered in or run out every time the speed of the train is changed, and the more quickly this is accomplished, the greater will be the resulting shock. Also, the extent of the shock will depend on the number and position of the loaded cars in the non-air section, and on the extent to which the air section resists the blow as the slack is bunched or run out. If there is a sufficient number of air cars to hold well and the loads are at the rear end of the train, the shock will be severe if the slack is bunched quickly; consequently, a train should always be bunched or stretched gradually.

In making a service stop with a part-air train, close the throttle at a sufficient distance from the stopping point, and let the train drift for a short distance, or until it has bunched fairly well. A reduction just sufficient to close the leakage grooves should then be made, and ample time allowed for any slack to run in before a second reduction is made. The second and succeeding reductions should be sufficiently light and numerous to bring the train smoothly and gradually to rest at the proper point, care being taken that one reduction is not made until after the train-pipe exhaust of the previous one has ceased.

As a rule, the brake should be held on until the train has come to rest, as otherwise a shock tending to tear the train in two will be caused, due to the slack running out. They should be released immediately after stopping, however, so that the brakes on the air cars may not be rigidly set when the non-air cars run back—as they will do when the spring slack eases up.

Use of Hand-Brakes.—It should not be necessary to use hand-brakes to assist the air brakes in making a service stop; but in case this has to be done, the brakes immediately back of the air cars should be used, and not those at the rear end of the train. If the brakes were set on the rear end there would be danger of breaking the train in two if the engineer should release the air brakes with the train in motion, before the hand-brakes were released. In backing a part-air train out of a siding, however, a few hand-brakes should be applied at the rear end of the train before the air brakes are applied, so that the slack of the non-air section will not run out violently when the air brakes are applied to stop the train.

Water-Tank and Coal-Chute Stops.—It is difficult to apply or release the brakes of either a part-air or an all-air freight train at slow speeds, without a severe shock resulting; hence, the safest way to make a close, accurate stop with a freight train is to stop short of the tank or chute, cut off the engine, take coal or water, and then couple up to the train again. Most roads require that this be done.

32. All-Air Freight Trains.—Although in making stops with an all-air train the engineer does not have to deal with a lot of free slack, as in the case of a part-air train, yet if the train is very long, he will have trouble with slack, since the head-end brakes apply and release sooner than the rear ones; consequently, the slack plays in or out when the first reduction is made or the brakes are released. Also, uneven distribution of load and unequal travel of the brake pistons complicate matters so that good judgment and skill must be exercised in handling such a train or else rough treatment of freight is sure to follow. Both the first and succeeding reductions must be heavier (according to the length of the train) than for short freight or for passenger trains. The first should be sufficient to cover all of the leakage grooves, and no succeeding reduction should be made before the train-pipe exhaust, due to the previous one, has ceased. After one or two applications of the brake, the engineer can judge quite closely what reductions to make in order to handle the train smoothly.

In making a service stop with a long all-air freight train, the first reduction should be made at a sufficient distance from the stopping point, and once the brakes are applied they should be held on until the train has come to a standstill unless the engine is provided with the straight-air brake, or engine retainer for holding in the slack. It is almost impossible to release the brakes on a very long train at slow speed without breaking the train in two, unless the retainers are used on the engine or head end of train. Some roads are equipping their engines with retainers or an independent brake to prevent the slack from running out violently when it is necessary to release at slow speeds. The straight-air brake is valuable for this purpose and is being adopted by many roads. When this is used, the brakes can be safely released at any speed.

If necessary to release brakes while the train is moving, sufficient excess pressure should be pumped up to insure the prompt release of the brakes. A high main-reservoir pressure is very desirable and gives the best results in releasing brakes on a long air-brake train, because the air is thrown back quicker and with greater force and for that reason is surer of operating all triples. Also, the engine retainers, if the engine is supplied with them, should be cut into service. If the train drifts some distance with the brake set, there is danger that so much of the driver-brake air has leaked away as to render the use of that retainer of no value in releasing at slow speed. Care should always be taken not to work steam until all brakes on the train have released, and even then the throttle should be opened cautiously; for, if steam is worked before the rear-end brakes have released, the train is very apt to be torn in two. After going to release, 1 second for each car in the train should be allowed before steam is used, so that sufficient time will be allowed for all brakes to release and the drawbar springs to adjust themselves, thus guarding against shocks.

Some roads allow brakes to be released a few at a time, after a full application, by placing the brake valve on running position for a few seconds and raising train-pipe pressure at suitable intervals just enough (1 or 2 pounds) to move a few of the triples to release position each time the pressure is raised. In a short time the train is running free, then with high excess pressure go to full release and raise train-pipe pressure suddenly enough through its whole length to kick off any sticking triples.

EMERGENCY STOPS

33. Brake Stops.—In cases of actual emergency, the brake valve should be thrown to full-emergency position and left there, and sand should be used. It is possible to get the emergency action of the brakes without losing all the train-pipe air, but never try it in times of danger. If several cars with plain triples or with brakes cut out happen to be placed together, only the brakes ahead of such cars will go into quick action, while the ones back of them will set with a partial-service application only. If the valve is left in emergency position, a full application will be had on the cars back of, and full emergency on those ahead of, the cars with plain triples. Another possibility is that the engineer may, in trying to bring the valve back to lap, move it to running position, thus releasing the brakes; or, if the valve is moved to lap too quickly, the surge of the air in the train pipe may kick off the forward brakes.

The only safe plan is to move the valve to emergency position and leave it there. In case of emergency, no matter what the position of the brake valve or the kind of train, whether all-air or part-air, the brake valve should be moved to emergency position. It makes no difference whether the brakes have been applied in a partial, or even a full, service application—the handle should be moved to emergency just the same. In the former case, a full-emergency application may not be obtained, but a partial-emergency may; and certainly a full-service application would be. In the latter case, if all the brakes were set full, no advantage would be gained, but if any of the brakes had not equalized with their auxiliary, or if some of the brakes had partly or wholly leaked off, the reduction would cause them to equalize with their auxiliaries, thus making them hold better.

34. Reversing the Engine.—No matter how poor the driver- and tender-brakes are, if they are applied, the engine should never be reversed with the expectation of making a shorter stop than could be made with the brakes alone; reversing the engine under such conditions may cause the brake to lock and slide the drivers, in which case the retarding power of the engine is greatly reduced and slid flat wheels result. It was proved by actual trial in the Galton-Westinghouse tests in England, and later in tests made by Mr. J. W. Thomas, Jr., General Manager of the N. C. & St. L. R. R., that a stop cannot be made in as short a distance with the brake set and drivers sliding as when the brakes alone are used.

35. Accidental Emergency Stops.—Under this head are supposed to be included all emergency stops other than those purposely made by the engineer. Whenever the brakes apply suddenly without his aid, the engineer should immediately lap the brake valve and leave it in that position, so as to bring the train to a standstill as soon as possible and save main-reservoir pressure for releasing brakes when the proper time comes for so doing. A sudden, unexpected application of the brakes may be caused by a conductor's valve being opened, by a burst hose, or by the train parting.

RUNNING

POSITION OF BRAKE VALVE

36. The F-6 brake valve should be carried in running position while the brakes are off, since this is the only position in which excess pressure can be carried and train-pipe leaks supplied by air from the main reservoir. By *excess pressure* is meant the amount that the main-reservoir pressure exceeds the train-pipe pressure. The excess pressure is carried in the main reservoir, and it is very important that it be carried and maintained at all times. Sufficient excess should be carried so that when it is turned into the train pipe to release the brakes, it will do so and recharge the auxiliaries promptly. To do this the excess must be sufficient to force the air back through the whole length of the train pipe and reach all the triples at as nearly the same instant as possible.

The brake valve should not habitually be carried in release position. It should be moved to that position until brakes have released, which takes about 1 second for each car in the train, or until the black and red hands of the gauge have equalized *below* 70 pounds. If the pressures equalize above 70 pounds, move at once to running position.

If an F-6 brake valve is left in release position too long, the train pipe will equalize with the main reservoir at 90 pounds pressure. If the valve is then moved to running position, the feed-valve will be held closed until train-pipe pressure has been reduced 20 pounds, or from 90 to 70 pounds. In case the train pipe has been overcharged, it is best to make a number of light applications and releases to reduce the train-pipe pressure to 70 pounds.

If a D-8 valve is left in lap position until the main reservoir is overcharged, the train pipe will be overcharged as soon as the valve is moved to running position, but the regular amount of excess pressure will still be carried. If the train pipe is so badly overcharged that it is advisable to reduce it, apply lightly and release a few times, as before.

This can only happen with a short train. With a long train or one with a number of train-pipe leaks it is the general custom to carry the D-8 valve on full release and pump direct to the leaks, as the excess valve will not pass enough air to hold the pressure in a long train pipe up to the standard amount. With a long train there is usually time between the application and release to pump up the required excess for releasing brakes.

SETTING OUT A CAR

37. In setting out a car at a way station, first of all release the brakes; then close the angle cock on each side of the hose that is to be parted; then part the hose by hand, and hang up properly in the dummy couplings the hose of the car that is to be set out. Before the car is left in the side track, the air brake should be released and the hand-brake applied (if necessary) to hold the car. The air brake should never be depended on to hold one or more cars on a grade for any length of time when not connected to the engine, since the brake may leak off and allow the cars to escape down the grade uncontrolled. In case cars must be left standing on a grade, always release the air brakes and apply the hand-brakes.

PICKING UP CARS

38. When the engine is backed up to a number of cars that are to be switched or picked up, on which cars the train pipe and auxiliaries may be empty, it is well to apply and release the engine brakes several times without recharging the auxiliary, and then place the brake valve on lap before the tender angle cock is opened. The auxiliary pressures on engine and tender will then be so low that if the engine brake does set in full when the angle cock is opened, the auxiliary and brake cylinders will equalize at such a low pressure that the main-reservoir pressure can very readily release them, and thus time will be saved, as the cars can be charging while they are being moved.

In coupling up cars that have been picked up and may not be fully charged, the following precautions should be observed in order to save both time and air: First, be sure that the rear angle cock on the rear car is closed; then, after coupling the hose, open the angle cock on the car that was picked up, and then the one on the charged section of the train, opening the latter cock slowly so that air will not be fed into the undercharged car faster than it is supplied to the train pipe from the main reservoir.

HOSE BURSTING

39. In the event of a hose bursting, the engineer should immediately lap the brake valve, and, as soon as the train stops, send out flags. The hose should be replaced by a new one (if at hand) or by the extra hose on the last car of the train, and the brakes then tested to see whether they operate properly. If unsafe to replace the hose and test the train at the time, the angle cock immediately in front of the burst hose should be closed; the brakes back of it should then be bled off, and the train moved to a safe place, where the hose can be replaced and the brakes tested.

To Locate a Burst Hose.—If the leak is not too large, the brake valve should be left in partial-running position; the leak can then be located by the sound made by the escaping air, while at the same time main-reservoir pressure can be maintained. With a large leak, however, it will be impossible to open the valve wide enough to make a sound and still maintain the main-reservoir pressure; consequently, the brake valve should be moved periodically from lap to full release and back again. This will produce an intermittent sound by means of which the leak can be located.

BLEEDING BRAKES OFF

40. There are two methods by which a triple valve can be made to release a brake. One is to increase the train-pipe pressure above that in the auxiliary—the other to reduce the auxiliary pressure below that in the train pipe. The first is the usual way—the second method is to bleed off a brake. To do this, the release valve, or bleed cock as it is often called, should be held open until air escapes from the triple exhaust or pressure-retaining valve, when it should immediately be closed. The blow at the exhaust or pressure-retaining valve indicates that the triple has moved to release position, and any further reduction of auxiliary pressure is not only a loss of air, but also causes a reduction in the train-pipe pressure, which in some cases may cause other brakes to apply.

BREAKING-IN-TWO OF TRAIN

41. In case an all-air train should break in two, the brake valve should be lapped at once and the engine throttle closed, so as to bring the front section to a standstill as soon as possible. With such a train, the engineer should not attempt to keep the head end out of the way of the rear end, for the reason that they are pretty sure to come together in any event; and the less the two sections separate, the less damage will be done. Flags should be whistled out, and as soon as the sections come to a standstill, both the open angle cocks should be closed and the brakes on the front section released. As soon as the signal is given, the front section should be backed up and coupled to the rear section, and the brakes on the whole train released. A test should then be made to see whether the brakes are working properly.

In the event of a part-air train breaking in two, the course to pursue will depend on whether the break occurs in the air section, or back of it. If it occurs in the air section, pursue the same course as with an all-air train; if it occurs in the non-air section, the brakes, of course, will not set, and the engineer should endeavor to keep the head section out of the way of the rear section until the latter can be brought to a standstill.

HANDLING TRAINS ON LONG DOWN GRADES

42. The manner in which the braking should be done on a long down grade depends on local conditions, which may differ on different hills; consequently, no rule can be given that covers all conditions. To give instructions for braking on any particular hill, the location of the easy and heavy parts of the grade should be definitely known. Instructions are usually issued by companies, covering their conditions.

In the absence of specific instructions, however, the following will serve as a guide: The pump should be run faster than usual while on the grade, so as to recharge the main reservoir promptly to have a supply of air for recharging the auxiliaries. Turn the retainer handles up just before the descent is begun, using as many as possible without their stopping the train at any easy place on the grade, and make a moderately heavy reduction while the speed of the train is slow. Just after pitching over the top of the grade, it is a good plan to make a full application and note if it controls the speed of the train so a full stop can be made if necessary at any time. A given reduction will cause the brakes to hold better at slow than at high speed; much better control of the train can be maintained, and air saved, by making the first reduction before the train has gained much headway. The auxiliaries must be recharged after a release as quickly as possible, with the brake valve in full-release position and a high pressure in the main reservoir. The greatest safety will be assured by keeping the auxiliary pressure high and the speed low; therefore, advantage must be taken of every favorable opportunity for recharging. Retainers are of great value on steep grades, they not only hold the brakes set while recharging the auxiliaries but they save brake-cylinder air, which must be replaced by auxiliary air. With retainers enough in use the applications and releases at the brake valve can follow each other rapidly and still have a high cylinder pressure with moderate train-pipe reductions; this method holds the auxiliary pressure high. On grades where auxiliaries cannot be recharged frequently the speed of the train should be kept lower than it otherwise would. Curves and easy parts of the grade should be selected on which to recharge the auxiliaries, the reduction before releasing being heavier than the others, so as to slow down the speed, as the cylinder pressure has a greater effect at the slower speed. Charge the auxiliaries fully just before the steep parts of the grade, so as to have sufficient braking power while descending. The piston travel should be moderately short, as that gives a higher cylinder pressure with a small amount of air from the auxiliary. If very short, the retainers are not as effective while recharging, as they reduce to 15 pounds quicker than with a longer travel. Where a train is to stand 10 minutes or more on a grade, the air brakes must be released and the train held entirely by the hand-brakes. It is not safe to depend on the air brakes under such conditions as they will leak off and allow the train to run away. However, the air brake should be kept fully charged. The use of retainers does not interfere with the operation of the triples in quick action, provided that there is standard pressure and the triples are in release position.

QUICK ACTION DURING SERVICE REDUCTION

43. If, when making a service reduction, the brakes set quick action, the trouble may be a broken pin in the graduating valve of the triple; the graduating valve badly gummed up; the triple piston gummed up or frozen, or having a gritty or very tight-fitting packing ring; or, if the train is short, a broken graduating spring *22* in the triple. In *Westinghouse Air Brake*, Part 4, it was explained how these defects cause the brake to apply quick action.

LOCATING DEFECTIVE TRIPLE

44. Quick action during a service reduction is due to one of the triples, for some reason, not operating in service position, but only in emergency position, thus causing the others to fly on also. If the trouble is due to a sticky triple, or to a broken or gummed-up graduating valve, it may be located as follows: Make a light service reduction and, since all brakes but the defective one will apply, look for a brake that has not set. This, when found, may be cut out at once and the brakes again tested, to see if the brake cut out is the one that has been causing the trouble. Another method is to make a light reduction and, when a brake is found that has not applied, make a second or even a third reduction, if necessary, while some one watches the brake to see if it goes on quick action only; if so, it should be cut out. Should the trouble be due to a weak or broken graduating spring *22*, the triple will move to emergency position when a light reduction is made, and thus cause all the brakes to fly on. Generally, a triple with a broken graduating spring is rather hard to locate. To do so, the brakes may be watched to see which goes on quick action first; or an angle cock in the middle of the train may be closed to see on which half the defective triple is located, this being repeated with the portion of the train containing the defective triple until but a few cars have to be watched. These can either be cut out one at a time, or else they can be watched to see which piston moves out first. When located, the defective triple should be cut out.

BRAKES STUCK ON

45. If it is found that the brakes cannot be released by placing the brake valve in full-release position, it should be placed on lap if the D-8 or the special high-pressure control apparatus is used; or with F-6 valve make a heavy service reduction to obtain extra excess pressure, and then throw brake valve into full release. The brakes on a long train with quick-action triples are especially liable to stick after an emergency application, on account of the auxiliary and brake-cylinder air equalizing at a higher pressure than usual. On a very long train, the rear brakes are liable to stick after a very light application, because the train-pipe pressure cannot be raised enough to move the sticky triple; with a heavier reduction this triple will very likely release promptly.

USE OF SAND

46. It is well known that by the proper use of sand the wheels may be made to grip the rails much better, thus lessening the danger of the wheels being flattened from sliding. On the other hand, if the sand is not properly used and the wheels begin to slide, the flat spots formed will be worse than if no sand were used.

When necessary to use sand in making a stop, the rails under the entire train should be sanded by the time the first application is made, or at least before the brakes have applied very hard, and the sand should be used continuously until the train comes to a standstill. Sand should never be used after the wheels have begun to slide, since it will not start them turning again, but will simply increase the wear on the wheel and thus make the resulting flat spot larger than it otherwise would be. In the event of the wheels sliding, the brakes should be released, if practicable, and the rails sanded, after which the brakes may be applied again, but the rails should be continuously sanded until the stop is made. Whenever the rails are bad, sand should be used in applying the brakes, to avoid skidding the wheels. It is bad practice to attempt making a stop without using sand and then, after the brakes have been fully applied and it looks as though the train would not stop soon enough, to drop sand on the rails. Some of the wheels may be sliding at the time, and the sand will thus be the cause of some very bad spots. A two-application stop is used on slippery track because it tends to prevent wheel sliding at road crossings and spoiling wheels.

WHEELS SLIDING

47. When the brakes are applied, there are two forces acting on the wheels: one, the force exerted by the brake, which tends to prevent the wheel from turning, and thus tends to cause it to slide over the rail like a sled runner; the other, the force exerted between the wheel and the rail, which resists this tendency to slide, and thus tends to keep the wheel turning. As long as the latter force is greater than the former, the wheel will continue to revolve; but if, for any reason, the force exerted by the brake is the greater, the wheel will slide. It will thus be seen that a wheel may be made to slide either by reducing the adhesion between the wheel and the rail (as when the rails are greasy), or by increasing the force exerted by the brake above a certain amount.

Apart from the matter of slippery rails, therefore, the wheels may be slid: if the piston travel is too short, whether due to its adjustment, to the hand-brake being partly set, or otherwise; if the leverage is too great; if the brake fails to release after making a stop; if a heavy reduction is made when the train is moving slowly; or if the auxiliaries are overcharged and allowed to equalize with the brake cylinders. Cam driver brakes improperly designed may lock and skid the wheels if the piston travel is too long.

USE OF CONDUCTOR'S VALVE

48. In passenger service, each car is provided with a valve called the conductor's valve (see Fig. 1, *Westinghouse Air Brake*, Part 1), by means of which the brakes can be applied from the cars. This valve is connected to the train pipe by means of a branch pipe, and when the valve is open it makes a direct passage from the train pipe to the atmosphere. The conductor's valve is intended to be used only in cases of emergency, when it is necessary to stop the train at once. It should be held open until the train comes to a stop, for if closed while the engineer's brake valve is in running position, the brakes will be released again.

DOUBLE-HEADING

49. In **double-heading**, the leading engineer should test the brakes since it is his duty to handle them, and the cut-out cock under the brake valve of the following engine should be closed, to give the leading engineer absolute control. The engineer of the following engine should place his brake valve in running position and keep his pump operating to maintain the full main-reservoir pressure. If the leading engineer desires assistance in releasing brakes, the following engineer should open the cut-out cock under his brake valve and place his valve in full release. The brake valve should be moved to running postion, and the cut-out cock closed again as soon as the brakes release or the leading engineer cannot control the train.

If the following engine is not supplied with a cut-out cock, the brake valve should be carried on lap instead of running position; a blow may then occur at the train-pipe exhaust when brakes are released. When the leading engineer places his valve in release, he increases the train-pipe pressure above that in chamber *D* of the following engineer's valve, and the equalizing piston of that valve may be raised, and open train-pipe exhaust. The brake valve should be placed in full release until the blow ceases, and then be returned to lap. On some roads, the main reservoirs are connected by a separate pipe and hose connections to give the leading engineer the use of the air supply on the second engine. Other roads use the air-signal pipe with a by-pass around the reducing valves to connect the reservoirs.

NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 6, which was its former title.

FOUNDATION BRAKE GEAR

OPERATING AND TESTING—(Continued)

PISTON TRAVEL AND ITS ADJUSTMENT

LONG AND SHORT TRAVEL

1. The subject of *piston travel* and its adjustment is an important one, and should be thoroughly understood, since not only the efficiency of the brake but also the smoothness with which a train can be handled depends, to a great extent, on the proper adjustment of the brake-piston travel. By **piston travel** is meant the distance the brake piston travels from the pressure head of the brake cylinder when the brake is applied. This distance is measured along the piston rod.

The auxiliary reservoir used with any brake cylinder is of such a size that if charged to 70 pounds it will equalize with the brake cylinder at 50 pounds, if the travel of the brake piston is adjusted to 8 inches. If the piston travel is less than 8 inches, the auxiliary and brake cylinder will equalize at a higher pressure than 50 pounds; while if the travel is more than 8 inches, they will equalize at a lower pressure. When a train-pipe reduction is made, air passes from the auxiliary (into the brake cylinder) until the pressures in auxiliary and train pipe are about equal. Thus, for any given train-pipe reduction, until the brake-cylinder pressure equalizes with the auxiliary, the same amount of air is discharged into the brake cylinder, regardless of the length of the piston travel. That is to say, if a 7-pound reduction were made, the same amount of air would pass into a brake cylinder having a 5-inch piston travel as would pass if the travel were 8 inches. With the 5-inch travel, however, the air would have to occupy less space than with the 8-inch travel; hence, the brake with the short travel will develop the greater pressure.

EQUALIZATION TESTS

2. Table I gives the results of a number of tests made with a freight equipment, each pressure being the average of several trials with each piston travel. It shows the pressure obtained in the brake cylinder for different piston travels in both service and emergency applications of the brake.

TABLE I

BRAKE-CYLINDER PRESSURES

Service Reduction From 70 Pounds Train Pipe Pounds	Piston Travel. Inches							
	4	5	6	7	8	9	10	11
	Pressure in Pounds							
7	25	23	17½	13	10½	8		
10	49	43	34	29	23½	19½	17	14
13	57	56	44	37½	33	29	24	20
16	57	56	54	47½	41½	35	29	24
19	57	56	54	51	47	40	36½	32
22	57	56	54	51	50	47½	44	39
25	57	56	54	51	50	47½	47	45
Emergency reduction	62	61	59½	58½	57½	56½	55½	55

EXPLANATION OF TABLE I.—The first column on the left gives the reduction in train-pipe pressure; the second column gives the brake-cylinder pressure resulting from the corresponding reduction in column 1, when the brake-piston travel is only 4 inches; the third column gives the resulting brake-cylinder pressure when the piston travel is 5 inches, and so on for the other columns. For example, a train-pipe reduction of 7 pounds will result in a brake-cylinder pressure of 25 pounds with a 4-inch travel, or 8 pounds with a 9-inch travel; a 10-pound reduction will result in 43 pounds brake-cylinder pressure with a 5-inch travel, and only 14 pounds with an 11-inch travel.

By studying the table carefully, it will be found that short-travel brakes equalize quicker, and with a less reduction, and also exert a greater pressure than do long-travel brakes. For instance, a 13-pound reduction will cause all brakes with 4-inch travel to equalize at 57 pounds pressure, and with 5-inch ones to equalize at 56 pounds; while a 25-pound reduction is necessary to set a brake full with a 10- or 11-inch travel, and then they equalize at only 47 pounds and 45 pounds, respectively.

It will be seen, also, that if three brakes with, say, 4-, 8-, and 11-inch travel, respectively, were in the same train, the retarding force exerted by each would vary greatly at each reduction. For instance, a 7-pound reduction would cause the first to develop 25 pounds pressure per square inch; the second, 10½ pounds; while the pressure in the cylinder having the 11-inch travel would not be sufficient to move the piston out the full stroke. Now, if the brake cylinders were of 10-inch diameter, a pressure of 25 pounds per square inch in the short-travel brake would develop a total force of 1,963 pounds; 10½ pounds per square inch in the medium-travel brake would develop a total force of 825 pounds; while the long-travel brake would hardly develop sufficient power to force the piston to its full stroke. Thus, of these three brakes, with a 7-pound reduction, the holding power of the first would be nearly 2½ times as great as that of the second, while the third would be altogether ineffective. It is this difference in holding power, due to unequal piston travel, that makes it so difficult to handle freight trains smoothly.

To sum up briefly, the table shows: That the short-travel brakes in a train hold harder at each reduction than the long-travel ones; that they equalize with their brake cylinders with a less train-pipe reduction, hence equalizing sooner than the long-travel brakes; that they equalize at a higher pressure; that since they equalize at higher pressure, they must release later than the brakes with long travel after a full reduction.

When the train-pipe pressure is increased to release the brakes, it will release those having a 10-inch travel at 47 pounds pressure, but it must be increased 9 pounds more, or to 56 pounds, to release those having a 5-inch travel. As soon as the first brakes release, their auxiliaries commence recharging, thus making train-pipe pressure increase more slowly than it otherwise would, and delaying the release of the short-travel brakes. If sufficient excess pressure to release the short-travel brakes is not carried, the wheels will probably be slid while the brakes are being pumped off, and bad spots will result. Besides this, the train is subjected to severe wrenches tending to break it in two, on account of the long-travel brakes releasing before the others. However, if the travel is adjusted within certain limits, all brakes will start releasing at about the same time, the tendency being for the long-travel brakes to release first. If the travel were uniform throughout the train, the tendency would be for the brakes nearest the engine to release first, since train-pipe pressure is increased there first. If none of the brakes have been set in full, they should begin releasing at about the same instant (regardless of the difference in piston travel); this is due to the fact that until a brake equalizes, its auxiliary pressure is practically equal to train-pipe pressure.

The last row of figures in the table shows that the resulting brake-cylinder pressure obtained in an emergency application of the brakes decreases as the piston travel is increased.

RUNNING TRAVEL

3. In speaking of piston travel, the terms *standing travel* and *running travel* are commonly used. The travel of the piston when the brake is applied with the car not in motion is called the **standing travel.** The piston travel is greater by from 1 to 2 inches when the train is running than when standing still, on account of: loose journal brasses, allowing the wheels to move; loose boxes in pedestals; loose truck kingbolts, allowing the trucks to pull together; and the "spring" in the brake beams, levers, or connections. The amount that the brake piston travels when the brakes are applied and the train is in motion is called the **running travel.** Brake beams are sometimes so hung that the brake shoes pull down lower on the wheels when the brakes are applied, and since in that case the shoes travel farther to touch the wheels, the piston travel is increased.

Also, the travel is generally greater when the car is loaded than when unloaded. If the brake beams are hung to the side sills of a car or to the bolster, they will be lowered (consequently increasing the travel) when the car is loaded, and raised again (shortening the travel) when it is unloaded. To avoid this bad effect, some roads hang the brake beams to such a part of the truck that the center of the brake shoes is always the same distance from the rails, regardless of whether the car is loaded or not; this method gives very good results.

THE PROPER PISTON TRAVEL

4. The different parts of the air-brake apparatus are so designed and constructed that the proper brake-shoe pressure will be obtained—in a full-service application of the brakes—with a pressure of 50 pounds per square inch in the brake cylinder. The brake, therefore, would be safer and more efficient if the piston travel were always to remain such as to just give 50 pounds pressure in the brake cylinder—between 7 and 8 inches—but as the brake shoes wear quite rapidly, the travel is bound to increase unless, as such wear proceeds, this travel is automatically adjusted by means of a *slack adjuster*. Automatic slack adjusters not being in general use, it has been customary on most roads to take up the shoe slack on passenger cars and tenders until the piston travel is about 6 inches; the brake is then allowed to run until the wear of the brake shoe increases the travel to 8 inches, when the slack is again taken up.

The limits between which the piston travel is allowed to vary are, on most roads, as follows: For passenger-car and tender brakes, between 6 and 8 inches; for standard freight cars, between 5 and 9 inches. If the piston travel is so long that the piston is at the end of its travel, very little, if any, braking power will be had. On the engine, one auxiliary reservoir supplies air for the two driver-brake cylinders; consequently, a 1-inch travel of each of the driver-brake pistons is equivalent to a 2-inch travel of a car-brake piston. On some roads the driver-brake piston travel is allowed to vary between one-third and two-thirds of the full stroke of the piston. The better practice, however, is to use an air gauge on the brake cylinder and adjust and maintain the travel so that 50 pounds per square inch will be obtained in the brake cylinder on a full application of the brakes.

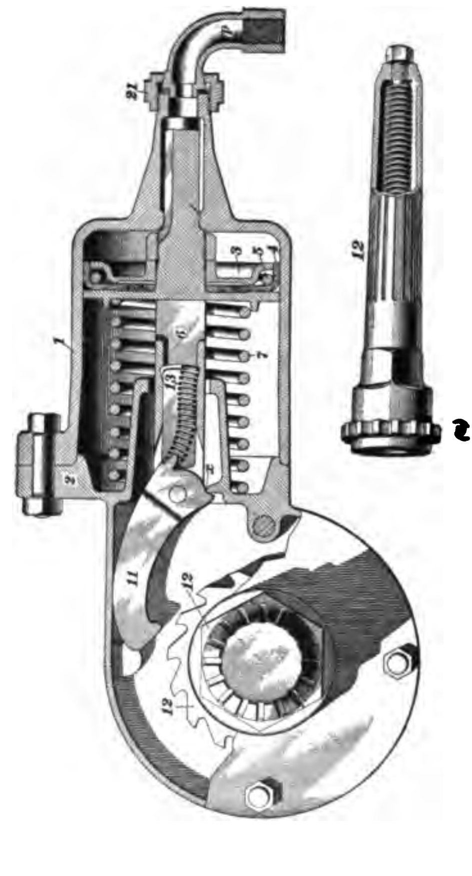
Engine-truck brakes are now equipped with a cylinder having a 12-inch stroke; the piston travel of this brake should be kept as near as possible to 7 inches. With the old-style truck-brake cylinder having 8-inch stroke, keep the piston between 6 and 7 inches.

When brake beams are hung from the body of the car or to the truck bolster above the springs, the brake shoes will hang lower on the wheels when the car is loaded than when empty; hence, the piston travel can be adjusted a trifle shorter than the above limits if the adjustment is made while the car is unloaded.

MEASURING THE PISTON TRAVEL

5. To measure the brake-piston travel, force the push rod—if one is used—into the sleeve until it bottoms on the brake piston, and the latter is forced against the cylinder head; then make a mark on the piston sleeve of a freight brake or on the crosshead of a passenger brake at the non-pressure head. Apply the brake in full, and measure from this mark on the sleeve or crosshead to the non-pressure head; this measurement will be the amount that the piston travels.

To measure the piston travel on an uncharged car, proceed as before. In this case the mark will be made on the



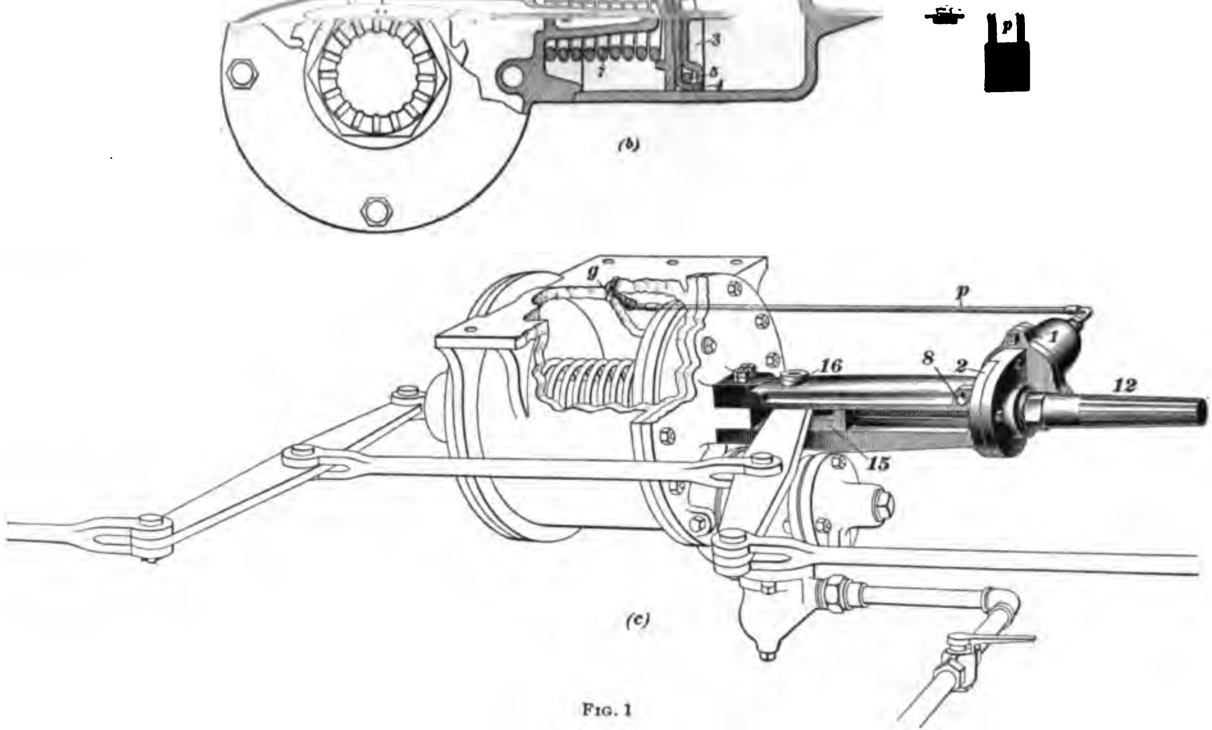


FIG. 1

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push rod at the end of the sleeve, and the brakes will have to be set by hand, using a bar of wood or iron as a lever to set them up tight. This method can only be used on cars on which the air brakes and hand-brakes move the cylinder live lever in the same direction in applying the brake.

THE AMERICAN AUTOMATIC SLACK ADJUSTER

6. As the power and efficiency of the air brake depends largely on the piston travel, the best work is done at a medium point between a very short piston travel and a long one, where the travel should, if possible, be maintained. This cannot be done, however, without closer attention to the matter than the inspectors can give, so mechanical means for keeping the travel at its proper limit have been designed. As the travel does not get shorter while the brake is in service, except when new shoes are applied or the positions of the levers or lengths of the rods are changed, the mechanical device only needs to take up the increased travel caused by the wear of the brake shoes.

The **American automatic slack adjuster** is shown in Fig. 1 (*a*), (*b*), and (*c*). It consists of a cylinder *1* in which moves a piston *3* having a packing leather *4* and an expander ring *5*. This piston is held in its normal position when the brake is released by a spring *7*. The piston rod *6* has attached to it at one end a pawl *11*—the other end of the piston rod moves in the cylinder head as a guide to keep the piston in line. *12* is a ratchet wheel that forms part of and moves a nut *12*, shown in view (*c*). When in normal position, this pawl is raised out of the teeth of the ratchet nut by a projection on the pawl striking a stop *x*. The small spring *13* pushes down the pawl and forces it to engage with a tooth of the ratchet wheel when the pawl is moved forwards by the piston, as shown in view (*b*).

Connected to the adjuster cylinder at the union nut *21* is a pipe *p* leading to the brake cylinder, shown in view (*c*). This pipe is connected to a small hole *g* drilled in the side of the brake cylinder a distance from the edge of the piston packing leather, when the piston is in release position, equal to the proper running travel for that brake. The brake piston, when this travel is exceeded, acts as a valve to open port *g*, so that brake-cylinder air can pass into the adjuster cylinder and move piston *3* into the position shown in view (*b*), when the pawl engages with a tooth of the ratchet, as shown.

When the brake is released, the brake piston moves back of the port and the air in the adjuster cylinder escapes into the brake cylinder on the non-pressure side of the piston and passes out to the atmosphere. The spring *7* then, as soon as the strain on the dead cylinder lever is taken off, returns the piston *3* and pawl *11* to their normal positions, turning the nut *12* far enough to move the end of the dead cylinder lever $\frac{1}{32}$ inch.

The air pressure moves the piston *3* ahead to engage with a tooth of the ratchet nut and the spring *7* returns the piston that turns this nut when the strain has reduced on the brake rigging; thus, the adjuster piston and ratchet nut only moves when the brake piston exceeds the proper running travel.

The stop *x* raises the pawl out of the teeth of the ratchet nut *12* so that this nut can be turned either way by hand to take up or let out slack in the brake rigging.

When it is necessary to replace worn shoes with new ones, or change the length of any rods or position of levers, turn the nut *12* so as to move the dead lever fulcrum jaw back toward the brake cylinder. After the shoes are replaced and the rods and levers are adjusted, try the brakes with air to see if the piston travel is correct. Remember that the adjuster works when the running travel is exceeded; a standing test should show less piston travel than the adjuster is set to work at.

In case the adjuster is not given attention when the fulcrum jaw *15* is nearly up against the case *2* of the adjuster nut, this fulcrum jaw may come up solid against the case, so the ratchet nut cannot be moved by the pawl; in this event, when the pawl is pushed ahead by the adjuster piston and catches on a tooth it locks the pawl so that the nut *12* cannot be turned by hand. In this event, with the old type of adjuster, take off the cover of this case and raise the pawl out of the ratchet; this will allow the spring to move the piston and pawl to the normal position, when the ratchet nut can be turned to move the dead lever back to a position near the brake cylinder. A later type of the adjuster has a stop-screw *8* located near the adjuster cylinder, so arranged that the jaw comes in contact with it instead of with the cylinder; by removing this screw and turning the ratchet by hand, the pawl is released. The latest type of adjuster has this stop-screw *8* in the end of the sleeve of the nut *12* where the adjuster screw will strike the stop-screw at the end of its travel. To remove the pin that connects the dead lever to the fulcrum jaw, move the jaw to the brake-cylinder end of the adjuster, take out the nut *16* above the pin, and it can be pushed out from below.

ADJUSTING BRAKES

7. Adjusting Car Brakes.—In regulating the piston travel of a coach brake (Hodge system), the slack of the brake shoes is taken up at the dead lever guide by moving the truck dead lever so as to reduce the shoe clearance; the smaller this clearance, the less the piston will have to move to draw the shoes up against the wheels. The end of the dead lever is held by a pin that runs through a guide and the lever. The position of the lever in the guide can be changed by removing the pin and moving the lever until it connects with one of the many holes in the guide. Extra holes are sometimes put in the bottom connections of the brake rigging so that part of the slack may be taken up there. If sufficient slack cannot be taken up at the truck dead lever, one or two holes should be taken up in the other connection and the travel then adjusted by means of the truck dead lever. With the Stevens system, on coach equipment, there are no dead levers so that the slack is taken up in the bottom rods.

On most freight cars, and on mountainous roads with passenger cars, both the hand-brake and the air brake move the levers in the same direction in applying brakes; hence, they are said to work together. On nearly all passenger, and a few freight, cars, however, the hand-brake and the air brake move the levers in opposite directions; if, then, the hand-brake chain is wound up a little, the piston travel will shorten a corresponding amount when the air brake is next applied. When the hand-brake and the air brake work together, winding up the brake chain does not shorten the piston travel.

The practice of shortening the piston travel by winding the hand-brake up a little, instead of moving the dead lever, or shortening the bottom connections, is a bad one, and is decidedly dangerous. If the brake dog on the hand-brake should work out of the ratchet, the slack would run out; also, the extra strain on the brake chain tends to break it. If too much chain is wound up, the travel may be shortened so much that the piston will not cover the leakage groove and the brake will not apply. Then, again, if the air brake tends to turn the hand-brake wheel in a direction opposite to that which it must be turned by hand to set the brakes, there is always danger of a person being hurt should he try to turn the hand-brake when the engineer happens to be setting the air brakes.

In taking up slack, make sure that the hand-brakes are off and the slack is all taken out of the upper connections, so that the truck levers do not go within 1 inch of the truck timber or other stop when the brake piston is all the way back in release position.

8. Cam Driver Brakes.—In Fig. 2 are shown two views of the push-down type of **cam driver brake,** (*a*) being a side view and (*b*) an end view. As air is admitted into the brake cylinder *C*, the piston, and consequently the crosshead *h*, is forced downwards, thus causing the cams to roll on each other and move the cam-screw pins outwards, pressing the shoes against the wheels.

The distance between the link pin *a* and the cam-screw pin *b* can be changed by means of the cam-screw *c*, and it is

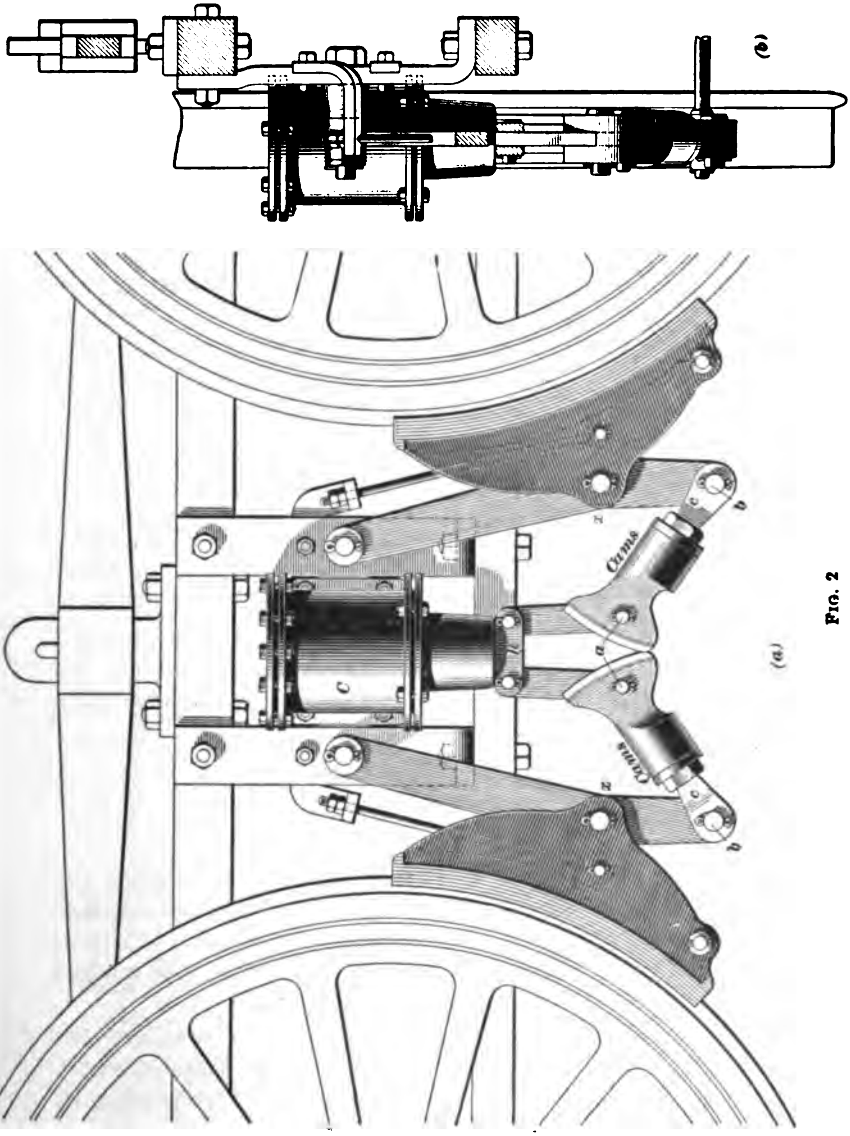


FIG. 2

by means of this screw that the piston travel is adjusted. To shorten the travel, the distance between the pins is lengthened.

In taking up the slack of the brake shoes, care must be exercised to lengthen both cam-screws the same amount, so that the point of contact of the cams will be in line with the center of the brake cylinder. Sufficient shoe clearance should be allowed.

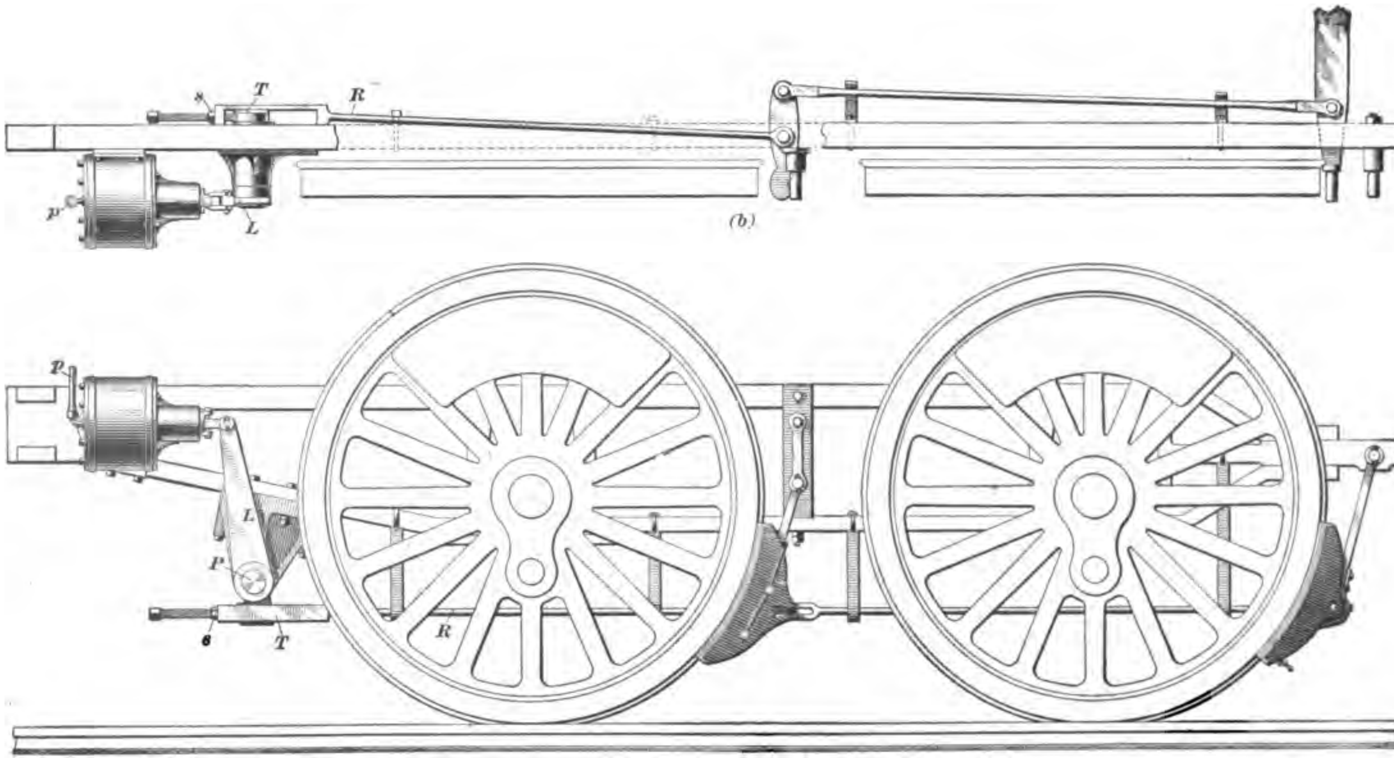
9. Outside Equalized Driver Brake.—In Fig. 3 are given two views of the American outside **equalized driver brake** as generally used at the present time on engines having two pairs of drivers, (*a*) being a side view and (*b*) a plan view. In this type of brake the piston is connected to the brake rod *R* by a bell-crank lever *L* that turns on the pin *P*, so that when the brake piston is forced outwards, the brake rod *R* is drawn backwards and applies the brake shoes to the wheels.

A slack adjuster *T* (popularly spoken of as a *turnbuckle*) is provided for the purpose of taking up the slack as the brake shoes wear. This is accomplished by loosening the lock-nut *s* on the screw bolt, and turning the bolt in such a way as to pull the brake rod *R* backwards, thus moving the brake shoes nearer the wheels. The pipe *p* leads from the brake cylinder to the triple valve.

LEVERS AND LEVERAGE

10. The foundation brake gear on engines, tenders, and cars consists simply of a system of levers connected together by rods; and it is by means of these levers that the force developed in the brake cylinder is transmitted and applied to the wheels.

It is desirable, therefore, to be able to calculate the braking power that a system of levers is capable of exerting, and to do this the different classes of levers must be studied.



(a)

Fig. 8

SIMPLE LEVERS

11. A **lever** is any bar that is capable of being turned about an axis or pivot, called the *fulcrum*. In Figs. 4, 5, and 6, the object to be lifted is called the *weight*, the force employed to lift the weight is called the *power*, and the point around which the lever turns is called the *fulcrum*.

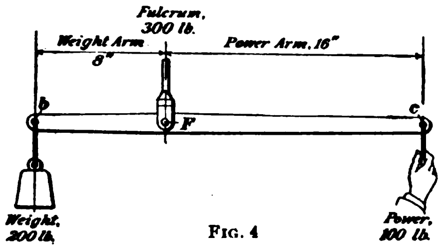


FIG. 4

That part of the lever between the fulcrum and the weight is called the *weight arm* of the lever, while the part between the fulcrum and the power is called the *power arm*. The weight arm is also called the *work arm*. As the calculations in brake leverage relate to the work done by the power through the medium of the levers, we will use the term work arm instead of weight arm in this explanation.

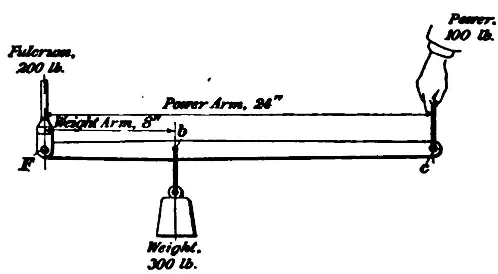


FIG. 5

12. Classes of Levers.—Levers are divided into three classes, depending on the relative positions of the fulcrum and the points of application of the power and the weight.

In levers of the *first class*, Fig. 4, the fulcrum is between the points of application of the power and weight. Fig. 7

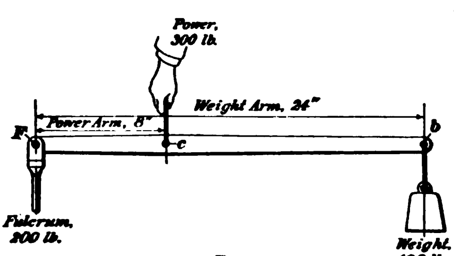


FIG. 6

represents a car-truck lever of this class applied to a car wheel; these levers are used in some cases for inside-hung brake beams. The live cylinder lever is of the first class.

With levers of the *second class*, Fig. 5, the power is attached at one end, the fulcrum is at another, while the weight, or work, is between the fulcrum and power. This class is shown in Fig. 8 as applied to a car-truck wheel. Car-truck levers are usually of this class.

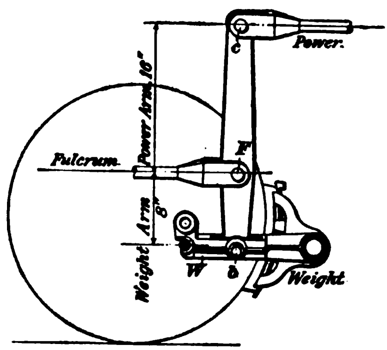


FIG. 7

With levers of the *third class*, Fig. 6, the power comes between the fulcrum and the work. Very few truck levers are of this class. The dead cylinder lever and the Hodge, or floating, levers are of this class. This class is shown in Fig. 9, as applied to a car-truck wheel.

13. Weight Sustained By Fulcrum.—The force exerted on the fulcrum of a lever can be ascertained by adding the forces at the ends for a first-class lever. For second- and third-class levers, subtract the force at one end from the force or strain between the ends; the remainder will be the force exerted on the fulcrum.

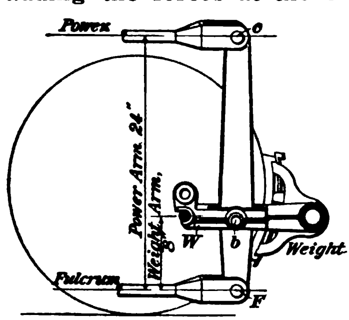


FIG. 8

In any leverage calculation, there are four quantities to be taken into consideration, the power, the length of the power arm, the weight, and the length of the weight arm. When any three of these quantities are known, the fourth can be ascertained. For instance, if the power is multiplied by the power arm and the product divided by the weight arm the quotient will be the weight. Or, if the weight is known, multiply it by the weight arm and divide this product by the power arm; the quotient will be the power. Similar calculations will give the length of either arms. From this we get the following rule.

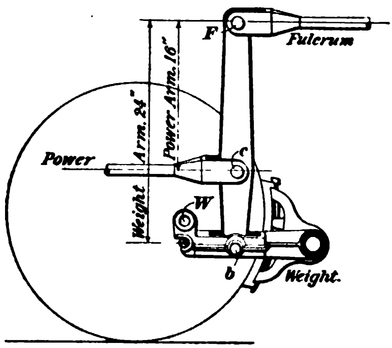


FIG. 9

Rule.—*The power multiplied by the power arm is equal to the weight multiplied by the weight arm.*

Taking Fig. 4 as an example, 100 × 16 = 1,600 ÷ 8 = 200, the weight; or, 100 × 16 = 1,600 ÷ 200 = 8, the weight arm. Then, 200 × 8 = 1,600 ÷ 100 = 16, the power arm. With Fig. 5, 100 × 24 = 2,400 ÷ 8 = 300, the weight, or 300 × 8 = 2,400 ÷ 100 = 24, the power arm.

14. With all classes of levers, the power and the weight move in proportion to the work being done. Suppose that the weight arm of the lever shown in Fig. 10 is twice as long

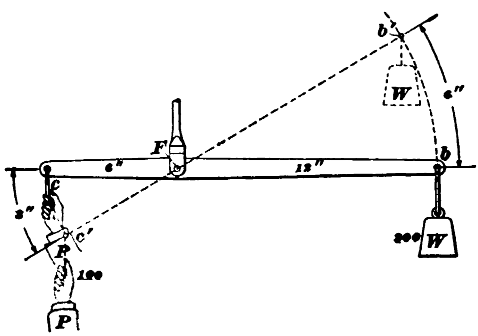


FIG. 10

as the power arm; then, if the lever is turned about the fulcrum *F* until it occupies any other position, it will be found, by actual measurement, that the point *b* of the lever travels just twice as far in moving to *b'* as *c* does in moving to *c'*.

If the weight arm were four times as long as the power arm, it would be found that the point *b* would always travel four times as far as the point *c* when the lever was moved through any distance. In other words, the distances through which the power and the weight move are always in the same ratio as the lengths of their arms.

This being true, we may, in place of the statement that the power multiplied by the power arm is equal to the weight multiplied by the weight arm, write:

Rule.—*The power multiplied by the distance through which the power moves is equal to the weight multiplied by the distance through which the weight moves.*

If, as shown in Fig. 10, the power moves 6 inches while the weight moves 3 inches, we will have 100 multiplied by 6 and the product 600 divided by 3, which equals 200, the amount of weight that could be balanced by a force of 100 pounds with a lever of the dimensions shown.

COMPOUND LEVERS

15. Description.—A **compound lever** is a combination of simple levers so arranged that when a power is applied to the first lever it actuates all the others and causes a force to be exerted by the last lever of the combination.

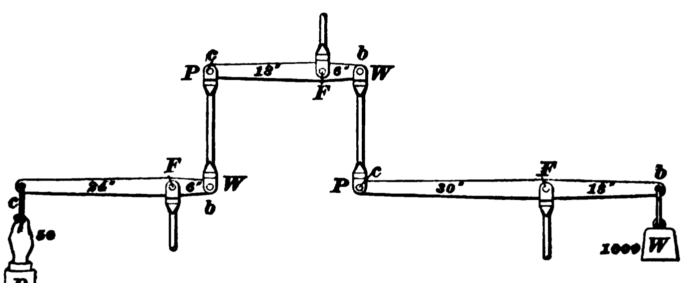


Fig. 11

When a force is applied to the first lever, it exerts a force that is applied to the second lever; the force exerted by the second lever is applied to the third; and so on.

Such a lever is shown in Fig. 11, in which there are three simple levers; the weight arm of the first is connected to the power arm of the second, and the weight arm of the second to the power arm of the third. It will be seen that by applying sufficient power at *P* to operate the first lever the others will also be operated, and the weight *W* of the third lever will be raised.

It will be noticed, also, that the force exerted by the end of the weight arm of the first lever is the power applied to the second; and the force exerted by the second is the power applied to the third; and so on for any number of levers.

16. Law of the Compound Lever.—The law that governs the compound lever may be stated as follows:

Law.—*The power P multiplied by the product of the power arms of all the component simple levers, is equal to the weight W multiplied by the product of the weight arms of all these levers.*

From this law the following rules may be deduced:

Rule I.—*The power P that must be applied to a compound lever to balance a given weight or produce a given pressure W, may be found by multiplying the product of the weight arms of all the simple levers by the weight, and dividing this by the product of the power arms of all these levers.*

EXAMPLE 1.—How much power must be applied at *P*, Fig. 11, to balance 1,000 pounds at *W*?

SOLUTION.—The weight arms of the levers are 6, 6, and 18 in., and the power arms 24, 18, and 30 in., respectively. Hence, from rule I, the power

$$P = \frac{6 \times 6 \times 18 \times 1{,}000}{24 \times 18 \times 30} = 50 \text{ lb.} \quad \text{Ans.}$$

Rule II.—*The weight that a given power will balance, when applied to a compound lever, may be found by multiplying the product of the power arms of all the simple levers by the power, and dividing this by the product of the weight arms of all the levers.*

EXAMPLE 2.—If a force of 50 pounds is applied at *P*, Fig. 11, how many pounds will it balance at *W*?

SOLUTION.—From rule II, it will be found that 50 lb. at *P* will balance a weight of

$$W = \frac{24 \times 18 \times 30 \times 50}{6 \times 6 \times 18} = 1{,}000 \text{ lb.} \quad \text{Ans.}$$

LAWS OF LEVERS APPLIED TO BRAKE GEARS

17. In order to apply these laws to any particular system of levers, it is best to make a diagram showing the position of the fulcrums, length of lever arms, and the line of direction of the forces applied to, or exerted by, the lever. Then, since the force developed by the brake cylinder is generally known, the power exerted by the lever can readily be found by applying the proper rules or formulas.

To illustrate the application of the laws of levers to actual brake gears, the braking power of the Hodge and the Stevens systems of car-brake levers, and of the cam and the American equalized types of driver brakes will be determined.

COACH BRAKES

18. The Hodge System.—A diagram of this system is shown in Fig. 12. It consists of two compound levers operated by the same brake cylinder, each compound lever consisting of four simple levers. The first of these is called the *cylinder lever;* the second, the *floating lever;* the third, the *live truck lever;* while the fourth is called the *dead truck lever.* The fulcrum of each lever is marked, as well as the points at which the power is applied and work done. The live and dead cylinder levers are of the first and third classes, respectively; the floating levers are of the third class; while the truck live levers and truck dead levers are of the second class. The brake cylinder is assumed to exert 4,700 pounds pressure in an emergency application.

Calculating the Power of the Hodge System.—To calculate the power applied to the brake shoes, it is simply a question of using the proper rules for the separate levers. For the first, or cylinder lever, the power is 4,700; therefore, $W = \frac{4,700 \times 12}{12} = 4,700$ pounds, which is the force applied to the floating lever. The power of the floating lever is 4,700; therefore, $W = \frac{4,700 \times 18}{36} = 2,350$ pounds, which is

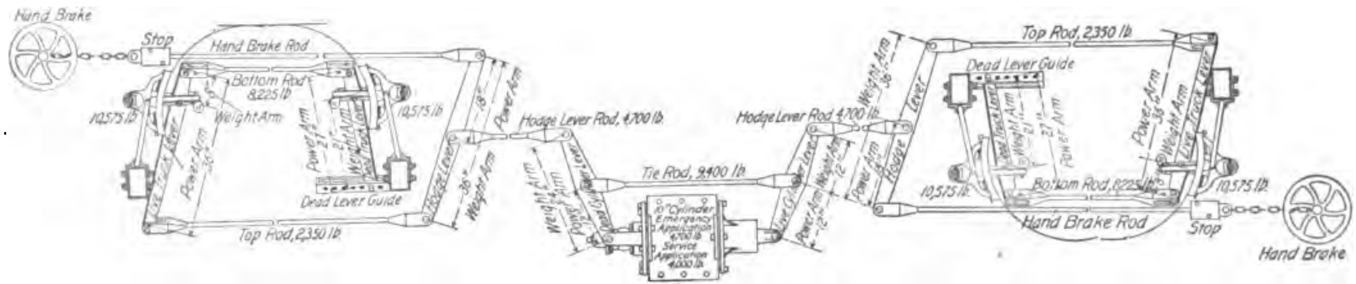

Hand Brake
Stop
Hand Brake Rod
Bottom Rod 8,225 lb
10,575 lb
Weight Arm
Power Arm
Dead Lever Guide
Top Rod, 2,350 lb
Hodge Lever
Hodge Lever Rod, 4,700 lb
Tie Rod, 9,400 lb
10" Cylinder Emergency Application 4,700 lb Service Application 4,000 lb
Dead Cylinder Lever
Live Cylinder Lever
Hodge Lever Rod 4,700 lb
Top Rod, 2,350 lb
Dead Lever Guide
Live Truck Lever
Dead Truck Lever
Bottom Rod, 8,225 lb
10,575 lb
Hand Brake Rod
Stop
Hand Brake

Fig. 12

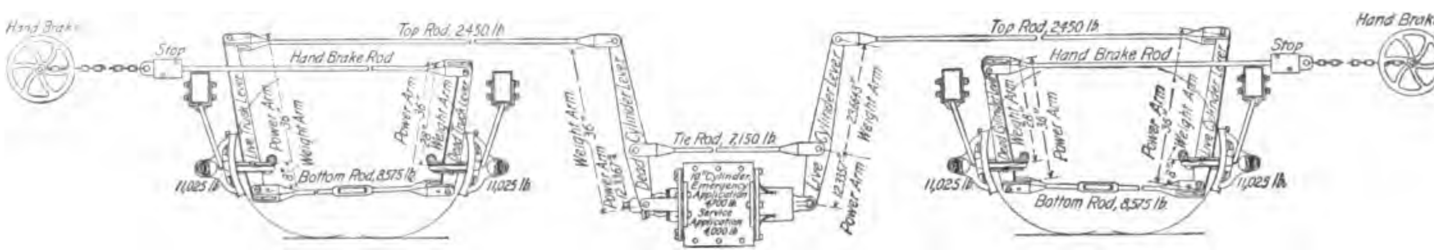

Hand Brake
Stop
Top Rod, 2,450 lb
Hand Brake Rod
Live Truck Lever
Dead Truck Lever
Power Arm
Weight Arm
Bottom Rod, 8,575 lb
11,025 lb
Dead Cylinder Lever
Tie Rod, 7,150 lb
10" Cylinder Emergency Application 4,700 lb Service Application 4,000 lb
Live Cylinder Lever
Power Arm
Weight Arm
Top Rod, 2,450 lb
Hand Brake Rod
Dead Cylinder Lever
Live Cylinder Lever
Bottom Rod, 8,575 lb
11,025 lb
Stop
Hand Brake

Fig. 13

the power that goes to the live truck lever, and the pressure on the hand-brake rod is 4,700 − 2,350 = 2,350 pounds. The power of the live truck lever is 2,350 pounds; as this is a second-class lever its work arm is 36 inches and its power arm is 8 inches; therefore, $W = \frac{2{,}350 \times 36}{8} = 10{,}575$ pounds, the force applied to the wheels. The force of the live truck lever is 10,575 − 2,350 = 8,225, which is the force at the dead truck lever; hence, $W = \frac{9{,}400 \times 27}{21} = 10{,}575$ pounds, the force applied to the wheels by the dead truck lever, while the force exerted at the fulcrum is 10,575 − 8,225 = 2,350 pounds.

The calculations for the left-hand compound lever are made in the same way, beginning with 9,400 pounds applied to the middle of the dead cylinder lever.

19. The Stevens System.—The Stevens system of coach-brake levers is shown in Fig. 13. It will be noticed that there are no floating levers, the cylinder levers being lengthened sufficiently to allow the work arm to be coupled directly to the live truck lever. It will be noticed, also, that the live cylinder lever is of the first class, the dead cylinder lever is of the third class, and all the truck levers are of the second class.

Calculating the Power of the Stevens System.—To calculate the power applied to the brake shoes in this system of levers, proceed as with the Hodge system. For example, if the brake cylinder exerts a force of 4,700 pounds, a force of $\frac{4{,}700 \times 12.34}{23.66} = 2{,}450$ pounds will be exerted on the cylinder lever, while the force on the fulcrum will equal 4,700 + 2,450 = 7,150 pounds. 2,450 pounds applied to the live truck lever will cause a force of $\frac{2{,}450 \times 36}{8} = 11{,}025$ pounds to be exerted at the brake shoes, while the force on the fulcrum will be 11,025 − 2,450 = 8,375 pounds. With a force of 9,400 pounds exerted at the dead truck lever, a force of

$W = \frac{8{,}375 \times 36}{28} = 11{,}750$ pounds will be applied to the brake shoes by this dead lever, while the fulcrum will be subjected to a force of $11{,}750 - 8{,}375 = 2{,}450$ pounds. The force applied to the other brake shoes can be found in a similar manner.

A coach brake usually has brake-beam springs to pull the shoes from the wheels when the brake is released. Some of these springs are so stiff as to absorb considerable of the power of the piston and nearly all the power developed by the hand-brake. These springs should be tested with a gauge on the brake cylinder to see how much pressure it takes to hold all the shoes against the wheels.

FREIGHT-CAR BRAKES

20. Stevens Freight-Brake System.—The Stevens system is generally used in freight-brake equipment, as it has the fewest number of levers. By attaching the fulcrum end of the dead cylinder lever to a bracket fastened to a car sill instead of to the pressure head of the brake cylinder as is done with coach equipment, the truck levers come at the same relative angles on both trucks.

A diagram of the Stevens freight brake with brake beams hung inside the trucks is shown in Fig. 14. As in the Stevens system of coach brake, the end of the live truck lever is coupled direct to the live cylinder lever by means of the top rod, and the brake-piston rod, the tie-rod, and the hand-brake are connected to the live cylinder lever as shown.

With an 8-inch brake cylinder and quick-action triple valve, the power exerted on the brake-cylinder piston is 3,000 pounds. The leverage calculations are made the same as for Fig. 13. The lengths of the power arms and work arms of the different levers, together with the strains at each point, are shown in the diagram.

When measuring brake levers for the purpose of computing the force delivered at the shoes, apply the brake sufficiently to take out all the slack between the pins and the holes in the connections, or the measurements may be incorrect.

Besides the Stevens system, other types of brakes, such as the chain equalized brake and special designs of brake rigging required on hopper-bottomed cars to allow the rods and levers to move without interfering with any of the dumping devices, are used.

ENGINE DRIVER BRAKES

21. Cam Driver Brake.—The following very simple method for determining the braking power developed by a **cam driver brake** was invented by Mr. H. A. Wahlert, of the American Brake Company:

Take two pieces of wire of the same diameter, say $\frac{1}{4}$ inch, and place them between the top and bottom toes of one of the brake shoes and the wheel; then apply the brakes fully and measure the piston travel; also, measure the exact distance between the centers of the pins x, x, Fig. 2, connecting the brake shoes to the levers. Next release the brake, remove the wires, and again apply the brakes fully. Now measure the piston travel and find how much it increases with the wires removed; also, measure the distance between the centers of the pins x, x and see how much this distance, which is the increased brake-shoe travel, differs from the measurement with the wires in. Divide the increase in piston travel by the increase in brake-shoe travel and multiply this

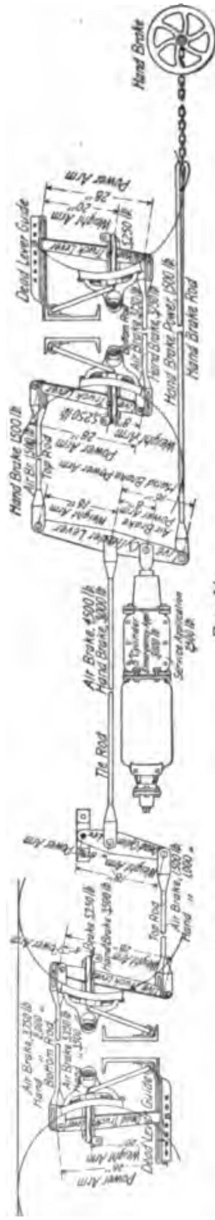


FIG. 14

by the power of the piston, in pounds; this will give the pressure on each shoe.

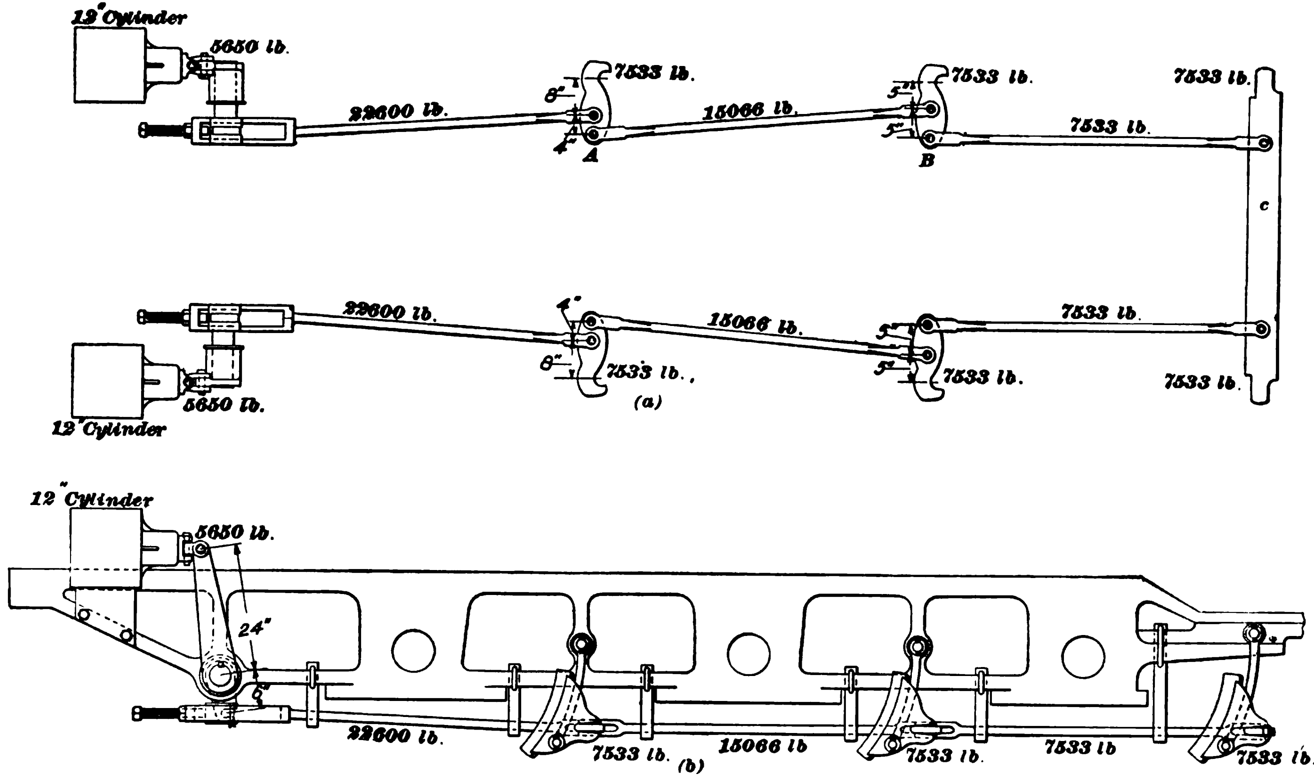
The wires are used to find the relative amount of travel of the weight arm (the brake shoe) and the power arm (the piston); by subtracting the amount of piston travel when the wires are in place from that when they are removed, the distance the piston travels while the brake shoe travels, the thickness of the wire can be determined. Knowing the relative travel of the brake shoe and the piston, and the force developed by the cylinder, the force exerted on one brake shoe can be determined by the rule given in Art. **14.** The rule, as applied to this case, may be stated as follows: The force exerted on one brake shoe of a cam driver brake is equal to the increase in piston travel (as determined above) multiplied by the force developed by the brake cylinder, in pounds, and divided by the diameter, in inches, of the wire used.

To find the total force exerted on the four shoes, multiply this amount by 4.

As an example of the use of this rule, suppose the diameter of the wires used to be $\frac{1}{8}$ inch, the piston travel with the wires inserted to be 4 inches, and when removed, $4\frac{1}{2}$ inches. In this case the increase in piston travel would be $4\frac{1}{2} - 4 = \frac{1}{2}$ inch. Then, if a total force of 2,500 pounds was developed by the brake cylinder, the force exerted on each brake shoe would be $W = \frac{2{,}500 \times \frac{1}{2}}{\frac{1}{8}} = 10{,}000$ pounds. This would give a total force on the four shoes of $4 \times 10{,}000 = 40{,}000$ pounds.

22. American Outside Equalized Brake.—This type of brake is illustrated in Fig. 3, and a diagram of it, as applied to an engine having three pair of drivers, is given in Fig. 15. In a brake of this kind, the levers are so proportioned that the braking power developed at the brake cylinder is distributed equally among the drivers, the force applied to the different brake shoes being maintained equal; hence, the brake is said to be an equalized brake.

In the figure, the cylinder lever is of the first class, while



12" Cylinder
5650 lb.
22600 lb.
8"
4"
A
7533 lb.
15066 lb.
5"
5"
B
7533 lb.
7533 lb.
7533 lb.
c
22600 lb.
4"
8"
7533 lb.
15066 lb.
5"
5"
7533 lb.
7533 lb.
7533 lb.
5650 lb.
12" Cylinder
(a)
12" Cylinder
5650 lb.
24"
6"
22600 lb.
7533 lb.
15066 lb
7533 lb.
7533 lb
7533 lb.
(b)

FIG. 15

the others are of the third class, the lengths of the lever arms being given in each case. The total force developed in the brake cylinder is 5,650 pounds. This will cause a force of $\frac{5{,}650 \times 24}{6} = 22{,}600$ pounds to be exerted on the brake rod to the first lever *A*, which in turn will cause a force of $\frac{22{,}600 \times 4}{12} = 7{,}533$ pounds to be exerted at the brake shoe of lever *A*.

The force exerted on the brake rod to lever *B* will be 22,600 − 7,533 = 15,066 pounds. This will produce a force of $\frac{15{,}066 \times 5}{10} = 7{,}533$ pounds at the brake shoe of lever *B*, and a force of 15,066 − 7,533 = 7,533 pounds on the brake rod to the beam *c*. The 7,533 pounds acting on the beam *c* exerts a pressure on both ends of the beam, being divided in accordance with the length of the arms of the beam. If the arms were 1 to 6, then it would be $\frac{7{,}533 \times 1}{6} = 1{,}255$ pounds exerted on the far end of the beam, and 7,533 − 1,255 = 6,278 pounds on the near end. The force exerted on the beam by the brake rod on the opposite side is divided similarly, so that each shoe will have 6,278 pounds from the brake cylinder on its side, and 1,255 pounds from the brake cylinder on the opposite side, making 7,533 pounds for each shoe. The result, therefore, is just the same as though each shoe got the full 7,533 pounds from the brake cylinder on its side.

BRAKE POWER

PRESSURES APPLIED TO BRAKE SHOES

23. The statement has been made that if the frictional resistance exerted between the wheel and the shoe were greater than that exerted between the wheel and the rail, the wheel would slide. With a good rail, these frictional resistances will be practically equal when the force applied at the brake shoe is equal to the pressure of the wheel on the rail, so that the force applied to the brake shoe must be less than the pressure of the wheel on the rail, to insure the wheel against slipping when used under the varying conditions of service. Practical experience has demonstrated that the best results will be obtained by the use of the following as the maximum safe pressures on the brake shoes in the different classes of service: For passenger cars, $\frac{9}{10}$, or 90 per cent., of the weight on the rail under the wheel when the car is empty; for freight cars in interchange service, $\frac{7}{10}$, or 70 per cent., of the weight on the rail when the car is empty; for tenders, 100 per cent., or the entire weight on the rail when the tender is light, as tenders rarely run empty. The driving wheels move the pistons and valve-motion work while drifting, and as these act as a brake only $\frac{75}{100}$, or 75 per cent., of the weight under the drivers when the engine is ready for the road is used. For Prairie and Atlantic type locomotives, a braking power of between 68 and 70 per cent. of the weight of the wheels on the rails is used for both driving and trailer wheels. Engine trucks are braked at 75 per cent.; the truck brake usually has no sanding device. With compound locomotives, the back pressure against the large low-pressure piston while drifting with steam shut off is so much more than with simple engines of the same power that the driver brake is generally adjusted to about 40 per cent.

CALCULATION OF BRAKING POWER

24. The method of calculating the proper braking power to use in any case is as follows: First find the weight on the rail under each wheel, by dividing the entire weight of the empty car by the number of wheels. Then, if the car is a passenger car, take nine-tenths of this, or, if a freight car, take seven-tenths, as the maximum force to be used on each brake shoe. In other words, this is the allowable force per shoe; therefore, the total braking force can be found by multiplying this amount by the number of wheels that are fitted with brakes, and from this the proper proportion of brake levers can be determined.

Example.—What is the maximum braking power that should be allowed at each brake shoe of a 72,000-pound passenger car having six-wheel trucks, four wheels only of each truck being supplied with brakes? Also, what will be the total braking force?

Solution.—If this car weighs 72,000 lb. and has twelve wheels, there will be a pressure of $\frac{72,000}{12} = 6,000$ lb. on the rail under each wheel; hence, the highest allowable braking force per wheel should be $.9 \times 6,000 = 5,400$ lb. The total allowable braking force of the car, therefore, will be $8 \times 5,400 = 43,200$ lb., since only eight wheels are braked.

25. Force Exerted in Brake Cylinder.—The total allowable braking force should not be exceeded when an emergency application of the brakes is made, since at such

TABLE II

FORCE EXERTED IN BRAKE CYLINDER

Size of Cylinder Inches	With 50 Pounds Pressure	With 60 Pounds Pressure
6	1,400	1,700
8	2,500	3,000
10	3,900	4,700
12	5,650	6,800
14	7,700	9,200
16	10,000	12,000

times it is especially important that no wheels slide, as a sliding wheel exerts but little retarding force. For this reason, the braking power is calculated on the assumption that, in an emergency application, 60 pounds pressure is obtained in the brake cylinder with a quick-action brake, and 50 pounds with a plain triple.

The total force, in pounds, that a brake cylinder will develop when subjected to 50 and 60 pounds pressure per square inch, has been calculated for several sizes of cylinders; the results are given in Table II.

The force exerted in a brake cylinder is found by multiplying the area of the piston, in square inches, by the pressure per square inch in the cylinder. Thus, if the piston has an area of 154 square inches, it will develop a force of $154 \times 50 = 7{,}700$ pounds under a 50-pound pressure.

The area of a piston may be found by multiplying the diameter of the piston, in inches, by itself, and by 11, and dividing by 14. Thus, the area of a 10-inch piston is $\frac{10 \times 10 \times 11}{14} = 78\frac{1}{2}$ square inches, nearly. Another, and slightly more accurate, method of calculating the area of a piston is to multiply the diameter, in inches, by itself, and by .7854.

CALCULATION OF BRAKE-CYLINDER PRESSURES

GENERAL CONSIDERATIONS

26. To thoroughly understand the calculation of brake-cylinder pressures, it is necessary to have a knowledge of the behavior of air under expansion and compression. This further requires a knowledge of *atmospheric pressure* together with an understanding of the difference between *gauge pressure* and *absolute pressure*.

27. Atmospheric Pressure.—By atmospheric pressure is meant the pressure exerted by the atmosphere, due to its weight. The atmosphere consists of a fluid, called *air*, that completely surrounds the earth and is held in place by its own weight. While a cubic foot of air weighs but little, the weight of a column of air 40 miles high is such as to exert a pressure of 14.7 pounds per square inch at the sea level in all directions. In all ordinary calculations the weight of the atmosphere is assumed to be 15 pounds per square inch, so as to simplify the calculations; but in more accurate calculations 14.7 pounds is used. The higher above the sea level we go, the less the weight of the atmosphere is found to be, because there is less air above us to exert a pressure. Also, it is found that the air becomes more and more rarefied the higher up a mountain we go, so that the air at the top is not nearly as dense as it is at the bottom. The rapidity with which the density of the atmosphere decreases at different heights above the sea level will be better understood from the fact that one-half of the entire bulk of the atmosphere is supposed to be contained in a layer that surrounds the earth to the height of nearly $2\frac{3}{4}$ miles from its surface. The other half is above that, and expands into an unknown height, estimated to be about 40 miles high. At the level of the sea the pressure of the atmosphere is 14.7 pounds per square inch; 5,000 feet above the sea it is 12.1 pounds; 10,000 feet, it is 10 pounds; at 15,000 feet, it is 8.28 pounds; 6 miles, it is 4.37 pounds. The density of the air is proportional to the weight it is subjected to, and on account of this difference in density an air pump must work longer at the top of a high mountain than at the bottom to pump up standard pressure in the main reservoir.

28. Measuring Air Pressures.—The pressure exerted by the atmosphere is measured by the height of a column of mercury that it will sustain. At the sea level, the atmosphere sustains a column of mercury practically 30 inches high, and since a column of mercury 1 square inch in cross-section and 30 inches high weighs 14.7 pounds, nearly, we know that the pressure of the atmosphere must equal that amount. The pressure of the atmosphere cannot be measured by a gauge. This statement can readily be proved by opening the main-reservoir drain cock any time that the air gauge registers zero. The open drain cock makes an opening to the atmosphere through which the reservoir will be kept charged to atmospheric (15 pounds) pressure, yet the gauge will stand at zero. After the drain cock is closed there is still 15 pounds pressure in the reservoir, although the gauge does not indicate it. Start the pump and compress air into the reservoir until the gauge indicates 15 pounds. The gauge will then only indicate half the pressure in the reservoir because there was 15 pounds pressure before the gauge began to indicate; consequently, when the gauge indicates 15 pounds there really is 30 pounds pressure in the reservoir. Likewise, when the gauge registers 30 pounds there really is 30 + 15 = 45 pounds pressure in the reservoir. In fact, no matter what the gauge registers there will always be 15 pounds more pressure in the reservoir than is indicated because the gauge does not register the first 15 pounds. In the calculations of pressures, therefore, we have two distinct scales of pressure: one, called the **gauge-pressure scale** (the zero point of which is reckoned at atmospheric pressure) which does not take atmospheric pressure into account; the other, called the **absolute-pressure scale** (the zero point of which is reckoned at the point of absolutely no pressure) which includes atmospheric pressure. Gauge pressure, therefore, is the pressure that is indicated by a gauge; it is always 15 pounds less than absolute pressure. Absolute pressure is always 15 pounds greater than gauge pressure and is found by adding 15 pounds to the gauge pressure. When the gauge indicates 40 pounds the absolute pressure is 55 pounds, and so on. No gauge is made that will measure absolute pressures, hence it can only be determined from the gauge pressure.

Air pressures are sometimes measured by *atmospheres* instead of by pounds per square inch. One atmosphere represents a pressure of 0 pounds on the gauge; two atmospheres represent 15 pounds; three atmospheres, 30 pounds; four atmospheres, 45 pounds; and so on. In reckoning pressures by atmospheres, the pressures must always be reckoned from absolute zero.

29. Behavior of Air Under Compression and Expansion.—Through experiments made by Boyle, in 1662, and Mariotte, in 1676, the relationship between the volume and pressure of a gas was found to be as follows: In a true gas (such as air) the volume is inversely proportional to the absolute pressure to which the gas is subjected. This means that if the absolute pressure of a volume of air be either increased or decreased the volume will be decreased or increased (as the case may be) in exact proportion to the change in pressure. For example, if the absolute pressure is doubled, the volume will be halved; if increased four times, the volume will be reduced to one-fourth the original volume. Likewise, if the absolute pressure is halved, the air will expand to double its volume; if reduced to one-fourth the original pressure, the volume will increase to four times the original volume, and so on. It means also that if the volume of air be either compressed into a smaller space or expanded into a larger, the absolute pressure of the air will either be increased or decreased (as the case may be) in exact proportion to the change in volume. That is, if the volume be reduced one-half, the absolute pressure will be doubled; if expanded to twice the volume, the absolute pressure will be halved, and so on. The relationship of pressure and volume may then be stated as follows: If the absolute pressure and the volume before compression or expansion takes place be multiplied together, the product will always equal the product of the absolute pressure and the volume after compression or expansion.

For example, suppose that 4 cubic feet of air at 30 pounds pressure (45 pounds of absolute pressure) is expanded into 8 cubic feet. As the volume has been expanded to twice the original, we know that the absolute pressure must have been reduced one-half, or to $22\frac{1}{2}$ pounds. Therefore, the product of the absolute pressure and the volume before expansion is $45 \times 4 = 180$; after expansion it is $8 \times 22\frac{1}{2} = 180$, which is the same as before expansion.

30. From the above we can now deduce the following rules for finding the pressure or volume after expansion or compression has taken place.

Rule I.—*After a volume of air has been either expanded or compressed the resulting absolute pressure will equal the product of the absolute pressure and the volume before expansion or compression, divided by the volume occupied by the air after expansion or compression.*

In the examples that follow, gauge pressures will be given, which must always be reduced to absolute pressures before using the rules.

EXAMPLE 1.—If 4 cubic feet of air at 50 pounds pressure is expanded to 10 cubic feet, what will be the resulting absolute pressure?

SOLUTION.—The absolute pressure equals $50 + 15$, or 65 pounds; therefore, from rule I, the pressure will equal $\frac{4 \times 65}{10} = 26$ lb. absolute, or $26 - 15 = 11$ lb. gauge pressure. Ans.

EXAMPLE 2.—If 10 cubic feet of air at 11 pounds pressure is compressed into 4 cubic feet, what will be the resulting pressure?

SOLUTION.—In this case the absolute pressure equals $11 + 15 = 26$ lb.; therefore, from rule I, the resulting pressure will equal $\frac{10 \times 26}{4} = 65$ lb. absolute, or 50 lb. gauge. Ans.

Rule II.—*After a volume of air has been either expanded or compressed, the resulting volume is equal to the product of the absolute pressure and the volume before expansion or compression, divided by the resulting absolute pressure.*

EXAMPLE 3.—If a volume of 4 cubic feet of air at 50 pounds pressure is expanded until its pressure is 11 pounds, what will be its volume?

SOLUTION.—The absolute pressure before expansion equals 65 lb.; after expansion, 26 lb.; therefore, from rule II, the volume will equal $\frac{4 \times 65}{26} = 10$ cu. ft. Ans.

EXAMPLE 4.—If 10 cubic feet of air at 11 pounds pressure is compressed until it exerts a pressure of 50 pounds, what will be its volume?

SOLUTION.—The absolute pressure before expansion equals 26 lb.; after expansion, 65 lb.; therefore, from rule II, the volume will equal $\frac{10 \times 26}{65} = 4$ cu. ft. Ans.

It must be remembered that absolute pressures only are used in these rules, and that gauge pressures must be reduced to absolute pressures before using. Also, the pressures obtained by use of these rules are absolute pressures, and must be reduced to gauge pressures if absolute pressures are not wanted.

The principles embodied in these rules form the foundation on which all calculations in compressed air are based. All that is necessary to remember, in using them, is to always use *absolute* pressures, and to be sure and use the right volume into which the air is expanded or contracted. The rules will now be applied in the calculation of brake-cylinder pressures.

PRELIMINARY CALCULATIONS

31. Cross-Sectional Area of Cylinders or Reservoirs.—Before taking up the calculation of brake-cylinder pressures, it will be necessary to take up the calculation of the capacity of brake cylinders and reservoirs; this may be done by the following rule:

Rule.—*To find the cross-sectional area of a cylinder or reservoir, in square inches, multiply the internal diameter, in inches, by itself and by .7854.*

EXAMPLE.—What is the cross-sectional area of a cylinder whose internal diameter is 10 inches?

SOLUTION.—The area equals $10 \times 10 \times .7854 = 78.54$ sq. in.; call it $78\frac{1}{2}$ sq. in. Ans.

Table III gives the cross-sectional areas for the standard sizes of brake cylinders.

TABLE III

CROSS-SECTIONAL AREA OF AIR-BRAKE CYLINDERS

Size of Cylinder Inches	Area Square Inches
8	$50\frac{1}{4}$
10	$78\frac{1}{2}$
12	113
14	154
16	201

32. Capacity of Cylinders.—The capacity of a brake cylinder may be found by applying the following rule:

Rule.—*To find the capacity of a brake cylinder, in cubic inches, multiply the cross-sectional area of the cylinder, in square inches, by the piston travel, in inches.*

EXAMPLE.—What is the capacity of an 8-inch brake cylinder having an 8-inch piston travel?

SOLUTION.—The area of the cylinder (from Table III) is $50\frac{1}{4}$ sq. in. The travel of the piston is 8 in. Hence, the capacity of the cylinder is $8 \times 50\frac{1}{4} = 402$ cu. in. Ans.

The capacity of a brake cylinder is really greater than the amount calculated by this rule, for the reason that there is extra capacity that the rule does not take into consideration. In freight equipment, the capacity of the auxiliary tube and the cylinder clearance (the space between the brake cylinder piston and the end of the auxiliary when the piston is in the position it assumes when the brake is released) is not considered, while in passenger equipment, the capacity of the passage in the brake-cylinder head and the cylinder clearance must be added to the cylinder capacity. Usually about 48 cubic inches is added to the calculated capacity of a brake cylinder to make up for the cylinder clearance, etc.

In Table IV the capacities of the standard brake cylinders are given, due allowance having been made for cylinder clearance, etc.

TABLE IV

CAPACITY OF AIR-BRAKE CYLINDERS

Size of Cylinder Inches	Piston Travel Inches	Capacity Cubic Inches
8	8	450
10	8	675
12	8	950
14	8	1,280
16	8	1,650

If the rule for the capacity of a cylinder be applied for a piston travel of 1 inch, it will be found that the number of cubic inches the capacity of a brake cylinder will change for each inch increase or decrease of piston travel, is numerically equal to the area of the cylinder. For example, the capacity of an 8-inch cylinder will change $50\frac{1}{4}$ cubic inches for every 1 inch of change in the piston travel; that of a 10-inch cylinder will change $78\frac{1}{2}$ cubic inches; that of a 12-inch cylinder, 113 cubic inches; and so on.

33. Capacity of Reservoir.—The capacity of an air-brake reservoir may be found by means of the following rule:

Rule.—*To find the capacity of a reservoir, in cubic inches, multiply its cross-sectional area, in square inches, by the inside length, in inches.*

EXAMPLE 1.—What is the capacity of a reservoir 18 inches in diameter and 100 inches in length (inside measurements)?

SOLUTION.—The cross-sectional area of the reservoir is 20 × 20 × .7854 = 314.16 sq. in. The length is 100 in. Therefore, the capacity is 314.16 × 100 = 31,416 cu. in. Ans.

The outside measurements and capacities of the standard sizes of auxiliary reservoirs are given in Table V.

To approximately calculate the capacity of a main reservoir from its outside dimensions, subtract ½ inch from its diameter and 3 inches from its length, so as to reduce the outside measurements to inside measurements; then proceed as in the above rule. The ½ inch from the diameter allows for the thicknesses of metal in the walls, while the 3 inches from the length allows for the thicknesses of metal of the ends and for the way the ends are secured in place.

TABLE V

CAPACITY OF AUXILIARY RESERVOIRS

Size Inches	Capacity Cubic Inches
10 × 24	1,488
10 × 33	2,156
12 × 33	3,030
14 × 33	4,120
16 × 33	5,322
16 × 42	6,995
8-inch freight	1,620

EXAMPLE 2.—What is the capacity of a main reservoir 26½ inches in diameter by 96 inches long?

SOLUTION.—The internal dimensions of the reservoir (found by subtracting ½ in. from diameter and 3 in. from the length) are 26 in. in diameter by 93 in. long. The area of a 26-in. reservoir is 503.93 sq. in.; therefore, its capacity is 503.93 × 93 = 49,377 cu. in., say 49,400. Ans.

Table VI gives the cross-sectional areas of the standard sizes of main reservoirs. The areas were calculated after subtracting ½ inch from the diameters, so that multiplying them by the length of a reservoir, after subtracting 3 inches from its length, will give the capacity of the reservoir, in cubic inches.

TABLE VI

CROSS-SECTIONAL AREAS OF STANDARD AIR-BRAKE MAIN RESERVOIRS

Diameter Inches	Cross-Sectional Area Square Inches	Diameter Inches	Cross-Sectional Area Square Inches
12	103.87	26½	503.93
14	143.14	28½	615.75
16	188.69	30½	706.86
18½	254.47	32½	804.20
20½	314.16	34½	907.90
22½	375.83	36½	1,017.90
24½	452.39		

CALCULATING BRAKE-CYLINDER PRESSURES

NOTE.—The 15 used in these calculations represents the pressure of the atmosphere. If a closer approximation to this pressure is required, use 14.7 pounds.

34. The pressure at which an auxiliary reservoir will equalize with its brake cylinder can be found as follows:

Rule.—*Add 15 to the auxiliary-reservoir pressure in pounds; multiply this by the capacity of the reservoir, in cubic inches; then divide by the sum of the capacities of the auxiliary reservoir and brake cylinder, and subtract 15. The result will be the gauge pressure of equalization, in pounds per square inch.*

EXAMPLE.—If the auxiliary reservoir of a standard 8-inch freight equipment is charged to 70 pounds pressure, at what pressure will it equalize with its brake cylinder if the piston travel is 7 inches?

SOLUTION.—The capacity of the auxiliary reservoir is 1,620 cu. in.; the capacity of the cylinder at 7 in. piston travel is $7 \times 50\frac{1}{4} + 48 = 400$ cu. in.; the combined capacity of the auxiliary and brake cylinder is $1,620 + 400 = 2,020$ cu. in. The absolute pressure in the auxiliary reservoir is $70 + 15 = 85$ lb. Therefore, the pressure of equalization $= \frac{85 \times 1,620}{2,020} - 15 = 53$ lb. gauge pressure. Ans.

35. The brake-cylinder pressure resulting from a given reduction in auxiliary pressure can be found as follows:

Rule.—*Multiply the capacity of the auxiliary reservoir, in cubic inches, by the number of pounds reduction in order to find the volume of air at 1 pound pressure that is to be compressed into the brake cylinder; divide this by the capacity of the brake cylinder for the piston travel desired, and subtract 15. The result will be the pounds gauge pressure per square inch in the brake cylinder.*

EXAMPLE.—Suppose that in setting the brakes of a standard 8-inch freight equipment, auxiliary pressure was reduced 10 pounds. What brake-cylinder pressure would result if the piston travel were adjusted to 9 inches?

SOLUTION.—The capacity of the auxiliary reservoir is 1,620 cu. in.; the capacity of the brake cylinder at 9-in. piston travel is $9 \times 50\frac{1}{4} + 48 = 500$ cu. in.; the reduction of auxiliary-reservoir pressure is 10 lb. Hence, according to the rule, the brake-cylinder pressure, resulting, in this case, from a 10-lb. reduction, will equal $\frac{1{,}620 \times 10}{500} - 15 = 17.5$ lb. gauge pressure. Ans.

36. The pressure at which the main reservoir will equalize with the train pipe and auxiliaries, depends on how much pressure there already is in the train pipe and auxiliaries. This is a case where the air, before expansion takes place, is separated into two volumes at different pressures; hence, in applying the rule to this case, the expression, "the product of the absolute pressure and the volume before expansion, etc.," must be understood to mean the sum of the products of the absolute pressure and the volume of the air in both the main reservoir and in the train pipe and auxiliaries. Therefore, the pressure of equalization of the main reservoir, train pipe, and auxiliaries may be found as follows:

Rule.—*Multiply the main-reservoir capacity, in cubic inches, by its absolute pressure; then multiply the sum of the train-pipe and auxiliary-reservoir capacities by their absolute pressure, and add to that of the main reservoir. Next, divide by the sum of the capacities of the main reservoir, train pipe, and auxiliaries, and subtract 15. The result will be the gauge pressure at which equalization takes place.*

The capacity of the train pipe and hose of a 34-foot freight car is 640 cubic inches; that of a 60-foot passenger car is

660 cubic inches; while that of a 70-foot passenger car is 750 cubic inches.

EXAMPLE 1.—The main-reservoir capacity for a 50-car freight train is, say, 50,000 cubic inches; the pressure carried is 90 pounds gauge. At what pressure will the main reservoir equalize with the train when the air-brake system is uncharged?

SOLUTION.—The absolute main-reservoir pressure is 105 lb.; the absolute train-pipe and auxiliary pressure is 15 lb., since both are charged to atmospheric pressure. The train-pipe capacity of the 50 cars is $50 \times 640 = 32,000$ cu. in.; the capacity of the auxiliaries is $50 \times 1,620 = 81,000$ cu. in.; the sum of the train-pipe and auxiliary capacities is 113,000 cu. in.; the sum of the main-reservoir, train-pipe, and auxiliary capacities is $50,000 + 113,000 = 163,000$ cu. in. Applying the foregoing rule, the pressure of equalization of main-reservoir pressure with the empty air-brake system is $\frac{50,000 \times 105 + 113,000 \times 15}{163,000} - 15 = 27.6$ lb. per sq. in. gauge pressure. Ans.

EXAMPLE 2.—With the same train and same main-reservoir capacity as in example 1, at what pressure would equalization take place after train-pipe and auxiliary pressure was reduced to 50 pounds?

SOLUTION.—With the exception that train-pipe and auxiliary pressure is higher in this example, it is exactly the same problem as the preceding. In this case, absolute train-pipe and auxiliary pressure is $50 + 15 = 65$ lb., so that equalization will take place at a pressure of $\frac{50,000 \times 105 + 113,000 \times 65}{163,000} - 15 = 62.2$ lb. gauge pressure. Ans.

37. The pressure at which an auxiliary will equalize with its cylinder with the retainer in use can be found as follows:

Rule.—*Multiply the auxiliary capacity, in cubic inches, by its absolute pressure; then multiply the capacity of the brake cylinder by the absolute pressure of the air in the cylinder, and add the two results. Divide by the sum of the capacities of the auxiliary reservoir and the brake cylinder and subtract 15. The result will be the gauge pressure of equalization.*

EXAMPLE.—With 15 pounds retained in the brake cylinder of a standard 8-inch freight brake having 8-inch travel, at what pressure will the cylinder equalize with the auxiliary?

SOLUTION.—The absolute auxiliary pressure is 85 lb.; the absolute brake-cylinder pressure is 30 lb.; the capacity of the auxiliary is 1,620 cu. in.; the capacity of the brake cylinder at 8-inch travel is

450 cu. in.; the combined capacity is 1,620 + 450 = 2,070 cu. in. Therefore, the pressure of equalization is $\frac{85 \times 1{,}620 + 30 \times 450}{2{,}070} - 15 = 58$ lb. gauge pressure. Ans.

The results obtained by the use of the foregoing rules will vary somewhat from results obtained from tests. This is to be expected, however, as the rules do not make allowances for air that is lost through the leakage groove and past the packing leather when the air first enters the brake cylinder, or for variations in cylinder clearance and in the size of auxiliary reservoirs. Also, the results of tests may not be strictly accurate, due to inaccuracies in the gauges used and in the observations made.

TABLE VII

PROPER TRIPLE VALVES AND SIZES OF AUXILIARY RESERVOIRS AND BRAKE CYLINDERS FOR LOCOMOTIVES, TENDERS, AND CARS OF DIFFERENT WEIGHTS

Type of Brake Equipment	Diameter of Cylinders Inches	Approximate Light Weights for Cylinders for Sizes Specified Pounds	Type of Triple Valve	Size of Auxiliary Reservoir Inches
Driver brakes for all locomotives, with or without truck brake or high-speed attachments	8	Up to 40,000	H-24	10 × 33
	10	40,000 to 85,000	H-24	12 × 33
	12	70,000 to 115,000	F-46	14 × 33
	14	110,000 to 170,000	F-46	16 × 33
	16	145,000 to 225,000	F-46	16 × 42
Passenger-engine tenders	8	15,000 to 30,000	F-36	10 × 24
	10	30,000 to 47,000	F-27	12 × 33
	12	47,000 to 68,000	F-29	14 × 33
Freight- and switch-engine tenders	8	15,000 to 30,000	G-24	10 × 24
	10	30,000 to 47,000	G-24	12 × 33
	12	47,000 to 68,000	F-25	14 × 33
Passenger cars	8	15,000 to 30,000	F-27	10 × 24
	10	30,000 to 47,000	F-27	12 × 33
	12	47,000 to 68,000	F-29	14 × 33
	14	68,000 to 92,000	F-29	16 × 33
	16	92,000 upwards	F-29	16 × 42
Freight cars	6	Up to 15,000	F-36	Standard cast-iron reservoir
	8	15,000 to 40,000	F-36	
	10	40,000 upwards	H-49	

NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 7, which was its former title.

AIR-SIGNAL SYSTEM

TRAIN AIR-SIGNALING SYSTEM

GENERAL ARRANGEMENT OF APPARATUS

1. The general arrangement of the train **air-signaling apparatus** on an engine, tender, and passenger car is shown in Figs. 1 and 2. This system has gradually taken the place of the old bell-cord-and-gong method of signaling on passenger trains, on account of the ease and certainty with which signals can be transmitted to the engineer from any part of the train.

The engine, tender, and each of the cars are piped with a ¾-inch pipe, which is connected between cars by means of hose, so that when all the hose is coupled, the signal-pipe line extends throughout the entire train.

A *car discharge valve*, Fig. 1, is provided on each car. This is usually located outside the car above the door, as shown in the figure, and is piped to the train signal pipe. Sometimes, however, it is placed inside the car above the door, to guard against the valve being clogged in winter. The former position is preferable, however, as the chances of clogging are small, and the annoyance caused by the sharp sound of discharging air every time the valve is opened to make signals is avoided.

A signal cord is attached to the lever of the discharge valve, and one end extends across the platform and is fastened in a suitable manner to the hood, while the other

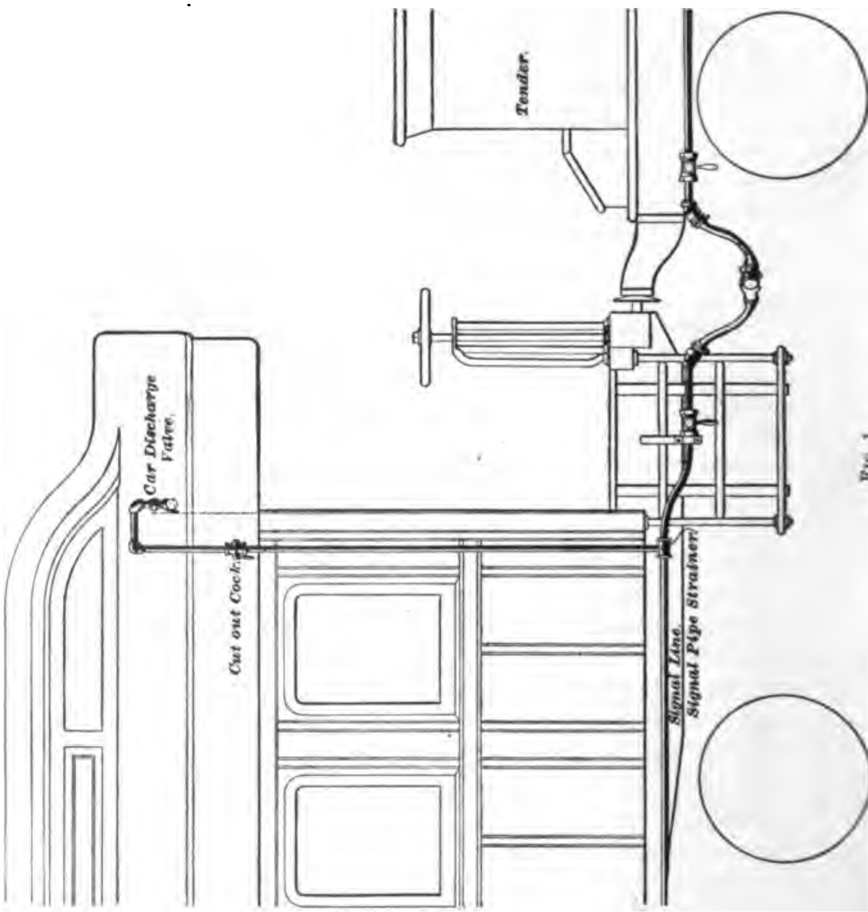

Tender.
Car Discharge Valve.
Cut out Cock
Signal Line.
Signal Pipe Strainer.

Fig. 1

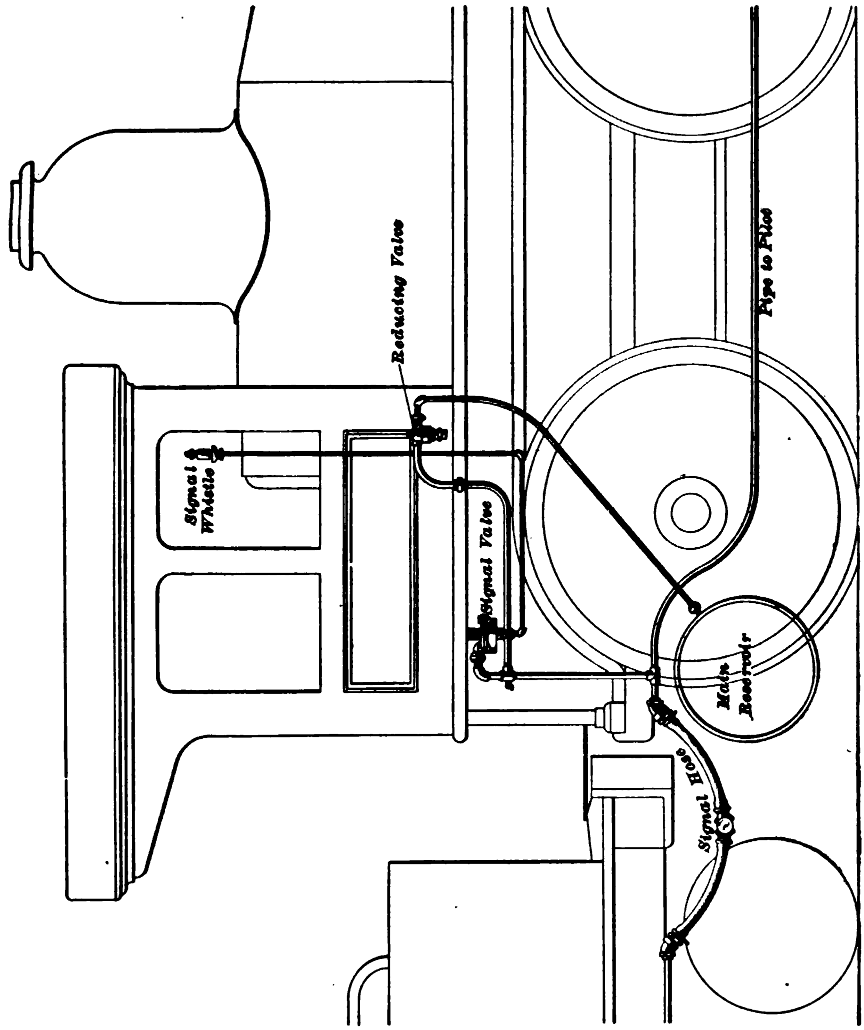

Reducing Valve
Signal Whistle
Signal Valve
Pipe to Pilot
Main Reservoir
Signal Hose

FIG. 2

end extends through the car and is fastened to the hood on the other end of the car. This cord enables the discharge valve to be operated from any part of the car.

The air-signal apparatus on the engine, Fig. 2, consists of the *signal valve*, *signal whistle*, and *pressure-reducing valve*. A $\frac{3}{8}$-inch pipe leads from the main reservoir to an air strainer, then to the reducing valve, and thence leads to, and connects with, the **T**-fitting *s* in the signal pipe. Air from the main reservoir can thus pass through the pressure-reducing valve and thence into the signal pipe and signal valve, but at a reduced pressure. A pressure of 40 pounds with the improved valve, and 25 with the old valve, is usually maintained in the signal system, and the duty of the reducing valve is to diminish the pressure from 90 pounds (main-reservoir pressure) to the required pressure for use in the signal system.

The **signal whistle**, Fig. 3 (a small whistle located in the cab, as close to the engineer as practicable), is piped to the signal valve, and it is the operation of the latter that causes the whistle to blow.

When the conductor wishes to transmit a signal to the engineer, he gives the signal cord in one of the cars a pull. This opens the discharge valve on that car and allows some of the air in the main signal pipe to escape to the atmosphere, thus reducing the signal-pipe pressure. The reduction in pressure operates the signal valve on the engine, which consequently discharges a small quantity of air through the signal whistle in the cab, thus causing it to sound a short blast. Each time the cord is pulled, the signal whistle gives a blast.

The bowl *1* forms the base of the whistle and connects with the whistle pipe at *X*. The passage *a'* and port *a* form a passage from the whistle pipe into chamber *A*. The disc *2* deflects the escaping air and makes it strike the edge of the bell *3* of the whistle. The tone of the whistle depends on the depth of chamber *B*. The check-nut *4* and cap nut *5* act as locknuts to lock the bell of the whistle in position after it has been adjusted.

An imperfect adjustment of the whistle bell, or its bowl being filled with dirt, will either cause the whistle to work badly or prevent its working at all. No set rule can be given for the adjustment of the whistle, but it must be so adjusted as to give the best sound. To adjust the whistle, slack off nut *5* and turn the whistle bell up or down until the

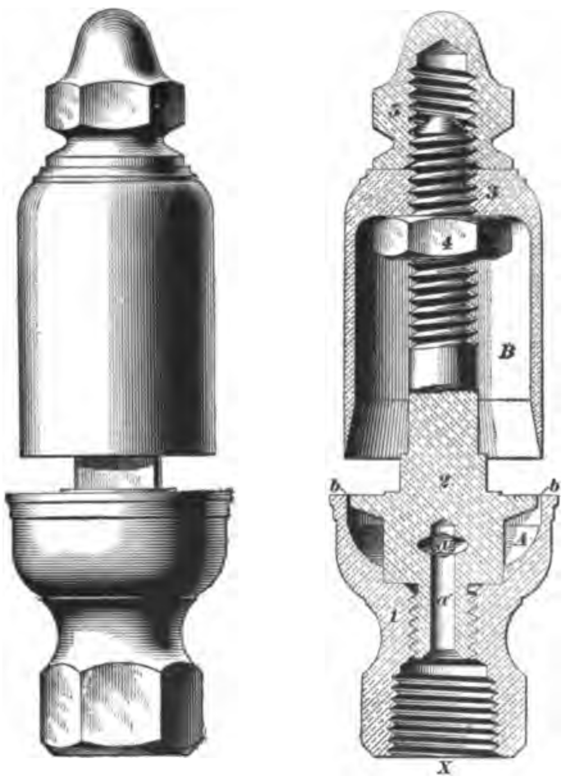


FIG. 3

desired result is obtained. A jam nut *4* on the whistle stem is an aid to the locknut in holding the whistle bell in any desired position. Care should be taken not to locate the whistle near one of the cab windows where a current of air will be liable to blow across it. as a strong current of air blowing across the whistle will render it inoperative.

DESCRIPTION OF APPARATUS

REDUCING VALVE (OLD STYLE)

2. Although this style of **reducing valve, Fig. 4,** has been superseded to a great extent by the improved valve, there are still a sufficient number in use to warrant a description of them being given here.

The main-reservoir connection is made at *X*, while a pipe leads from *Y* to the signal pipe. *4* is the supply valve that regulates the admission of air to the signal system; it is operated by the stem of the reducing-valve piston *8* and by the supply-valve spring *10*. *7* is the rubber diaphragm; *6*, the diaphragm ring; and *9*, the regulating spring. In this style of valve, the spring *9* was made strong enough to just resist a pressure of 25 pounds per square inch in chamber *B*. In some instances, however, it has been replaced by a spring that requires 40 pounds pressure per square inch to compress it. The outlets *e, e* in the cap *3* prevent air (due to leakage) from accumulating back of the piston and piston stem and rendering the valve inoperative.

3. **Operation of Valve.**—The operation of this valve is as follows: The spring *9*, acting on the piston *8*, causes the stem of the piston to hold supply valve *4* from its seat, so that main-reservoir air entering at *X* is free to pass through the passages *2, 2*, past valve *4* and into chamber *B*, and thence through the outlet *Y* to the signal pipe. This increases the pressure in the signal pipe and chamber *B* until it reaches 25 pounds per square inch, when the diaphragm 7 and piston *8* are forced upwards against the action of the spring *9*. The supply-valve spring *10* then forces the supply valve to its seat, and prevents the further passage of air from the main reservoir to the signal pipe. As long as the pressure in chamber *B* remains at 25 pounds, spring *9* will be compressed and the supply valve will remain closed. Any reduction of pressure in chamber *B*, however, will cause the regulating spring to force the diaphragm 7 and piston *8*

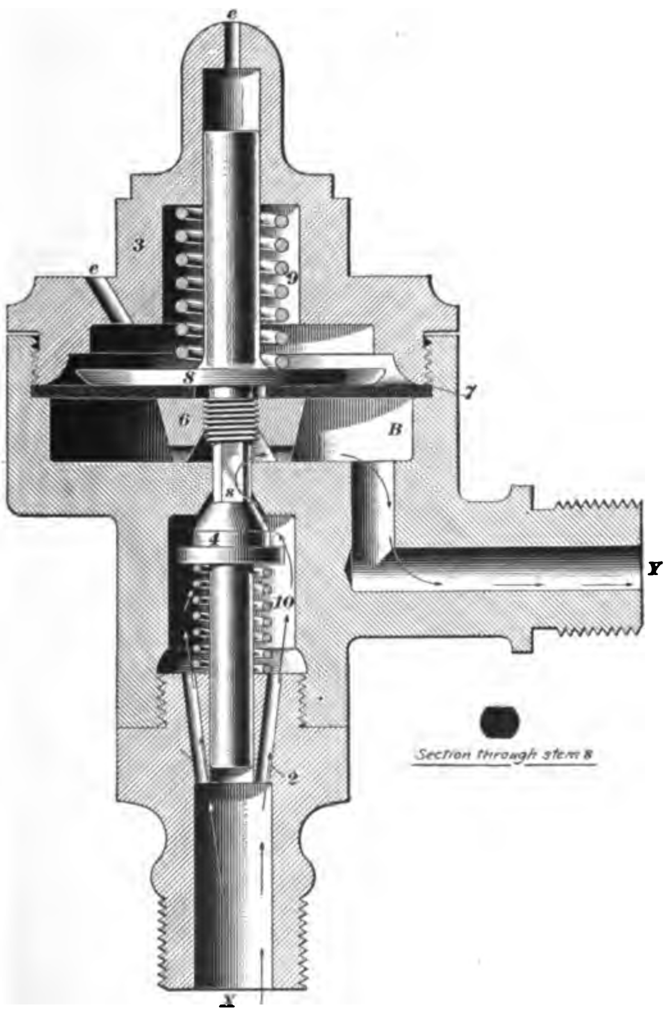


FIG. 4

downwards, thus forcing the supply valve from its seat and allowing sufficient air to pass to the signal pipe to again raise its pressure to 25 pounds, when the supply valve will close. The old-style valve has no regulating nut by means of which the tension of the regulating spring can be adjusted to alter signal-pipe pressure. If it is necessary to increase the signal-pipe pressure, the regulating spring *9* will have to be replaced by one that is stiffer. The weak part of this valve was the diaphragm *7*, which deteriorated rapidly, allowing air to leak through it to the atmosphere.

REDUCING VALVE (IMPROVED)

4. The improved reducing valve is shown in Fig. 5; *16* is a choke plug that restricts the flow of air through the valve so that the reducing valve cannot supply air to the signal pipe faster than the car discharge valve can reduce the pressure; *2* is a plug cock that, in the position here shown, is allowing air to enter the reducing valve, but, when turned at right angles to its present position, cuts the valve out of service; *3* is the lower cap; *4*, the supply valve; *5*, the supply-valve cap nut; *6*, the supply-valve spring; *7*, the reducing-valve piston; *8*, a rubber diaphragm consisting of two pieces of rubber; *9*, the regulating spring; *10*, the diaphragm ring; *11*, the piston packing ring (which, together with the diaphragm, serves to prevent leakage of air past piston *7*); *14*, the regulating nut by means of which the tension of the spring *9* is adjusted; and *15*, the check-nut. The passage *e* is to allow any air leaking past the piston *7* to escape to the atmosphere.

5. Operation of Valve.—The tension of the regulating spring *9* is adjusted to just withstand a pressure of 40 pounds per square inch in chamber *B*. When the pressure is less than this amount, the spring *9* forces piston *7* upwards and the piston stem unseats the supply valve *4*. Main-reservoir air (entering at *X*) is then free to pass through the plug cock *2*, supply valve *4*, and thence out through *Y* to the signal pipe. As soon as the pressure in the signal pipe and chamber *B* reaches 40 pounds, piston 7 is forced downwards and the spring *6* forces the supply valve to its seat, closing communication between the main reservoir and the signal pipe. Any reduction in signal-pipe pressure will allow the

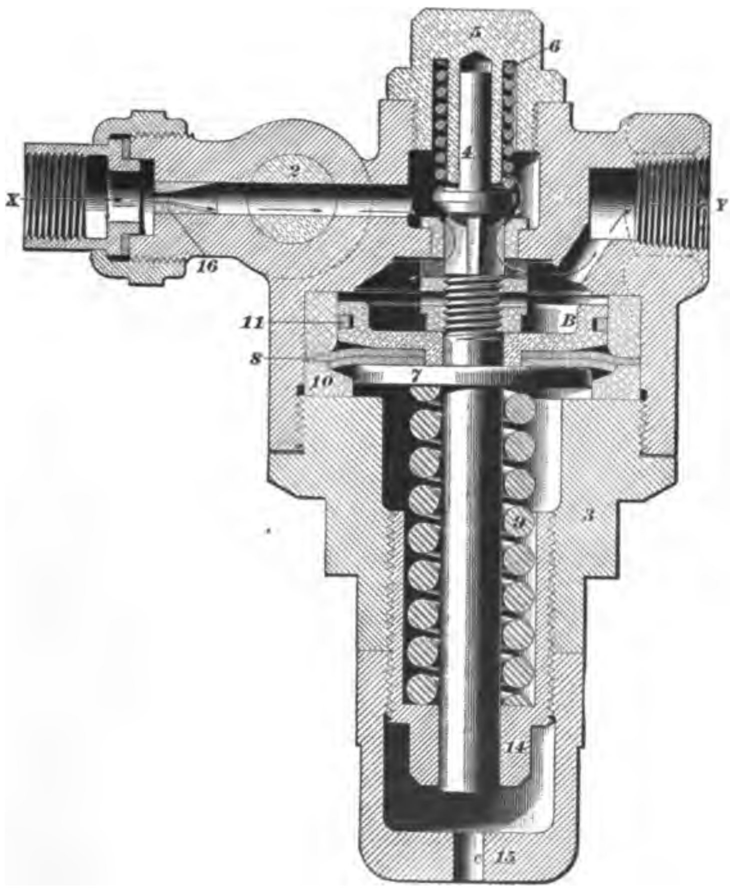


FIG. 5

spring *9* to force piston 7 upwards, thus opening the supply valve again. The valve then remains open until the signal-pipe pressure is again raised to 40 pounds, when it closes.

The reducing valve should be placed in the cab, in some moderately warm place, if possible, to prevent its freezing in cold weather.

With the improved valve, the signal-pipe pressure may be increased by screwing up the regulating nut *14*, or decreased by unscrewing this nut.

CAR DISCHARGE VALVE

6. A sectional view of the **car discharge valve** is shown in Fig. 6, in which *3* is the discharge valve and *4* the discharge-valve spring that holds this valve up against its seat. *5* is the lever, or handle, to which the signal cord is attached, while *6*, *6* are stop-pins. There is a union connection at *a* to which the branch pipe from the signal pipe is connected, while the exhaust port *b* leads to the atmosphere.

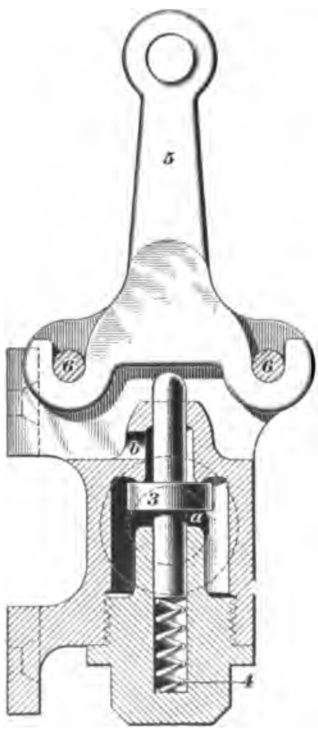


FIG. 6

7. Operation of Valve. When the signal cord on either side of the discharge valve is pulled, the lever *5* is caused to strike the stem of the discharge valve *3* and force the valve from its seat. Air from the signal pipe then passes through the branch pipes and out to the atmosphere through the union connection *a* and the port *b*, causing a reduction in signal-pipe pressure. As soon as the signal cord is released, the spring *4* forces the discharge valve to its seat again and stops the discharge of air from the signal pipe.

Referring to Fig. 1, it will be seen that the branch pipe to the discharge valve is supplied with a strainer (where it connects with the main signal pipe) and a cut-out cock, the former to prevent dirt from reaching the discharge valve, and the latter to enable the discharge valve to be cut out in case it is disabled. The handle of the cut-out cock stands parallel with the pipe when the discharge valve is cut out, and at right angles to it when cut in. Also, the cut-out cocks in the signal pipe on either side of the signal hose are closed when the handles stand parallel with the pipe, and open when at right angles to it. The couplings in the signal hose are of a different size than those in the air-brake hose, so the signal hose and brake hose cannot be coupled by mistake.

THE SIGNAL VALVE

8. The **signal valve,** Fig. 7, is located under the cab, either on the engineer's or the fireman's side. The signal

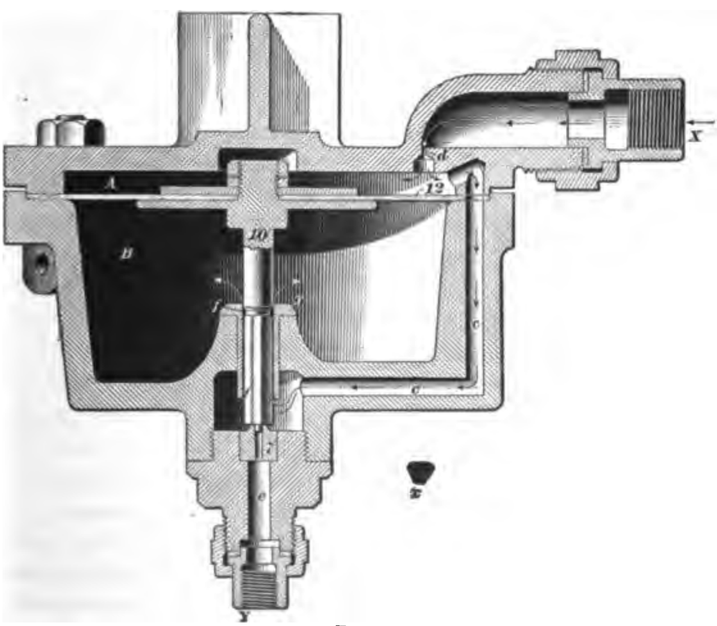


FIG. 7

pipe connects at *X*, while a pipe leads from *Y* to the whistle. The valve body is divided into two chambers *A* and *B* by the rubber diaphragm *12*, which is attached to and operates the diaphragm stem *10*. This stem extends through the bushing *9*, and its end forms a valve (with seat in bushing *7*) that controls the passage *e* leading to the whistle: A small portion of the stem *10* fits the bushing *9* snugly; below this a groove *f* is cut around the stem. Below groove *f* the stem is milled to a cross-section like that shown at *x*. Port *d* is made small so as to restrict the flow of air into and out of chamber *A* sufficiently to cause chamber *A* pressure to charge at about the same rate for different lengths of train. This is necessary in order to make the signal valve operate the same on both short and long trains. A given reduction in signal-pipe pressure can be made much more quickly on a short train than on a long one, so that if port *d* were not restricted, chamber *A* pressure would change much faster on a short train than on a long one. With port *d* of its present size, however, chamber *A* pressure charges at nearly the same rate for long and short trains, so that the signal valve operates about the same on trains of different length.

9. Operation of Valve.—When the signal pipe is being charged, air enters the signal valve at *X*, and, passing through the small port *d*, charges chamber *A*. It also passes through the passage *c c* and feeds up slowly past the stem *10* into chamber *B*, charging this to the same pressure as chamber *A*. The pressures in chambers *A* and *B* and the signal pipe are equal when the pipe is fully charged.

When the signal cord is pulled and a reduction is made in the signal pipe, it causes a reduction of pressure in the signal valve also; but, since the stem *10* makes a rather snug fit, the pressure in chamber *A* above the diaphragm reduces faster than the pressure in chamber *B*; consequently, the diaphragm is forced upwards, and raises the stem *10*, thus opening the port in valve seat *7*. The stem *10* is lifted until the groove *f* is above the bushing *9*, when the air in chamber *B* escapes quickly through the groove *f*, the milled spaces in the stem *10*, and the passage *e*, out to *Y* and the whistle, causing the latter to give a blast. Air also escapes from chamber *A* to the whistle, through the passages *c c* and *e*, but is restricted in its passage from the train signal pipe into *A* by the small port *d*.

The same reduction of pressure that operates the signal valve also opens the reducing valve, allowing air from main reservoir to flow into, and raise the pressure in, the signal pipe. This increase of pressure, following the closing of the car discharge valve, and immediately after the reduction in signal valve, increases the pressure in chamber *A* faster than in chamber *B*, thus forcing the diaphragm downwards, closing the valve leading to passage *e*, and stopping the blast of the whistle.

SIGNALING

10. In **transmitting signals** by means of the air-signaling system, certain precautions must be observed in order to obtain good results. For each blast of the whistle, the car discharge valve should be held wide open just long enough to reduce the pressure in the signal pipe clear up to the signal valve on the engine, when it should be closed. It should then be allowed to remain closed until the pressure has equalized throughout the system, before it is again opened to transmit another signal. If the discharge valve is opened a second and, possibly, a third time before the whistle has ceased to blow due to the first reduction, the whistle will give one long blast instead of two or three short ones, as intended. If it is opened a second time before the pressure has fully equalized in the signal pipe, the whistle will give a blast after each discharge, but the last blast will be weak on account of the pressure being less than 40 pounds. If the discharge valve is not held wide open when giving a signal, the reducing valve may feed air into the signal pipe as fast as it escapes from the car discharge valve and the whistle will not give a blast.

In transmitting signals, the best results will be obtained if the car discharge valve is allowed to remain closed from 2 to 3 seconds between blasts, depending on the length of the train. In other words, for each blast, pull the signal cord straight downwards and hold the discharge valve wide open for 1 second; then allow from 2 to 3 seconds for the pressure to equalize throughout the signal pipe before it is again opened for another blast. As it takes a longer or heavier discharge from the signal pipe from the rear car of a long train than from the front car, therefore it takes longer for the train pipe to equalize and a longer interval between the blasts is necessary to get perfect signals.

DEFECTS IN THE SIGNALING SYSTEM

11. Although there are but comparatively few parts in the air-signaling system, it requires good judgment to locate defects that cause incorrect signals to be given. Also, it should be borne in mind that it is not so much the amount of the reduction as the rapidity with which it is made, that causes the whistle to blow.

SIGNAL PIPE FAILS TO CHARGE

12. If it is found that no air passes into the signal pipe, first see whether the cocks on each side of the hose between the tender and train have been opened. If so, the opening in the plug *16* of the reducing valve, Fig. 5, may be stopped up with oil and dirt, or the lining in the hose may be loose and blocking the passage; or, if the weather is cold, the signal pipe on the engine or tender may be stopped up with ice, or the reducing valve may be frozen up.

NO EXHAUST FROM DISCHARGE VALVE

13. If no exhaust occurs at the discharge valve when the signal cord is pulled, the signal pipe being properly charged, the trouble may be due to the cut-out cock, Fig. 1 (usually placed in the saloon), being turned so as to cut out the discharge valve, or to a loose seat in discharge valve *3*.

WHISTLE FAILS TO BLOW

14. If an exhaust occurs at the discharge valve when the signal cord is pulled, but the signal whistle fails to give a blast, the trouble may be due to the strainer in the **T**, where the branch pipe connects with the signal pipe, being stopped up (see Fig. 1). In this case, the exhaust may sound all right, since there is considerable air in the branch pipe between the strainer and the discharge valve, but the air in the main pipe cannot get past the strainer fast enough to make a sufficiently quick reduction to operate the signal valve. If the trouble is not in the strainer, it may be that: port *d* of the signal valve is stopped up, in which case no air can enter the valve to charge it; stem *10* of signal valve has worn sufficiently loose in bushing *9* to allow pressure in chamber *B* to reduce about as fast as that in chamber *A*; the signal-valve diaphragm is bagged or, possibly, cracked; the bell of the signal whistle is imperfectly adjusted or its bowl is full of dirt; the whistle is so situated that wind blowing across the bowl prevents it from sounding; or it may be dirt in port of bushing *7*.

If poor rubber is used in the diaphragm, or if oil gets on it, the rubber will, in time, stretch and bag. In that event, when a signal-pipe reduction is made, the diaphragm will respond to it without raising the stem *10* from its seat in *7*, and no blast will result. An overheated air pump also tends greatly to heat the rubber and buckle or distort the diaphragm. In some cases, the diaphragm cracks, causing chambers *A* and *B* to become directly connected, in which case it is impossible to produce the difference in pressure on the two faces of the diaphragm necessary to operate the signal valve.

WHISTLE GIVES ONE LONG BLAST

15. If, in transmitting a signal, the whistle simply gives one long blast, it may be due either to the reductions being made too close together, or to the diaphragm stem *10* of the signal valve working stiffly in the bushing *9*, in which event the passage at *e* would remain open until a sufficient difference of pressure existed in chambers *A* and *B* to force the stem *10* to its seat.

WHISTLE BLOWS WHEN BRAKES ARE RELEASED

16. If the whistle blows every time that the brakes are released, it indicates that there is direct connection between the main reservoir and signal pipe, and that the latter is charged to main-reservoir pressure. This may be due either to valve *4* of the reducing valve being held open by dirt on its seat, to there being too much tension in the spring *9*, or to the cap nut *5* being screwed up so tight that it is twisted out of shape and will not allow supply valve *4* to seat properly; or (in the old-style reducing valve, Fig. 4) to the spring *10* being broken or too short, so that it does not force valve *4* to its seat.

The reason why the whistle blows when the brakes are released is as follows: Since there is a direct opening between the signal pipe and the main reservoir, air will flow from the former to the latter every time the main-reservoir pressure is reduced in releasing the brakes. This causes a reduction of signal-pipe pressure right at the signal valve, which, if the opening through the reducing valve is large enough and the main-reservoir pressure is reduced sufficiently fast, will operate the signal valve and cause the whistle to give a blast. If the opening through the reducing valve is small, the whistle may not sound if the signal pipe is long, whereas it may do so on a very short train or on a lone engine.

Main-reservoir pressure in the signal pipe can be detected from the train by a stronger discharge of air from the discharge valve when the signal cord is pulled; on the engine it will be indicated by the signal whistle screeching, due to the fact that the bell of the whistle is adjusted for 40 pounds pressure and not for 90.

If the signal-pipe pressure is much less than 40 pounds, the discharge will be weaker than it should be when the cord is pulled, and the whistle will give a weaker blast than it should.

WHISTLE GIVES WEAK BLAST

17. Sometimes the whistle only gives a weak blast when the cord is pulled. This may be due to the regulating spring of the reducing valve being too weak, so that there is less than 40 pounds in the signal pipe; the whistle may be full of dirt or be improperly adjusted; or the passage through the bushing *7* in the signal valve, Fig. 7, may be partly stopped up with oil and dirt.

SIGNAL VALVE LEAKS

18. If, in the signal valve, Fig. 7, the valve formed by the end of the stem *10* leaks or is held from its seat on bushing *7* by dirt, there will be a constant blow at the whistle.

LEAKY CAR DISCHARGE VALVE

19. A leaky car discharge valve, due either to dirt on the seat of the valve or to a defective valve seat, is a common source of trouble. If dirt on the valve seat is the cause of the leak, opening and closing the valve will blow the dirt off. As a rule this leak will be supplied by the reducing valve without causing a blast of the whistle. If the leak is such as to sound the whistle, and the valve cannot be replaced or repaired on the road, cut the valve out of service by closing the cut-out cock on the signal-pipe cross-over pipe.

STEM *10* TOO TIGHT IN BUSHING *9*

20. The accuracy with which signals can be transmitted depends, to a considerable extent, on the fit of the stem *10* in the bushing *9*. If it makes too tight a fit, the whistle will give one long blast instead of the usual short ones, as already explained. Also, signal-pipe leakage is liable to operate the signal valve and cause the whistle to sound a blast, and the signal valve will not respond to a short, light reduction.

WHISTLE BLOWS ON SHORT TRAIN BUT NOT FROM REAR END OF LONG TRAIN

21. If the fit of the stem is too loose or the diaphragm is baggy, the signal valve may not be affected by leaks; neither will it respond to a light, quick reduction in signal-pipe pressure. Also, when the train is short, the signal valve will respond to a reduction made on any of the cars in the train; but on a long train, the volume of air in the signal pipe is so much larger that a reduction through the car discharge valve from the rear cars may not produce a reduction sufficiently rapid at the signal valve to operate that valve, and the whistle will not sound.

WHISTLE GIVES TWO OR MORE BLASTS INSTEAD OF ONE

22. If the stem *10* of the signal valve fits too loosely in bushing *9* and the train is short, the whistle, when the cord is pulled, is liable to give two or three blasts instead of one. This is brought about as follows: As the cord is pulled, a reduction is made in the signal valve above the diaphragm, which causes the diaphragm to be raised, thus allowing air to escape from chamber *B* to the whistle, causing it to give a blast. The pressures .in chambers *A* and *B* immediately equalize, causing the stem valve to close and stop the whistle. Then, as the reduction in the signal pipe continues, another difference in pressure forms between chambers *A* and *B*, causing the stem valve to be again opened and sounding another blast. In this way, two or more blasts may occur when but one reduction is made. When the stem fits properly, the pressure in the chamber above the diaphragm increases much faster than that in the chamber below it; hence, the diaphragm is held down and a second blast does not occur. In case the signal whistle gives two blasts when the cord is pulled, it can be remedied by lowering the stem *10* in the bushing *9*. The length of fit of the stem in its bushing should never be less than $\frac{1}{32}$ inch, nor more than $\frac{1}{16}$ inch, measuring from the top of groove *f* to the top of bushing *9*.

WHISTLE BLOWS WITHOUT APPARENT CAUSE

23. This is caused by a leak in the signal pipe, and occurs while the engine is running along. The leak reduces the pressure in chamber *A* of the signal valve just a little below that in chamber *B*, so that a very slight jar of the engine will sometimes cause the diaphragm to rise and open stem valve *10*, thus causing a blast of the whistle. This trouble is aggravated if the supply valve of the reducing valve rusts a little or sticks, caused by its freezing or otherwise.

DOUBLE-HEADING

24. In double-heading, the whistles on both engines should sound each time a signal-pipe reduction is made. If they do not, close the cut-out cock in the reducing valve on the second engine; this reducing valve feeding into the signal valves prevents the signal-pipe reduction passing to the head engine to operate the signal valve.

TERMINAL TEST OF AIR-SIGNAL APPARATUS

25. In making up a train, the air-signal hose should be connected up at the same time the air-brake hose is, and all the signal-pipe cocks opened except the rear cock on the last car of the train; this should be closed, and the signal hose hung up properly. While looking over the train for leaks, the signal hose and couplings and also the car discharge valves should be inspected to see if they are in good condition. If a discharge valve is found to be leaking, jerk it open a few times; if this does not remedy the leak, the valve needs a new gasket. If a discharge valve is found defective while on the road, it should be cut out by closing the cut-out cock in the branch pipe; the conductor should be notified and report the same for repairs at the end of the run. In testing the signal system, signals should be transmitted from the rear car, from a car in the center, and also from the car next to the engine.

To test the reducing valve from the brake valve, start the pump with the brake valve on lap and the tender angle cock open. When the pressure reaches 50 pounds, stop the pump and at regular intervals move the brake valve to running position for a few seconds and back to lap. This will reduce the reservoir pressure gradually; when it reaches the pressure at which the reducing valve operates, air will pass out of signal pipe into reservoir, causing a signal-pipe reduction that makes the whistle blow.

TESTING DEVICE

26. A device for testing the signal apparatus consists of a signal-hose coupler fitted with an air gauge and a small petcock having a $\frac{1}{8}$-inch hole in it. When this device is coupled to the signal hose, and the signal-pipe stop-cock opened, the signal-pipe pressure will be indicated by the air gauge, while, by means of the petcock, a reduction of any amount or duration may be made in the signal-pipe pressure.

27. Using the Device.—The **testing device** may be used to determine the condition of the air-signal reducing valve as follows: First connect the device into the signal pipe and charge the latter to standard pressure; then open the petcock wide, make a 10-pound reduction, and note the time required to raise the pressure to standard again. If the pressure rises slowly and the reducing valve is of the improved type, the passage through the valve is probably reduced by gum and dirt, and the valve should be thoroughly cleaned. If the reducing valve is of the old style, it may be that the supply valve does not open sufficiently to admit of its feeding faster, and the valve should be taken down and repaired.

To test the signal valve, make a slow, gradual reduction of about the same magnitude as the leaks in the signal pipe would amount to; then gradually increase the rate of discharge until the signal whistle sounds. If the whistle blows when a slow gradual reduction is being made, it indicates that the stem *10* is not too loose a fit in the bushing *9*, and that the pressure on the under side of the diaphragm cannot escape as the pressure above is reduced. The consequence is that the pressure in chamber *B* raises the diaphragm as soon as a sufficient difference of pressure is established between the chambers on either side of the diaphragm, and air discharges into the whistle, causing it to sound. If the whistle does not blow when a slow, gradual reduction is made, the indications are that the stem *10* fits too loosely in the bushing *9* or the diaphragm is bagged. If the stem is too tight in bushing *9*, the signal valve will not close promptly and the blast will be drawn out longer than it should.

This device should be used as frequently as convenient so as to keep the apparatus in good condition. The test should be made before engine leaves the roundhouse so that all necessary repairs can be made before the engine is coupled to the train.

NOTICE

In all text references this Paper is referred to as *Westinghouse Air Brake*, Part 8, which was its former title.

HIGH-SPEED BRAKE

THE HIGH-SPEED BRAKE

HIGH-SPEED SERVICE

1. It is the average speed of a train between terminals that determines the service to which the train belongs. A *high-speed train* is one that makes a high average speed; hence, the conditions of its operation must necessarily differ very materially from those of an ordinary express train. The express train may make an average speed of 35 to 40 miles an hour, while the average speed of the high-speed train may be 60 miles or more. The express train may attain a maximum speed for a short distance that is considerably greater than that attained by the high-speed train, but certain parts of the run that are comparatively safe are chosen for these bursts of speed. The high-speed train, on the other hand, must maintain a high rate of speed throughout the run, regardless of whether passing through yards or over bridges, switches, etc., so that the chances of having to make emergency applications of the brake are much greater than in ordinary service. Also, it is much harder to stop a train when traveling at high speed, and a greater distance is necessary in which to do so.

It has been found that, under the same conditions, the distance required to stop a train traveling at the rate of 40 miles an hour is about twice as great as when traveling 30 miles; at 50 miles an hour, between three and four times the distance is required; while at 60 miles, about five times the distance is necessary. Hence, since emergencies are more liable to occur with high speeds, and since the distance in which a train can be stopped increases very greatly with its speed, it has become imperative that a more powerful brake than the quick-action brake be employed on trains running at high speed; the present *high-speed brake* is the direct result of this necessity.

The Westinghouse-Galton experiments, made in England in 1878, and the more recent experiments of the Master Car Builders' Association of this country have demonstrated: that the friction exerted between the wheel and the rail is practically constant at all speeds; that the friction exerted between the brake shoe and the wheel is very much less at high than at low speeds, being only one-third as great at a speed of 55 miles per hour as it is when the wheels are only just moving; that on account of this reduction of frictional resistance at high speed, a considerably greater pressure can be applied to the brake shoe when the speed is high, without danger of sliding the wheels; and that in order to make a brake shoe exert as great a retarding force at high as at low speeds, it must be subjected to a greater pressure at high speeds.

The high-speed brake was made to conform with all these requirements, since it provides a very high cylinder pressure when the brake is first applied in emergency, and gradually reduces the pressure until it is low enough at slow speeds to avoid sliding the wheels.

GENERAL ARRANGEMENT OF APPARATUS

CHANGES NECESSARY IN CAR EQUIPMENT

2. The general arrangement of the apparatus of the **high-speed brake** on an engine, tender, and passenger car is shown in Fig. 1. It is here seen that the apparatus and its general arrangement is practically the same as that of the quick-action automatic brake, but that the former contains a few pieces of apparatus not employed in the latter, these special pieces being shown heavily lined in the figure. For

instance, the only difference in the equipment of a high-speed and a quick-action brake, as applied to a passenger car, is the addition, in the former, of an automatic reducing valve, together with sufficient pipe to connect it to the brake cylinder. Also, in the high-speed brake every wheel on the car is fitted with a brake.

A, Fig. 1, illustrates the use of a small safety valve that may be attached to extra cars not fitted with the regular automatic reducing valve when they are to be temporarily attached to high-speed brake trains. This valve is simply intended to temporarily take the place of an automatic reducing valve, and it should not be used as a permanent fixture.

CHANGES NECESSARY IN ENGINE EQUIPMENT

3. General Remarks.—The chief changes necessary to transform the ordinary quick-action brake into a high-speed brake, are made in the engine equipment. In the first place, the engine-truck wheels, as well as the drivers, are supplied with brakes in the high-speed system, as, by so doing, a gain of about 10 per cent. in the braking power can be made; this is not usually done with the quick-action brake. It will be observed that the engine-truck brake cylinder is connected with a flexible hose connection to its branch pipe. This is necessary, since the cylinder is fastened rigidly to, and therefore turns with, the engine truck.

The engine is also supplied with a triple valve of special design that operates both the driver and engine-truck brakes, a cut-out cock in the branch pipe being necessary for the purpose of cutting out the valve in case of accident to driver brake. The engine-truck brake has a separate cut-out cock, so that it can be cut out without interfering with the driver brake. An automatic reducing valve is connected to the pipe that leads from the triple valve to the brake cylinders, thus performing the work of three separate reducing valves connected one to each brake cylinder.

It is now the practice to equip an engine having a driver and engine-truck brake with two auxiliaries; one of the proper size for the driver brake, and the other of the proper size for the truck brake. These auxiliaries are coupled to the triple valve with a **T** connection, a cut-out cock being placed in the pipe to each auxiliary so that either reservoir and its brake can be cut out of service without disturbing the brake of the other auxiliary. In case either the driver or the truck brake is cut out of service, its auxiliary should be cut out also; if this is not done, both auxiliaries will furnish air for the brake that is not cut out, and will equalize at too high a pressure with that brake.

The 10″ × 12″ equalizing reservoir is replaced by a standard 10″ × 14½″ reservoir, which is attached to the engineer's brake valve in the usual manner. This is done in order to make chamber *D* reductions more gradual to suit the higher train-pipe pressure.

In the tender equipment, a quick-action triple valve is used in place of the plain triple employed with the ordinary automatic tender brake, and an automatic reducing valve is attached to the tender cylinder. In order to attach the quick-action triple to the tender cylinder, it is necessary to use a special cylinder head, and, since the quick-action triple does not contain a cut-out cock, one must be placed in the branch pipe leading to it.

4. Duplex Governor.—The ordinary form of pump governor is replaced by a **duplex governor,** and the feed-valve attachment on the brake valve is replaced with a pipe bracket that enables a *duplex feed-valve attachment* to be used. Both the duplex governor and duplex feed-valve attachment really consist of two ordinary instruments combined for the sake of cheapness and convenience, and each duplex instrument could be replaced with two regular instruments of the same kind. Both air ends of the duplex pump governor are connected with, and are therefore operated by, main-reservoir pressure, since the pipe *g* leads to the main-reservoir connection on the brake valve. The regulating spring of one is adjusted to just withstand a pressure of 90 pounds per square inch on the governor diaphragm; the regulating spring of the other is adjusted for a higher pressure—about 120 pounds per square inch in some cases, and higher still for longer trains. This head should be adjusted high enough to give sufficient pressure for the train and service in which it is to be used. A cut-out cock is placed in the pipe to the low-pressure governor, so that if the engine is to be used with a high-speed brake, it can be closed, thus cutting out the low-pressure governor and allowing the high-pressure one to govern the air pump. The cut-out cock is closed when the handle stands at right angles to the pipe, and open when the handle is parallel with it. If the engine is used with the ordinary quick-action brake, the cut-out cock is opened and the pump is then governed by the low-pressure governor. Some roads connect the low-pressure side of the duplex governor to the low-pressure side of the reversing cock, so that the 90-pound governor is cut out when the 70-pound feed-valve is cut out, or when the brake valve is on lap or on application position.

5. Feed-Valve Attachment.—The two valves of the **duplex feed-valve attachment** are adjusted for different pressures. The regulating spring of one is adjusted to just withstand a train-pipe pressure of 70 pounds per square inch, while the spring of the other is adjusted to about 110 pounds. The mechanism of each valve is exactly like the valve shown in connection with the F-6 brake valve. The feed-valves are secured to the body of the reversing cock, and the passage *i* of each is connected with the pipe *b* by means of a chamber in the reversing cock. Also, the passage *f''* of both valves is connected with the pipe *a* by means of another chamber, and the cock is so constructed that either feed-valve can be cut out of, or into, service by means of the handle *h*. When the engine is coupled to a train equipped with ordinary quick-action brakes, the feed-valve that is adjusted to 70 pounds is used, and the other one is cut out. When the engine is coupled to a train equipped with the high-speed brake, the high-pressure feed-valve is cut into service.

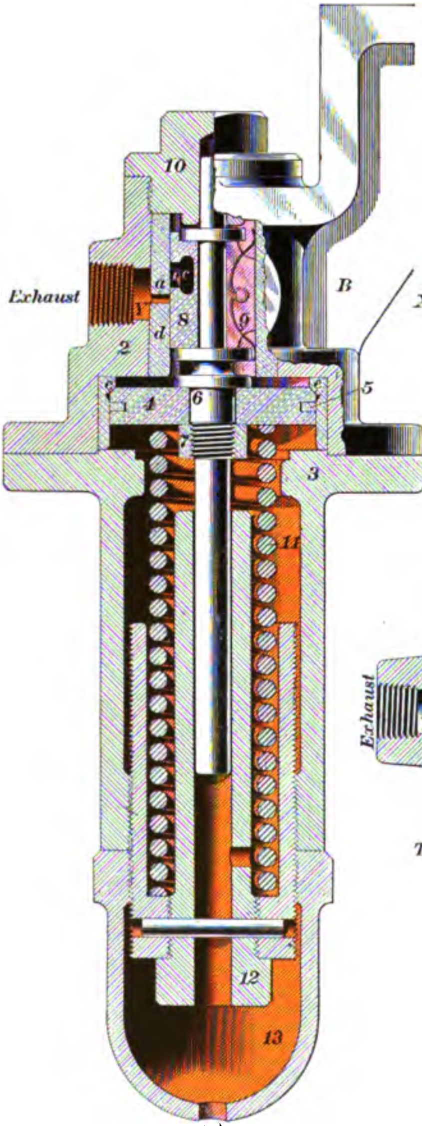
There are two positions in which the handle *h* of the reversing cock may stand. The one shown in Fig. 1 is the position used when the engine is to be coupled to a train having the ordinary quick-action brake. In this position, the feed-valve that is adjusted for 70 pounds is cut in and the one for 110 pounds is cut out, and the train-pipe pressure is regulated to 70 pounds per square inch. If the engine is to be coupled to a high-speed brake train, the handle of the reversing cock is moved around to the right into the second position. This cuts into service the feed-valve that is adjusted for 110 pounds, and the train-pipe pressure is then regulated to that amount. This duplex feed-valve is usually placed in the cab.

OPERATION OF APPARATUS

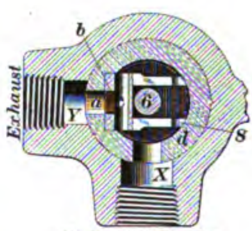
AUTOMATIC REDUCING VALVE

6. Description.—In Fig. 2 are given various sectional views of the **automatic reducing valve**, (*a*) representing a side view with half of the valve removed, while (*b*) is a horizontal cross-section taken through the slide valve, and viewed from above; (*c*), (*d*), and (*e*) are rear views with the back portion of the upper half of the valve broken away so as to show, in section, the reducing-valve piston and slide valve, the section of the slide valve being taken through port *c*.

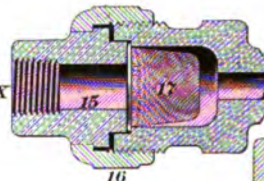
Referring to the figure, *B* is the bracket by means of which the valve is attached to the car or engine; *2*, the valve body; *3*, the spring box; *4*, the reducing-valve piston; *5*, the piston packing ring; *6*, the piston stem; *7*, the piston-stem nut; *8*, the slide valve; *9*, the slide-valve spring; *10*, the cap nut; *11*, the regulating spring; *12*, the regulating nut and guide for piston *4*; *13*, the check-nut; *14*, a union stud; *15–16*, a union connection; and *17*, the strainer. The pipe to the brake cylinder connects with the valve at *X*, while the exhaust port *Y* leads to the atmosphere. Since the brake cylinder is connected at *X*, it is evident that the space within bushing *d* is

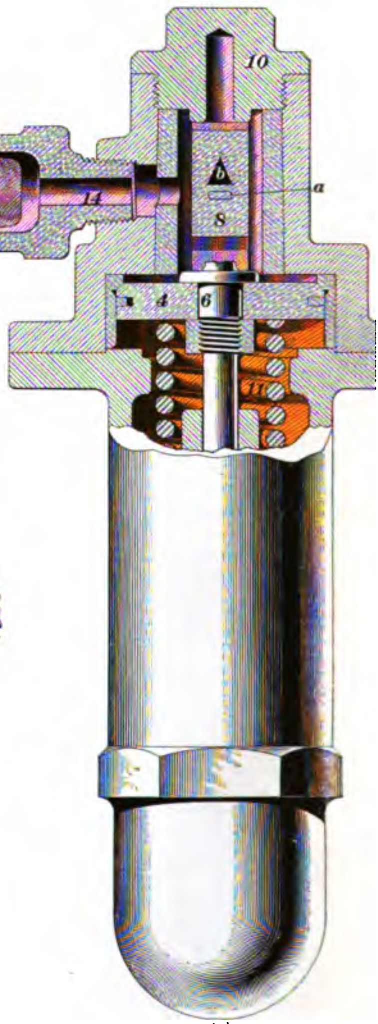


(a)
Release

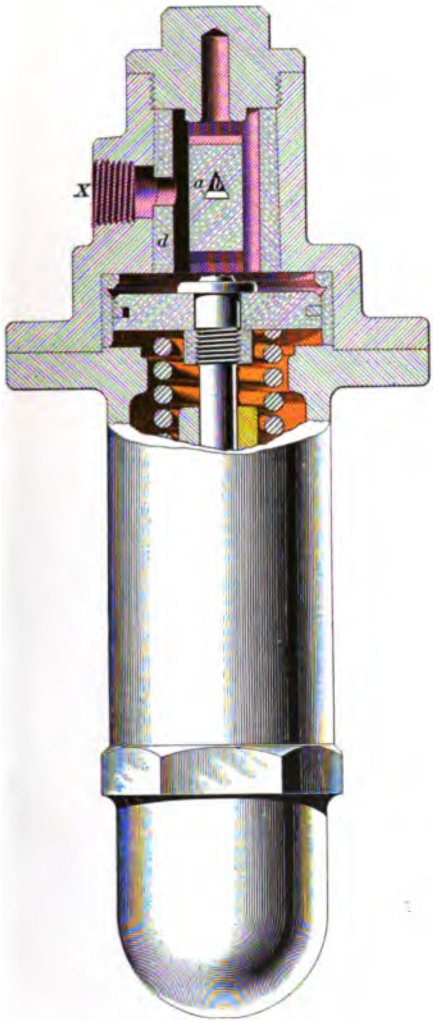


To Brake Cylinder.
(b)

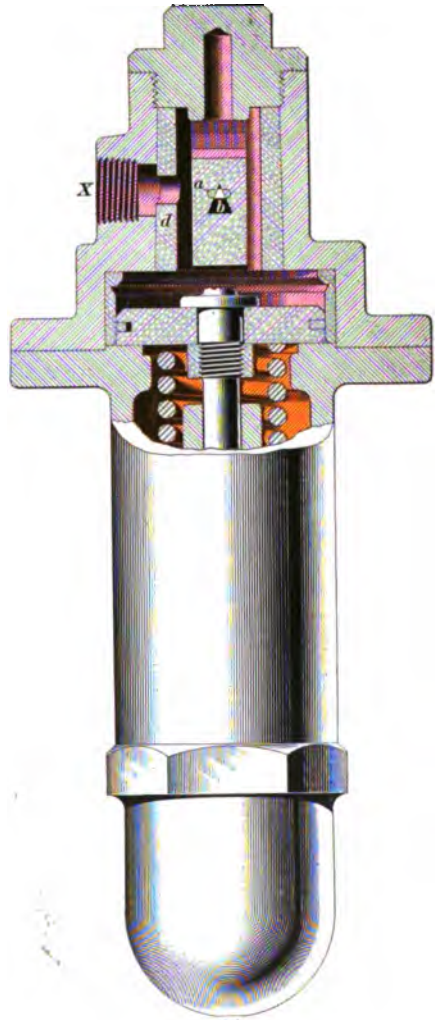




(c)
Release



(d)
Service; Pressure Exceeding 60 Pounds



(e)
Emergency

FIG. 2

§ 8 13180

always charged to the same pressure as the brake cylinder; hence, the slide valve *8* and the upper side of piston *4* are at all times subjected to brake-cylinder pressure also. A port *c*, views (*a*) and (*b*), passes through the slide valve from one side to the other; also, a triangular port *b* leads from port *c* to the face of the slide valve. A small port *a* passes through the seat of the slide valve and connects with the exhaust *Y*. In views (*c*), (*d*), and (*e*), the covered part of port *a* is represented by dotted lines.

When the valve is used on a car, the regulating spring *11* is adjusted to just withstand a pressure of 60 pounds per square inch on the piston *4*; when used on an engine, it is adjusted to withstand 50 pounds pressure.

7. Operation of Valve.—Views (*a*) and (*c*) show the position of port *a*, with respect to port *b* of the slide valve, for all pressures under that for which the regulating spring is adjusted, which is usually 60 pounds. Port *a* is, of course, stationary; the slide valve *8*, however, fits in between the shoulders of the piston stem *6*, and is operated thereby; hence, port *b* moves up and down with the piston.

As long as the cylinder pressure remains less than 60 pounds per square inch, the reducing valve plays no part in an ordinary service application of the brake, the valve remaining in its normal position, with port *a* blanked, views (*a*) and (*c*). Suppose, though, that in making a service application, the brake-cylinder pressure should increase above 60 pounds; in that event, the pressure above the piston *4* would be sufficient to compress the regulating spring, and the piston and slide valve would be forced downwards until ports *a* and *b* assumed the position shown in view (*d*). In this position, brake-cylinder air is free to flow to the atmosphere through the ports *c*, *b*, and *a* until the pressure is reduced to 60 pounds, when the regulating spring forces the piston and slide valve upwards into their normal positions again. View (*d*) therefore shows the relative positions of ports *a* and *b* in a service application during the time that the brake-cylinder pressure exceeds 60 pounds. The area of the opening through ports *a* and *b* in this position is such that air can discharge from the cylinder as fast as it enters through the service port in the slide valve of the triple.

The relative positions of ports *a* and *b* in an emergency application of the brake is shown in view (*e*). Here, air enters the brake cylinder from the train pipe and auxiliary reservoir in much greater volume than it could possibly escape through the ports *a* and *b* of the reducing valve; hence, piston *4* of the latter is forced downwards the full length of its stroke, and assumes the position shown in view (*e*). In this position, the passage through ports *a* and *b* is small, and air discharges quite slowly from the cylinder. As the pressure in the cylinder, and consequently above piston *4*, gradually decreases, due to the discharge through ports *a* and *b*, the regulating spring gradually raises the piston and slide valve, and, as the slide valve is raised, the opening through ports *a* and *b* gradually increases; consequently, the discharge from the cylinder increases accordingly until the brake-cylinder pressure is reduced to a safe amount (60 pounds), when the reducing valve assumes its normal position, covering the opening *a* so that no more air can escape from the brake cylinder until brakes are released.

IMPROVED AUTOMATIC REDUCING VALVE

8. The latest form of the high-speed automatic reducing valve is shown in Fig. 3. This is an improvement on the valve just described, the changes, however, not being very great. In the old-style valve, Fig. 2, it will be noticed that the piston *4*, when in its normal position, is intended to make an air-tight joint with the bushing at *e*, the piston and bushing being beveled for that purpose. This joint was not always tight, so in the later pattern the piston *4* includes a leather washer *e*, which forms, when the piston is in normal position, a tight joint with the projection on the bushing. The stem *6* has been shortened and rests on the spring abutment *22*, which replaces the guide *12* used in the old valve.

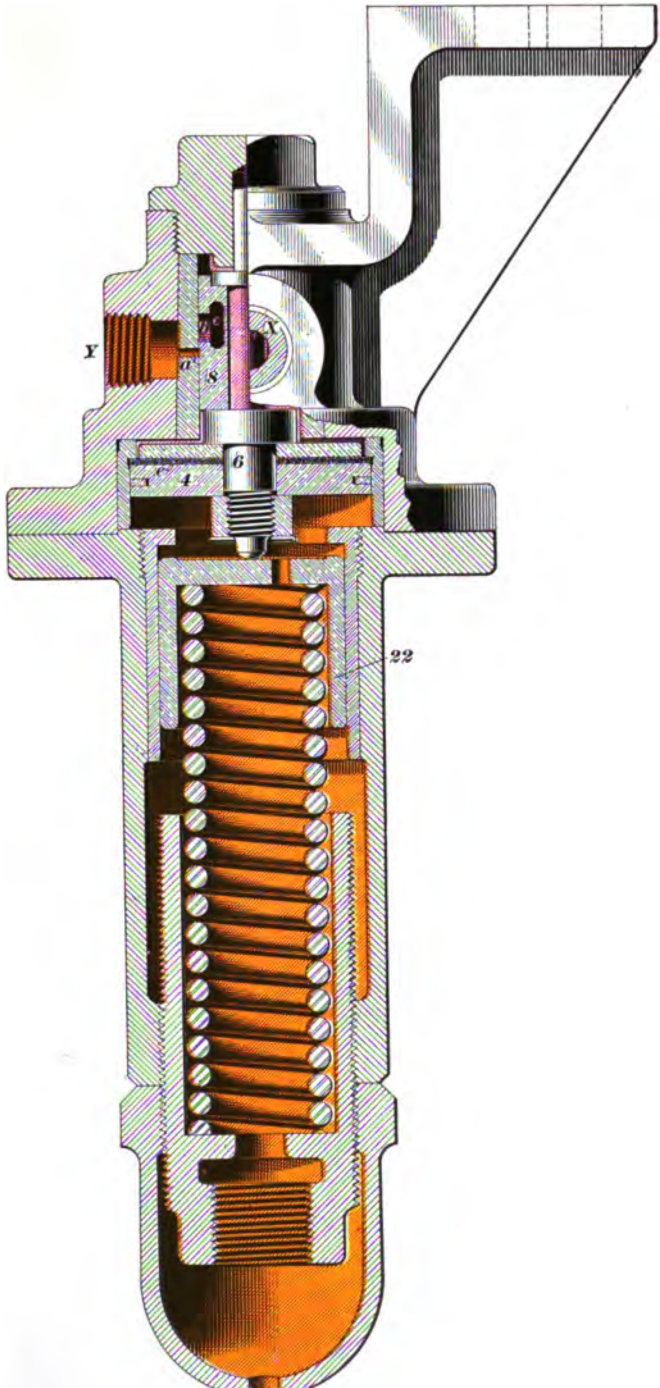


FIG. 3

Three reducing valves are now made for use with 8-inch brake cylinders, 10- and 12-inch cylinders, and 14- and 16-inch cylinders, the only difference in the valves being in the valve body *2* and slide valve *8*. The size of ports *a* and *b* are so proportioned in the different valves that brake-cylinder pressure will be reduced in the different size cylinders in about the same time. The operation of this reducing valve is exactly the same as that of the old-style valve.

SAFETY VALVE

9. In cases where a car equipped with an automatic brake must be used in connection with high-speed brakes, and there is not sufficient time in which to equip it with a regular automatic reducing valve, a small safety valve is screwed into the oil hole in the brake-cylinder head and used as a substitute during the trip. A sectional view of this safety valve is shown in Fig. 4. It consists of the valve body *2*, the valve *3*, regulating spring *4*, adjusting nut *5*, and lock-cap *6*. The end *X* is screwed into the oil hole in the cylinder head, and, consequently, that portion of the valve marked *a* is always subjected to brake-cylinder pressure. Ports *y*, *y* connect the chamber above valve *3* with the atmosphere.

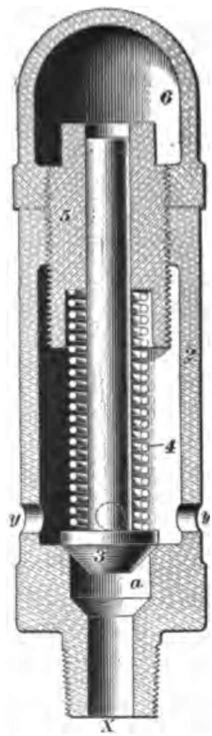


FIG. 4

The spring *4* is adjusted by means of the nut *5* until it resists from 50 to 60 pounds pressure per square inch on the valve *3*. In adjusting either the safety valve or the automatic reducing valve, a gauge is attached to the brake cylinder, and the tension of the regulating spring is then adjusted until the gauge shows that the valve just retains the proper brake-cylinder pressure.

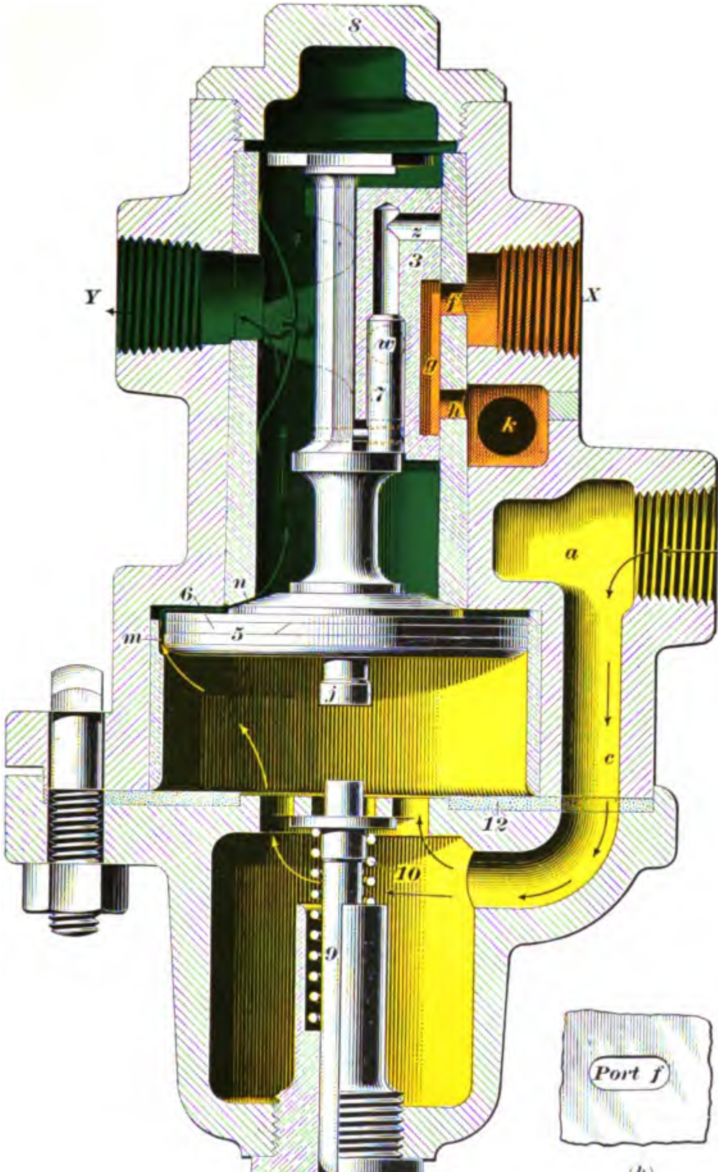
The operation of the safety valve is as follows: As is the case with the automatic reducing valve, the safety valve remains in its normal position as long as the brake-cylinder pressure is less than that for which the valve is set to operate. If, however, the pressure in the brake cylinder exceeds that to which the spring *4* is adjusted, the valve *3* will be forced upwards, compressing the spring *4*, and the brake-cylinder air will exhaust to the atmosphere through the valve *3* and exhaust ports *y*, *y* until it is reduced to the pressure for which the valve is set; the spring *4* will then force valve *3* to its seat and the remaining air will be retained in the cylinder.

10. With this valve the pressure is reduced very rapidly at first and slowly when near 60 pounds—just opposite to the action of the high-speed automatic reducing valve. This safety valve is also used with the combined straight-air and automatic brake, and with the schedule **U** apparatus for the control of heavily loaded trains on grades. As this is not a very reliable form of valve, it should only be employed temporarily in cases where the other form cannot be obtained.

In the event of a train with the high-speed brake picking up a car that is not equipped for such service, the engineer should turn the handle of the reversing cock to the position that would give a train-pipe pressure of 70 pounds, and run with that pressure as long as the car is in the train unequipped for the service.

HIGH-SPEED BRAKE TRIPLE VALVE

11. Ordinary quick-action triple valves are used on the cars of a high-speed train. The plain triple used on the tender with the quick-action brake, however, is replaced in the high-speed brake by a quick-action triple, while the plain triple used on the engine is replaced by another plain triple of special design. The engine triple, it will be remembered, operates both the driver and engine-truck brakes; hence, it is necessary to use a triple designed especially for that purpose. Such a one is illustrated in Fig. 5. By comparing Fig. 5 with the triple used with driver-brake cylinders of 12- and



(a)

FIG. 5

14-inch diameter, it will be seen that practically the only difference between these triples is in the size of port *f*, view (*b*), which is made oval, instead of round, in the high-speed triple so a greater amount of air can pass through it in emergency position. The operation of this valve and the one shown in *Westinghouse Air Brake*, Part 1, is exactly the same. The corresponding parts of both triples are lettered and numbered similarly.

SPECIAL CYLINDER HEAD

12. In order to use a quick-action triple on the tender-brake cylinder, it is necessary to replace the plain cylinder head with one like that shown in Fig. 6. The triple is

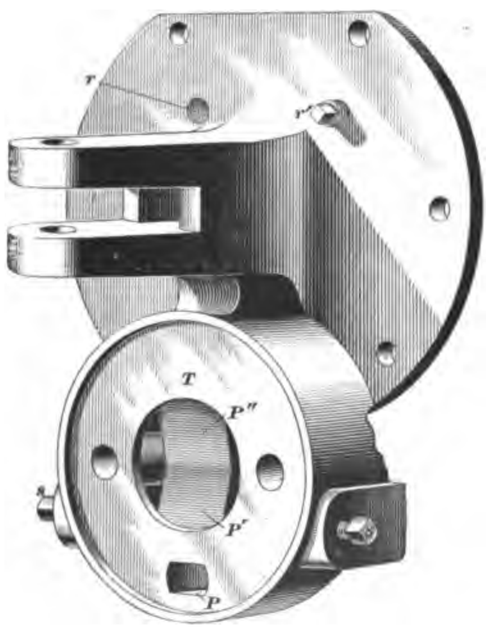


FIG. 6

secured to the part *T* in such a way that the port *d* of the triple, Fig. 3, *Westinghouse Air Brake*, Part 2, connects with the passage *P* in the cylinder head, while port *Y* connects (through the large central hole) with the space within *T*. The two tap bolts *s*, *s* serve as plugs for the two ports that lead to the space within *T*, and the pipe that leads from the auxiliary reservoir is screwed into either of the ports, as required. Air passes from the triple and enters the cylinder head at *P* and passes through the interior of *P′ P″* and into the brake cylinder. The automatic reducing valve is screwed into the cylinder head at *r*; *r′* is the cylinder oil plug.

FEED-VALVE PIPE BRACKET

13. In order to use the duplex feed-valve with the F-6 brake valve, it is necessary to remove the original feed-

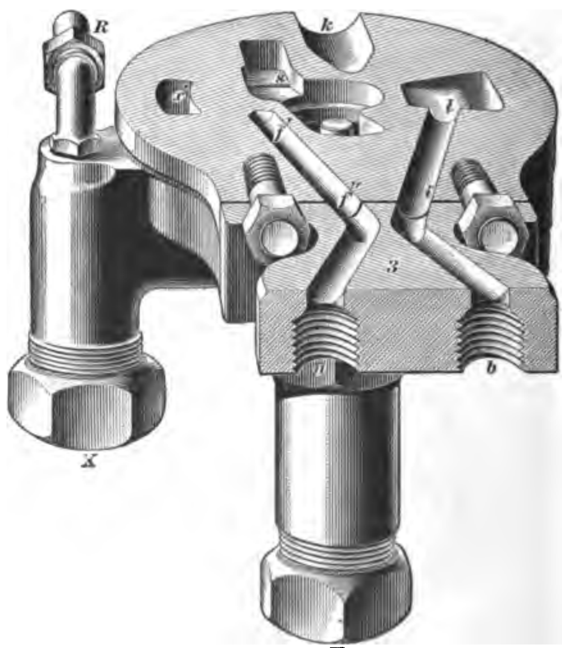


FIG. 7

valve attachment and put a **feed-valve pipe bracket** in its place. A sectional view of this bracket, connected to the brake valve, is shown in Fig. 7. This figure represents the same section of the F-6 brake valve as is given in view (*e*) of Fig. 11, *Westinghouse Air Brake*, Part 2.

The two pipes *a* and *b*, Fig. 1, that lead to the duplex feed-valve, screw into the pipe bracket *3* at *a* and *b*, Fig. 7. Thus, when the brake valve is in running position, air on its way to the train pipe flows through the passage *f f'* and the pipe *a*, thence through whichever feed-valve happens to be cut in, and back through the pipe *b* and the passages *i* and *l* to the train pipe.

OPERATING THE BRAKE

MAKING THE REDUCTIONS

14. The brake on a high-speed train is operated in precisely the same manner as the ordinary quick-action brake, stops being made by means of two applications. A number of reductions are made in a service stop, as with the latter, and the brake will be set in full or at about its maximum pressure when a reduction of from 20 to 22 pounds is made in the train-pipe pressure, if the piston travel is adjusted to 8 inches. In the high-speed system, the train pipe and auxiliaries are charged to about 110 pounds pressure per square inch, so that the brake may be applied three times in full, and still have the same pressure for the fourth application as would be had for the second application of the quick-action brake. That is, if train-pipe pressure is reduced from 110 to 90 pounds, sufficient air will pass from the auxiliary reservoir to the brake cylinder to raise its pressure to about 50 pounds. If, now, the brake is released without recharging at all, and the train-pipe pressure is reduced from 90 to 70 pounds, the brake will again be set with a pressure of 50 pounds. A second release, and a reduction from 70 to 50 pounds, will set the brake for the third time with a 50-pound pressure, and the train pipe and auxiliary will stand equal at 50 pounds. With the quick-action brake, a 20-pound reduction from 70 pounds train pipe will apply the brake with 50 pounds pressure, and the train pipe and auxiliary will stand equal at 50 pounds also. In fact, with either brake, a 20-pound reduction from a pressure of 70 pounds or more will apply the brake with a pressure of 50 pounds per square inch.

With no leakage, a 22-pound reduction would set the brake with about 60 pounds pressure; hence, if a greater reduction is made, air will simply be wasted, since the reducing valve will not allow over 60 pounds pressure to remain in the brake cylinder.

With a 30-pound service reduction and an 8-inch piston travel, the auxiliary and brake cylinder would equalize at about 80 pounds per square inch were the reducing valve inoperative; while, in an emergency application, they would equalize at about 85 pounds per square inch, on account of some air passing from the train pipe into the brake cylinder. In an emergency application, however, the reducing valve gradually reduces the brake-cylinder pressure from 85 pounds to 60 pounds.

When coupling a locomotive to a train where the high pressure is to be used, the reversing cock must be turned to cut in the high-pressure feed-valve, and the low-pressure side of the governor should be cut out. The pressure can then be raised in the train pipe to the proper amount and the low-pressure governor, being cut out, will allow the main-reservoir pressure to have the amount of excess necessary to release the brake. When dropping from the high pressure to 70 pounds, cut in the low-pressure side of the governor and so turn the handle of the reversing cock as to cut out the high-pressure feed-valve and cut in the 70-pound feed-valve. Then apply and release the brake until the train-pipe pressure is reduced to 70 pounds.

If an engine carrying the low pressure, such as a switch engine, is coupled to a high-pressure train, as soon as the hose is connected and the angle cocks opened, the high train-pipe pressure in the cars will at once pass to the brake valve in which the pressure is much less. As the pressure in chamber *D* will be considerably less than 110 pounds, the equalizing piston will at once be raised and held up until the entire train-pipe pressure is reduced to that in chamber *D*.

The train brakes will apply hard, usually in quick action, and the automatic reducing valves will reduce the auxiliary and cylinder pressure to 60 pounds. Do not move the brake valve to full-release position in an effort to seat the equalizing piston, but rather lap the valve at once, and keep it lapped until the train-pipe air has ceased flowing from the train-pipe exhaust; this will save the excess in the main reservoir for use in releasing.

On account of the higher pressure, reductions can be made both from chamber *D* and from the train pipe in less time than from 70 pounds. For that reason the reductions from the brake valve should be made more moderately than with the 70-pound pressure, in order that any triples that are dry or sticky, or not otherwise in good order, may not go into quick action. The larger size of equalizing reservoir used is designed to help this matter.

Both the brake valve and all the triples need cleaning and oiling at closer intervals than with the 70-pound pressure, if they are to work smoothly in service applications.

On a long train, triples on the rear cars are more liable to stick after a light application with the high pressure, as the leakage from train pipe to auxiliary past the packing ring will be no less and the pressure on the slide valve is much more than with 70 pounds. They are not likely to stick after a moderately heavy reduction, as in that case there is a greater difference between the train-pipe pressure and that of the main reservoir.

Do not use a very heavy service reduction (over 20 pounds) *at a slow speed* as the consequent high cylinder pressure may slide the wheels. Emergency applications should not be made at a train speed of less than 30 miles per hour, unless in an emergency; the wheels are apt to slide at slow speeds.

BRAKE TESTS

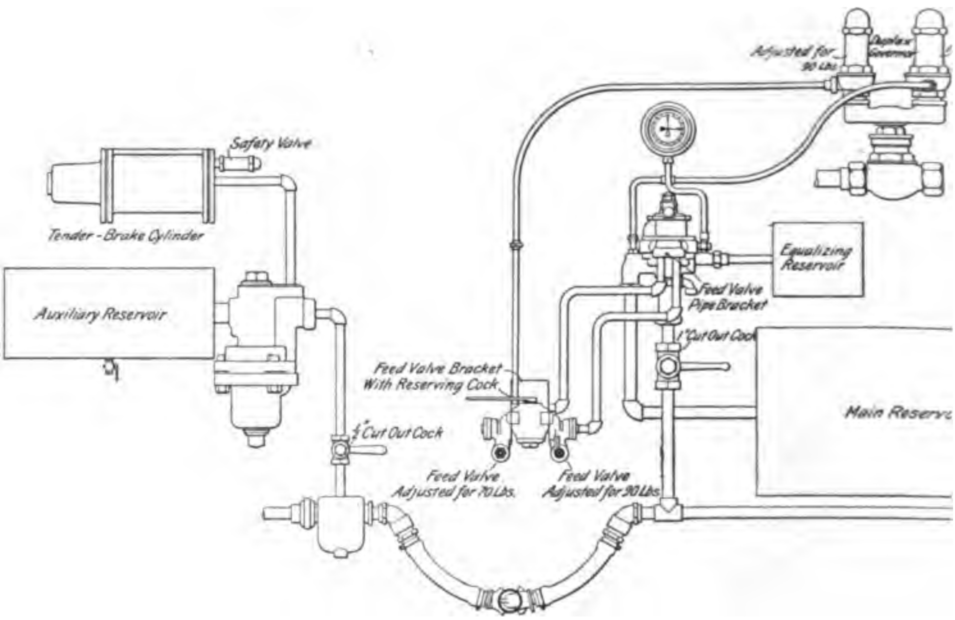
15. The following table gives the results of tests made on the Central Railroad of New Jersey at Absecon, N. J., in May, 1903. The train consisted of a locomotive and seven coaches, the locomotive having brakes applied to the engine truck, drivers, trailers, and the tender.

The percentage of braking power on the entire train was 72.8. Six of the coaches had 92.9 per cent., while the other, a chair car, had only 68.9 per cent. The locomotive's per cent. of braking power was 48.3; it was reduced by the unbraked weight of the coal and water on the tender. The total weight of the train was 774,650 pounds; the locomotive alone weighed 294,700 pounds, six of the coaches averaged close to 62,000 pounds, and the chair car weighed 107,600 pounds. Ordinary cast-iron brake shoes were used on the cars and tender, and steel shoes on the engine. This train was from the service and represented ordinary conditions; the track where the tests were made was level.

Tests were made with the 70-pound quick-action brake and with the 110-pound high-speed equipment.

The table gives in the first column the speed in miles per hour; in the second, the distance in which the high-speed brake made the stops; in the third, the distance in which the 70-pound brake made the stops; and in the fourth column, the difference in feet in favor of high-speed brake.

Speed in Miles per Hour	Length of Stop, in Feet		Distance Saved By the High-Speed Brake
	High-Speed Brake	Quick-Action Brake	
45	560	710	150
50	705	880	175
60	1,060	1,360	300
70	1,560	2,020	460
80	2,240	2,780	540


Adjusted for 90 Lbs.
Duplex Governor
Safety Valve
Tender - Brake Cylinder
Auxiliary Reservoir
Equalizing Reservoir
Feed Valve Pipe Bracket
1" Cut Out Cock
Feed Valve Bracket With Reserving Cock
½" Cut Out Cock
Main Reserv
Feed Valve Adjusted for 70 Lbs.
Feed Valve Adjusted for 90 Lbs.

F

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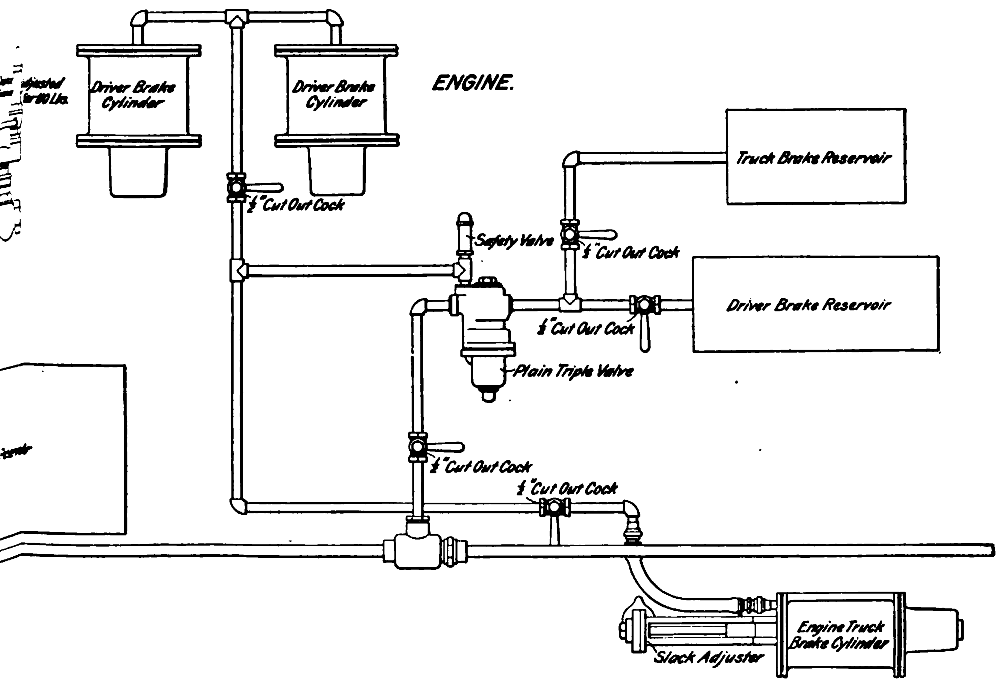


Driver Brake Cylinder
Driver Brake Cylinder
ENGINE.
Truck Brake Reservoir
½" Cut Out Cock
Safety Valve
½" Cut Out Cock
Driver Brake Reservoir
½" Cut Out Cock
Plain Triple Valve
½" Cut Out Cock
½" Cut Out Cock
Engine Truck Brake Cylinder
Slack Adjuster

IG. 8

CONTROL OF HEAVY FREIGHT TRAINS ON GRADES

HIGH-PRESSURE CONTROL APPARATUS

16. This apparatus, often called the **schedule U apparatus,** consists of appliances by means of which the engineer can, at will, change the train-pipe and main-reservoir pressures from 70 and 90 pounds to higher pressures, or vice versa.

It was intended especially for use on heavy grades where the train is taken down loaded and up empty, a train-pipe pressure of 90 pounds being used in taking down the loaded cars, and a train-pipe pressure of 70 pounds used when the empties are hauled up the grade.

A car braked to 70 per cent. of its light weight, as is the usual practice, is only braked to about 20 per cent. of its loaded weight, so that there is no danger of sliding wheels with the higher train-pipe pressure used in this service.

GENERAL ARRANGEMENT

17. The schedule U apparatus and its arrangement on the engine and tender is shown in Fig. 8. It will be seen to differ from the ordinary equipment in that: the pump governor is replaced by a duplex governor; the feed-valve attachment, by a duplex feed-valve; and the engine triple valve, by a special high-speed triple. The latter is necessary, since the engine-truck wheels, as well as the driving wheels, are fitted with brakes. Also, a safety valve, like that used with the high-speed brake, is connected to the engine and tender-brake cylinders to prevent the cylinder pressure from increasing above 50 pounds per square inch, as it is not considered desirable to increase the pressure in either cylinder above that amount.

The duplex feed-valve is exactly the same as that used in connection with the high-speed brake, and is attached to the brake valve in the same manner. One feed-valve is adjusted for 70 pounds, while the other is usually adjusted for 90 pounds.

The duplex pump governor, also, is the same as the one used with the high-speed brake, but it is piped differently. In the high-speed brake, both diaphragm cases of the governor are piped to the engineer's brake valve at *R*, while in the schedule **U** equipment, only the high-pressure diaphragm case is piped to *R*, the other case being piped to a connection in the reversing cock, which connects with the passage *f' f''* in the brake valve leading to the feed-valve that is set at the lower pressure. Pipes *c* and *a*, therefore, connect with the same chamber in the reversing cock. By this arrangement of the piping, it is possible: to regulate the train-pipe pressure to 70 pounds and the main-reservoir pressure to 90 as long as the brake valve is left in running position, and when the brake valve is moved to lap, service, or emergency position to pump up main-reservoir pressure to 110 pounds; or to continuously regulate the train-pipe pressure to 90 pounds and main-reservoir pressure to 110 pounds.

OPERATION OF APPARATUS

18. Ordinary Running Conditions.—With the reversing-cock handle turned to the left, as shown in Fig. 8, train-pipe pressure is regulated by the feed-valve. Now, suppose the brake valve to be in running position and the pump working: air from the main reservoir can pass through the passage *f' f''* in the brake valve and pipe *a* to the feed-valve, and thence through pipe *c* to the pump governor. As soon as main-reservoir pressure is raised to 90 pounds, the governor will stop the pump. Main-reservoir pressure will then be maintained at 90 and train-pipe pressure at 70 pounds, as long as the brake valve is carried in running position.

If a reduction in train-pipe pressure is made and the brake valve is then lapped, the supply valve of the feed-valve will be forced from its seat by the regulating spring, and the air in pipe *c* will consequently be reduced to train-pipe pressure. Now, since the brake valve is lapped and no air can pass from the main reservoir through the brake valve into pipe *c*, the pressure in the pipe must remain less than 90 pounds as long as the brake valve is lapped; hence, the low-pressure side of the pump governor is cut out of service. The pump, therefore, will operate until 110 pounds pressure is accumulated in the main reservoir, when it will be stopped by the high-pressure side of the pump governor. With 110 pounds in the main reservoir with which to release the brakes, a quick release and prompt recharging of the auxiliaries is assured.

19. Descending Long Grades.—When the train is to descend a long grade, the handle of the reversing cock is turned in the opposite direction to that shown in the figure, cutting into service the feed-valve that is adjusted to 90 pounds and cutting out the side of the governor that is adjusted to 90 pounds. Thus, when descending long grades, the main reservoir is charged to 110 and the train pipe and auxiliaries to 90 pounds.

The brakes are operated in exactly the same manner as the quick-action brake, the only difference being that with the auxiliaries charged to 90 pounds, a full-service application of the brakes will result in a brake-cylinder pressure of about 65 pounds per square inch instead of 50 pounds. A 20-pound reduction will give 50 pounds in the brake cylinder.

In case there are empty cars in a train using the higher pressure, their brakes must be cut out to avoid sliding the wheels. This precaution applies to air-braked cabooses also, unless they are provided with safety valves.

The schedule **U** apparatus was at first designed for use with freight trains that run one way empty and return loaded, as, for instance, coal and ore cars going to and returning from the mines. However, it can be used with any train consisting entirely of loaded cars.

When grades are exceptionally long and heavy, so that the driver brakes have to be held on hard for a considerable length of time, trouble is generally experienced with the driving-wheel tires heating, the friction between the brake shoe and the wheel generating heat that expands the tire. On such grades, therefore, the brake known as the *water brake* can be used to good advantage.

THE WATER BRAKE

PRINCIPLES INVOLVED

20. If the valve gear of a locomotive is reversed while the locomotive is running forwards with throttle closed, the engine cylinders will be converted into air compressors. As the piston moves either forwards or backwards, a vacuum is created in the cylinder behind it and hot gases from the smokebox are drawn in to fill the vacuum. The gases in the cylinder ahead of the piston are compressed, and offer a resistance that acts to stop the movement of the piston, and thus the speed of the engine is retarded.

With the valve gear in the reverse direction to which the engine is running, therefore, the engine cylinders act as brakes to retard the speed of the train. If the air drawn into the cylinders were cool and free from cinders, this method of braking would be simple and very efficient for use on engines on long down grades. As it is, however, cinders would be drawn into the cylinders and cause trouble; also, the gases in the smokebox are very hot, and, when drawn in, their temperature is still further increased by compression; hence, serious injury would result to the cylinders, valves, and valve seats if this method of braking were used without some means of preventing the hot gases and cinders from entering the cylinders.

The water brake (sometimes spoken of as the *LeChatelier brake*) overcomes the objections to this method of braking by introducing wet steam at a low pressure into the cylinders, thereby excluding the hot gases. Unfortunately, the term "water brake" is a misnomer when applied to the LeChatelier method of braking, and is very liable to create the impression that water is used in the cylinders, whereas, in reality, the braking is done by means of low-pressure wet steam. It is scarcely necessary to remark that water in the cylinders has too often been the cause of considerable trouble for any one to voluntarily introduce it there.

CONSTRUCTION OF BRAKE

21. The **water brake** was invented nearly 50 years ago by a prominent French engineer named LeChatelier, but it was not introduced in this country until years afterwards, being first used on the early mountain roads in the Rocky Mountains, a region where it has proved a very valuable auxiliary braking device. This brake is shown applied to an engine in Figs. 9 and 10, the former being a plan view of engine and the latter a view taken at rear of cylinders. The brake apparatus consists of an ordinary globe valve *a* and sufficient piping *b b b* to connect the valve with the exhaust passages in the cylinder saddle at *c*, *c*. The globe valve is set in the boiler head, on a level with the crown sheet and at a point where it will be within easy reach of the engineer. The pipe used in connection with the globe valve is either a ⅜-inch or a ½-inch pipe, depending on the size of the engine cylinders. It divides into two branches at the cylinder saddle, each branch leading to, and opening into, one of the exhaust passages, as shown.

OPERATION OF PARTS

22. As previously stated, the duty of the water brake is to supply low-pressure steam to the cylinders when the engine is running reversed, so that, by acting as compressors, the cylinders can be used as an auxiliary braking device without being injured by hot gases and cinders from the smokebox. It is well known that water will boil at 212° F. if in the open air; if subjected to a boiler pressure of, say, 180 pounds gauge, however, it will not boil until its temperature has been raised to about 380° F. If some of

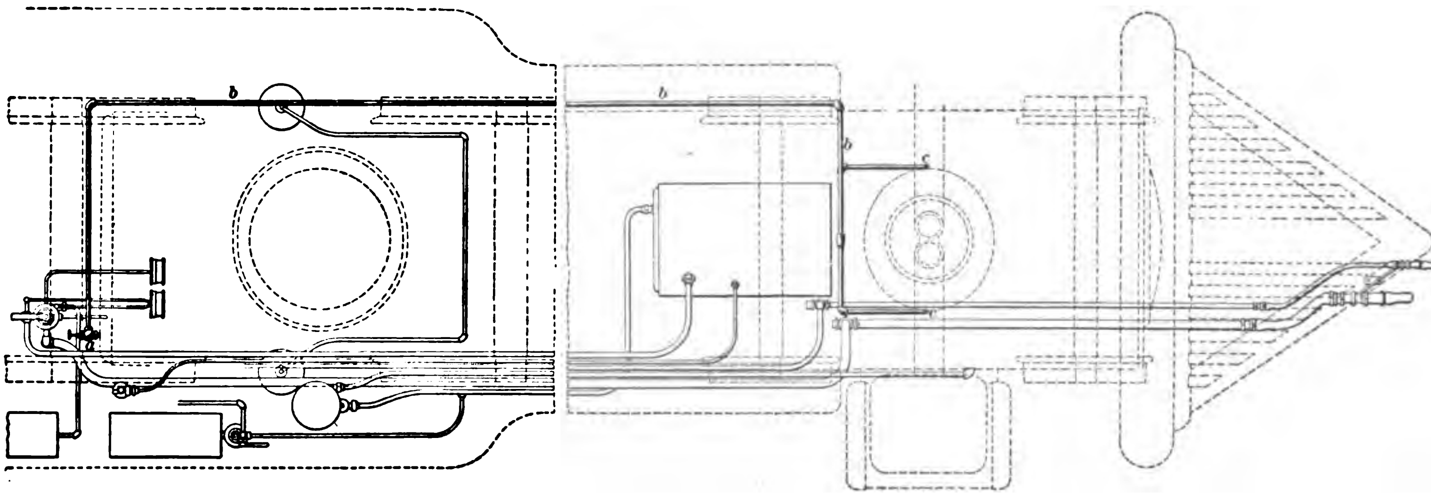


FIG. 9

the water in the boiler is allowed to escape into a pipe or vessel connected with the atmosphere, its temperature will be far greater than 212° F.; hence, it will boil and be converted into steam. The temperature of this steam, however, will fall considerably during this conversion, so that the pressure exerted by it will be reduced accordingly.

The valve and piping of the water brake simply provides the engineer with a convenient means of introducing water from the boiler into the exhaust passages in the cylinder saddle, where it is immediately converted into steam for use in the cylinders. By introducing the water into the

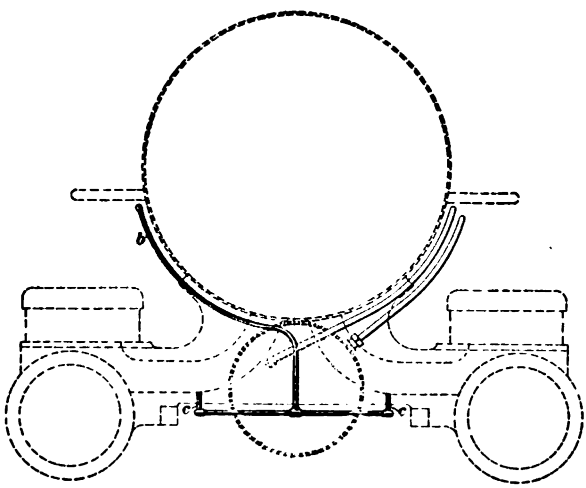


FIG. 10

exhaust passages, a vacuum is prevented from forming therein; hence, there is no tendency for the hot gases in the smokebox to be drawn into the cylinders.

Thus it will be seen that the operation of this brake depends on the excess temperature of the water in the boiler over that required to boil water under atmospheric pressure; if the water in the boiler were at a temperature less than 212° F., it would not be converted into steam when discharged into the exhaust passages, and the result would probably be a broken cylinder head.

OPERATING THE BRAKE

23. The water brake should always be operated in a *certain regular order*, which is as follows: First, be sure that all the cylinder cocks are open and that the throttle valve is shut; next, open the water valve (i. e., the globe valve *a*) about one-quarter turn; then immediately place the reverse lever of the engine one or two notches back of the center and note the color of the steam issuing from the cylinder cocks. If dense white in color, the water valve is open sufficiently, but if the steam has a bluish color at the cylinder cock, which gradually changes to grayish white as its distance from the cock increases, the water valve should be opened a little wider until the steam has a dense white appearance from the moment it leaves the cylinder cocks. If the engine throws water from the stack, the valve is opened too wide and should be closed sufficiently to stop the trouble.

The amount of braking power exerted by the water brake depends on the position of the reverse lever. When it is in the first notch from the center, it exerts the least braking power, and the braking power is increased as the lever is moved toward the corner notch. The retardation of speed should therefore be regulated by placing the reverse lever in the notch required, and the water valve should not be changed after once being adjusted.

The water brake can be used when the engine is running either forwards or backwards, by simply placing the reverse lever so as to convert the cylinders into air compressors, observing the same rules of operation regardless of the direction of running.

When it is desired to shut off the water brake, first close the water valve *a* and then slowly move the reverse lever toward the center, to avoid throwing water from the stack.

The water brake, it must be remembered, acts to stop the rotation of the drivers, so that if the air driver brake is used in conjunction with it, the braking force acting on the drivers will be too great, and they will be skidded. The water brake is simply an auxiliary braking device and should be used intelligently. It is most effective on a steady motion of from 3 to 12 miles per hour, is less effective at speeds greater than 12 miles per hour, and it should not be used at a greater speed than 18 miles per hour.

In double-heading on a grade, the engineer not operating the air brake assists in retarding the speed of the train by using the water brake to whatever extent advisable.

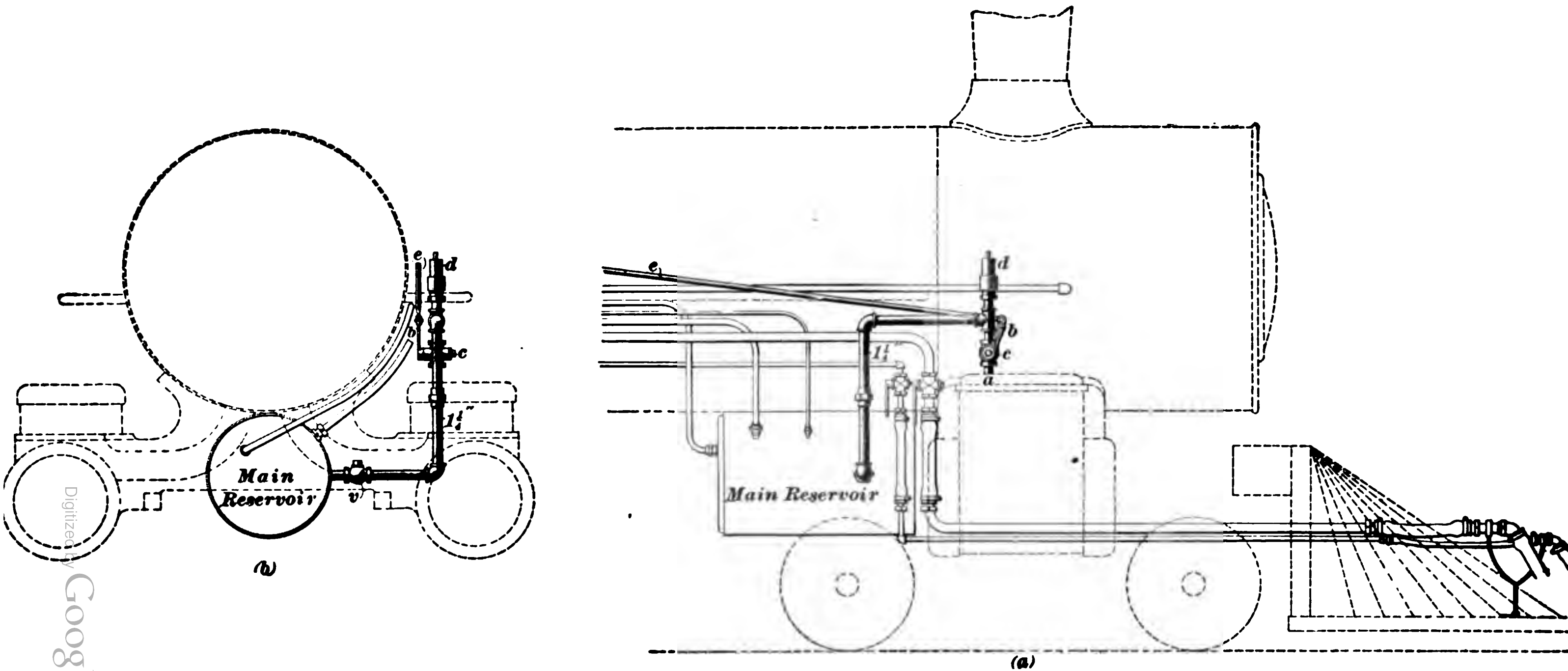
THE SWEENEY AIR COMPRESSOR

PRINCIPLES OF WORKING

24. The **Sweeney air compressor,** or the "Sweeney," as it is commonly called, is an air-compressing device that is used on Western roads where the grades are heavy. It is not intended to replace the ordinary air pump, but rather to act as an auxiliary compressing device to supply air in case the pump becomes disabled. This device is used only when the pump is disabled, as the air forced into the main reservoir is very hot and may spoil the gaskets and injure the hose.

CONSTRUCTION OF COMPRESSOR

25. Two views of the Sweeney, applied to an engine, are given in Fig. 11 (*a*) and (*b*). It will be seen that a 1¼-inch pipe is tapped into the top of the steam chest at *a*, and thence leads to the main reservoir. A stop-cock *c* is placed in the pipe so as to control the passage through it. This stop-cock can be opened and closed from the engine cab by means of the rod *e*, which is connected to the lever *b* of the stop-cock. Pushing the handle forwards opens the cock, while pulling it backwards closes it. Also, a check-valve *v* is placed in the pipe, close to the main reservoir. The object of this valve is to prevent air flowing from the main reservoir back through the pipe to the steam chest. A safety valve *d* is also provided, which prevents the main



e
d
b
c
$1\frac{1}{4}''$
Main Reservoir
v
(b)
e
d
b
c
a
$1\frac{1}{4}''$
Main Reservoir
(a)

FIG. 11

reservoir from being overcharged, since it will open and allow the air to discharge from the cylinders to the atmosphere when main-reservoir pressure is raised to the pressure for which the safety valve is adjusted.

OPERATING THE COMPRESSOR

26. To operate the Sweeney, the throttle must, of course, be closed and the engine running. The cylinder cocks should first be left open while the drivers make two or three revolutions, so as to get rid of any water there may be in the cylinders. The engineer's brake valve should then be placed on lap, to prevent the hot air and gases that are drawn in from the smoke arch passing directly into the train pipe and hose. The stop-cock *c* is then opened, and the engine reverse lever placed several inches back of the center notch, assuming the engine to be running forwards. By reversing the valve gear while the engine is running, the cylinders are converted into air compressors, and air is compressed and forced into the steam chest and thence through the $1\frac{1}{4}$-inch pipe to the main reservoir. As the capacity of the steam cylinders is large compared with that of the air-pump cylinder, the main reservoir is charged in a very short time by this method. The reverse lever must be left back of the center notch at least 15 seconds after the gauge indicates standard pressure.

To throw the Sweeney out of service, place the reverse lever in the forward motion and close the stop-cock *c*; care must always be taken to see that the stop-cock is closed before steam is used, since, if it is left open, the air-brake system will be charged with steam when the engine throttle is opened, and trouble will surely result.

INDEX

NOTE.—All items in this index refer first to the section and then to the page of the section. Thus, "Air gauge 1 6" means that air gauge will be found on page 6 of section 1.

A