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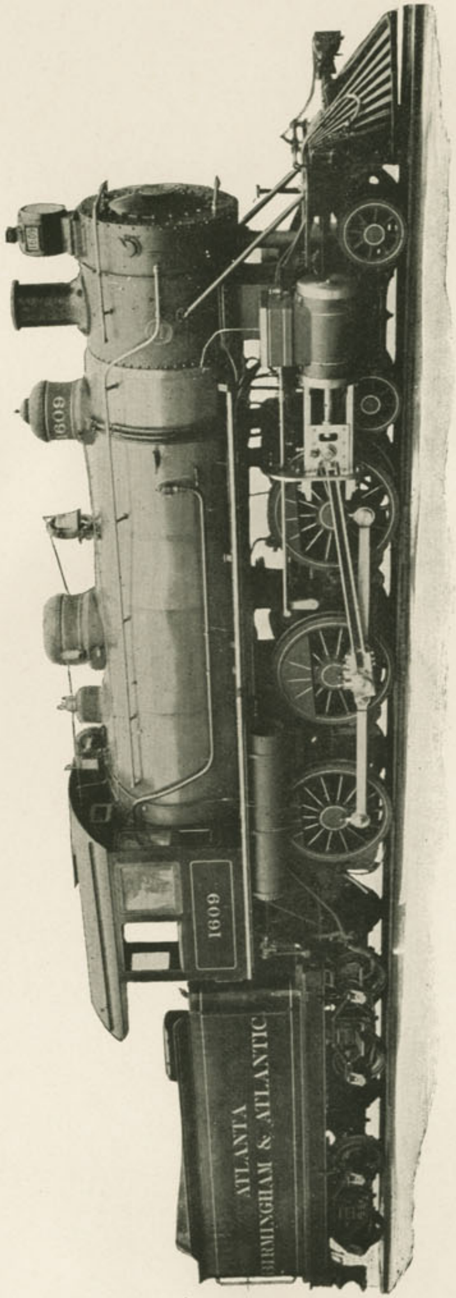

TEN-WHEEL TYPE OF LOCOMOTIVE USED FOR FREIGHT AND PASSENGER SERVICE ON THE ATLANTA, BIRMINGHAM & ATLANTIC R. R.
(Baldwin Locomotive Works)

PRACTICAL RAILROADING

A NEW, COMPLETE AND PRACTICAL TREATISE ON STEAM, ELECTRIC AND MOTOR CAR OPERATION

INCLUDING

A DESCRIPTION OF ALL THE VARIOUS PARTS OF THE DIFFERENT TYPES OF LOCOMOTIVES, THEIR PRINCIPLES OF OPERATION, MANAGEMENT, REPAIR AND MAINTENANCE; ALSO THE AIR BRAKE, MECHANICAL STOKERS, FEED WATER HEATERS, SUPERHEATERS, AND THE LATEST DEVELOPMENTS IN THE RAILWAY FIELD

WRITTEN EXPRESSLY FOR THE

MASTER MECHANIC, TRAVELING ENGINEER
LOCOMOTIVE ENGINEER AND FIREMAN

OSCAR C. SCHMIDT
Consulting Editor

PROFUSELY ILLUSTRATED WITH HALF-TONES, DIAGRAMS AND LINE CUTS

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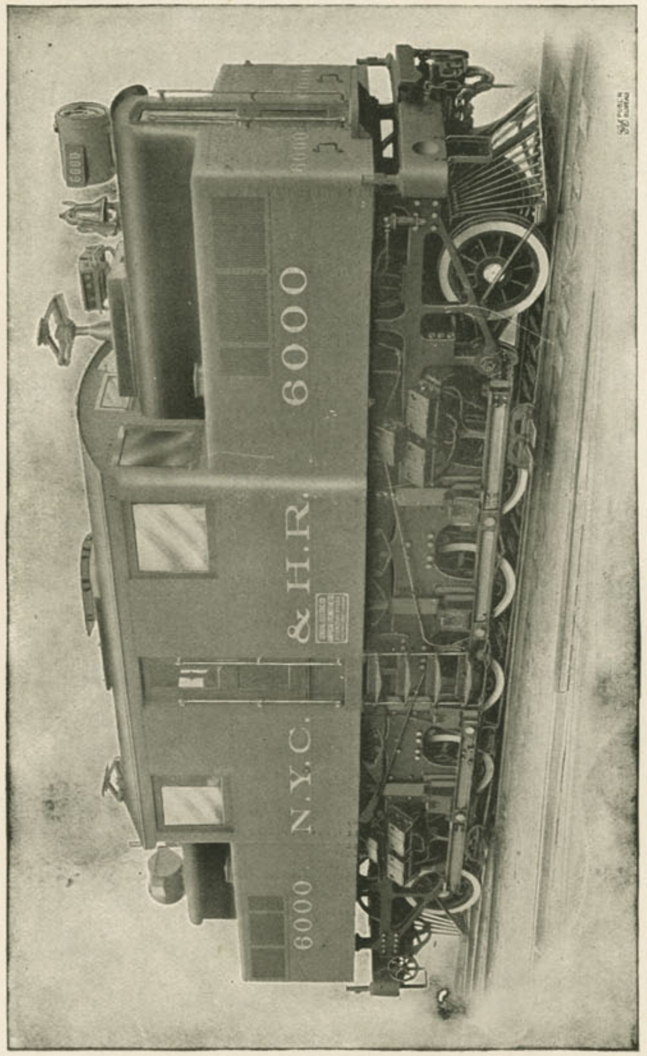


ELECTRIC LOCOMOTIVE USED ON THE NEW YORK CENTRAL RAILROAD
(General Electric Company)

Signals and Signal Systems.

As the traffic on railroads has grown so rapidly, and as the speeds of equipment have constantly increased, it has become necessary to provide the most efficient systems of signaling to safeguard the method of conducting traffic. The old method of operating trains by train orders and telegraph has imposed such a difficult task for the train dispatcher that other methods are being used which will lessen his labors and responsibilities.

Telegraph and Train Order System. The earliest method of operating a train, and the one which is still in most extensive use, is by means of the telegraph and train order system. In this method of operating trains by telegraph, a train order is filled out by the station master in response to telegraphic orders received from the train dispatcher, and handed to the engineer and conductor of every train affected by the order. The possession of this order is the engineer's authority for running his train, but before he proceeds he must telegraph the train dispatcher his understanding of the order, so as to minimize the chances of error. After the train has left, the operator at the station notifies the train dispatcher, who enters the name of the station and the time on a sheet before him, so that he can tell at a glance where every train on the division is and how to direct their movements. With this system it is essential that a man stand ready to receive messages and wave a red flag, or hoist a signal to a mast head, if it is desired to stop a train at any particular station to await the orders.

The chance of error on the part of the train dispatcher or telegraph operator increases very rapidly with the number of train movements required, and for this reason a system of signaling has been developed whereby trains automatically set signals behind them to prevent following trains approaching too closely. The train dispatcher's duties are thus greatly reduced, as with an automatic signal system he is only required to keep a record of their positions, so as to stand ready to relieve confusion in case of failure of the signals.

Block Signals. The method of signaling in general use makes use of an arrangement known as block signals, by means of which the engineer can tell when to run cautiously or when to stop; thus when one signal is set at danger and the other at clear, the engineer knows the block before him is clear, but the one beyond is occupied. He then proceeds expecting to find both of the next signals at danger, indicating that there is a train in the next block, and he must stop. One of the signals on the post is therefore known as a distant signal, since it indicates the position of a signal one block in advance, and the other is known as the home signal. The distant signal is interlocked with the home signal, so that it can show clear until the home signal a block in advance is cleared. The reason why one signal at the beginning of a block does not provide sufficient protection for trains when running at high speed is because it cannot be seen in time to make a stop with the ordinary service application of brakes without running by a signal. The distant signal, therefore, serves to forewarn the engineer by repeating the indication of the home signal far enough in the direction of an approaching train to enable a stop to be made under the worst conditions before the home signal is reached. It is evident, therefore, that this signal should be placed at least 1,500 to 2,000 feet from the home signal on a level track, a little less on an up grade and a greater distance on down grade.

A length of a block will depend upon the headway and speed of the train, but it is always of sufficient length to allow the engineer to gain control of his train and stop before reaching a home signal, after the distant signal is seen. On roads where the traffic is heavy the blocks are made short, so that a train may run through the block quickly, and not hold it against another train which may be waiting. A high-speed train will run through a long block in the same time a slow-speed train will run through a short block, therefore for high-speed trains the block should be made longer, requiring fewer signals for a given length of track, and affording greater safety, as the trains are kept further apart.

When the blocks are long and the train allowed to run at full speed after passing the distant signal, which may be set at danger, it is customary to place an intermediate distant signal far enough in advance of the home signal to permit a stop being made before the home signal is reached. This method is particularly advantageous in case the home signal is at the end of a long curve, or the contour of the country is such as to prevent its being seen before it is too late to stop. In the case of very long blocks it is customary to omit the distant signal at the beginning of the block, the intermediate signal affording ample protection.

Block Systems. The block system is a series of consecutive blocks so arranged as to regulate the movement of railroad trains in order that an interval of space may be maintained between trains moving in the same direction on the same track. There are four different block systems in general use, the simplest of which is the Manual Block System, the others being the Controlled Manual Black System, the Electric Train Staff System, and the Automatic Block Signal System.

Development of the Block System. The block system was first used in America in 1863 or 1864, and the interlocking about 1870. For many years the Pennsylvania, which in 1872 leased the lines east of Philadelphia, on which the block system had been first introduced, was the only road using it. A few roads in New England began using wire-circuit automatic block signals about 1871, but the time interval rules were maintained in full force, so that the signals were of little use in increasing the capacity of the railroads. In 1879 the track circuit was introduced, making automatic block signals effective as against the danger of false clear signals being given by the accidental separation of a train into two parts (and incidentally affording a means of detecting broken rails), and from that time the use of the automatic system has progressed as fast as railroads have found themselves able to make the heavy investment necessary to install it.

Statistics of Roads Using Block Signals. From data given by the government, 47,876 miles of railroad are operated by the manual block signals. Of this mileage 40,040 miles are regulated by the use of the Morse telegraph; on 3,287 miles it is done by means of telephones; on 839 miles by electric bells; on about 2,400 miles by controlled manual apparatus, without track circuits; on

727 miles by controlled manual apparatus, with track circuits at stations; on 212 miles by controlled manual apparatus, with track circuits continuous throughout the block sections, and on 234 miles by the electric train staff.

The principal roads using telephones for block signaling are the Atchison, Topeka & Santa Fe, 1,438 miles (including some double track); Chicago, Burlington & Quincy, 753 miles (including some double track); Illinois Central, 769 miles; Michigan Central, 68 miles; Pennsylvania, 203 miles (including some double track); West Jersey & Sea Shore, 29 miles (all double track).

The principal road using electric bells (not controlled manual) is the Erie, on which there are 723 miles worked in this way, including both double track and signal lines. Other lines are the Long Island, the Pennsylvania and the Wabash.

The principal roads using controlled manual, with no track circuits, are the Chesapeake & Ohio, 147 miles; Chicago & Eastern Illinois, 69 miles; Chicago, Burlington & Quincy, 1,252 miles; Illinois Central, 769 miles. Nearly all of this mileage is single track.

The roads using controlled manual, with track circuits at the stations, are the Chesapeake & Ohio, 92 miles; Chicago & Alton, 19 miles; Long Island, 8.6 miles; New York Central & Hudson River, 373 miles; New York, New Haven & Hartford, 229 miles.

The roads using controlled manual, with continuous track circuits, are the Chesapeake & Ohio, 29 miles; Chicago, Burlington & Quincy, 61 miles; New York Central & Hudson River, 70 miles (234 miles of track); Pennsylvania, 14 miles. The electric staff is in use on 20 roads, but only five of these have more than 10 miles each. These five are the Atchison, Topeka & Santa Fe, 34 miles; Chicago & Alton, 18 miles; Great Northern, 15 miles; Southern Pacific, 101 miles; Union Pacific, 11 miles.

The 100 roads on which manual block signals are in use report the number of block signal stations as 9,438, and 2,600 of these stations (on 62 roads) are closed part of the time.

On 23,196 miles of road worked by the manual block system, most, or all, of the block stations have but one signal each for movements in each direction. This signal is usually fixed opposite the station office, and trains ordinarily are allowed to pass a signal indication "stop" sufficiently far to stop the cars at the station platform. About 3,600 miles of the lines here referred to are double track.

Automatic block signals are now used on about 11,000 miles of American railroads.

Definitions of Various Terms Used in Block Signaling. In order to understand the working of a block system, there are a number of different terms which must be defined, as railroad signaling is a comparatively new art which is rapidly growing, and its nomenclature is unsettled.

Block Signal. The block signal is a fixed signal at the entrance of a block section, used to give indications regulating the movement of trains in that section.

Block Section. A block section is a section of tracks of defined length, the use of which is regulated by a fixed signal at the entering end, or on a single track line by such signals at both ends.

Home Signals. A home signal is a fixed signal situated at the point at which trains are required to stop when the signal does not indicate proceed. As a block signal it stands at the entrance of the block. It is also used to protect switches, crossings, draw bridges, etc. When a home signal shows clear, it indicates that the track governed by the signal has been made ready for the movement of the train on it. When a manual or controlled manual block system is used, the home signal must not be passed except upon orders from the proper authority.

Semaphore home signal arms are usually made with square ends to distinguish them from distant signals, the arms of which are made with forked ends. Sometimes a further distinction is made by using arms with pointed ends for automatic home block signals, and square end arms for other home signals.

Advance Signal. An advance signal is one which has the same function as a home signal. It is placed some distance in advance of the home signal at a block or interlocking signal station. It provides a short block system in which the signalman may hold a train while not interfering with the movement of trains in the main block section, either in advance or in the rear. The signalman can accept another train from the rear block as soon as the arriving train has passed completely beyond his home signal, and he can hold the arriving train at the advance signal until the block in advance is clear.

Distant Signal. In order to run a train safely at a given speed, it is necessary to keep the engineer informed at all times of the conditions of the track in front of him, so that he may know that it is proper for the train to proceed. If it is not safe to proceed, the engineer must be informed at a point sufficiently far away from the stopping point, in order to enable him to bring the train to a stop before entering the danger block. Of course, the higher the speed of the train the greater the distance from the stopping point should the indication to stop or to proceed be given. This distance generally carries from 1,500 to 2,000 feet or more in the rear of a home signal. This distance indicated is therefore known as the distant signal, and is generally so interlocked that it never can be cleared until the home signal is clear, and should there be other signals for that track, the distant signal is so interlocked that all of them must be cleared before it can be cleared.

In the automatic block signal system the distant signal is controlled by the home signal, and is usually mounted on a post with the first home signal in the rear. When the three-position automatic block signals are used, each signal gives a distant indication for the next signal in advance.

Caution Signals. A caution signal is a signal indication which denotes that a train may proceed under some restrictions, with the understanding that a preceding train moving in the same direction may be overtaken at any point in the block section, and that, therefore, the speed must be very slow, except when the engineer is able to see a clear track for a considerable distance ahead. A caution signal is sometimes used so that it means proceed, in which case the next home signal will indicate stop. Should the home signal become clear when it is reached, the caution signal does not then, of course, have any value.

Permissive Block Signals. Permissive block signaling permits one or more trains moving in the same direction to enter a block section before the last preceding train has passed out at the other end. In such cases the following train is allowed to proceed slowly expecting to find the track blocked, and the engineer must be prepared to stop without being warned by a flagman or otherwise.

Permission to proceed is given by a written card from the signalman, or by a signal indication such as the intermediate position of a three-position signal or by a flag or hand lantern. In automatic block signals the practice is generally permissive, because if a signal is out of order and indicated stop, the line would be blocked until the signal could be repaired. The most common rule for permissive block signals, where automatic signals are used, is to stop at a signal indicating stop, wait one minute, then proceed through the block with speed under control. On some special lines or single-track roads it is a rule to send a flagman ahead before proceeding. Permissive signaling, however, is ordinarily only allowed with freight or slow-speed trains, absolute blocking being enforced before and behind passenger trains.

Clear Signal. A clear signal always denotes the position of a signal, which indicates that the train may proceed.

Distant Switch Signal. A distant switch signal is one arranged like a mechanical distant signal, but is only to indicate the position of an outlying switch. Its lever is usually interlocked with the lever of the switch. It had its widest use before block signals came into extensive use.

Dwarf Signal. A low semaphore signal, which is used for giving indications for low-speed movements, is generally termed a dwarf semaphore signal, and they are used generally with an interlocking plant for determining the movements of a train in the reverse direction to the current of traffic on or from a side track. They are also used to give indications in the normal direction, as in the case of movements of a train from the main track to the side track, and they are frequently used at terminals in the normal direction.

Three-position Block Signals. On some roads semaphore signals are used which give three different indications, and are generally used to provide the protection of distant signals without the duplication of signal arms usually involved. Each signal arm is so arranged that it must be put in any one of three positions, the position depending upon the rules of the particular road upon which it is equipped. In the most usual form of manually operated signals the horizontal position on the arm indicates stop, the arm inclined downwards 45 degrees, caution, and inclined downward about 75 degrees, proceed. On a few roads the arrangement for horizontal is stop, upward 45 degrees, caution, and downward 45 degrees, proceed. The signal goes to the stop position when the train enters the block; when the train has cleared the block it moves to the caution position, and remains in that position until the next signal in advance goes to the caution position, when it goes to the clear position. A train is thus always protected by a stop signal in the rear, and a caution signal one block further back.

At night a red light indicates danger, yellow light caution, and a green light clear.

Manual Block System. The manual block system is the simplest form of block system in general use. The signals at a block station are moved by hand by an attendant on information conveyed to him from adjacent block stations by telegraph, telephone or electric bells. With the manual block system the blocks are of different lengths, each block station having two home signals, one to govern the movement of trains in each direction. In order to more closely regulate the speed of trains, distant signals and advance signals are generally used. All of these signals are moved by levers in the signal tower, and stand normal in the stop position, being cleared only on the approach of a train, and if the block ahead is clear they return to the normal position after the train has passed.

This system differs from the automatic block signal system and the controlled manual block system in the respect that in the former the signals are worked by electrical or magnetic power controlled automatically by the train as it passes in and out of a block section, and in the latter system it differs from the manual block system because electric locking devices are attached to the levers by which the signals are moved, so that in order to admit one train to a block the simultaneous action of the signalman at both ends of the block is required.

Since 1898 the use of manual block signaling has been quite rapidly extended throughout the country, and it now covers over 40,000 miles of road, besides several thousands more on which the protection is less complete. This manual signaling is on lines which carry a considerable traffic, but which yet are not profitable enough to justify the initial expenditure necessary to install automatic signals. But as fast as automatics can be afforded many

companies are substituting them for the other systems; for, once installed, their operation, requiring no signaling, is much less costly.

Controlled Manual Block Systems. As explained above, the controlled manual block system makes it necessary that both signalmen must work simultaneously in order to clear that block. This is done by means of electric locks which are attached to the signal levers and controlled from the adjoining block stations. The controlled manual block systems have the additional advantage that by the addition of a complete track circuit throughout the length of the block sections, provision is made against collision due to the accidental breaking of a train. Because as long as part of the train is in one block it is impossible for the signalman to give a clear signal, as he ordinarily would if part of the train passed and the other part remained in the block.

Electric Train Staff System. The electric train staff system is a method for regulating the movement of trains on a single track railroad.

Automatic Block Signal Systems. An automatic block signal system is a series of consecutive blocks. An automatic block signal is one which is worked by electric or pneumatic agency, which is controlled by the passage of the train into, through and out of the block section to which the signal is connected. The entrance of a train in the block sets the home signal at stop, and the clearing of the block section by the passage of the train out of it sets that signal clear. The apparatus is generally so arranged that the misplacement of a switch or the accidental entrance of a car from a side track will set the signal at stop.

Danger, Caution or Clear Indications. There are several ways of indicating a danger, caution or clear condition of the track, among which are: First, colored systems; second, position systems; third, motion systems. A type of the first is a colored disc moving before a white surface, the second a blade or semaphore which is held at various angles to the track. When horizontal the danger or stop is indicated, and when nearly vertical, proceed or clear. Semaphores may be colored also, and thus become of the first type. The third, or motion signal, utilizes a revolving member, whose motion indicates that an approaching train may continue to move, and when stationary that the engine must come to a stop. This latter system, however, has been abandoned.

Normal Clear vs. Normal Danger Signals. The position of a signal may be either normally at clear or normally at danger. Automatic block signals in their simplest form are called "normal clear," because at all times, when their block sections are unoccupied with the switches closed and all apparatus in working order, the home signals stand at "clear," indicating "proceed." In the "normal danger" system the home signals indicate stop at all times, even when the block is clear, except when a train is approaching, and then they indicate "clear" only when block is clear. This latter practice resembles manual signaling, except when it is necessary to clear them for the passage of a train.

There has been a large amount of argument as to whether it is better to use normal danger or normal clear circuits, each of which has its advocates. In general, however, it is better to place the dependence of a safety condition or a danger indication upon the opening of a circuit rather than upon its closing. In the low voltage circuits used in signaling there is greater certainty in opening than in closing a contact. This is because a poor connection may introduce a sufficient resistance to oppose the desired flow of current. With a close circuit type, with an open switch, the track must be short-circuited to let the signal at danger, and with the open circuit arrangement the signal circuit must be open to let the signal at danger. This latter is obviously the most reliable, as a poor contact will merely mean false contact condition, while in the primary it will set up a false clear signal.

So far as preventing accidents is concerned, the normal danger position is considered the best, and has been used extensively on systems using the mechanically operated semaphores, while on electric operated circuits the normal danger position is also favored. The normal danger system admits of the employment of normally open track circuits. This condition allows the use of open circuit batteries with consequent economy of operation. The circuits are closed in the preceding two blocks by the approaching train, and should anything be wrong with the block, the track relays will receive no energy.

With the normal clear system, the closed circuit gravity cells

are employed, which require frequent attention and renewing, and it has been the continual heavy demand upon track batteries by the low resistance track relays under a clear condition that has been one of the greatest disadvantages of the normal clear system.

In a normal danger system the indication members are always in the danger position, except when a train is approaching them. In all the normal clear systems the signal semaphores or discs are in the clear position at all times, except when a train is in the block protected, or an otherwise dangerous condition exists. This implies that the clearing or retaining devices are normally in circuit with the power battery, and that their control is the effect with front relay contacts.

Comparing the extent of mileage used by the two systems, the data published by the Interstate Commerce Commission, January 1, 1908, shows that there were 14,354 miles of track operated on the normal clear system, and 4,157 miles operated on the normal danger system, the total mileage of track operated by the automatic signals being 18,511.

False Signals. There are a number of conditions in either type of circuit which may set up false or dangerous conditions in a signal system. The failure at danger can only wrongly delay a train; but failures at clear, by giving the engineer a clear indication when such may not be safe, are the ones which are the most dangerous. Such failures, however, are very few in practice.

Among the causes of false clear conditions are, fusing of control contacts, improperly counterweighted tracks or semaphore, breaking of the color spectacles, rusting of the sliding parts, stray currents, residual magnetism in relays, imperfect contacts, foreign matter in relay boxes, crossing or grounding of wires, breaking of mechanical connections, poorly insulated circuit wires, etc.

Failures at danger may be caused by a broken rail, bond wires rusted off, or broken leakage of current between the tracks, broken wires in the relay, track battery or signal circuit, track or main battery being exhausted, poor connections, unsoldered joints and open circuit at motor commutator, etc.

Semaphore Signals. Of the many signals in use at the present time the semaphore type is the most popular, and the tendency is now to adopt this type as a standard. A semaphore has a long blade pivoted near one end to an upright post at a convenient height, so that it may be clearly seen at a distance. The short end of this blade is fitted with a light casing, with two or more holes for inserting colored bull's-eyes of sufficient size to permit of their being seen at a distance at night, when a light is placed behind them. This blade is suitably connected by means of a connecting rod to a mechanism usually at the base of the post, so that it can be turned around its pivot through an angle of about 60 degrees. In the horizontal position the semaphore indicates danger, and

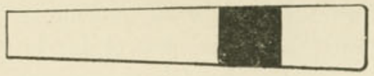


Fig. 1.

Square End Semaphore Blade, Used for Home Signals.

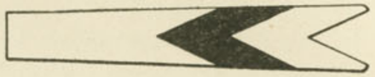


Fig. 2.

Notched or Fish Tail Semaphore Blade, Used for Distant Signals.

when pointing downwards indicates clear. In the daytime the engineer is governed by the position of the blade, whereas at night a light is made to shine through a red bull's-eye for danger, and through a green bull's-eye for clear. The adoption of a green light to indicate clear, instead of a white light, has been occasioned by the fact that white lights in the vicinity of the signal were often mistaken at a distance for the signal when the signal light was out, and in the case of a broken red glass a clear indication would be given instead of danger.

Fig. 3.

Pointed End Semaphore.

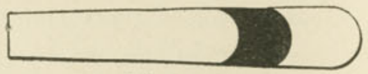


Fig. 4.

Rounded End Semaphore.

Figs. 1, 2, 3 and 4 represent the shape of semaphore blades in general use. Fig. 1 represents the square end semaphore blade used for block and interlocking home signals; Fig. 2 represents a notched or fish-tail semaphore blade used for block and interlocking distant signals; Fig. 3 represents a pointed-end semaphore blade usually used for automatic home block signals or for train

order signals; Fig. 4 represents a round end semaphore used for a train order signal, for a block signal or for an interlocking signal under special rules.

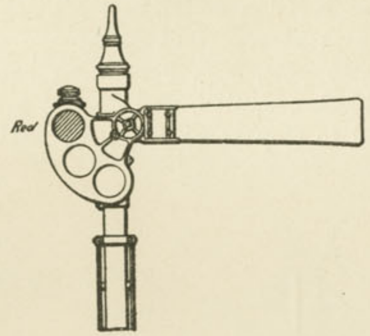


Fig. 5.

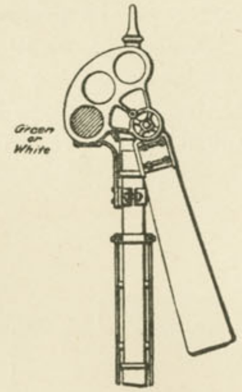


Fig. 6.

Two-Position Semaphore Home Block Signals.

The most general arrangements of home and distant semaphore signals are shown in Figs. 5, 6, 7, 8, 9, 10, 11, 12 and 13.

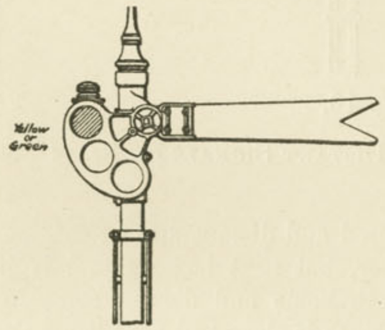


Fig. 7.

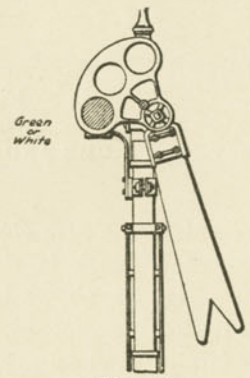


Fig. 8.

Two-Position Semaphore Distant Block Signals.

Figs. 5 and 6 represent semaphore home block signals in two positions, Fig. 5 representing the arm in stop position, and Fig. 6

when the block is clear. Figs. 7 and 8 represent two positions of a semaphore distant block signal, Fig. 7 showing the arm in caution, which indicates to the engineer that he must be prepared to stop at the next home signal, and Fig. 8 indicating that the next home signal is in the proceed position and that the block in advance is clear. Figs. 9, 10 and 11 represent semaphore and distant block signals on the same post, Fig. 9 showing home arm horizontal, indicating stop, block occupied, and distant arm horizontal indicating be prepared to stop at next home signal. Fig.

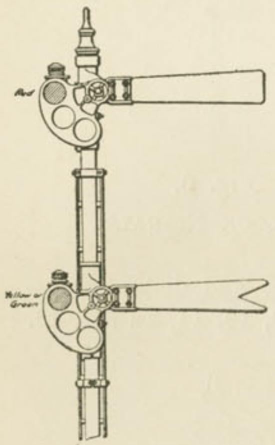


Fig. 9.

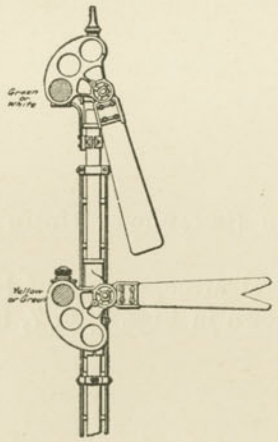


Fig. 10.

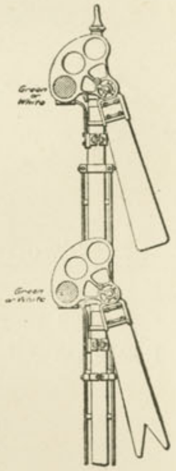


Fig. 11.

Semaphore Home and Distant Signals on Same Post.

10 represents home arm cleared and distant arm at caution, indicating proceed, block is clear, but next home signal is in stop position. Fig. 11 shows both home and distant arms in clear position indicating proceed, block is clear and next home signal in advance is also in clear position.

When the three-position semaphore block signal is used, the indications are shown in Fig. 12 or Fig. 13. The horizontal arm in each case represents stop; the arm in the inclined position shows caution position, indicating proceed, block is clear but next signal in advance is in stop position. The arm in the vertical position

shows clear position, indicating proceed, block is clear and next signal in advance is either clear or in caution position.

Enclosed Disc Signals. Besides the semaphore, or position and color system, there is a system of signals used on the Lehigh Valley, Philadelphia & Reading, and Chicago & Northwestern Railroads known as the Hall System. This system is purely a color system, the general arrangement of which is shown in Figs. 14, 15, 16 and 17. The home banner is shown in Fig. 14, which may be made of red silk, cotton or aluminum, and is about 18 inches in diameter. Below the home signal is a distant banner, which is of

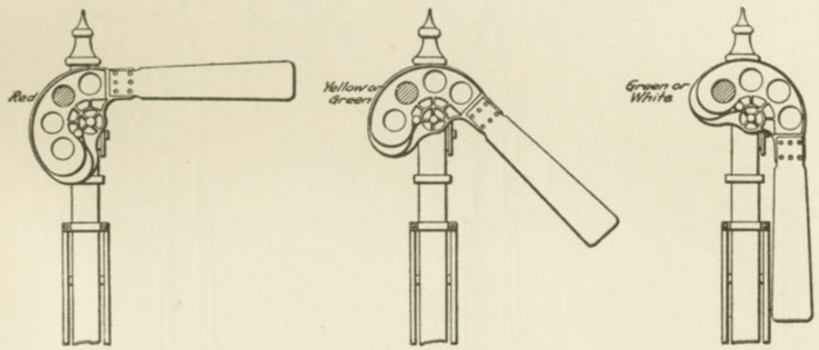


Fig. 12.

Three-Position Semaphore Block Signal, Downward Inclination.

green fabric, as shown in Fig. 16. The inside of the case is painted white, so that when the discs are drawn aside the inside of the case will show white in distinction to the surrounding case, which is painted black. Lamps are placed back of small openings at L, which openings contain red or green glass of the same colors as the disc. These, of course, are used for night signaling.

This system is a normal danger system, as the tendency of gravity is to hold the discs in a position so that they will always show danger unless the magnets are energized by an approaching train.

Advantages and Disadvantages of Disc Signals. The advantages of the enclosed disc signal are the protection of the moving parts against the weather, and the small power required to operate the moving parts, only about 2½ watts being necessary to energize the electro-magnet which operates the banner.

The disadvantages claimed against the enclosed system are the tendency of sleet and snow to obscure the disc by covering the glass, and thus giving a white effect; the reflection of the sun on

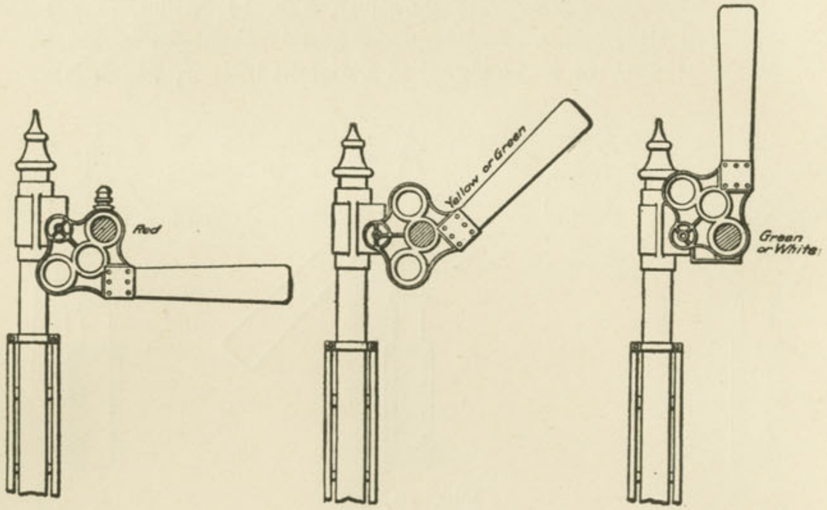


Fig. 13.

THREE-POSITION SEMAPHORE BLOCK SIGNAL, UPWARD INCLINATION.

the glass in front of the banner may prevent the engineer from seeing the banner, and the glass spectacles are likely to fall out.

The mechanism of the enclosed signal apparatus is very simple. It consists of an electro-magnet whose armature moves a member to which the banner and disc and colored glass are attached. The indications are always danger except when the circuit is closed, in which case the magnet is energized if the tracks ahead are clear, which turns the banner and spectacle around, causing the indication to show white. When the train passes out of the block, the circuit is again open and the signal is again automatically returned to danger.

Hall Revolving Signal. In order to give more positive indication of the position or indication of a given signal, the Hall revolving signal has been devised. It consists of a semaphore arm pivoted at the center, as shown in Figs. 18 and 19.

The principle of the signal is motion, not position. Its language to the engineer is: If I am in motion, you can be; if I have stopped, you must stop.

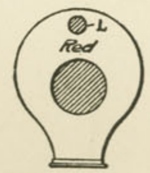


Fig. 14.

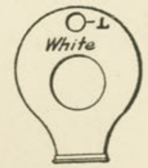


Fig. 15.

DISK HOME BLOCK SIGNAL.

As a day signal, its revolution makes it far more distinct with a bad landscape background than a signal at rest in a defined position for safety. For night signaling, the lantern, shown in Fig. 19, gives the usual steady red light for danger, but there is no spectacle in the semaphore to get broken, and thereby show safety when it should be danger, as in the case with the ordinary position.

Fig. 16.

Fig. 17.

DISK DISTANT BLOCK SIGNAL.

The semaphore revolving in front of the bull's-eye flashes the light, thus making a safety signal absolutely distinct from all surrounding city lights, and preventing trouble from color blindness.

The engineman knows that the semaphone is revolving because by that means the light is flashed. The semaphore blades make ten revolutions per minute, therefore there are twenty obscurations and flashes per minute. When the light is not being flashed, the engineer knows the semaphore is at rest, indicating danger, and gives at night substantially what is given in the daytime.

The signal can either be applied as an "automatic" signal or

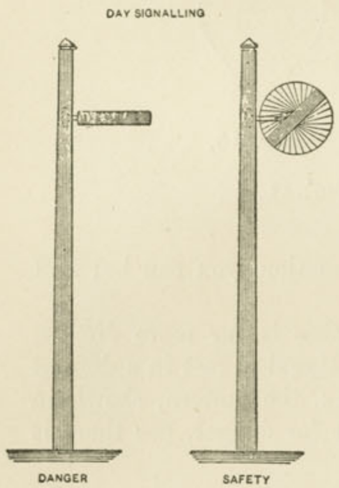


Fig. 18.

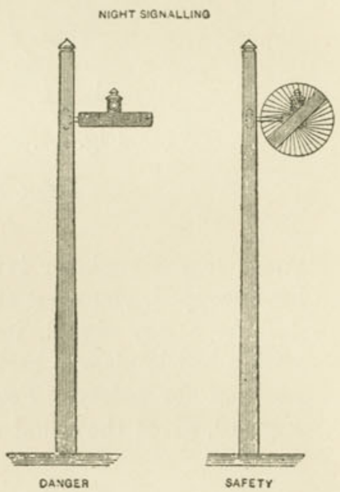


Fig. 19.

HALL REVOLVING SIGNAL.

be operated from a signal tower. The usual overlap, or a home and distant signal on the same post, may be used.

Normally, the signal is in the horizontal position, signifying danger, in the same manner as the ordinary position semaphore. Should it from any cause fail to assume the horizontal position, it is nevertheless a danger signal, because it is not in motion and its mechanism stops it in the horizontal position.

The principle of revolving the signal to indicate safety is so utilized in the above signal that the following claims are made for it:

1. No dependence upon automatic mechanism in any part of

the system to change the signal from the indication of safety to that of danger. The presence of a train in the block beyond the signal cuts out the track battery. This is electrical law, and can therefore be depended upon. This source of power being removed, the signal can only complete its last revolution. In doing so, it mechanically forces all mechanism in the system to the required condition of the danger indication. As the movement of the signal indicates safety, should there be a movement to the mechanism as above described the signal is a danger signal because it cannot revolve. Therefore, failure from any cause can only indicate danger, and it is, therefore, impossible for this signal to remain at safety behind a train.

2. Foreign currents (say trolley currents) cannot cause a signal to indicate safety behind a train. This is accomplished without extra contact points, relays, or insulated rail joints.

3. Permissive block is safe as regards the signaling system, because it is impossible for a signal to continue at safety behind a train.

4. Sparking by the opening of the motor circuit is not a source of trouble, and should lightning weld any contact points the signal can only indicate danger.

Manual Block System. Any semaphore system of blocking trains may be operated by means of levers located in the switchman's tower, and suitably connected with the signal through bell cranks and connecting rods or steel wires, or even by compressed air controlled by electrically operated valves, but such a system requires the constant attendance of an operator to properly set the signals. The physical effort required to operate mechanically controlled signals limits the distance at which they may be placed from the tower, and in case of compressed air it is necessary to supply a suitable air compressor equipment for each tower. Signals when thus operated will necessarily be placed further apart, and distant signals must be dropped from the same pole as the home signals and placed near the tower from which they are controlled. In this instance the signals are so placed that the sections they control overlap, that is, a certain short section will be controlled by two signals, one at the beginning of the block, and the other at the beginning of the next block, so that if a train should break down immediately after passing a signal the preceding signal could not clear; thus an approaching train would be sufficiently warned to prevent its colliding with the disabled train.

Interlocking Signals. The function of all fixed signals, no matter by what name they are called, is to inform the engineer whether or not he may run past the signal, and if he is allowed to pass, on what conditions may he proceed. The engineer depends entirely upon the signal, and is guided in handling his train by the position of the signal before him. In order to prevent the signalman from giving a clear signal simultaneously to two trains moving in opposite directions the interlocking system was devised.

Interlocked signals are operated from an elevated signal tower by means of rods or wires supported near the ground at regular intervals by ground rollers. Two wires are as a rule used, the first wire being the signal at clear, and the second, or return wire, is used in order to make sure the proper return of the signal to the normal or stop position, although the counterweight alone should perform this function.

Requirements of Interlocking. In order to secure a reasonable degree of safety, it is essential that the following requirements be met:

All derails, movable frogs, locks, switches and home signals should be worked by pipe; signals worked by wire should have two wires, front and back; all pipe and wire lines should be automatically compensated for changes in temperature; all derails, movable frogs and facing point switches should be provided with duplex facing point locks, so arranged that the normal plunger cannot lock the switch reversed, and *vice versa;* all cranks and pipe compensators should be fixed on rigid foundations set in best quality concrete; no facing point switch more than 600 feet from the cabin should be taken into the system; no lever should be overloaded by putting on it such a number of switches or bars as to prevent a man of average strength from throwing it with one hand.

The general arrangement of interlocked switches and signals is the same no matter how complicated the system may be, the main function of the interlocking feature being, as mentioned above, to prevent the display of conflicting signals.

Interlocking Machines. The interlocking machine, as shown in Fig. 20, consists principally of as many levers placed side by side on a common shaft as are necessary to move the switches and signals. Two switches may be moved by a single lever, and two or more signal arms on the same position as near it may be operated by the same lever, the position of the switch connections being made to govern the switch of the arm to be moved. The operator grasps a lever primarily to pulling and lifts the latch rod, and in so doing turns the locking shaft on its axis, the latch acting

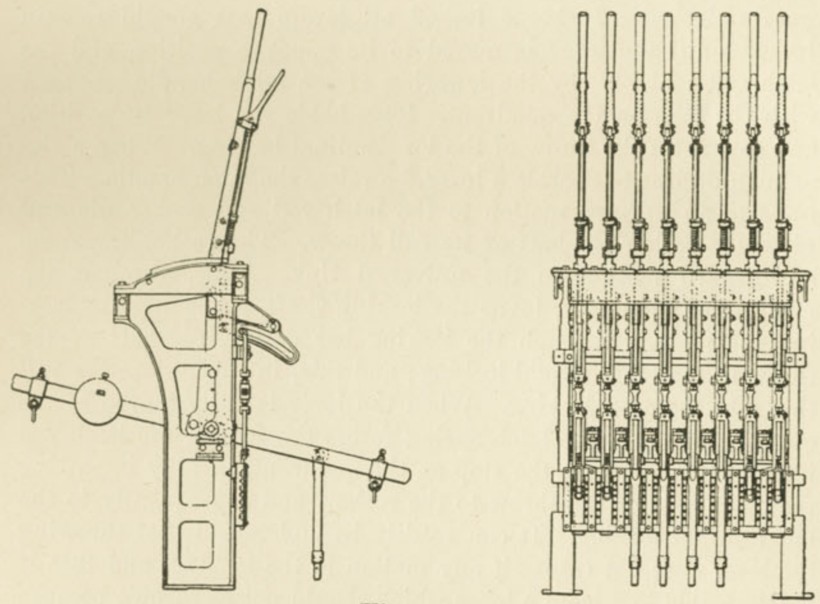


Fig. 20.

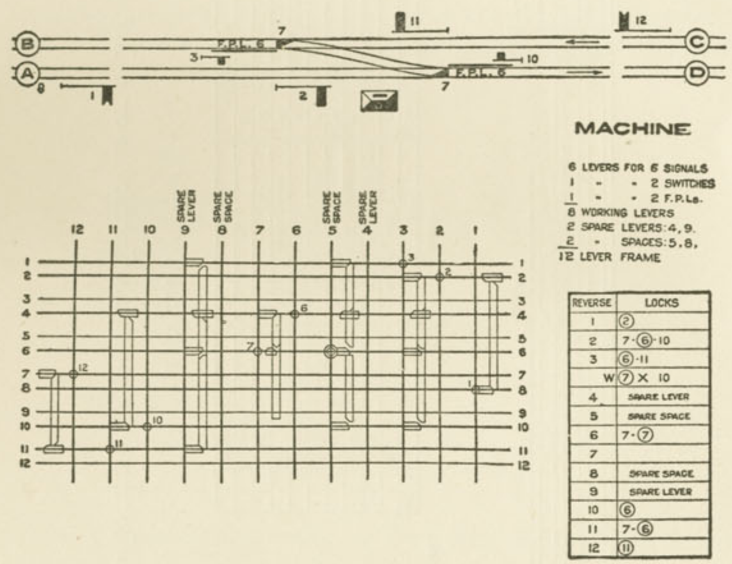
JOHNSON INTERLOCKING MACHINE.

through the link. This moves one of the interlocking bars lengthways, and by means of cross locks obstructs the movement of some other bar. This operation, called preliminary locking, insures that no lever shall be pulling until all conflicting levers are fastened in a safe position. The latch, having performed its locking function, and having interlocked the lever, is pulled over and the latch is allowed to drop, after which it may be moved to the position desired.

To convey a clear idea of the operation of the locking, in an interlocking machine, it will be necessary to give an explanation of preliminary latch locking. A lever in a machine is held in position until the latch rod foot has been raised above the quadrant by the raising of the latch handle. Through the rocker and locking shaft this movement of the latch handle imparts one-half of the full throw to the longitudinal locking. This, in turn, actuates the cross locking and locks all conflicting levers that before this action were unlocked. It keeps locked all levers that should remain locked until the lever is moved to its opposite position and the latch rod foot has, by the lowering of the latch handle, engaged with the stop on the quadrant. This holds the lever in position and completes the throw of the longitudinal locking. When a signalman desires to operate a lever, he raises the latch handle. This imparts an upward motion to the latch rod and rocker die and gives the rocker one-half of its full throw. The rocker transmits an upward motion to the universal link. This, through the medium of the crank, turns the locking shaft. Turning the locking shaft gives, through the locking bar driver, one-half of the throw to the longitudinal locking; and this, in turn, gives the full throw to the cross-locking. When the lever is fully moved to the opposite position, the latch spring forces the foot of the latch rod into engagement with the stop on the quadrant, thereby imparting the other half of the throw to the rocker, and consequently to the longitudinal locking. It can readily be understood that throwing the lever does not transmit any motion to the locking, and that it is impossible to release a lever which should not be thrown because the latch cannot be raised. As very little power can be applied to the latch handle, the strain on the locking is small compared with that in machines where the locking is actuated by the movement of the lever.

Dog Charts. A dog chart is a diagrammatic representation of the mechanical locking for an interlocking machine, and is used as a working plan in making up and fitting the locking. Before proceeding to make a dog chart, it is necessary to ascertain from the locking sheet whether or not any two or more levers lock any other lever or levers in certain positions. Dog charts for interlocking machines are made to suit the conditions. Fig. 21 represents a dog chart for a cross-over on double track.

The long horizontal lines represent the locking bars, and are numbered in the order in which they are placed in the machine, commencing with the one next to the levers. A small circle drawn on this line shows by which lever the bar is worked and where the connection is made. Locking brackets are numbered to correspond with the levers. Cross locking is stamped with the number of the bracket in which it is to be placed. It is also stamped at each end



REVERSE	LOCKS
1	2
2	7-6-10
3	6-11
W	7 X 10
4	SPARE LEVER
5	SPARE SPACE
6	7-7
7	
8	SPARE SPACE
9	SPARE LEVER
10	6
11	7-6
12	11

Fig. 21.

SAXBY AND FARMER'S DOGCHART AND LOCKING SHEET.

with the number of the locking bar under that end. This is done in order that the bars and cross-locking may be easily replaced in the machine if they have been removed for any reason. The cross-locking is represented as being placed close to the dog by which the locking is performed; the clearance necessary to allow it to be moved is left next to the other dog. This is done in order to facilitate reading of the dog chart by showing which lever does the locking. When one lever locks two or more levers the cross-locking is notched for as many dogs as there are levers to be locked.

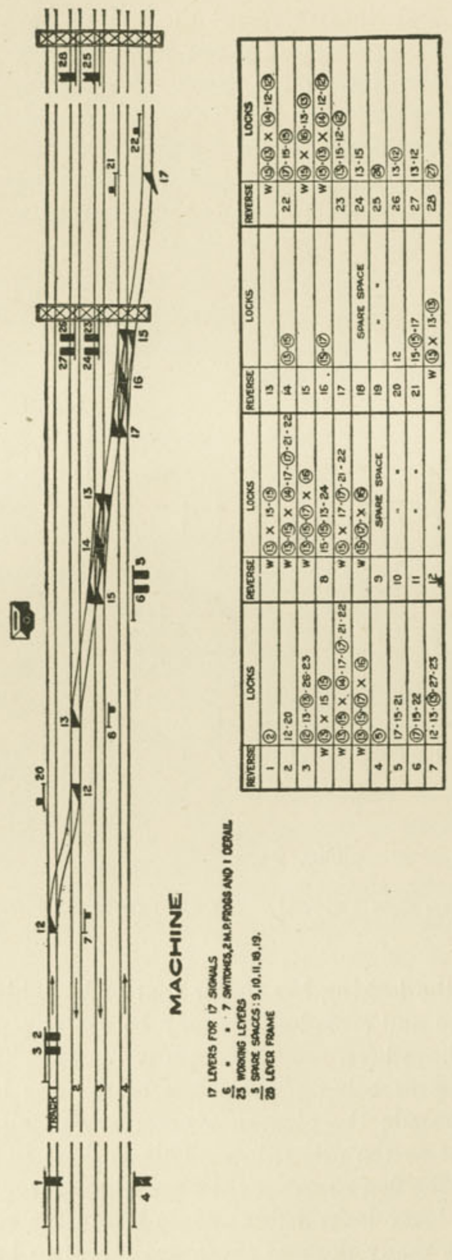


Fig. 22.

Interlocking Plan and Locking Sheet for a Crossover on a Four-Track Road.

Reversal of the locking lever forces the cross-locking over against the dogs of the other levers and locks them. If one of the other levers has been reversed, the cross-locking will strike against the dog of that lever and prevent the lever from being reversed.

Locking Sheets. A locking sheet is an arrangement used by the signalman which gives in tabular form a statement of the locking operations which are provided for in a given interlocking machine. It shows the sequence in which levers must be locked and unlocked preparatory to giving clear signals for each route in the plant. An interlocking plan and locking sheet for cross-overs

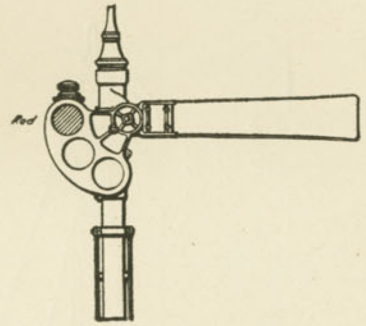


Fig. 23.

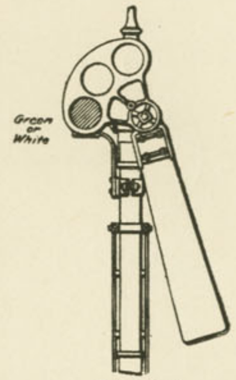


Fig. 24.

Stop and Proceed Positions of One-Arm Semaphore Interlocking Home Signals.

on a four-track road, using double-slip switches with movable joint frogs, is shown in Fig. 22.

Semaphore Interlocking Signals. The various signal indications are arranged so that they all show the same consistent meaning, whereby only one train can occupy the same place at the same time. Figs. 23 and 24 represent a one-arm semaphore interlocking home signal, Fig. 23 representing stop, and Fig. 24 proceed. Figs. 24 and 25 represent a one-arm semaphore interlocking distant signal, in which Fig. 25 represents caution, and Fig. 26 represents proceed. Figs. 27, 28 and 29 represent a two-arm semaphore interlocking home signal, and Figs. 30, 31 and 32 represent a two-arm interlocking distant signal. Fig. 27 represents stop, no route is clear; Fig. 28 represents proceed over high-speed route; Fig. 29 represents proceed over inferior or low-speed route; Fig. 30 represents caution, indicating that both corresponding home signals are stop; Fig. 31 represents the top arm clear, indicating that home signal for main route is at proceed; and Fig. 32 shows the lower arm clear, indicating that home signal for inferior route is at proceed.

There are a large number of other arrangements which may be used, such as three-arm and five-arm arrangements, etc.

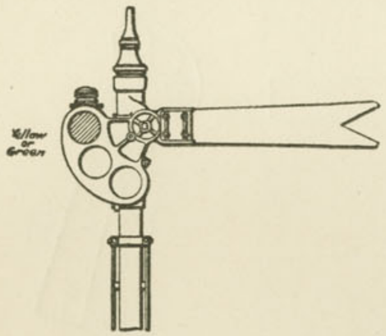


Fig. 25.

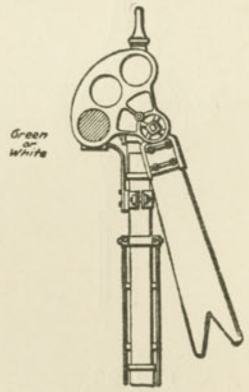


Fig. 26.

ONE-ARM SEMAPHORE INTERLOCKING DISTANT SIGNAL.

Power Interlocking. The fatigue incident to working mechanical levers at a busy plant is often severe, so that if the plant is large it is sometimes necessary to employ as many as eight men for each of three shifts of eight hours each. Moreover, under certain conditions it is costly to operate such a plant. Where the distance between the extreme switches to be operated is over 1,600 feet it is generally necessary to provide two mechanical interlocking cabins.

To overcome these and other disadvantages, power interlocking has been devised in which the various functions are worked by air under pressure, by electricity or by a combination of the two. With power, switches and signals can be worked at any desired distance from the cabin; the apparatus being so safeguarded that switches must actually be moved and securely locked in the proper position before a signal governing movements over them can be cleared. Each signal, when cleared, automatically locks the lever operating it in such a manner as to prevent the release of levers controlling conflicting signals and switches until such signal has been again completely moved to the stop position,

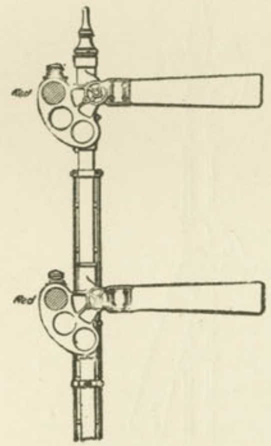


Fig. 27.

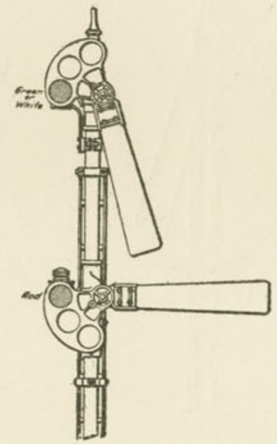


Fig. 28.

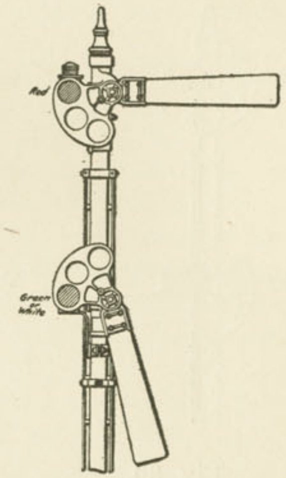


Fig. 29.

TWO-ARM SEMAPHORE INTERLOCKING HOME SIGNALS.

thus effectually providing against the simultaneous display of two conflicting clear signals. There being no moving parts between cabin and switches and signals, wear of mechanism, lost motion and the troublesome effects of expansion and contraction of metal connections are eliminated. Much less room is required for lead-out connections than in a mechanical plant, valuable space thus being saved. Cabins may be much smaller and of lighter design. The operation at the machine requires so little physical exertion that one man can do an amount of work that in a mechanical plant would require three or four.

Systems of Power Interlocking. There are three systems of power interlocking in general use, electric interlocking, electro-pneumatic interlocking, and low-pressure pneumatic interlocking.

In the electric interlocking system the switches and signals are operated by electric motors, the current to actuate them being furnished by a storage battery charged from a dynamo driven by an electric motor or gas engine. Control of the valve functions is effected through an interlocking machine.

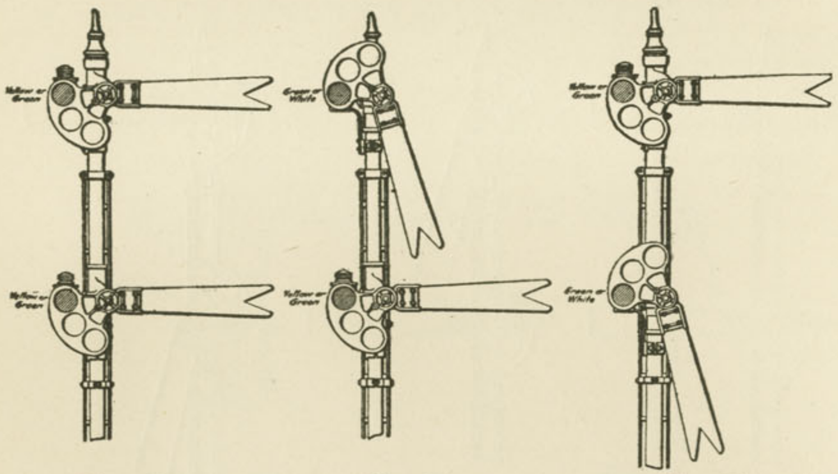


Fig. 30. Fig. 31. Fig. 32.

Two-Arm Semaphore Interlocking Distant Signals.

In the electro-pneumatic interlocking system the operating power is usually supplied by means of air compressed at some convenient point, stored in one or more reservoirs and conveyed to each function by suitable connections. The control of this power is effected by means of electro-magnets, the necessary current being obtained from any source, such as primary or storage batteries or from a generator. The ordinary air pressure used is about 70 pounds per square inch, although most apparatus will work satisfactorily with any pressure between 50 and 100 pounds. The air pressure acts on the piston of the cylinders, fixed to the signal piston or to the ties near the switch, as the case may be.

Near each cylinder is a small reservoir to provide a sufficient supply of air to insure quick action of the piston at every operation. The admission and exhaust of air in the cylinder are governed by electro-magnetic valves controlled by the wires from the interlocking machine.

In order to avoid trouble from moisture condensing and freezing in the small air passages, the air on leaving the compressor is passed through a condenser consisting of a number of cooling pipes, and a large percentage of the moisture is removed. Any remaining moisture is neutralized by alcohol, which is placed in the pipes and reservoir in freezing weather.

In the low-pressure pneumatic interlocking system, the interlocking apparatus is worked by compressed air at a low pressure of about 15 pounds per square inch. This system has no electric features, the compressed air in separate pipes being employed to control the admission of pressure to the switch and signal cylinders. Pressure is admitted to working cylinders by valves actuated by large rubber diaphragms which are worked by air at seven pounds pressure. The lever of a switch cannot complete its stroke until the switch has actually moved to its proper position and conveyed an indication of the fact to the cabin.

Electric Interlocking System. There are a number of different electric interlocking systems in general use, the best known being built by the General Railway Signal Co., the Union Switch and Signal Co., the Federal Signal Co., and the American Railway Signal Co.

General Railway Signal Co.'s Electric Interlocking System. In this system switches and signals are operated by electric motors, the current to actuate them being usually furnished by a storage battery charged from a dynamo driven by an electric motor or a gas engine. Control of the various functions is effected through an interlocking machine. The release locking, or indication, is effected by an electro-magnetic device located immediately below each interlocking lever, these magnets being energized by a dynamic current furnished by the switch or signal motor controlled by that lever; the arrangement is such, however, that this cannot occur until a switch has moved to a position corresponding with that of the lever and is properly locked in that position, or when a signal arm has assumed the full horizontal position. Precautions are taken in both circuits and mechanical arrangement to prevent crosses in circuits from resulting in the improper movement of a switch or in a signal giving a false "proceed" indication.

A switch failing to complete its movement owing to some obstruction in the switch point, or for any other cause, may be restored to its original position, and the lever operated back and forth, thus frequently dislodging the obstruction, and preventing failure and incidental detentions.

Federal Signal Co.'s Electric Interlocking System. This electric interlocking machine is similar to the Saxby and Farmer mechanical interlocking machine, except that it is equipped with circuit controlling and indicating devices which adapt it to use in electric interlocking.

Union Switch & Signal Co.'s Electric Interlocking System. The electric interlocking system of the Union Switch & Signal Company has been under development some three years, and since 1904 has been in railroad service.

This interlocking machine, an end and front elevation of which is shown in Fig. 33, and a rear view in Fig. 34, resembles very much in general appearance the well-known electro-pneumatic machine, and the levers have the same movements. The preliminary movement, limited by the indication latch, effects the locking of all levers whose movements would conflict with the new position of the lever. The final movement, which can take place only after the indication is received, unlocks all levers whose movements would not conflict with that position of the lever. The preliminary movements in reverse directions overlap to such an extent as to permit a range of movement sufficient to throw the electric controlling switch from one controlling position to the other at the will of the operator.

The switch points are made to follow the movements of the lever by sending a current through one or the other of two independent series of field windings on the switch-operating motor, which causes rotations in opposite directions. Each independent switch requires one lever, but any two switches which must be operated simultaneously, as two switches of a cross-over, have but one lever.

The signal levers stand normally in the middle position, and are moved to the right or left for the purpose of operating oppos-

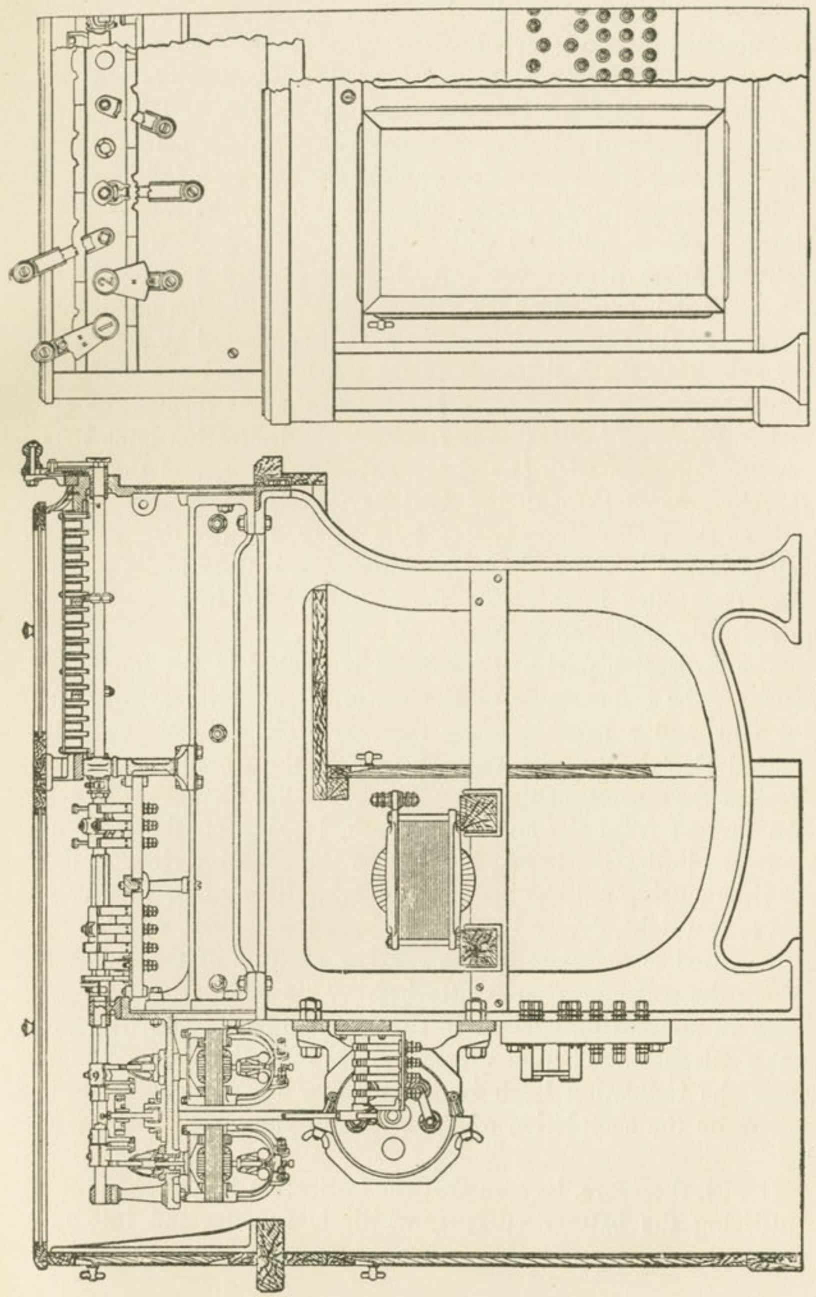


Fig. 33. ELECTRIC INTERLOCKING MACHINE. (Union Switch and Signal Co.)

ing signals. Two or more signals, governing diverging routes, are also controlled by one lever when the signals are those operated by one motor, as, for instance, when two or three arms are carried by one post. The selection between the arms in this latter case is effected by means of selectors operated by the switch points themselves, or by the levers which control the movements of the points.

In the accompanying cuts, Figs. 33 and 34, the interlocking machine is shown equipped with a stroke completing attachment, which comprises a swinging arm, loosely pivoted to each lever shaft, and pawls carried by the frames of the indication quadrants for engaging these arms. The arms are all connected by means of a bar extending the full length of the machine, and are made to oscillate by means of a motor connected to the bar through an eccentric. When an indication is received, the indication latch lifts a pawl engagement with one of the swinging arms, and the lever is thereby rotated through the final part of its movement. The circuit to the motor is controlled by a relay, the exciting coil of which is placed in the main lead between the battery and the machine. Controlled in this way, the motor is only in action when required for completing the stroke of a lever.

The indication part of the system is worked in the following manner: The commutator of the motor is provided with a collector ring and a brush bearing thereon. The collector ring is connected electrically with one segment of the commutator. At the end of the movement the automatic controller changes the path of the current from the operating brush, bearing on the commutator to the indication brush, bearing on the collector ring, at the same time cutting out the magnetic clutch. The motor then continues to run light, driven by current from the battery, which current is caused to undulate by the varying position of the segment to which the collector ring is attached. This undulating current induces an alternating current in the secondary of a transformer, and this alternating current drives a small induction motor which releases the indication latch in the manner hereafter described, and permits the completion of the stroke of the lever on the machine.

It will, therefore, be seen that the indication is brought about by utilizing the battery current, which is transformed into an

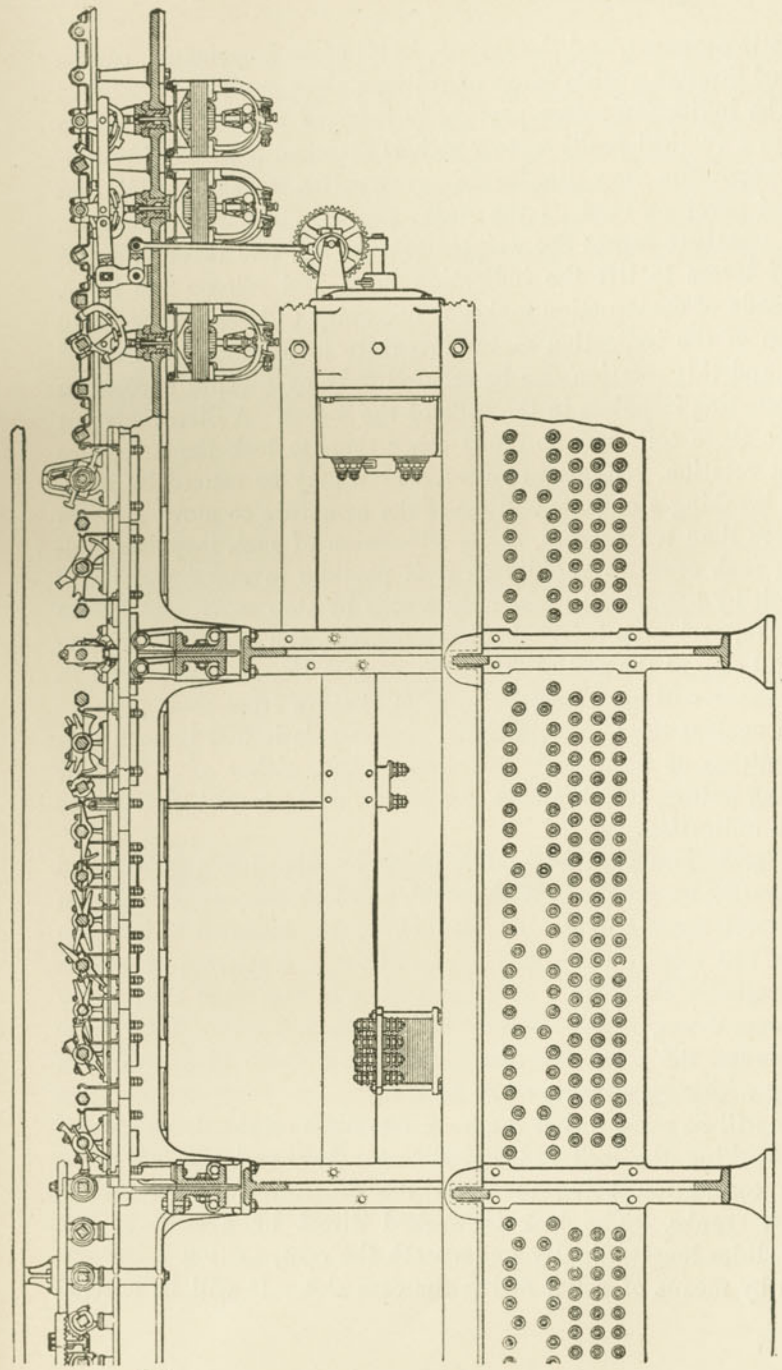


Fig. 34.

Back Elevation of Electric Interlocking Machine.
(Union Switch and Signal Co.)

alternating current, and the system, in all of its movements, can be operated through a wide range of voltages.

The indication motor previously referred to has its armature shaft in a vertical position, to which is attached a piece of centrifugal apparatus very similar in construction to the well-known form of governor used on the steam engine. The rapid rotation of the armature causes the weights to separate, and through a system of levers to lift the indication latch and release the lever. This mode of construction makes it necessary to have a very rapid rotation of the indication motor armature to produce the desired effect, and this rotation can be secured only by a rapid succession of alternating impulses in the coils of the motor. A direct current through these coils has no effect other than to lock the armature against rotation. Single impulses, which may be caused by making or breaking a circuit, will cause the armature to move through not more than ten degrees, and a succession of such impulses, following each other as rapidly as it is possible to make and break a circuit by hand, will cause only a step by step movement of the armature, each step being about ten degrees, the armature coming to a full stop at the end of each step, so that impulses produced in this manner will not cause the weights to move from their position of rest against the armature shaft. From this it will be seen that no condition of improperly connected wires, either of a fixed or swinging nature, which makes and breaks contact, will give rise to a false indication.

Fig. 35 is a plan and a side elevation, showing a switch and its operating mechanism. The switch and lock movement is driven by a direct current motor of about $1\frac{1}{2}$ H. P., designed to be operated at 110 volts. The shaft of this motor is connected by means of a magnetic clutch to a shaft extension in the same line, working a cam drum, which operates the switch and lock. Intermediate between the magnetic clutch and drum there is a reduction gearing with a speed ratio of 25 to 1.

It will be noticed that there are two cams on the drum, one of these working the lock rod and detector bar, and the other the switch connection being made to the detector bar and switch through cranks. The lock is worked direct by a straight bar which slides longitudinally underneath the cam, motion being imparted by means of a lug fitting the cam slot. It will be noticed

that in each case the cam slot, for a portion of its travel, moves in a plane at right angles to the shaft, so that while that portion is passing the hub on the driving bar or crank no movement of the latter takes place; it is only while the hub is engaged by the diagonal portion of this slot that movement is imparted to the switch or lock mechanism. The operation is, therefore, on the principle of the switch and lock movement, and briefly is as fol-

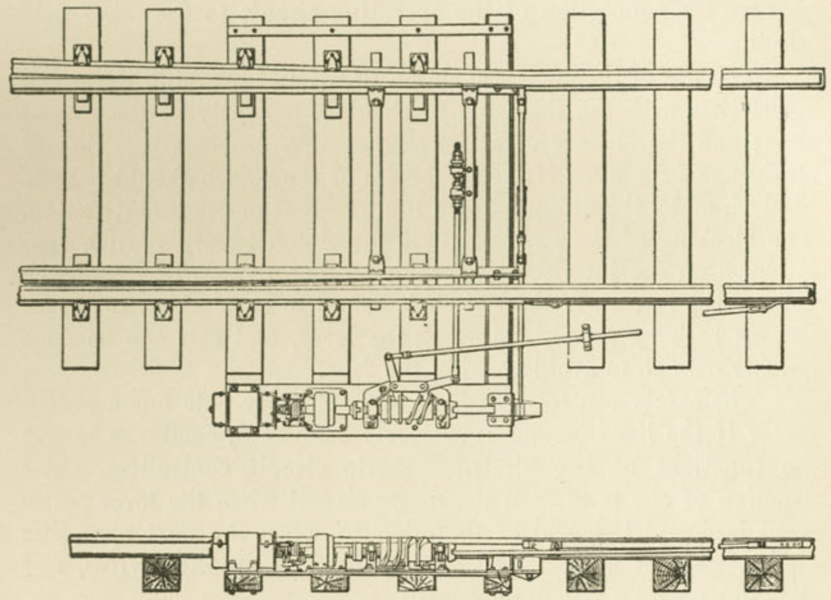


Fig. 35.

Plan and Side Elevation of an Electric Switch and Lock Movement.

lows: When the drum is revolved by the motor, the lock rod and detector bar immediately begin to move, and as soon as these have completed their stroke the motions of these mechanisms cease and the movement of the switch begins. After the switch has been moved over against the stock rail, further motion of the lock bar locks the switch, and at the same time operates a knife switch which opens the control circuits and closes the indication circuit.

The cam drum is reversible, so that the movement can be operated either right or left, the position of the motor and clutch remaining the same, merely by changing the drum end for end. The motor, clutch and drum are all attached to a steel base plate.

The direction of rotation for reversing the switch is controlled by means of a double field winding, one of which is cut out while the other is in circuit. When the switch is to be thrown in the reverse direction, the lever on the interlocking machine merely changes the connection of the operating circuit to the other field winding.

The use of the magnetic clutch permits of breaking the motor connection with the throwing mechanism instantly at the proper time; and the absence of a rigid connection prevents breaking or straining of the parts if the movement of the switch should become blocked, as by the dropping of a lump of coal or other obstruction. The blocking of the switch causes the clutch to slip until a fuse is blown on the interlocking machine. The motion of the switch follows the lever. If the switch is found to be blocked, it can be thrown back by simply reversing the lever, and this can be done quickly enough to avoid blowing the fuse.

The safety controller, which automatically cuts out a switch motor if the lines become improperly connected, combines in one the functions of two electro-magnetic circuit controllers. The function of one is to open the motor circuit when the lever movement is completed, and of the other to open the next operating circuit when it is energized improperly by connected wires, and thus to prevent a wrong movement.

The solenoid safety circuit controller is illustrated in Fig. 36, and comprises two solenoids A and A′, fixed to a cast iron base V. Each solenoid has a movable core D, connected by means of a jaw E to a lever F. The lever F is pivoted at its middle to a fixed support G and is connected at its upper end to a rod H, free to move longitudinally. The rod H carries a contact bridge I, which will connect the contacts J and K when the core D is drawn into the solenoid, and will connect the contacts L and M when the core D is drawn outward. The levers F and F′ are connected near the lower ends of a spring Z, which causes the bridge I′ to connect L′ and M′, when the core D is drawn into its solenoid A to nearly the full extent. Similarly the contact bridge I is made to connect

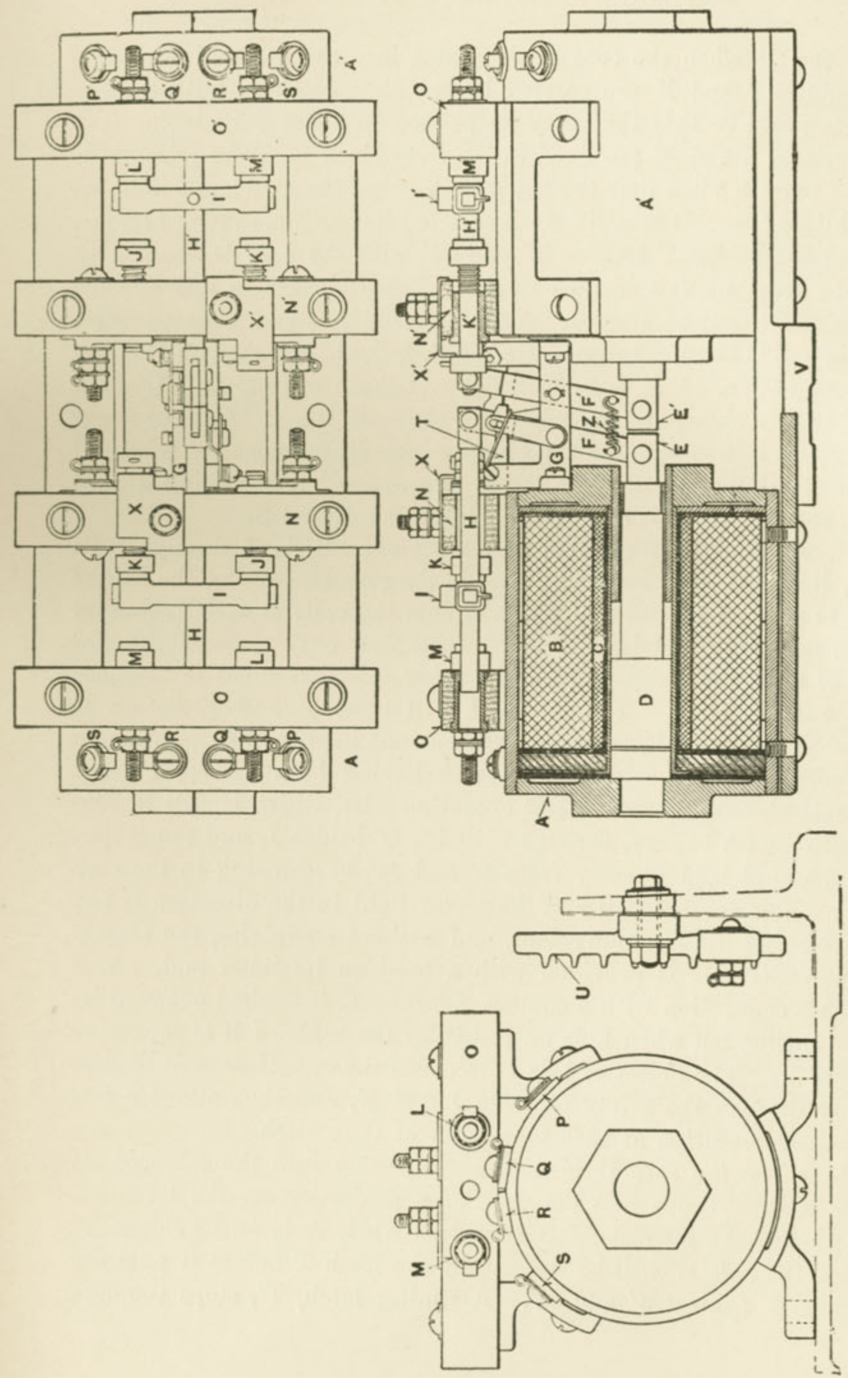


Fig. 36. Solenoid Safety Circuit Controller.

L and M when the core D′ is drawn into the solenoid A′. The contacts J and K are carried by the slate block N with springs interposed so that they may be pushed in about 3-16 inch. The contacts L and M are fixed to the slate block O. The relation of the parts is such that the bridge I touches the contacts J and K, while the core D is still 3-16 inch from its complete inward stroke, and the bridge I′ touches L′ and M′ with the core D about 1-16 inch from its full inward stroke. These clearances are allowed for making good contact. Each solenoid has two coils of wire. The coil C has 100 turns of No. 13 B. & S. G., and the coil B 1,100 turns of No. 15 B. & S. G. The resistance coils U and U′ each of twenty ohms, are in series with the coils B and B′ at the starting of a movement, and the circuits including them may be called the starting circuits. The coil B is connected to terminals P and Q, and the coil C is connected to terminals R and S.

At the beginning of a movement current flows through coils C, B and U in series, and draws in the core D, causing the bridge I′ to connect L′ and M′, which shunts the coils B and U, so that the operating and indicating currents flow only through the coil C of a very low resistance, but having sufficient turns to hold the core D in place. The bridge I will touch J and K before I′ touches L′ and M′, so that if the current happened to come from a foreign source without the lever having been moved, current would also flow from the last operating wire, which is still in connection with battery, through coils C′, B′ bridge I, and the motor, and would hold I′ away from L′ and M′ by drawing in the core D′. This current will run the motor light in the direction it ran in making the last movement, and without energizing the clutch. The contact K is provided with a head on its inner end, which makes connection with a contact X, when K is pushed outward by the spring, but when K is pushed in by the bridge I it is separated from X. The object of this is to cause the cut-off current to flow only through the safety contacts J and K, and thus afford a test of their condition at each movement of the switch.

When the core D is drawn completely into the solenoid A, the latch T drops into the path of a projection on the lever F′, so that if the magnet A′ is energized while A is still holding its core, the core D′ will be stopped by the latch T before it puts the bridge I′ against J′ and K′. A similar latch, T′, stops the core

D under similar conditions. These latches come into play in the action of the cut-off current last above-mentioned. If in that case the bridge I′ were allowed to move far enough to touch J′ and K′, the safety circuit to be mentioned later would be temporarily closed, and cause sparking at the contacts.

The circuits of a single switch can be understood from an inspection of Fig. 37. In the position of the parts as shown, which is the beginning of the reverse movement, current will flow from battery 1 through primary 2, fuse 3, wire 4, spring 5, bridge 11 (11, 11a and 11 are one piece on machine), spring 9, wire 14, field 16, wire 18, coil V of A, connector 26, coil B of A, wire 20, contacts K′ and X′, resistance U, wire 22, contacts 37 and 38 of knife switch 33, wires 23 and 45, clutch 52 by brushes 50 and 51, armature 53 by brushes 49 and 47, thence by common wire to battery. This current will energize the magnet A, the bridge I will connect J and K, and the bridge I′ will connect L′ and M′. The above circuit remains the same up to wire 18, thence through coil C of A, wire 28, contact M′ bridge I′, contact L′, wire 30, contact 35, knife 33, contact 38, to wire 23, whence it is the same as above. The current in the coil C holds the core D and the bridges I and I′ in position last noted.

When the switch movement is completed, the knife 33 is moved from contact 38 to contact 36, still remaining in contact with 35. This cuts off the current from the clutch 52, and causes it to flow through wires 43 and 46, indication brush 48, armature 53, brush 47, and common to battery. The current still flows through the coil C, thus holding I and I′ in positions noted. The current entering the armature 53, by the way of the brush 48, which bears on a ring connected to a segment of the commutator, is thereby rendered pulsating in character. In flowing through the primary 2 of the transformer, it develops magnetism of a like character in the iron core. This in turn induces alternating current in the secondary coil 55, which flows through the induction motor 56, by means of which the latch is lifted, thus releasing the lever to make its final movement.

The final movement of the lever puts the bridge 12 in contact with spring contacts 8 and 10, which closes a branch circuit, and current flows from armature 53 by way of brush 49, wires 32 and 31, contact J, bridge I, contact K, wire 19, coil B′ of A′,

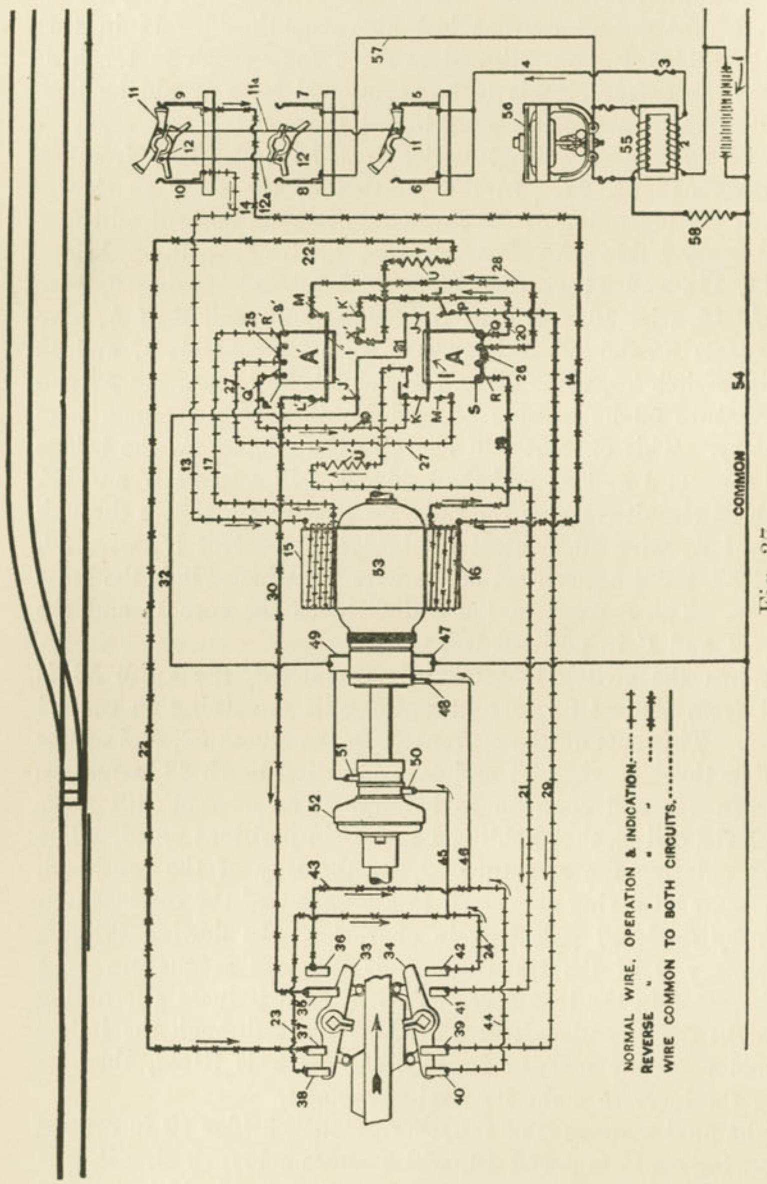


Fig. 37.

Electrical Circuits for a Single Electric Interlocking Switch.
(Union Switch and Signal Co.)

connector 25, coil C′ of A′, wire 17, field 15, wire 13, spring 10, bridge 12, spring 8, wire 57, motor 56, and secondary 55 in parallel, and resistance 58 to battery. This current energizes magnet A′, draws in its core D′, and pulls the bridge I′ away from contacts L′ and M′, thus cutting off all current.

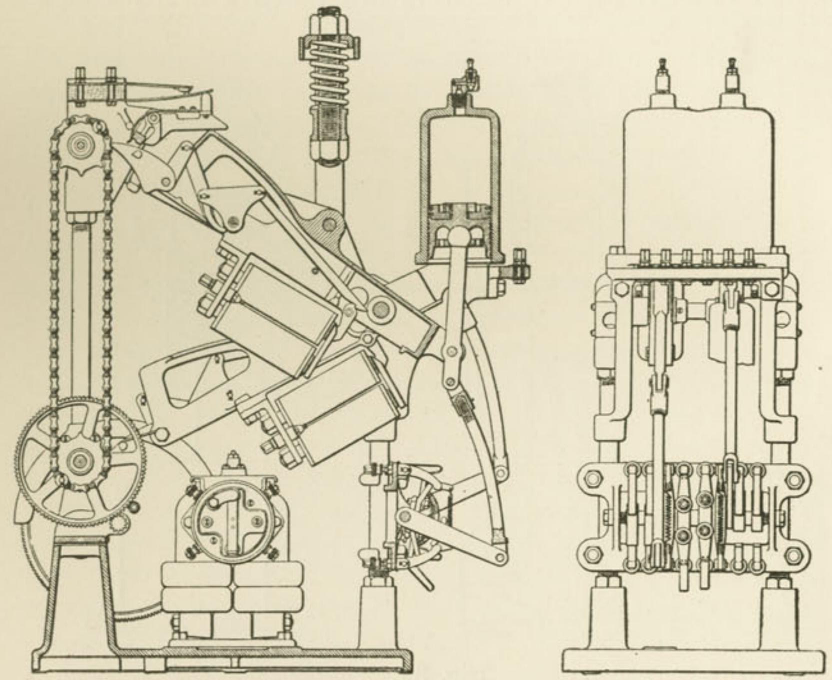


Fig. 38.

Signal Mechanism Used for High Signals.

There are a large number of other wiring conditions which are met with in this apparatus, but their complete explanation is too lengthy for a book of this kind. Complete explanations may be had of all the wiring circuit of this, as well as other signal apparatus, by writing to the various manufacturers of signal instruments.

For high signals, use is made of the ordinary electric semaphore, with the addition of a third brush to the motor, to give the indication in a manner similar to that described for the switch machine, with other slight changes made necessary by the use of a higher voltage. The high signal mechanism is illustrated in Figs. 38.

The dwarf signal, Fig. 39, is actuated by an electric motor, similar in all respects to that used in connection with the high

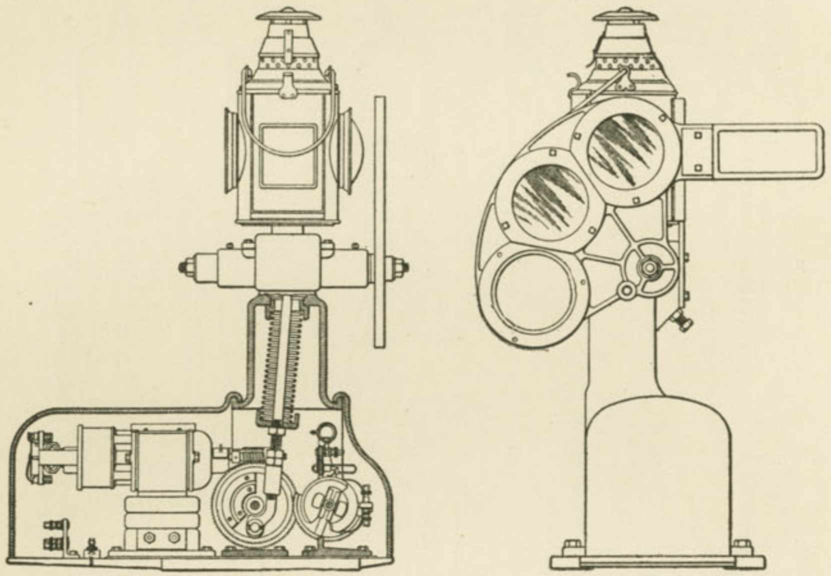


Fig. 39.

Electric Motor Dwarf Signal.

signals. The motor is geared to and drives, by means of a worm gear, a horizontal shaft to which the armature of an electro-magnetic clutch is fixed. The other part of the clutch enclosing the exciting coil is fitted loosely on the shaft. This loose part of the clutch has a crank pin affixed to which the operating rod of the signal is attached. When the signal is at "normal" or danger position, the crank pin is vertically under the shaft; when clear the crank pin is about 45 degrees above the horizontal. The ex-

citing coil of the clutch is connected in series with the motor, and when the operating current is switched on both the motor and clutch are excited, the first causing the clutch armature to rotate, and the second causing the loose part of the clutch to adhere to the armature and move with it. When the signal reaches "clear," a circuit switch cuts in sufficient resistance to reduce the holding clear current to a very small amount and to stop the motor.

The dwarf signal is locked in the normal position by means of a hook-shaped formation on the eye of the operating rod, which engages with the shaft carrying the clutch, if the rod is moved upwardly a very short distance. Sufficient lost motion is allowed in the crank pin hole to permit a slight upward movement of the rod without turning the clutch.

The amount of current required to operate this signal is very small, not more than one and one-quarter amperes, while that required to operate the solenoid dwarf signal, heretofore extensively used, is from three to five amperes. Although the saving in current consumption may not be a matter of very much importance, since the time during which the signal is being operated is a very small fraction of the whole time, yet the reduction in size of operating wires, permissible with the motor-driven signal, will materially lessen the cost of installation and maintenance of the plant.

This method of operating the dwarf signal permits the use of the same kind of current for actuating the indication mechanism that is used in connection with the high signal; that is, the battery current is transformed into an alternating current, which frees it from the dangers of false indications to which the solenoid type of signal is subject. The construction of the high and dwarf signal levers, including the indication mechanism, is also made uniform.

The signals are protected against improper movements due to stray currents by means of a fuse placed in the signal operating circuit between the slot coil and the motor. When the signal lever is in the normal position, the indication wire is connected to the common wire, and as the indication wire is also connected to the control wire at the signal motor, both being connected to the same brush on the armature, a current which might reach the control wire would be short-circuited back to battery through the indication wire, and would cause a very heavy current to flow and blow the fuse in the operating circuit, thus cutting off current from the signal motor and preventing a false movement.

If a contact with a foreign source should occur beyond the fuse, it would also be beyond the slot, so that the slot magnet would not be energized and the signal would not clear. The same arrangement is followed in reference to the safety controller in connection with the switch motor. The coils of the magnets spoken of are both placed between the field coils of the motor and the armature, so that if the contact should occur beyond these protecting magnets it would also be beyond the field magnet coils, and consequently in this case the field magnets would not be energized, so that the armature would not rotate.

The special advantages secured by this method of protecting switches and signals against stray currents are that absolute protection is afforded, and the operation of these safety devices does not in any way interfere with any other part of the plant, except the particular switch or signal affected by the fault.

Electro-pneumatic Interlocking Systems. Electro-pneumatic signal systems, which are used on many lines, employ low voltage controlling circuits, the working medium for operating switches and semaphores being compressed air, supplied by a local compression plant and conveyed to the point of application through underground pipes. In electro-pneumatic interlocking the electric control is managed by the signalman in the cabin. In electro-pneumatic block signaling the air valves at the signal are controlled at the track circuit. The air pressure acts against the piston of a cylinder fixed to a signal post or near the switch as the case may be. Near each cylinder is a small auxiliary reservoir to provide a sufficient supply of air to insure quick action of the piston at every operation. The admission and exhaust of air in the cylinder is governed by electro-magnetic valves controlled by lights from the interlocking machine.

An electro-pneumatic interlocking machine, as manufactured by the Union Switch & Signal Company, is shown in Figs. 40, 41 and 42. In this machine the levers are only a few inches long and very light, their principal work being to open and close electric circuits and to operate the mechanical locking between each other. These levers appear as cranks on the front of the machine, each lever having a latch by which it is held in any desired position,

but this latch has nothing to do with the interlocking of one lever with another. Instead of pulling or pushing the lever, the signalman turns it to the right or left and operates a horizontal shaft which revolves on its axis through an arc of 60 degrees. The indication from a switch or signal actuates the armature of an electric magnet fixed in the machine. This armature engages with

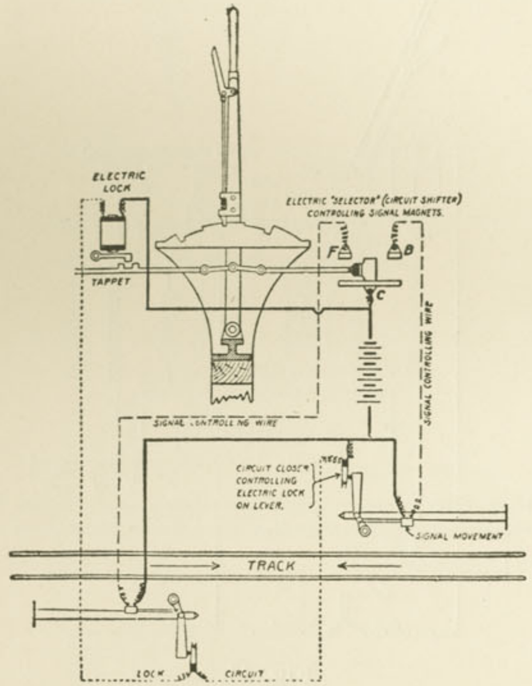


Fig. 40.

CENTER POSITION OF ELECTRIC INTERLOCKING LEVER.

suitable notches in a segment attached to the lever. As arranged with switch levers, this magnet when de-energized locks the shaft after it has been turned far enough to move the switch, and prevents the signalman from completing the stroke of the lever until the switch has finished its movement and is locked in the new position. The indication being received, the stroke of the lever may be completed, and the lever for the signal, giving a right to proceed over this switch, may be reversed.

The general principles governing the switch and signal operation are as follows: As shown in Fig. 40, the ordinary lever of a mechanical type is shown standing normally on center, it has

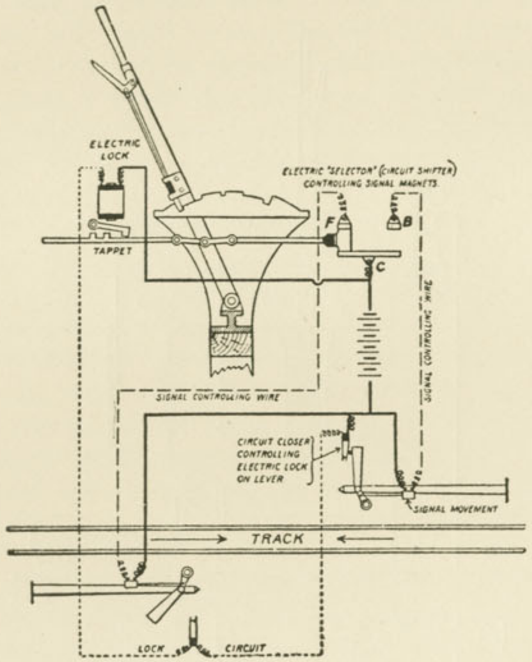


Fig. 41.

Release Position of Electric Interlocking Lever.

attached to it a circuit controller and closes a circuit operating one signal when moved to the left, and closes a similar circuit for a second signal which conflicts in function with the shaft when moved to the right. When the lever is normal both signals are in the stop position and the lever is not engaged between the electric lock. When the lever is released to clear a signal, the latter on leaving the stop position opens the circuit controlling the work,

which immediately releases the lever and prevents its complete return to normal, as illustrated in Fig. 41. The lock, however, permits of a partial return of the lever to normal, as shown in Fig. 42. This amount is insufficient to release any mechanical locking which it operates and which must remain effective until

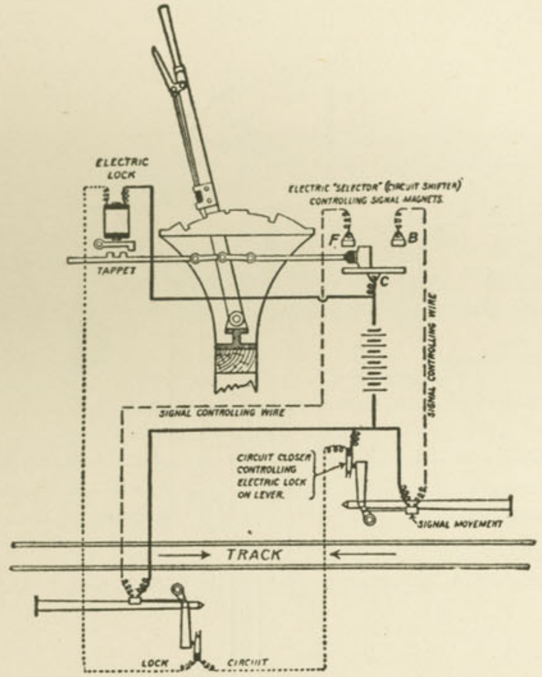


Fig. 42.

Partial Return Position of Interlocking Lever.

the signal is actually in the stop position. This partial movement of the lever toward normal cuts off the current holding the signal in the proceed position, and permits its return by gravity to the stop position. If for any reason it should fail to do so, it is obvious that the lever would be prevented from being put normal, and hence change of route from the one governed by the deranged signal is prevented. This reverse movement of the signal, besides forming a means of selecting and operating signals, also provides within itself an effective form of locking between two conflicting signals, since one lever cannot assume two positions at the same time.

The principal parts of the interlocking machine are shown in Figs. 43 and 44. The whole apparatus is encased in a wooden

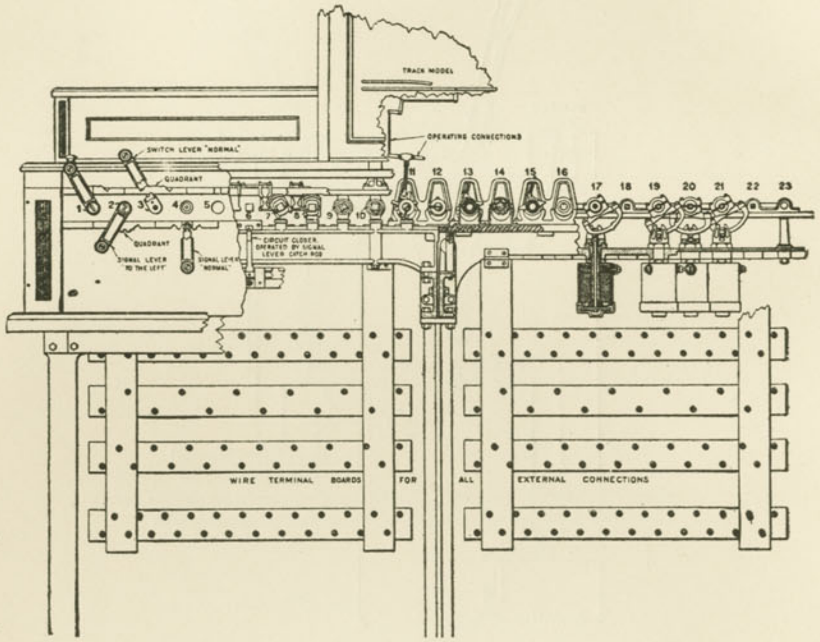


Fig. 43.

FRONT ELEVATION OF THE UNITED SWITCH AND SIGNAL CO.'S ELECTRO-PNEUMATIC MACHINE.

case with a glass top. The wire connections are all run to points on the rear of the frame surrounding the machine. Suppose, for instance, that lever No. 3, shown in Fig. 43, is to be moved. All signals would give a clear route over the switch in its present position, being in the stop position, so that the interlocking will not interfere with the intended movement. The signal now moves

the lever to the right, revolving the shaft. As shown, after this revolution has begun, the driver in the shaft, shown in Fig. 59, has moved the locking bar a short distance, so as to lock the machine, which has moved and prevents turns to interfere with the intended movement. This locking effects the further revolution of the shaft, causing air pressure to be admitted to the valve cylinder.

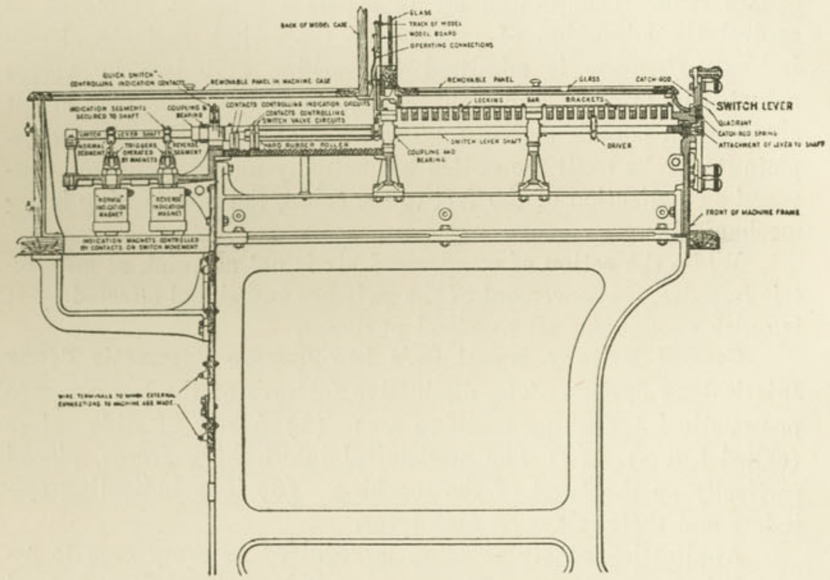


Fig. 44.

SIDE VIEW OF THE ELECTRO-PNEUMATIC MACHINE AS MANUFACTURED BY THE UNITED SWITCH AND SIGNAL CO.

The piston movement produced by this air pressure controls the switch itself. The locking of the switch having been completed, the contact in the indication box engages its proper indication contact in the machine, and the signalman is then able to complete the stroke of his lever, leaving it inclined to the right. This final movement pushes the locking bar to its final stroke and locks it in position, the signalman then permitting a train to pass over the switch in its new position.

Each switch cylinder, by means of its piston, moves the switch indicator bar and lock; or two or more switches together may be moved by the same cylinder when it is found desirable to do so.

Low-pressure Pneumatic Interlocking. A number of railroads use compressed air at low pressure for operating the interlocking apparatus, the air pressure being usually about 15 pounds per square inch. Compressed air in separate pipes is employed to control the admission of pressure to the switch and signal cylinders. Pressure is admitted to working cylinders by valves actuated by large rubber diaphragms, which are worked by air at about seven pounds pressure. The lever of a switch cannot complete its stroke until the switch has actually moved home and conveyed an indication of the fact to the cabin, the interlocking being mechanical.

While the action of compressed air is not as quick as an electric impulse, the movement of the switches and signal effected by it is quick enough for all practical purposes.

General Railway Signal Co.'s Low-pressure Pneumatic Power Interlocking System. The distinctive features of the low-pressure pneumatic interlocking machine are: (1) A row of slide valves (called levers). (2) The mechanical interlocking frame, placed vertically on the front of the machine. (3) The indicating cylinders and their relays on each lever.

Application of air pressure is required in every case to accomplish any movement. To move a switch or signal from normal to reverse position and to receive a return indication at the machine, an air pressure must be applied at the lever. All signals are held in the proceed position by air pressure under the piston, the entire reverse operating line being charged from the tower to the signal when the signal lever is reversed. Thus absence or failure of power will always leave the signal in the stop position.

The principal parts are switch rails, lock rod, throw rod, motion plate, switch cylinder, indicating valve, controlling valves or relays, operating bar and slide valve on lever, indication cylinders, interlocking tappet, and air reservoir.

To reverse the position of the switch the signalman pulls the lever. In doing this he admits air (from the main supply through the valve) through pipe to valve, which opens communication from

the supply pipe to the right-hand end of the cylinder, pushing the piston to the left. After about one-half of the stroke has been completed it is stopped by the piston rod, but the operation of the valve, already accomplished, causes the motion plate to move through the whole of its stroke. This stroke is uninterrupted, but it performs in succession three functions. The first part of the stroke, say one-third, does not move the switch, but the indicating valve is moved far enough to close the two pipes, while others are left open to the atmosphere. At the same time lock bar has been liberated by withdrawal of a dog attached to the motion plate from notch in lock bar. As the motion plate moves through the next or middle portion of its stroke, it moves the switch; but it now produces no effect on the indicating valve, because the rod of the indicating valve is now engaged by the straight portion of its slot in the motion plate. The switch being set, the third and final part of the stroke of the motion plate locks the switch by pushing a second dog attached to the motion plate through a second notch in the lock bar, and also (but not until after the dog has entered its notch) the plate changes the indicating valve so as to connect together the two reversing pipes. This conveys pressure from the supply through the relay and indicating valve, which valve then admits air from the supply to the reverse cylinder, forcing the piston rod upward, and forcing it to complete its stroke. This return action takes place at ordinary distances in from one to three seconds. By the action of the slide valve the reverse control pipe is not opened to the atmosphere, the relay valve is released from pressure and is closed; so that the pipe to the switch cylinder and its connection to and through the indicating valve are open to the atmosphere. All four operating pipes are now at atmospheric pressure. To move the switch back to its original position the opposite set of pipes is used.

A cross-over switch or slip with movable point frogs is operated in the same manner excepting that the functions are connected in series, the air leaving the indicating valve, going to the diaphragm, operating the second function in the same manner as described for the operation of the first function. Pipes to any number of movements may be connected in series and operated from one lever in this manner, the indication from a preceding movement operating a following one, the last movement to operating giving the indication at the machine and automatically completing the stroke of the lever.

To work a signal, valves and operating pipes are used of the same general style as those for a switch, but there is only one indicating valve and one indicating cylinder, as it is considered unnecessary to assure the attendant that a signal is in the proceed position. The principal parts of the signal apparatus are: Signal arm; signal cylinder; lever to work indicating valve; indicating valve; diaphragm valves or relays, controlling the admission of air to the top and bottom, respectively, of the signal cylinder; diaphragm valve controlling admission of air to cylinder. The signal being in the normal or stop position, the indicating valve is in a position to maintain a connection between the two pipes attached to it; but as soon as the signal arm leaves the horizontal position the valve shuts off this connection.

To clear the signal the signalman pulls lever to the left the whole length of its stroke. By this movement air is admitted to pipe which supplies air to the lower end of signal cylinder and pushes up the piston, putting the signal in the proceed position. The signal remains in the proceed position as long as the lever is pulled to the left. To restore it to the normal or stop position, the lever is pushed to the right until it is stopped by the piston rod of the indication cylinder.

The function of the diaphragm valve, which is called the "relay," is similar to that of an electro-magnetic relay in electrical apparatus. This valve is actuated by air at seven pounds pressure. This pressure, admitted beneath the circular rubber diaphragm eight inches in diameter, pushes up the cylindrical valve, placed vertically in the upper part of the case, and thereby admits air at 15 pounds per square inch to move the piston in the switch or signal cylinder. The movement of the diaphragm is only $\frac{1}{4}$ inch.

The operating and indicating pipes extending to switches and signals are $\frac{1}{2}$ inch in diameter. The supply pipes from the air reservoirs are larger, the size being varied according to the number of switches and signals to be operated. The air as it comes from the compressor is run through cooling pipes for the purpose of precipitating moisture.

Any number of signals controlling relative movements over the same switches may be connected up to one signal lever by placing selector valves at switch points to control the admission of air to the proper signal line. This method provides practically the same protection as bolt locking the switch points with signal lines at mechanical plants.

Fig. 45 shows the general arrangement of a switch connected up to the low-pressure system, for either rear or advance bar movements, as used by the General Railway Signal Co.

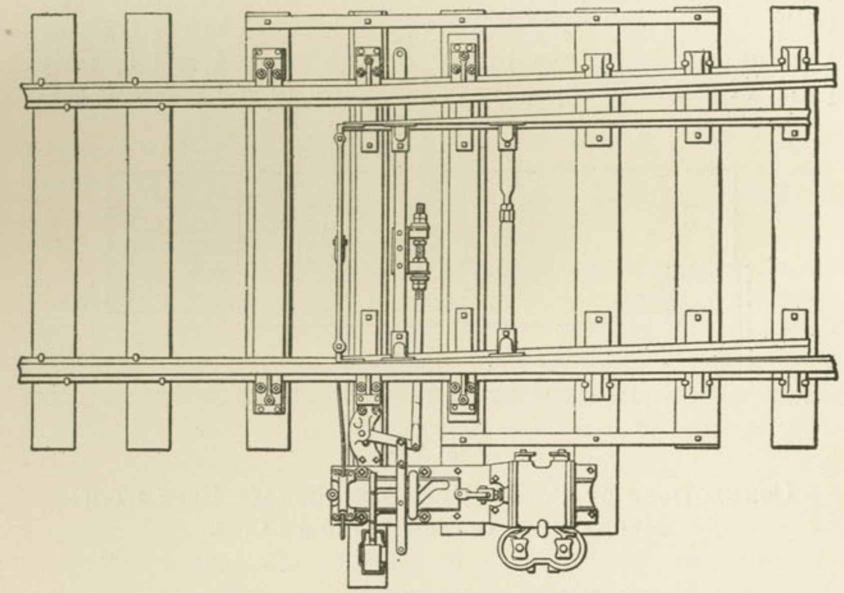


Fig. 45.

Low Pressure Pneumatic Switch and Lock Movement Used on the New York Central and Hudson River R. R.

Power-operated Signals. At mechanical interlocking plants where power-operated semi-automatic signals are used, provision is usually made to compel the signalman to put his signal lever normal after the passage of a train. Such signals, if they are of the automatic type, will clear as soon as the train leaves the block; if the lever remains reversed they permit another train to follow, which might result in delays. For this purpose an arrangement, shown in Fig. 46, is used, and is known as a "stick" relay wiring. The circuit controllers are operated by the lever latch, and the relay, which has a resistance of 500 ohms, is kept energized under normal conditions by a circuit as follows: From the battery D, through wires 4, 6, circuit controller A, wires 9 and 12, coils of relay, wires 10 and 8, circuit controller C and wire 3 to battery. Current can also flow through wire 5, relay point, wires 11 and 12 and to battery through coils. Raising the latch opens circuit controller A. Lowering latch with lever reversed closes circuit controller B and opens C; C does not open, however, before B closes. Current now flows from battery through wires 4 and 5, relay point, wires 11 and 12, coils of relay, wires 10 and 7, circuit con-

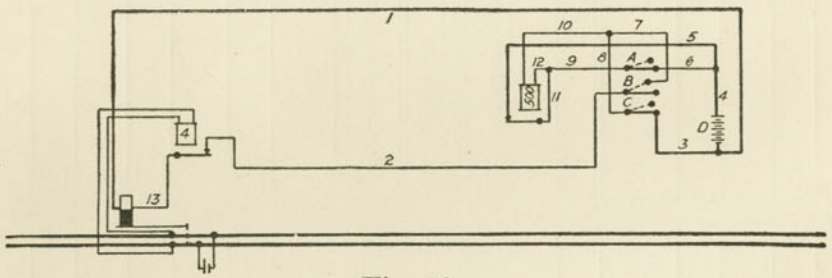


Fig. 46.

Connections of Power Operated Signals Used with Mechanical Interlocking Plants.

troller B, wire 2, track relay point, wire 13, signal mechanism, wire 1, to battery. This clears the signal. Passage of a train opens the track relay points, putting the signal to the stop position and opening the circuit of the 500-ohm stick relay. As the signal control circuit passes through the point of this relay, the signal cannot again clear, because this relay will not be energized again until the lever is latched in the normal position. In this case it is assumed that the coil through which this current passes at the signal is wound to 500 ohms; if that resistance is less the stick relay winding should be reduced accordingly.

Track Circuit Locking. To overcome a number of difficulties when high speeds and heavy rails are used, track circuit locking is

resorted to. As applied to mechanical interlocking it involves the use of electric locks on the latches of certain levers, usually those of the home signals. Another method is to have the home signals locked as soon as cleared, and released only when a train has reached a certain point within or beyond the locking limits. This is known as "approach" locking.

At power plants with electric control electric locks on the levers may be used. Usually there are no latches or latch locking at these plants, consequently the lever itself must be locked. Another difference is that there are usually no separately operated facing point locks at power plants; therefore a derail or switch lever must be used for the route lever, and be controlled by the electric locking. If signal levers are to be locked, it is often convenient to break their indication circuits through relay or indicator contacts, thus avoiding the necessity of an additional electric lock. Also with the same effect the control circuits of switches and derails are broken through such contacts.

If the indication circuit of all signals concerned are broken while a train is occupying the route or section of route governed, the protection will be complete. For, when the indication circuit is broken, the releasing device on the lever cannot act, and the lever is held in an intermediate position, thus locking all opposing and conflicting routes as if it were at full reverse. Usually, however, the indication circuits of the high home signals only and the control circuits of the switches and derails in a route are broken. This is done, because if, with no means of holding the switches, a signal should be out of order, and if it were necessary to flag a train through, there would be no protection; this for the reason that there would be nothing to compel the signalman to reverse his signal lever, and with the signal lever normal the route would not be locked. The best system would seem to be a combination of lever locking and circuit control; that is, to break the high home signal indication circuits and the switch and derail control circuits and lock route levers.

In another system of electric locking, conflicting routes only are locked; that is to say, a train in a certain route locks switches and derails in conflicting routes only. This is no more than dog locking is designed to do, except that it holds after the signal lever has been put normal until the route is clear.

At power plants controlled otherwise than electrically, lever locking is the only kind that can be economically and efficiently applied. Valves and their controlling apparatus are cumbersome and expensive.

Where any one of these systems is applied only to track sections within the home signal limits, the use of detector bars can hardly be dispensed with. It takes an appreciable length of time for a track relay to act, and the indicator and lock consecutively consume equal periods. Therefore, before the lock has acted it may be possible to change at least one of the switches or derails in the route. Consequently it is advisable to have a detector bar at the entrance to each high-speed route at least.

Approach Locking. To overcome this difficulty and to better prevent any change of route after a train has passed the distant signal at clear, approach locking has been introduced. This is an arrangement of circuits whereby the lock on the home signal or route lever latch operates when a train approaches the interlocking plant with the governing signals in a certain position.

Broadly, there are in use two systems: In one the lock acts as above when the train is approaching the distant signal with the home signal clear, and holds until the train has reached a point within or beyond the interlocking limits. This may be modified so as to require the distant signals also to be clear; or it may be made to act when a train has passed the distant signal with the home signal clear. In the other system the route is locked as soon as the home signal is cleared, regardless of whether a train is approaching or not. Of course, in dealing with electrically controlled power plants the above may be modified so as to break control and indication circuits.

Check Locking. In electric and electro-pneumatic interlocking systems there is usually provided in each tower a separate lever for each track over which reverse movements are to be made. These levers are connected with the mechanical locking devices in such a way that when they are in their normal position the signal for reverse movements is locked in the stop position, and the signal for movements with the current of traffic are free to be moved. This is done electrically by interlocking the levers in the two adjacent interlocking towers.

Semi-automatic Signals. A semi-automatic signal is one hav-

ing automatic locking devices, but which is controlled from the manually operated signal, circuit controller or similar device. They are most frequently used in connection with interlocking or manual signal towers, and they constitute an adjunct or an extension of the latter. Manual signaling cannot be effected over any great length of track on either side of the tower; therefore semi-automatic distant signals have been applied to most of such cases.

Due to the fact that interlocking enables one signalman to prevent errors made by another, and with the use of continuous track circuits as an auxiliary control, the semi-automatic or "controlled manual" system represents the highest present development of visual signaling.

With automatic signals enginemen will occasionally be careless, because they are not watched, and with the simple manual system signalmen sometimes blunder; but with the "controlled manual" the presence of the signalmen keeps the enginemen vigilant, and the machinery is an efficient check on the signalmen.

Staff Signaling. A staff is a piece of wood 22 inches long, suitably lettered, and is the authority given to the engineman to run his train between two sections. After passing out of one section he receives another staff for the succeeding section, and so on. In order to be able to reach and take a staff with the electric train staff system, a post with suitable bars to support a staff is fixed near the track.

Electric Train Staff System. For operating trains on single track, the electric train staff system has become one of the cheapest, simplest and most efficient methods in general use.

In the operation of the electric train staff, the track to be protected is divided into blocks or sections of such length as to best accommodate local and traffic conditions. These blocks usually terminate at existing stations or telegraph offices, although occasionally, as in the telegraph block system, additional block signals have to be installed when the distance between any two existing stations is too great for the rapid handling of traffic. Each section is controlled by two instruments, as shown in Fig. 47, one at each end, and which for convenience are referred to as X and Y. Each instrument is equipped with a sufficient number of staffs, varying from 10 to 35, to take care of the traffic conditions of the road. No train is permitted to proceed between X and Y in either direction unless the conductor or engineer has in his possession one of these staffs, which is in effect a metal train order. The two instruments at X and Y are electrically connected and synchronized so that the withdrawal of a staff from either can only be effected by the joint action of the operators at X and Y, and but one staff can be out of both instruments at the same time.

Development of the Electric Train Staff System. The electric train staff system of to-day is a gradual development from a simple principle for the operation of roads which was recognized in England as early as 1840; namely, that to safely pass over a given section of single track every train should have in its possession a tangible right to do so in the form of some specific article of which there is only one obtainable. The first train staff was a metal bar about two feet long, which had cast or engraved on it the names of the two stations between which it alone gave authority for any train to proceed. Unless trains moved alternately in opposite directions the staff had to be returned over the section by a special engine or in some cases by road.

To partially overcome this difficulty the staff and ticket system was devised, in which device the original staff became a key that would unlock a box at either end of the section and permit tickets to be taken therefrom. If it was desired to forward say three trains from one station to another before one should proceed in the opposite direction, the ticket box was unlocked with the staff and a ticket given to the first and second trains, the third train receiving the staff.

Since an engineer or guard of any train when receiving a ticket was required to see the staff as well, this system, while making head-on collisions impossible, did not permit trains to enter a section from the end at which the staff did not happen to be. To accomplish this result Mr. Edward Tyer in 1878 introduced his electric tablet apparatus, which consisted of two instruments, one at either end of a section, each instrument containing a certain number of tablets, any one of which constituted the right of a train to pass over that section. The two instruments were electrically connected and synchronized, so that the removal of a tablet from either instrument absolutely prevented any other being taken out.

In 1889, Mr. Webb, Chief Mechanical Engineer, and Mr. Thompson, Signal Superintendent of the London & Northwestern Railway, invented the Webb & Thompson Electric Train Staff, in which staffs were substituted for the tablets in the Tyer system, and a permissive feature added whereby several trains could follow each other into a block section if desired in a manner similar to that employed in the non-electric staff and ticket system.

The first instruments were installed in May, 1894, on the Chicago, Milwaukee & St. Paul Railway between Savanna, Ill., and Sabula, Iowa, and since that time this staff system has been introduced on the Chesapeake & Ohio; the Cincinnati, New Orleans & Texas Pacific; the Atchison, Topeka & Santa Fe; the Chicago, Rock Island & Pacific; and the Canadian Pacific Railways.

The main objection to the extended adoption of the Webb & Thompson apparatus was the size of the staff, which made it difficult to catch at high speed. To overcome this objection, the Union Switch & Signal Company in 1900 introduced what was known as its High-speed Train Staff System, which, although based on the same general principles and method of operation as the Webb & Thompson, possessed the essential advantage of employing staffs only six inches in length, weighing 6½ ounces; as against staffs 22 inches long, weighing 4 pounds, of the Webb & Thompson system, thus greatly simplifying the problem of taking the staff at high speeds.

This latter system was installed on the Chesapeake & Ohio; Cincinnati, New Orleans & Texas Pacific; Gulf, Colorado & Santa Fe; Philadelphia & Reading; Chicago, Milwaukee & St. Paul; Chicago & Great Western; Chicago & Alton; Southern; and the Atchison, Topeka & Santa Fe Railways.

On the last-named railroad among other places this system was applied to a section extending from Trinidad, Colorado, to Raton, New Mexico, a distance of 25 miles, which was divided into seven block sections. This portion of the Atchison comprises mountain grades averaging 3½ per cent. for a greater part of the distance, over which a traffic of approximately 60 trains a day is operated. On account of the number of trains, and also the fact that each train required two, and sometimes three, engines on the up grade, an average of one hundred and fifty train orders was issued in each twenty-four hours, most of which were sent to not less than two stations, so that the total delay of trains awaiting these orders can easily be imagined. With the introduction of the staff system as many trains, or more, have since been handled over this section, with no collisions and a minimum of delays.

At the intermediate stations on this section staff cranes are provided, from which the enginemen can take the staffs at a speed up to 25 miles an hour without the use of any special attachments on the engines.

At another point where this apparatus is in use the practice is followed by handing the staff to an engineer by means of a rattan hoop about two feet in diameter, similar to the method followed by many railroads for delivering "19 orders" and clearance cards. The staff being small and light is as easily delivered on such a hoop as a train order. This method may be safely followed for all trains which can afford to reduce speed to 25 miles or even 30 miles an hour when passing the staff station, thus avoiding any special apparatus on the majority of the locomotives.

On the Cincinnati, New Orleans & Texas Pacific Ry., which operates a number of staff stations, the practice is to deliver the staff to any train which can afford to slow down to 30 miles an hour without any special attachments to the locomotives, such a device being only applied to their fast expresses, on which the staff has to be caught at speeds frequently exceeding 60 miles an hour.

The latest type of staff instrument, known as the Electric High-speed Train Staff, Model No. 2, has been developed during the past four years, and employs a staff of practically the same size and weight as the Model No. 1 instrument, over which it possesses the following advantages:

By having separate drums for putting in and taking out the staffs, equal wear on all staffs is secured; whereas, in the earlier instrument some of the staffs would be practically worn out from constant use, while others would hardly ever be used.

The second advantage lies in the special type of indicator employed in this instrument, which plainly shows the operator by the display of a white or red disc, whether or not his instrument is in condition for him to remove a staff, and thus leaves him no excuse to strain the mechanism.

Advantages of the Electric Train Staff System. The advantages claimed for the electric train staff system are as follows: It acts as a mechanical assistant to the train dispatcher, issuing metal train orders and giving trains the right to proceed over portions of the track, and will issue only one such order at one time for any section, except in the case of following trains when the permissive system is used, thus obviating all danger of "lap orders;" it avoids delay in waiting for train orders; it provides the engineer with evidence in the shape of a staff of his right to the particular block section he may occupy; it does not interfere with other safety systems; a knowledge of telegraphy is not necessary, and the operation of the staff takes up considerably less time than is now expended on telegraph train orders.

Union Switch & Signal Co.'s Train Staff. The operation of an electric train staff system, as constructed by the Union Switch & Signal Company, is as follows: Calling X the entering end of the block and Y the leaving end, the manipulation of the instruments consists of the operator at X pressing the bell key shown at A, Fig. 47, the number of times prescribed by the bell code. This rings the bell at Y. The operator at Y first acknowledges receipt on his bell key, ringing bell at X and then holds it closed, thereby deflecting the "current indication needle" at X to the right. This informs X that Y has furnished current, and he proceeds to remove the staff by turning the preliminary spindle handle B to the right as far as it will go. This unlocks a revolving drum, and indicates the fact by displaying a white instead of a red disc in the indicator at H. The operator now moves the end staff E up the vertical slot into engagement with the drum. The outer guard N, having been turned to the right position, revolves the latter through a half turn, using the staff as a handle, and finally withdraws the staff through the opening at M. In making the half turn the drum has reversed the polarity of the operating current, thereby throwing the instruments at X and Y out of synchrony with each other and moving the "staff indicating needle" at X from "Staff In" to "Staff Out," as shown at G. Immediately on withdrawing the staff, the operator at X once more presses his bell key A, which indicates to the operator at Y by moving his needle from "Staff In" to "Staff Out" that the operation is completed.

The staff withdrawn is not delivered to the train by hand if the train is at rest, or passing at a speed of less than 25 miles per hour. For high speeds the staff is placed in a special holder and delivered by methods similar to those followed in the railway mail service, the engine being fitted with a catching and delivering device, as shown in Fig. 48.

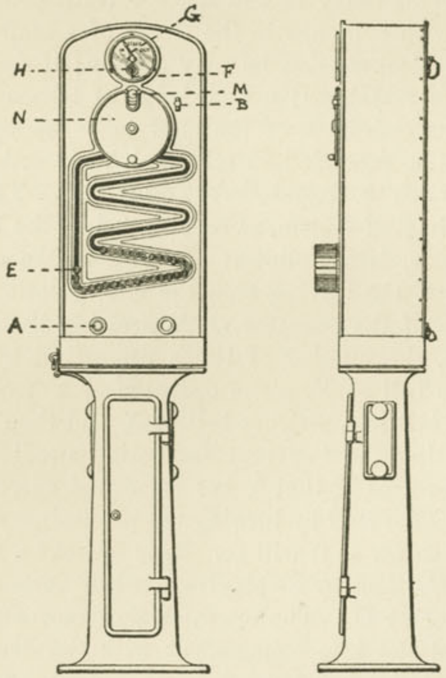


Fig. 47.

ABSOLUTE ELECTRIC TRAIN STAFF INSTRUMENT.

As mentioned before, in taking out a staff the polarity of the operating current is reversed. This prevents a second staff from being taken out of either instrument, as will be noted from the following:

Permissive Feature. While the absolute system, where but one train is allowed in any section, is the ideal arrangement, yet cases

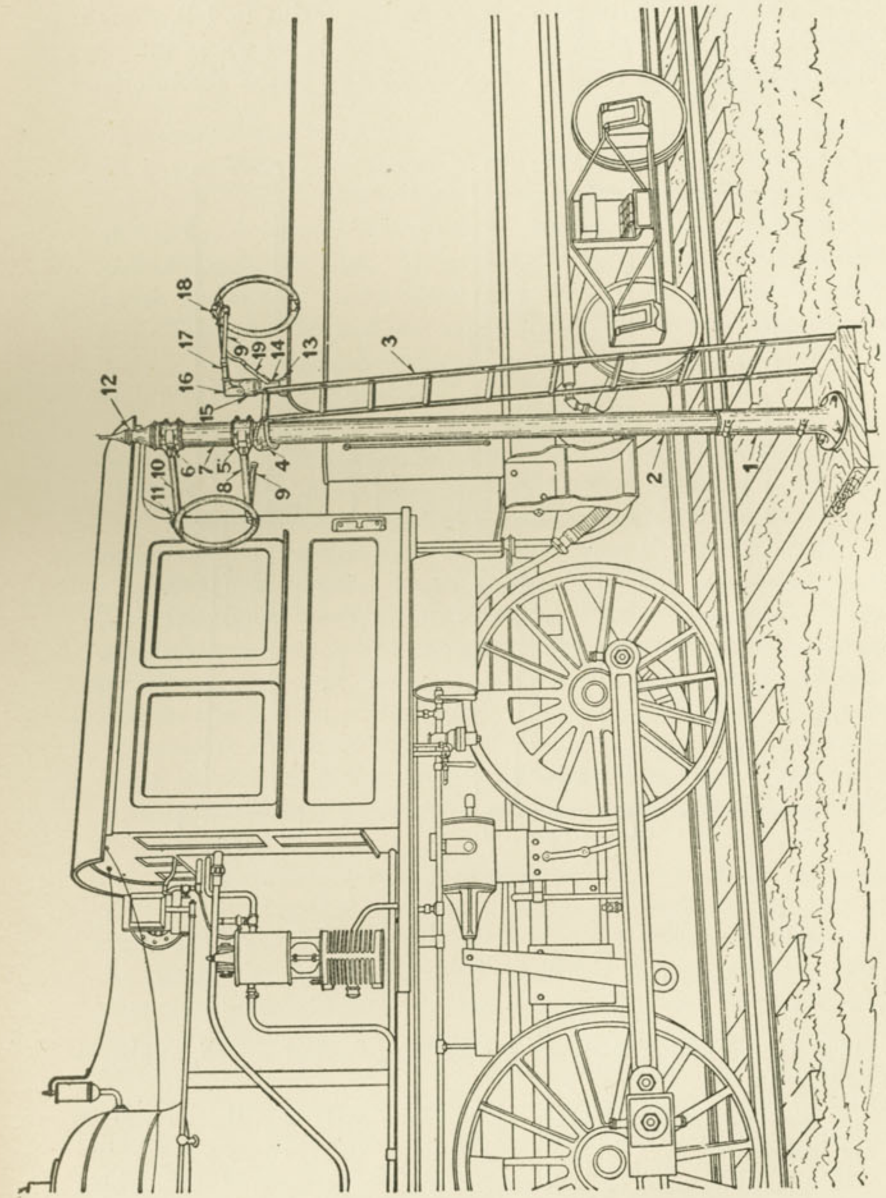


Fig. 48.

TRAIN STAFF CATCHER AND DELIVERER.

occur where it is desirable to allow several trains to follow each other into the block at short intervals. This is known as the permissive system, and consists of an attachment to the absolute ma-

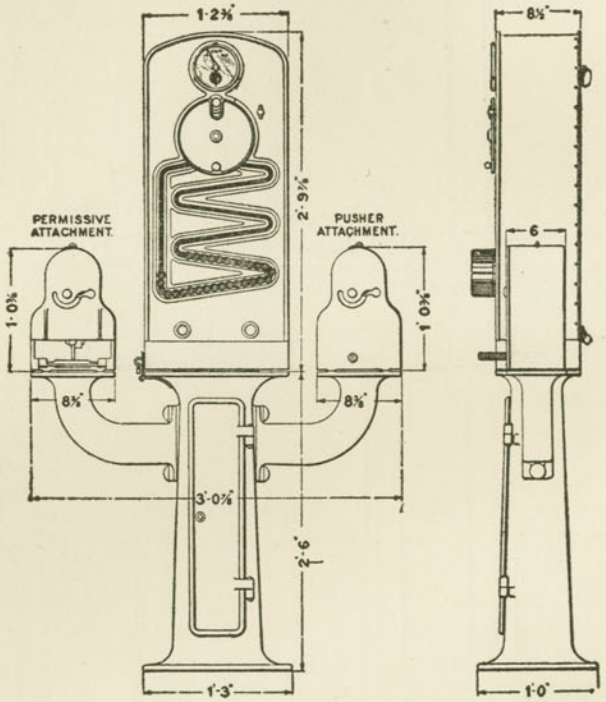


Fig. 49.

Electric Train Staff with Permissive and Pusher Attachments.

chine at each end of the section with one permissive staff, as shown in Fig. 49.

To operate this feature an absolute staff is withdrawn from the instrument at X in the usual manner and used as a key to unlock the attachment or base containing the permissive staff, which is then taken out. The opening of the base and the removal of the permissive staff locks the absolute staff in the permissive attach-

ment, there to remain until the permissive staff is replaced. The permissive staff consists of a steel rod and 11 removable rings, any one of which authorizes a train to pass through the section to Y. If less than 12 trains are to follow each other, the last one takes all the remaining rings and steel rod. When all the rings and rods are received at Y, the operator reassembles them into the complete permissive staff, which he then places in the permissive attachment or base, and locks it therein by the absolute staff already in the lock of this attachment. By so doing he releases the absolute staff, which he restores to the absolute instrument in the regular manner. The machines are now synchronized, and a movement can be made with an absolute staff in either direction, and from Y to X with the permissive staff.

If it is again found necessary to move several trains from X to Y under the permissive system, the permissive staff must be obtained by Y, as before described, and forwarded to X as a whole by the first train moving in that direction. The entire permissive staff confers the same rights as does an absolute staff.

Control of Signals. In its capacity as a key the absolute staff has a number of uses in addition to that already described. Where signals are used to indicate to an approaching train whether or not it will receive a staff, an instrument known as the staff and lever lock is attached to each lever operating such signals. This instrument is shown in Fig. 50. To clear a signal the staff, after being withdrawn, is first used to unlock the lever lock. The signal is then cleared and the staff removed from the lock and delivered to the train.

To insure the signal being placed at danger behind a train, the act of unlocking the signal lever opens the staff circuit, and no communication can be made between the two staff stations until the signal is at danger and the lever locked in that position. This does not indicate, however, that the operator will have the staff ready for delivering by hand or in the mechanical deliverer. To cover this point an electric slot is attached to the signal governing train movements into the staff section, which slot is controlled by the staff and lever lock and the mechanical deliverer, so that before the signal can be cleared the staff must be released, used to unlock the signal lever and put in the staff deliverer, which closes the circuit on the electric slot. The signal can then be cleared.

With this arrangement, therefore, a clear signal cannot be given until the staff is actually in the deliverer.

When the train picks up the staff, the circuit on the slot is opened automatically, setting the signal to danger, and it cannot again be cleared until the operation described above is repeated.

Automatic Block Signal Systems. An automatic block signal

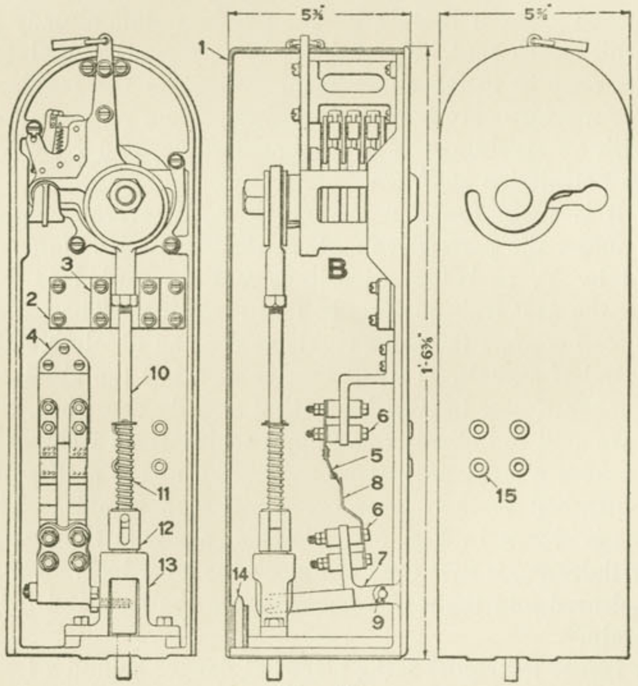


Fig. 50.

STAFF LEVER LOCK.

system consists of a number of consecutive blocks, which are worked by electric or pneumatic agency, which in turn is controlled by the passage of a train into, through and out of the block section to which the signal is connected. The first installation of an automatic block system was on the Boston & Maine Railroad in 1871, and since that time 11,000 miles of road, or about 18,500 miles of track, have been equipped with the automatic system.

Types of Automatic Block Systems. Automatic block signals must work without the care of an attendant, and most of them at places remote from a source of power. They were first operated by a simple electro-magnet (the enclosed disc signal), the parts being made very light. To avoid the disadvantage of the glass enclosure the "clock-work" was next introduced, this apparatus furnishing power enough to move a disc exposed to wind, rain, snow and frost. Discs, however, were generally regarded as inferior to semaphores, and the next improvement was the electro-pneumatic mechanism, moving full-sized semaphores, which was introduced in 1885. This system, however, with its air pipe the whole length of every line which is signaled, is too costly for roads with any but the heaviest traffic, and it was not until the perfection of batteries and electric motors capable of economically operating full-size outdoor semaphores (with an independent source of power at each signal) that automatic block signals became universally popular. Since 1900 the electric motor signal has made great progress. The electro-gas signal has come into use to some extent as a competitor of the electric motor.

Principles of Operation of Automatic Block System. On account of the advantages of the automatic block system, the blocks may be made shorter, and additional safety is secured by eliminating the attention of the tower operator. Fig. 51 shows a diagram of the system of track circuits employed on steam roads at the present time. At the beginning of each block the rails are insulated from the preceding section, so as to form an insulated section known as a block. At one end of the section is a close insulated circuit battery of sufficient capacity to operate a relay at the other end of the block. This relay opens and closes a secondary circuit through a second battery, which operates the mechanism moving the signals. This mechanism usually consists of a small series motor connected with the semaphore shaft through triple reduction gearing and a proper controlling device, whereby the motor is cut out and the signal held in position by means of an electrically operated pawl or lock. A signal may, however, be operated by means of compressed air stored in a tank in the base of the signal post, but this method is not considered as satisfactory as the electrical method.

When there is no train in the block the track circuit current operates on the relay, which closes the operating circuit, reversing the home signal to clear, and locking it in place. After the train has passed the next block the home signal in advance returns to clear and closes the interlocking circuit, which holds the distant signal at the beginning of the preceding block at danger, thereby allowing it to return to clear. When the train first enters a block the front pair of wheels short-circuits the rails, causing the relay to open and allowing the pawls to drop out. The counterweights on the semaphore spring both the home and distant signals to the horizontal position, where they remain as long as there is a pair of wheels on the block.

In the case of a broken rail or an open switch, the track circuit will open and cause the signals to return to danger the same

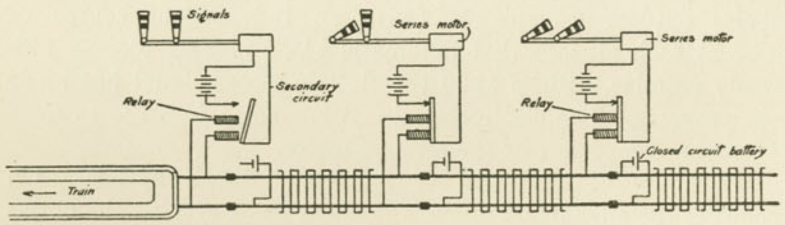


Fig. 51.

Direct Current Automatic Block Signal Circuits.

as if there were a car in the block. The batteries employed for the operation of these signals are usually of the gravity cell type, located at the side of the track in water-proof manholes, below the frost line, to prevent freezing in cold weather. On some of the large four-track systems, storage batteries are used and charged from a main generating plant.

Electric Motor Semaphore Signal. The electric motor semaphore signal, which has come into extensive use, has several advantages, among which may be mentioned: 1, that it is self-contained, and therefore independent of all other signals; 2, it has a comparatively large reservoir power; 3, an isolated plant is not required for its operation; 4, economy of installation and operation; 5, working and controlling functions are unified; 6, external simplicity of design.

Among the disadvantages may be mentioned—1, that the motor and controlled mechanism are somewhat complicated, which introduce numerous factors of failure; 2, the motor itself is not a perfectly reliable device; 3, a failure structure must be utilized to transform the high-speed rotary movement into a slow direct reciprocating motion; 4, the frost may accumulate upon the commutator, the lubricant may gum or the mica may cause an open circuit, thus resulting in breakdown; 5, the clutch magnet armatures may also freeze, which will prevent them from acting.

Signal Motors. Signal motors are of small size, series wound, and for direct current only. As they are generally operated by battery current, the terminal voltage is of necessity low.

The sizes of the motors usually vary from 1-12 to 1-5 of a horse-power, and from ten to twenty Edison and Gordon cells are used to operate these motors. The larger motors used in electric systems of interlocking are supplied with current from a storage battery having considerable voltage. Derailing and switch moving motors have a maximum of about one horse-power, although they may be operated at considerable less power than this.

The motors for signals may be located either at the bottom of the mast or at the top of the mast, the latter position being considered to be better.

Advantages of Top-mast Motor Mechanisms. The advantages of locating the motor mechanism at the top of the pole or mast, as compared with its usual location at its base, are as follows:

1. The direct application of the power to the semaphore shaft avoids the necessity of changing from a rotary motion to a straight line motion, and *vice versa,* in order to transmit power from the bottom to the top of the mast. This construction, therefore, permits a simplicity, rigidity and compactness in design that cannot be secured with any other location of the motor mechanism; 2, A direct connected signal having fewer parts, and operating with less friction, is more positive and less liable to derangement. The moving parts are also removed from inside the mast; 3, Up-and-down rods, jaws, pins and guides are unnecessary, and the friction of such parts is entirely avoided; 4, All moving parts, except the blade and spectacle, being contained in the mechanism case, the signal may be installed with a minimum of labor; the location of all the moving parts at a distance from the ground lessens the

liability of the accumulation of dirt inside the mechanism case. This construction also obviates any difficulty from floods and surface moisture.

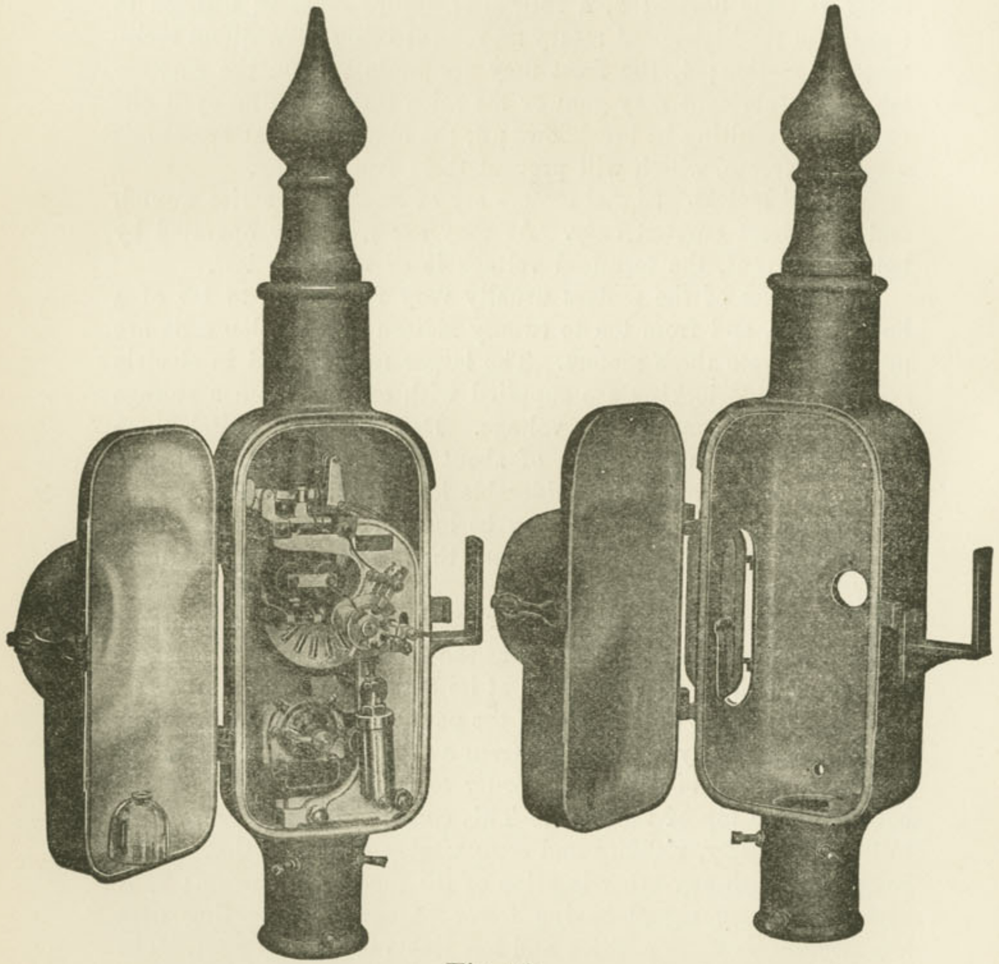


Fig. 52.
Top-Mast Two- or Three-Position Motor Signal Mechanism.
(General Electric Co.)

Top-mast Mechanism. The mechanism used on the top mast for two and three-position motor signals is shown in Figs. 52 and

53. It is operated by means of an electric motor, which is supplied with current from storage or primary batteries, usually at a po-

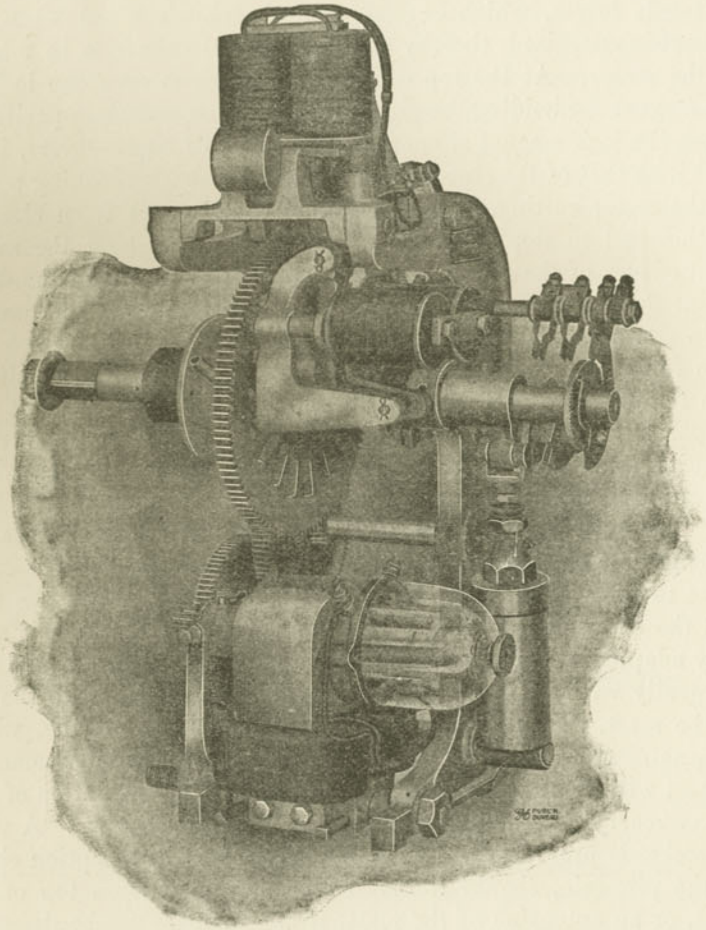


Fig. 53.
Top-Mast Two- or Three-Position Motor Signal Mechanism Removed from Case.
(General Electric Co.)

tential of ten or twelve volts. The motor is geared so as to revolve the clutch wheel, which turns freely about the main shaft. This shaft extends through the back of the case for the reception of the signal arm. Mounted upon the main shaft and rigidly attached thereto is the sector casting, which supports the clutch magnet and its toggle levers, which engage with the clutch wheel when the magnet is energized, thereby causing the main shaft to be rotated by the motor. At the top of the mechanism is seen the lock or slot magnet for holding the signal in its caution and clear positions. When the lock magnet is energized a system of toggle levers, identical with that of the clutch, makes engagement with locking points on the sector casting. The free gravity movement from clear to caution and to stop positions is accomplished without the movement of any of the gearing, and is retarded by means of the dash-pot at the front of the mechanism connected to the crank on the main shaft. This dash-pot is filled with a special oil, which has been found by actual test to remain in a perfectly fluid condition at a temperature of 45 degrees below zero. The main shaft also supports the controller segments by means of which the various circuits are made and broken through the contact fingers, which are supported on studs rigidly secured to the frame.

The supporting frame of the mechanism which carries the bearings for the signal shaft and the reduction gearing is made so as to form a weather-proof case. The joint between the door and the case is made with a gasket of elastic felt, which is specially adapted to this purpose. At the bottom of the case, and cast integrally with it, is the socket by which it is secured to the top of the mast. Inside this socket is an insulating bushing, which eliminates the possibility of grounds, even if the wiring comes in contact with the case, or if, through accident, the insulation of any current-carrying part of the mechanism be broken down. A similar socket is provided at the top of the case for the reception either of the pinnacle, should the signal be at the extreme top of the mast, or an extension of the mast, if one or more mechanisms are to be placed above.

The operating parts of this signal consist primarily of a motor, reduction gears, means for engaging and disengaging the signal shaft from the driving gear, means for preventing shock to the signal parts when the signal returns by gravity to its stop position, and the necessary electrical contact devices for securing the desired movements.

Operation of Top-mast Mechanism. When the signal circuit is closed, current will flow through the shunt coils of the slot-magnet, and thence through the motor control sector and its contact fingers to the armature and series field of the motor. At the same time a portion of the current will flow around the armature of the motor through the shunt field. As the armature of the slot-magnet is resting against the stop pins in the pole pieces when the signal is in the stop position, only sufficient energy is required in the slot-magnet to hold the armature from being drawn away by pressure of the driving pins against the pawl. The slot-magnet

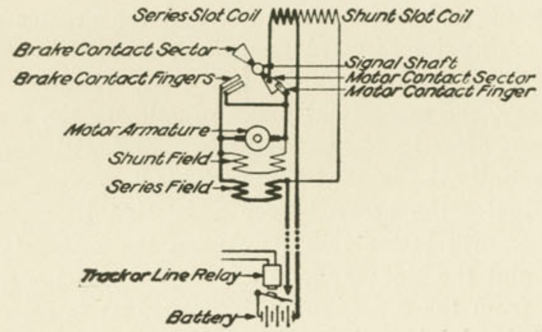


Fig. 54.

CONNECTIONS FOR TOP-MAST MOTOR DRIVEN SIGNAL.

being energized, the pawl is held in the path of the driving pins, and, as the motor revolves, one of the driving pins is forced against the pawl, thereby turning the slot-arm and the signal shaft to which it is connected. When the arm of the signal has come almost to its extreme position of "proceed," the motor current is broken by means of the controller; but this does not arrest the movement of the signal, on account of the inertia of the revolving armature and other parts. It is evident that, on account of a shunt field winding, the motor, driven by its own inertia, becomes a generator, maintaining its field excitation. Immediately after the circuit between the motor and the battery is opened, connection is made through another contact sector, closing a low resistance circuit between the motor brushes, thus converting the motor into a powerful electric brake to arrest the further movement of the signal. A diagram of the circuits which accomplish this result is shown in Fig. 54.

As soon as the motor stops the ball ratchet, before mentioned, prevents any backward rotation of the motor armature, and the signal is held in its clear position until the main circuit between the signal and battery is opened. It will be understood that the higher the voltage of the battery the greater will be the speed of the motor at the time the battery current is cut off, and the greater will be the inertia of the moving parts. It is also evident that the greater the speed of the motor the higher will be the E. M. F. generated in its armature, and the greater will be the current opposing its forward movement when it is acting as a generator. It will, therefore, be seen that, whatever the voltage of the battery, the motor will make practically the same number of revolutions after its current is broken, and will stop the signal arm at essentially the same position. This method of stopping the motor eliminates the necessity for a friction brake, and at the same time secures better results. When the main signal circuit is opened, and the slot-magnet de-energized, its heavy armature falls away from the cores, and this movement is assisted by the pressure of the driving pin against the pawl. This movement of the armature throws back the pawl from engagement with the driving pin, and the signal shaft, together with the slot-arm, are free to assume the position to which they are normally carried by gravity. As the signal arm comes to its stop position, the rotation of the slot-arm causes the armature to swing back against the poles of the magnet, so that it is in position to be held firmly in place when current is again applied.

Automatic Block Signals with Storage Batteries, L. S. & M. S. Ry. The Lake Shore & Michigan Southern Ry. is equipped with automatic block signals, which are operated by stationary storage batteries charged by line circuits from power house plants at intervals averaging 15 miles.

The average length of the blocks is about one mile. The home signal for each block, and the distant signal for the block beyond, are displayed on the same post. The typical arrangement is a steel pipe bracket pole carrying two masts for the signals of the two tracks in each direction. In places where only two or three

tracks now exist the poles are set at such distances as will afford the proper clearance when the additional tracks shall be constructed. For instance, where only two tracks now exist a bracket pole is erected on either side of the roadbed, each of these poles

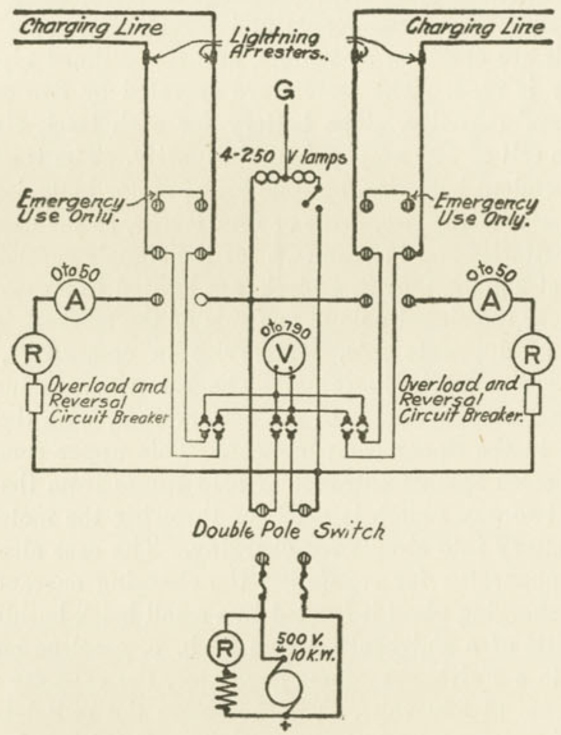


Fig. 55.

SWITCHBOARD AND CHARGING CIRCUITS AT POWER HOUSE, LAKE SHORE & MICHIGAN SOUTHERN R. R.

carrying one mast for the two signals of the track which it governs. As the third and fourth tracks are built, the other mast and signals will be added to each pole.

In the standard arrangement for the four-track line the two interior tracks are for the passenger traffic, and the outside tracks are used by the freight trains, the reader bearing in mind that on the L. S. & M. S. Ry. the trains run left-handed. At points where special conditions exist, signal bridges instead of the bracket poles are used.

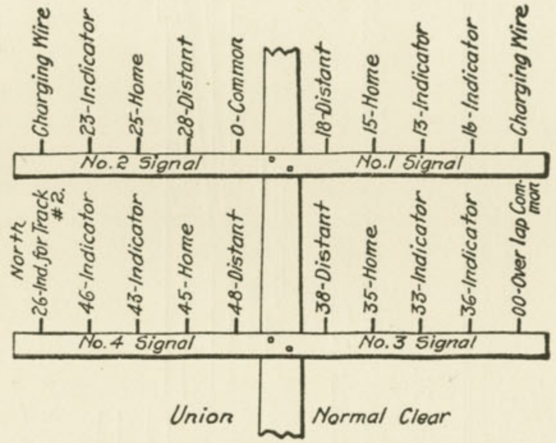
The feature of chief interest in this installation is the operation of the signals by stationary storage batteries charged by line circuits from power-house plants at intervals averaging 15 miles. The signals are operated by motors, and the Willard type of storage battery is used. The motors are operated by five cells of 40 ampere-hours' capacity. The battery for each track circuit consists of one cell of 120 ampere-hours' capacity. The track circuits have independent batteries, but one set of motor batteries operates all the signals for the two, three or four tracks, as the case may be.

The batteries and instruments for the signals governing all of the tracks at a station, or in a block, are located in a cast iron case standing near the signal pole at one side of the tracks. These batteries are in duplicate sets, for service in emergency, and for alternate service while charging. The batteries are installed in the two lower compartments of the battery case, with the switches and relays in the upper compartment. This upper compartment is tightly sealed against entrance of acid fumes from the batteries below. A two-way switch is used for throwing the motor battery or track battery into circuit for charging. The case also contains resistance apparatus for regulating the charging current.

Each charging plant is located in a small brick building. The plant consists of a Fairbanks Morse 15 h. p. gasoline engine belt connected to a Fairbanks Morse generator, the capacity of which is 18 amperes at 550 volts. Fig. 55 shows the switch-board and charging circuits. The latter extend 7½ miles in each direction from the power-house, on the average all the batteries on one side of the power-house being charged in series, the two sets in both directions from the power-house being in multiple with the plant. The track batteries are charged separately, with current of 10 amperes, at intervals of about seven days, and the motor batteries are charged at five amperes about every 10 days. The charging circuit is of No. 7 weather-proof wire. For emergency use a portable charging plant has been set up in a box car, which can be placed on side-track and used in lieu of a stationary plant

if circumstances require. Fig. 56 shows the standard arrangement of line wires, the charging wires being on the outside of the upper arm.

Fig. 57 shows the arrangement of the signal circuits, Fig. 58 the circuits for a cross-over from main track to main track, and Fig. 59 the standard circuit for a cross-over from main track to siding. Indicators are provided at all switches. At the end of



Positive Charging Wire on Track Side.

Fig. 56.

STANDARD ARRANGEMENT OF LINE WIRES FOR AUTOMATIC BLOCK SIGNALS USED ON THE LAKE SHORE & MICHIGAN SOUTHERN R. R.

commencement of a third or fourth track route-directing signals are provided. At interlockings the interlocking distant signal acts as the distant signal for both the interlocking home signal and the automatic block signal in advance. At other places the distant signal for a block in advance is placed on the same mast with the interlocking home signal, and the distant signal for the interlocking home signal is placed on the same mast with the automatic block signal at the rear of the interlocking plant, all home signals being slotted and route-locking being provided.

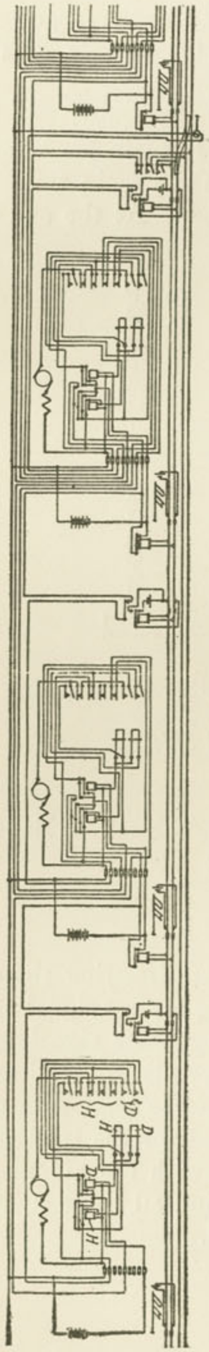


Fig. 57.

Normal Clear Automatic Block Signal Circuits as Used on the Lake Shore & Michigan Southern R. R.

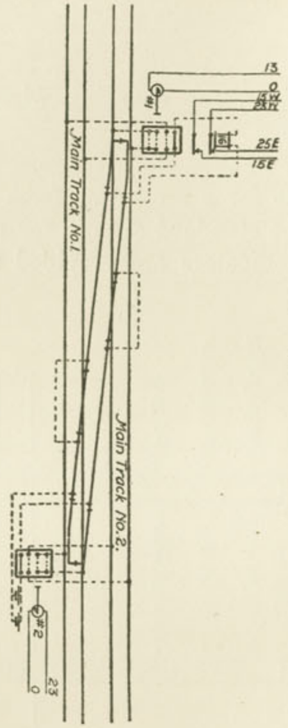


Fig. 59.

Cross-Over Circuit, Main Track to Main Track.

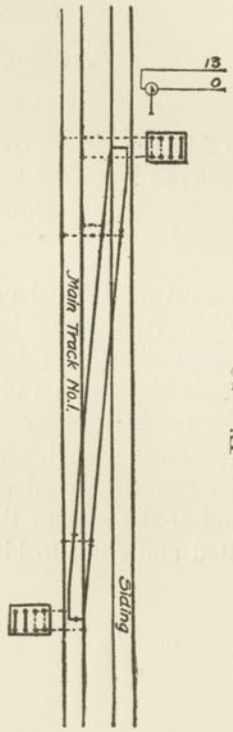


Fig. 58.

Cross-Over Circuit, Main Track to Siding.

Automatic Electro-pneumatic Systems. On a considerable number of electrically operated roads the electro-pneumatic signals are used. Where the trains make certain stops, as on suburban lines, the signals are generally set normal clear, and the stops are generally normal danger. The signals are operated primarily for a closed track circuit, which is energized by alternating current furnished from transformers along the line. As used on some systems, these transformers have a primary winding for 1,100 volts, and two secondary windings, one to supply the track circuit at 10 volts, and the other to supply the current for lighting the signals at 55 volts. The return circuit is through one of the rails, which is divided into blocks for the signal system. The 10-volt alternating current is fed into one end of the block through a cast iron grid resistance, which can be adjusted to suit the local conditions of the block it is to feed. An alternating current relay is bridged across the two rails of the track at the opposite end of the block from the track feed. This relay will respond only to alternating current. Its windings, however, would be subjected to the heating effects of returned direct current were it not for a low resistance impedance coil which is bridged across the terminals of the alternating current relay, and shunts out the direct current from the relay, at the same time offering enough impedance to prevent any appreciable shunting of the alternating current. A pair of battery mains at 14 volts are extended the entire length of the line. It is fed by six sets of storage cells, which are kept charged from the third rail. This battery circuit is used in actuating all magnetic valves on the pneumatic movements, and also for actuating the direct current relays which are used to light the signals.

The operation of the block signal may be briefly described as follows: Alternating current is fed into the leading end of the block, and is taken from the entering end of the block to an alternating current relay. When the train enters the block, the presence of an axle between the rails of the track shunts the alternating current relay, de-energizing it and breaking its secondary circuit. The secondary circuit is from the 14-volt battery mains through the magnetic valves on the cylinders of the signal mechanism. The breaking of this contact de-energizes the magnetic valves, allowing the air pressure in the cylinder to exhaust. A counterweight on the signal blade then draws the blade to the danger position by the action of gravity. The movement of this blade is repeated to the distant blade through a wire extending back one block.

As the train leaves the block the shunting action of the axle is removed. The alternating current relay is again picked up, closing its secondary circuit. This in turn energizes the magnetic valve, applying air to the cylinder, which draws the blade to the clear position against the action of the counterweight. It is apparent that the breaking of any wire of the signal or air pressure will cause the signal to fall to the danger position. The only possible means for a clear failure are a defective alternating current relay, or foreign currents applied directly to the magnet valve circuit.

Air pressure is supplied at 90 pounds per square inch through a two-inch galvanized iron pipe, which extends the length of the line. This pipe is supplied from air compressors which may be driven either by steam, gas or electric power.

Electro-gas Signal. One of the latest developments in automatic signaling has been the design and adoption of the electro-gas signal. The controlling power of the electro-gas signal is electricity, and the operating power liquified carbonic acid gas. The liquified gas, stored in a receptacle in proximity to the signal is normally at a pressure of from 600 to 1,200 pounds per square inch, and is reduced through a regulating valve to from 40 to 60 pounds pressure per square inch for the operation of the signal.

As constructed by the Hall Signal Co., it is used not alone as an automatic signal, but it is taking the place of advance home and distant mechanical signals at interlocking plants, where the latter cannot be reliably operated from interlocking cabins by mechanical connections.

The Hall Electro-gas Signal mechanism for a two-arm semaphore is shown in Fig. 60. The signal rod which operates the semaphore arm is connected to the clamp 31 attached to the cylinder rod, and the gas, when admitted to the cylinder 1, causes the cylinder and its rod to move upward, and the arm to assume the clear position. The cylinder is movable, and its piston is fixed. The flow of gas into the cylinder, and its egress therefrom, are controlled through valves 9-10, which in turn are controlled by the electro-magnets 16. The lever or clutch which holds the

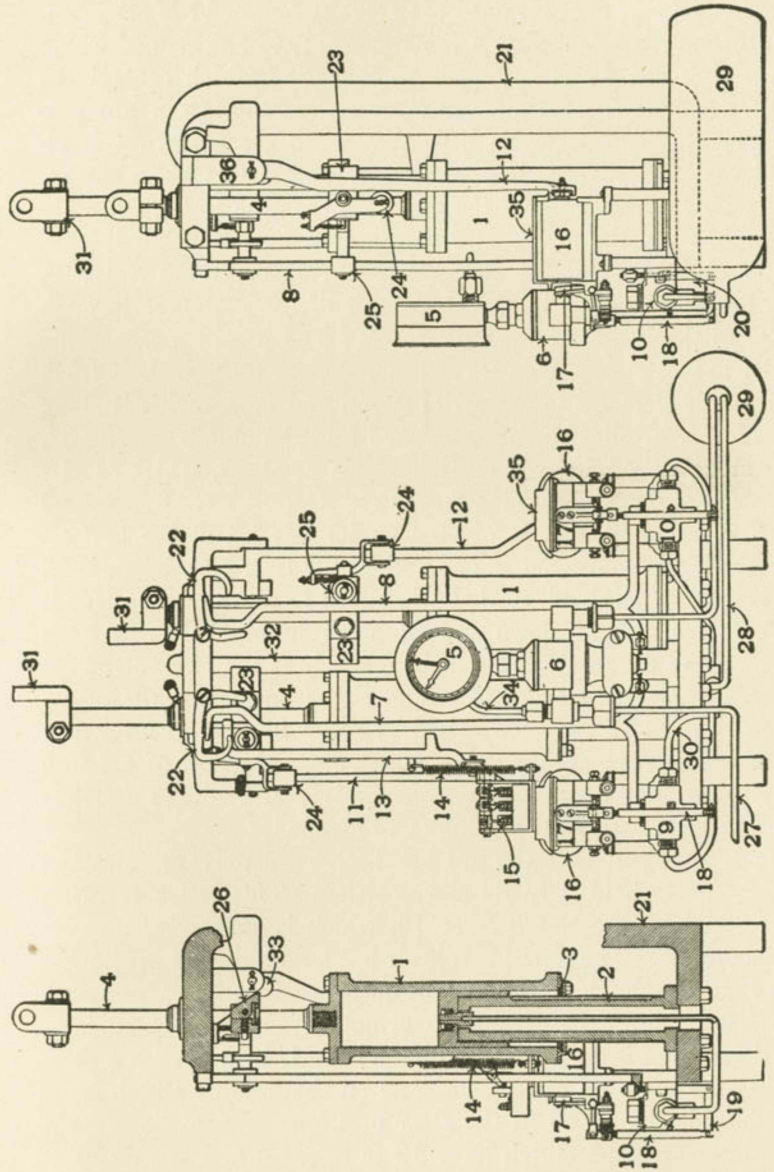


Fig. 60. Electro-Gas Signal Mechanism for Two-Arm Semaphore. (Hall Signal Co.)

signal clear is controlled by a back armature on these magnets. When the magnets are energized the front armature 17 is attracted. This armature is attached to a pivoted crank, to one arm of which a connecting rod 16 is fastened. The valves which control the flow of gas into the cylinder and its escape therefrom are controlled by this connecting rod, so that when the armature is attracted the supply valve is opened and the exhaust valve closed, which makes a free path for the gas from the tank to the cylinder. This path, from the gauge and regulator 5-6, is through the expansion chamber and its connection 29, through the valve 9, which has been opened by the movement of the armature through tube 30 to the inside of the cylinder 1. The pressure causes the cylinder to move upward on its piston and clear the signal. Clutch casting 23 is clamped to the cylinder rod and moves with it along the guide 32. Roller stud 25, screwed into the clutch casting 23, moves along cut-off lever 8 until it raises pawl 22, which is pivoted on a stud screwed into the frame 21. Cut-off lever 8 is shaped like an inverted T, and is pivoted on its left leg at the bottom. The right leg is connected to one end of the link 20. The cut-off lever is counterweighted, so that when free to move on its pivot it will force the link 20 down and close the supply valve. At the same time the exhaust valve will be opened, as the two valves are connected, and any movement which closes one opens the other. As soon as pawl 22 has been raised by roller 25, cut-off lever 8 is released, closing the supply valve, which stops the flow of gas into the cylinder and opens the exhaust valve, and allows the gas which has been used in the cylinder to escape.

It is apparent that the gas has been used only to raise the cylinder, not to hold it in its new position. This latter function is performed by the clutch lever 12, which is suspended on pivoted bearing 36. The top of this lever has a nose-shaped projection which engages a latch on the back of clutch casting 23. The lower end of clutch lever 12 carries an armature for magnet 16, and when the magnet is energized the clutch lever is held in such a position that the latch on casting 23 rests on the nose of clutch lever 12, and holds the signal in the clear position. When the magnet becomes de-energized clutch lever 12 is released and the counterweight of the signal, falling, causes clutch lever 12 to fly backward on the pivot 36 a sufficient distance to allow the latch and

clutch casting 23 to pass the projection on the clutch lever 12; and the signal drops to the stop position. The escape of gas or air from the cylinder through the exhaust valve is so regulated that the piston and cylinder become a dash-pot, preventing any violent drop of the cylinder when the signal assumes the stop position. Circuit breaker 15 is used to control the distant and other circuits. It is operated by rod 13 through a crank. The upper end of rod 13 is bent at right angles and has a lug, as shown. Roller 25 moves 13 up by striking against the bent

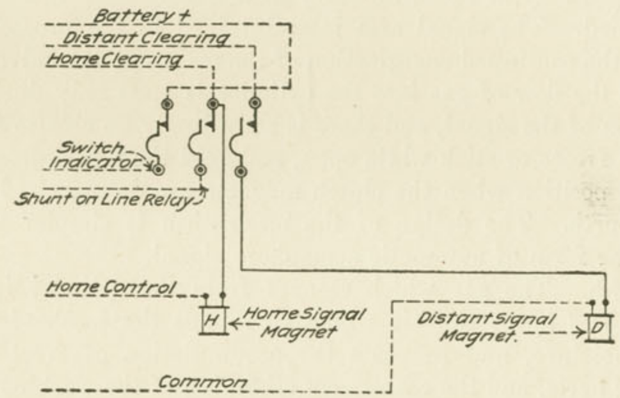


Fig. 61.

Wiring for Normal Danger, Double Track, Hall Electro-Gas Automatic Block Signal.

top, or down by striking the lug. Spring 14 will pull 13 down in case the lug should break. Cut-off lever 7 is left-handed, and 8 is right-handed, and the same is true of 11 and 12.

The piston and cylinder are made of phosphor-bronze, ground to a true fit. The cylinder being inverted and moving on the piston, it can have a solid head, certainly preventing the entrance of water. Its pedestal has a brass bushing.

The local wiring arrangement for an electro-gas mechanism, when used in the normal danger systems, is shown in Fig. 61.

Advantages of the Hall Electro-gas Signal. In addition to the small cost of operation, the following advantages are claimed for the gas signal over other forms of automatic semaphore signals, viz:—

First. As an independent power signal, its advantages over all forms of compressed air signals are apparent, in that the power for each signal is independent of all other signals in a system, and any derangement or accident to the connections of a signal affect that signal only.

Second. The power available to operate the gas signal can be made as great as desired; accordingly the counterweight of the signal arm may be made as heavy as desired.

Third. The signal arm is maintained in the proceed position by the continued energization of the magnets; the valve which controls the flow of gas into the cylinder is open only during the operation of the signal, and there is accordingly no chance for this valve to freeze or stick while open, and hold the signal arm in the proceed position when the clutch magnets are de-energized.

Fourth. The design of the mechanism is simpler than in any other form of automatic semaphore signal.

Fifth. The gas which escapes from the cylinder into the signal cases keeps the air which surrounds the mechanism free from moisture, and prevents the accumulation of frost on the working parts, and the consequent stiffening of the working joints.

Sixth. There are no delicate parts in the mechanism, such as motor commutators, that are affected by exposure to weather influences. From tests made in actual practice, it has been found that the electro-gas signal will reliably operate when exposed to the severest storms.

Seventh. On account of the small amount of electrical energy required to operate the clutch magnets on the gas machine, quite as good results are obtained from potash batteries placed in the signal cases during severe winter weather as during the milder seasons.

Automatic Stops. An automatic stop is a piece of apparatus which may be operated either mechanically or by means of an electro-magnet, which is used for stopping trains by some means which is operated from outside the train. In the simplest form an automatic stop consists of a trip fixed on the roadway and moving in unison with the usual visual signal. This trip is made

to operate an air valve on the engine or car, thereby applying the power brakes or shutting off the propeller power independently of the engineman or motorman.

Automatic signals reach their highest perfection in such installations as those on the New York subway and the Boston and the Philadelphia elevated road, where automatic stops are provided to guard against physical or mental disablement, or carelessness on the part of the engineman or motorman. Because of the difficulty of maintaining this auxiliary apparatus on lines exposed to drifting snow and carrying a heavy miscellaneous traffic, and also because of the cost of maintenance and the reduction in the traffic capacity of the railroad, the automatic stop has not yet been used, except in special conditions like those of the roads named.

Signal Circuits. Commercial signal circuits may be divided into two kinds, one known as the control circuit, and the other as the working circuit. A control circuit has usually a low voltage, and the circuit wires are not of great length. The most common type of control circuit is that constituting what is ordinarily termed the track circuit, which includes the rails of the section to which it is applied, with the requisite track battery relay and interconnecting rails. The primary purpose of the control circuit is to close and open the circuit, the latter delivering considerable energy and operating the devices included in the direct operation of the signal semaphore. The working circuit, therefore, includes the mechanism of the semaphore. The main battery, which is in this circuit, is always open-circuited, so that the working circuit is only in operation when the control circuit affects it.

Signal Relays. The relay is a most vital part of a railway signal system, as it is on its action that the performance of the other apparatus depends. In a track circuit the relay is delicately adjusted to close its armature on the passage of the weak current of the track circuit. This in turn closes the strong local circuit which works or controls the signal. When the armature of the relay is attracted it closes front contact, and when the coils on the magnet are de-energized and the armature falls away by gravity, or is drawn away by a spring, it closes a wire contact. A relay often has an armature which bears on a number of contacts, so that a number of different local circuits may be opened and closed by its action.

Track Circuits for Automatic Block Signals. The track circuit is the vital feature of modern block signaling, and has made the present high development of automatic signaling possible. Its essential feature is a section of track insulated at each end from the adjoining sections of the track. Each rail in the section is connected to the ones adjoining by bond wires, for the purpose of making a continuous conductor from one end of the section to the other. The contacts made by ordinary rail splices are not good electrically owing to wear, rust and the loosening of bolts. Two bond wires are usually used at each joint, so that should one break, the circuit will remain continuous through the other. These bond wires are secured to the rail by means of "channel pins," or other

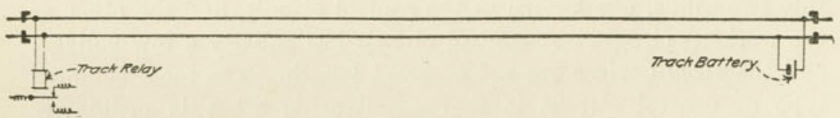


Fig. 62.

Simple Track Circuit for Automatic Block Signals.

suitable devices. On electrically operated roads, where tracks are bonded for the return propulsion current with heavy copper bonds, no additional bond wires are necessary. At one end of the insulated track section is a battery, the positive terminal being connected to one rail and the negative terminal to the other. At the other end of the section is a relay connected to the rails in a similar manner. Fig. 62 shows a typical track circuit. Current flows from the positive side of the battery through the lower rail, the relay and the upper rail back to battery. This keeps the relay energized.

Fig. 63 represents an arrangement of track circuit and connections for normal clear automatic block signals. If the car or train occupies the track between the insulated joints, J-J, it shunts the relay R. This allows the armature to drop, opening the local circuit, de-energizing the magnet, which, when energized, holds the signal in the clear position.

Elements Affecting the Track Circuit. Notwithstanding the fact that the track circuit is the governing and most important factor in an automatic signal system, it has only been within recent years that its principles and theory have been generally understood by signal engineers. There are five principal elements in a track circuit which govern its operation: First, the voltage and internal resistance of the track battery; second, the resistance of the rails and joints; third, the leakage between the rails; fourth, the resistance of the relay coils; and fifth, the leakage through the insulated joints. In addition to these, stray earth currents or foreign currents frequently cause interference with the operation of the track circuit. The resistance of the relay coils is the only constant in the above qualities.

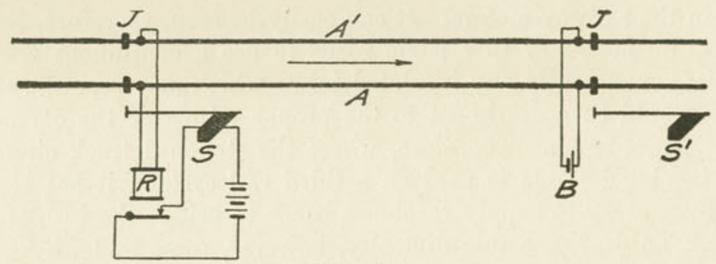


Fig. 63.

Track Circuit and Connections as Used on Normal Clear Automatic Block Signals.

Reliability of Track Circuits. Since the conditions which enter into the control of a track circuit are known, it is feasible, by proper attention to batteries, proper bonding, care of ballasting, regulating the length of track circuits, etc., to control these conditions and operate track circuits very reliably. Experience gained by the use of track circuits, the limits of variation of the track battery, rail resistance and track leakage, have caused these factors to be more thoroughly understood. Among the most troublesome factors in track circuits is the leakage through the insulated joints and its protection against foreign currents. At the present time these are still very troublesome factors in the operation of track circuits, and, although the methods of control may be said to be comparatively reliable, they will never be absolutely so until these leaky factors have been entirely removed.

Insulated Joints. Joints have always been considered an essential for the separation of blocks in automatic signal installations, and the efforts of signal engineers have always been to improve the design and manufacture of these joints. Notwithstanding the fact, however, that there has been a large number of improvements made in the joints for installation between rails, a perfect joint which has no disadvantages has not yet been devised, and it is claimed by signal engineers that any form of joint is a drawback to signal systems and the maintenance of the track.

With the advent of the electric locomotive the insulated joint has become a still greater problem, because in third rail systems the running rails are used as conductors for the return of the current used in the railway motors. It can easily be seen, therefore, that it is quite necessary in electric roads to use a continuous track circuit; consequently any insulated joints which may separate the blocks would be a detriment to the proper return of the current to the power-house. Therefore, where the standard track circuit with insulated joints is used on a third rail system, it has been found necessary to supply reactance bonds to bridge the insulated joints. To overcome this difficulty, however, some systems have been installed for electric roads in which one rail was used for the return power current, the insulated joints for the separation of the block sections at the signals being provided in the other rail.

Track Relay. The track relay is a development of the instrument of the same name used in the telegraph. It consists of an electro-magnet of the horseshoe type, provided with an armature. The armature is attracted to the magnet when the latter is energized, and is drawn away by gravity or by a spring when the magnet is de-energized. The armature carries one or more fingers for making or breaking electric circuits through points or stops.

The presence of a pair of wheels or train in the section will short-circuit the battery, shunting the current out from the relay and causing its armature to drop, because the resistance through the wheels and axle of an ordinary car or engine is infinitesimal compared with that of a relay of $3\frac{1}{2}$ ohms or more. Consequently the relay is deprived by the wheels and axles of current necessary

to maintain its attractive power for the armature. The minimum resistance usual in track relays is $3\frac{1}{2}$ ohms.

In normally open-track circuits the resistance of the relay should be lower than in normally closed. Their use is necessarily limited to track sections of a few rail lengths only; in longer sections the low insulation resistance from rail to rail would allow the flow of enough current to hold up the relay after a train had passed out of the section. Gravity battery should not be used unless the traffic is very heavy, as a gravity cell soon deteriorates and becomes inoperative on an open circuit.

The use of normally open-track circuits is also limited on account of the fact that there is no certainty that the relay will pick up. Any failure of the apparatus, such as a broken rail, exhaustion or breakage of the battery cell, breakage at any of the wires, will render the apparatus inoperative. Such failures are not readily detected, as they merely maintain the apparatus in its normal condition. With a normally closed circuit the reverse is true. Here any failure will be almost immediately detected, and will be on the side of safety.

Voltage and Length of Track Circuits. Circuits for the control of various signaling devices are broken through the contact points of the track relay. Such apparatus cannot be operated directly by the track circuit, because to furnish them with sufficient current a battery of large electro-motive force would be needed. On account of the low insulation resistance of the ties and ballast it is unwise to use a battery of more than two volts potential. With any higher voltage the leakage from rail to rail, especially in wet weather, becomes equivalent to the presence of a train in the section. For the same reason track circuits cannot be made of unlimited length. The resistance of the rails also has to be considered in determining the length of a track circuit.

Where it is necessary to control signaling apparatus by track circuits over such a length of track that one circuit would not work, two or more circuits are employed. The control circuits may be broken through the relays of the successive track circuits, or "cut sections" may be introduced.

Batteries for Track Circuit. Almost any kind of closed circuit primary battery can be used to supply current to a track circuit, but in practice gravity or storage is ordinarily used. Gravity battery is used to a greater extent than any other type of primary battery on account of its suitability to closed circuit work. It has a high internal resistance compared with its electro-motive force, and, therefore, will not exhaust so rapidly as other types. Potash or soda batteries might be used by inserting resistance in the same manner as with a storage battery, except that they are found not to be so economical in practice. When a gravity battery is used not more than two cells are usually placed in series.

When the secondary or storage battery is used it is necessary

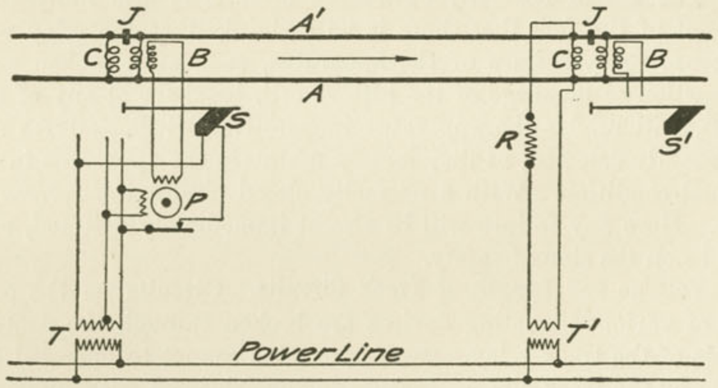


Fig. 64.

Simple Alternating Current Track Circuit Using One Rail for Signal Track Circuit.

to insert a resistance in one or both battery leads to restrict the flow of current, and prevent the battery from becoming exhausted by the passage of one train, and otherwise injured by over-discharge, as explained in the definition of storage batteries.

The Alternating Current Track Circuit. In the signaling of roads employing steam as the motive power, the track circuit is comparatively simple. When, however, the rails are required to carry the heavy currents called for by electric traction, the track circuit problem becomes more difficult.

First. Because the rails must be made electrically continuous throughout to serve as a return for the propulsion current,

and, at the same time, must be divided into electrically insulated sections as far as signaling current is concerned.

Second. Because the traction current flowing in the rails would tend falsely to operate the track relays were they of the usual direct current type; hence, the necessity of employing relays which are unaffected by the traction currents, and supplying a signal current of the right character to operate them.

Third. Because of traction purposes cross-bonding between

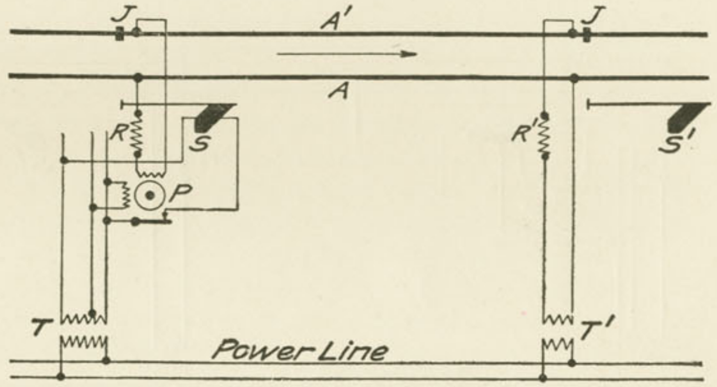


Fig. 65.

Signals Controlled by Alternating Current Track Circuits.

tracks is necessary at frequent intervals, thus influencing the arrangement of track circuits.

Figs. 64, 65 and 66 show three types of track circuits, which fulfil the requirements imposed by electric traction. In all of these alternating current is used for signaling purposes. The track relay contacts are operated by a small two-phase induction motor, one winding of which is energized through the track rails, and the other winding direct from the power line. This relay is not affected by direct current, no matter what frequency, within reasonable limits, is used for signaling, and is not affected by alternating current if a frequency distinctively different from that of the traction current is used. For in a two-phase induction motor, if the phase in one set of field coils varies greatly from that in the other, the motor will not operate. As both sets of fields in the two-phase induction motor relay are fed from transformers on the same single-phase power line, some agency must be provided to produce different angles of lag in the two secondary circuits, otherwise the relay would not act. Such agency exists in the different apparent resistances of the line circuit and the track rails; also in inductive and impeding effects of the rails and bonds. It is not necessary, however, to use two-phase motor relays,

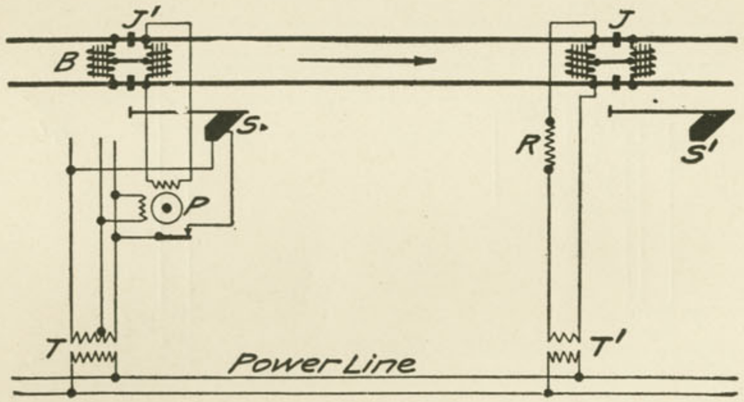


Fig. 66.

ALTERNATING TRACK CIRCUIT USING TWO RAILS FOR CONTROLLING THE SIGNALS.

as single-phase induction relays may be used, but where the track circuit is long and leakage heavy it is better to use two-phase relays, as they have a good torque with a small current from the track.

Single and Double-rail A. C Track Circuit. On account of the fact that alternating current is used for signaling, and that either one or both of the rails may be used for the propulsion current return, the circuits are known as "Single-rail A. C. Track Circuits" or "Double-rail A. C. Track Circuits."

Fig. 64 shows the "single-rail" circuit, which is the simplest form of A. C. track circuit, and is only used where it is permissible to give up one of the rails for signaling purposes only. It is best adapted to roads employing direct current for propulsion. The rail A is continuous throughout, and is used as a return for the traction current. Rail A^1 is insulated at the joints J-J, and is used only for the signaling current. P is an alternating current relay of the two-phase type. When both windings are energized the motor revolves, and being geared to the contact closes it, the contact acting as a stop to the movement of the armature, which now ceases to turn, but bears against the contact, holding it closed.

When a train enters the track circuit the current from transformer T^1 is shunted out of the relay, as already described, in the ordinary direct current track circuit, and, although current from the transformer T still continues to flow through one winding, the motor loses its torque, the armature is revolved in reverse direction by gravity and the relay contact opens.

R and R^1 are resistances so proportioned that the drop in potential in rail A, caused by the flow of traction current, will not cause injurious currents to flow through the relay P, or the secondary at the track transformer T^1. The resistance R^1 also prevents an excessive flow of current from transformer T^1 when a train is standing at the transformer. These resistances are of the non-inductive type. They are made of cast iron grids. It can readily be seen from their form that current passing through them produces no magnetic effects. The grids are mounted on two or more rods, which are provided with the necessary insulation, and can be built up to any desired resistance. On roads using direct current for propulsion where traffic is heavy it has also been found desirable to use a small impedance coil or "ironless" reactance bond connected in multiple with the track winding of the relay. This coil, being of very low ohmic resistance, assists the grid R in keeping direct current out of the relay.

T and T^1 are step-down transformers, which reduce the voltage from the power line to that required for track circuit and other purposes. Cross-bonding for traction purposes may be made at any point on the continuous rail A.

Fig. 65 represents a type of alternating current track circuit in which both rails are retained for propulsion purposes, and which permits of cross-bonding from one rail of either track to one rail of the other track at any point desired. It is best adapted to installations where the track circuits are very long, and where the traffic, and consequently the propulsion, current return is light. It is applicable only to roads using direct currents for propulsion. Rail A is continuous throughout, and rail A^1 is divided by the insulated joints JJ. Both rails are available for the propulsion current, rail A because it is continuous, and rail A^1 because it is made continuous by the "transformer bond" B and "reactance bond" C, which are of very low ohmic resistance, and have a current capacity of half that per track. The "transformer bond" B has a secondary winding, as shown, which is connected directly to and energizes one of the windings of relay P. If the relay winding in question were connected directly to the rails, an excessive amount of direct current would flow through it, owing to the low resistance of the relay winding and the drop of potential in the main coil of bond B, due to the flow of traction current; hence, the secondary winding on this bond.

The track relay P and its operation are the same as described for Fig. 64, and the transformers and resistance grids are of the same general character. With good rock ballast track circuits of this type, up to 9,000 feet in length, have been operated satisfactorily. It is, however, possible to operate with equal satisfaction track circuits of twice this length by placing the energy transformer bonds B and track relays P at both ends, the signal control circuit being carried through the contacts of both these relays in series. If cross-bonding is required to the insulated rail at the center of the section, a reactance bond C would be connected across the rails as shown.

Fig. 66 shows another type of alternating current track circuit, in which both rails are retained for propulsion purposes, but in which cross-bonding to adjacent tracks can occur only at the ends of track circuits. This type of track circuit is especially adapted to roads where the traffic is very heavy and the blocks of medium lengths, and is applicable to either alternating current or direct current traction. As shown, both rails are insulated at the signal locations by the points J, and are made continuous as concerns the traction current by the iron core reactance bonds B. The bonds consist of a few turns of very heavy copper wound around a laminated iron core, and so connected to the rails that the traction current in each rail flows through one-half the bond in such a manner as to have no magnetic effect unless more current is flowing in one rail than the other, in which case there would be a tendency to saturate the iron core and thus reduce the reactance of the bond. The tendency is, however, limited by an air gap in the magnetic circuit. This difference of current is called unbalancing. This can be better understood if it is noted that propulsion current flows in the same direction in each rail, Therefore, the bond is in effect two electro-magnets of equal strength wound on the same cores in opposition. Thus the magnetic effects due to direct current in one winding will neutralize those in the other, unless more current should flow in one rail than in the other. If the iron core were continuous, the effect of an unbalanced propulsion current would be to shift the neutral magnetic point along the core a distance proportional to the amount of unbalancing. For this reason the air gap is introduced in the magnetic circuit, and the wider the gap the less the neutral point will shift for a given amount of unbalancing, because air is a poor conductor of magnetic lines of force compared with iron. But the wider the air gap is made the lower becomes the inductive effects of the iron, (which is a maximum when the core is continuous), and the greater the leakage of alternating current across the rails, due to the impaired reactance.

Track circuits, as shown by Fig. 65, may be satisfactorily operated to a length of about 2,500 feet, and to a length of 5,000 feet by applying the energy at the center of the section.

Coleman System of Signaling. Since an ordinary track current is not available for successful block signalings on alternating current track circuits, other systems have, of necessity, been devised, one of which merits a particular description. This system is known as the Coleman system of signaling for electric roads, and was placed in operation on the Long Island Railroad in June, 1908; and it is said that there has not been one failure of operation of the system since that time. This system does not require the use of insulating joints, and is, therefore, particularly advantageous on any line of railroad, but more especially one using an alternating current circuit. On the Rockaway Beach Division of the Long Island Railroad the electric trains are operated by the third rail system, with 500 volts direct current as the operating power. At the sub-station an alternating current is transformed from 6,600 volts, 25 cycles, to 2,200 volts, 25 cycles, at which voltage it is carried through the different sections of the road where automatic signals are used on two No. 2 bare copper wires for the signal supply current. A three kilowatt step-down transformer is used for reducing the voltage to 220, which is the voltage used for the signal supply for the system. Fig. 67 shows the locations of the signals installed with the Coleman system of track circuit control. It will be noted that the signals for both directions are located on one side of the track, which in this particular case is found necessary in order to obtain a view of the signals, as the telegraph line obstructs the view on the other side. The blocks are approximately 2,700 feet in length, and home and distant signals are used as on other sections of the road. At each signal location a storage battery of five cells in duplicate, charged from the third rail through resistance, is used for operation of the motors and slots. At one of the signal locations, however, the storage battery is not used, but in its place is substituted a rectifier of special design which is connected to the alternating current circuit through the regular relay transformer, which provides a direct current at 12 for the operation of the motors and slot magnets at this location. Fig. 68 shows the circuit for the operation of the track circuit. At each signal location two No. 0000 copper cross-bonds connect the rails, forming a short-circuit between the rails and these points. A track transformer, the primary of which is connected to the signal supply wires, and the secondary to the two rails, and which supplies alternating current at 25 cycles at approximately 4 volts to the track, is provided at the center of each block. A path for this current is from secondary connection "A" to the rail "B," through cross bonds "C," rail "D," connection "E," and then to the other side of the transformer secondary. At the same time a current of equal value passes from the secondary connection through the other rail, cross bonds, to the transformer, so that the alternating current passes continuously through both rails throughout the block. At each end of the block a coil of wire is placed along the rail, with its terminal connected to the armature of an alternating current relay of the two-circuit type. This coil is wound continuously as in a transformer or magnet coil along and between the rails. The wire is protected from mechanical injury by angle irons along the

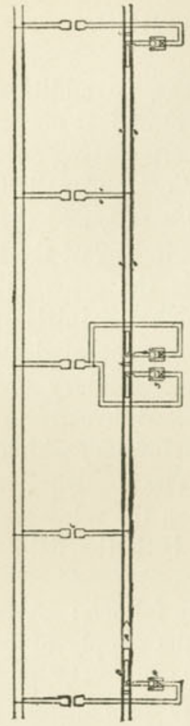


Fig. 68.
Track Circuit.

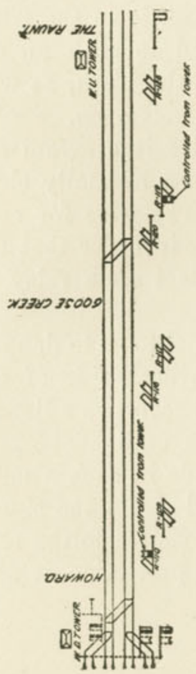


Fig. 67.
Coleman System of Track Circuit Control.

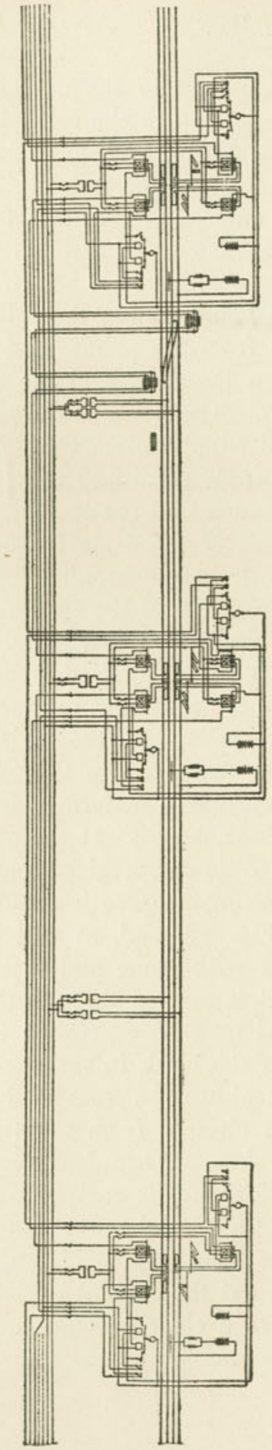


Fig. 69.
Complete Operation and Signal Circuit Diagram of the Coleman System of Signalling.

rails and clamped to them. These angle irons, in addition to forming protection to the coils, increase their electrical efficiency by providing a core. As shown in Fig. 68, the alternating current which passes along the rail "B," cross bonds "C" and rail "D," produces a current of the same frequency in this coil, and the induced current is carried through the armature winding of the two-circuit relay "R." This action on the coil is the same as the action of a transformer; the rails through which the initial current passes from the primary of the transformer, the angles and clamps form the core, and the coil forms the secondary of the transformer. The fields of the relay are connected directly to the main signal supply wires through a field transformer, which reduces the supply from 220 volts to 55 volts. The construction of the relay is such that the operation depends upon the relay receiving a current of the same frequency through both the field and armature coils in synchronism.

The operation of the Coleman system is as follows: A train entering a block as at "A," Fig. 68, cuts off the supply of track coil "B," which is supplied from track transformer "C," and in consequence the armature or track relay "R" is de-energized and the contact opens. As the train proceeds in the block and approaches the center where the connections are made to the track transformer, this transformer is short-circuited to such an extent that the relay "S" at the opposite end of the block, as well as relay "R," is de-energized and its front contacts open.

The complete operation and the signal circuit diagram are shown in Fig. 69, and, as will be noted, it is a normally clear wire circuit with home and distant control. The wire for each home signal is carried through the home block, in order that the home signal may be controlled through a contact on a relay at each end of the block in series circuit.

The breaking of a cross bond causes the signal to go to danger, because the circuits from the transformers on each side of the bond are broken. When, however, a train is between two adjacent track transformers, it completes a circuit from each. The connections of the transformers and relays are made in such a manner that the train approaching the broken bond clears the signal in advance, but the current to the train from a source to the rear will not give a clear indication. Broken rail protection is also

afforded on both rails, since a broken rail will cut off the supply to the track coil at one end of the block and de-energize the relay at that end. It is also feasible with this system to cross-bond between tracks on a two or more track road at each signal location without interference with the operation of the system or the protection afforded by it.

This system is equally practicable for steam roads. The only effective remedy for foreign current interference with the operation of track circuits is the use of alternating currents for track circuits, with relays which respond to the alternating current supply only. Not only does the system provide these safeguards, but, by dispensing with the insulated joints, it provides a track circuit free from the serious defects of direct current track circuits as ordinarily used.

Signal System Used in the "Electric Zone" of the New York Central & Hudson River R. R. The signal system designed by the General Railway Signal Co. and installed at the New York City terminal of the New York Central & Hudson River R. R. illustrates the use of an automatic electric block signal system for a direct current electric road, in which alternating current is employed for the operation of the track circuits and all the signal devices.

The signals are of the two-arm, two-position, semaphore type, with a full block overlap arranged on the normal clear principle. The signals are spaced from 800 feet to 3,200 feet apart to conform to the condition of the grades, the allowable speed at different points and the safe braking distance.

Twenty-five cycle, single-phase alternating current is used for the operation of the entire block signal system. It is normally obtained from the railroad company's 11,000 volt, 25 cycle bus-bars, and stepped down, by means of static transformers, to 2,200 volts for distribution. As a reserve, in case of failure of the 11,000 volt power, motor generators are installed taking power from the railroad company's 650 volt storage battery. The switchboard circuits are arranged so that the transformer and motor generator can operate signly or in multiple, as desired.

There are eight sub-stations, arranged six miles apart, varying in capacity from 60 to 100 k. w. In addition to the power required for the block system, these sub-stations also supply the power for operating the battery, charging motor generator sets, signal lights, indicators, relays, etc., employed in the interlocking plants in the Electric Zone.

The transmission line is interrupted midway between adjacent sub-stations, so that normally each sub-station feeds both ways, being independent of its neighbor; this to avoid the need of keeping them in synchronism. In case of emergency, however, the transmission lines can be connected at the center and be supplied from either sub-station. The transmission line is partly aerial and partly underground. The aerial line consists of No. 0 hard-drawn copper wire strung on the railroad company's transmission line poles on the inside pins of the lower cross-arm. The underground line consists of No. 6 twin conductor lead-covered cable run in tile ducts or iron pipe, as required.

Small 2,200 to 55-volt line transformers, from 1 to 5 k. w. capacity, are suitably located near each group of signals or other required centers of distribution. They are connected to the aerial lines by plug cut-outs, so designed that a transformer may be disconnected without danger. They are connected to the cable lines by combined fuse and junction boxes. Cartridge fuses are supported on porcelain insulators and mounted in separate slate compartments, and the cables terminate on binding posts, so that either cable may be disconnected without disturbing the other. The 55-volt line transformer secondaries are protected from the 2,200-volt primary in case of insulation failure by a grounded shield.

Double-rail alternating current track circuits with iron core reactance bonds are employed. Each reactance bond is wound with eight turns of copper, having a sectional area of one square inch, with a continuous carrying capacity per track of 5,000 amperes, a short-time overload of 10,000 amperes and an unbalancing capacity of over 1,000 amperes, the latter without varying the reactance over 5 per cent. The apparent resistance of the bond to alternating current is approximately five one-hundredths of an ohm.

The bonds are provided with an adjustable air gap in the magnetic circuit to limit the effect of unbalancing, as explained above, so that the reactance or unbalancing capacity can be varied as required to suit local conditions. The bonds are put up in pairs and mounted in iron cases. They are set between or outside of tracks. A connecting chamber is provided in the case between the coils, in which all coil ends terminate, and where all connections to the rails, transformers, relays and cross-bonds are made, and then concealed by a suitable cover.

The copper connections after leaving the bond terminals go downward and underground to the rails, where, after passing for a short distance above the ground to insure flexibility, they are connected to the rails.

This construction leaves the space between the ties and rails free from obstruction (thus facilitating the repair of the tracks), and also conceals the copper as much as possible, tending to prevent theft. The bond connections to rails consist of two 500,000 circular mill flexible cables in multiple. The coils are immersed in transformer oil. The track circuits and relay local phases are supplied with energy from small track transformers. The transformers are wound for a primary voltage of 55, a track secondary voltage, variable by means of taps, from 2 to 6, and a relay secondary giving two volts. The transformers have a closed magnetic circuit, and are provided with slate terminal boards having a binding post for each terminal or tap. They are oil-cooled, and are kept in water-proof iron cases, provided with six outgoing flexible leads.

The track relays employed on the Electric Zone are of the single-contact polyphase type. They are used as primary relays to operate secondary or repeater track relays, which in turn are equipped with a suitable number of contacts for the control of the various circuits. The relay is immune to the effects of direct current, and can be made immune to the effects of alternating current traction currents by employing a distinctively different frequency for signaling, it being apparent that the relay cannot operate unless the frequency in the track and local phases is in synchronism. All contacts and other working parts are visible through glass-covered openings. Rubber gaskets make the relay water-tight. These relays give a rubbing pressure between the contacts in closing, and are wide open when de-energized.

The secondary track relays, as mentioned above, and all motor control relays, are of the alternating current tractive type. These relays are equipped with a three-legged laminated magnet, having coils of different reactance, whereby a phase difference between the two coils is produced, the combination resulting in a uniform magnetic pull when the relay is energized by single-phase alternating current. The relay has a capacity of four front and four back contacts, and is wound to operate on 55 volts. It is glass-enclosed and made water-tight by gaskets. The track secondary relays are equipped with platinum to graphite contacts, and the motor control relays with heavy carbon to carbon contacts.

The signal mechanism is designed for heavy duty, high-speed service, it being necessary to clear the signals in two seconds. On account of the heavy spectacle used, the upward thrust on the operating rod is over 200 pounds. The mechanism is operated by a one-fourth horse-power single-phase induction motor, having starting and working coils. An automatic centrifugal switch is used to open the starting coils as the motor speeds up. The motor revolves in one direction in clearing the home arm, and in the other direction in clearing the distant arm, a ratchet arrangement being provided for this purpose.

Single-track Automatic Systems. Until within the past five years single-track lines (with one exception, the Cincinnati, New Orleans & Texas Pacific) made little use of automatic signals, for there are peculiar difficulties on such lines. To make the signals efficient in preventing collisions between trains running in opposite directions, the controlling circuits must be more extended and complicated than those on double track, for each of the two trains approaching each other must set signals at "stop" against the opposing train so far in advance of itself as to insure that both trains will receive stop indications in time to stop before meeting. And, in addition, when a train finds a signal at "stop" it must not proceed, as it would on double track, merely looking out for a train standing or moving in the same direction as itself, but must suffer considerable delay by sending a man ahead with a red flag or light, because there is the possibility that a train may be approaching in the opposite direction. In spite of these difficulties, however, automatic signals are being installed in large numbers on single-track lines by some companies. The arrangement of track circuits is such that every other insulated section controls signals for trains going in one direction, and the remaining section control signals for trains going in the opposite direction. These signals are placed on opposite sides of the track, so that they will be in view of the engineer when the train is going in either direction. These signals, moreover, are suitably interlocked by means of auxiliary contacts on the track relays, so that the train is actually protected for at least three blocks ahead.

The operation of the relays and signals is the same as used in connection with double-track signals, except that the signals are dependent upon three relays instead of one. Assuming a train entering a block, one signal is set behind the train and two in advance. Upon entering the next block an auxiliary contact on the next relay prevents the operating circuit from being closed through the signal protecting its rear, and another auxiliary contact prevents the signal farthest in advance from returning to clear. The intermediate signal, however, returns to clear, and operation is repeated on entering the succeeding block. Hence it will be seen that signals which are set for the guidance of trains going in the opposite direction return to clear as soon as they are passed, and the other signals turn to danger upon passing the signal, and remain at danger while the train is running through three blocks.

Overlap. When block signaling is used, the signals are so placed that the sections they control overlap; that is, a certain short section will be controlled by two signals, one at the beginning of one block, and the other at the beginning of the next block, so that, if a train should break down immediately after passing a signal, the preceding signal could not be clear, in which case an approaching train would be sufficiently warned to prevent its colliding with a disabled train.

On single-track lines, automatic block signals are arranged so as to prevent the occurrence of a collision between trains moving toward each other, which without overlap might pass clear signals at the same moment. The opposing signals are so situated that each train will encounter a stop signal before it can meet the other.

An arrangement of overlap is shown in Fig. 70. When signal A indicates stop, it cannot be cleared until the train has passed beyond the overlap, in which case signal B will indicate stop before A is cleared.

Batteries Used for Signal Installations. There are two types of batteries used in signal installations, the primary battery and the storage battery. When primary batteries are used they are always of the closed circuit type; that is, they are capable of withstanding continuous full normal current discharge. There are three types of primary cells used, Gravity, Gordon and Edison primary cells.

Gravity Batteries. In the gravity, which is of the two-fluid type, the different specific gravities of the liquids used is the only principle involved in keeping them apart, porous cups and diaphragms being thereby eliminated. The liquids used consist of a saturated solution of copper sulphite and a diluted solution of zinc sulphate and sulphuric acid, the acid being formed only during the action of the cell. The general arrangement of a gravity cell is shown in Fig. 71. The copper element is shown

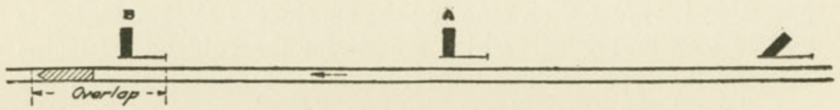


Fig. 70.

Overlap as Used with Block Signals.

at C, and rests upon the bottom of the jar, and is connected to the external circuit by an insulated wire. The copper is partly covered with crystals of copper sulphate, these coppers being surrounded by a strong solution of copper sulphate. Above this latter solution, and separate from it, is the solution of zinc sulphate, in which the zinc Z is immersed. The zinc is connected to the other side of the external circuit.

The action of a gravity battery is as follows: When the external circuit is closed the small amount of sulphuric acid which is always present attacks the zinc, forming zinc sulphate and hydrogen. The zinc sulphate remains in the upper part of the liquid, while the hydrogen passes to the copper sulphate, and thus forms sulphuric acid and metallic copper. The copper is deposited upon the copper element, while the sulphuric acid rises and attacks the zinc. This action continues as long as the external circuit is closed.

When a gravity battery is in proper condition there should be a blue line of separation about midway between the top of the cell. The electro-motive force of this cell or open circuit is about 1.1 volt, and the interior resistance will be found to vary ½ to 3 ohms. Under these conditions it will give a current or circuit varying from ½ to 2½ amperes. A gravity cell of this type is more commonly used for track circuits, its principal disadvantage, however, being its particularly high internal resistance.

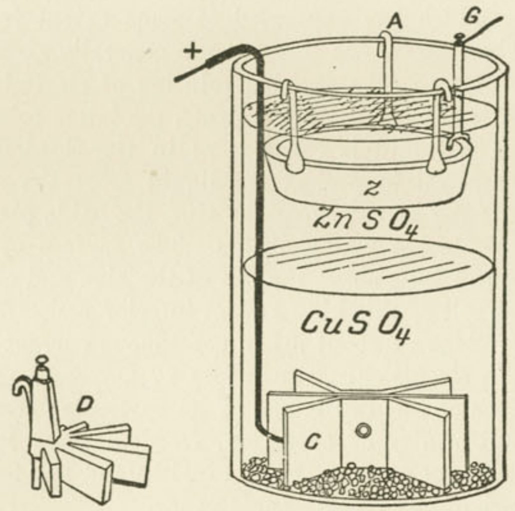


Fig. 71.

Gravity Cell Used in Signalling Systems.

Gordon Batteries. Another type of primary battery used for signaling is known as the Gordon cell, the elements of which are iron and zinc, while the electrolyte is a strong solution of sodium hydrate or caustic soda. In this type the positive zinc element is generally bent in a cylindrical form about ⅛ inch in thickness. It is thoroughly amalgamated to prevent local action, and is fastened to a perforated cylinder, which it surrounds. This interior positive cylinder is partly filled with a flaky oxide of copper, the iron and this compound forming the negative element. The electrolyte generally consists of a 25 per cent solution of caustic soda; that is, three or four pounds of water are used to one pound of caustic soda. A heavy mineral oil is used to cover the surface of the liquid. This is done because caustic soda has a strong affinity for carbon-dioxide in the atmosphere. An ordinary cell of this type is what is known as a 300-ampere hour cell, the jar being about 6 inches in diameter by 8 inches high. When the cell is renewed it is usual to throw the entire cylinder and its contents, and also the zinc, away and to renew the entire interior of the cell.

Edison Batteries. The Edison battery is another type of primary battery which has been used to some extent for signaling purposes. The elements of this cell are generally zinc plates and copper oxide plates. The exciting solution or electrolyte consists either of caustic soda or sodium hydrate, the latter being the more preferable. The liquid is covered, as in the Gordon cell, with a heavy mineral oil to protect the liquid from the atmosphere. The cell is renewed by removing the zinc, the oxide plates and the solution and replacing new elements. The surface of the liquid should be about 1 inch above the top of the zinc and oxide plates. A 300-ampere cell of this kind has an interior resistance of about .025 ohm, a voltage of about .67, a continuous current of about 6 amperes, and a circuit current of about 27 amperes. The low interior resistance of this cell is one of its particular advantages, as is also the uniformity of operation, freedom from local action, constancy of current output, ability to withstand low temperatures and the absence of any objectionable vapor.

The principal disadvantages of both the Gordon and Edison cells are the low terminal voltage, the rapidity with which they give out and the excessive heat caused by the dissolving of the caustic soda in water. The use of oil on the surface of a liquid is also rather troublesome, as the outside of the jars must be frequently cleaned.

Storage Batteries. Storage batteries have many advantages over primary cells which make them particularly adaptable to certain kinds of signaling. When large amounts of energy are not required, storage cells may be economically used for supplying a large amount of current for a considerable length of time. Storage or secondary batteries consist of a hard rubber or glass jar, in which is placed a series of lead plates, half of which are connected to the positive terminal, and the other half to the negative terminal. A weak solution of sulphuric acid covers the plates, which are held together with thin pieces of hard rubber. The plates are charged from some external source of direct current, which sets up in the cell certain chemical actions. The positive plates become coated with a reddish brown substance, which is known as peroxide of lead, and the negative plates are deoxidized, leaving a clean surface of lead. After the plates are charged with a direct current they are discharged by the current used in the various secondaries, and after the voltage has dropped to about 1.8 volts for each cell they are recharged again. This process of charging and recharging may be done many times before the cell deteriorates to any extent. The voltage of a cell should be about 2.2 volts when fully charged, and they never should be allowed to fall below a voltage of 1.8 volts. When a cell has reached this voltage any further discharge will cause it to deteriorate very rapidly. An indication of whether the cell is charged or discharged can be obtained by examining the specific gravity of the sulphuric acid. The specific gravity of a cell should be about 1.2 when it is fully charged, and it should not be less than 1.18 when it is fully discharged. Storage batteries are rated according to their capacity, the usual unit used for this purpose being the ampere hour; that is, they are rated according to the number of ampere hours they are capable of discharging until the indicator gives 1.8 volts per cell, assuming the cell originally to have been fully charged. A 300-ampere hour cell may be charged at a normal rate of 30 amperes, the charging continuing for 10 hours. In the care of storage batteries the frequent use of a voltmeter and hydrometer is necessary, as the greater part of the troubles found in storage cells can be attributed to improper voltage. The voltmeter should be connected in succession to each cell and the readings compared to see if they are uniform. The cells giving low readings require attention. The hydrometer gives the density or specific gravity of the volts. The regular use of these two instruments, a careful attention to the discharge rate, regular inspection of the cells, and adding water which may be lost by evaporation so as to keep the tubes of the plates always covered, constitute the most vital points connected with the use of storage batteries. The principal troubles of storage batteries are short-circuting, buckling, sulphating, weakened electrolyte, and worn out portions. Short-circuits are usually caused by buckling of the plates or by the dropping of portions of the active material of the plates. It may also be caused by the sediment in the bottom of the jar or tank. A buckling plate is usually caused by a continuous excessive overcharge or a heavy discharge. To assist in preventing it the plates are separated by glass or rubber distance pieces. Sulphating is caused by carrying the discharge of a battery too far or letting it stand too long without recharging. This is remedied by constant charging.

Storage Batteries for Electric Interlocking Systems. In all electric interlocking systems 110 volts is the standard voltage. Therefore, 55 cells are generally connected in series to obtain this electro-motive force. The capacity of the individual cells which are installed in any plant will depend upon the work they are required to perform in a given time. At the end of each period of discharge they must, of course, again be charged. With a storage battery installation, a switch-board is necessary, and it should contain an ammeter, a voltmeter, pilot lamps for indicating grounds, circuit switches, charging rheostat, fuses for overload and reverse current circuit breakers.

Mercury Rectifiers. For charging storage signal batteries from alternating current mains, a mercury converter or rectifier is often used. This device straightens out the alternating current and converts it into a pulsating direct current. Mercury rectifiers are generally mounted upon a switchboard, connecting the main switches, and connect with a transformer as a variable secondary voltage. With this arrangement alternating current may be transmitted over long distances, and any isolated plant may be charged at any voltage required.

Installation of Storage Batteries. Storage batteries should be installed in a dry place, having an average temperature of about 70 degrees. They may be charged from a commercial power circuit or by means of a portable generating plant. When a portable plant is used, it generally consists of a gasoline engine directly connected to a direct current generator. If direct current is not available for charging storage batteries, the alternating current is converted to direct current by a motor generator or mercury rectifier.

When batteries of any kind are used it is advisable to install them where there will be the least likelihood of freezing. A battery house is generally built where the batteries are to be located, and they are generally lined with felt asbestos or similar

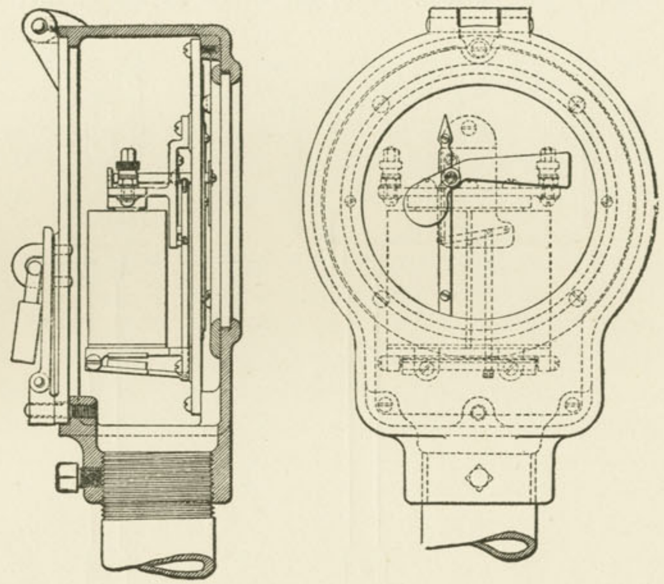


Fig. 72.

Semaphore Switch Indicator.

material for protection from the varying temperatures of the outside air.

Switch Indicator. A switch indicator is a device used to indicate either to the eye or ear, or both, whether or not a train has entered or is approaching the block in which the switch about to be moved is placed. It is usually principally in connection with automatic block signals. One type of switch indicator consists of a pair of magnets and an armature, to which it attached a small movable disc or miniature semaphore arm. The whole apparatus is inclosed in a weather-proof case having a glass front, which is mounted on a post near the switch stand.

The magnet coils in the switch indicator are energized by a line wire circuit, which extends back at least two full block sections, and which passes through normally closed contacts on all the intervening track relays, or through normally closed contacts on the home signal arms. When the circuit is broken by the presence of a train anywhere within the limits of the circuit which

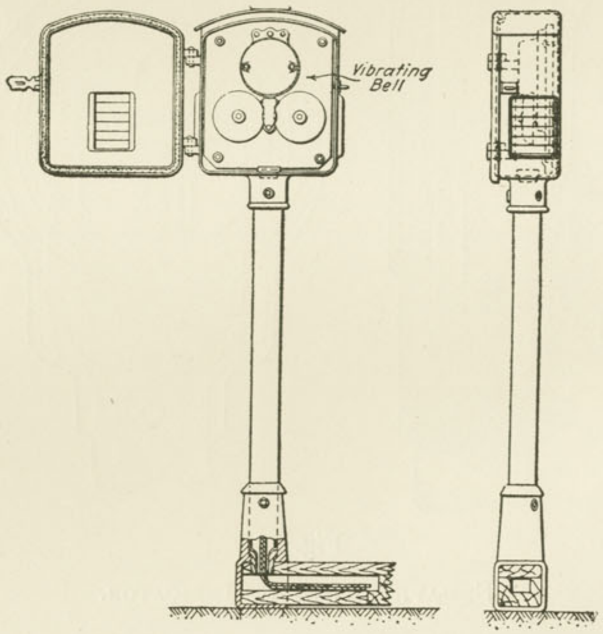


Fig. 73.

Bell Switch Indicator.

would open one or more contacts, the armature drops and moves the disc or semaphore arm into the position, indicating the approach of a train, which gives warning against opening the switch, as shown in Fig. 72. In another type of switch indicator, as shown in Fig. 73, a vibrating bell is used, and is connected in a similar manner, and is arranged to ring only when a train is approaching the block, and is cut out as the train enters the block.

Block Indicators. For the purpose of indicating to a signalman whether or not the track circuit is occupied by a train, an electro-magnetic device known as a block indicator is used. The electro-magnet is generally actuated directly or through relay by the track circuit, and has on it an armature, which moves a small semaphore on giving the proper indication corresponding to the condition of the track.

Train Describer. A train describer is an electrical instrument designed to give information regarding the origin, destination, class or character of trains, engines, or cars moving along the road. It is used in signal cabins to announce trains from one cabin to another, or from train sheds to cabins or despatchers' offices.

Track Indicator. This is an arrangement used at interlocking plants. It consists of a map-like reproduction of the railroad tracks, made on transparent glass. Electric lights which are controlled by the track circuits are arranged behind the glass, and they show for different sections of the track, whether or not such sections are occupied by a train or locomotive. The lights are red and white, so that when a track circuit is unoccupied the lights burn white. The presence of a train in a block extinguishes the white light and causes the red light to burn, so that a signalman is kept constantly informed of the condition of the track sections of his plant.

REVIEW QUESTIONS.

SIGNALS AND SIGNAL SYSTEMS.

1. Describe the general method of operating trains with the telegraph and train order systems.
2. What are the errors most likely to creep in when the telegraph and train order system is used?
3. What are the advantages of the block signal system over the train order system?
4. Describe in a general way how block signals are operated.
5. What is the general length of a block system and upon what does the length depend?
6. Name four different types of block systems with which you are familiar.
7. How many miles of railroad are now operated upon the block signal system?
8. Name four principal railroads which are now using telephones for block signaling.
9. Name the principal railroads which use the controlled manual block system.
10. Give the definitions for the following terms used in block signaling:—block signal, home signal, advance signal, distant signal, caution signal.
11. What is meant by permissive block signaling?
12. Describe in a general way how the manual block system is operated.
13. Of what particular value is the three-position block signal which is now being used on many railroads?

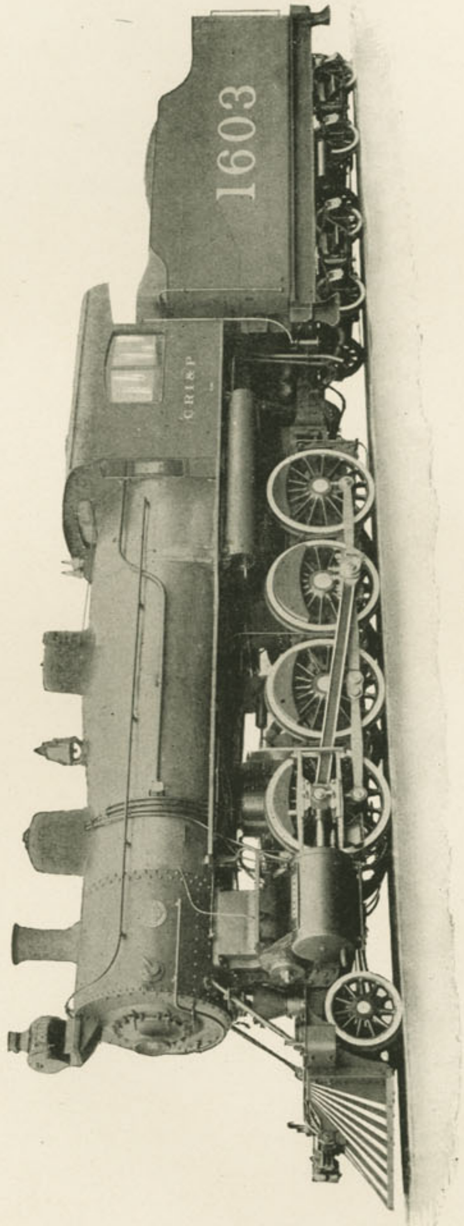
14. What are the advantages of a normal clear signal system?
15. What are the advantages of a normal danger signal system?
16. What are false signals and how may they occur?
17. What are the advantages and disadvantages of disc signals over semaphore signals?
18. What are the requirements for an interlocking signal system?
19. Describe briefly how one form of interlocking machine operates.
20. What are the advantages of power interlocking over the manual system?
21. Name three different types of power interlocking systems which may be used.
22. Describe in a general way how the electro-pneumatic interlocking system operates.
23. What is meant by approach locking? and describe how it is used.
24. Describe the electric train staff system which is used for signaling.
25. What are the advantages of the electric train staff system?
26. Describe the permissive feature as used with the electric train staff system.
27. What are the advantages of an electric motor semaphore signal?
28. What are the advantages of using the signal motor on top of the signal mast?
29. Describe briefly the Hall electro-gas signal system.
30. What kind of batteries may be used with track circuits?
31. Upon what does the voltage and length of track circuit depend?
32. Describe briefly several systems of track circuits used for automatic block signals.
33. How does the alternating current track circuit differ from the usual form of track circuit?
34. What is meant by overlap when block signaling is used?
35. When are mercury rectifiers used in connection with a signal system?

36. What is the dog chart? and explain how it is used in connection with an interlocking machine.

37. What is a locking sheet? and explain what value it is to the signalman.

38. Describe one type of single track automatic block system.

39. What are the advantages of storage batteries over other types for track circuits?



CONSOLIDATION TYPE OF LOCOMOTIVE USED ON THE CHICAGO, ROCK ISLAND AND PACIFIC R. R.
(American Locomotive Company)

Modern Air Brake Equipments

Early Inventions. The railway air brake as we know it is just forty years old. This marvelous invention, which is now an absolutely indispensable adjunct to modern railway travel, was unknown prior to 1869, and though there had been frequent attempts to devise brakes for moving vehicles many years before this, only three of them had used air pressure in any form to work the brake. The modern air brake was the invention of George Westinghouse.

In his work on the "Development of the Locomotive Engine," Dr. Angus Sinclair has carefully summarized the various efforts made between 1770 and 1870 to devise brake mechanism for vehicles. During that period there were about 190 patents granted in England for various kinds of brake apparatus applicable to common road vehicles. Out of the total number only 46 inventors applied the brake shoe to the tread of the wheel. Twenty-eight applied pressure to the hub of the wheel, twenty-one braked specially designed fly wheels, eight brought pressure to bear on the axle, twenty-seven were operated by the movement of the horse drawing the vehicle, four relied upon momentum, three endeavored to accumulate power for subsequent propulsion, three were governed by electromagnetic agency and three were pneumatic. The rest were miscellaneous in character. In America 170 patents had been granted, of which twenty-one were automatic.

The advent of the locomotive naturally stimulated inventive genius in the direction of brake mechanism, and in the first seventy years of the Nineteenth Century, we are told, that as many as 650 patents for brakes were granted in Great Britain. In 1833 Robert Stephenson patented a brake which consisted of a small cylinder with piston and rod, which was actuated by steam.

This was connected by a series of rods and levers to a cam. James Nasmyth, the inventor of the steam hammer, with Charles May were the first to attempt the application of a vacuum brake. In 1848 Samuel C. Lister patented an air brake, but it was never used in service. During the same time there had been 305 air brake patents granted in the United States.

Straight Air Brake. George Westinghouse was familiar with mechanism from his earliest days. His father was the owner of a machine shop, and in it the tools of the day were the toys of the boy. In 1869 he invented a form of air brake generally known as the "Straight Air Brake." This form of atmospheric brake consisted of a steam actuated air pump for compressing air, a reservoir carried on the engine for containing the accumulated pressure, and a pipe, connected between the cars with rubber hose, traversed the length of the train. On each car was a cylinder communicating with the brake pipe by a short connection. The cylinders were fitted each with piston, rod, levers, etc., by which the brake shoes were drawn against the treads of the wheels when, by operating a three-way cock in the cab, the engineer permitted the compressed air to flow through the brake pipe. The release of brakes was accomplished by letting the brake cylinders exhaust back through the brake pipe and out to the atmosphere through the three-way cock in the cab.

The straight air or earliest form of compressed air brake was wholly dependent for its action upon the operation of the three-way cock in the cab by the engineer, as shown in Figs. 1 and 2. Viewed in the light of present achievements, this was no doubt a crude form of brake, yet its superiority over the hand brake was even in those days unquestioned. The inventor, keenly alive to the possibilities of the air operated brake, introduced in 1872 what is known as the "Automatic Brake." This form was a marked improvement upon the straight air brake, and embodied in its essential features the principle which is in use in the most advanced form of air brake to-day.

Automatic Air Brake. In the straight air brake, the brake pipe was empty at all times except when the brake was applied, but with the automatic brake the brake pipe was constantly full of compressed air, and the reduction of the air in this pipe set the brakes. With this new arrangement it is obvious that the

bursting of a hose between the cars, or the separating of two hose connections, as would inevitably occur if the train broke in two, at once applied the brake to both portions of the train by the liberation of the air contained in the brake pipe, as it is correctly called. The operation of the brake was thus not confined exclusively to the action of the engineer, and as the brake was effectively applied by the bursting of a hose connection, or the parting

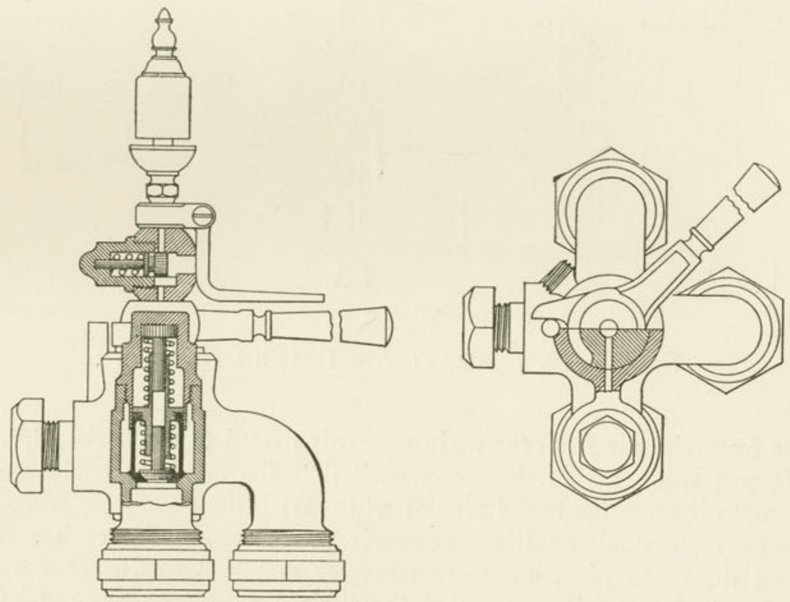


Fig. 1. Fig. 2.

SECTION AND PLAN OF ORIGINAL THREE-WAY COCK.

of the train, the name "Automatic Air Brake" was used to fittingly describe it. In order to render the brake still more efficient a branch pipe was carried up into each car, the top of which was closed by a valve within reach of the conductor, so that in case of necessity the brake could be applied by someone on the train other than the engineer.

The automatic brake was even a greater step in advance of the straight air brake than the original form had been over the old hand brake. The automatic brake, however, had, as might be expected, more apparatus in connection with it than had been required with the straight air. The essential features of the automatic brake consisted, as had the previous form, of an air pump, a large reservoir on the engine called the main reservoir, the brake pipe and the brake cylinders under the cars, as shown in Fig. 3. The three-way cock was still retained on the engine, and by it,

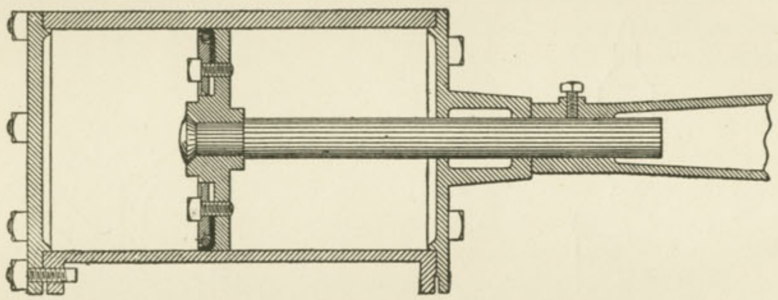


Fig. 3.
SECTION OF ORIGINAL AIR BRAKE CYLINDER.

as formerly, air from the main reservoir passed to the brake pipe. It was through this three-way cock that the engineer could exhaust air from the brake pipe at will. With the automatic brake, however, a small auxiliary reservoir was placed under each car, and the brake pipe, auxiliary reservoir and brake cylinder were all united to what was called the "triple valve" on account of this threefold connection.

THE PLAIN TRIPLE VALVE.

The plain triple valve, shown in Figs. 4 and 5, as this most ingenious device is called, consisted of a small vertical cylinder with piston, and to the rod of which a small slide valve was attached. Brake pipe pressure from the engine, acting on the under side of the triple piston, forced it up to its extreme position and placed the slide valve so that the brake cylinder would have free communication with the atmosphere through the cavity in the slide valve. The extreme or uppermost position of the triple

piston uncovered a groove in the small cylinder, so that brake pipe air passed through this "feed groove" and past the triple piston to the auxiliary reservoir, and in this condition the brakes were off, and the auxiliary reservoir became charged and the brake pipe was also full of compressed air. Any reduction of brake pipe pressure, whether accidental or intentional, caused the auxiliary reservoir pressure on the triple piston to predominate,

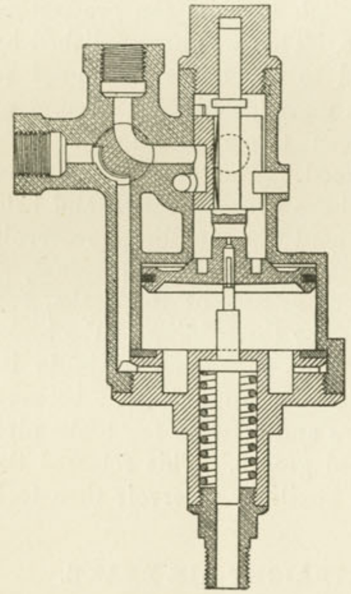


Fig. 4.

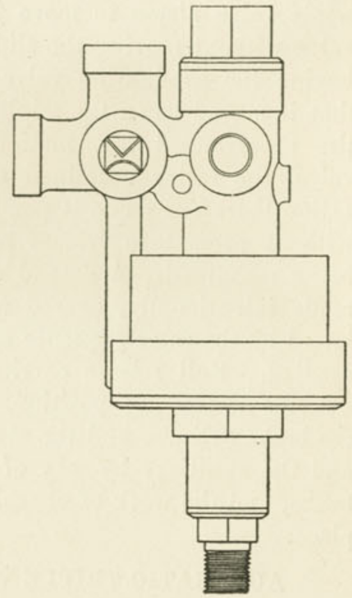


Fig. 5.

SECTION AND ELEVATION OF ORIGINAL TRIPLE VALVE.

and the piston moved down past the feed groove and also carried with it the slide valve, which thus cut off communication of the brake cylinder to the atmosphere and opened a direct port leading from the auxiliary reservoir, through the slide valve, to the brake cylinder, thus filling the latter with air and applying the brake.

In order to prevent the depleted pressure in the auxiliary reservoir, caused by its supply being turned into the brake cylinder, from becoming so low that the remaining pressure in the brake pipe would predominate and so drive the triple piston up to the release and charging position described above, a very cleverly devised arrangement was introduced for the purpose of closing off the flow of air from auxiliary to brake cylinder before premature release should occur. This device was practically a small stopper in the passageway of the slide valve, and this small stopper was called the graduating valve. A slight predominance of brake pipe pressure over that in the auxiliary reservoir caused the triple valve piston to move just enough to close the graduating valve without moving the slide valve. This was accomplished by having the graduating valve pinned to the triple piston-rod so that it moved when the triple piston moved, while, on account of the prearranged lost motion between triple piston and slide valve, the latter remained as it stood. The graduating valve action therefore made it possible to have brakes applied and held without premature release and without the auxiliary reservoir being recharged. A second reduction of brake pipe pressure, if made intentionally, caused a stronger setting of the brake, followed by the same sequence of events for the holding of the brake applied. Full release carried the triple piston up again to its extreme uppermost position, established communication between the brake cylinder and the atmosphere and between the brake pipe and the auxiliary by way of the feed groove. This released the brake, and the work of charging the auxiliary reservoir then took place.

AUTOMATIC TRIPLE WITH STRAIGHT AIR BRAKE.

The change from "straight air" to the automatic form, desirable as it certainly appears, was nevertheless gradual. The railroads which had adopted the first form of Westinghouse Air Brake naturally desired to make the change by degrees. In order to do this the plain triple valve was provided with a four-way cock which, according to the position of the handle, either cut out the brake altogether from a particular car if the brake was found to be defective, or it cut out the triple valve alone and allowed the brake to be operated on the straight air system, or it cut in the triple so as to produce automatic action. In this way cars equipped with the plain triple valve could be used in straight air trains.

THE NEW STYLE PLAIN TRIPLE VALVE.

The introduction of the plain triple valve, Fig. 4, involved the gradual abandonment of the straight air principle and the adoption of the automatic brake. Soon a new style of plain triple valve, Fig. 6, was brought out, by which two improvements were effected. One was the absence of the four-way cock, as this new style of equipment compelled the abandonment of the straight air brake, and the other improvement was the emergency

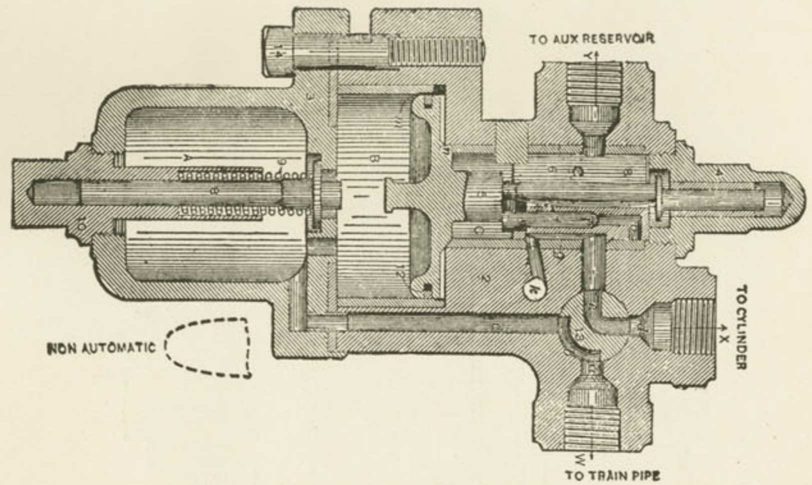


Fig. 6.

IMPROVED TRIPLE VALVE.

feature. By this latter arrangement a rapid fall in the brake pipe pressure, such as would take place if the train broke in two or if the engineer was suddenly confronted with some imminent danger, resulted in the extreme downward travel of the triple piston carrying the slide valve with its restricted opening entirely clear of the port leading from the auxiliary reservoir to the brake cylinder, and so producing a more powerful and rapid application of the brake. The new sayle of triple valve worked well in service applications on long trains in conjunction with the "engineers' brake and equalizing discharge valve" which had been devised. The new style of triple, however, was found to be too slow in its action in the emergency application on long trains, and to meet this condition the quick-action triple valve was designed.

THE ENGINEERS' BRAKE VALVE.

In this necessarily brief summary of events in the development of the air brake, a word must here be said concerning what

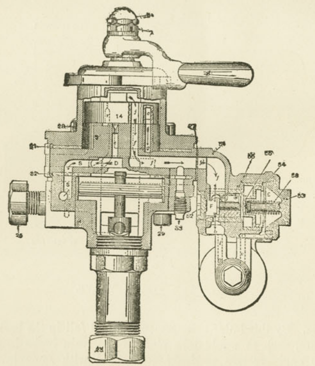


Fig. 7.
G-6 Engineers' Brake Valve.

was called the Engineers' Brake and Equalizing Discharge Valve, Fig. 7. The exhaust of brake pipe air from the three-way cock

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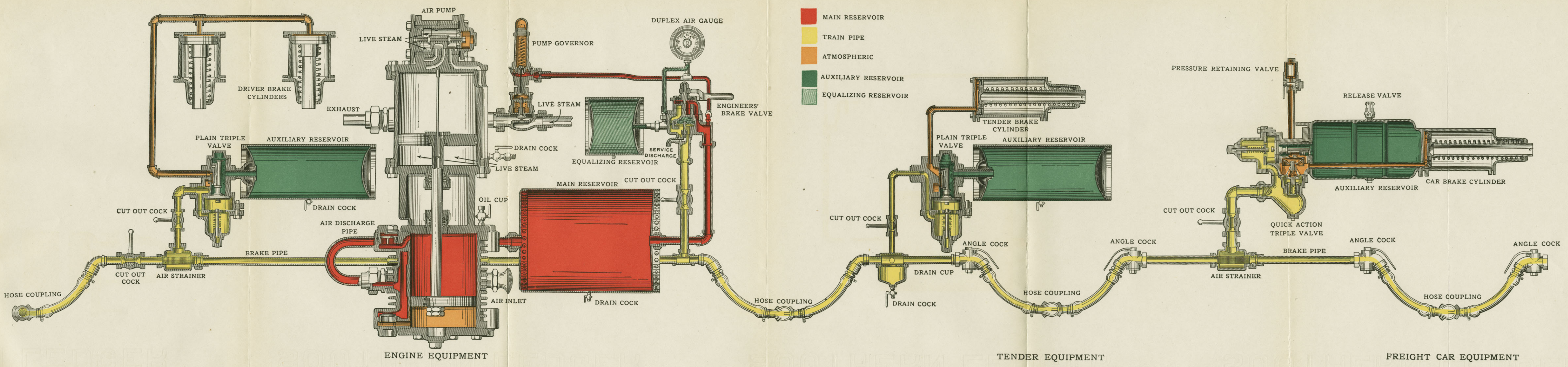

WESTINGHOUSE AIR BRAKE EQUIPMENT USED FOR FREIGHT SERVICE was governed entirely by the engineer, and much or little could be let out by him according to his individual judgment in order to produce a normal service application. Skill was acquired solely by practice and was aided by good judgment, consequently no two men operated the brake exactly alike, and good and bad braking was the result with the same equipment. It was also found that when a reduction of air was made in the brake pipe and the front cars' brakes applied, the engineer would probably shut off the brake pipe exhaust. The brakes in the rear of the train experiencing brake pipe reduction later, were set later, and further, the surge of air from the rear in its movement toward the now closed exhaust opening on the engine raised the pressure in the brake pipe at the front sufficiently to release the forward brakes while holding those at the rear set. This undesirable condition was met by the brake valve, whose construction was such that a small piston very similar to the triple piston was held down, closing the brake pipe exhaust, by the pressure of air in a small reservoir on the engine, the pressure in which exactly equalled that in the brake pipe. With this valve the engineer governed the escape of air, not from the brake pipe direct, but from the small cylinder, and an air gauge was added to show the amount of air thus discharged. The outflow of air from the small reservoir permitted the equalizing piston, as it is called, to rise and open the brake pipe exhaust. Air from the brake pipe was consequently discharged until its pressure fell slightly below the amount retained in the small reservoir. The action of the Engineers' Brake Valve therefore amounted to this, that although the engineer could indirectly cause the discharge of air from the brake pipe and could close his valve, it was out of his power to close the exhaust from the brake pipe. That was done automatically, and the surge of air from the rear of the train helped to hold the equalizing piston up and keep the exhaust open until the whole brake pipe pressure was slightly less than that in the small reservoir. An excess pressure valve, also part of the equipment, maintained a higher pressure in the main reservoir than that in the brake pipe, and this was available for the prompt and certain release of brakes.

THE QUICK-ACTION TRIPLE.

The quick-action triple valve, Fig. 8, which appears now as one of the orderly steps in the development of the air brake, was introduced after the celebrated Burlington brake tests, in 1886-7. The plain triple worked satisfactorily for service stops in connection with the Engineers' Valve, but in emergency applications the

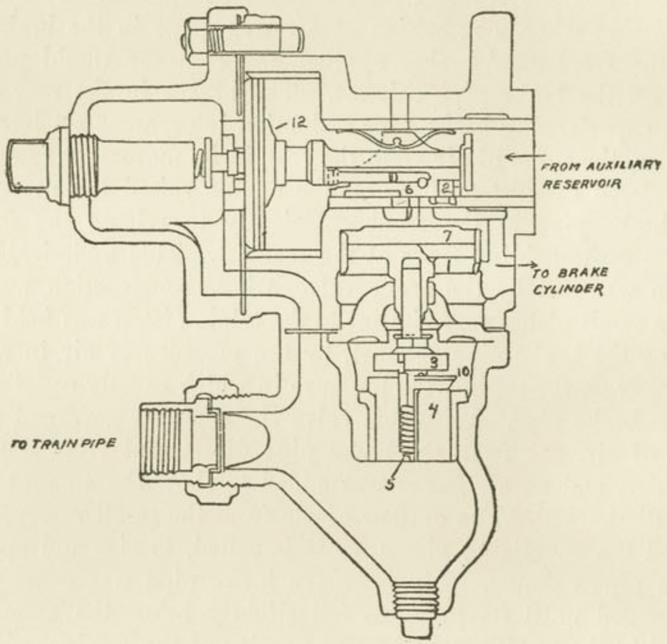

Fig. 8.

Quick Action Triple Valve.

head end brakes set a very considerable time with full force and before the rear brakes were applied and the slack of the train ran in with damaging force. The quick-action feature of the new triple consisted of an emergency piston and check valve, so arranged that a sudden reduction of brake pipe pressure opened communication from the brake pipe to the brake cylinder, and a certain quantity of brake pipe air now passed, not through the brake valve exhaust to the atmosphere, but into the brake cylinder. The discharge of air from the brake pipe helped to fill the empty

brake cylinder and so produced a higher brake power in emergency. Each triple valve acted upon the one behind it by suddenly lowering the brake pipe pressure in the immediate vicinity. There was thus no surge of air toward the front end, and the rapid reduction of brake pipe pressure was accomplished by the separate exhausts made by each triple from the nearby brake pipe into its brake cylinder. The emergency application of the brakes ran down the train like a "feu-de-joi" fired by a regiment of soldiers, where each man pulls the trigger of his rifle at the moment that his comrade to the right has fired. In this way the quick action of the brakes easily outsped the "run in" of train slack, and less than three seconds on a fifty-car train was all that was required to secure the maximum braking power on every car in the train, under the shadow of impending danger.

The gradual improvement of the air brakes, like other developments in mechanical contrivances, has followed the law of evolution, which holds good in the intellectual advancement of mankind as well as in his physical being. The steps were slow, but each advantageous modification of the mechanism was but the vantage ground for further effort. We who study the air brake to-day see only the splendid result achieved without perhaps fully appreciating the amount of time, thought and labor expended in the production of the now indispensable air brake.

THE HIGH SPEED BRAKE.

From the very earliest days, the development of the means of defense has followed closely upon the evolution of weapons. The shield has been a contemporary of the sword, and in modern times the armor belt and the ships' citadel have been created, and have had their resisting qualities augmented in almost the same ratio that has marked the advance of the high power gun or the explosive shell. It is not stretching the analogy too far to say that in the steady progress made in the peaceful art of transportation the effort to obtain speed with safety in railway operation had carried forward the work of inventive genius in the direction of successfully controlling that speed. The greatest factor in the production of fast train movement to-day is the ability to stop, and this is guaranteed to the locomotive runner when he lays his hand on the Engineers' Brake Valve in the cab of one of our modern high speed machines.

In the evolution of the air brake the premier place belongs to George Westinghouse, and when the masterful conception of the means of using compressed air as the brake operating power has been acknowledged, as it must be by all, to be of the first and greatest importance, one may turn to the work of investigation which called into being the high speed brake, and find it to be perhaps the second epoch-marking discovery in the series of achievements in mechanical science which has put the world in possession of the modern air brake equipment.

In the year 1878, Mr. Westinghouse read a paper before the Institution of Mechanical Engineers of London, and in this paper he pointed out the fact that while testing the action of various kinds of brake shoes he observed a great difference in the friction of the shoes upon wheels moving at high speed and upon those moving at low speed. In other words, it seemed to him that the same brake shoe did better work, or developed a greater amount of friction, when pressed against a slowly revolving wheel than when pressed against a rapidly revolving wheel, the same force being used in each case.

With the object of ascertaining how far these observations were true, and, if true, through what range this variation of friction extended, Mr. Westinghouse offered to design and construct the necessary automatic recording apparatus, and to conduct a series of experiments under the direction of a competent mechanical engineer to be designated by the President of the Institution. This offer was readily accepted, and Captain Douglass Galton was appointed to direct the experiments. The London, Brighton and South Coast Railway subsequently placed a locomotive and brake-van at the disposal of Captain Galton, and offered every facility for the prosecution of the investigation.

The result of these experiments, which have been called the Galton-Westinghouse tests, demonstrated the truth of Mr. Westinghouse's observation, and brought the whole subject within the domain of practical science. It was found that a brake shoe when applied to the tread of a wheel with a constant pressure did not produce anything like the same retarding force upon a rap-

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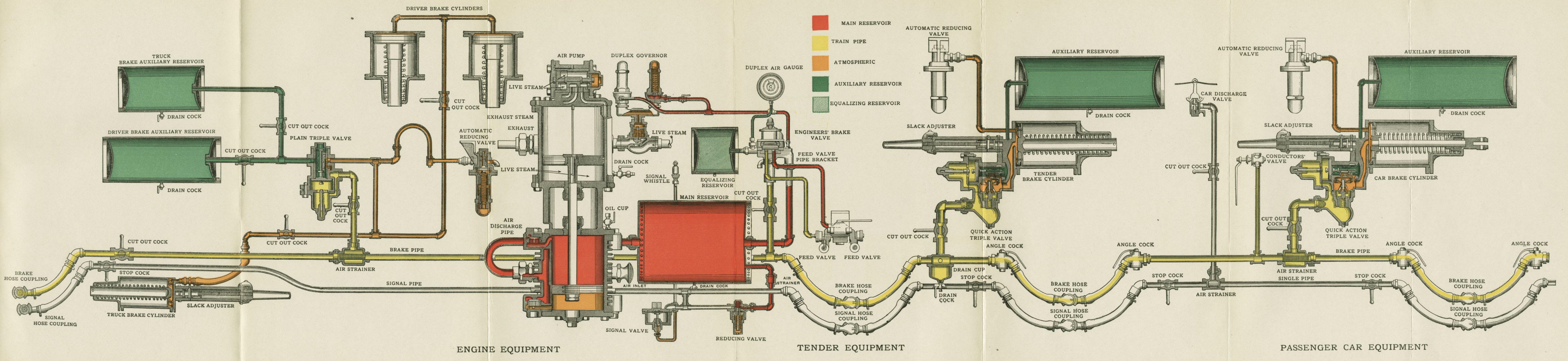


WESTINGHOUSE HIGH SPEED AIR BRAKE AND SIGNAL EQUIPMENT USED FOR PASSENGER SERVICE idly revolving wheel that it did when the wheel had been slowed down and was revolving with comparatively low velocity.

Co-efficient of Friction. The measure by which what may be called "amounts of friction" are computed, is named the co-efficient of friction. This is simply a convenient method of stating in the form of a fraction what proportion of the weight of a body is required to slide it along the surface of another body of the same or different material. For example, if a piece of cut stone weighing 32 pounds was capable of being slid on a flat, smooth level board by a force of 8 pounds, the co-efficient of friction for stone on that kind of wood becomes 8-32, or .25. That is, one-quarter of the weight of the stone would be required to move it over the board. The decimal fraction .25 is called the co-efficient of friction in this case. The effect of lubrication at once becomes apparent, for if the surface of the board was greased, it is manifest that a very much smaller amount of friction would be developed and the co-efficient of friction would become less. If the greased board allowed the stone to be moved by the application of only 4 pounds, the co-efficient of friction would be reduced to .125.

In the Galton-Westinghouse tests it was discovered that the co-efficient of friction between cast iron brake shoes and steel-tired wheels amounted approximately to .33 for a speed under 5 miles an hour, while at a speed of 60 miles an hour the co-efficient of friction for the same kind of brake shoe, applied with the same force to the steel-tired wheel, was only about .074. Viewed in the practical light of train operation it amounted to this: When brake shoes are applied to the dry wheels of a rapidly moving train running upon smooth dry rails, their retarding effect is practically equivalent to the friction developed between lubricated surfaces, and as the speed diminishes the friction increased very much, as if the lubricant had been gradually rubbed off. It was to the solving of this problem in railway train braking, disclosed by these tests, that what is known as the high-speed brake was successfully devised.

THE HIGH SPEED EQUIPMENT.

The high speed brake is the ordinary quick-action equip-

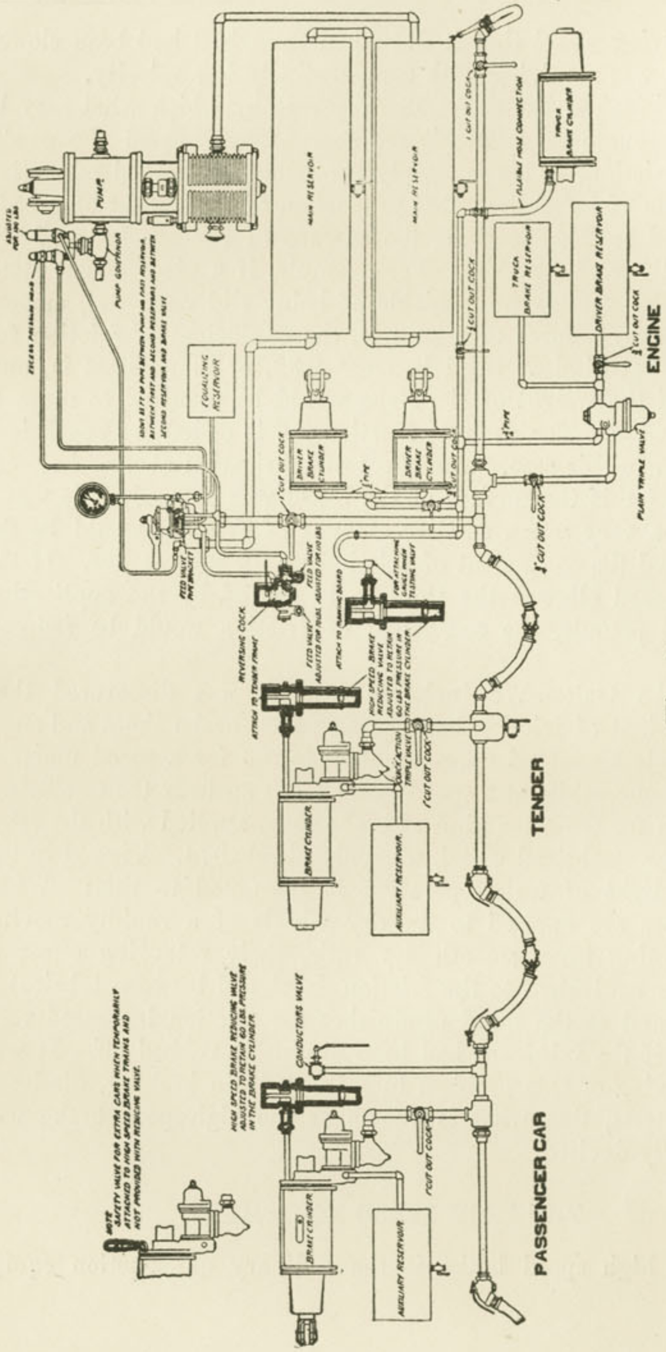


Fig. 9.

Diagrammatic Illustration of High Speed Brake Equipment.

ment, Fig. 9, with a reducing valve, Fig. 10, applied to the brake cylinder. The alteration of the car and engine equipment consists in the addition of the reducing valve to the brake cylinder of the cars and on the engine and tender. On the locomotive, how-

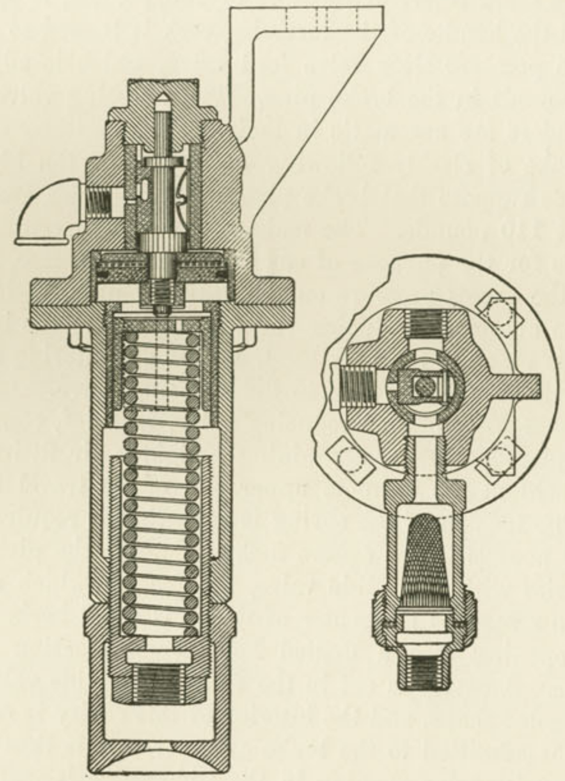


Fig. 10.

Section of High Speed Reducing Valve.

ever, a duplex pump governor, and two slide valve feed valves with reversing cock, are used, and as one feed valve is cut in the other is cut out. A stop cock is used in connection with the duplex pump governor, so that the low-pressure head may be cut in or cut out as desired.

With these additions to the equipment it is now possible to use either the standard 70 pounds brake pipe pressure, or a brake pipe pressure of 110 pounds may be used. When the higher pressure is employed the duplex governor is used as a matter of convenience, and the head of the duplex pump governor, which is adjusted for a main reservoir pressure of 130 pounds, is called into action, and the handle of the reversing cock is turned so as to cut in the high pressure slide valve feed valve, which is adjusted to give 110 pounds in the brake pipe. The reducing valves on the brake cylinders are automatic in their action.

For sake of clearly following the action of the high speed brake, let us suppose that brake pipe and auxiliaries are charged with air at 110 pounds. The main reservoir will contain air at 130 pounds for the purpose of ensuring certain release, as is the case with the excess pressure on the ordinary quick-action equipment. The automatic reducing valve is applied to the brake cylinder and is piped to the back head, so that air entering the brake cylinder will have free access to the reducing valve.

Reducing Valve. The reducing valve, in brief, consists of a vertically placed chamber containing a tightly air fitting piston, which is held at the extreme upper end of its travel by a coil spring. The tension of the spring is such that it requires a pressure of 60 pounds to the square inch to depress the piston. The piston carries with it a slide valve, the face of which moves up or down on a seat, in the center of which is a flat horizontal slotted port opening into a drilled hole communicating with the atmosphere. A cavity is cut in the face of the slide valve, which is of triangular shape, and the interior of this cavity is reached by air which is admitted to the brake cylinder. It is thus manifest that if the triangular opening in the slide valve is made to register with the port in the slide valve seat, air from the brake cylinder will find its way to the atmosphere.

The Emergency Stop. While the above is the bare statement concerning the construction of the reducing valve, its marvelously accurate performance is a source of the keenest pleasure to those who comprehend its action. As we said, the brake pipe and auxiliary reservoir are charged with air at 110 pounds' pressure, and suppose an emergency stop has to be made at a speed of 60 miles an hour. The rapid reduction of pressure in the brake pipe

causes the quick-action triple to act, and some air at 110 pounds from brake pipe and from auxiliary pours quickly into the brake cylinder, and at once finds its way into the reducing valve. The brake shoes are brought tightly against the treads of the whirling wheels with a force resulting from the equalization of brake cylinder and auxiliary pressures, which is far above the pressure which would skid the wheels if they were revolving slowly. This pressure, great as it is, does not skid the wheels, but applies to them a check which bears some definite relation to their speed.

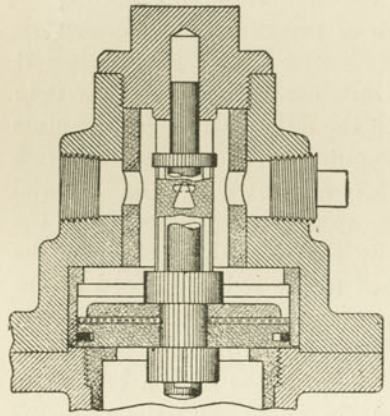


Fig. 11.

High Speed Reducing Valve Cap—Emergency.

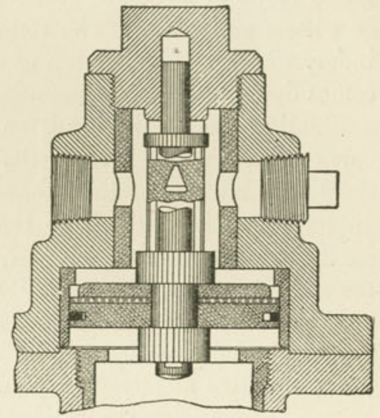


Fig. 12.

High Speed Reducing Valve Cap—Service.

Air at this equalization pressure in the brake cylinder enters the reducing valve and easily depresses the little piston against the upward effort of the coil spring, which is adjusted to just hold against a pressure of 60 pounds. The piston in moving down carries with it the slide valve and places its triangular port in register with the port leading to the atmosphere, as shown in Fig. 11. The result of this is that no sooner has the brake cylinder filled with air at from 85 to 88 pounds, than it begins to blow away to the atmosphere.

The port in the slide valve through which this exhaust takes place is triangular in shape, and the reason for this form now becomes apparent. The port in the slide valve seat is a small horizontal slit, and as the triangular port has its apex on top, the full travel of the reducing valve piston places the narrow upper part of the triangle in register with the little flat horizontal opening to the atmosphere. The exhaust from the brake cylinder, though clear and free, is nevertheless restricted by the upper portion of the triangle being brought in register. The high pressure in the brake cylinder and auxiliary reservoir is thus steadily though slowly reduced as the speed of the train slackens, the lessened brake cylinder pressure being still effective on the reduced speed of wheels and train. The reduction of pressure in the brake cylinder, which is also on top of the reducing valve piston, when it comes down to about 65 pounds, permits the coil spring below it to gradually raise the little piston with the slide valve. As the slide valve rises, a wider area of the triangular port now registers with the little flat horizontal exhaust port, as shown in Fig. 12, and an increased flow of air to the atmosphere takes place from the partly depleted brake cylinder, while the retarding action of the brake is thus practically proportioned to the reduced speed of the wheels. The exhaust is slow at first and remains so for a comparatively long period. The auxiliary reservoir and brake cylinder equalize at about 88 pounds, which is too high a brake cylinder pressure for the slackening train speed, and the reducing valve, when its upward movement begins, brings the wide base of the triangular port in register with the exhaust port, and thus provides the maximum opening to the atmosphere through which the air from brake cylinder and auxiliary reservoir is rapidly discharged. When the combined pressure sinks to 60 pounds to the square inch, the coil spring thrusts up the piston to its uppermost position and cuts off the exhaust, thus holding a brake cylinder pressure of 60 pounds until the train stops, or more correctly until brake release takes place.

In this emergency application there was the sudden filling of the brake cylinder with air at high pressure. The steady blow down effected by the reducing valve, automatically restricted at first while train speed was fast, but increased in volume as the train slowed, until when the pressure of 60 pounds was reached, the speed of the wheels was such that the maximum brake pressure, which it is safe to apply at comparatively slow speed, was held. The high speed brake in emergency gives practically the fullest and most powerful brake pressure which it is safe to obtain, and the retarding action of this application will stop a train in a distance 30 per cent. shorter than that obtained by the best emergency performance of the ordinary quick-action brake.

The Service Stop. The service application of the high speed brake gives evidence of the same careful attention to detail on the part of the designer as does the action of the high speed brake in emergency. The service stop with parts, as shown in Fig. 12, is usually made as when using the ordinary 70-pound brake pipe pressure. The service application reduces the brake pipe pressure, and if brake cylinder pressure is less than 60 pounds, the reducing valve does not act, and the brake applies in the usual way. If, however, the initial brake cylinder pressure exceeds 60 pounds, the reducing valve piston descends only a portion of its full stroke, and consequently the reducing slide valve is carried down so that the lower and wider portion of the triangular opening registers with the horizontal exhaust port. This causes a comparatively rapid discharge of brake cylinder air to the atmosphere, and this is strictly in keeping with more gradual stop required in coming into a station. When the auxiliary reservoir pressure becomes somethng less than the brake pipe pressure, the predominance of brake pipe pressure causes the triple valve to act, and forces the triple piston to move so as to blank the port to the brake cylinder, and auxiliary pressure is thus cut off from the brake cylinder. A second application raises the pressure in the brake cylinder, after which the brake cylinder is again cut off from the auxiliary reservoir, and the brake cylinder pressure, if above 60 pounds, blows down to 60 pounds by the action of the reducing valve. In full release position, shown in Fig. 13, the brake cylinder is completely emptied by the action of the triple valve in the usual way.

Comparative Distances in Stopping. An interesting comparison is given by Mr. R. H. Blackall, in his Air Brake Catechism, of the comparative efficiency of the high speed and the ordinary quick-action brakes on a train representing average conditions and equipped with cast iron wheels and soft cast iron brake shoes. At a speed of 45 miles an hour the quick-action brake stopped the train in 710 feet, while the high speed brake halted the train in

560 feet, which is 150 feet less distance than that required by the quick-action brake. At a speed of 50 miles an hour the figures stood 880 feet for quick-action, as against 705 feet for the high-speed, a shorter stop by 175 feet. At 60 miles an hour the automatic stopped the test train in 1,360 feet, and the high-speed in 1,060 feet, or 300 feet less. At 70 miles an hour, the automatic brake required 2,020 feet, while the high-speed accomplished the work in 1,560 feet, or a gain in favor of the high-

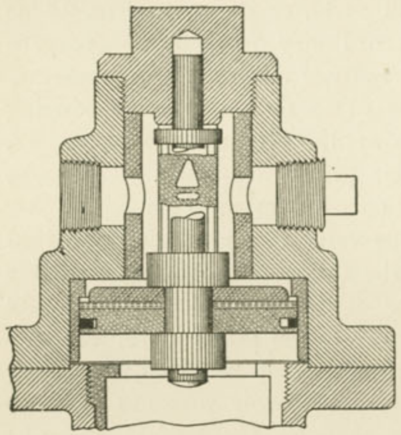


Fig. 13.
SECTION OF HIGH SPEED REDUCING VALVE CAP—RELEASE.

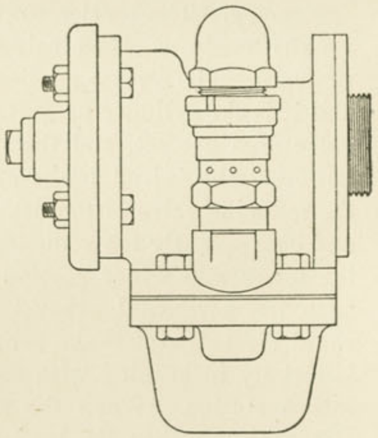


Fig. 14.
L TRIPLE VALVE.

speed brake of 460 feet. At a speed of 80 miles an hour, the automatic brake brought the train to rest in 2,780 feet, the high-speed brake stopping it in 2,240 feet, being a distance of 540 feet to the credit of the high-speed equipment.

In speaking of the relative efficiency of the two forms of brake, Mr. W. A. Buckbee, road foreman of engines on the Rutland Railroad, selected a test made on the West Jersey & Seashore Railroad. He said: "With a train consisting of a locomotive and six coaches and 110 pounds brake pipe pressure, the brake was applied at a speed of 67 miles per hour, and the train was brought

to a stop in a distance of 1,250 feet. With the same equipment, but with 70 pounds brake pipe pressure, and brake applied at a speed of 65 miles per hour, the train was stopped in a distance of 1,640 feet. The speed of the latter, when passing the point at which the train had stopped in making the first trial with 110 pounds brake pipe pressure, was 35 miles per hour. It is easy to imagine what the result would have been had there been an obstruction at this point."

THE TYPE "L" TRIPLE VALVE.

In order to obtain what may be called greater flexibility in service operation, the Westinghouse Air Brake Company have lately brought out an improved triple valve, which, although it can be used with the ordinary passenger equipment, is thoroughly well adapted to use on trains equipped with the high-speed brake, and it is for this reason that the "L" triple valve, as it is called, Fig. 14, is here considered. The features which this triple valve embodies are, (1) Quick recharge of auxiliary reservoirs, (2) Quick service, (3) Graduated release, and (4) High emergency cylinder pressure.

The "L" triple valve forms part of what is known as the L-N Passenger Car Equipment, and is one of the quick-action, automatic, "pipeless" type. The name pipeless is applied to it from the fact that in removing this triple valve no pipes need be disconnected. The loosening of the three bolts used to hold it in place is all that is required.

The "L" triple valve is designed to meet the exacting requirements of modern passenger service, where within the last few years trains have become heavier and speeds higher. In order that these trains may be controlled easily and smoothly when running either fast or slow, without the danger of wheel sliding or discomfort to passengers, the use of this triple valve is recommended. The ends sought are, to provide suitable means whereby a light brake pipe reduction will produce a moderate brake cylinder pressure with uniform retardation of the whole train, and a heavy service brake pipe reduction may be made quickly without producing quick action. It enables the engineer to make brake applications in rapid succession up to full power without too quickly depleting the reservoir, and it eliminates the necessity for retaining valves. It provides for a high brake cylinder pressure for emergency applications where a short stop is imperative.

In connection with the "L" triple valve there is used a supplementary reservoir, which is nothing more or less than a second,

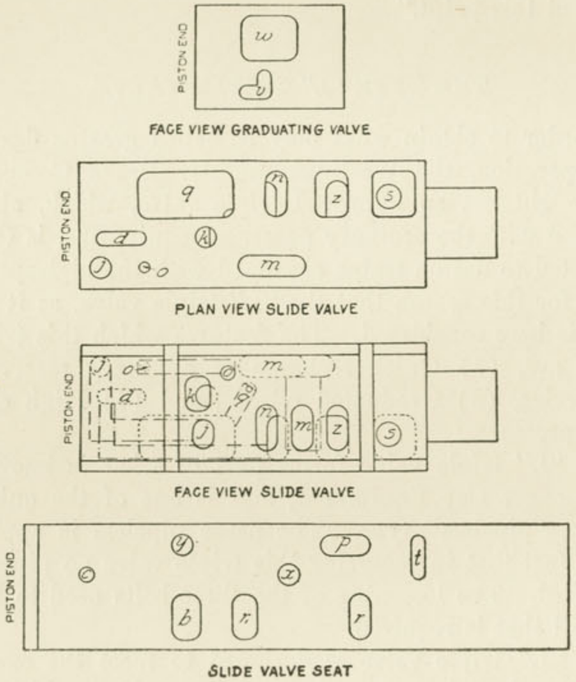


Fig. 15.

Plan of Graduating Valve, Slide Valve and Slide Valve Seat.

though larger, auxiliary reservoir. It is in fact approximately double the size of the ordinary auxiliary reservoir. Its function is to aid in what is called the graduated release, and in producing high emergency cylinder pressure. The ability to obtain high emergency pressure makes this practically a high-speed brake when using 90 pounds brake pipe pressure, and it gives even

better results than using the old standard equipment with 110 pounds brake pipe pressure. If a more powerful brake is required, it can be obtained by using a higher brake pipe pressure.

The "L" triple valve has as part of its mechanism a by-pass valve, and a safety valve is also attached. Fig. 15 represents the plan view of the graduating valve, slide valves and seat, and Fig. 16 represents a section of the complete "L"-triple valve.

Full Release Position. When the "L" triple valve is in full release and charging position, air from the brake pipe flows to the

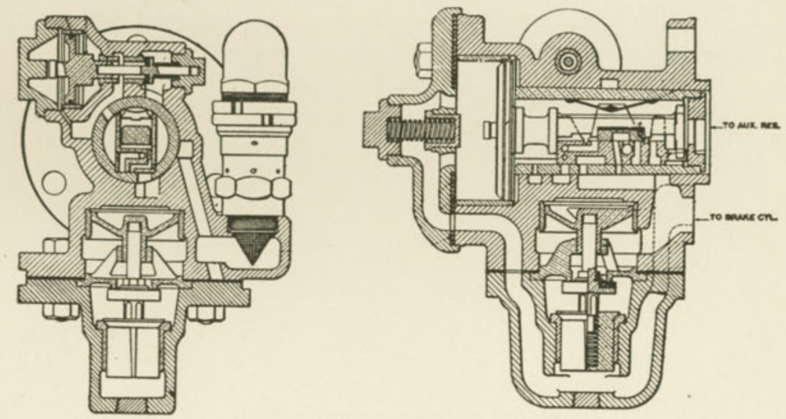


Fig. 16.

Section of Type L, Triple Valve.

auxiliary reservoir past the main triple valve piston by way of the feed groove in the ordinary manner, as seen in Fig. 17, which is a diagrammatic representation of the triple and not a sectional view. Brake pipe air also enters the auxiliary reservoir by what may be called a secondary auxiliary charging route, which is past the triple check valve 15, through a passage in the body of the valve marked y, and through the slide valve by a passage j. At the same time brake pipe air enters the supplementary reservoir from the auxiliary reservoir through a passage k in the triple slide valve and by passage x in the body of the triple valve. This may be called the direct supplementary reservoir charging route.

Both auxiliary and supplementary reservoirs are thus quickly charged at the same time and with the same pressure as that in the brake pipe. The brake cylinder is by the position of the slide valve placed in communication with the atmosphere, and full release is thus effected.

Service Applications. With a light or ordinary service application the brake pipe pressure is reduced. This is sufficient to move the main triple piston, carrying with it the graduating valve

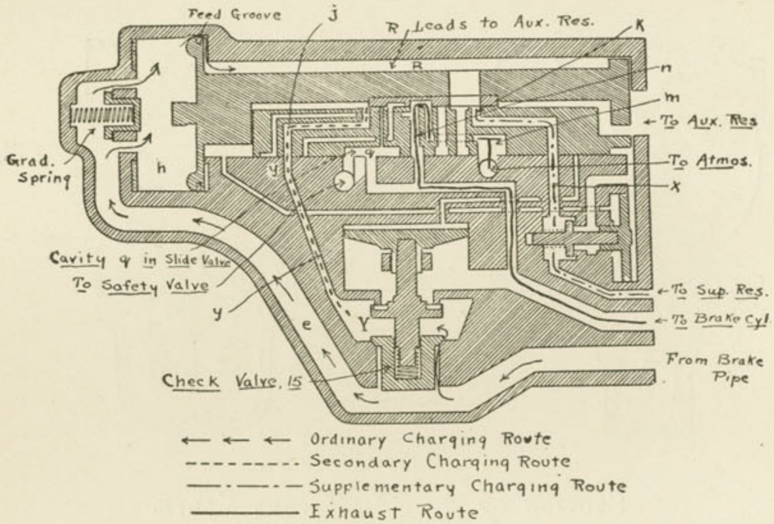


Fig. 17.

Full Release and Charging Position, L Triple.

and the slide valve, thus the feed groove supply of air to the auxiliary reservoir is cut off. The face of the graduating valve now covers two ports in the back of the slide valve, and thus blocks the secondary route to the auxiliary reservoir, and also blocks the direct supplementary reservoir charging route. The exhaust passage from the brake cylinder to the atmosphere is closed, and direct communication is opened from the auxiliary reservoir to the brake cylinder through the graduating valve, the slide valve, and the body of the triple valve, through ports z and r, thus ap-

plying the brake, Fig. 18. The movement of the graduating valve places the small cavity in its face, marked v, Fig. 16, so as to connect quick service ports q and o in the slide valve. Quick service port q extends vertically out of slide valve cavity q. The opening of the quick service ports establishes communication with passage y, which was, in full release position, part of the secondary charging route, and this passage now admits air from the brake pipe to flow directly into the brake cylinder. This constitutes the quick service action of the triple valve, and is caused by a slight reduction of brake pipe pressure, made at the engineers' brake valve,

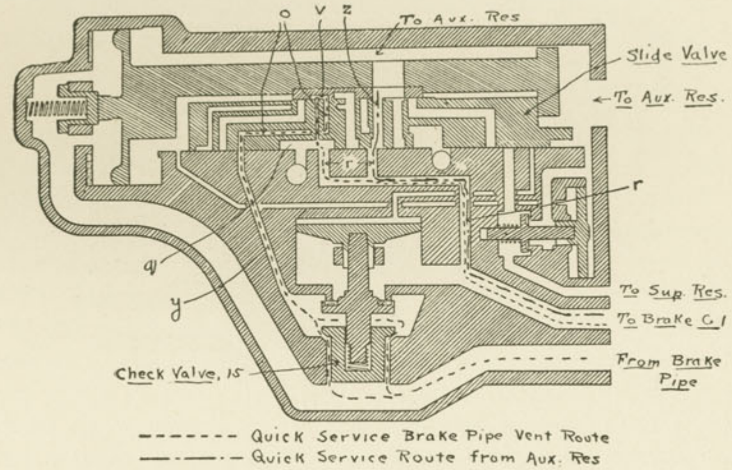


Fig. 18.

Quick Service Position, L Triple.

and the venting of a small quantity of brake pipe air into the brake cylinder ensures a rapid and uniform action of all the triples along the train, in a manner similar, though less violent, than that which takes place in the emergency. The quantity of air passing from the brake pipe to the brake cylinder through the quick service ports is not great, because the passages and ports are small, and because the venting of brake pipe air into the brake cylinder causes a more rapid fall of brake pipe pressure, and this forces the triple piston to move to full service position, and this movement gradually restricts or blanks the quick service ports just before the service port z is fully open. When this port becomes fully open, the triple valve is in the full service position.

The full service position of the triple valve, Fig. 19, can be had at once by a comparatively heavy service reduction of brake pipe pressure. In fact, the amount by which the service port z is opened depends on the rate of brake pipe pressure reduction, as compared with that of the auxiliary reservoir reduction. If the brake pipe pressure falls rapidly, as it would with short trains,

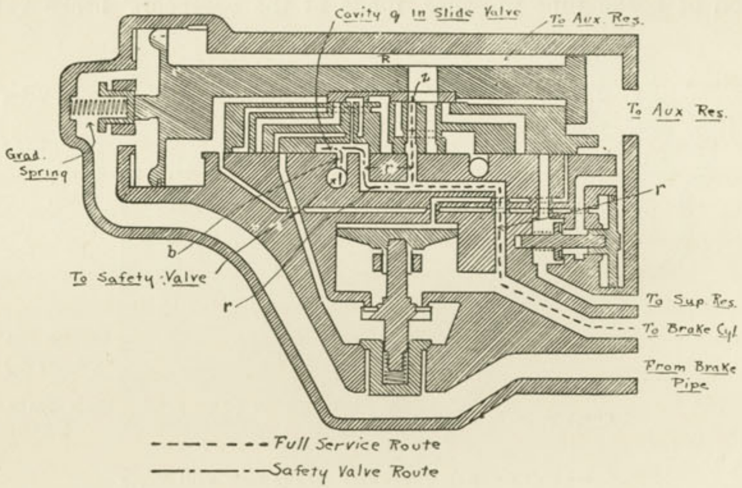


Fig. 19.

Full Service Position, L Triple.

the higher auxiliary reservoir pressure moves the triple piston toward or to the full service position, and so partially or fully cuts out the quick service feature. The rate of brake pipe pressure reduction, as compared with that of the auxiliary reservoir pressure reduction, practically graduates the amount and intensity of the quick service action, and determines how much, if any, quick service may be had in any given case. When full service action is promptly produced by a heavy brake pipe reduction, the fall of brake pipe pressure is so rapid that it cuts out the quick service feature, which is now of no advantage. The service port z,

connecting the auxiliary reservoir with the brake cylinder, is much larger than the quick service port q, connecting the brake pipe to the brake cylinders. The amount of opening of the port z depends on the rate of brake pipe pressure reduction as compared with that of the auxiliary reservoir reduction. If the brake pipe pressure reduces more rapidly than that in the auxiliary reservoir, as would be the case with short trains, the triple piston is moved promptly to the full service position, and the quick-service operation is exceedingly brief, taking place only while the valve is moving. In the full service position the graduating spring is compressed.

If the fall of brake pipe pressure is slower than that in the auxiliary reservoir, as would be the case with long trains, the triple piston assumes the quick-service position, and the flow of air from the brake pipe to the brake cylinder takes place. The restricted opening of the service port z is nevertheless larger than that through port q. This fact prevents an emergency application from taking place when a service application is intended. It also prevents brake pipe pressure reduction continuing, owing to the quick service port q remaining open after the reduction of pressure has ceased at the engineers' brake valve. While the slide valve is in quick service position, the brake cylinder port r is connected by means of cavity q in the slide valve with port b, leading to the safety valve. This may be called the safety valve route through the triple valve. The safety valve is usually set to blow at 62 pounds, so that when the brake cylinder pressure rises above that pressure the safety valve opens, discharges air, and thus prevents any further rise of pressure in the brake cylinder. The safety valve blows away all pressure in the brake cylinder above 62 pounds, and in this its action is similar to that of the high-speed reducing valve. The pressure maintained in the brake cylinder during a full service application, due to a heavy reduction of brake pipe pressure made by the engineer, is thus seen not to be sufficient to skid the wheels, while giving a prompt and powerful brake action. In the emergency application the safety valve is automatically cut out.

The Service-lap Position. The service-lap position, Fig. 20, is when all the ports in the triple valve are blanked. This is brought about when the handle of the engineers' brake valve has been placed in the lap position and the flow of air from the brake pipe has been stopped. When the flow of air from the auxiliary reservoir to the brake cylinder has lowered the auxiliary pressure slightly below that of brake pipe, brake pipe air moves the triple piston and the graduating valve to the service-lap position. The flow of air to the brake cylinder therefore ceases. The slight difference in pressure which was capable of moving piston and graduating valve is not sufficient to move the triple slide valve. The slide valve may previously have been in the quick service position

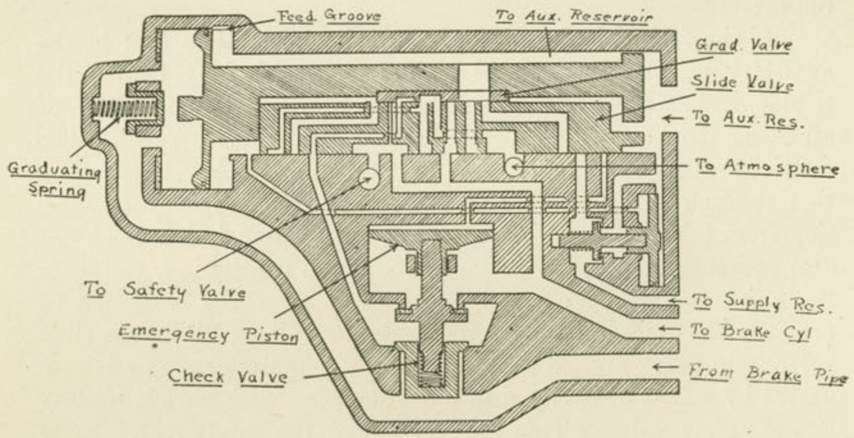


Fig. 20.

GRADUATED RELEASE LAP POSITION. L TRIPLE.

or in the full service position, but in either case the piston and graduating valve movement blanks the ports.

Release and Recharge. The triple slide valve being in the quick service position, a rise of brake pipe pressure for the release of brakes causes the piston, slide and graduating valves to move to the right and assume the release and recharging position. Air from the brake cylinder now exhausts to the atmosphere, while the auxiliary reservoir is being recharged through the feed groove and the secondary auxiliary charging route. At the same time port x leading from the supplementary reservoir is opened, and the higher supplementary reservoir pressure rapidly equalizes with

that of the auxiliary reservoir. During this operation the brake pipe and auxiliary reservoir pressures quickly come in balance, and this ensures a ready response in case a second application of brakes should be made. As soon as the supplementary and auxiliary reservoirs have equalized, the charging of both goes on by brake pipe air passing through the feed groove and the secondary auxiliary charging route, the supplementary reservoir receiving

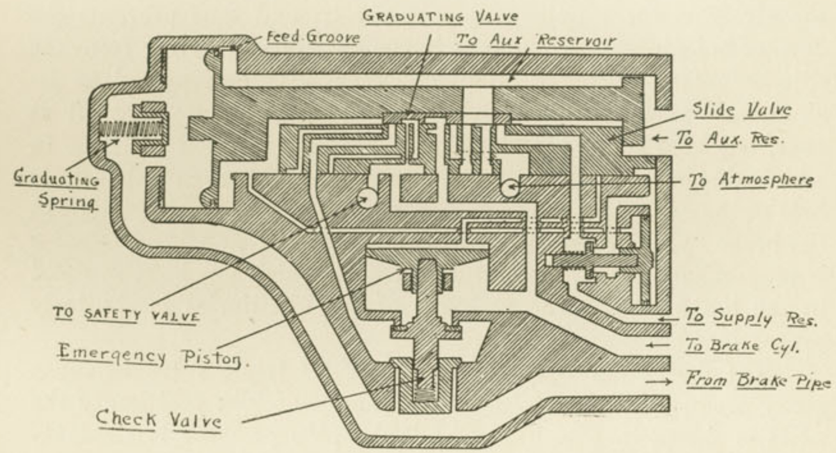


Fig. 21.

SERVICE LAP POSITION, L TRIPLE.

its supply from this auxiliary reservoir through port k in the slide valve and port x in the body of the triple.

The Graduated Release. Another and important feature of the "L" triple valve is the graduated release. This feature enables the engineer to let some air out of the brake cylinder and hold what remains. The graduated release-lap is shown in Fig. 21. The graduated release may be used several times, and is in fact a partial or step-down-and-hold reduction of the pressure in the brake cylinder. If the brakes have been applied and it is desired to partly release them, the engineers' brake valve is manipulated so as to permit only a slight increase in brake pipe pressure, and is then turned to lap. Only sufficient air is introduced into the brake pipe to move the triple piston with the slide and graduating valves to the release position. The flow of air from the supplementary reservoir continues for a brief space of time, only sufficient to raise the pressure in this auxiliary reservoir slightly above that of the brake pipe, and the triple piston and the graduating valve move to the left and assume what is called the graduated release-lap position. In this position the graduating valve stops the exhaust of air from the brake cylinder to the atmosphere, holding what is in the cylinder, and also shuts off the air from the supplementary reservoir, and thus prevents the further building up of pressure in the auxiliary reservoir from the supplementary reservoir. This operation may be repeated as desired, and thus the brake cylinder loses its pressure, not all at once, but by a series of exhausts, separated by periods of time in which the brake cylinder pressure, reduced by each exhaust, is held at the discretion of the engineer. The amount of reduction in the brake cylinder pressure for any one of the step-down releases is proportional to the amount of pressure which has been restored in the brake pipe. The recharge of the auxiliaries is similarly proportioned.

The Emergency Application. The "L" triple valve in emergency produces a very powerful brake action. The position of the parts is shown in Fig. 22. The brake pipe pressure is suddenly reduced, and the triple piston is forced by auxiliary reservoir pressure to move to its extreme or full travel position to the left, where it compresses the graduating spring. Air from the auxiliary reservoir enters the brake cylinder by port s in the slide valve, and r in the triple body. This may be called the emergency route for the air from the auxiliary reservoir; port t, in the triple body, is uncovered by the end of the slide valve, and auxiliary reservoir pressure flows to the top of the emergency piston. The emergency piston is then pushed down and forces the emergency valve from its seat. Brake pipe pressure lifts the check valve v, so that air from the brake pipe finds a direct passage to the brake cylinder. The position of the slide valve in the emergency is such that air from behind the by-pass piston flows through port c in the triple body, and d in the slide valve, and so to the brake cylinder. This causes the by-pass piston to move to the left and unseat the by-pass valve, compressing the by-pass spring. The by-

pass valve being open permits air from the supplementary reservoir to flow to the auxiliary reservoir, thus giving practically an auxiliary reservoir volume approximately three times its normal amount. Air from the supplementary reservoir continues to flow into the auxiliary reservoir and brake cylinder until all three are very nearly equalized, when the by-pass spring closes the by-pass valve and cuts off pressure from the supplementary reservoir. The cavity q in the slide valve has now moved past the brake cylinder port r, and has thus cut out the safety valve, so

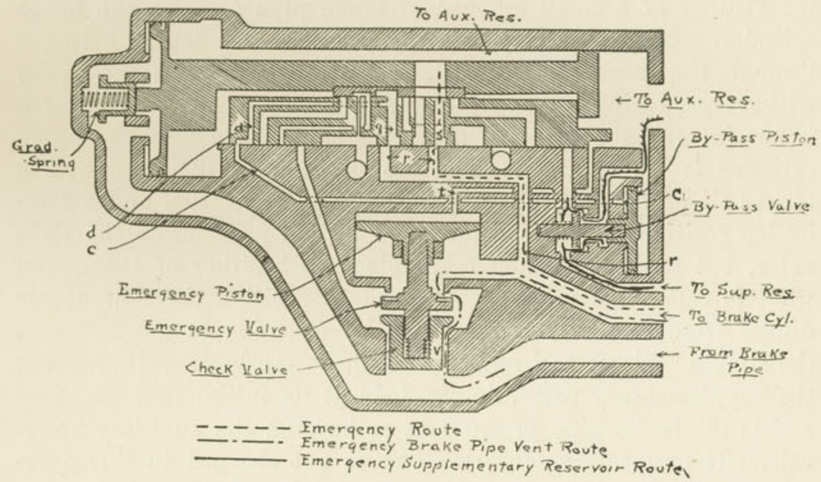
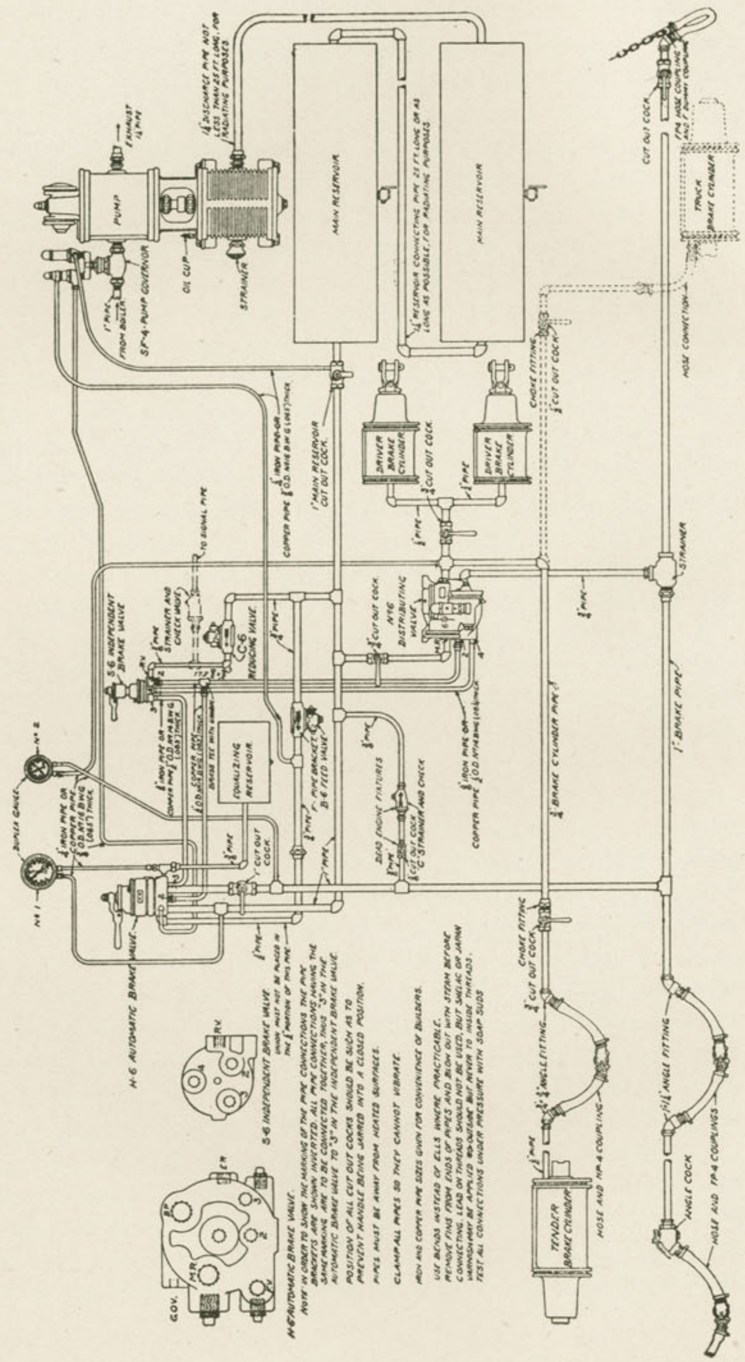


Fig. 22.

EMERGENCY POSITION, L TRIPLE.

that there is no escape of air from the brake cylinder until the brakes are regularly released. In this way the emergency application causes the brake cylinder pressure to rise very nearly to maximum brake pipe pressure, which is higher than that obtainable with the old standard high-speed brake, and the brake cylinder pressure is held at the maximum until the brakes are released.

Recapitulation of the Action of the "L" Triple Valve. To recapitulate briefly these various brake actions, one may say that in charging and full release the brake cylinder is emptied, and the auxiliary and supplementary reservoirs are filled with air at brake pipe pressure. In quick service application brake pipe pressure is reduced; this moves the triple piston to the left and shuts off communication between brake pipe and the auxiliary and supplementary reservoirs, closes the brake cylinder exhaust, and isolates supplementary reservoir pressure. Air from the auxiliary reservoir flows to the brake cylinder, while air from the brake pipe is momentarily vented into the brake cylinder. Full service application is obtained by a more rapid brake pipe reduction than in quick service, and it cuts out the quick service feature, which is the venting of a small amount of brake pipe air into the brake cylinder. The auxiliary reservoir feeds the brake cylinder through the large service port, and strongly applies the brake without producing an emergency application. The safety valve is cut in, and the pressure above 62 pounds fed into the brake cylinder is blown away. The lap position of the triple valve blanks all ports. There is a quick-service-lap position and a service-lap-position which is determined by the position of the slide valve, but no brake action takes place with either of them. In what is called the release and recharge position the flow of air differs from that of full release and recharging in the fact that the simple "release and recharge" empties the brake cylinder, but the supplementary reservoir air, held at its initial pressure, now assists the brake pipe pressure in recharging the auxiliary reservoir. The supplementary reservoir is not charged in this operation until after its pressure has equalized with that of the auxiliary reservoir, but supplies air to the auxiliary reservoir, and the auxiliary reservoir is at the same time being charged from the brake pipe through the feed groove and the secondary charging route. After equalization with the auxiliary, the supplementary reservoir is charged from the auxiliary reservoir. The graduated release prevents further charging of the auxiliary reservoir from brake pipe and supplementary reservoir, prevents recharging the supplementary reservoir, but permits the release of brakes to take place as desired by the movement of the graduating valve, causing a series of step-down-and-hold exhausts from the brake cylinder. In the emergency application brake pipe air is quickly vented into the brake cylinder, auxiliary reservoir pressure flows freely to the brake cylinder through a large port, and the sup-



PIPING DIAGRAM OF THE No. 6 ET EQUIPMENT

plementary reservoir adds its volume to that of the auxiliary reservoir, the safety valve is cut out and the maximum brake cylinder pressure is held until released.

THE No. 6 ET LOCOMOTIVE BRAKE EQUIPMENT.

The ET locomotive brake equipment of the Westinghouse Air Brake Company is so called from the initial letters of the words engine and tender. What is known as the No. 6 ET equipment is the most recent design, and has very much less apparatus than the combined automatic and straight air brake. While it secures the advantages of that form of brake, it has several new features of value. The ET equipment, being intended for the engine and tender alone, can be applied to any locomotive, whether used in high-speed passenger, ordinary passenger or freight service, and whether or not the double pressure control apparatus is used or not.

Advantages of the ET Equipment. The advantages gained by the ET brake equipment are that the locomotive brakes may be used in connection with, or independently of, the train brake, and without reference to the position of the locomotive in the train. The locomotive brake, which in this case includes that of the tender, may be applied at any time with any pressure between the maximum and the minimum. The pressure-maintaining feature automatically keeps up the brake cylinder pressure against leaks, and without reference to variations of brake-cylinder piston travel. The brake can be graduated on or off with either the automatic or the independent brake valves.

Parts of the ET Equipment. The parts of the equipment are, of course, the air pump, the main reservoir, a duplex pump governor, two duplex air gauges, one of which shows equalizing-reservoir pressure and main reservoir pressure, the other indicates brake pipe pressure, and also that of the locomotive brake cylinders. There are also the driver, engine-truck, and tender brake cylinders, with connections, hose, strainers, couplings, cut-out-cocks, fittings, etc.

The parts of the equipment which are peculiar to the ET equipment are, first the distributing valve attached to a small double chamber reservoir. This valve and its reservoirs perform the functions of triple valves, auxiliary reservoirs, double check valves and high-speed reducing valves for the locomotive brakes. In fact, it may be said that these parts, usually separate and distinct with each brake cylinder, are here combined in one device, so that all the engine and tender brake cylinders are filled and emptied at the same time and to the same amount by the action of one distributing valve placed on the engine. There are also two brake valves in the cab, one the automatic engineers' valve, which operates locomotive and train brakes at the same time, and an independent brake valve which is used to operate the locomotive brakes only. In connection with the automatic brake valve, there is a feed valve to regulate brake pipe pressure, and a reducing valve in connection with the independent brake valve to reduce main reservoir pressure for the independent valve and also for the signal system when used.

The fundamental principle of the air brake is that a brake pipe reduction sets the brake, whether done intentionally at the brake valve or accidentally brought about by the bursting of a hose, or the break-in-two of the train. This principle is maintained in the ET equipment. The car triple valves supply auxiliary reservoir pressure to the brake cylinders throughout the train, but the distributing valve always supplies main reservoir pressure to the engine and tender brake cylinders. These two modes of brake application take place when the brake pipe pressure is reduced. The use of the independent brake valve sets the engine and tender brakes without applying the train brakes, and releases them without producing any effect on the brakes of the rest of the train.

The No. 6 Distributing Valve and Double Chamber Reservoir. The No. 6 distributing valve is a cleverly devised piece of mechanism, which acts as a sort of central triple valve for all the brake cylinders on the engine and tender, and always supplies main reservoir pressure to them without interfering with the auxiliary reservoir method of brake cylinder supply as used on the train. The distributing valve itself is practically a plain triple valve, Fig. 23, with what amounts to an auxiliary reservoir attached. There is also another small cylinder with piston and rod, the latter carrying two slide valves, one to admit main reser-

voir pressure to the brake cylinder, and the other to free this pressure from the brake cylinders when the brake is released.

The Westinghouse Air Brake Company have applied distinctive names to these various parts of the distributing valve which, to a certain extent, indicate their use. The part of the

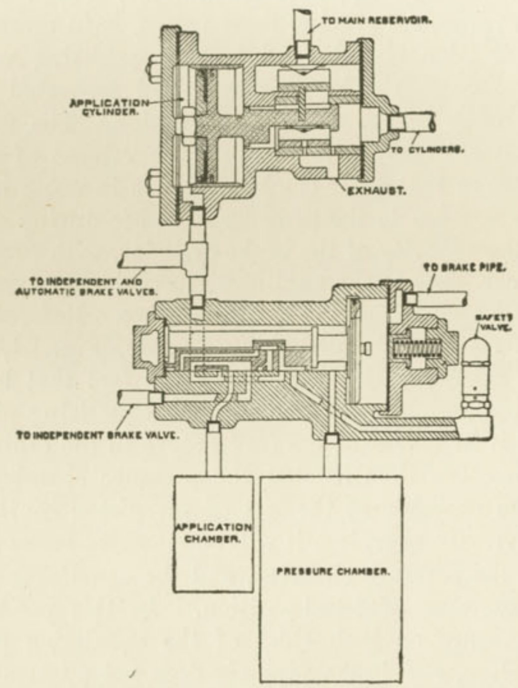


Fig. 23.

DIAGRAMMATIC VIEW OF THE ESSENTIAL PARTS OF THE DISTRIBUTING VALVE AND DOUBLE CHAMBER RESERVOIR.

distributing valve which corresponds to the plain triple slide valve is called the equalizing valve, and this valve has in connection with it a graduating valve in the usual way, and what otherwise would be the auxiliary reservoir is now called the pressure chamber. These parts of the equalizing valve are used in automatic brake valve applications only, and a reduction in brake pipe pressure operates the equalizing and graduating valves in the usual way, and these, governing the flow of air from the pressure chamber, operate the application portion of the distributing valve, which is the one having the feed and exhaust valves governing the access of main reservoir pressure to the locomotive brake cylinders. The exhaust valve governs the escape of air from the brake cylinders. The application cylinder, which contains a tightly fitting piston for moving these valves, is in communication with the application chamber while the equalizing valve is in release, service or service-lap position, and separated when the equalizing valve is in the emergency position. The function of the application chamber is to increase the volume of the application cylinder, so that their combined space in cubic inches will bear the same relation to the pressure chamber during service applications as the capacity of the brake cylinder, with proper piston travel on the car, does to the auxiliary reservoir supplying it.

Charging Through the Distributing Valve. Reference to the diagrammatic view of the distributing valve, Fig. 24, which is shown in the release position, discloses the fact that brake pipe pressure reaches the right-hand side of the equalizing piston, and passes around it by means of the feed groove in the ordinary way. Brake pipe pressure thus reaches the pressure chamber and, of course, fills the chamber at the left of the piston containing the equalizing valve. In charging, it will be seen that brake pipe pressure soon fills the pressure chamber, and the equalizing piston remains at its extreme left-hand position. In this position, with brake pipe pressure on both sides of the equalizing piston, no motion takes place, and brake pipe air does not penetrate beyond the pressure chamber and the chamber containing the equalizing valve. The brake is then in a condition ready to respond to any brake pipe reduction. This is the position assumed by the parts of the distributing valve in full release, either automatic or independent.

The Service Application. In making a service application with the automatic brake valve, a reduction of brake pipe pressure is effected, with the result as shown in Fig. 25. This causes the equalizing piston to move to the right, thus cutting off the supply through the feed groove. The movement of the piston carries with it, first, the graduating valve, and then the equalizing

valve. The position assumed by these parts when the piston has reached, and been stopped by, the graduating sleeve and spring, is such that air from the pressure chamber reaches the application chamber, and communication is also established between the ap-

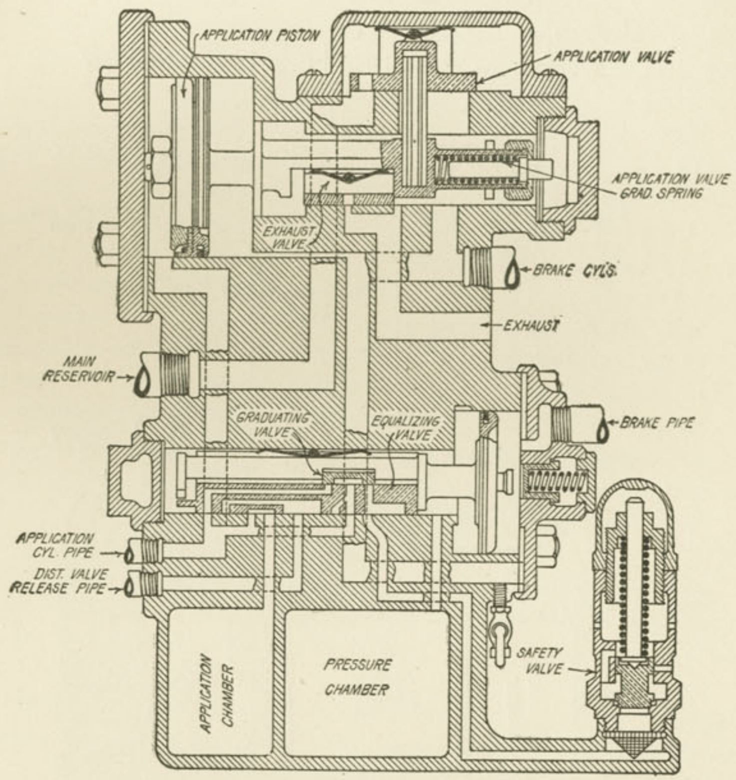


Fig. 24.

Distributing Valve—Release, Automatic or Independent Position.

plication chamber and the safety valve, which is set to blow off at 68 pounds. Pressure chamber air also reaches the application cylinder pipe which leads to the independent brake valve, but as that valve is practically closed under these conditions, it need not now be considered.

Under these conditions a pressure has now been introduced into the application chamber and cylinder according to the amount of brake pipe reduction. It acts on the left of the application piston, and forces it to the right. The back or inner side

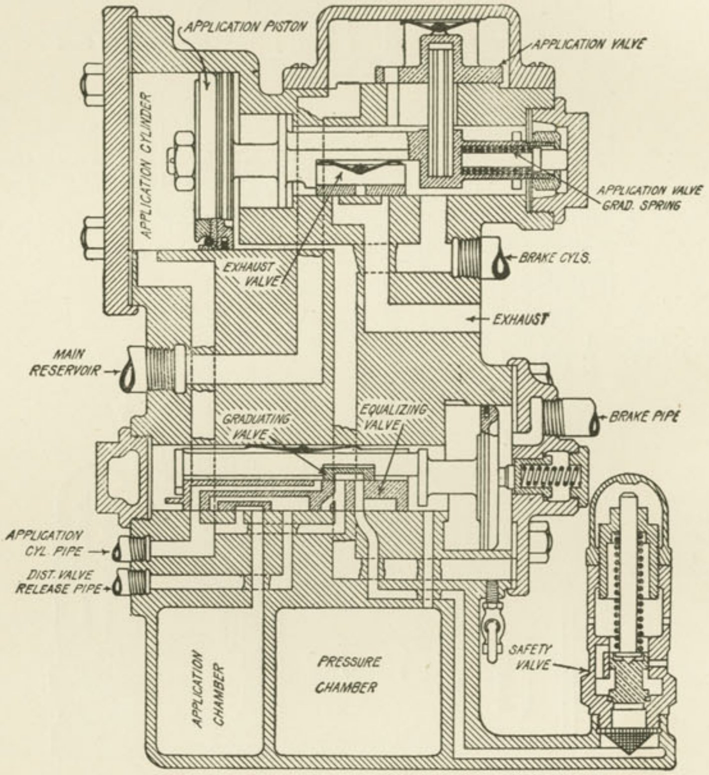


Fig. 25.

Distributing Valve, Service Automatic Position.

of the application piston is in communication with the brake cylinders, and as there is now no pressure in these cylinders, the movement of the application piston is positive. The piston-rod of this application piston carries on it two slide valves. The lower or exhaust one closes off communication between the brake cylinders and the atmosphere, and thus prepares the cylinders for the introduction of air pressure from the main reservoir. This movement of the application piston to the right compresses its graduating spring, and at the same time carries the upper or application slide valve over, so as to open direct communication between the main reservoir and the brake cylinders. The air that reaches the application chamber under present conditions is substantially at the same pressure per square inch as that which would be developed in a brake cylinder through the ordinary triple valve for the same brake pipe reduction.

Main reservoir pressure is in any case higher than even maximum brake cylinder pressure, and in this series of events sufficient air was admitted to the application cylinder to make a partial application only. As a result, a gush of main reservoir air now reaches the brake cylinders and applies the brakes, and this main reservoir air in the brake cylinders, though prevented from escaping to the atmosphere by the closure of the exhaust valve, is nevertheless able to reach the inner or back side of the application piston. Brake cylinder pressure acting on the application piston, aided by the application piston graduating spring, forces the application piston to move to the left, and promptly shut off the flow of air from the main reservoir to the brake cylinders when this pressure becomes equal to that in the application cylinder, as the application slide valve is pinned directly to the application piston-rod, and moves in strict accord with it, and without any lost motion.

Service-lap Position. This movement to the left of the application piston does not release the brakes, for the simple reason that the exhaust slide valve is not directly attached to the application piston-rod, but is moved by shoulders on the piston-rod, and these are so spaced as to permit just sufficient travel of the piston-rod to release the graduating spring without forcing the exhaust slide valve to uncover its closed ports. This is the service-lap position, shown in Fig. 26. All this time, that is, in the service application, it must be remembered, the application chamber had been put in communication with the safety valve, and thus the movement of the application piston to the service-lap position has been hastened by the reduction of application chamber pressure, if that pressure was higher than the adjustment of the safety valve, which in the first place moved the application piston against its graduating spring and introduced main reservoir pressure to the brake cylinders, which in turn acted on the inner or back

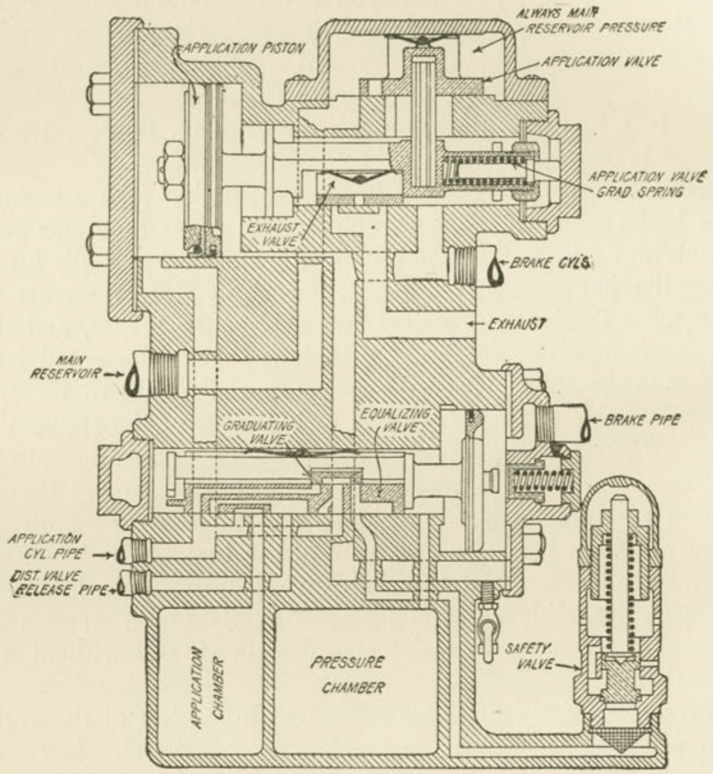


Fig. 26.

DISTRIBUTING VALVE, SERVICE LAP POSITION.

side of the application piston so as to shut off further flow from the main reservoir and so hold the brakes applied.

The return of the application piston to the service-lap position has thus been effected by the combined action of two agencies, viz.: its graduating spring and increase of brake cylinder pressure. The brakes set rapidly under main reservoir pressure, and the

movement to service-lap position was thus sufficiently rapid to prevent an excessive rise of brake cylinder's pressure, even though supplied directly from the main reservoir. The fall of pressure in these chambers reduces the pressure on the inner or back side of the equalizing piston and permits brake pipe pressure to predominate sufficiently to move the equalizing piston to the left, and so move the graduating valve without moving the equalizing valve itself. The graduating valve carried on the back of the equalizing valve, when so moved, cuts off the flow of air to the safety valve, and at the same time blocks the passage of air from the pressure chamber to the application chamber. The air in the application chamber is thus shut in and isolated in the service-lap position, with the brakes set.

Effect of Leakage on Brake Cylinder. With things in this condition, we may now consider what would take place if a leak from any one of the brake cylinders depleted the pressure now holding the brakes set. A leak from any one brake cylinder on the engine and tender affects the pressure in all, but would be promptly dealt with by the application valve. Leakage from a brake cylinder would, of course, diminish the power of the brake, and in time would practically amount to a release if the depletion from such leakage was not prevented. It should be remembered that brake cylinder pressure is at all times exerted on the inner or back side of the application piston while in service-lap position, which we are now considering, and the isolated air exerting its pressure in the application cylinder is acting on the other side. While each balances the other no movement of the application piston can take place. Leakage from a brake cylinder would reduce the pressure on the back or inner side of the application piston, and the isolated pressure on the other side of this piston would predominate sufficiently to move the application piston far enough to again open the application slide valve without moving the exhaust valve. Main reservoir air would at once supply the deficiency caused by the leak, augment the cylinder pressure sufficiently to once more force back the application piston, and so cut off main reservoir pressure from the brake cylinders, and thus keep up the brake cylinder pressure. The action, caused by a leak, would thus produce an intermittent movement of the application piston and application valve back and forward, giving them an exceedingly small stroke, and the weakening effect of the leak would thus be constantly and readily neutralized. This action is called the pressure-maintaining feature, and is one of the greatest importance in holding the locomotive brake to its work with practically no fluctuation even in the presence of leakage. Another good feature of the ET equipment is that long or short brake cylinder pistor travel has no effect upon the power of the brake.

Full Release Position. The release of the brake is effected in the usual manner. The restoration of brake pipe pressure forces the equalizing piston to its extreme left position, and, carrying with it the equalizing and graduating valve, opens the feed groove again. This movement cuts off communication between the pressure chamber and the application cylinder, and permits brake pipe air to again enter the pressure chamber, and releases, through the distributing valve release pipe (leading through the automatic engineers' valve to the atmosphere), the pressure in the application cylinder which had been isolated in the service-lap position, and thus cause the brake cylinder pressure to move the application piston to its extreme left position, and with it the exhaust slide valve, and permit it to uncover the brake cylinder exhaust ports and release the brake.

Principle of Distributing Valve Action. The action of the distributing valve so far described is in a way analogous to the action of a telegraph relay. The relay is on the main line wire, and is actuated by the making and breaking of the main line circuit by the telegraph key under the hand of the operator. The to-and-fro movement of the relay armature-bar makes and breaks the contact for a local though powerful battery current which actuates the sounder in the telegraph office. In like manner the equalizing portion of the distributing valve, analogous to the main line relay, responds to train pipe pressure fluctuation, and its to-and-fro movement is the means of operating the application portion of the distributing valve which directly controls the local but high pressure contained in the main reservoir.

Independent Brake Valve Action. The application and release of the locomotive brakes, which, of course, includes the tender, may also be effected by the use of the independent brake valve. This valve receives main reservoir pressure, limited by the reducing valve to 45 pounds on top of its rotary. This independent

brake valve is on a loop of pipe, if one may so say, the two ends of which communicate with the distributing valve, one by the application cylinder pipe and the other by the distributing valve release pipe, and between the independent brake valve and the automatic brake valve there is a connection from the application cylinder pipe and through the independent valve from the distributing valve release pipe, which, when the automatic brake handle is in running position, communicates with the atmosphere. The application cylinder pipe at the automatic brake valve end is blanked when the handle of that valve is in running position. The independent brake valve, when in running position, makes connection between the application cylinder and the automatic brake valve, so that the application cylinder brake pipe is closed. With the automatic brake valve in running position, it will be seen that the independent brake valve in running position keeps these two pipes as described, that is, application cylinder pipe closed and distributing valve release pipe open to the atmosphere.

Independent Application Positions. The independent brake valve is now able to produce a locomotive brake application on its own account without setting or releasing the train brake. It has two modes of making its application, one when its handle is placed in the "slow application position, and another when in the "quick" application position. In the slow application position, main reservoir air, when reduced to 45 pounds, flows through the independent rotary valve by a very small port, and so reaches the application cylinder pipe, as shown in Fig. 27. This reduced main reservoir pressure is fed comparatively slowly through the restricted port in the independent valve, and flows directly to the outer or front side of the application piston, which it moves to the right, thereby closing the brake cylinder exhaust and uncovering the supply port leading from the main reservoir to the brake cylinders. The same action takes place when the automatic brake valve is used, and forces the application piston valve to assume the service-lap position, and the pressure maintaining feature operates as before. When the independent valve handle is put in lap position, it blanks its ports and holds the brakes applied with whatever force was secured in the slow application position. The position assumed by the distributing valve parts, when the independent brake valve is on lap, is called the independent-lap position,

Fig. 28, of the distributing valve. In the quick application position, the independent brake valve opens a larger port for air to pass through it, and consequently the flow of reduced main reservoir air to the application cylinder is more rapid and fuller than

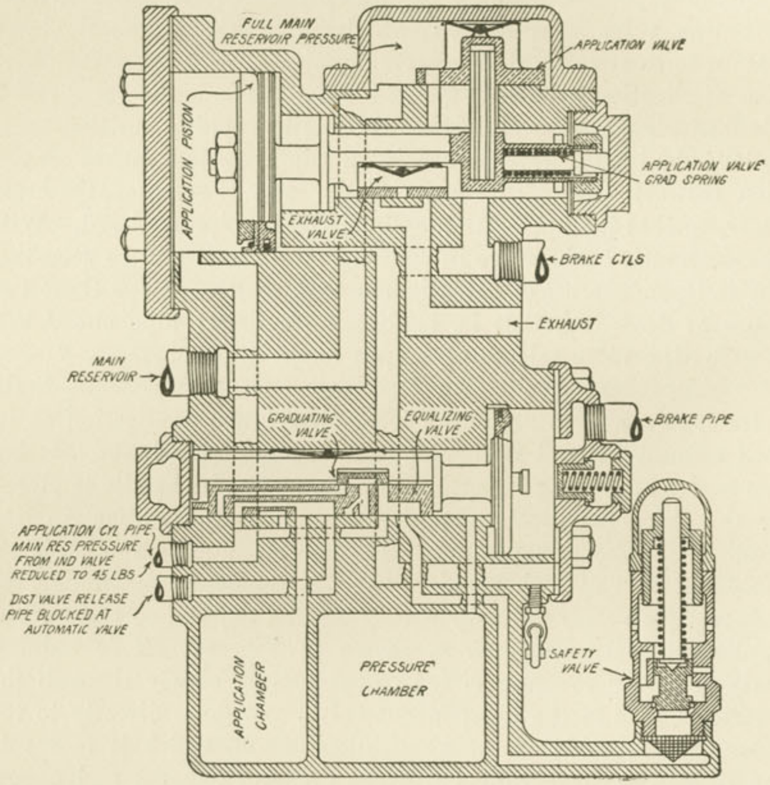


Fig. 27.

Distributing Valve, Independent Application Position.

with slow application. The pressure maintaining feature again operates, and when the independent brake valve handle is placed in lap position, it isolates the pressure in the application cylinder just as the automatic valve did when the distributing valve was in the service-lap position.

The maximum pressure that can be introduced into the application cylinder by the independent brake valve is 45 pounds, because the independent valve never gets higher pressure from the reducing valve; therefore it follows that this is the highest brake

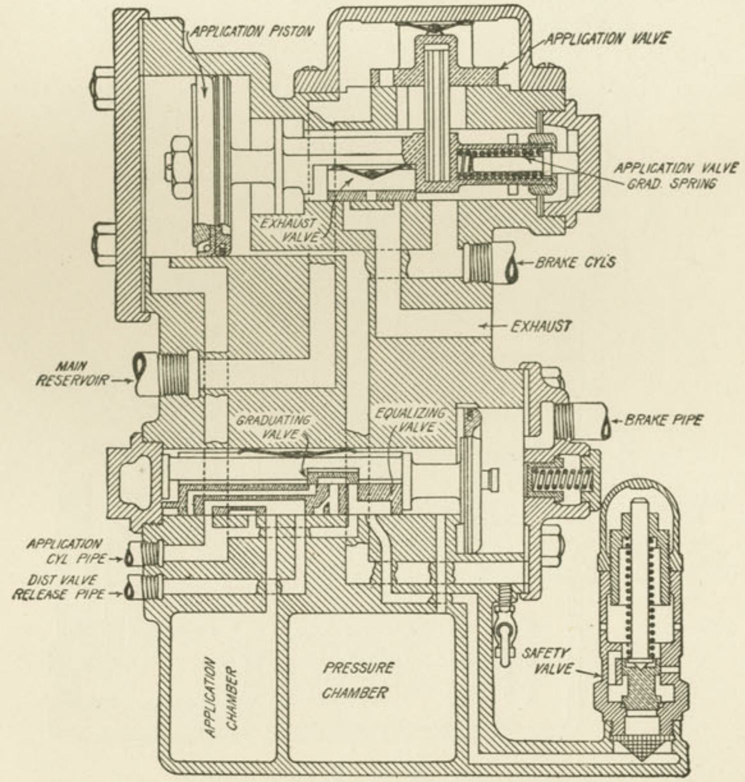


Fig. 28.

Distributing Valve, Independent Lap Position.

cylinder pressure which can be obtained by the use of the independent brake valve. The release of brakes by the independent valve can be graduated as in the case of the automatic valve. The independent release, Fig. 29, is effected by returning the independent brake valve to its running position, whereby communication is established between the distributing valve release pipe and the atmosphere through the automatic brake valve, provided that valve is in running position. If it is not in running position, the

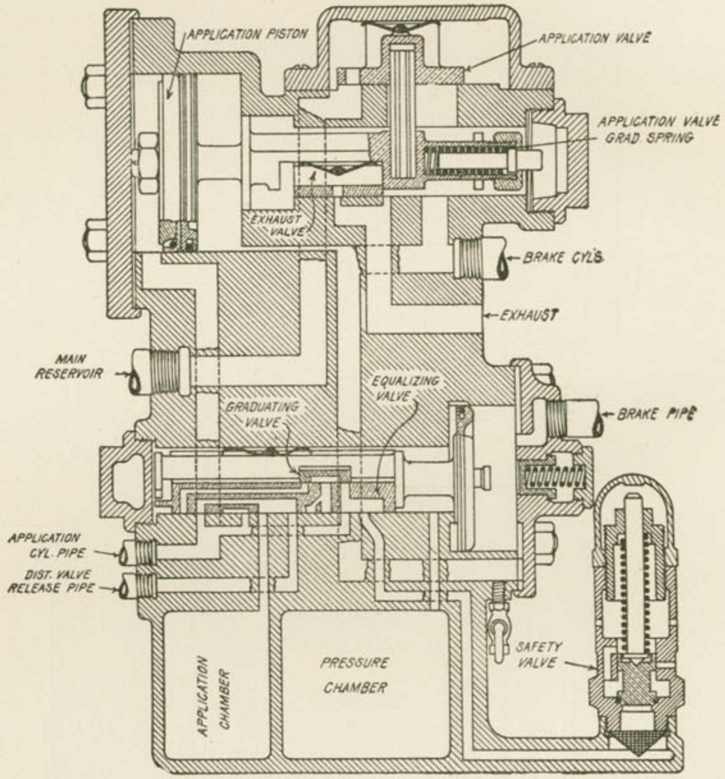


Fig. 29.

Distributing Valve, Release by Independent Valve After Automatic Application.

independent release can still be effected by the independent valve handle being placed in release position, when the independent brake valve establishes communication between the distributing valve release pipe and the atmosphere through its own exhaust port.

Independent Brake Valve. The independent brake valve, Fig. 30, is provided with a return spring, which automatically moves the handle from release to running position as soon as the engineer lets go of it. This arrangement is for the purpose of preventing the handle being left in release, as it would then be impossible to operate the locomotive brake with the automatic brake valve, for the reason that the release position of the independent brake valve, if permanently assumed, would be equivalent

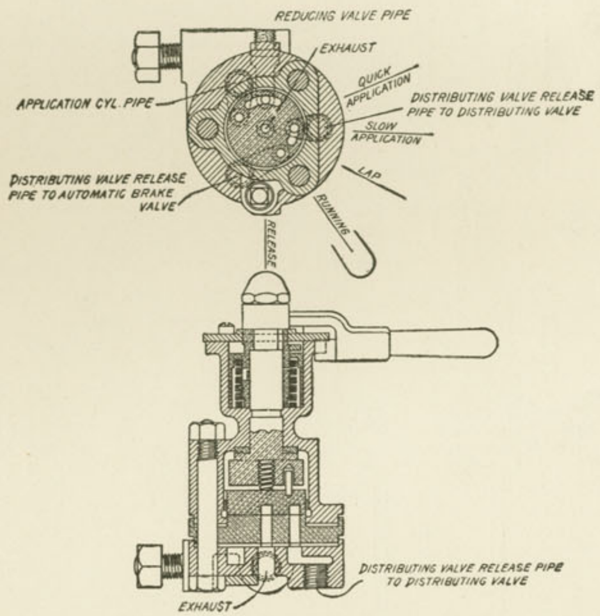


Fig. 30.

S-6 Independent Brake Valve.

to a broken distributing valve release pipe. When in the release position a warning port is opened, and the blow from this would notify the engineer that the independent valve was in release position if the return spring became inoperative. The return spring on the independent brake valve serves another purpose as well as that just described. It automatically returns the independent brake valve handle from quick to slow application position, unless held by the engineer. This is done for the purpose of checking an unintentional movement to the quick application position when the slow application was desired. The tension of the return spring causes the engineer to feel that he has passed the slow appli-

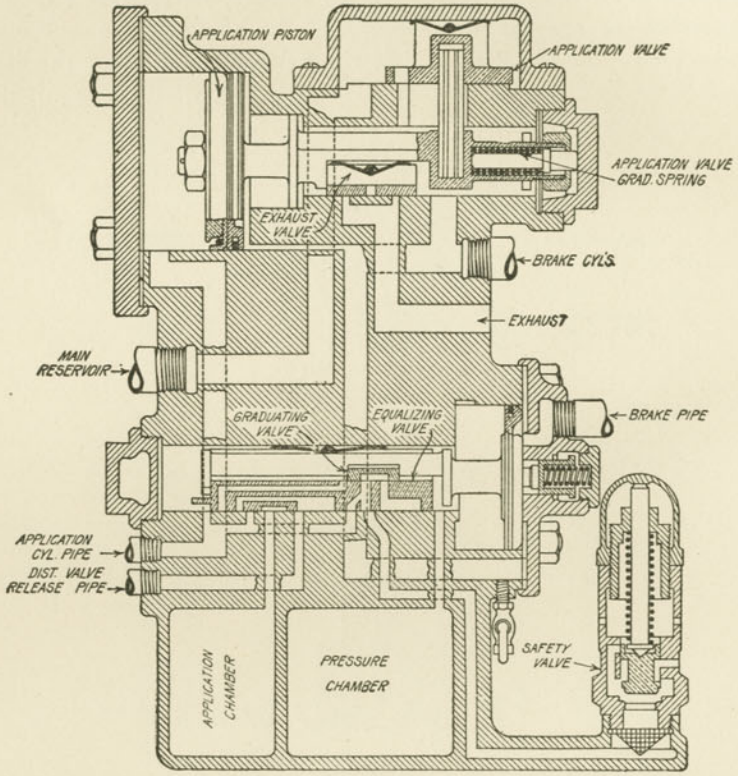


Fig. 31.

Distributing Valve, Emergency Position.

cation position; he thus avoids a heavy application, when only a light one was intended.

Emergency Application. The emergency application of the ET brake, Fig. 31, is made by the automatic brake valve. When the handle is thrown to the extreme righthand position, there is, of course, a sudden and heavy brake pipe reduction similar to that

which would occur if a hose burst. The escape of air from the brake pipe acting on the distributing valve causes the equalizing piston to move to its extreme right position and fully compress the graduating spring. This causes the equalizing valve to open direct

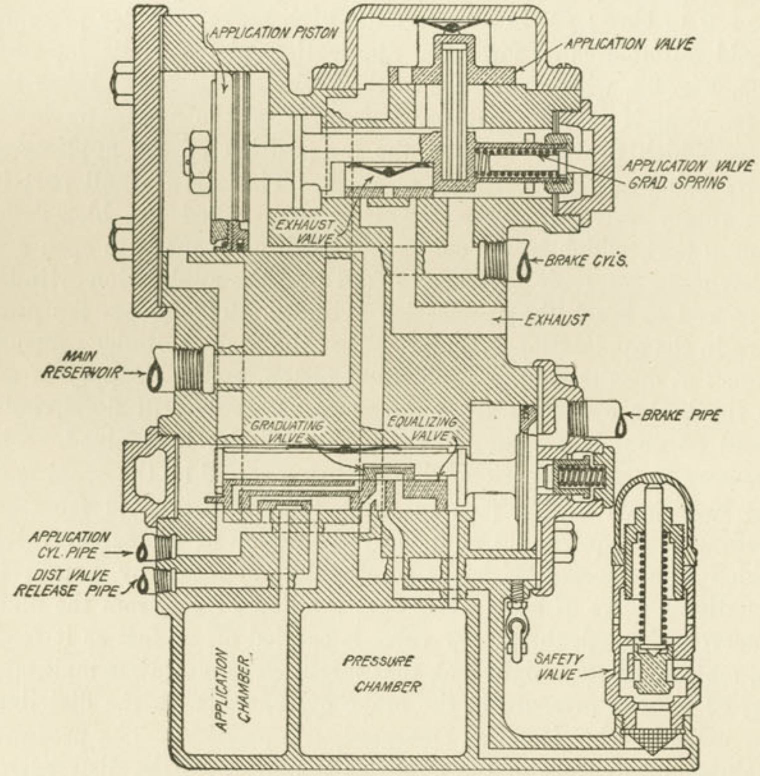


Fig. 32.

Distributing Valve, Emergency Lap Position.

communication between the pressure chamber and the application cylinder without opening the port leading to the application chamber which it thus cuts out. Pressure-chamber air, containing original brake pipe pressure, quickly equalizes in the small application cylinder, and a resultant pressure of about 65 pounds is secured, which acts on the application piston and drives it to its extreme right-hand position. This movement has the effect of promptly closing the exhaust passage from the brake cylinders and fully opening the port by which main reservoir pressure pours into them. The safety valve passage is also connected with the application cylinder, though the application cylinder pressure is now too low to blow; yet in any case the high brake cylinder pressure would automatically force the application piston to its lap-position, Fig. 32, with a pressure in the brake cylinders far below the maximum, if it were not for a feature of the automatic brake valve which provides against the lap-position of the application valve being now prematurely assumed. There is a small port in the rotary valve of the automatic valve, called the blow-down timing port, which in the emergency position is made to open and allow main reservoir pressure to feed into the application-cylinder pipe and so reach the application cylinder. This raises the pressure in the application cylinder so that the brake cylinder pressure cannot at once move the application piston, and the supply of air to the brake cylinders from the main reservoir still flows, until about 68 pounds pressure in the brake cylinder is obtained. The pressure in the application cylinder, being raised by the opening of the blow-down timing port in the rotary, is prevented from exceeding the required 68 pounds by the action of the safety valve, which is connected with the application cylinder by a port in equalizing valve of such a size that the flow of air from the main reservoir through the rotary valve is carried off as fast as it feeds in, making up any slight leak that might exist, and thus maintaining 68 pounds pressure in the brake cylinders, with the distributing valve in what is called emergency-lap position. The pressure-maintaining feature of the application portion of the distributing valve is now, as in other cases, still operative, and the effect of leaks is thus neutralized, and a constant pressure of 68 pounds to the square inch is held steadily in the brake cylinder until the brakes are definitely released.

Arrangement for "Double-heading." In "double-heading," the handles of the automatic and the independent brake valves on both engines are kept in the running position. The distributing valve release pipe is open to the atmosphere through the automatic valve on the leading engine; the double-heading cock below the automatic

valve is closed on the second engine. The action of the distributing valves takes place as described in automatic brake valve applications. In double heading the distributing valve action on the second engine is similar to the triple valves on the train. In case the engineer of the second engine wishes to apply or release his

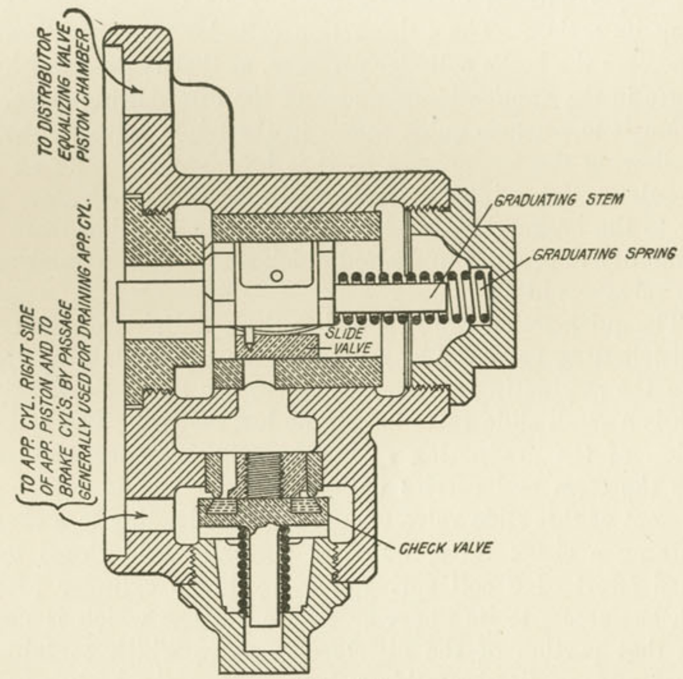


Fig. 33.

Quick Action Cylinder Cap.

locomotive brake, he can do so by using his independent brake valve, without touching his automatic valve.

Quick-action Cylinder Cap. In connection with the distributing valve there is an attachment which is supplied by the Westinghouse Air Brake Company when specially ordered. This attachment is very desirable when engines are used in double-heading, and is called the quick-action cylinder cap, and is shown in Fig. 33. Its function is to add the quick-action feature of the

"L" triple to the distributing valve when it is deemed advisable to cause brake pipe air to be vented into the brake cylinders in the emergency application. The equalizing portion of the distributing valve corresponds to the plain triple valve of the old standard locomotive brake equipment, and the addition of the quick-action head practically transforms the distributing valve into a quick-action triple without otherwise altering its construction or disturbing its action. The quick-action cylinder cap operation does not increase the brake cylinder pressure, as that is governed by the pressure in the application cylinder of the distributing valve. Its function is to produce quick action in the triple valve on the first car following the tender, and as it is less sensitive than an ordinary quick-action triple, it is placed in comparatively close proximity to the brake valve, and it performs its function there with less liability to produce undesired quick action than a quick-action triple valve would do.

The quick-action cap is bolted to the equalizing piston end of the distributing valve. The head contains the graduating spring, but on the graduating spring stem there are two collars, between which is a small slide valve having no lost motion. The full compression of the graduating spring in an emergency application moves the stem and carries with it the small slide valve. The movement of this slide valve uncovers a port leading to a chamber containing a check valve, which is normally held closed by the upward effort of a coil spring, and by brake cylinder pressure which has access to its under side by a passage which is used to drain that portion of the distributing valve which contains the exhaust and application slide valves. When the brakes are not set there is no air pressure below the quick-action check valve, and it is held to its seat by the coil spring beneath it. The sudden reduction of brake pipe pressure in an emergency application fully compresses the emergency spring, carries the emergency slide valve over so as to permit brake pipe pressure to reach the quick-action check, unseat it and flow directly into the brake cylinders. The rise in pressure in the brake cylinders, now filling with brake pipe and main reservoir air, quickly augments the pressure below the quick-action check, and, aided by the spring below, it closes the check. The action of the check valve in opening and closing under these circumstances is exceedingly rapid, but the venting of brake

pipe air into the brake cylinders of the locomotive equipment produces the almost instantaneous quick-action of the triple on the first car following the tender, and this action is carried on quickly throughout the entire train brake system. The quick-action feature of any triple valve is such that each promptly causes the next to act, and by introducing this feature, when required, into the

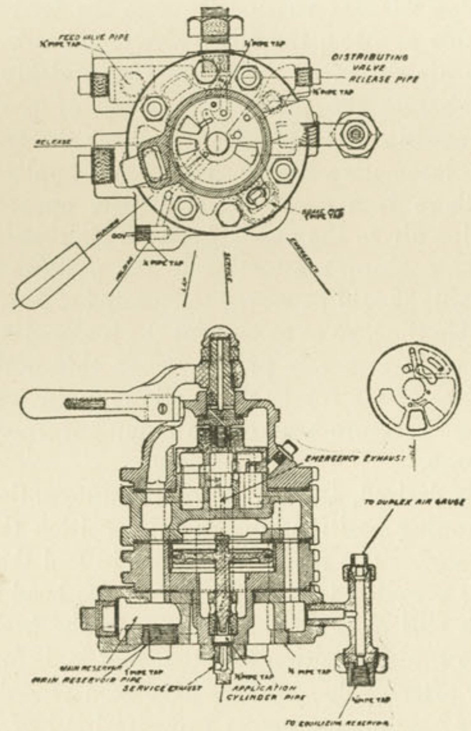


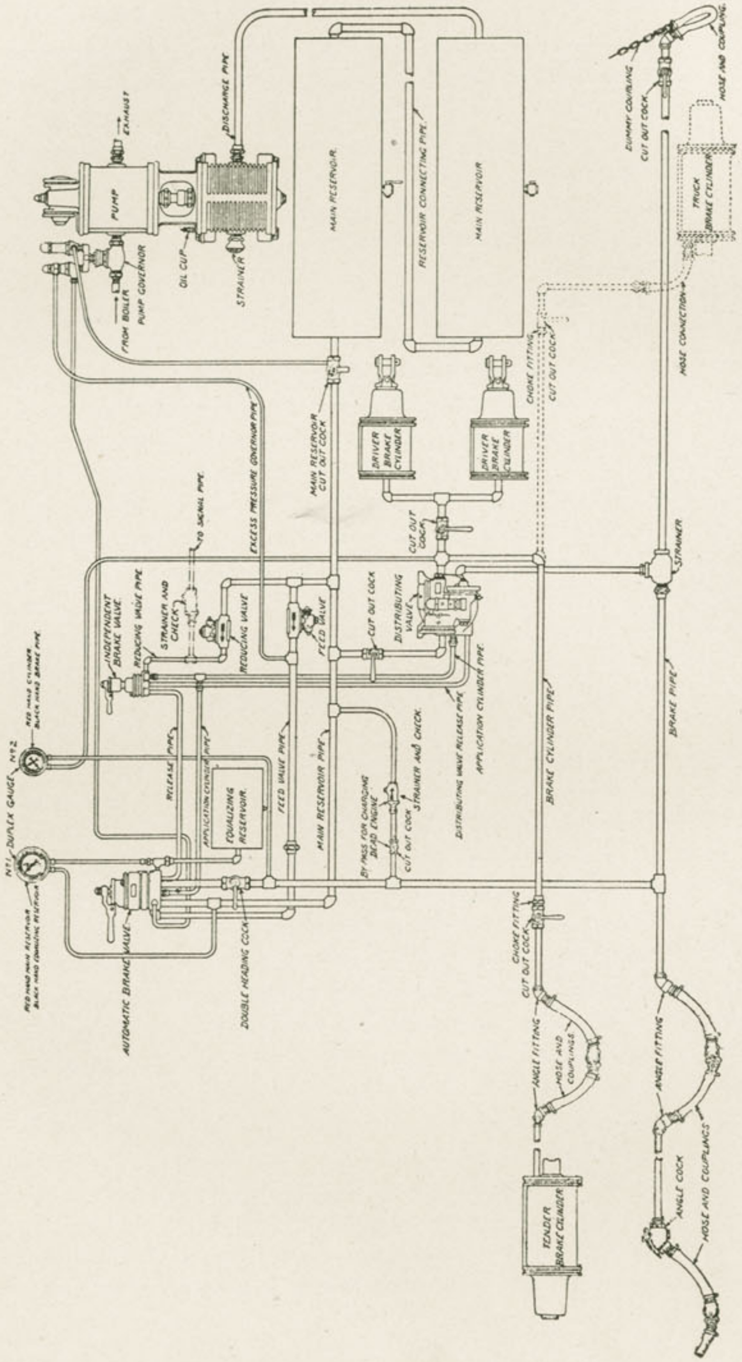
Fig. 34.

H-6 Automatic Brake Valve.

behavior of the distributing valve, it practically amounts to securing the normal distributing valve performance, plus the quick-action feature of the ordinary quick-action triple valve.

The H-6 Automatic Brake Valve. The engineers' brake valve used with the ET equipment is called the H-6 automatic brake valve, as shown in Fig. 34. It contains the features embodied in the previously designed automatic brake valves, but it is modified so as to suit the requirements of the No. 6 distributing valve. The charging and release position of the automatic brake valve is such that the relationship which its various parts are made to assume provides a large and direct passage from the main reservoir to the brake pipe, and a free supply of air from the main reservoir flows to the brake pipe without passing through the feed valve. With the handle in this position, the feed valve is cut out. The flow of main reservoir air direct to the brake pipe quickly releases the brakes and recharges the pressure chamber of the distributing valve and the auxiliary reservoirs throughout the train, but does not release the locomotive brakes if they are applied. While in this position there is a small warning port opened which discharges feed pipe air to the atmosphere. This makes sound sufficient to call the engineer's attention to the position of the brake valve. The handle should be moved to running or holding position, after a reasonable time, so as to prevent the brake system becoming charged up to main reservoir pressure. In this position a small groove in the face of the rotary valve allows main reservoir air to flow to the excess pressure head of the pump governor, which then controls the pump.

When it is desired, the handle of the automatic brake valve is placed in running position, and in this position the locomotive brakes are released. The feed valve is cut in and the main reservoir pressure is supplied to the excess pressure head of the pump governor which still controls the pump. If the brake valve has been placed in running position too soon, that is, before the brakes are charged, or after uncharged cars have been placed in the train and angle cocks opened, the excess pressure head of the governor will stop the pump until the difference in the main reservoir pressure and that of the brake pipe, as shown by the red and black hands on the Duplex Gauge No. 1, becomes something less than 20 pounds. The stoppage of the pump, owing to the rise of main reservoir pressure to maximum while the feed valve is supplying the brake pipe at a comparatively slow rate, indicates at once to the engineer that the running position has been assumed too early, and that by so doing he is unnecessarily delaying the recharging of the brake, as release position is intended to be maintained until



INSTRUCTION DIAGRAM OF THE NO. 6 ET EQUIPMENT

all the brakes have been released and the system very nearly fully recharged.

In the service-position of the automatic brake valve a gradual reduction of brake pipe pressure takes place, owing to the reduction of pressure in the chamber above the equalizing piston, and in the equalizing reservoir, which are always in communication. The exhaust of air from the chamber and the equalizing reservoir is slow, owing to the size of the port opened. The pressure therefore falls gradually. All the other ports are closed and the brake pipe pressure raises the equalizing piston, opens the piston valve and allows brake pipe air to escape to the atmosphere through the angle fitting. As soon as the required reduction of pressure in the equalizing reservoir has been made, the handle of the automatic brake valve is placed in lap position, and the flow of air from the chamber and the equalizing reservoir ceases. The escape of air from the brake pipe, however, continues until the larger volume of air in the brake pipe sinks to a pressure slightly below that of the equalizing reservoir, thus ensuring brake application. The gradual reduction of brake pipe pressure thus effected prevents quick-action, and what amounts to the practical equalization of the pressure in the whole length of the brake pipe with that of the equalizing reservoir, and also prevents premature release of the brakes at the front of the train. These features of the H-6 automatic brake valve are common to the preceding designs of engineers' brake valves.

The lap position closes all ports, and is used, as previously described, to stop the flow of air from the equalizing reservoir, and while in this position the brakes, if already set by a service application, are held set, until either a further reduction of brake pipe pressure is made by a second service application, or until it is desired to release the brakes. The lap position has hitherto been resorted to in case of a burst hose, a break-in-two, or if the conductor's valve has been opened, so as to prevent the loss of main reservoir pressure under these circumstances; but the Westinghouse Air Brake Company now recommend the emergency position of the brake valve in order to ensure the brake remaining applied under all conditions.

In describing the release position, it was stated that the train brakes would be released, while the locomotive brake, if applied, would be held so. The excess pressure from the main reservoir flows into the brake pipe, and when the brakes have been released and auxiliaries almost charged, the automatic brake valve handle is placed in either running position or in holding position. In the holding position the train brake is released, and brake pipe pressure reaches the auxiliary reservoirs and maintains pressure against leaks, while the distributing valve release pipe is prevented from discharging air isolated in the application chamber, and the locomotive brakes remain set, although the pressure chamber of the distributing valve now receives brake pipe pressure through the feed groove. Running position releases the locomotive brake by discharging the air isolated in the application chamber of the distributing valve, as well as permits the flow of main reservoir air to the brake pipe in the usual way. This running position releases every operative brake on the cars, engine and tender, while holding position releases the car brakes while keeping the engine and tender brakes set.

In the emergency position a large port, connecting the brake pipe with the atmosphere, is opened. This ensures a rapid and heavy reduction of brake pipe pressure, and the distributing valve and the car triple valves all go to their emergency position, and thus give maximum braking pressure in all the brake cylinders. At the same time the main reservoir air is enabled to flow through a restricted opening in the automatic valve rotary and reach the application cylinder of the distributing valve. This restricted flow of main reservoir air through the blow-down timing port in the automatic brake valve holds the application piston in position to apply the locomotive brakes with a pressure equal to that to which the safety valve of the distributing valve has been set, which is 68 pounds.

The B-6 Feed Valve. The feed valve furnished with the engineers' brake valve in the ET equipment is called the B-6 feed valve. It is an improved form of the slide valve type, and differs from preceding feed valves in the fact that it charges quicker to the predetermined pressure, and in its ability to maintain that pressure with less fluctuation, whether the train be long or short, and in spite of somewhat indifferent maintenance of the brake system. It is not intended, as it were, to authorize poor brake maintenance, but it is designed to meet actual conditions of rail-

way brake service where one train may be in better condition than another. It is supplied with air directly from the main reservoir and regulates pressure in the feed valve pipe, and also in the brake pipe when the handle of the automatic brake valve is in either running or holding positions. One of its particular features is an ingenious device whereby high or low pressure control is quickly and readily secured by a most simple adjustment.

This feed valve, as shown in Figs. 35 and 36, may be described as consisting of two parts, called respectively the supply portion and the regulating portion. The supply portion controls

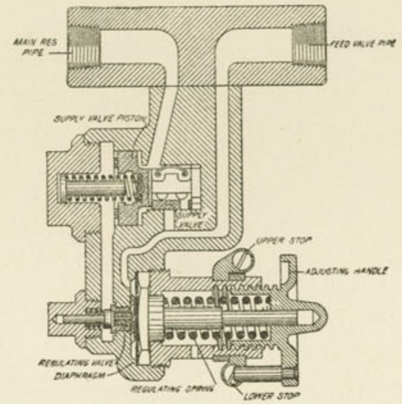


Fig. 35.

Diagram of B-6 Feed Valve, Closed.

the flow of air through the valve, and is made up of a slide or supply valve and its spring, and the supply piston and its spring. The regulating portion contains the regulating valve with its spring, a diaphragm, diaphragm-spindle, regulating spring and the regulating handle by which the adjustment for high or low pressure control is accomplished.

The operation of the feed valve is simple. The entrance of main reservoir pressure moves the supply piston to the left, and causes the supply valve, which is in the form of a slide valve, to move to the left and uncover a port leading to the diaphragm chamber of the regulating portion and also to the feed-valve pipe. Main reservoir pressure, therefore, has at first free access to the feed-valve pipe. At the same time main reservoir pressure is able to flow past the loose-fitting supply piston and so reach the regulating valve, which is normally kept open by the diaphragm spring. Main reservoir pressure therefore passes through the regulating valve and finds its way to the feed-valve pipe. The flow of air past the regulating piston is somewhat restricted, and it is also somewhat restricted in its passage past the regulating valve. As soon as the predetermined feed-valve pipe pressure is reached, the

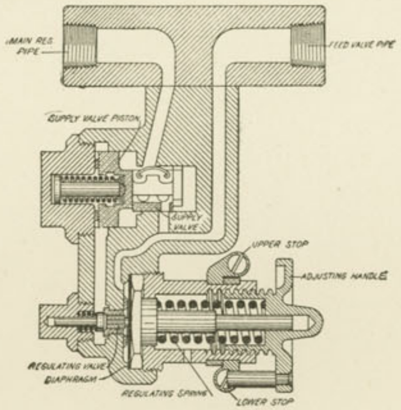


Fig. 36.

Diagram of B-6 Feed Valve, Open.

pressure on the diaphragm causes it to compress its spring, and in so doing allows the regulating valve, aided by its spring, to seat, and the pressure behind it rapidly rises, holds it shut and backs up against the left side of the supply piston. When the pressure on both sides of the supply piston becomes equal the supply piston spring acts. The supply piston is thus moved to the right, carrying with it the supply valve, which by this movement is closed and main reservoir pressure is shut off from the feed-valve pipe. Any fall of feed-valve pipe pressure causes the automatic operation of the parts to take place, as described above, and main reservoir pressure reaches the feed-valve pipe again and rapidly builds up to

the predetermined pressure when closure of main reservoir communication takes place again. In this way slight variations of feed-valve pipe pressure are rapidly and automatically made up, and the predetermined pressure is constantly maintained.

Setting Feed Valve for High or Low Pressure Control. The regulating device by which an engineer may set the apparatus for high or low pressure control is exceedingly simple. It consists of a corrugated handle very much like that used on some types of globe valves. The movement of this handle through half a turn one way compresses the regulating spring, and thus increases its pressure on the diaphragm. Half a turn of the handle in the opposite direction reduces the compression of the regulating spring against the diaphragm. The greater compression of the regulating spring holds the regulating valve open until a higher feed-pipe pressure has been secured, thus ensuring the maintenance of the high pressure control for brake operation. The lesser compression of the regulating spring is all that is necessary to secure low pressure brake control, the feed valve responding automatically in each case.

The required adjustment for the high or the low pressure control is obtained by the simple half-turn movement of the regulating handle by the engineer, and as the exact half turn is all that is required, the handle is equipped with a pin which strikes on one of two stops placed so as to secure just the required movement of the handle. When it is remembered that formerly two separately adjusted feed valves were required, one of which was cut in as the other was cut out in order to maintain either the high or the low pressure control, the simplicity, convenience and economy of parts in this design is easily apparent.

The SF Pump Governor. The pump governor called the SF type, Fig. 37, has a duplex head; one is called the excess pressure head and the other the maximum pressure head. When the automatic brake valve handle is in either the release, running or holding positions, main reservoir pressure flows to the excess pressure head. Air from the feed-valve pipe also enters this head, and main reservoir pressure at all times reaches the maximum pressure head; and when the excess pressure head is cut out, as it is when the handle of the automatic brake valve is in lap, service or emergency positions, or when cut out by the main reservoir cut-out cock, the maximum pressure head controls the pump.

When the automatic brake valve handle is in running position, as it is during most of the time on the trip, comparatively little excess pressure is required, and the adjustment of the excess

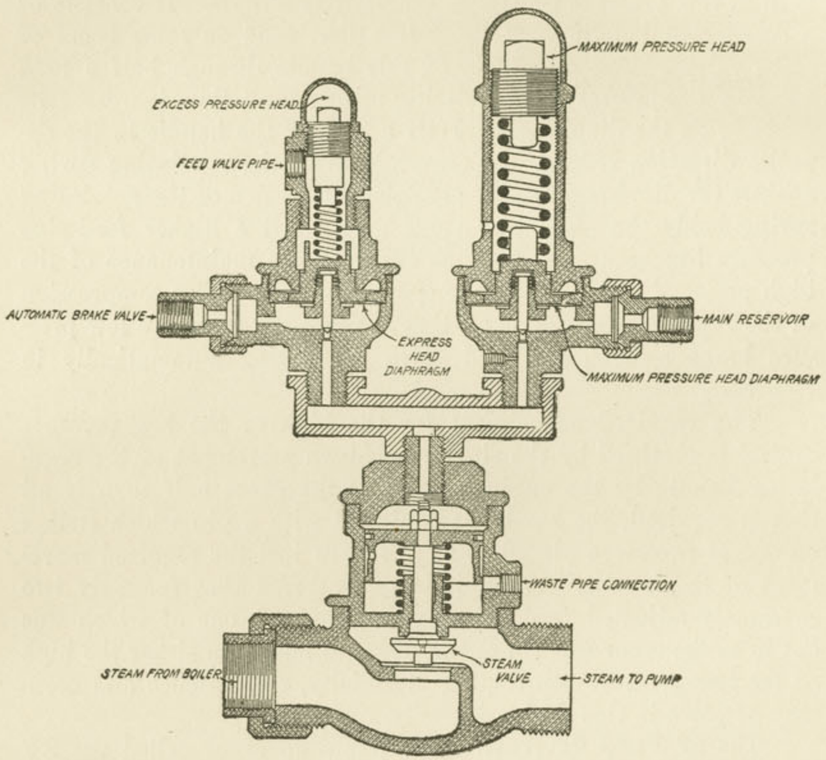


Fig. 37.

S-F-4 Pump Governor.

pressure head is arranged to maintain about 20 pounds higher pressure in the main reservoir than that in the brake pipe. As soon as the handle of the automatic brake valve is brought to lap, service or emergency positions, the maximum pressure head is brought into action and the pump works freely until maximum

main reservoir pressure is obtained, so that prompt and positive brake release is thus provided for. The excess pressure head is very sensitive, and not only is the work of the pump made comparatively light while it governs, but the slight fluctuations of pressure due to leaks are at once made up by the almost constant but slow action of the pump. When brake pipe pressure is raised, as it is in high-speed work, the pump governor responds to the altered condition, while at the same time maintaining the other admirable features just described.

Advantages of the SF Pump Governor. With the use of the SF pump governor, another advantage is secured. While descending

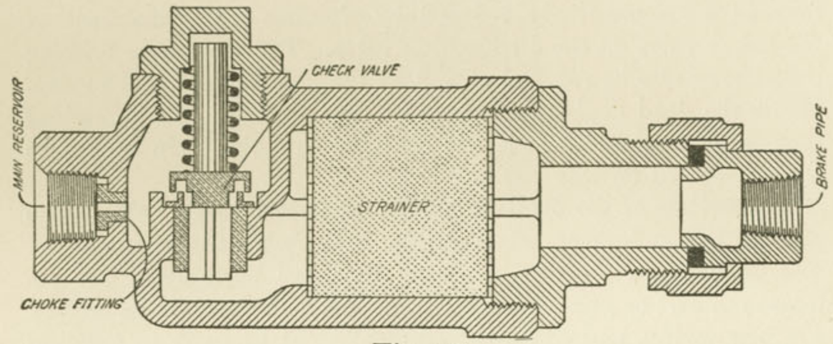


Fig. 38.

Combined Air Strainer and Check Valve.

steep grades the engineer is enabled to raise and maintain brake pipe pressure 20 pounds higher than that allowed by the feed valve, by the simple expedient of placing the automatic brake handle in release position and leaving it there during the descent of the grade. The stored excess pressure is thus allowed to reach the brake pipe, and the pump maintains that pressure, as previously described. Lap or service positions (as well as the emergency) will at once put the maximum pressure head in control, and the pump will work freely and so raise main reservoir pressure very quickly, so that it can be used for prompt and effective release of brakes.

The "Dead Engine" Feature. What is known as the "dead engine" feature, Fig. 38, is contained in the combined air strainer, check valve and choke fitting which is part of the ET equipment. The dead engine feature is designed to permit the application of brakes to be made on a dead engine. As the dead engine feature is only used when a locomotive is disabled by being broken down or for want of steam, a cut-out cock is provided which brings this apparatus into action or eliminates it, as desired. When the dead engine feature is in use, air for operating the locomotive brake on such an engine is supplied from the other engine on the train through the brake pipe, and the handles of both brake valves on this engine should be kept in the running position. If by reason of the absence of water in the boiler of the dead engine its working weight is reduced, the braking power may be correspondingly reduced by altering the adjustment of the safety valve on the distributing valve. The maximum braking power may also be reduced at will by the independent brake valve. While the dead engine feature is in operation the double-heading cock must be closed. It is not intended that the train brakes be set or released on this engine.

Functions of the Combined Air Strainer and Check Valve. The parts of this apparatus, while simple, have their definite functions. The curled hair strainer protects the other parts from the intrusion of dirt or grit. The check valve is held down on its seat by a strong spring, and while allowing sufficient pressure to accumulate in the main reservoir to ensure locomotive operation on this engine, it also keeps the main reservoir pressure somewhat lower than that in the brake pipe in order to minimize the effect of main reservoir leaks, should there be any. The choke bushing through which the air must pass in order to reach the main reservoir of the dead engine is designed to prevent a sudden lowering of brake pipe pressure, and the consequent undesirable application of brakes in case an uncharged dead engine main reservoir was cut in on a fully charged brake pipe. The choke bushing in the dead engine apparatus is thus analagous to the small feed groove in the triple valve.

The E-6 Safety Valve. The safety valve, which forms an important part of the distributing valve, is known as the E-6 type of safety valve, shown in Fig. 39. This device has been designed so as to quickly respond to slight differences in pressure, and in its ability to seat firmly it resembles the action of the ordinary steam

"pop" safety valves used on locomotives. The valve itself is held on its seat by a spring, capable of suitable adjustment. When the pressure below the valve becomes greater than that of the spring above it, the valve lifts and discharges the air below it to the atmosphere. The air rushing upward past the valve, when open, encounters a collar on the valve above its face. The increased area

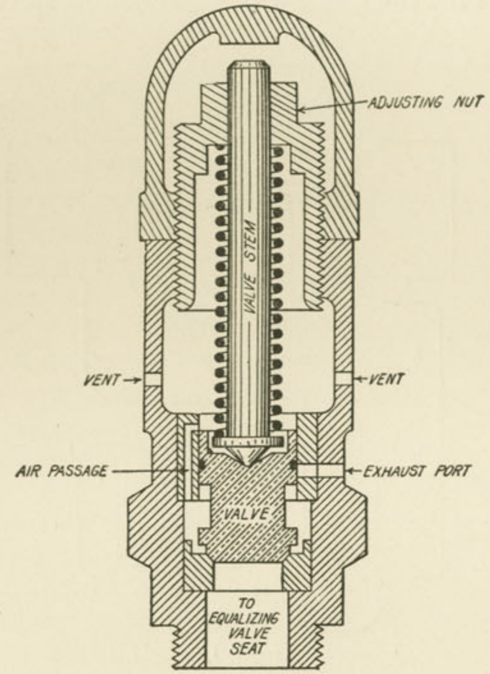


Fig. 39.

E-6 Safety Valve.

thus exposed to the air causes a quick upward movement of the valve and a free discharge of air through the exhaust port near top of valve. The upward motion of the valve speedily closes two vertical ports in the valve bushing by which, as the valve rises, escaping air reached the chamber above the valve, and was discharged to the atmosphere through two small vents. As the pressure below the valve decreases, owing to the rapid discharge afforded by the large exhaust port to the atmosphere, the spring on top of the valve forces it down and closes the large port to the atmosphere and again opens the vertical ports leading to the spring chamber. Although air escaping to the atmosphere does so through openings made small enough to restrict the outflow, a certain amount of pressure necessarily accumulates in the spring chamber above the valve, and with the aid of the spring closes and

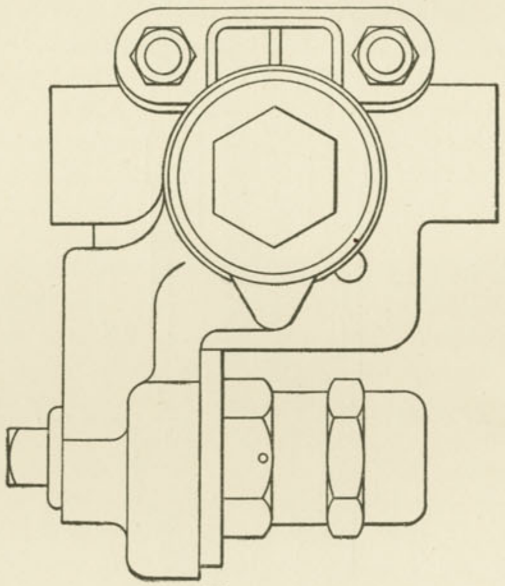


Fig. 40.

C-6 Reducing Valve.

firmly seats the valve. The adjustment of the safety valve should be such as to ensure its blowing off at 68 pounds pressure.

The C-6 Reducing Valve. This valve, shown in Fig. 40, is in reality the feed valve that has been for years in regular use with the G-6 brake valve. This reducing valve has been designed so as to secure a fixed and permanent reduction of main-reservoir pressure, which with the ET equipment is 45 pounds. The name reducing valve is used with this equipment to distinguish it from the

specially designed B-6 feed valve. The only difference between it and the B-6 feed valve is that the C-6 reducing valve has the ordinary adjusting nut and cap used on former types of feed valves instead of the hand-adjusting wheel used on the B-6 feed valve. In the ET equipment it is placed on the pipe leading from the main reservoir to the independent brake valve, and in this position main reservoir pressure is always reduced to 45 pounds before reaching the independent brake valve.

Difference Between No. 5 and No. 6 ET Equipment. The ET equipment, which has here been described, is known as the No. 6 ET locomotive equipment, and is a modified and more recent design of the older No. 5 ET equipment. The No. 6 equipment is designed to produce the same brake action by simpler means, as well as carrying with it some additional advantages. In double heading the handle of the brake valve on the second engine is kept in running position with the No. 6 ET equipment, whereas in the older form, designated as No. 5, the brake handle was kept in lap position. The No. 6 equipment therefore conforms in this respect to the practice in vogue with the old G-6 brake valve. The release position of the independent brake valve will release the locomotive brake under any and all conditions.

The No. 5 ET Equipment. A word should be said concerning the previously designed form of the ET equipment, known as No. 5. The brake valves used in both the No. 5 and No. 6 equipments are similar in appearance, though they differ in construction, the No. 6 being the later and improved form. The distributing valves of both equipments are also similar in appearance, though slight structural differences exist. In case of a parted train or burst hose, the pressure in the application chamber of the No. 5 distributing valve was free to escape to the atmosphere through the brake valves, unless the handle of either automatic or independent brake valves had been moved to running position.

With the H 6 distributing valve the application chamber pressure is also open to the atmosphere through the brake valves when in running position, if the equalizing valve of the distributing valve is in release position, and in case of an open brake pipe the equalizing valve would be moved and would intercept the escape of air from the application chamber, and so prevent release of the locomotive brakes. In emergency, the H 5 distributing valve allows equalizing reservoir pressure to flow into the application chamber. The H 6 in the emergency empties equalizing reservoir air to the atmosphere. With the H 5 equipment, when double-heading, the handle of the automatic brake valve is placed in lap position and the double-heading cock under the brake valve is closed. With the H 6 equipments the double-heading cock is also closed; but the handle of the automatic brake valve is placed in running position.

The H-5 equipment has a duplex and a single pointer air gauge, the H-6 has two duplex gauges. With the H-6 equipment, the larger of the two shows main reservoir and equalizing reservoir pressures, while the smaller gauge indicates brake pipe and brake cylinder pressures. The connection to the smaller is made so as to show brake pipe pressure at all times, regardless of where the engine is in the train when double-heading. The H-5 and the H-6 distributing and brake valves are not interchangeable, and though somewhat similar are of different construction.

Advantages of the ET Equipment. One of the advantages which is claimed for the ET equipment is that the locomotive and the train brake can be used alternately in descending a long grade. The release of the train brake, with the use of retaining valves, enables the engineer to recharge the train auxiliaries while there is a certain amount of brake power still operative on the train. To this the full power of the locomotive brake can be added, and when the train brake is again applied the locomotive brake can be released so as to prevent heating of tires, with the train still under full control. The independent brake forms a safety feature of the highest value, as it will hold a locomotive with a leaky throttle or a heavy train on a fairly steep grade. The whole apparatus has been designed with minute attention to detail, and it provides a locomotive engineer with the latest and, one may truly say, one of the most efficient safety devices in the whole range of modern railway operation.

THE QUICK-ACTION FREIGHT TRIPLE, TYPE "K."

The old adage that "circumstances alter cases" is as good in the mechanical world as outside of it, and the altered conditions in modern railway service have brought new brake problems to the

front. It is with a view of meeting the severer requirements which prevail to-day that the Westinghouse Air Brake Company have brought out their triple valve of the type "K" for freight cars. These modern conditions are the increase of train lengths beyond the practical 50-car maximum of the days when the first

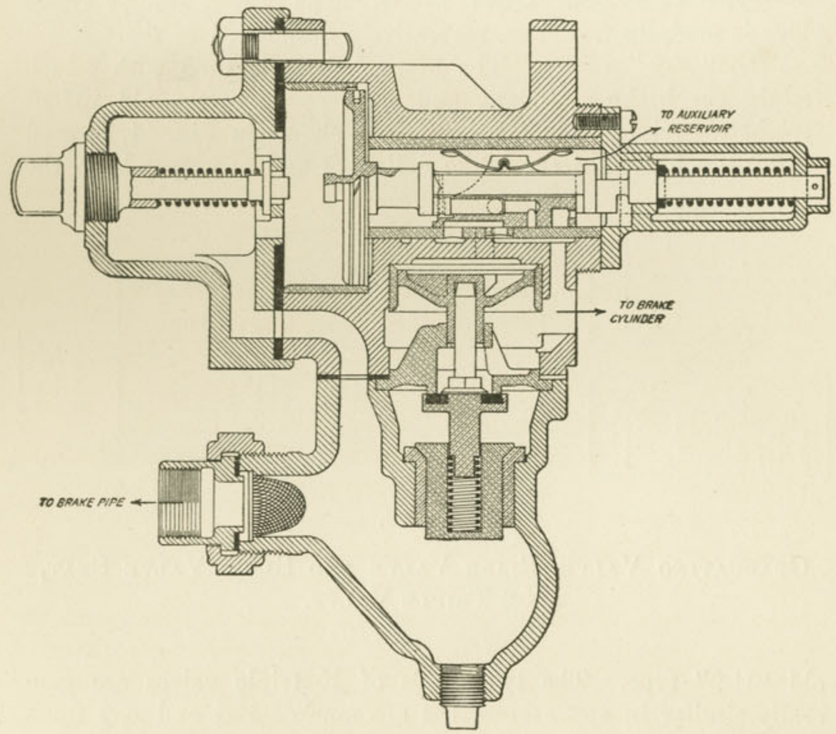


Fig. 41.

SECTION OF K-2 TRIPLE VALVE.

quick-action triple was designed. Higher speeds and greater car capacities have also had to be dealt with, and the "K" quick-action freight triple valve is intended to meet the situation.

Advantages of "K" Quick-action Freight Triple Valve. This valve, while it embodies all the features of the older form, has three new features, which are "quick-service," "retarded release" and "uniform recharge." It has the added advantage, not directly contained in its structural makeup, of being able to be used with the old type of valves, and it actually improves their action when both kinds are in the same train. The old style or "H" freight triple valve can be changed into the newer type, K, with the change of only a few parts.

Types of Freight Triple Valves. The "K" freight triple valve is made in two sizes, respectively designated as the "K-1" and the "K-2" valves. The first of these is used with 8-inch freight car brake cylinders, and corresponds to the old "H-1" freight car triple. The "K-2" triple, shown in Fig. 41, is used with 10-inch freight car brake cylinders and corresponds to the

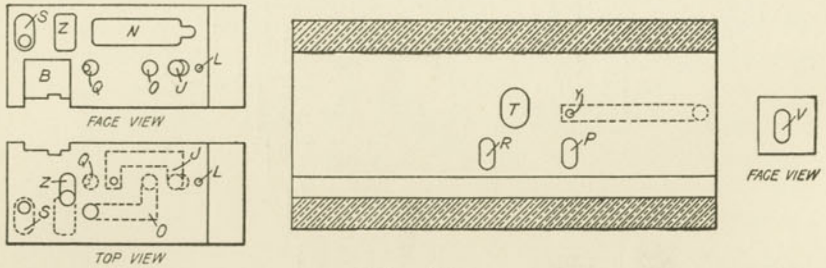


Fig. 42.

GRADUATING VALVE, SLIDE VALVE AND SLIDE VALVE SEAT, K-2 TRIPLE VALVE.

old "H-2" type. The two kinds of K triple valves are generally similar in appearance, but are marked K-1 and K-2 upon the body of each. A further and conspicuous difference between them is that the K-1 valve has two bolts in the auxiliary reservoir flange and the K-2 has three such bolts. In order to distinguish the K triples from the H triples, both the K valves have each a lug cast on the top of the body and the H valves have not. It is thus easily determined by the presence or absence of the lug whether a valve belongs to the K or the H family, and the number of bolt holes in the reservoir flanges of the K and the figure on the body show which style of K any valve is.

Full Release and Charging Position. The illustrations, Figs.

42 and 43, are diagrammatic representations of the K triple valve, showing the passages and parts. They do not, of course, accurately represent the structural details, as these could not be very well shown in a sectional view. A glance at the illustration will make it plain that brake pipe air enters the triple in the usual way and reaches the triple piston, which it forces into the position shown. Brake pipe air therefore reaches the auxiliary reservoir by way of the feed groove. Here it should be mentioned that the feed groove in both K valves is of the same size as that

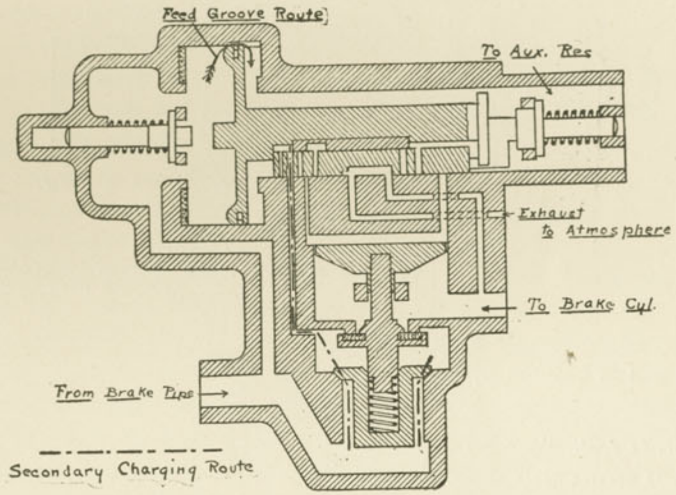


Fig. 43.

FULL RELEASE AND CHARGING POSITIONS, K-2 TRIPLE.

of the older H-1 triple, which was designed to charge the auxiliary reservoir of an 8-inch brake cylinder. The difference between the K-1 and the K-2 triple valves, internally, is that the K-2 triple, which supplies air for the auxiliary reservoir of a 10-inch brake cylinder, has an extra passage for auxiliary supply as well as the feed groove, and the K-1 valve is without this extra passage, as will be duly explained.

In the charging position the K-2 valve, which we are considering, feeds the auxiliary reservoir through the feed groove, and, in addition to this, air passes by the check valve and from the chamber above it, flows up through the quick service passage in the body of the triple and up through a straight port in the slide valve and enters the auxiliary reservoir. The supplies, by way of the feed groove and through this quick service passage, which latter we may call the secondary charging route, are together able to quickly charge the larger auxiliary reservoir used with the 10-inch brake cylinders. The time occupied in charging the larger reser-

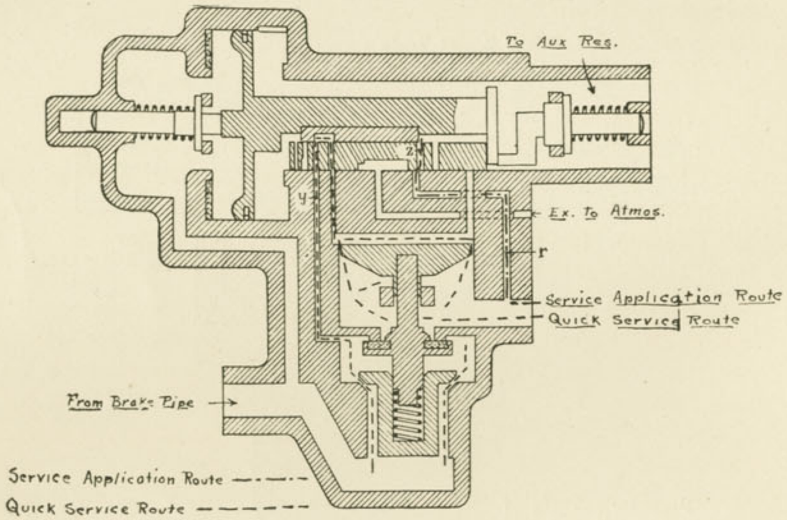


Fig. 44.

Quick Service Position, K-2 Triple.

voir through the feed groove and by the secondary route about equals that occupied in charging the smaller reservoir used with the 8-inch brake cylinder through the feed groove only.

Quick-service Application. In order to secure a quick-service application, brake pipe pressure is gradually reduced and the triple piston moves so as to cut out the feed groove, as shown in Fig. 44. The consequent movement of the slide valve now brings a port z in the slide valve into part register with port r in the triple body, and air flows directly to the brake cylinder by what

we may call the service application route. The exhaust port from the brake cylinder is blanked. The flow through the service application route is restricted by the partial registration of the slide valve port with that in the triple body. This position of the triple valve brings the quick-service feature into play. This feature is the venting of some train pipe air into the brake cylinder, but it is done without sufficient force to cause an emergency application, yet at the same time it helps to quickly fill the brake cylinder, and the consequent fall of brake pipe pressure is rapid enough to produce the quick-service action on the triple valve on the next car in the rear, and so on back.

The quick-service action is produced by the movement of the graduating valve which connects passage y in the body of the triple, by means of the cavity in the graduating valve, with the passage which leads to the chamber above the emergency piston. (The quick-service passage y is the same one which in the charging position formed part of the secondary charging route.) Air from the brake pipe entering, in small quantity as it does, the chamber above the loosely-fitting emergency piston, flows past this piston and enters the brake cylinder. It is thus that the comparatively gentle flow of air from the brake pipe past the emergency piston constitutes the quick-service feature, and its result is similar to, though much less violent than, the emergency action. The quick-service feature therefore causes brake pipe reduction to travel quickly back throughout the train, and, if an ordinary quick action triple is away back in the train, its response is as prompt as if it had been on one of the leading cars. The quick-service feature, therefore, acts beneficially on the standard equipment of older design when mixed in the train. The quick-service feature causes a brake action about twice as fast throughout the train as that obtained with the older equipment on a 50-car train. The quick-service has the further advantage, that, by reason of the venting of some brake pipe air into the brake cylinder, a much less initial brake pipe reduction is required through the engineers' brake valve than formerly, and the brakes apply more quickly and draw a less quantity of air from the auxiliaries. The rapid filling of the brake cylinder forces the brake cylinder piston to travel rapidly in its stroke over that portion where the leakage groove lies, and thus a further economy in the use of compressed air is effected.

Full Service Application. In the full service application, Fig. 45, if the brake pipe reduction is greater than the reduction of auxiliary reservoir pressure, due to its flow to the brake cylinder, the triple piston is therefore compelled to move far enough to the left to slightly compress the graduating spring. In this position the quick-service port in the body of the triple is blanked, and the port z in the slide valve is brought into full register with

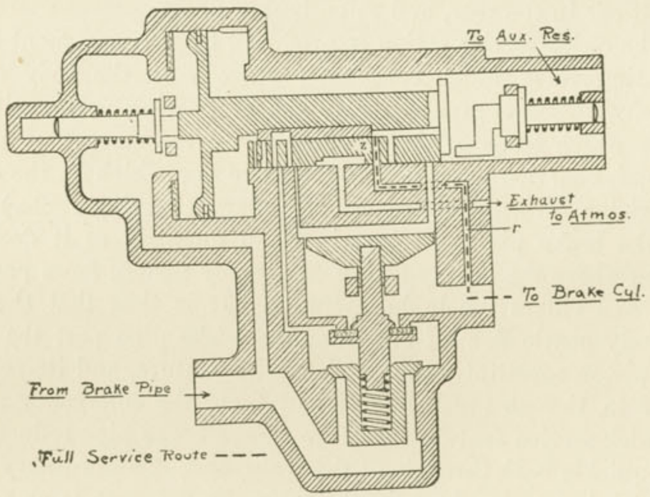


Fig. 45.

FULL SERVICE POSITION, K-2 TRIPLE.

the passage r in the triple body leading to the brake cylinder. Brake pipe air is not vented into the brake cylinder, but a more copious flow of auxiliary reservoir air reaches the brake cylinder through the full registration of the slide valve port and triple body passage.

The Lap Position. In this position, Fig. 46, all the triple valve ports are blanked and there is no flow of air from the auxiliary reservoir, and the air in the brake cylinder remains as it is with brakes set. A further reduction of the brake pipe pressure

brings about the state of affairs just described, and as soon as the reduction of auxiliary reservoir pressure falls slightly below that of the brake pipe, the triple valve again moves to lap position and holds the brakes set without any further flow of air from the auxiliary reservoir.

The Retarded Release and Charging. The triple parts are made to assume the position shown in Fig. 47 for retarded release and charging. This position differs from the full release position

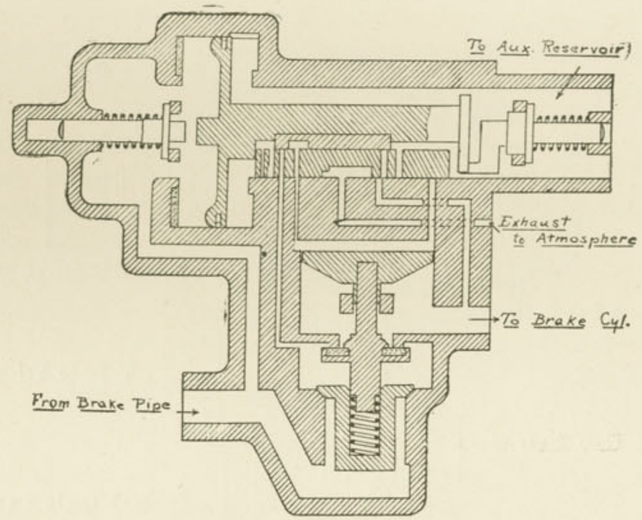


Fig. 46.

LAP POSITION, K-2 TRIPLE.

in several particulars, the net result, however, being that the brakes are held set for a considerable time owing to the restricted exhaust passages through which the air escapes, while the auxiliary reservoir is charged through the quick service passage y in the body of the triple. It will be remembered that when retaining valves were used the triple valve parts were made to assume the full release position, and the fact that air was held in the brake cylinders was due solely to the action of the retaining valves, which permitted only a slow exhaust to take place, and finally blocked the brake cylinder exhaust at 15 pounds pressure, and held it there indefinitely. The retainer was a separate piece of mechanism which required to be cut in or cut out by hand on each car.

Here the retarded release, as its name suggests, permits the slow but continuous exhaust of brake cylinder pressure, and the time required to empty the brake cylinder is taken advantage of to recharge the auxiliary reservoir. This position of the triple valve permits brake pipe pressure to reach the auxiliary reser-

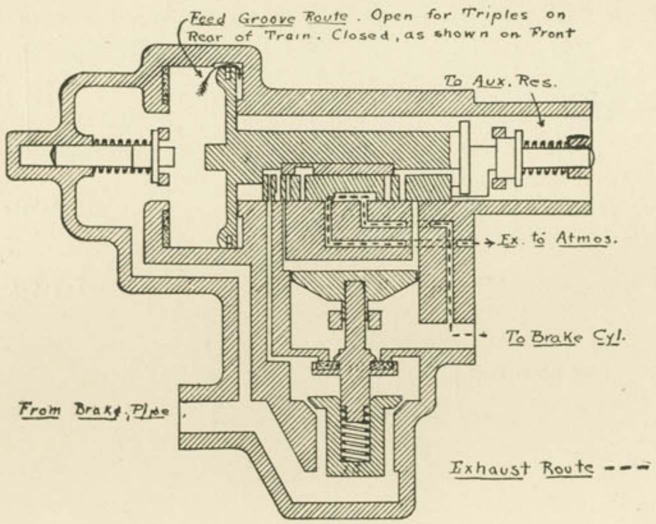


Fig. 47.

RETARDED RELEASE POSITION, K-2 TRIPLE.

voir at the same time that brake cylinder air is being exhausted and brakes are slowly releasing. The action in this case is very much as if brakes were permitted to slowly leak off while recharging was going on, but the expression retarded release is preferable, as the word "leak" implies the existence of an undesirable state of affairs, and the slow release of brakes, as here produced while charging is going on, is thus rendered legitimate.

The object of the retarded release is to let off the brakes on long trains practically at the same time and to secure a uniform

recharge throughout their entire length. The danger of shock or break-in-two is avoided, and the premature quick release and subsequent automatic re-application of the brakes on the cars at the front of the train are prevented.

There is one condition which is always persistently before the designer of air brake equipment, and that is that the source of the compressed air supply is always at one end of the brake pipe, and the car at the other end of the train has to be fed by air which has traversed the entire length of the brake pipe, be the train long or short. This condition does not necessarily exist in either electrical or water supply service for industrial purposes, and it has been provided for very ingeniously in the retarded release and recharging position of the triple valve parts. As an illustration of the condition which always confronts the air brake designer, we may refer briefly to a curious suggestion which was once made by a gentleman obviously unacquainted with engineering science.

This gentleman proposed to water the streets of a city in hot weather by laying a pipe along the gutter on each side of the roadway. This pipe was to be perforated along its entire length by a series of holes something like a very much elongated flute, and water flowing from all these holes was expected to cover the area of roadway and thus obviate the necessity for watering carts. It is hardly necessary to say that the flute-like water pipe proposed by this gentleman might be more or less effective for the first few lengths of pipe; that the holes in the middle stretch would give very little flow, while those remote from the source of supply could not deliver any water.

The analogy, however, holds good in the case of a long train with the source of supply necessarily placed at one end of the brake pipe. In the release and charging position air driven into it from the main reservoir on the engine flows along the brake pipe, which on each car is absorbed by a partially empty auxiliary reservoir ready to drink up as much air as possible, regardless of others more remote from the source of supply. This very real condition, which would result in the release of brakes on the front of the train while others remained set on the rear end, is dealt with by the triple valves themselves by a sort of automatically produced "community of interest," whereby the position of the triple parts are made to assume certain positions corresponding to the place in the train occupied by any given car.

The K triple has two release positions, which are the full release and the retarded release. Between these two positions the triple valves in a long train arrange themselves, and practically all intermediate positions are assumed in a sort of graduated series like the successive poses of a moving figure as photographed by the kinenetograph.

When brakes are released on a long train, air flows into the brake pipe in considerable quantity and raises the pressure in that pipe. The natural result of this with the older designs of triple valve was that the cars at the head end of the train were released at once, but the air in the brake pipe, on its way to release brakes further back on the train, was absorbed by the auxiliaries on the front cars, and with the friction caused in passing along the pipe, the pressure capable of ensuring brake release did not travel through the brake pipe in sufficient quantity until the forward auxiliaries were full. Brakes were thus released at the front, but remained set at the back. The flow of air into the brake pipe with the K triples causes the triple piston of the cars at the front of the train to move to their extreme right-hand position, and the end of the triple stem now strikes a spring and stem not hitherto called into play. This is the retarding device.

The triple in the retarded release position, although it has opened the feed groove, has nevertheless traveled so far as to bring the back of the piston in contact with the slide valve bushing, and as these two surfaces are ground, an air-tight joint is made at once. The feed groove supply is thus cut out. At the same time the slide valve has been pushed over so far to the right that only a very restricted extension of the exhaust cavity now registers with the passage in the triple body leading to the atmosphere. The exhaust of air from the brake cylinder is therefore rendered very slow and gradual, while what we have called the secondary charging route is open, and is the only entrance afforded for brake pipe pressure to reach the auxiliary reservoir. This secondary charging route has half the area of the feed groove, so that the supply reaching the auxiliary reservoir is now about one-third of what it would be in the full release and charging position.

The effect produced by this position of the triple valve parts

is to cause not only a retarded release, but also to restrict the flow of air to the auxiliary. In consequence brake pipe air is enabled to travel back more rapidly, and by the time it reaches the rear portion of the train, it does not enter the rear triple valves with sufficient pressure to force their pistons to the extreme right-hand travel, so that the triple piston is not moved against the tension of the retarding device spring, as it had done at the front of the train, and thus the full release position is assured. In this position, as already explained, the exhaust from the brake cylinder is free, and both feed groove and secondary charging route supply air to the auxiliary. The result is that although the brakes at the front end of the train begin to release and the front auxiliaries begin to charge early, yet they take longer to complete their release and charging than those at the rear, which, while beginning to act later, are able to perform their operations more quickly.

The different action of the front and rear car triple valves as described, if no further adjustment took place, would result in the regular release of the rear car brakes much earlier than those at the front, with the consequent undesirable drag of front end brakes and loss of time, but the action of the front end triples provides for a quickened release when the rear auxiliaries have become partially charged. When the pressure in the auxiliaries at the front becomes nearly as great as that in the brake pipe, the retarding device spring pushes the triple piston to the left and places the parts in the full release and charging position, and what air was held in the brake cylinder by the retarded release is exhausted and the auxiliary reservoir is charged through the feed groove and the secondary charging route at the same time. The net result is that practically a simultaneous release of brakes takes place throughout the whole train, and what amounts to a uniform recharge of all the auxiliary reservoirs is also brought about at this same time. These conditions act beneficially upon old style triple valves if mixed in the train.

The Emergency Position. The emergency position of the K triple valve, Fig. 48, is the same as that assumed by the older form Type H, with a sudden and large reduction of brake pipe pressure. The fall of brake pipe pressure carries the triple piston to its extreme left-hand travel, in which position it compresses the graduating spring and the piston itself seats firmly against the gasket at the end of the triple cylinder in which it moves. The movement of the slide valve introduces auxiliary pressure to the emergency piston by a short direct port in the triple body, uncovered by the slide valve, and this opens the emergency valve. The check is lifted by brake pipe pressure, and brake pipe air is vented rapidly into the brake cylinder. This movement also opens a direct port from the auxiliary reservoir to the brake cylinder, which we have called the emergency route. As soon as the brake pipe and brake cylinder pressure equalize, the check and emergency valves close,

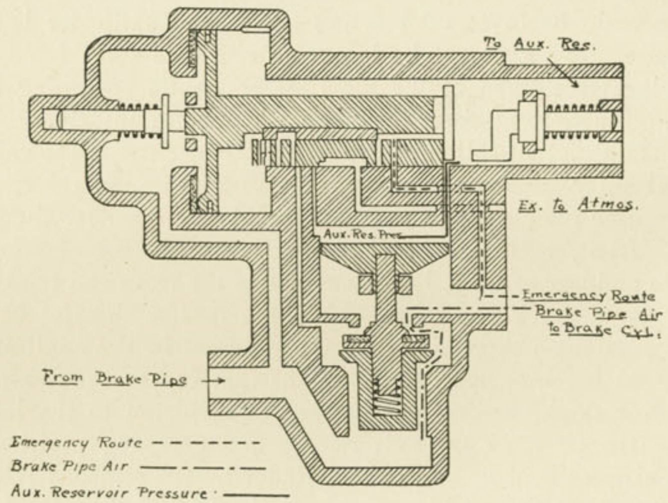


Fig. 48.

Emergency Position, K-2 Triple.

so preventing the air thus supplied to the brake cylinder from flowing back into the brake pipe. The areas of the ports and passages, forming what we have called the emergency route from the auxiliary to the brake cylinder, are of such a size that the venting of brake pipe air into the brake cylinder is much more rapid than the flow through the emergency route. This ensures the rapid filling of the empty cylinder, the quick movement of the brake cylinder piston over the leakage groove, and the flow of air from the auxiliary reservoir now coming upon a brake cylinder

already supplied with compressed air raises the pressure in the brake cylinder and causes the pressure of equalization between auxiliary and brake cylinder to be about 10 pounds greater than that produced by service applications. The sudden reduction of brake pipe pressure by reason of the quick vent of air into the brake cylinder causes the triple valve on the next car in rear to feel at once the fall of pressure and to instantly respond. Each triple valve acts as if it was in close proximity to the engineers' brake valve, and the impulse by which the successive fall of brake pipe pressure is produced traverses the entire length of the brake pipe with marvelous rapidity.

Sound travels through air at the rate of about 1,120 feet a second, and on a train of fifty cars the sound of the locomotive whistle would be heard in the caboose in about 1¾ seconds after it had been blown on the engine. So rapid is the transmission of the quick-action impulse, which causes the full accomplishment of 50 similar but separate and distinct mechanical actions to take place within the triple valves, that this impulse, passing through a pipe more or less complicated with bends, turns, valves and hose, is yet fairly comparable to the speed of sound. If at the instant that a torpedo on the track was exploded by the engine the "emergency" took place, the sound of the detonation would reach the caboose only three-quarters of a second before the rearmost triple valve had set the brake with the maximum retarding power of which the mechanism is capable.

Positions of the Quick Action Freight Triple Valve, Type K. There are six positions assumed by the Quick Action Freight Triple Valve, Type K. The full release and charging position is the one in which the air in the brake cylinder is quickly exhausted, and the auxiliary reservoir is charged with air from the brake pipe by way of the feed groove and the secondary charging route. The quick service application blanks the brake cylinder exhaust, cuts out both supply routes from brake pipe to auxiliary, allows a restricted flow of auxiliary reservoir pressure to reach the brake cylinder, and vents some air from the brake pipe to the brake cylinder. The full service position produces the same conditions with the exception that no brake pipe air is vented into the brake cylinder, and a fully opened port conveys air in larger quantity direct from the auxiliary reservoir to the brake cylinder. The lap position blanks all ports. The retarded release and charging, retards the release of brakes by restricting the exhaust passage and admits air to pass from the brake pipe to the auxiliary by the secondary charging route only. The emergency position vents a larger quantity of air from brake pipe to brake cylinder, opens a larger port than when making service applications between auxiliary reservoir and brake cylinder, thus giving maximum brake power in the shortest time, and causing the quick action to successively operate on each car on the train from front to rear. The time required for this impulse to travel the length of a 50-car train being about 2½ seconds.

THE DOUBLE PRESSURE CONTROL, OR SCHEDULE U.

Westinghouse Rule for High Braking Power. The rule adopted by the Westinghouse Air Brake Company, in order to obtain as high a brake power as possible without the liability of wheel sliding, is to so proportion the brake rigging as to bring against the treads of all the wheels of any vehicle a total pressure calculated on 70 per cent. of the light weight of the car for freight service and 90 per cent. of the light weight for passenger service.

These percentages so used practically amount to this, that a freight car weighing 40,000 pounds without load and braked on both trucks is, for the purpose of the calculation, assumed to be 30 per cent. lighter than it really is, or 28,000 pounds. The reason for this assumption is that some definite amount of brake power had to be provided in designing brake rigging, which while applicable to all nominally similar cars, yet allowed for the possibly large range of tare weights found in freight cars of the same nominal weight. Taking 70 per cent. of the light weight, as if it was the actual tare weight, was in principle similar to the introduction of the factor of safety into boiler or bridge design. The 90 per cent assumed in the case of passenger equipment, although allowing a smaller margin, yet preserved a sufficiently high factor of safety to guard against possible differences in actual and alleged weights, and it also took into account, and thus provided for, the varying conditions of the rail in actual service.

Method of Designing Brakes. In designing brakes for a 40,000-pound freight car, it was treated as if it weighed only 70 per cent. of that amount, or 28,000 pounds, and each of its eight wheels would on this assumption carry a weight of 3,500 pounds. When this car was loaded up to its capacity, say 100,000 pounds, the total weight of the car would for braking purposes amount to 128,000 pounds, or a wheel load of 16,000 pounds. It is manifest that a brake shoe pressure designed not to skid the wheels of the empty car would fall very much below that which would skid them, when fully loaded, and how far this is below the amount required to skid the wheels becomes apparent when we consider the friction between shoe and wheel and between wheel and rail.

Static and Dynamic Friction. A car wheel standing upon a rail has one point of contact with the rail: it is where tread and rail-top touch. When the wheel is rolling along the rail the point of contact, though constantly changing, is at every instant at rest so far as the wheel and rail are concerned. The part of the wheel tread resting on the rail for the moment is proved to be at rest with reference to the rail, as it does not slide upon it, and the friction which prevents the wheel from sliding along the rail is not the friction of motion, but the friction of rest, and thus between wheel and rail there always exists what is called static friction. A revolving wheel, therefore, cannot be stopped and slid along the rail until the static friction is exceeded. For ordinary purposes the co-efficient of static friction between wheel and rail may be taken approximately at 0.2, or even 0.25, and, therefore, the unloaded car weighing as assumed 28,000 pounds, with its wheel load of 3,500 pounds would develop a static friction of 700 pounds for each wheel. If all the wheels were locked so that they could not revolve, the car would resist sliding with a force of 5,600 pounds.

It was demonstrated in the Galton-Westinghouse tests that the co-efficient of dynamic friction between shoe and wheel varies with the speed, and is less at high speed than it is at low speed. At 60 miles an hour the co-efficient of dynamic friction was about 0.074, while at less than 5 miles an hour it came up to about 0.273. Referring again to the light car moving at 30 miles an hour with a dynamic friction co-efficient of 0.166 and 3,500 pounds carried by each wheel, the retarding force of the brake on the moving wheel would become 581 pounds per wheel, or 4,648 pounds for the whole car. The resistance to sliding due to static friction being 5,600 pounds for the whole car, the wheels would have no tendency to slide along the rails when retarded by a total dynamic friction of 4,648 pounds, and the margin existing between the two amounts at this speed to 1,052 pounds. At 60 miles an hour the dynamic friction caused by the pressure of the shoe on the rapidly revolving wheel amounts to 259 pounds on each wheel, and the resistance to skidding, owing to the static friction of wheel on rail being 700 pounds for each wheel, the margin in favor of non-sliding is 441 pounds. The wide difference between these two kinds of friction acting on the wheel when the car is light or loaded is the fundamental reason for the introduction of the system of double pressure control, and is a legitimate endeavor to secure greater efficiency in brake service by reducing what may be called waste of available brake power, on a heavily loaded car.

Special Use of the Double Pressure Control. The equipment called the double pressure control is specially intended for a particular kind of railroad service where there is a more or less regular movement of empties in one direction and loads in the other. Some roads are compelled to do a coal carrying business in this way, and the double pressure control apparatus, which entails no alteration of car equipment, is peculiarly suited to these conditions. Railroads operated over heavy grades can also use this equipment with advantage.

Locomotive Equipment Under Schedule U. The double pressure control equipment, shown in Fig. 49, is practically that of the high-speed brake already described, with but few modifications on the locomotive. There is no change in freight car equipment. Schedule U therefore applies entirely to locomotives. Safety valves on the driver and tender brake cylinders take the place of the reducing valves on the engine and tender, and plain triple valves are also used. There is a reversing cock and a feed valve pipe bracket. With this equipment there are two slide valve feed valves connected with the reversing cock, and the feed valve pipe bracket is an attachment added to the engineers' brake valve for the purpose of readily connecting the reversing cock, with its two feed valves, to the engineers' brake valve.

The two feed valves are exactly similar in construction and operation, but one is adjusted to permit a brake pipe pressure of 70 pounds to be carried, with 90 pounds in the main reservoir, and

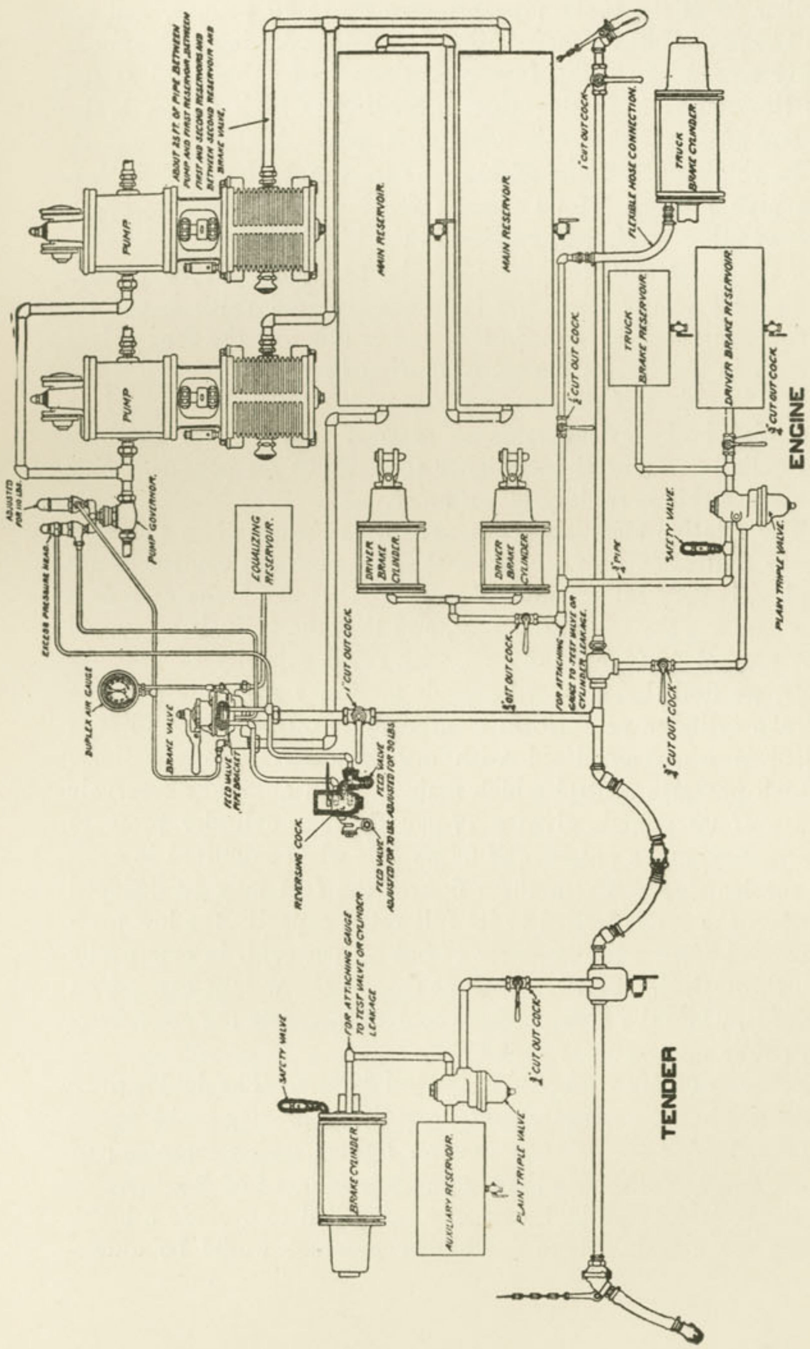


Fig. 49. Diagrammatic Illustration of Double Pressure Control Apparatus, or Schedule U, With Two Separate Air Pumps.

the other feeds the brake pipe pressure up to 90 pounds, and retains 110 pounds in the main reservoir. The reversing cock affords a ready means of cutting in one of these feed valves and at the same time cutting out the other, according as high or low brake pipe and auxiliary reservoir pressure is required.

In this way a train of loaded cars can be handled with a brake pipe pressure of 90 pounds for use in descending heavy grades or other service, by cutting in the high pressure feed valve, and a similar train of empties can be handled with 70 pounds brake pipe pressure when the low pressure feed valve is cut in. The reversing cock is so made that one or other of the feed valves is always in service, as the act of cutting in the one cuts out the other. The object of the safety valves which are placed on driver and tender brake cylinders is to prevent the pressure in these brake cylinders from rising higher than about 50 pounds. Any excess above this is rapidly blown away.

The relative effective brake action, as shown when the high pressure control is used, or when the low pressure control comes into play, is very interesting. Assuming that the brake cylinders on the cars are the usual diameter, and that the train is composed of the normal 40,000-pound cars, with rated capacity of 100,000 pounds, we find that with 70 pounds auxiliary reservoir pressure the brake cylinder pressure in emergency is 60 pounds, and it is 50 pounds when equalized with ordinary service applications. The high pressure control which maintains an auxiliary reservoir pressure of 90 pounds gives a 77-pound brake cylinder pressure in emergency, and a pressure of 65 pounds when equalized in ordinary service stops. From these figures the fact may be deduced that when the car is loaded to its full rated capacity the low pressure control gives a brake power of but 20 per cent. in emergency of the theoretically possible amount due to the weight carried on the wheels, while the high pressure control increases the emergency brake power up to 26 per cent.

Economy of Air with Double Control System. The double pressure control has the advantage of providing a greater brake power on heavy, loaded trains than that on lighter trains composed of empties, and in doing this the air pump is relieved of considerable work in the latter case by being only compelled to provide a lower pressure for a train where the higher pressure would be unnecessary. There is also another economy of air which this equipment possesses in common with the high speed brake. The pump governor is piped as in the ordinary equipment, and when the handle of the engineers' brake valve is in the lap, service or emergency positions, main reservoir pressure is prevented from reaching the excess-pressure diaphragm of the pump governor. In running position the excess pressure diaphragm of the pump governor is acted upon by main reservoir pressure. When brakes have been applied and the brake valve handle is on lap, main reservoir pressure is then pumped up to the maximum, and this high main reservoir pressure ensures prompt release and quick recharge, and the pump has only to maintain this high pressure in the main reservoir during the time that the brakes are applied. When the high pressure control is used, a brake pipe reduction of about 25 pounds is required to produce equalization between auxiliary reservoir and brake cylinder, otherwise the brake operates in the same way as it does for the ordinary 70 and 90-pound brake pipe and main reservoir pressures.

NEW YORK AIR BRAKE EQUIPMENTS.

There are three important locomotive brake equipments manufactured by the New York Air Brake Company, known as the B-1, B-2 and B-3 equipments. The B-2 and B-3 equipments are practically the same as far as the work performed by them is concerned. However, the B-3 equipment has some structural improvements over the B-2 equipment. The present features of these two equipments, which are considered improvements over the B-1 equipment, are the method of brake pipe pressure control, the combination of the automatic and straight air brake features in the one brake valve and the accelerator valve, which accelerates the brake pipe reduction in service, thereby increasing the efficiency of the brakes on long trains by causing an application with ordinary service reductions which could not be done with the older equipments without making exceedingly heavy reductions. Since the general operation of the three equipments is very similar, only the B-3 equipment will be described in detail.

NEW YORK B-3 LOCOMOTIVE EQUIPMENT.

Designation of Systems. The New York Air Brake Company's brake equipment, Schedule B-3, is so arranged as to cover the requirements of four different kinds of service. The ordinary form B-3, where a single brake pipe pressure is used, is designed for freight or passenger engines, and automatic or straight air can be used on the engine equipment as desired. The schedule known as the B-3—S is for switching engines only, the letter S denoting that fact. The B-3—HP is for freight service where heavy trains are handled on grades, generally where loads are taken down grade and empties are hauled in the opposite direction. The letters HP denote the ability to use the high pressure control. The B-3—HS is the high speed equipment for passenger service, and the terminal letters in the designation signify this form of brake.

The B-3 Brake. The B-3 schedule, as we have said, is intended for both passenger and freight service, and the piping diagram, Fig. 50, shows the general arrangement in diagrammatic form. There is only one brake pipe pressure used for the automatic brake, which is always on the train, and which may be used if desired on the locomotive brake, which includes the tender, the engine-truck and the driver brakes. When desired, the automatic brake may be cut out on the locomotive and straight air substituted. The independent brake valve has been done away with in this equipment, and when straight air is used on the locomotive brake the B-3 automatic and straight air engineers' brake valve, Fig. 51, performs not only the functions of governing the brake pipe pressure for the train, but it also controls the supply of main reservoir pressure, reduced to 40 pounds, which reaches the brake cylinders of the locomotive equipment. In this respect the B-3 brake valve can be made to perform its own proper functions, and it can in addition take the place of the discarded independent brake valve when required.

The B-3 equipment is provided with a single-head pump governor, which regulates the main reservoir pressure and also the automatic starting and stopping of the pump. The N. Y. plain triple valves are used on the engine and tender in connection with the automatic system. On the pipe leading from the main reser-

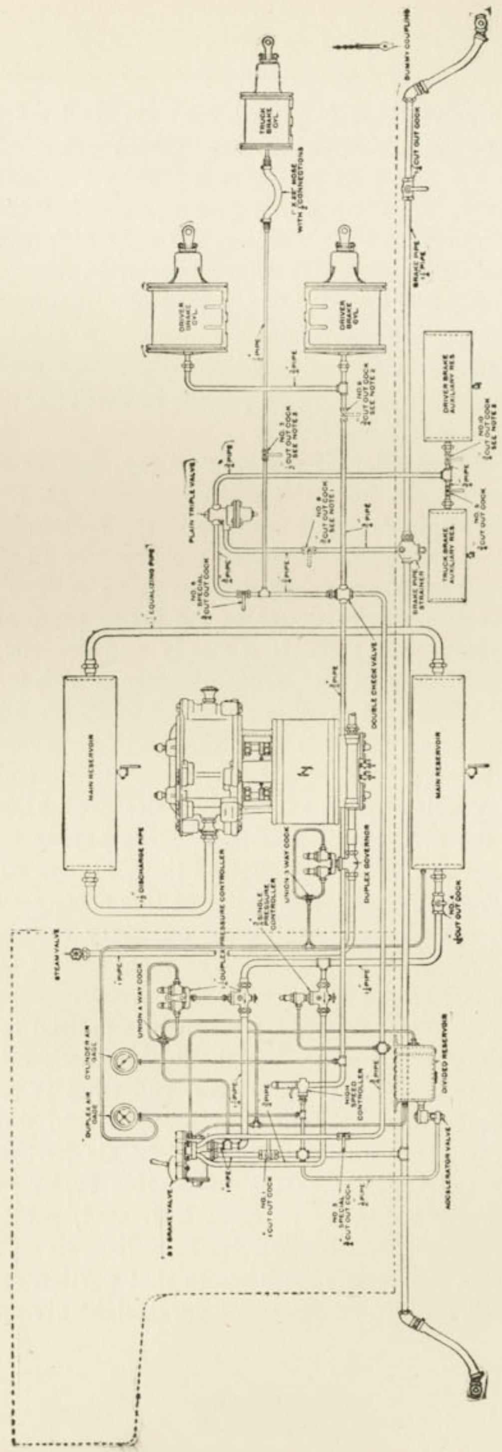


Fig. 50.

Piping Diagram. Schedule B3. (Single Pressure System.) New York Air Brake.

voir to the brake valve there is placed what is called the pressure controller, which corresponds in function to the Westinghouse feed valve, and is thus really part of the engineers' valve. The pressure controller is practically a pump governor and is interchangeable with it, being structurally similar, the only difference being in its adjustment. The pump governor limits main reservoir pressure to 90 pounds, while the pressure controller prevents brake pipe pressure rising higher than 70 pounds. In this way the pump governor deals with main reservoir pressure exclusively, and constantly maintains an even 90 pounds in that reservoir without reference to how it is used.

The pressure controller, if one may so say, acts as a sort of filter which permits air from the main reservoir, at 70 pounds only, to reach the engineers' valve and so to the brake pipe. The pressure controller thus confines the excess pressure in the main reservoir. When brakes are released there is no sudden rush of high main reservoir pressure direct to the brake pipe, as in the Westinghouse system, but there is a steady and copious flow of air through the controller at 70 pounds pressure, which is steadily maintained by the fact that there is an excess of 20 pounds stored in the main reservoir. In this way the main reservoir stands ready, like the reserve fund in a bank, to meet any sudden demand which may arise by reason of the release of brakes on a long train, and the pressure controller, like the paying teller, delivers the required amount in the allotted time, always backed up by the main reservoir excess. The object of this arrangement is to eliminate the chance of overcharging the auxiliary reservoirs and the possible re-application of brakes at the front end of the train, if the forward auxiliaries had become overcharged.

Straight Air on the Locomotive. When it is desired to use the straight air on the engine and tender, the double check valve automatically cuts out the plain triple valves, and what is called the straight air pipe in this equipment is brought into use. This pipe leads from what we may call the straight air portion of the engineers' brake valve direct to the locomotive brake cylinders. The engineers' brake valve, as we have intimated, performs the functions of the independent brake valve as well as its own, and a branch of the main reservoir pipe leads to that portion of the engineers' brake valve which is concerned in straight air operation.

On this pipe there is a second but smaller pressure controller, called the straight air controller, similar to the pump governor, and this valve reduces main reservoir pressure flowing through it to 40 pounds, so that only that pressure can reach the locomotive brake cylinders when the plain triple valves have been cut out and the straight air brake is operative. The pipe leading from the straight air portion of the brake valve direct to the locomotive brake cylinders is, as we have said, the straight air pipe, and on this pipe, within easy reach of the engineer, is placed what is

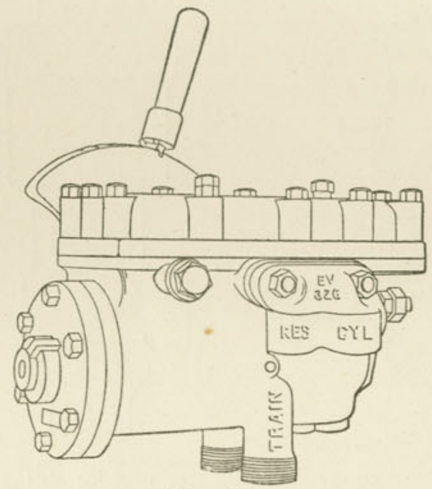


Fig. 51.

B-3, New York Brake Valve.

called the lever safety valve. The use of the lever safety valve is to enable the engineer to graduate off, or fully release, the locomotive brakes while holding the train brakes applied, and its operation does not affect the engineers' brake valve, which, under these conditions, would be in the lap position. The lever safety valve will be described later.

The Accelerator Valve and the Divided Reservoir. The device known as the Accelerator Valve, Fig. 52, is used with this equipment, and, as its name implies, it is intended to assist or accelerate the discharge of brake pipe air when a service reduction is made on a long train. The divided reservoir, as shown in Fig. 54, is simply the ordinary supplementary reservoir for the brake valve with a larger chamber cast integral with it, there being no communication between them. The union of the two reservoirs in one casting is for the sake of economy of space. The accelerator valve is attached to the larger chamber of the divided reservoir. When a brake pipe reduction is made for a service application, air is exhausted from the brake pipe through the engineers' valve to

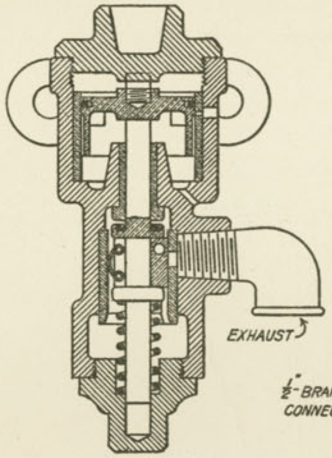


Fig. 52.

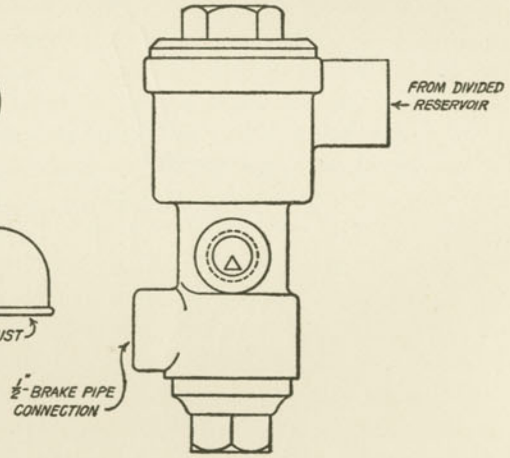


Fig. 53.

SECTION AND OUTSIDE VIEW OF ACCELERATOR VALVE, NEW YORK AIR BRAKE.

the atmosphere in the usual way, but in addition to this some of the brake pipe air is permitted to flow to the large or accelerator chamber of the divided reservoir. The accelerator valve contains a piston, as shown in section in Fig. 52, with a slide valve on its stem, and also a leather gasket on the same stem. Brake pipe air reaching the accelerator chamber, which is empty, requires about four seconds to accumulate pressure enough to move the accelerator piston down, and so carry its slide valve with it, to such a position that the port in the valve may register with a triangular port in the body of the valve leading to the atmosphere. (Fig 53.) The registra-

tion of the slide valve port with the triangular exhaust permits air from the brake pipe which surrounds the accelerator slide valve to escape to the atmosphere. The triangular shape of the exhaust, with point uppermost, affords a restricted passage at first and a rapid exhaust later. The depression of the accelerator piston, while securing a rapid discharge of brake pipe air, also at once begins the gradual reduction of air in the accelerator chamber, so that the accelerator valve can only operate for a limited time. A pressure of from 10 to 12 pounds in the accelerator chamber is required to cause the accelerator to act, and as soon as the automatic closure of escaping air from the engineers' brake valve takes place, the supply to the accelerator also stops, and about 4 seconds is then required for the accelerator reservoir pressure to escape, and

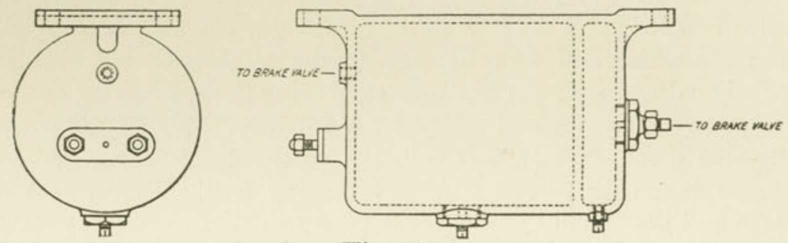


Fig. 54.

THE DIVIDED RESERVOIR, NEW YORK AIR BRAKE.

so permit the accelerator piston, aided by a coil spring, to slowly rise and gradually close off the flow of air from the brake pipe to the atmosphere. There is a small port through the accelerator piston communicating with the chamber below it, so that even after the accelerator valve has ceased to act the accelerator chamber pressure escapes to the atmosphere, and the accelerator chamber remains at all times empty until filled by the flow of air from the brake valve during a service application.

The accelerator valve, as its name implies, accelerates the discharge of air in a service application, but the reductions of brake pipe pressure are not on this account any greater than with former types of N. Y. engineers' valves. The accelerator acts automatically and only responds to reductions made for trains longer than about eight cars. In all brake pipe reductions there is a certain amount of back flow of air from the auxiliary reservoirs through the feed grooves of the triple valves to the brake pipe, and from the brake cylinders to the atmosphere through the leakage grooves. The accumulated effect of this back flow and leakage causes the brake pipe pressure reduction to be somewhat slow for a long train, and it is in such cases that the accelerator valve performs its work. The action of the accelerator causes a much larger volume of brake pipe air to be discharged to the atmosphere than could flow out from the engineers' brake valve in the same time. It is obvious that in a short train, where the total back flow of air is comparatively small, the reduction of brake pipe air is more easily accomplished, and even although a certain amount of air is fed into the empty accelerator chamber, it has not time to accumulate sufficient pressure to operate the accelerator before the engineers' brake valve is lapped and the flow to the accelerator chamber is stopped. The air which did find its way to the accelerator chamber is quietly exhausted to the atmosphere, leaving the accelerator chamber empty as before and ready for a further supply of air when occasion demands. In this way the accelerator acts, one might almost say, with discrimination according to the length of the train and the amount of the brake pipe reduction made. It stays open longer with a long train than it does with a short one, and does not act at all when the engineers' brake valve is competent to make the required brake pipe reduction in the required time.

Schedule B-3—S. The B-3—S equipment of the New York Air Brake Company, shown in Fig. 55, is intended for use only on switching engines. The automatic brake can be used on locomotive and train, or the automatic brake may be used on the train and straight air on the locomotive if required. A single pump governor and a single pressure controller are used. The controller is adjusted so as to give 70 pounds brake pipe pressure, and the pump governor gives 90 pounds main reservoir pressure for ordinary switching operations. The lever safety valve is provided for the purpose of graduating off or releasing the locomotive brake while holding the train brake applied. The accelerator valve and the divided reservoir are not used in this equipment, but the supplementary reservoir for the engineers' brake valve, which is part

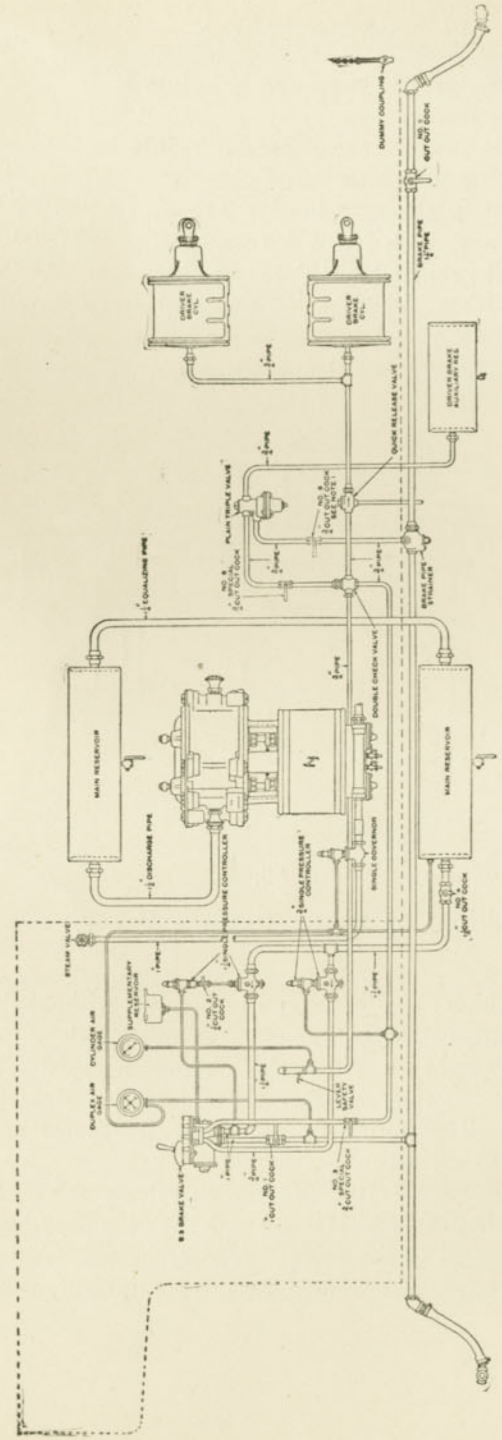


Fig. 55.

Piping Diagram. Schedule B3-S. New York Air Brake for Switch Engines. The Accelerator Valve and Divided Reservoir are not Used with this Schedule; the Supplementary Reservoir of Schedule B is Substituted for the Divided Reservoir.

of the regular equipment, known as Schedule B, is used in place of the divided reservoir.

Provision is made in the B-3—S schedule for switching passenger trains using high brake pipe pressure. This is effected by adjusting the pump governor to give 110 pounds main reservoir pressure, and a stop cock No. 2 between the regulating and supply portions of the controller is closed, so that main reservoir pressure can flow without interruption and without reduction to the engineers' brake valve and from it to the brake pipe. The closing of this cock simply cuts out the pressure controller, and therefore

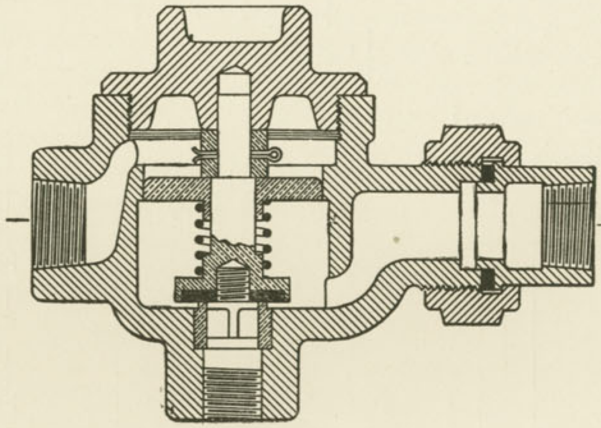


Fig. 56.

Section of Quick Release Valve.

trains using the high speed brake can be handled without the alteration of any part of the equipment. A quick release valve is placed on the straight air pipe, which causes a rapid release of brakes on the locomotive, whether the automatic or straight air brake be used. This quick release valve facilitates switching movements and so saves time.

The Quick Release Valve. The quick release valve is placed on the straight air pipe, and is connected with the pipe leading to the double check and to the driver brake cylinders. Air passing from the plain triple valve, used in this equipment, enters the

quick release valve on its way to the driver brake cylinders. When an automatic or straight air application has been made, air flowing to the brake cylinders enters above a piston in the quick release valve, Fig. 56, and pushes it down. The body of the quick release valve fits the piston closely when the piston is in its uppermost or normal position, but is of greater diameter than the piston below it. A slight depression of the quick release piston brings it down into the wider portion of the valve-body, and air then flows readily past the piston and reaches the driver brake cylinders. The depression of the piston compresses a small coil spring, and at the same time the piston bottoms on the collar of an exhaust valve below it and holds this exhaust valve tightly to its seat. Air therefore passes in full volume from the plain triple valve to the driver brake cylinders.

As soon as the engineers' brake valve has been placed in the release position, air from the driver brake cylinders flows back through the pipes by which it entered them, and encounters the quick release valve. The piston, which was formerly depressed by the flow of air toward the driver brake cylinders, is now raised by the back flow from the driver brake cylinders, and the piston fits closely again into the restricted portion of the valve-body, and the upward movement of the piston carries up with it the exhaust valve below it, and a large opening to the atmosphere is at once provided through which driver brake cylinder air rapidly exhausts. When the cylinders are empty the tension of the coil spring under the quick release piston closes the exhaust valve, and the quick release device is ready for a second application.

The position of the quick release valve just described is such that the driver brakes are rapidly released, whether an automatic or straight air application has been made. If, however, it is desired to hasten the release of the straight air brake on the engine and tender and leave the release of the automatic brake normal when used, the position of the quick release valve may be altered in the shop. The new position of the quick release valve, while still on the straight air pipe, is now between the double check valve, Fig. 57, and the engineers' brake valve. When using the automatic brake on the locomotive, brake cylinder release will be normal, and in this new position the quick release valve will be inoperative; but when the straight air brake is used on the locomotive, the driver and tender brakes will secure the benefit of the quick release. See diagram, Fig. 55.

The High Pressure Control B-3—HP Schedule. The high pressure control of the New York air brake system, Fig. 58, is intended for use in heavy freight service where large loaded trains are handled on grades, or where loads are taken down steep inclines and empty cars are hauled in the opposite direction. In this, the B-3—HP schedule, the terminal letters indicate the words "high-pressure." With this arrangement the pump governor and the

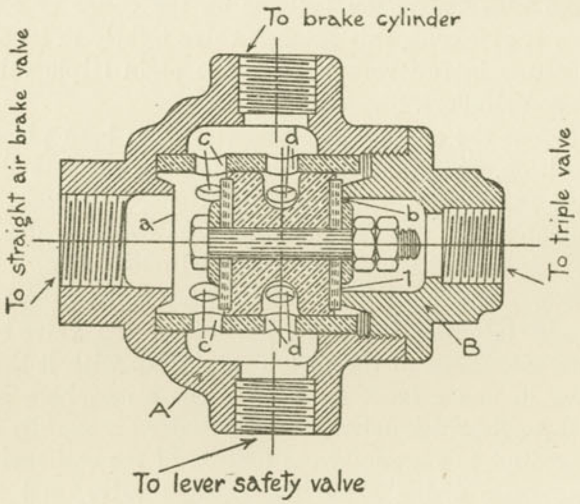


Fig. 57.

DOUBLE CHECK VALVE, NEW YORK AIR BRAKE.

pressure controller have each duplex heads so that main reservoir pressures of 90 or 110 pounds may be carried, and brake pipe pressures of 70 or 90 pounds may be had as desired. The B-3—HP brake apparatus permits the use of the automatic or the straight air brake on the locomotive equipment. When the higher brake pipe pressure is used on the train, it is, of course, not always intended that the automatic brake be operative on the locomotive brake cylinders, for the reason that the maximum brake pipe and auxiliary reservoir pressure, used most satisfactorily on heavily

loaded cars, would be far too high for the locomotive whose working weight is practically constant. But where the automatic brake is used the safety valves on the engine and tender, blow the brake cylinder pressure down to the pressure for which the safety valves are set. In this case the straight air brake is used on the locomotive, and the straight air controller limits the brake cylinder pressure to 40 pounds. When the low-pressure control is used on a train composed principally of empties, the automatic brake can be worked on the locomotive by cutting out the straight air. This is done by closing cut-out cock No. 3 in the straight air pipe below the engineers' brake valve. See Fig. 58.

Pump Governor and Pressure Controller. The pump governor and the pressure controller are one and the same mechanism, though applied to separate uses and differently adjusted, and the description of one covers both. The straight air controller is a similar, though in part smaller, piece of mechanism, and is adjusted for its own particular service of restricting the straight air brake cylinder pressure to 40 pounds to the square inch. The pump governor or pressure controller consists of two parts, the regulating heads and the supply bases. The heads of the pump governor, the pressure controller and the straight air controller of this equipment are all alike in make and size. The supply portions of the pump governor and pressure controller are also alike in make and size, but the straight air controller is made for a $\frac{3}{4}$-inch pipe, while the others are used on $1\frac{1}{4}$-inch pipes. The controller is made with heads in two styles, single or duplex, to meet the requirements of the different schedules. The single head controllers go with the schedules previously described, but on the B-3—HP schedule, which we are now considering, the duplex heads are used on the pump governor and the pressure controller. Fig. 59 is a sectional view of the duplex pressure controller or of the pump governor head. Fig. 60 is a sectional view of the base, and Fig. 61 is a section of the single head.

Referring to the piping diagram, Fig. 58, of the high pressure control, Schedule B-3—HP, it will be seen that the duplex head of the pump governor is connected to the pipe leading to the duplex air gauge, and main reservoir pressure reaches the heads. On the connecting pipe a three-way cock is placed so that either one of the heads is put in communication with the main reservoir,

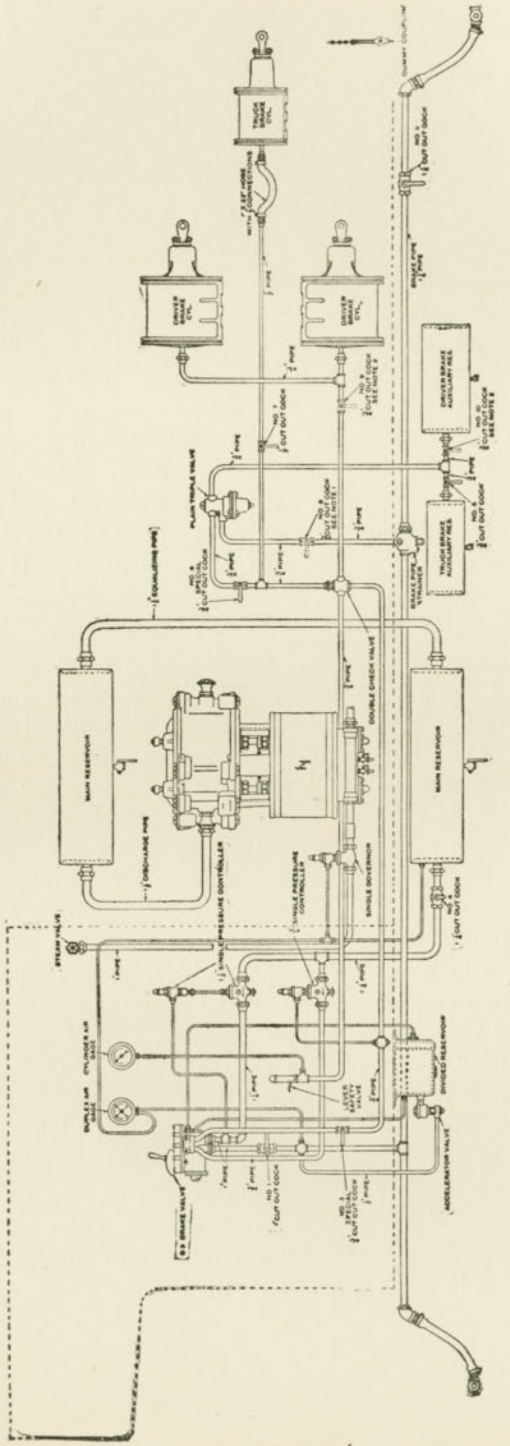


Fig. 58.

Piping Diagram. Schedule B3-HP. New York Air Brake for Use in Freight Service. (High Pressure Control Apparatus.)

and the one cut in becomes operative, while the other head is cut out. The two heads are structurally and functionally alike. The low-pressure head is adjusted by the tension of the coil spring in the head to give a main reservoir pressure of 90 pounds, and the high pressure head is adjusted in a similar manner to give 110

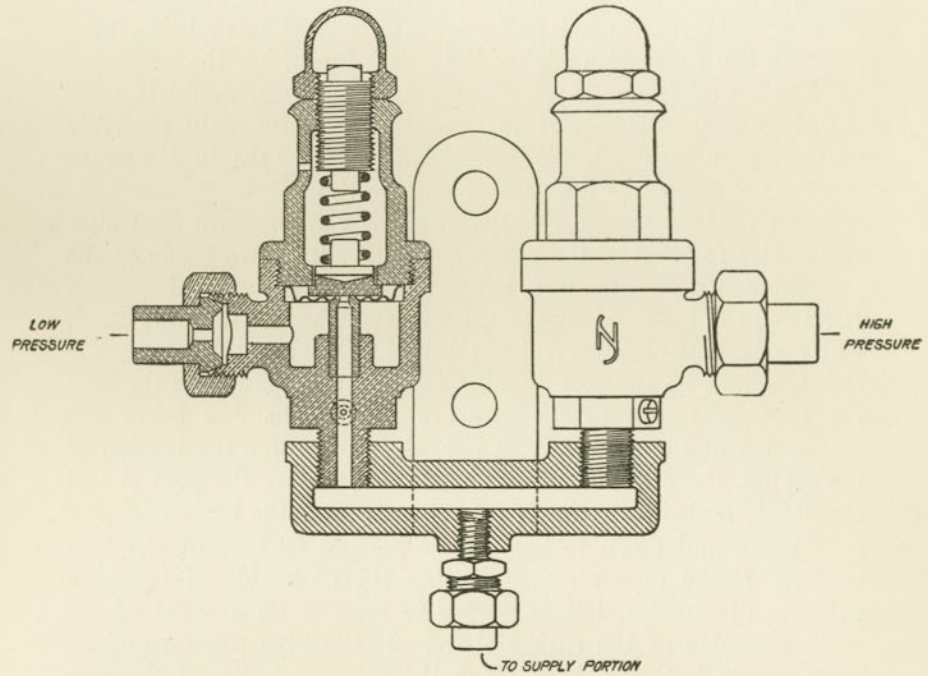


Fig. 59.

Duplex Regulating Portion of Pressure Controller.

pounds main reservoir pressure. The three-way cock cuts in one head and cuts out the other, so that only one head can be operative at a time; and the main reservoir pressure and the stopping and starting of the pump is then exclusively under control of the head, which for the time being may be cut in.

The pressure controller similarly limits the brake pipe pressure, and the three-way cock in its head connection cuts in or out the high or low brake pipe pressure head, and so limits brake pipe pressure to 70 pounds, or maintains it at 90 pounds, according to whether the high or low pressure control is in use on the train. If by mistake the high-pressure pump governor head should be cut in at the same time that the low pressure controller head was operative, the discrepancy would at once appear on the duplex gauge showing an abnormal excess pressure in the main reservoir of 40 pounds. This would not prevent brake operation, as brake pipe pressure can never rise higher than that for which the operative head of the controller is set. The pump, however, would be compelled to work uselessly in maintaining a higher main reservoir pressure than required. An intelligent glance at the duplex gauge would at once lead to the necessary correction.

An explanation of the operation of the pressure controller will suffice for that of the pump governor. The two heads of the pressure controller are alike, but with differently adjusted springs. Air from the brake pipe enters, let us say, the low pressure head, and reaches the chamber below the spring. Here a diaphragm is tightly seated on the port opening into the passageway to the supply base. As soon as the pressure in the chamber below the diaphragm and spring is great enough to overcome the tension of the spring, the diaphragm is raised and uncovers the port it had previously sealed. Brake pipe air then flows to the horizontal passage below and down to the supply portion or base of the controller. Brake pipe air also reaches the underside of the high pressure diaphragm, but is unable to raise it on account of the greater tension of the spring above. Brake pipe pressure of 70 pounds only is thus able to reach the supply portion of the controller.

When the high pressure head is cut in and the low pressure head cut out, air accumulates in the brake pipe up to 90 pounds pressure, which is the amount required to raise the high pressure diaphragm and compress the spring above it. Brake pipe pressure at 90 pounds is thus able to reach the supply portion of the controller. Air at 90 pounds, however, flows along the horizontal passage connecting the heads and up the small passage leading to the center of the low pressure diaphragm, and although it may slightly raise the low pressure diaphragm and leak into the connecting pipe, it is prevented from traveling beyond the three-way

cock by which the low pressure head is cut out. The operation of the two heads is thus apparent. Brake pipe pressure at 70 pounds or at 90 pounds is permitted to reach the supply portion of the controller according to whether the low or the high pressure head is cut in. In the vertical passages leading to the supply portion of the controller, below the diaphragms, there are two small ports connected with the atmosphere, and air above the piston of the supply portion of the controller can slowly but constantly escape. As both of these small ports perform the same function, one of them may be plugged when the duplex head is used. As soon as

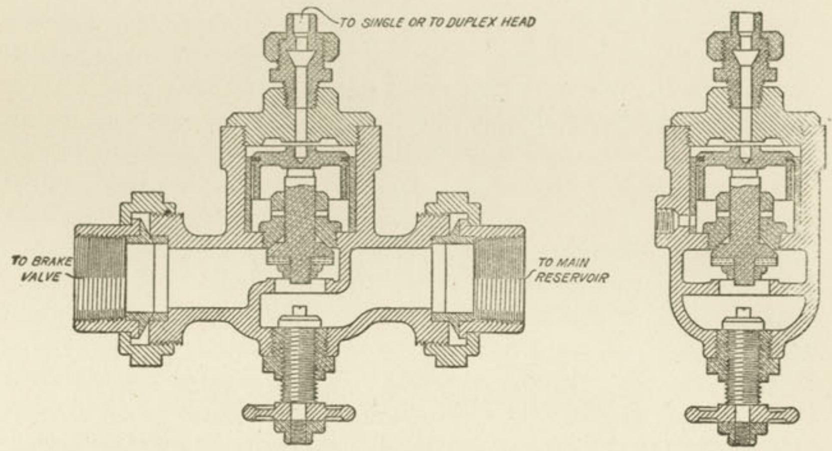


Fig. 60.

SECTION OF SUPPLY PORTION OF PRESSURE CONTROLLER.

the operative diaphragm seats and closes off brake pipe air from the supply base, the air held above the supply piston escapes to the atmosphere and removes the pressure on the top of the supply piston.

The Supply Portion of the Controller. The base or supply portion of the pressure controller, Fig. 60, consists of a passageway leading from the main reservoir to the engineers' brake valve, and in this passage is a valve which closes or opens the through passage. This valve is seated or unseated by the motion of a piston above it to which it is attached. Main reservoir pressure reaches the underside of the valve and tends to raise it and pass to the engineers' brake valve. The supply valve is, however, held to its seat by brake pipe pressure of 70 or 90 pounds above it, introduced by the action of one or other of the duplex heads. If the low-pressure head is operative, and 70 pounds pressure reaches

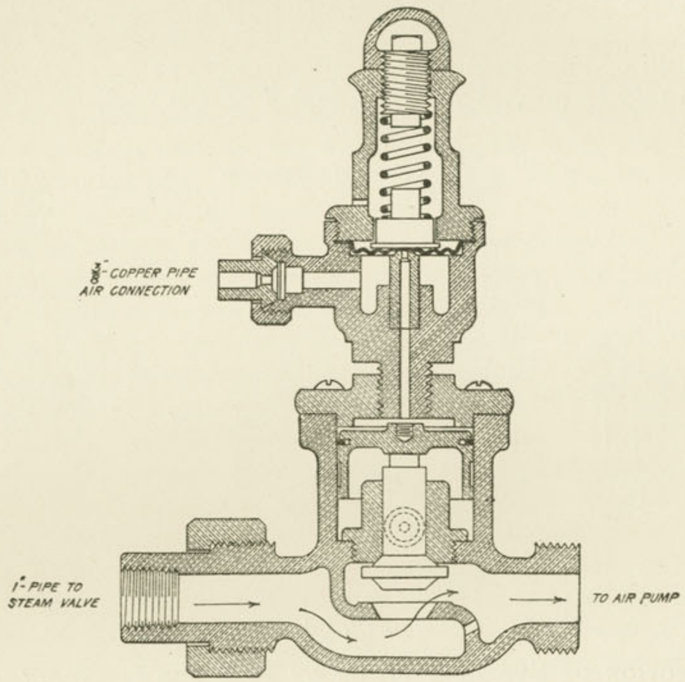


Fig. 61.

SECTION OF SINGLE HEAD PRESSURE CONTROLLER.

the supply piston, the area of which is greater than that of the valve, the valve is held to its seat, and the supply of air from main reservoir to brake pipe is limited to that amount. As soon as brake pipe pressure sinks below 70 pounds, its effect is felt at once in the regulating head, and the regulating diaphragm closes off the air reaching the supply piston. The small exhaust port to the atmosphere in the vertical passage below the diaphragm re-

leases the air above the supply piston, and the main reservoir pressure raises the supply valve and flows to the brake pipe. The building up of brake pipe pressure to the required amount again operates to raise the regulating diaphragm, and air is again introduced above the supply piston with the result that it moves downward and closes the supply valve. The chamber below the supply piston and above the supply valve is open to the atmosphere, so that the supply piston can move freely and also discharge any air that may leak past the supply piston from above. In connection with the supply portion of the controller there is a hand wheel provided, with stem projecting up below the valve in the through passage. By screwing the wheel up, its stem will lift the valve off its seat and allow free passage of air from main reservoir to brake valve. This hand wheel can be used if any defect of the valve should develop, or in case its action becomes slow or uncertain. The valve, when held off its seat by the stem of the hand wheel, renders the controller inoperative and main reservoir pressure reaches the engineers' brake valve.

The New York High Speed Brake. The schedule which comprises the New York High Speed Brake is B-3—HS, Fig. 62. The terminal letters indicate the high speed feature. This equipment, like the one previously described, is such that the straight air brake can be used on the locomotive. There are, in this equipment, the duplex pressure controller and the duplex pump governor. The regulating heads of the pressure controller are set for 70 and 110 pounds respectively, so that either the ordinary automatic brake or the high speed brake may be used. The pump governor heads are adjusted for 90 and 130 pounds respectively. The pump governor connection is supplied with a three-way cock, as in the previously described high pressure control brake. There is, however, a four-way cock placed in the pipes leading to the regulating heads of the pressure controller. This is a specially designed cock, with a connection leading to each head. One of these connections goes to the supply pipe between the controller and the brake valve, and the other to the pipe between the controller and the reservoir of the accelerating valve. One of the functions of this four-way cock is that when its handle is in the position to operate the regulating head, adjusted to 110 pounds brake pipe pressure, a small port in the accelerator reservoir connecting pipe

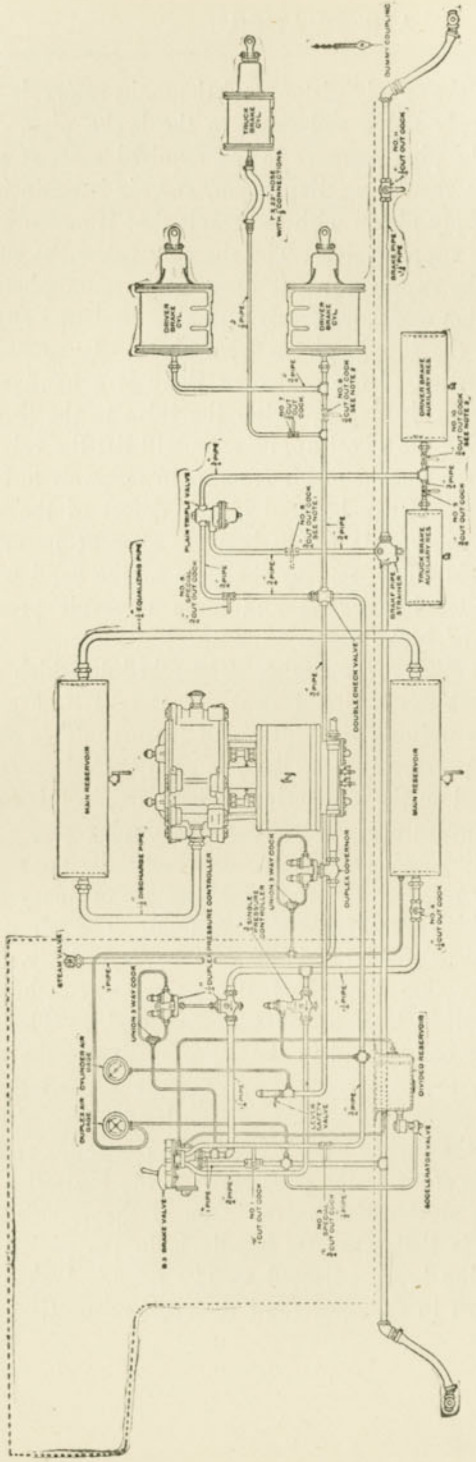


Fig. 62.

Piping Diagram. Schedule B3-HS. New York Air Brake for Use in Passenger Service. (High Speed Brake.)

is opened to the atmosphere. This opening prevents more than the usual predetermined reduction of brake pipe pressure, which is obtained with the graduating notches on the engineers' brake valve, from taking place when the 110 pound brake pipe pressure is used in high speed work.

The Lever Safety Valve. On all the other brake equipments

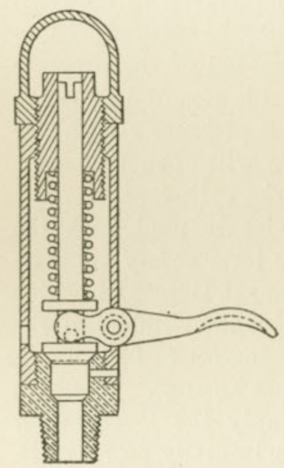


Fig. 63.

Section of Lever Safety Valve.

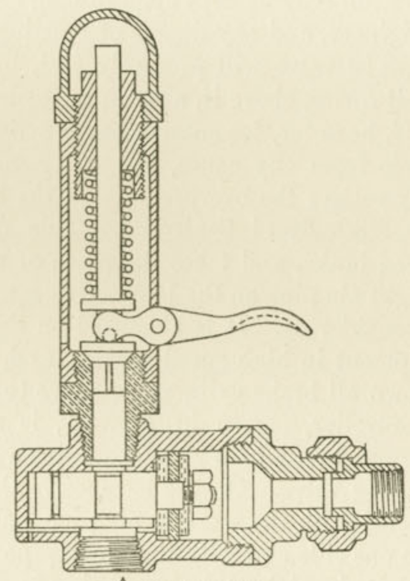


Fig. 64.

Section of High Speed Controller, New York Air Brake.

of the New York Air Brake Company the lever safety valve is used on the straight air pipe for the purpose of separately graduating off or releasing straight air on the locomotive brake while the automatic brake remained set. It may not inappropriately be described here. The lever safety valve, as shown in Fig. 63, consists simply of an ordinary butterfly valve held to its seat with a coil spring above it and an adjusting nut and cap on top. The spring is adjusted to hold a pressure of 53 pounds, so that whether used alone or with the high speed brake, the locomotive brake cylinders will always be relieved if the pressure in them should rise above that amount. The valve is provided with a collar under which, and above the top of the valve, is inserted the short end of a small hand lever. The depression of the handle-end of this lever compresses the spring above and raises the safety valve off its seat, and so discharges air from the brake cylinders to the atmosphere. The valve can only be kept open so long as the lever is in the hand of the engineer, and any degree of opening may be secured by him at will. The valve will promptly seat, by reason of the pressure of the coil spring above it, as soon as the hand is removed from the lever. If, however, locomotive brake cylinder pressure rises above 53 pounds from any cause, the safety valve will open and automatically relieve the overpressure in the brake cylinders.

The High Speed Controller. This device is used with the high speed brake, and takes the place of the lever safety valve on the straight air pipe on the locomotive equipment B-3—HS, which we are considering. It is also used on the brake cylinders of the car equipment in high speed service, and, being set to 53 pounds, blows down all brake cylinder pressure to that amount. The high speed controller, shown in Fig. 64, is simply the lever safety valve mounted on a base which contains a horizontally moving piston and plug valve. On the locomotive this lower portion or base is connected with the straight air pipe leading from the brake cylinders at one side and with the brake pipe at the other. The valve itself is a horizontal solid plug, fitting in a cylindrical chamber below the safety valve. The plug valve is on the stem of a piston which is constantly acted on by brake pipe pressure. This pressure keeps the piston and plug valve at their extreme left-hand position, and a slight reduction of brake pipe pressure is not sufficient to move the piston and valve, as the piston fits tightly in its chamber. The plug valve has two grooves cut round its circumference. One of them is quite large and the other is quite small. During ordinary service applications the large groove remains immediately under the passage up to the safety valve. This is the normal position when piston and plug valve are at their extreme left-hand position. When the parts are so arranged, air from the brake cylinders, on cars and locomotives, has full and free access to the safety valve, and any pressure above that for which

the safety valve is set, viz.: 53 pounds in the brake cylinders, is rapidly blown away. This constitutes the brake cylinder reduction for ordinary high speed service stops.

When a high speed emergency application is made, the fall of brake pipe pressure is rapid and heavy, and under these circumstances the brake cylinder pressure, acting on the plug-valve piston, and on the side remote from the brake pipe pressure, easily carries the piston and plug-valve over to their extreme right-hand position. When this takes place, the small annular groove in the plug valve is brought in place below the safety valve, and consequently only a restricted opening is afforded for the escape of the high brake cylinder pressure to the safety valve. This delays the blowing away of brake cylinder pressure and lengthens the period of time in which the high brake cylinder pressure, produced by an emergency application, acts in retarding the motion of the train. When the pressure in the brake cylinders sinks to 53 pounds, the safety valve closes and holds that pressure in the brake cylinders until brakes are released. When release occurs, piston and plug-valve are forced by brake pipe pressure to assume their usual extreme left-hand position with the large annular groove in the plug valve immediately below the safety valve.

The New York Duplex Air Pump. The New York duplex air compressor is practically two pumps placed side by side, as shown in Fig. 65. The air cylinders are on top and the steam cylinders are below. This arrangement is intended to prevent any of the water of condensation being carried on the piston rods from the steam to the air cylinders. The air compressor may be described as simple, as far as the two steam scylinders are concerned, and compound with reference to the air cylinders. The steam cylinders are placed side by side and are of the same size. Each has an independent valve gear, and each takes steam direct from the boiler.

The Valve Gear. The valve gear of one is operated by the movement of the piston of the other, in a manner somewhat similar to the well-known Worthington Steam Pump, and, like the Worthington Pump, the piston of one is at rest while the other is moving. The valve gear is very simple in design, and consists in each case of a plain slide valve which works in a steam chest and is operated by a valve stem which extends into the hollow piston rod of the steam cylinder.

The Cylinder Sizes. The pumps most commonly used on locomotives are the No. 5 and the No. 6. The steam cylinders of the No. 5 pump are 8 x 12 inches, with air cylinders 8 and 12 x 12 inches. This pump, when operated under 200 pounds steam

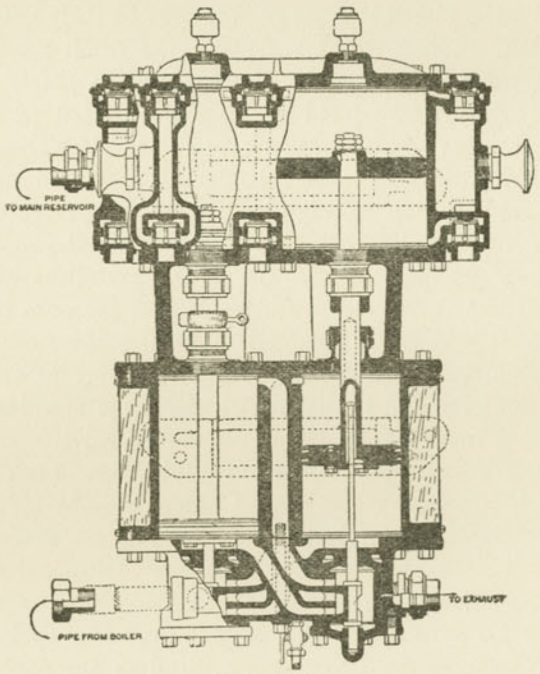


Fig. 65.

SECTION OF NO. 6 DUPLEX AIR PUMP, NEW YORK AIR BRAKE.

pressure and against an air pressure of 90 pounds, delivers 129 cubic feet of free air per minute. No. 6 pump, with steam cylinders 7 x 10 inches, and air cylinders 7 and 11 x 10 inches, operating with 200 pounds steam against an air pressure of 90 pounds, delivers 84 cubic feet of free air per minute. The special No. 5 has steam cylinders 10 x 12 inches, and air cylinders 8 and 12 x 12 inches, operating under 100 pounds steam pressure against 150 pounds air pressure; it delivers 28 cubic feet of free

air per minute. The No. 6 special has steam cylinders 9 x 10 inches, air cylinders 5 and 9 x 10 inches, and, operating under 115 pounds steam pressure and against an air pressure of 230 pounds, delivers 33 cubic feet of free air per minute. The two special pumps, when working against the exceedingly high air pressures just quoted, should not be kept constantly in operation for a longer period than 15 minutes, without giving the air cylinders a chance to cool.

The Air Cylinders. The pistons of the air cylinders are double-acting; that is, they compress air on both the up and down stroke. Both cylinders are filled with free air after each stroke. The high-pressure piston remains at rest until the contents of the large low-pressure air cylinder have been compressed into the high-pressure cylinder, and on the next stroke of the high-pressure piston this partly compressed air is further compressed and forced into the main reservoir. In this way three measures of air are compressed by the use of two measures of steam, and an economy of steam is of course the result. The air valves are simple checks and seat by gravity. These pumps, like all other direct acting air compressors, should be started slowly, not only on account of the condensation which necessarily takes place in the steam cylinders, but because, before there is sufficient air compressed to act as a cushion for the pistons, if they are driven with force by full steam pressure, they are apt to pound against the pump heads and possibly break or do damage.

The action of these pumps when properly operated is very regular, one might almost say rhythmical. The steam piston of the left-hand pump rises first and drives up the large low-pressure air piston above it. Air is drawn in below this piston and is ready to be compressed on the next stroke. Just as the upward stroke is nearly completed, the button on the top of the valve rod engages with the tappet plate on the underside of the piston and carries the valve rod up, and with it the slide valve, which feeds steam to the other steam piston. This piston now rises, driving up the small high-pressure air piston which forces the partly compressed air from the low-pressure cylinder into the main reservoir. While this is taking place, the pistons on the low-pressure side are standing still, and the concluding motion of the right-hand steam piston moves the slide valve governing the flow of steam to the first cylinder, and the first steam piston makes its down stroke, while the second piston stands still. The concluding portion of the first piston's down stroke operates the slide valve governing steam admission to the second cylinder, and the second piston begins its down stroke. The cycles are regularly repeated and air compression is continuous. Steam entering either cylinder does work in that cylinder, and is then exhausted direct to the atmosphere through the exhaust pipe leading to the smoke box; but air entering the first or large low-pressure air cylinder is compressed into the second and smaller high-pressure air cylinder, and from that it passes to the main reservoir. When the high-pressure air piston is driving the air into the main reservoir, which had previously been partly compressed by the large low-pressure piston, free air from outside is able to follow the high-pressure piston, so that at the end of the stroke the high-pressure cylinder is filled with air at ordinary atmospheric pressure. This air cannot now escape, and it is into this cylinder that the low-pressure piston forces the contents of the large low-pressure cylinder. There are thus the contents of the low-pressure and the high-pressure cylinders forced to occupy the volume of the high-pressure cylinder, after the low-pressure piston has completed its stroke, and the following up of the high-pressure piston by free air from outside not only facilitates the movement of the high-pressure piston by not causing any vacuum behind it, but it entraps a cylinder full of free air and holds it ready for compression. The steam portion of each pump is simple, but the air compressing portion thus forms a two-stage compressor with economy of steam and a large air capacity.

The New York B-4 Equipment. The New York Air Brake Company are contemplating a modification of the various schedules which have been described under the general name of the B-3 equipment. The new schedules when they appear will be designated as the B-4 equipment. Among the improvements which will be brought out on the locomotive is a valve analogous in function to the Westinghouse distributing valve, which will replace the plain triple valves used on the engine and tender.

The general tendency to-day, especially in freight service, is to increase the length of the train, and the old-time maximum 50-car train has in many cases been replaced by the 75-car train, and

even a larger number of cars are hauled at once. Passenger trains have also increased in size and weight, and these modern conditions have demanded recognition. On long freight trains, by which we mean an aggregation of 75 cars and upwards, when a brake pipe reduction is made, the back flow of air out of the auxiliary reservoirs to the brake pipe through the feed groove, while the triple piston is beginning to move, together with the escape of air through the leakage groove in the brake cylinder as the brake cylinder piston is beginning its stroke, though each may be small on the individual car, are cumulative in their effect. With slow brake pipe reduction on a long train, they result in a considerable loss of compressed air. Comparatively slow brake pipe pressure reduction is necessary to prevent the brakes setting on the forward part of a train, and the consequent running in of the slack of the train.

The release of brakes on a long freight train has a tendency to manifest itself sooner on the forward cars than on those in the rear, with the result that the slack of the train runs out with possibly severe strains on the draw gear. There is also the danger of overcharging the auxiliary reservoirs at the front part of the train, when the engineers' brake valve has been moved to the release position. This overcharging of the forward auxiliaries, when it takes place, generally results in a reapplication of the forward brakes by reason of the drawing away from them of brake pipe air, consumed in charging the rear auxiliary reservoirs.

These irregularities in brake application and release are more strongly marked in long trains than they are in short ones, and in order to provide for these contingencies the newer forms of freight and passenger train equipment will embody features intended to correct them. One of the improvements will be the introduction of the quick action principle into service applications, which, while not so powerful as that obtained in the emergency, will nevertheless rapidly transmit a brake pipe reduction to the last car on a long train.

A slower release of brakes on the forward cars will also be a feature of the new triple valves. This will be automatically produced, while those on the rear cars will be normal in their action. A restricted and consequently slower charging of the forward auxiliary reservoirs will be automatically provided, while the auxiliary reservoirs at the rear of the train will be supplied in the usual way. This will produce a more equal release and recharge throughout the entire train.

STEAM-DRIVEN AIR COMPRESSORS.

The earliest form of air compressors used in connection with the air brake was a steam-driven pump with 6-inch cylinder actuating the piston of a similar air cylinder, over which it was placed. The cylinders were arranged in tandem, and the pump was double-acting; that is, steam followed the piston in the upper cylinder on its downward and its upward stroke, and the air piston drew free air into the end of the air cylinder from which it was moving, and compressed the air in the end toward which it was moving. This was accomplished by the arrangement of four check valves, two placed at the entrance and two at the exit provided for the air. The movement of the steam cylinder valve was accomplished by a simple piece of mechanism, which was made to move at the end of each stroke.

Westinghouse Single-stage Air Compressors. The standard sizes of Westinghouse single-stage air compressors are the "Eight-inch pump," having steam cylinder 8 inches in diameter, and air cylinder 7½ inches diameter by 10 inches stroke.. The "Nine and one-half inch pump," shown in Fig. 66, has cylinders 9½ x 10 inches. The "Eleven-inch pump" has cylinders 11 x 12 inches. These three types of air compressors, supplied by a one-inch steam pipe, and working respectively at 120, 110 and 100 single strokes a minute, have an actual capacity of free air, against a pressure of 100 pounds, of 20, 28 and 45 cubic feet per minute. There is another way of rating the capacity of these pumps, and that is the time occupied in compressing air to a given pressure. For instance, the eight-inch pump, operating under a steam pressure of 140 pounds, will compress air from zero on the gauge, which is 14.7 pounds absolute, to 70 pounds gauge pressure in a main reservoir 26½ inches diameter by 34 inches long, in 68 seconds, and from 20 to 70 pounds in 50 seconds. The reservoir of the size given has a volume of 8¾ cubic feet. The nine and one-half inch pump, working under the same steam pressure and pumping into the same reservoir, can compress air from zero on the gauge to 70 pounds in 38 seconds, and from 20 to 70 pounds in 27 seconds.

The Nine and one-half inch and the Eleven inch pumps have practically become standard for ordinary railroad work, for the reason that the large number of air braked cars now in use require a pump of ample capacity, and in descending grades where the onsumption of air is necessarily heavy the Eleven inch pump is ble to quickly recharge the auxiliary reservoirs.

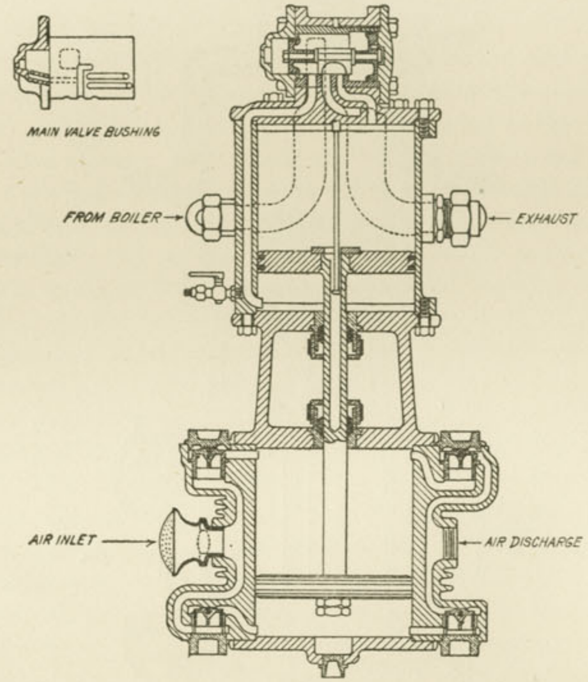


Fig. 66.

SECTION OF 9½-INCH WESTINGHOUSE AIR PUMP.

Pump Valve Gear. The valve gear of the Westinghouse Air Pump is an interesting piece of mechanism. That of the Eight inch pump is not quite so simple as that now used on the Nine and one-half inch pump, and also on the Eleven inch pump, and in describing the pump valve mechanism, the Nine and one-half inch pump will be considered. Fig. 67 is a diagrammatic view of this pump. With the exception of the reversing rod, which extends down into the steam cylinder piston rod, the whole of the valve gear is contained in the steam cylinder head. In this head are two slide valves, one moving vertically and called the reversing valve, and the other moving horizontally and called the main valve.

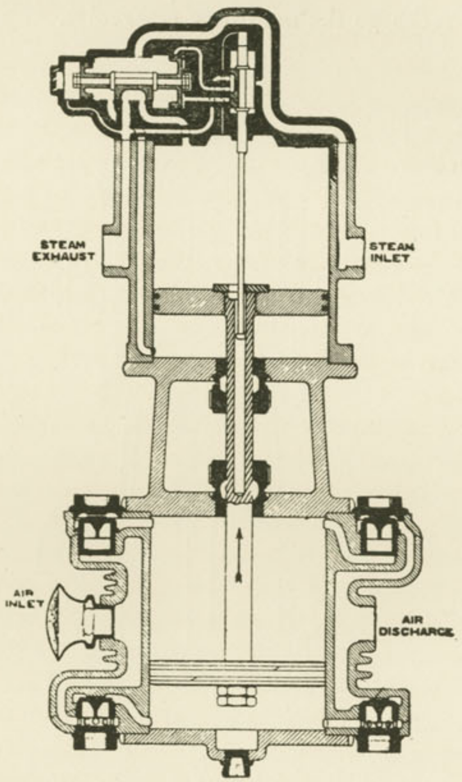


Fig. 67.

Diagrammatic View of $9\frac{1}{2}$-inch Air Pump, Up Stroke.

The reversing valve is in a small chamber, surrounded by steam, and it opens and closes three ports. One of these supplies steam for operating the main valve, and the other two are exhaust passages. The reversing valve is actuated by the movement of the reversing valve rod. This rod passes down through the top cylinder head and into the hollow piston rod of the pump. When the piston of the steam cylinder rises, and just as it is completing

its upward stroke, a shoulder on the reversing valve rod is struck by the reversing plate on the steam piston rod. The last part of this upward stroke therefore carries the reversing valve rod up, and the reversing valve is made to travel up also. By so doing the reversing valve uncovers the port leading to the main valve chamber. The action of the steam so admitted to the main valve chamber will be explained later.

When the steam piston begins its downward stroke, it leaves the reversing valve and rod in the position just referred to, but when the steam piston is completing its downward stroke, a button on the lower end of the reversing valve rod comes in contact with a flat plate, called the reversing valve plate, bolted to the upper side of the steam piston. This draws the reversing valve rod down and carries with it the reversing valve. This valve is now at its lowest point of travel and closes the port feeding live steam to the main valve chamber, and at the same time the cavity in the reversing slide valve connects the exhaust passage from the main valve chamber with a passage leading to the atmosphere. The function of the reversing valve is therefore to supply and exhaust steam to and from the main valve chamber.

The main valve is an ordinary slide valve moving horizontally and supplying and exhausting steam to and from the steam cylinder, in a manner similar to the slide valve of a locomotive. The main slide valve is in a chamber filled with steam direct from the locomotive boiler, and the valve is carried upon a piston-rod or stem which terminates in a piston at each end. The diameter of these two pistons is not equal, and the steam in the main valve chamber acts on the inside face of each. The pressure of steam on the larger piston tends to urge it to the right, and this is only partly counteracted by steam pressure on the inside face of the smaller piston. The greater area of the larger piston enables it to overcome the pull of the smaller piston to the left, and the net result is that the large and small pistons, with their connecting stem or rod, carrying the main valve, all move to the right, and the main piston uncovers the live steam port leading to the bottom of the steam cylinder, and the steam piston is forced to begin its upward stroke.

When the up stroke of the steam piston is completed, the reversing valve has been carried up and steam now flows from the reversing valve chamber to the main valve chamber through a small passage leading to the outside of the larger main valve piston. Steam therefore acts on the outside and inside faces of the larger main valve piston at the same time, and as the pressures are equal the larger piston, immersed in live steam, has no tendency to move owing to these pressures. Steam pressure is, however, acting on the inside face of the smaller piston, and this being unbalanced by any pressure on its outer face, the whole mechanism moves to the left, main valve, rod and the larger and smaller pistons all together. The left-hand movement of the main valve uncovers a port leading to the upper end of the steam cylinder. At the same time the cavity in the main valve connects the port leading from the lower end of the steam cylinder to the atmosphere. Steam is thus introduced above the steam piston and exhausted below it, and the steam piston begins its downward stroke..

In these operations it is clear that the steam pressure in the main valve chamber between the larger and smaller piston moves the main valve to the right and keeps it there, unless counteracted by the introduction of steam pressure on the outside of the larger piston, and this is accomplished by the action of the reversing valve. Steam from the reversing valve only enters the main valve chamber so as to reach the outer face of the larger piston, and though it intermittently neutralizes the pressure on the inner face of the larger piston, the steam between the two pistons and that from the reversing valve chamber do not mingle, and their entrance ways are separate.

Action of Air Piston. The up and down motion of the steam piston imparts an up and down motion to the air cylinder piston, as one is rigidly attached to the other. The upward stroke of the air piston creates a partial vacuum below it, and air rushes in from the atmosphere through the strainer and the air inlet and lifts the inlet valve and enters the air cylinder. On the down stroke of the air piston, the air which entered through the lower receiving valve is compressed by reason of the fact that it cannot escape through the passages by which it entered, as the lower receiving valve is closed by the pressure of the air above it, exactly as the water entering a boiler through the check valve cannot escape back again to the delivery pipe of the injector. The air is therefore compelled to pass out through the discharge passage, in

which there is a check valve similar to the receiving valve of the pump. This is the lower discharge valve. This valve is held down by main reservoir pressure, whatever that may be, and as soon as the air in the cylinder of the pump is compressed to a pressure greater than that in the main reservoir, the lower discharge valve rises and the compressed air enters the main reservoir. On the downward stroke of the air piston, a partial vacuum is created in the portion of the cylinder above the air piston, and air from outside passes in through the strainer and the inlet passage and lifts the upper receiving valve and so enters the pump. The air, which in the downward stroke is being compressed and forced into the main reservoir, cannot escape to the atmosphere, because it is compelled to act on the upper side of the lower receiving valve which it thus holds tightly closed, while it lifts the lower discharge valve and so reaches the main reservoir. The upper discharge valve is, during this downward stroke of the air piston, closed tightly by main reservoir pressure. The second upward stroke of the air piston repeats the suction of air below it and the compression of air above it as it did in the first place, and as this operation recurs on the next upward and all succeeding strokes the pump is enabled to store up compressed air of gradually increasing pressure in the main reservoir, drawing free air in from the atmosphere at every stroke. The pump is thus seen to be double-acting, as it delivers compressed air to the main reservoir at each stroke.

Storage of Energy. The mathematical definition of work is "pressure acting through distance," and the steam pressure acting upon its piston in the cylinder during its entire stroke the piston the recipient of work in the mathematical sense. The air piston being rigidly connected to the steam piston transfers the work of the steam piston to the elastic mass of air against which it moves, and the work of compression is thus accomplished. The air so compressed is stored in the main reservoir. The particles of air in the main reservoir have been forced closer together than they were in the free state, and they are ready to fly apart on the instant that an opening is presented to the compressed mass of air. This ability to fly back to normal conditions is due to the work done upon the air particles by the movement of the air piston upon confined air, and the work so done is stored in the compressed air in the main reservoir in the form of molecular displacement, and the energy residing in the compressed air is now in what is called the potential form.

When one winds up a clock, the tension of the main spring is increased by the somewhat similar process of molecular displacement, in which each particle of the steel is slightly forced out of its normal position, and the tightly wound spring is held in the position into which it has been forced, by the ratchet and pawl. The energy expended by the hand of the winder does work upon the tempered steel clock spring, and when held in its compressed and tense position it is said to be possessed of potential energy, or to put it in other words, it possesses the alility to give back when uncoiling the work expended upon it by the person who wound it up. The hand of the winder may have occupied only a few moments in the process of doing work upon the spring, but the energy so stored in the spring is faithfully given back in the continued movement of the hands over the face of the clock during many succeeding hours. Time is slowly measured as the escapement wheel and hair spring rhythmically and regularly liberate the amount of force necessary to mark each second, and the seconds grow to minutes with the motion of the hands.

The winding of the clock spring forms a fairly close analogy to the compression of air by the pump on an engine, and as far as the storage of energy in the potential form is concerned, the analogy is complete. The comparatively rapid winding of the clock and the compression of its spring develop a certain amount of heat which is, of course, quickly radiated. The amount of energy which is stored is that which remains after the friction of the clock mechanism and the heat developed by the molecular distortion of the spring have been deducted. The stored energy is therefore not quite the amount expended by the winder, but it is all the spring has to give back in the form of work. In like manner the friction of the moving parts of the pump, the lifting of the valves, etc., consume a minute portion of the work done by the steam from the boiler. The rapid compression of the air also develops some heat, and the heat so produced tends to raise the pressure of the compressed air. In the early forms of air pumps, the air cylinder was jacketed so as to prevent the radiation of the heat of compression, but in the later forms of pumps, where larger volumes of air are compressed and where the strokes of the pump are

rapid, the outside of the air cylinder is not only not covered, but in some instances is made with a series of projecting fins in order to facilitate the radiation of the heat produced in compressing the air. The outside of the main reservoir is not protected in any way, so that radiation of heat takes place from its surface, and the pressure of air indicated on the gauge is that of the air, cooled to very nearly that of the surrounding atmosphere, and is practically the measure of the potential energy contained in the compressed air stored in the reservoir.

If the heat of compression could be retained a higher pressure would result, but the pump would heat and other undesirable conditions would be produced. The compression of air, when every provision for the rapid radiation of heat is provided for, is called Isothermal compression, as the heat in the air before and after compression is as nearly as possible equal, the word Isothermal signifying equal heats. The more or less theoretical pressure resulting from compression, where heat is retained in the air, is called Adiabatic compression, and this word, of Greek origin, indicates that the heat of compression does not pass through the walls of the containing vessel. In this connection it is interesting to quote a table given by Mr. R. H. Blackall in his "Air Brake Catechism." He says: "The accompanying table shows the heat due to compression. This heat depends upon the initial temperature. The rise in temperature is due to the heat of compression." This is in another form the presentation of Gay-Lusac's law of thermodynamics, which states that the pressure of a gas varies directly as its temperature. The figures quoted by Mr. Blackall refer to the Fahrenheit thermometer. The figures are no doubt theoretically true, but are not readily apparent in practice.

Temperature of air before compression		60°	90°
Temperature of air compressed to	15 lbs	177°	212°
" " "	30 "	255°	294°
" " "	45 "	317°	362°
" " "	60 "	369°	417°
" " "	75 "	416°	465°
" " "	90 "	455°	507°
" " "	105 "	490°	545°
" " "	120 "	524°	580°

From this table it is apparent that the rise in temperature above that of the surrounding atmosphere is very great for each of the pressures given. Air on a hot summer day at a temperature of 90° F, when compressed to about half its volume and showing a gauge pressure of 15 pounds per square inch, is shown as raised to the temperature of boiling water.

The Cross Compound Pump. The cross compound pump, Fig. 68, is one of the latest of the air brake accessories, but it is not new in one sense of the word. As early as 1873, Mr. George Westinghouse designed and patented a compound pump only a short time after the air brake had been devised. One of the aims in pump design all the way through air brake development has been to produce a pump which would occupy as little space as possible on the locomotive, and this has been successfully achieved, notwithstanding that the air consumption on trains in the legitimate operation of air brakes has greatly increased, and at the same time the use of compressed air for various purposes on a train has had a steady growth. At the present time there are a number of so-called "parasites" on the air brake system, such as bell-ringers, track-sanders, water-scoops and a water-raising system in Pullman sleeping cars, as well as other appliances on engines and cars. All these tax the air pump, and in order to meet the greater demand for compressed air the cross compound pump has been devised.

The Siamese Design. The problem in air supply which has been met by the cross compound pump is the constant supply of a large quantity of compressed air without the production of an abnormally large pump, and at the same time the consumption of steam has been kept within reasonable limits. The cross compound pump as now built is the combination of two separate air pumps placed side by side and included in the one machine, as shown in Fig. 68. These pumps, each having a steam and an air cylinder, have been so closely associated together, and the steam supplied to one, after doing work, being compelled to traverse the passages of the second, and so continue the work of air compression, has suggested the name "Siamese," to describe the design. The name has, of course, reference to the famous Siamese twins, which were a pair of human beings born in Siam, that, owing to the peculiarity of their bodily structure, were closely connected together, so that the life of one was apparently bound up with that of the other, and for all practical purposes neither had a free and independent existence apart from the other.

The Tandem Pump. The Siamese cross compound pump is therefore easily distinguished from the tandem compound design, in which there are three cylinders placed in a vertical line, the one

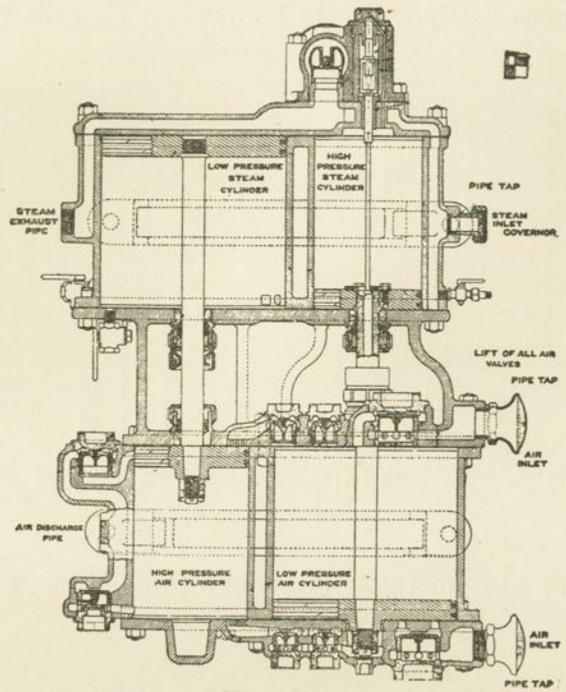


Fig. 68.

8½-INCH CROSS COMPOUND COMPRESSOR.

steam cylinder being on top. In the tandem pump the low-pressure air cylinder is 11 x 12 inches, and corresponds to the air cylinder of the 11-inch pump. The high-pressure air cylinder is 6¾ with 12-inch stroke, and the steam cylinder is 8 x 12 inches. The tandem pump is a two-stage compressor, and has considerably greater capacity than the standard 11-inch pump, with a decided steam economy. The air valves, etc., in the tandem pump are those of the standard $9\frac{1}{2}$-inch pump. The receiving and discharge valves of the new pattern 8-inch, the $9\frac{1}{2}$-inch, and the 11-inch pumps should have a lift of 3-32 of an inch.

The Eight and One-half-inch Cross Compound Pump. The cross compound air pump is called the $8\frac{1}{2}$-inch cross compound, as shown in Figs. 69 and 70, because the high-pressure steam cylinder has a diameter of $8\frac{1}{2}$ inches, with a stroke of 12 inches. This cylinder is placed immediately above the low-pressure air cylinder, which

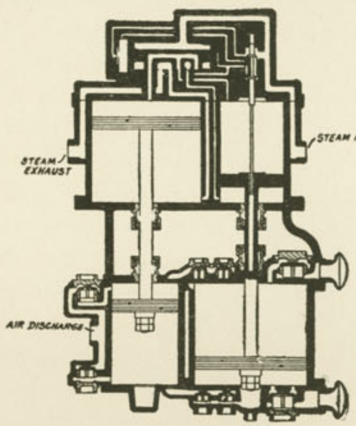


Fig. 69.

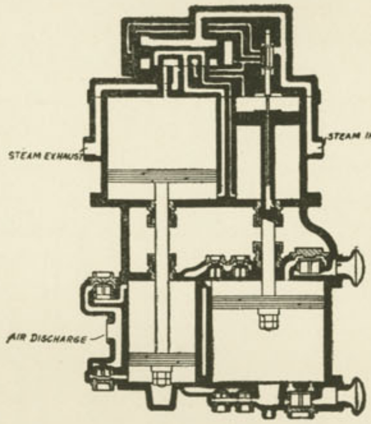


Fig. 70.

Diagram of $8\frac{1}{2}$-inch Cross Compound Compressor, Showing Different Strokes.

has a diameter of $14\frac{1}{2}$ inches and a stroke of 12 inches. The low-pressure steam cylinder, $14\frac{1}{2}$ inches in diameter with 12 inches stroke, is placed above the high-pressure air cylinder, which is 9 x 12 inches. The valve gear of this pump is placed in the high-pressure steam cylinder head and is similar in operation to that of the standard $9\frac{1}{2}$-inch and 11-inch pumps. The high and low-pressure air cylinders have respectively volumes of 1981.56 and 763.40 cubic inches, and this gives a ratio of between high and low as 1 is to 2.5957. The low-pressure steam cylinder does not operate any valve mechanism. The steam traversing its passage is governed by the movement of a slide valve working on the same stem

which carries the main valve of the high-pressure pump. The low-pressure steam piston and the high-pressure air piston are each attached to the same rod, and move up and down according as the flow of exhaust steam from the high-pressure cylinder enters above or beneath the low-pressure steam piston. The low-pressure steam piston and the high-pressure air piston have no mechanical connection with the valve gear, and consequently have no means of operating it or governing the supply of steam or air. They are simply floating pistons.

Steam, after doing work in the high-pressure cylinder, is expanded into the low-pressure steam cylinder, and, after moving it, is exhausted to the atmosphere. Air entering the low-pressure air cylinder is compressed by its forced entrance into the high-pressure cylinder, and the succeeding stroke of the high-pressure air piston continues the work of compression. The pistons on both sides of the pump have motion at the same time but in opposite directions. When the free air drawn into the low-pressure air cylinder has been compressed one stage by being forced into the high-pressure air cylinder, the resulting pressure in the high-pressure air cylinder is about 40 pounds, and it is against this pressure that the high-pressure air piston constantly operates. This arrangement has the advantage of permitting the air which occupies the clearance spaces in the low-pressure air cylinder to quickly expand to atmospheric pressure on the next stroke, so that free air is drawn into the low-pressure air cylinder more promptly and with less piston movement than would be possible if main reservoir pressure was holding down the receiving valves of the low-pressure air cylinder. A further advantage is secured by this arrangement, and this is that the high-pressure steam and the low-pressure air pistons are always able to make a full stroke, thus causing a complete movement of the valve gear without reference to whether the main reservoir pressure is small or great.

Boyle's Law. The compression of air presents some interesting problems which have been the subject of experiment by some of the most noted men of science. What is known as Boyle's Law states that the pressure of a gas varies inversely as the volume, and *vice versa.* This means that if a vessel full of air, such as the low-pressure cylinder of the cross compound pump, at the ordinary atmospheric pressure of 14.7 pounds per square inch, be compressed to half its volume it will have twice the pressure, or 29.4 pounds, absolute. If it be compressed to a quarter of its volume, the pressure will be four times as great, or 58.8 pounds, absolute. The converse of this holds true, and if air, at a given volume, has a pressure of 120 pounds, as in the main reservoir, be allowed to expand to twice its original volume the pressure will sink to half the amount, or 60 pounds to the square inch. This law is made use of in calculating the rise in pressure due to compression, and also in ascertaining the resulting pressure when a quantity of air under pressure is allowed to expand, as when the air in an auxiliary reservoir and a brake cylinder equalize. The ordinary auxiliary reservoir with air at 70 pounds pressure equalizes with the brake cylinder at about 50 pounds. Up to the point of equalization the pressure in the auxiliary reservoir sinks, and that in the brake cylinder rises. At the point of equalization, where both become the same, any further expansion of the air in either vessel, following Boyle's Law, would reduce the pressure in both. This is why, when the point of equalization has been reached, further brake pipe reduction is of no avail in the practical operation of the brake.

Gay-Lussac's Law. Gay-Lussac's Law, or, as it is sometimes called, Charles' law, states that the pressure of a gas varies as the absolute temperature. This takes into consideration the rise of temperature due to compression, or the loss of temperature due to expansion. The rise of temperature noticed in air when compressed by the pump is due to the work done to the air by forcing it to assume a smaller volume, and the cooling of the air when allowed to expand is due to the consumption of heat by it in the performance of work. Air at the temperature of melting ice, 0° Centigrade, is found to expand 1-273d of its volume for every addition of one degree Centigrade, and when 273° C. have been added the volume of the air would be doubled. The converse of this holds true also, and if from air at a temperature of 0° C. the subtraction of one degree Centigrade be made, it reduces the volume by 1-273d. It is thus manifest that if 273° Centigrade could be abstracted, the gas would shrink to no volume at all. This is the theoretical limit, and minus 273° Centigrade is called the absolute zero of temperatures. This is a degree of cold which has not yet been artificially produced, and even if it were possible

to reach that extreme point of refrigeration, 273° below that of freezing water, the gas experimented with would have become liquid and eventually solid long before this bitterly cold and final point could be reached.

In the case of the cross compound pump which we have been considering, it is probable that if the heat due to compression in one stroke of the large low-pressure air piston was not allowed to rapidly radiate from the walls of the containing vessel, a pressure of about 45½ pounds per square inch would be indicated on the gauge. There is no reason, from a theoretical standpoint, why the heat due to compression should have its escape facilitated, as any increase of temperature raises the pressure, but from a practical standpoint the slight advantage gained by the augmented pressure of the compressed air would be dearly purchased, as the inevitable heating of the pump itself would tend to destroy the lubricant used, and would cause the air cylinder to cut, and the pump eventually to blow through at each stroke and thereby seriously impair its efficiency.

Another well-known result of compressing air is the squeezing out of it the vapor it contains. Atmospheric air at ordinary temperatures contains a certain amount of watery vapor, and when the air is compressed this moisture is deposited in the form of water. The presence of water in any of the reservoirs of the air brake system reduces the volume of the vessel in which it lodges, and, if allowed to accumulate in pockets or bends of pipes, it obstructs the free passage of air, and in cold weather is liable to freeze, with disastrous results.

STREET RAILWAY AIR BRAKE.

The adoption of electric traction in street railway service, and the great advantages of air operated brakes, has led to the combination of the force of electricity and compressed air in the form of the motor-driven air compressor, and this useful machine is what has enabled the practical grafting of the air brake system on electric street railway cars, interurban trolley lines and the electrified portions of steam railroads. There are several types of air brakes for electric service now on the market, and from among them we have selected the air brakes of the General Electric Company, of Schenectady, N. Y., as a typical example. Air brakes may be applied not only to single motor cars but to one or more trailer cars as occasion requires. The whole train brake is operated by the motorman, just as the locomotive engineer controls the air brake on fast passenger trains or on long, heavy freights. Air brakes are now manufactured for all classes of service, whether for single cars, multiple unit trains or for single cars hauling one or more trailers continuously or intermittently. In all cases the brakes are operated by one brake valve in the vestibule of the leading car. The air compressor as used on street railway lines is operated by an electric motor, driven by current taken from the trolley or third rail line. This current is, if one may so phrase it, a branch from the circuit which conveys current to drive the car, but this air compressor circuit is not connected to the motorman's controller and must be turned on or cut off by a separate switch. In this way, as long as the car is connected with the trolley and the switch cut-in, current flows to the motor compressor, and air pressure can be pumped up and maintained whether the cars are in motion, either coasting or electrically propelled, or standing still. In connection with this switch there is a fuse of the enclosed type which protects the compressor motor from an electrical overload. The straight air system used on street railway lines is practically the same in principle as the original straight air brake designed for steam railroads by George Westinghouse. The details differ, as, for example, there being two motormen's brake valves, one on either end of the car, the main reservoir pipe is extended under the car so as to reach both valves, and the brake pipe is also connected to the two brake valves, and the brake cylinder is fed direct from the brake pipe. The main reservoir pipe is always full of compressed air when the main reservoir is full, and the brake pipe is always empty, as is the brake cylinder, except when brakes are applied.

The GE Straight Air Brake. The Straight Air Brake System is the simplest form of power brake. The diagram, Fig. 71, shows how the different parts of this system are connected, and the equipment consists of a Motor Compressor, Suspension Cradle for Compressor, Air Compressor Governor, Combined Switch and Fuse, Motormen's Valves, Removable Handle for Motormen's

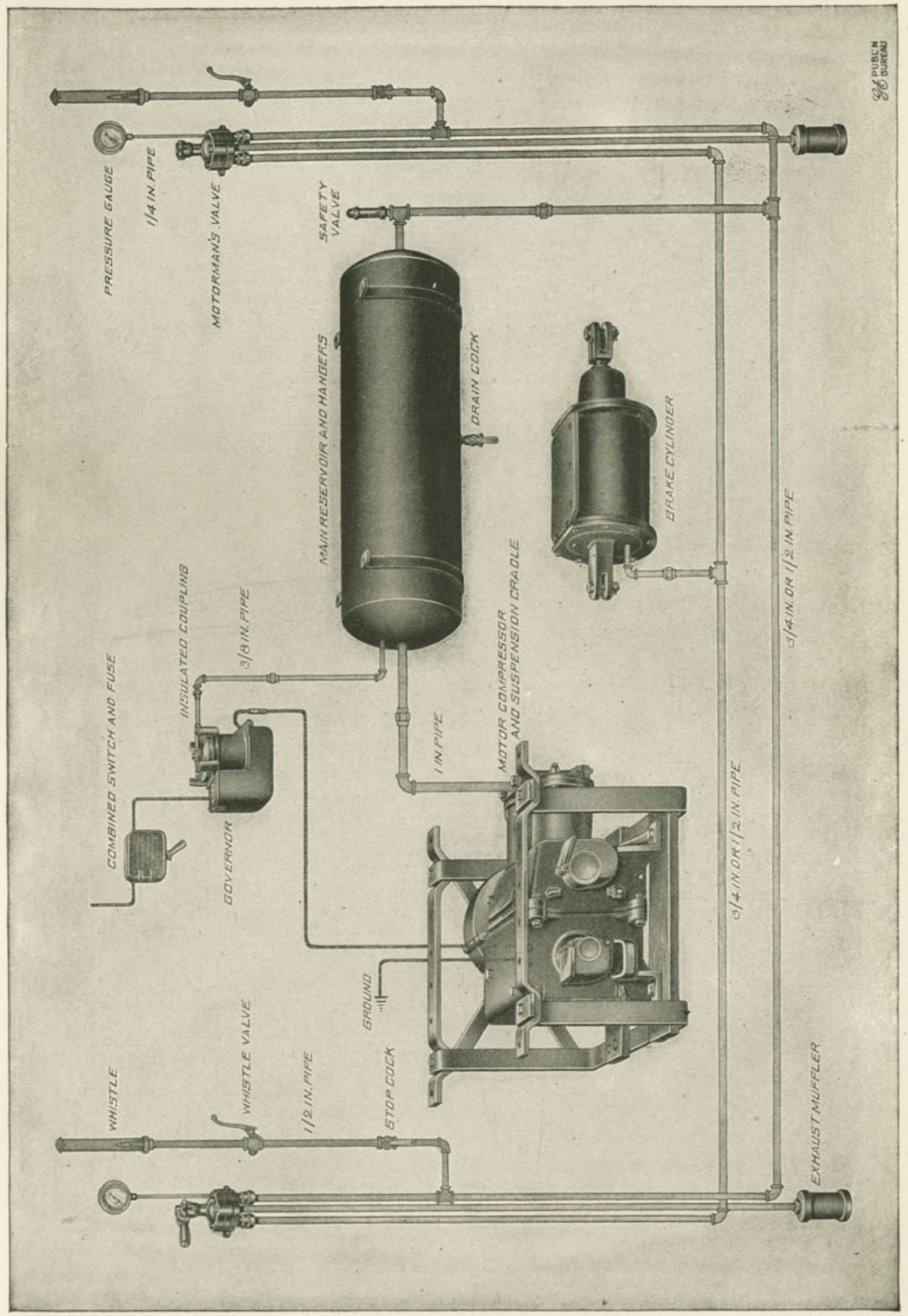


Fig. 71.
General Electric Straight Air Diagram of Brake as Applied to a Motor Car.

Valves, Brake Cylinder, Reservoir with Hangers and Drain Cock, Safety Valve, Pressure Gauges, and Exhaust Mufflers.

Air Compressor. The air compressor is driven by an electric motor connected by means of herring-bone gearing to an air pump. The air pump consists of two cylinders with single-acting pistons connected to a common crank shaft which has its cranks 180° apart, so that one piston is compressing while the other is drawing air into the cylinder. The electric motor is a four pole series-wound machine. The frame is of cast steel, and is made in one piece and provided with a removable head at one end of sufficient size to permit the armature to be drawn out of the field. The pole pieces are bolted to the frame, which forms part of the magnetic circuit. There are only two brush holders, each of which is rigidly secured to, and insulated from, the motor frame. The compressor is bolted to a specially designed cradle which is permanently fixed to the underside of the car. This arrangement facilitates the removal of the compressor when necessary. The air compressor and motor are of the enclosed type, in which all the parts are protected from dust and water, so that no external casing is necessary. Street or interurban cars are usually operated over very dusty roads, and not only is the protection of the working part very necessary, but the air drawn into the compressor has to be freed from dust and grit before entering the pump cylinders. This is done by providing the intake with curled hair strainers which are held in an easily removable casing.

Air Compressor Governor. A section of the air compressor governor is shown in Fig. 72. The movement of the switch is controlled by a small piston rod connected to a diaphragm supported by a coil spring. The upper side of the diaphragm is in a chamber which is piped to the main reservoir. The varying pressure of the air in the reservoir thus actuates a set of operating levers, one of which carries the contact finger, by means of which the motor compressor circuit is made and broken. As the compressor continues to operate, the air pressure is increased in the reservoir, thus raising the pressure in the chamber above the diaphragm, and forcing the piston downward against the action of the operating spring. The operating levers are thus moved and the contacts are separated with a quick snap, thus breaking the electrical circuit and stopping the compressor. As the pressure in the reservoir is reduced, the reverse action takes place and thereby pulls the contact finger upward, quickly closing the circuit. The pressure maintained in the main reservoir is from 60 to 100 pounds to the square inch, and a safety valve set as required is placed on the main reservoir pipe in order to prevent the possibility of higher pressure accumulating. The valve is similar to the ordinary pop safety valve used in steam and air brake practice. It can be readily set for any required pressure by turning the ad-

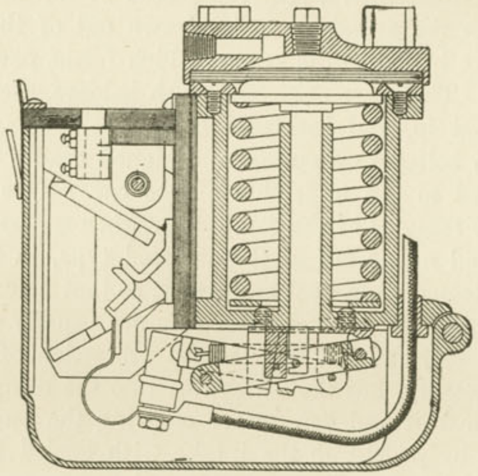


Fig. 72.

SECTION OF G. E. AIR COMPRESSOR GOVERNOR.

justing screw and increasing or lessening the tension of the coil spring above the valve.

Combined Switch and Fuse. A fire-proof combined switch and fuse is placed in the compressor circuit and is capable of opening the circuit positively under all conditions. The current carrying parts are enclosed in moulded insulation, and a powerful magnetic blow-out is provided for extinguishing the arc when the circuit is opened. This combined switch and fuse is illustrated in Fig. 73. This switch cuts in or out the flow of current to the air compressor, and is opened by hand.

The Motorman's Brake Valve. The motorman's brake valve, Fig. 74, is practically the three-way cock of the original Westinghouse brake, but is now designed in order to secure good wearing qualities and to meet the exacting conditions of modern street and interurban traffic. The handle of the motorman's valve is detachable, and can only be applied when the brake is in the lap position. When the handle is removed the stem for operating the valve is protected by a bonnet or casing, so that the valve cannot be operated or tampered with by passengers. The brake valve has three positions, application, lap and release. In the application position air from the main reservoir flows to the brake cylinder. In order to obtain a gradual application of the brakes when slowing up,

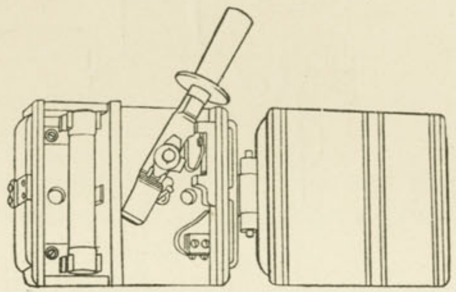


Fig. 73.

COMBINED SWITCH AND FUSE.

or for making a gradual stop, the application position is divided into two parts, namely, the service application position and emergency application position. When the handle is in the service application position a small port admits air from the reservoir to the brake cylinder, and when in the emergency application position, a large port is opened, which admits air from the reservoir to the brake cylinder, applying the brakes almost instantaneously. The lap position blanks the ports in the valve and holds the brakes applied with whatever pressure was introduced into the brake cylinder. This is the position in which the valve remains when the handle has been removed. A second application causes a rise of brake cylinder pressure and a tightening of the brakes.

The release position simply connects the brake cylinder with the atmosphere and cuts off the main reservoir's supply to the brake cylinder. At the end of the exhaust pipe from the motorman's brake valve a muffler is provided in order to deaden the sound of escaping air. This is designed so as not in any way to interfere with the prompt release of the brake, but is simple and effective in eliminating noise.

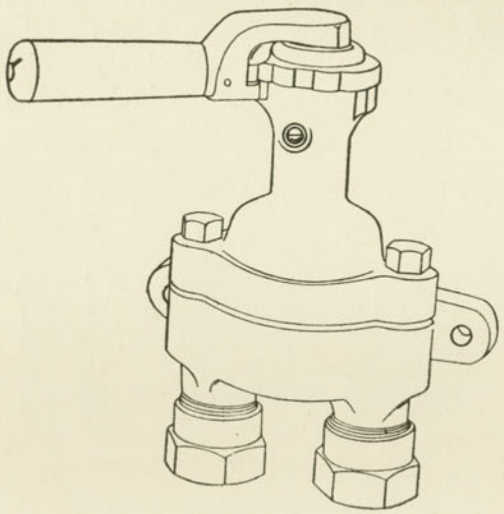


Fig. 74.

General Electric Motorman's Valve.

The motorman's brake valve is made in two styles, one with a rotary valve somewhat similar to the engineers' brake valve used in steam railroad practice, though the three-way cock principle is of course adhered to. The other form of motorman's brake is the one more commonly used, and is called the type S, form C, shown in Fig. 75. This device is made with a slide valve which moves in a straight path across the circular disc in the valve body. This straight slide valve motion is accomplished by providing the stem (moved by the motorman's handle) with a crank and square

socket which fits between two raised projections on the back of the valve. The valve is enclosed in a removable yoke which fits closely at the valve's edges and thus acts as a guide on each side.

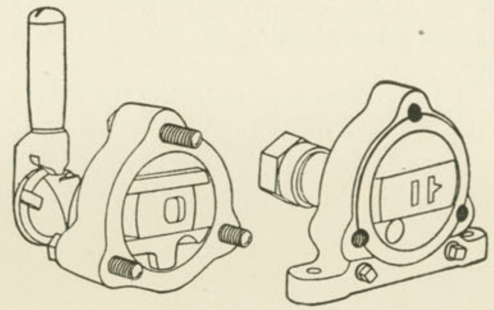


Fig. 75.

General Electric Motorman's Valve Showing Raised Seat.

A style of motorman's brake valve is also made, called type SS. This valve is intended for operating equipments where pneu-

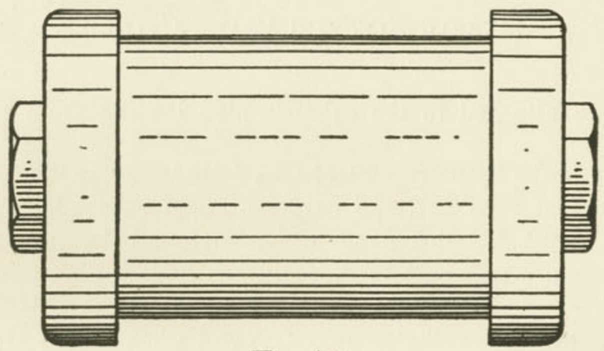


Fig. 76.

Exhaust Muffler.

matic sanders are used. The SS type differs from the others only by the addition of an auxiliary valve set in the stem of the main valve. This auxiliary valve opens or closes a port leading to the sanders. The valve is operated by a press-button attached to the head of the brake valve handle. The button can be touched by the motorman without letting go of the handle, and sand may thus be applied to the rail either when running with brake applied, or the rail can be sanded when starting the car with the brake valve in release position.

Mufflers. The mufflers for deadening the noise of the exhaust, as shown in Fig. 76, are made in the form of an iron cylindrical casting about three inches in diameter by four inches in length, filled with curled hair through which the exhaust air must pass.

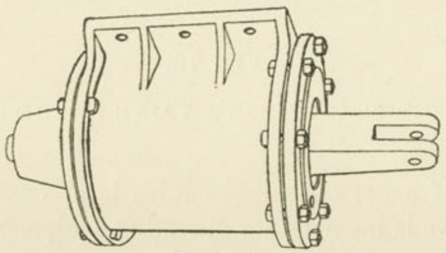


Fig. 77.

General Electric Brake Cylinder.

These are attached to the exhaust pipe leading from the brake valve.

The Brake Cylinder. The brake cylinders, Fig. 77, are of the same general type as those used on steam railroads. They are fitted with tubular piston rods which surround the push rods, and these rods are arranged to move in the hollow piston rods when the brakes are set by hand. This arrangement prevents the movement of the brake cylinder piston, except when brakes are applied by compressed air.

Operating a Trailer. The equipment used with a trailer car, operated in conjunction with the straight air brake, consists of a brake pipe and brake cylinder with hose couplings, angle cocks, etc. Stop cocks are provided to cut out the brake cylinder on the trailer and motor car, so that either car can be braked independently of the other. The hose couplings are provided with check valves, which prevent the escape of air from the main reservoir in case of a break-in-two.

Brake Application. To apply the brakes the motorman's valve handle is moved to the right, permitting air from the reservoir and reservoir line to flow to the train pipe which is directly connected to the brake cylinder. This pressure entering behind the brake cylinder piston causes it to move forward, carrying with it the push rod which is connected to the brake levers, thus causing the brake shoes to be forced against the wheels. The degree to which the brakes are applied depends upon the amount of air that is allowed to pass into the straight air brake pipe, and this is controlled by the motorman's valve.

Brake Release. To release the brakes the handle of the motorman's valve is moved to the left, permitting the air in the brake pipe and brake cylinder to exhaust to atmosphere. It passes through the muffler in transit, deadening the noise of the exhaust.

The Automatic Air Brake. On elevated roads, electrified steam roads and on any service where a number of cars are operated in a train, the automatic air brake equipment is employed. The necessity for the automatic equipment will be appreciated when it is remembered that should a train equipped only with straight air brakes be parted by accident, all the brakes would be inoperative, as the brake pipe would be opened to atmosphere.

With the automatic equipment, both the main reservoir and brake pipe are normally under pressure, and a triple valve is placed between the brake pipe, the brake cylinder and auxiliary reservoir. The function of the triple valve is to connect the brake cylinder to the atmosphere when the brakes are released, and to connect the brake cylinder and auxiliary reservoir when the brakes are applied. The triple valve is actuated by raising or lowering the pressure in the brake pipe, so that to apply the brakes the motorman's valve handle, on being placed in the application position, connects the brake pipe to the atmosphere, thus reducing the pressure in that pipe and thereby reducing the pressure on one side of the triple valve piston. This reduction of pressure causes the triple valve to move the service piston, carrying with it a slide valve which first cuts off communication between the brake cylinder and atmosphere, and then establishes communication between the brake cylinder and auxiliary reservoir, thus applying the brakes as in steam railroad practice. When the motorman's valve handle is moved to the release position, air is admitted to the brake pipe from the main reservoir pipe, charging the former to full pressure. This increase in the brake pipe pressure moves the triple valve to the release position, establishing communication between the brake cylinder and atmosphere, and at the same time permits air to flow from the brake pipe to the auxiliary reservoir, charging it to normal pressure. This action takes place on each car in the train simultaneously, as the brake pipe is connected throughout the train. Should the air brake hose burst or become ruptured, brake pipe pressure would be exhausted to atmosphere, causing an emergency application of the brakes throughout the entire train.

The Emergency Straight Air Brake. When two or more cars are operated with the straight air system, the reservoir pipe line connecting the cars is filled with air at main reservoir pressure, as shown in Fig. 78. In the event of a break-in-two this pipe line when parted would empty the entire reservoir system and prevent the application of brakes. To avoid this contingency, an emergency valve is employed so that the reservoir pressure acts above and below a piston carrying a slide valve, somewhat similar to the plain triple valve used on steam roads. The sectional view of the emergency valve, Fig. 79, shows the normal position of the parts while running, or when service applications of the brakes are being made. A strong spiral spring holds the piston in its upper position, thereby allowing a free flow of air from the reservoir pipe line through the strainer and to the chamber below the piston and past the edges of the piston by grooves in the casing, then through the slide valve chamber and so to the reservoir. In this position of the slide valve, the brake pipe is connected directly to the brake cylinder through the ports shown in the illustration. The slide valve is held firmly against its seat by air pressure, assisted by its spring.

In the event of a break-in-two or other accident to the reservoir pipe line, the piston is forced downward by the unbalanced pressure from the reservoir, and its lower edge is pressed against a leather gasket at the bottom of the cylinder, and an air-tight joint is thus made which cuts off all flow of air to or from the

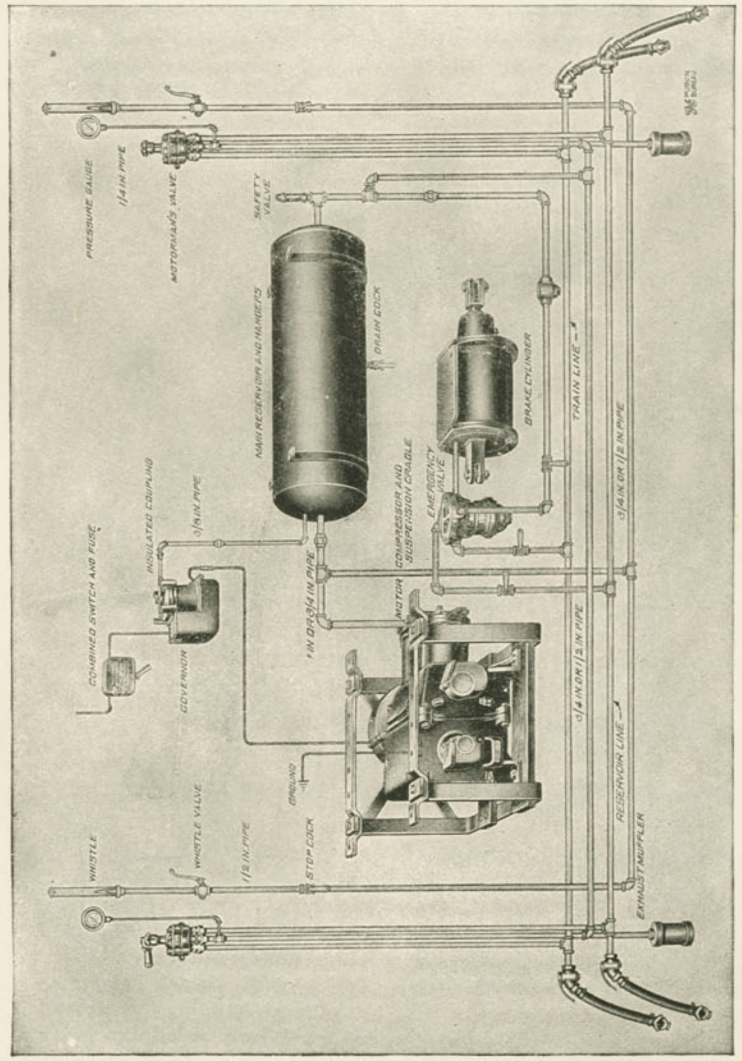


Fig. 78.
Emergency Straight Air Brake Equipment for Motor Cars—Schedule ESM-1.

reservoir pipe line. At the same time the slide valve is moved until the brake pipe port is closed, and all communication with the brake pipe is blocked. The movement of the slide valve opens a passage from the valve chamber to the brake cylinder through the upper port, and a direct connection is made between the reservoir and brake cylinder, thus applying the brake with full force Placing the motorman's valve handle in the emergency position connects the reservoir pipe to the atmosphere, or a break in the

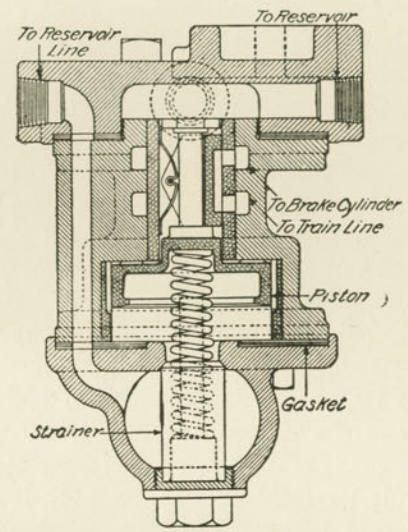


Fig. 79.

Section of Automatic Emergency Valve.

reservoir pipe line will, therefore, at once apply the brakes on all cars.

Release. In order to release the brakes after an emergency application has been made, the reservoir pipe line must be recharged to reservoir pressure. To do this the handle of the motorman's valve is moved to the emergency release position. In this position air flows from the main reservoir on the first car through a small port in the motorman's valve to the reservoir pipe line, and also opens the brake pipe to the atmosphere. The pressures above and below the pistons in all the emergency valves thus become equalized, and the spring moves the pistons and slide valves to their normal positions, and opens the port to the brake pipe, and the air then flows from the brake cylinders to the brake pipe and thence through the motorman's valve to the atmosphere. The reservoir pipe line is like the main artery in the human body. An accident to the pipe would at once bleed the entire system, but the emergency valve may be said to promptly and automatically apply a tourniquet, and not only stop the hemorrhage but turn the flow of air into the brake cylinder and so apply the brake.

Multiple Unit Operation. When one or more motor cars form a train and it is desired to operate the brake from the front of the leading car, the equipment is modified so that not only is there hose connection between the brake pipes of the cars, but additional hose connections are required on the main reservoir pipe lines, as shown in Fig. 80. In this way the main reservoirs under the several cars form a connected series along the same pipe line, and the brake cylinders also form another connected system along the brake pipe line. The various motor compressors, working at the same time, supply the connected reservoirs, and thus each does its share of the work and, although the same pressure is maintained all through the system, a large total volume of compressed air is stored up for the larger consumption of the multiple unit train. The air in the forward main reservoir supplies the brake cylinders of the cars. The main reservoirs on the other cars each supplies air to the reservoir next ahead, as its supply is depleted by the general application of brakes. This is inevitable where auxiliary reservoirs and triple valves are not used. This arrangement is not applicable to long trains, as the brakes on the forward cars would set first, and those behind one after the other. The system, however, works very satisfactorily with short trains.

Automatic Equipment. Long trains on electrically driven railways are equipped with the automatic air brake, similar in a general way to that used on steam railway passenger trains. All cars, whether trailers or motor cars, are equipped with auxiliary reservoirs and triple valves, and the train pipe pressure is constantly maintained. The main reservoirs on all the motor cars are connected together by the "main reservoir line," which is a separate pipe passing under the trailer cars as well as the motor cars. The entire main reservoir capacity of the whole train is used by

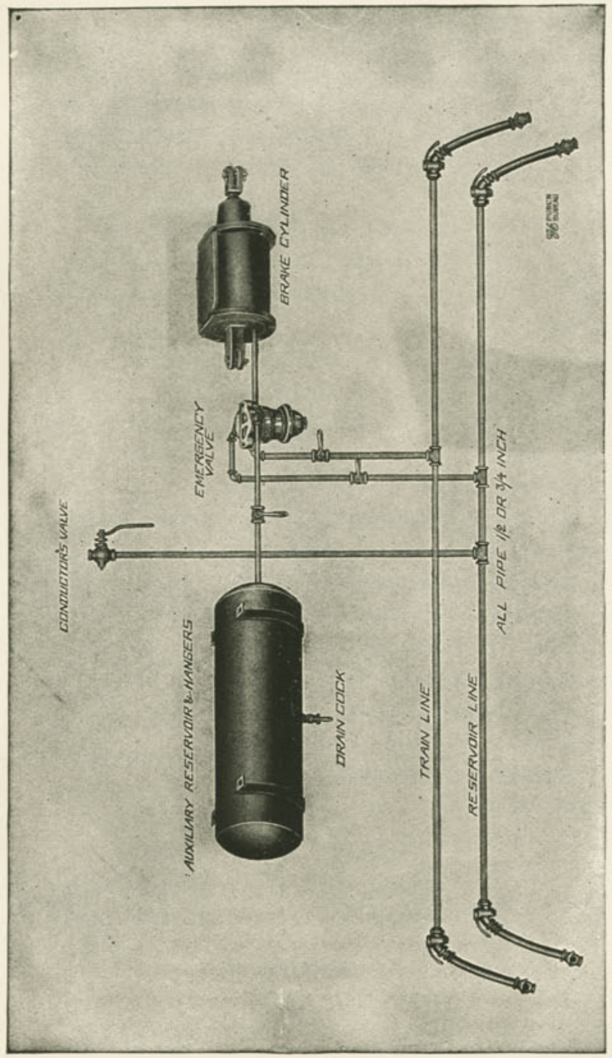


Fig. 80.

Emergency Straight Air Brake Equipment for Trail Cars—Schedule ES-1.

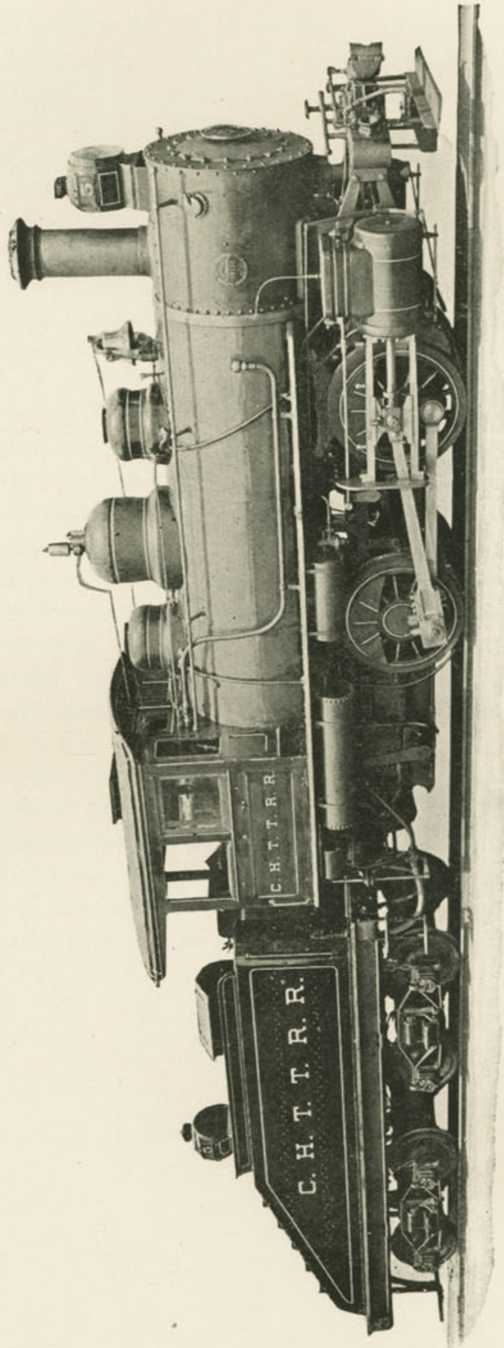
the motorman for all the cars. Each motor car thus resembles a locomotive equipped with the automatic brake, but the supply to the various auxiliary reservoirs comes from the series of main reservoirs and feeds into the brake pipe of the train through the motorman's brake valve which is being operated at the front of the train. With the automatic brake on an electrically operated road, excess pressure is carried in the main reservoirs for the prompt release of brakes. Quick-action triple valves are used, and a break-in-two of the train applies the brake just as it would do on a steam railroad.

The Electric Controller Safety Handle. On most of the electrically operated roads using motor cars, a safety device in connection with the motorman's controller is used. This consists of a knob or button on the top of the handle, and this button must be pressed down before the handle can be moved, and the electric current turned on to the driving motors of the car. The button can be depressed almost by the weight of the hand, the resistance being that of a light coil spring which does not require much muscular exertion to hold it down. Pressure on the knob carries it down about half an inch, and it may rise up as much as three-eighths of an inch without breaking the controller circuit. The object of this device is that in the event of a motorman fainting on duty, or being otherwise suddenly overcome, his failing grasp on the handle will at once take effect by the sudden interruption of the current. At the same time, by a most ingenious contrivance in connection with this safety handle, the air brakes on the train are applied in the emergency, and the train, deprived of the motorman's intelligent care, has its driving power at once cut off, and it promptly receives the maximum braking power of which the automatic system is capable. In case of emergency with imminent danger on the track ahead, the motorman will have done his duty fully by simply taking his hand sharply away from the controller.

The Automatic Stop. On the Boston Elevated, the New York Subway, and on the Chicago Elevated, and the Hudson Tunnels, there is an appliance known as the automatic stop. This consists of a T-headed trip placed outside one of the rails. When an automatic block signal is in the "danger" position, this trip assumes a vertical position, and when the signal is at "clear" the trip is inclined, so as to be out of the way. The cars are equipped with an air pipe, coming down so that the handle of a stop cock or a dummy coupling will be struck by the upright trip in case the car runs past a danger signal. This has the effect of applying the brakes in the emergency. When the signal is at "clear," the handle of the stop cock clears the head of the inclined trip.

If a motorman endeavored to pass a stop signal, the brakes would at once be applied with full force, and in case the controller handle was still kept in the "on" position, the sudden slowing down of the train by the emergency brake action would produce an electric overload on the motor circuit capable of blowing the circuit breakers, and thus automatically cutting off the current.

Safety Features. The electric controller with the safety button, sometimes grimly called the "dead man's handle," is a safety appliance of the greatest importance. The slackening of the nerveless hand of a disabled man, or the prompt release of the knob by a man keenly alert to his duty in the presence of sudden danger, not only cuts off the electric current, but it also powerfully applies the brakes. In the case of the automatic stop, which is another most important safety device, the sudden application of the brake by the trip beside the rail, with current full on, will blow the circuit breakers and cut off the electric current. In the one case, the cutting off of the electric current applied the brake, and in the other case the application of the brake causes the cutting off of the current. In this way the driving force and the stopping power are, as it were, linked closely hand in hand for the noble purpose of guaranteeing safety to the modern traveller, as far as it lies within the ability of the designing, constructing and operating engineer to do it.



FOUR-WHEEL SWITCHING LOCOMOTIVE WITH SEPARATE TENDER—CHICAGO HEIGHTS TERMINAL TRANSFER R. R.
(Baldwin Locomotive Works)

Air Brake Instructions.

[As Adopted by the American Railway Master Mechanics' Association.]

A.—GENERAL INSTRUCTIONS.

1. The following rules and instructions are issued for the government of all employes of this railroad whose duties bring them in contact with the maintenance or operation of the air brake and train air signal. They must be obeyed in all respects, as employes will be held responsible for the observance of same as strictly as for the performance of any other duty.

Every employe whose duties are connected in any way with the operation of the air brake, will be examined from time to time as to his qualifications for such duties by the Inspector of Air Brakes or other person appointed by the proper authority, and a record will be kept of such examination.

A book of information will be issued, in convenient form, giving a complete explanation of such parts of the air brake and train air signal equipment as is deemed necessary for the care and operation of same. Any employe of this railroad whose duties require a knowledge of the operation and maintenance of the air brake and air signal will be furnished with a copy of same upon application at place designated by special notice, and every employe will be held responsible for a full knowledge of his duties in the operation or maintenance of the air brake or signal equipment.

B.—INSTRUCTIONS TO ENGINEMEN.

2. Enginemen when taking charge of locomotives must see that the air brake apparatus on engine and tender is in good

working order, and that the air pump and lubricator work properly; that the devices used for regulating main reservoir and train pipe pressures are adjusted at the authorized amount: that brake valve works properly in all its positions; and that, when brakes are fully applied, with cam type of driver brake, the pistons do not travel less than 2 inches, nor more than $3\frac{1}{2}$ inches, and with other forms, from 4 inches to 6 inches, and that the tender brake piston does not travel less than 6 inches nor more than 9 inches. They must know that the air signal responds by opening hose cock on its train pipe.

Enginemen must report to roundhouse foremen, in writing, at the end of the run, any defects in the air brake or train air signal apparatus.

MAKING UP TRAINS, TESTING BRAKES AT TERMINAL POINTS AND BEFORE STARTING DOWN SUCH GRADES AS MAY BE DESIGNATED BY SPECIAL INSTRUCTIONS.

3. The train pipe under the tender must always be blown out, and maximum pressure obtained in main reservoir before coupling engine to train.

After the train has been charged with air pressure, the engineman shall, at the request of the inspector or trainmen, apply the brakes with full service application and leave them so applied until all brakes operated from the engine have been inspected and the signal given to release. The engineman must then release the brakes and must not leave the station until it has been ascertained that all brakes are released, and he has been informed by the inspector, or trainmen, of the number of brakes in service and their condition. In testing passenger brakes, the American Railway Association code of train air signals for applying or releasing must be used, one of which signals must be given from the discharge valve on rear car.

Following the separation of couplings for local switching, or when engine or train has been parted for any purpose, the above test need not be complied with further than to ascertain, by test, that the rear brakes are responsive to brake valve on engine, and that all brakes have properly released. However, when cars are

added to train, the brakes on such cars must be inspected as in terminal test. When a passenger train back-up hose is to be used to control the train, the brakes must be applied for test with the back-up hose, and released from the brake valve on the locomotive.

4. **Service Application.** In applying the brakes, to study the train on descending grades, or for reducing speed for any purpose, an initial train pile reduction of not less than five pounds must be made. Releasing brakes at low speeds must be performed with great care, dependent upon local conditions.

With freight trains, first allow the slack to run up against the locomotive. Great care must then be taken to apply the brakes with five to nine pounds reduction, according to length of train pipe, and not make a second reduction, until the effect of the first reduction is felt on entire train, in order to prevent shocks which otherwise might be serious. When a freight train must be brought to a full stop, the train brakes must be held applied until stop is made.

In making a service stop with a passenger train, ALWAYS RELEASE THE BRAKES A SHORT DISTANCE BEFORE COMING TO A DEAD STOP, except on heavy grades, to prevent shocks at the instant of stopping. Even on moderate grades it is best to do this, and then, after release, to apply the brakes lightly, to prevent the train starting, so that when ready to start, the release will take place quickly.

5. **Emergency Applications.** The emergency application of the brakes must be used, except in actual emergencies. Under such conditions, the brake valve must be left in emergency position until train has come to a full stop.

ENGINEMAN'S STRAIGHT AIR BRAKE VALVE ON LOCOMOTIVES.

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

b. Always carry an excess pressure of ten pounds, or more, in the main reservoir, as this is necessary to insure a uniformly satisfactory operation.

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

d. The straight air reducing valve should be kept adjusted at forty-five pounds, and the driver and tender brake safety valves at fifty-three pounds.

When a full application of straight air causes either or both safety valves to operate, it indicates that same are out of order, or too high adjustment of the reducing valve, or too low adjustment of the safety valve, or leakage of same. Have them tested and adjusted.

6. **Brakes Applied from an Unknown Cause.** If it is found that the train is dragging as though the brakes were applied, without rapid falling of the train line pointer, the engineman must make an effort to release the brakes, which may be done as follows: First, if train pipe pressure is less than the authorized amount, and the required excess pressure is carried in the main reservoir, move the handle of the brake valve to the full release position for a few seconds, and then return it to the running position; secondly, should the train pipe be fully charged with pressure, apply the brakes with a five or ten pounds reduction, according to the length of the train pipe, and release the brakes in the usual manner. In case the brakes can not be released, the train must be stopped, and the trainmen notified to examine the brakes.

If, however, the brakes go on suddenly with a fall of the train line pointer, it is evidence that (a) a conductor's valve has been opened, (b) a hose has burst or other serious leak has occurred, or (c) the train has parted. In such an event, the locomotive throttle should be closed, and the brake valve handle immediately placed on lap or emergency position, to prevent the escape of air from the main reservoir, and left there until the train has stopped and the brake apparatus has been examined, and the signal to release given.

7. **BRAKING BY HAND.**—NEVER USE THE AIR BRAKE when it is known that the trainmen are operating the brakes of the air brake cars by hand, except in cases of emergency, as there is danger of injury to the trainmen by so doing.

8. **Cutting Out Brakes.** THE DRIVER AND TENDER BRAKES MUST ALWAYS BE USED AUTOMATICALLY AT EVERY APPLICATION OF THE TRAIN BRAKE, unless defective, except upon such grades as shall be designated by special instructions.

When necessary to cut out either driver or tender brake, on account of defects, it shall be done by turning the handle of the four-way cock in the triple valve down to a position midway between a horizontal and a vertical position, first releasing the brake and leaving the bleed cock open. With the special types of triple valve, close the cut-out cock in the branch pipe.

9. **Double Headers.** When two or more locomotives are coupled in the same train, the brakes must be connected through to, and operated from, the head engine. For this purpose a cock is placed in the train pipe, just below the brake valve. Engineman of each locomotive, except the head one, must close this cock and carry the handle of brake valve in running position. He will start his air pump and let it run, as though he were going to use the brake, for the purpose of maintaining air pressure on his locomotive and enabling him to assume charge of the train brakes should occasion require it.

10. **An Extra Air-Brake Hose, Complete,** must always be carried on the locomotive, for repairs in case of burst hose. Upon locomotives having the air signal, a single hose, complete, must also be carried for the same purpose.

C.—INSTRUCTIONS TO TRAINMEN.

11. **Making up Trains and Testing Air Brakes.** When the locomotive has been coupled to the train, or when two sections have been coupled together, the brake and signal couplings must be united, the cocks in the train pipes—both brake and signal—must all be open, except those at the rear end of the last car, which must be closed, and the hose hung up properly in the dummy coupling, when cars are so equipped.

After the train has been charged with air, the engineman must then be requested to apply the brakes. When he has done so, the brakes of each car must be examined to see if they are properly applied. When it is ascertained that each brake is applied, the engineman must be signaled to release the brakes. (In testing passenger brakes, the American Railway Association train air signal whistle code for applying or releasing must be used, one of which signals must be given from the discharge valve on the rear car.) The brakes of each car must then be examined to see that each is released, and the engineman informed as to the number of brakes in service and their condition.

If any defect is discovered it must be remedied and the brakes tested again—the operation being repeated until it is ascertained that everything is right. The conductor and engineman must then be notified that the brakes are all right. Following the separation of couplings for local switching, or when engine or train has been parted for any purpose, the above test need not be complied with other than to ascertain, by test, that the rear brakes are responsive to brake valve on engine and that all brakes have properly released. At points where there are no inspectors, trainmen must carry out these instructions. No passenger train must be started out from an inspection point with the brakes upon any car cut out or in a defective condition, without special orders from the proper officers. The air brakes must not be alone relied upon to control any freight train with a smaller proportion of cars with the air brake in service than provided for by special instructions. When hand brakes are also used they must be applied upon those cars next behind the air-braked cars, except in cases of emergency.

12. **Detaching Loromotive or Cars.** First close the cocks in the train pipes at the point of separation, and then part the couplings, invariably by hand.

13. **Couplings Frozen.** If the couplings are found to be frozen together or covered with an accumulation of ice, the ice must first be removed, and then the couplings thawed out by a torch to prevent injury to the gaskets.

14. **Brakes Sticking.** If brakes are found sticking, the signal "brakes sticking" must be given as hereafter prescribed by the American Railway Association, or by special rules, in which case, if the brakes cannot be released from the locomotive, or if the brakes are applied to detached cars, the release may be effected

by opening the bleed cock in the auxiliary reservoir until the air begins to release through the triple valve, when the reservoir cock must immediately be closed.

15. **Train Breaking into Two of More Parts.** First close the cock in the train pipe at the rear of the first section and signal the engineman to release the brakes. Having coupled to the second section, observe the rule for making up trains—first being sure that the cock in the train pipe at the rear of second section has been closed, if the train has broken into more than two sections. When the engineman has released the brakes on the second section, the same method must be employed with reference to the third section, and so on. When the train has been once more entirely united, the brakes must be inspected on each car to see that all are released before proceeding.

16. **Cutting Out the Brake on a Car.** If, through any defect of the brake apparatus, it becomes necessary to cut out the brake upon any car, it may be done by closing the cock in the cross-over pipe near the center of the car where the quick-action brake is used, or by turning the handle of the cock in the triple valve to a position midway between a horizontal and a vertical, where the plain automatic brake is used, first releasing the brake. With the special types of triple valves, close the cut-out cock in the branch pipe. When the brake has been thus cut out, the cock in the auxiliary reservoir must be opened and left open upon passenger cars, or held open until all the air has escaped from the reservoir upon freight cars. THE BRAKE MUST NEVER BE CUT OUT UPON ANY CAR UNLESS THE APPARATUS IS DEFECTIVE, and when it is necessary to cut out a brake the conductor must notify the engineman and also send in a report stating the reason for so doing.

17. **Conductor's Valve.** Should it become necessary to apply the brakes from the train, it may be done by opening the conductor's valve placed in each car so equipped. THE VALVE MUST BE HELD OPEN UNTIL THE TRAIN COMES TO A FULL STOP, AND THEN MUST BE CLOSED AGAIN.

This method of stopping the train must not be used except in case of emergency.

18. **Burst Hose.** In the event of the bursting of a brake

hose, it must be replaced and the brakes tested before proceeding, provided the train be in a safe place. If it is not, the train pipe cock immediately in front of the burst hose must be closed, and the engineman signaled to release. All the brakes to the rear of the burst hose must then be released by hand, and the train must then proceed to a safe place where the burst hose must be replaced and the brakes again connected and tested, so as to ascertain that the rear brakes are responsive, by test, to the brake valve on engine. One extra air brake hose complete should be carried by all crews, and one extra signal hose complete carried by passenger crews for repairs.

19. **Brakes Not in Use.** When the air brakes are not in use, either upon the road or in switching, the hose must be kept coupled between the cars, or hung up properly to the dummy couplings, when cars are so equipped.

20. **Pressure-Retaining Valve.** When this valve is to be used, the trainmen must, at the top of the grade, test the brakes upon the whole train, and must then pass over the train and turn the handles of the pressure-retaining valves horizontally upon all or a part of the cars, as may be directed. At the foot of the grade, the handles must all be turned downward again. Special instructions will be issued as to the grades upon which these valves are to be used.

21. **Train Air Signal.** In making up trains, all couplings and car discharge valves on the cars must be examined to see if they are tight. Should the car discharge valve upon any car be found to be defective it may be cut out of use upon that car by closing the cock in the branch pipe leading to the valve. The conductor must always be immediately notified when the signal has been cut out upon any car, and he must report the same for repairs.

In using the signal, pull directly down upon the cord during one full second for each intended blast of the signal whistle, and allow three seconds to elapse between the pulls.

22. **Reporting Defects to Inspectors.** Any defects in either the air brake or air signal apparatus discovered must be reported to the inspector at the end of the run; or, if the defect be a serious one in passenger service, it must be reported to the nearest inspector, and it must be remedied before the car is again placed in service.

D.—INSTRUCTIONS TO ENGINE-HOUSE FOREMEN.

23. **General.** It is the duty of the engine-house foreman to see that the air brake and signal equipment is properly inspected upon each locomotive after each run. It must be ascertained that all pipe joints, connections and all other parts of the apparatus are air-tight, duplex gauges tested every thirty days, and that the apparatus is in good working order.

24. **Air Pump.** The air pump must be tested under pressure, and if found to be working imperfectly in any respect, it must be put into thoroughly serviceable condition.

25. **Pump Governor.** The pump governor should cut off the steam supply to the pump when authorized pressure has been obtained.

26. **Brake Valve.** This valve must be kept clean and known to be in working order in all its positions, before the locomotive leaves the engine-house.

27. **Adjustment of Brakes.** The driver brakes must be so adjusted that the piston travel on the cam type will be not less than 2 inches nor more than 3½ inches, and in other forms not less than 4 inches nor more than 6 inches. When the cam brake is used, care must be taken to adjust both cams alike, so that the point of contact of the cams shall be in line with the piston rod. The tender brake must be adjusted by means of the dead truck levers, so that the piston travels not less than six inches when the air brake is applied and the hand brake is released. This adjustment must be made whenever the piston travel is found to exceed nine inches.

28. **Brake Cylinders and Triple Valves.** These must be examined, cleaned and lubricated at least once every six months. A record must be kept of the dates of the last cleaning and lubrication of these parts for each locomotive.

29. **Draining.** The main reservoir, and also the drain cup in the train pipe under the tender, must be drained of any accumulation after each trip. The auxiliary reservoirs and triple

valves must also be drained frequently, and daily in cold weather, and the train pipe under the engine and tender blown out.

30. **Air Signal.** The train air signal apparatus must be examined and tested by suitable appliances from both the head of the engine and the rear of the tender, to know that the whistle responds properly. A pressure gauge must be applied to the air signal pipe once each month, and oftener if found to be necessary, to ascertain that the reducing valve maintains the authorized pressure per square inch in the train signal pipe.

E.—INSTRUCTIONS TO INSPECTORS.

31. **General.** It is the duty of all inspectors to see that the couplings, the pipe joints, the triple valves, the high speed reducing valve, the conductor's valves, the air signal valves, and all other parts of the brake and signal apparatus are in good order, of standard size for the car and free from leaks. For this purpose they must be tested under the full air pressure as used in service. No passenger train must be allowed to leave a terminal station with the brake upon any car cut out, or in a defective condition, without special orders from the proper officer.

If a defect is discovered in the brake apparatus of a freight car, which cannot be held long enough to give time to correct such defect, the brake must be cut out and the car properly carded, to call the attention of the next inspector to the repairs required.

Special rules will specify the smallest proportion of freight cars, with the air brakes in good condition, which may be used in operating the train as an air brake train.

32. **Making up Trains and Testing Brakes.** In making up trains, the couplings must be united and the cocks at the ends of the cars all opened, except at the rear end of the last car, where the cocks must be closed; the inspector must know that the air is passing through the pipes to the rear end, and that the couplings are properly hung up to the dummy couplings, if so equipped. After the train is fully charged, the engineman must be requested to apply the brakes. When the brakes have been applied, they must be examined upon each car to see that they are applied with proper piston travel. This having been ascertained, the inspector must

signal the engineman to release the brakes. (In testing passenger brakes the American Railway Association train air signal whistle code for applying or releasing must be used, one of which signals must be given from the discharge valve on the rear car.) He must then again examine the brakes upon each car to note that all have released. If any defect is discovered, it must be corrected and the testing of the brakes repeated, until they are found to work properly. The inspector must then inform both the engineman and conductor of the number of cars with brakes in good order.

This examination must be repeated if any change is made in the makeup of the train before starting.

HIGH SPEED REDUCING VALVES ON LOCOMOTIVES AND TENDERS must be tested at least once every month, and adjusted to authorized pressure, if necessary, and cleaned and lubricated at least once in three months, and oftener if tests show that same is necessary.

33. **Cleaning Cylinders and Triple Valves.** The brake cylinders and triple valves must be kept clean and free from gum. They must be cleaned and lubricated as often as once in six months upon passenger cars, and once in twelve months upon freight cars. The dates of the last cleaning and lubrication must be marked with white paint on the cylinder or reservoir, in the space left opposite the words:

Cylinder, cleaned and lubricated................

Triple, cleaned and lubricated..................

The triple valves and auxiliary reservoirs must be frequently drained, especially in cold weather, by removing the plug in the bottom of the triple valve and opening the bleed cock in the reservoir.

34. **Graduating Springs.** The graduating springs in the Westinghouse quick-action freight triple valves are .049-inch in diameter, nickeled-steel wire, 16 coils, 2¾ inches free height, 29-64-inch inside diameter, and in passenger .08-inch diameter, nickeled-steel wire, 13¼ coils, 2⅝ inches free height, 29-64 inch inside diameter. The graduating springs used in the Westinghouse plain valve in locomotive service are made of phosphor-

bronze wire, .083-inch in diameter, 12 coils, 2½ inches free height, 25-64-inch inside diameter.

35. **Adjustment of Brakes.** The slack of the brake shoes must be taken up by means of the dead truck levers.

In taking up such slack it must be first ascertained 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 back within one inch of the truck timber or other stop, when the piston of the brake cylinder is fully back at the release position. When under a full application the brake piston travel is found to exceed nine inches upon passenger or freight cars, the brake shoe slack must be taken up and the adjustment so made that the piston shall travel not less than six inches. In taking up the brake shoe slack it must never be taken up by hand brakes. Where automatic slack adjusters are applied to any car, such adjuster must be fully released before the slack is taken up elsewhere.

36. **Braking Power.** Where the cylinder lever has more than one hole at the outer ends, the different holes are for use upon cars of different weights.

It must be carefully ascertained that the rods are connected to the proper holes, so that the correct braking power shall be exerted upon each car.

37. **Repair Parts.** Inspectors must keep constantly on hand for repairs a supply of all parts of the brake and signal equipment that are liable to get out of order.

38. **Hanging up Hose.** Inspectors must see that, when cars are being switched or standing in the yard, the hose is coupled between the cars or properly secured in the dummy couplings, when cars are so equipped.

39. **Responsibility of Inspectors.** Inspectors will be held strictly responsible for the good condition of all the brake and signal apparatus upon cars placed in trains at their stations; they will also make any examination of brake apparatus or repairs to the same which they may be called upon to do by trainmen.

General Questions Regarding the Use of the Air Brake and Train Air Signal.

GENERAL.

(All parties who have to do with the use, adjustment, care or repairs of air brakes should be thoroughly examined on these questions, in addition to the special questions for each class of men following them.)

1. Question. What is an air brake?

Answer. It is a brake applied by compressed air.

2. Q. How is the air compressed?

A. By an air pump on the locomotive.

3. Q. How does the compressed air apply the brakes?

A. It is admitted into a brake cylinder on each car, and it pushes out a piston in that cylinder, which pulls the brake on.

4. Q. How does the piston get back when the brakes are released?

A. There is a spring around the piston rod which is compressed when the brakes are applied, and when the air is allowed to escape to release the brakes, this spring reacts and pushes the piston in again.

5. Q. Where is the compressed air kept ready for use in the automatic air brake?

A. In the main reservoir on the locomotive, in the smaller or auxiliary reservoir on each car, and in the train pipe.

6. Q. Where does the compressed air come from directly that enters into the brake cylinder when the automatic brake is applied?

A. It comes from the auxiliary reservoir on each car in service application, and from the auxiliary reservoir and train pipe in emergency application.

7. Q. How does it get into the auxiliary reservoir?

A. It is furnished from the main reservoir on the locomotive through the train pipe and triple valve when the brakes are released.

8. Q. How is the automatic brake applied and released?

A. The automatic brake is applied by reducing the air pressure in the train pipe below that in the auxiliary reservoir, and is released by raising the train pipe pressure above that remaining in the auxiliary reservoir.

9. Q. Why does the compressed air not enter directly into the brake cylinder from the train pipe?

A. Because the triple valve used with the automatic brake prevents the air from entering directly from the train pipe to the brake cylinder when the pressure in the train pipe is maintained or increased.

10. Q. What other uses has the triple valve?

A. It causes the brake cylinder to be opened to the atmosphere under each car, to release the brakes when the pressure in the train pipe is made greater than that in the auxiliary reservoir, and it opens communication from the train pipe to the auxiliary reservoir by the same movement; when the pressure in the train pipe is reduced, it closes the openings from the train pipe to the auxiliary reservoir and from the brake cylinder to the atmosphere, and then opens the passage between the auxiliary reservoir and the brake cylinder by the same movements, so as to admit the air and apply the brakes.

11. Q. How many forms of triple valves are there in use, and what are they called?

A. Two; the plain triple and the quick-action triple.

12. Q. How can you tell the plain triple from the quick-action triple?

A. The plain triple has a four-way cock in it, with a handle for operating the cock; the quick-action triple has no such cock in it, but there is a plug cock in the cross-over pipe leading from the train pipe to the triple, when the quick-action triple is used.

13. Q. What are these cocks for in both cases?

A. They are to be used to cut out brakes on one car, without interfering with other brakes on the train, if the brake on that car has become disabled.

14. Q. How does the cock handle stand in the plain triple when the pipe is open for automatic action?

A. It stands in a horizontal position.

15. Q. In what position does the same handle stand when the brakes are cut out by closing the cock?

A. It stands at an inclined position midway between horizontal and vertical.

16. Q. How does the handle in the plug cock in the cross-over pipe, used with the quick-action triple, stand for automatic action?

A. It stands with the handle crosswise with the pipe, and the groove in plug lengthwise when cock is open.

17. Q. How does the handle and groove stand when the cock is closed and brake cut out of action?

A. It stands with the handle lengthwise of cross-over pipe, and the groove crosswise when closed.

18. Q. How is the train pipe coupled up between the cars?

A. By means of a rubber hose on each end of the train pipe, fitted with a coupling at the loose end.

19. Q. How is the train pipe closed at the rear end of the train?

A. By closing the cock in the train pipe at the rear end of last car.

20. Q. How many such train pipe cocks are there to a car, on the air brake train pipe and on the air signal train pipe, and why?

A. Two for each pipe on each car, because either end of any car may sometimes be at the rear end of the train.

21. Q. How many kinds of train pipe cocks are there in use at the ends of the cars?

A. Two.

22. Q. Describe each and give the position of the handle and groove for open and closed in each case.

A. The older form of train pipe cock is a straight plug cock in the train pipe, not far from the hose connection; the handle stands crosswise with the pipe when it is open, and lengthwise with the pipe when closed; it is now found principally on the air signal pipe. The other form of train pipe cock now used on the air brake pipe is an angle cock placed at the end of the train pipe and close to the hose. The handle of the angle cock stands lengthwise with the pipe when open, and crosswise with the pipe when closed. The groove is also a guide to tell whether open or closed.

23. Q. What uses have these train pipe cocks besides to close the pipe at the end of the train?

A. They are used to close the train pipe at both sides of any hose coupling which is to be parted, as when the train is cut in two.

24. Q. Why is it necessary to close the train pipe on both sides of the hose coupling before it is parted?

A. To prevent the escape of air from the train pipe, which would apply the brakes.

25. Q. How must the hose coupling be parted when it is necessary to do so, and why?

A. The air brake must first be released on the train from the locomotive, then the adjacent train pipe cocks must both be closed and the coupling must be parted by hand, to prevent the possibility of injury to the rubber gasket in the coupling.

26. Q. Why must the brakes be fully released before uncoupling the hose between the cars?

A. Because if the brakes are applied upon a detached car they cannot be released without bleeding the auxiliary reservoir.

27. Q. In coupling or uncoupling the hose between the cars, what must be done if there is ice on the couplings?

A. The ice must first be removed and the couplings thawed out, so as to prevent injury to the rubber gaskets in uncoupling, and to insure tight joints in coupling the hose.

28. Q. What must be done with a hose coupling which is not coupled up, such as the rear hose of a train, or any loose hose on a car which is standing or running, but not in use?

A. It must be placed in the dummy coupling if provided for in such manner that the flat pad on the dummy will close the opening in the coupling.

29. Q. What pressure should be carried in the train pipe and auxiliary reservoir?

A. The authorized pressure, as per special instructions.

30. Q. Why should the authorized pressure be maintained?

A. Because this pressure is necessary to get the full braking force which each car is capable of using, and, if it be exceeded, there will be danger of sliding the wheels.

31. Q. How much pressure can be obtained in the brake cylinder by the service application of the brakes with seventy pounds pressure in the auxiliary reservoir?

A. About fifty pounds to the square inch, with an 8-inch piston travel.

32. Q. Why can only fifty pounds pressure be obtained under these circumstances?

A. Because the air at seventy pounds pressure in the auxiliary reservoir expands into an additional space when the auxiliary reservoir is opened to the brake cylinder, and when the pressure has become equalized it is thus reduced to fifty pounds.

33. Q. How much must the train pipe pressure be reduced, in order to get fifty pounds pressure in the brake cylinder, in ordinary service?

A. Twenty pounds.

34. Q. Can the brakes be applied so as to get only a portion of this fifty pounds pressure in the brake cylinder, and how?

A. They can be so applied by reducing the train pipe pressure less than twenty pounds.

35. Q. If the train pipe pressure be reduced ten pounds, what will be the pressure in the brake cylinder?

A. About twenty-five pounds.

36. Q. How is this graduated action obtained?

A. By means of the graduating valve in the triple valve.

37. Q. Is it important to keep all the air brake apparatus tight and free from leaks?

A. Yes.

38. Q. Why is this important?

A. In order to get full service from the air brakes, and to prevent the waste of air, and also to prevent the brakes applying automatically by reason of leak in the train pipe.

39. Q. Is it important to know that the train pipe is open throughout the train and closed at the rear end before starting out?

A. Yes, this is very important.

40. Q. Why is this very important?

A. Because if any cock in the train were closed, all the brakes back of the cock which is closed would be prevented from working.

41. Q. How can you ascertain that the train pipe cocks are all open when the train is made up?

A. By testing the brakes; that is, by applying and releasing them, and observing whether they all operate.

42. Q. Do you understand that no excuse will be acceptable for starting out the train without first testing the air brakes?

A. Yes.

43. Q. Why is this rule absolute?

A. Because the safety of passengers and of property depends upon the brakes being properly coupled up and in an operating condition before the train is started.

44. Q. At what other times should the brakes be tested?

A. After every change in the makeup of the train and before starting the train down certain designated grades.

45. Q. From where does the air signal apparatus receive its pressure?

A. From the main air reservoir through the reducing valve.

46. Q. How much air pressure should be carried in the air signal train pipe?

A. The authorized pressure.

47. Q. Is it important that this train pipe and its connection be also kept tight?

A. Yes.

48. Q. After taking up the slack of the brake shoes, how far should the brake piston travel in the cylinders on cars and tenders with a full application of the brake?

A. Not less than six inches, nor more than nine inches.

49. Q. What would happen if the piston traveled less than six inches when brakes are fully applied?

A. A partial application of the brakes might not force the piston beyond the leakage groove in the brake cylinder provided for the escape of small amounts of air.

50. Q. Why should the piston travel not be permitted to exceed nine inches on passenger cars, tenders, or freight cars?

A. Because if it travels further than this when sent out, a little wear of the brake shoes will cause the piston to travel far enough to rest against the back cylinder head when the brakes are applied, and this cylinder head would then take the pressure instead of its being brought upon the brake shoes.

51. Q. How far should the driver brake piston travel with a full application of the brakes and why?

A. Not less than two inches nor more than three and one-half inches for the cam type of brake, and from four to six inches for other forms.

52. Q. If the brakes stick upon any car so that the engineman cannot release them at any time, how should they be released?

A. By opening the release cock in the auxiliary reservoir and holding it open until air begins to escape from the triple valve, and then closing it again.

53. Q. What is the pressure retaining valve, and what is its use?

A. The pressure retaining valve is a small valve placed at the end of a pipe from the triple valve, through which the exhaust takes place from the brake cylinder. It is used to retard the brake release on heavy grades, and holds the brakes partially applied, so as to allow more time for the engineman to recharge the auxiliary reservoir.

54. Q. What precautions are necessary on every train in regard to hose couplings?

A. Every train must carry at least two extra hose and couplings complete, for use in replacing any hose couplings which may fail or become disabled. These extra hose and couplings are to be carried on such part of the train as is required by the rules and regulations.

SPECIAL FOR ENGINEMEN.

55. Q. How should the air pump be started?

A. It should be started slowly, so as to allow the condensation to escape from the steam cylinder and prevent pounding, which is more likely to occur when the air pressure is low.

56. Q. Why should the piston rod on the air pump be kept thoroughly packed?

A. To prevent the waste of air and steam.

57. Q. How should the steam cylinder of the air pump be oiled, and what kind of oil should be used?

A. It should be oiled as little as necessary through a sight-feed lubricator, and cylinder oil should be used.

58. Q. How should the air cylinder of the air pump be oiled? What kind of oil?

A. It should be supplied with valve oil as often as necessary, through a cup provided for that purpose. Also, a well saturated swab should be kept on the piston rod. Lard oil and other animal or vegetable oils should not be used, as their use causes the brake valve and the triple valves to gum up. The oil must never be introduced through the air inlet ports, as this practice would cause the pump valves to gum up.

59. Q. What regulates the train pipe pressure?

A. The train pipe governor, or feed valve, provided for that purpose.

60. Q. Why should the authorized pressure be carried in train pipe?

A. Because this pressure produces the strongest safe pressure of the brake shoes upon the wheels. A higher train pipe pressure is liable to cause the wheels to slide.

61. Q. What does the feed valve attachment on the brake valve accomplish?

A. When properly adjusted it restricts the train pipe pressure to the authorized amount, with the brake valve handle carried in running position.

62. Q. How often should the break valve be thoroughly cleaned and oiled?

A. At least once every two months.

63. Q. If the main valve in the break valve is unseated by dirt or by wear, what may be the result, and what should be done?

A. It may be possible to get the excess pressure; when the brakes have been applied they may keep applying harder until full on, or when they have been applied they may release. The main valve should be thoroughly cleaned, and if worn it should be faced to a seat.

64. Q. If the piston in the brake valve becomes gummed up or corroded from neglect to clean it, what will be the result?

A. It will be necessary to make a large reduction of pressure through the preliminary exhaust port before the brakes will apply at all, and then the brakes will go on too hard and will have to be released.

65. Q. How and why should the train pipe under the tender always be blown out thoroughly before connecting up the train?

A. By opening the angle cock at the rear end of the tender and allowing the air from the main reservoir to blow through. This blows out the oil, water, scale, etc., which may accumulate in the pipe, and which would be blown back into the train pipe and triple valves if not removed before coupling to the train.

66. Q. When the locomotive is coupled to the train, why is it necessary to have excess pressure in the main reservoir?

A. So that the brakes will all be released and the train quickly charged when the engineman's valve is placed in the release position.

67. Q. Why should the driver brakes be operated automatically with the train brake?

A. Because it adds greatly to the breaking force of the train, and the brakes can be applied alike to all the wheels for ordinary stops, and in an emergency the greatest possible breaking force is at once obtained by one movement of the handle.

68. Q. In making a service application of the brakes, how much reduction of the train pipe pressure from seventy pounds does it require to get the brakes full on?

A. About twenty-five pounds reduction.

69. Q. What should the first reduction be in such an application?

A. Not less than five pounds, so as to insure moving the pistons in the brake cylinders past the leakage grooves.

70. Q. What is the result of making a greater reduction of pressure than twenty-five pounds?

A. A waste of air in the train pipe, without getting any more breaking force, and therefore requiring more air to release the brakes.

71. Q. How many applications of the brakes are necessary in making a stop?

A. One or two applications.

72. Q. Why is it dangerous to apply and release the air in the brakes repeatedly in making stops?

A. Because every time the brakes are released the air in the brake cylinders is thrown away, and if it is necessary to apply them again before sufficient time has elapsed to recharge the auxiliary reservoirs the application of the brakes will be weak, and after a few such applications the brakes are almost useless on account of the air having been exhausted from the auxiliary reservoirs.

73. Q. In releasing and recharging the train, how long should the handle of the brake valve be left in the release position?

A. Until the train pipe pressure has risen nearly to authorized pressure.

74. Q. In making service stops with passenger trains, why should you release the brakes just before coming to a full stop?

A. So as to prevent stopping with a lurch; it also requires less time for the full release of the brakes after stopping.

75. Q. In making stops with freight trains, why should the brakes not be released until after the train has come to a full stop?

A. Because long freight trains are apt to be parted by releasing the brakes before rear brakes are fully released.

76. Q. In making service stops, why must the handle of the brake valve not be moved past the position for service application?

A. So as to prevent unnecessary jerks to the train, and the emergency action of the triple valve when not necessary.

77. Q. If you find the train dragging from the failure of the brakes to release, how can you release them?

A. By placing the handle of the brake valve in full release position for a few seconds and returning it to the running position, if the train pipe pressure is not up to the authorized amount; but if maximum pressure is in train pipe, the brakes should be applied with from five to ten pounds reduction, according to the length of train pipe, and released in the usual manner.

78. Q. When the brakes go on suddenly when not operated by the brake valve, and the gauge pointer falls back, what is the cause, and what should you do?

A. Either a hose has burst, or a conductor's valve has been opened, or the train has parted. In any event, the engine throttle should be closed, and the handle of the brake valve should immediately be placed on lap position to prevent escape of air from main reservoir.

79. Q. Are the brakes liable to stick after an emergency application and why?

A. The brakes are harder to release after an emergency application because they are on with full force, and it requires higher pressure than usual in the train pipe to release them again. In this case it is necessary always to have in reserve the excess pressure of the main reservoir to aid in releasing the brakes. With the quick-action triple valve this is especially necessary, because air from the train pipe as well as from the auxiliary reservoir is forced into the brake cylinder when a quick application of the brake is made, thus increasing the pressure in the brake cylinder without the usual reduction of pressure in the auxiliary reservoir, and requiring a correspondingly high pressure in the train pipe afterward to cause the brakes to be released.

80. Q. In using the brakes to steady the train while descending grades, why should the air pump throttle be kept well open?

A. So that the pump may quickly accumulate a full pressure in the main reservoir for use in recharging the train pipe and auxiliary reservoir when the brakes have been released again.

81. Q. In descending a grade, how can you best keep the train under control?

A. First, by commencing the application of the brakes early, so as to prevent too high a speed being reached; secondly, by making an initial reduction that will lightly apply all brakes in the train, and by slowing the train down just before it is necessary to charge the auxiliary reservoir, so as to give time enough to refill same before much speed is again attained.

82. Q. If the train is being drawn by two or more loco-

motives, upon which locomotive should the brakes be controlled, and what must the engineman of the other locomotive do?

A. The brakes must be controlled by the leading locomotive, and the engineman of the following locomotive must close the cock in the train pipe just below the brake valves. The latter must always keep the pump running and in order, and main reservoir charged with pressure, with the brake valve in the running position, so that he may quickly operate the brakes if called upon to do so.

83. Q. If the air signal whistle gives only a weak blast, what is the probable cause?

A. Either the reducing valve is out of order, so that the pressure is considerably less than forty pounds, or the whistle itself is filled with dirt, or not properly adjusted, or the port under the end of the signal valve is partly closed by gum or dirt.

84. Q. If the reducing valve for the air signal is allowed to become clogged up with dirt, what will the result probably be?

A. The signal pipe might get the full main reservoir pressure, and the whistle will blow when the brakes are released.

85. Q. If you discover any defect in the air brake or signal apparatus while on the road, what must be done?

A. If it is something that can not be readily remedied at once, it must be reported to the enginehouse foreman as soon as the run is completed.

86. Q. What is the result if water be allowed to collect in the main reservoir of the brake apparatus?

A. The room taken up by the water reduces the capacity for holding air, and the brakes are more liable to stick. In cold weather also the water may freeze and prevent the brakes from working properly.

SPECIAL FOR ENGINE REPAIRMEN.

87. Q. How often must the air brake and signal apparatus on locomotives be examined?

A. After each trip.

88. Q. Under what pressure must it be examined?

A. Under full pressure.

89. Q. Should the train pipe pressure exceed the maximum, where would you look for the cause of the trouble?

A. In the devices controlling train pipe pressure.

90. Q. How often must the main reservoir and the drain cup under the tender be drained?

A. After each trip.

91. Q. How often must the triple valves and the cylinders of the driver and tender brakes be cleaned and lubricated?

A. They must be thoroughly cleaned and lubricated once every six months. If the driver brake cylinders are so located that they become hot from the boiler, they may require lubrication more frequently.

92. Q. If there are any leaks in the pipe joints or anywhere in the apparatus, what must you do?

A. Repair them before the locomotive goes out.

93. Q. How is the brake shoe slack of the cam driver brake taken up, and what precautions are necessary?

A. By means of the cam screws, and it is necessary to lengthen both alike, so that when the brake is applied the point of contact with the cams will be in a line with the piston rod.

94. Q. How is the brake shoe slack of driver brakes on a locomotive with more than two pairs of driving wheels taken up?

A. By means of a turnbuckle or screw in the connecting rods.

95. Q. How is the slack of the tender brake shoes taken up?

A. By means of the dead truck levers; if they will not take it up enough, it must be taken up in the underneath connection, and then adjusted by the dead lever.

96. Q. How far should the driver brake piston travel in applying the brakes?

A. Not less than two inches, nor more than three and one-half inches with the cam type of brake, and from four to six inches with other forms.

97. Q. What travel of piston should the tender brakes be adjusted for?

A. Not less than two inches, nor more than three and one-half inches with the cam type of brake, and from four to six inches with other forms.

SPECIAL FOR TRAINMEN.

98. Q. How should you proceed to test the air brakes before starting out, after a change in the make-up of a train, or before descending certain specially designed grades?

A. After the train has been fully charged with air, the engineman must be required to apply the brakes; when he has done so the brakes must be examined upon each car to see that the air is applied, and that the piston travel is not less than six nor more than nine inches. The engineman must then be required to release the brakes; after he has done so, each brake must be examined again to see that all are released. The engineman and conductor must then be notified that the brakes are all right, if they are found so. (In testing passenger brakes, the American Railway Association train air signal whistle code for applying or releasing must be used, one of which signals must be given from the discharge valve on the rear car.)

99. Q. In starting out a passenger train from an inspection point, how many cars must have the brakes in service?

A. Every car in the train.

100. Q. When might you cut out a brake upon a passenger car?

A. Never, unless it gets out of order while on the run, in which case it must be reported to the inspector at the end of the run, or upon the first opportunity which may give sufficient time to repair it.

101. Q. If a hose bursts upon the run, what must be done, if the train is in a safe place?

A. The hose must first be replaced by a good one, and the engineman then signaled to release the brakes. The train must not proceed until the brakes have been reconnected and tested upon the train to see that all are working properly.

102. Q. If the train is not in a safe place when the hose bursts, what must be done?

A. The train pipe cock immediately ahead of the burst hose must be closed and the engineman signaled to release the brakes. The brakes at the rear of the burst hose must then be released by bleeding the auxiliary reservoirs, and the train must then proceed to a safe place to replace the hose and connect up the brakes, after which the brakes must be tested.

103. Q. If the train breaks in two, what must be done?

A. The cock in the train pipe at the rear end of the first section must be closed and the engineman signaled to release the brakes. The two parts of the train must then be coupled, the hose connected and the brakes again released by the engineman. When it is ascertained that the brakes are all released, the train may proceed.

104. Q. Explain how the pressure-retaining valves are thrown into action or thrown out of action, and when this must be done.

A. The pressure-retaining valve is thrown into action by turning the handle of the valve to a horizontal position, and it is thrown out of action again by placing this handle in a vertical position pointing downward. This handle should be placed in a horizontal position at the top of a heavy grade, and it should always be returned to a vertical position at the foot of the grade, as otherwise the brakes will drag on any cars which still have the handle of the pressure-retaining valve in the horizontal position.

105. Q. If the brake of any car is found to be defective on the run, how should you proceed to cut it out?

A. By closing the cock in the cross-over pipe of the quick-action brake, or in the triple valve of the plain automatic brake, and then opening the release cock in the auxiliary reservoir upon that car, leaving it open, if a passenger car, or holding it open until all the air has escaped from it, if a freight car.

106. Q. When it is necessary to cut out a defective brake upon a car, why should it always be cut out at the triple valve and never by the train-pipe cock at the end of the car, even if it is the last car of the train?

A. The train pipe should always be open from the locomotive to the rear end of the last car, so that if the train breaks in two the brakes will be automatically applied before the parts of the train have separated sufficiently to permit damage to be done by their coming together again, and so that the brakes may be applied with the conductor's valve upon any car.

107. Q. Should the train pipe burst under any car, what must be done?

A. The train must proceed to the nearest switching point, using the brakes upon the cars ahead of the one with the burst pipe, where the car with the burst pipe must be switched to the rear of the train; the hose must then be coupled up to the rear car and the cock at the rear end of the next to the last car opened, and the cock at the forward end of the last car closed, so that if the train should part between the last two cars he brakes will be applied.

108. Q. What is the conductor's valve, and what is its use?

A. It is a valve at the end of a pipe leading from the train-brake pipe upon each passenger car; it is to be opened from the car in any emergency when it is necessary to stop the train quickly, and only then. When used it should be held open until the train is stopped, and then it should be closed.

109. Q. What is the air signal for, and how is it operated?

A. It is to signal the engineman, in place of the old gong signal, and it is operated by pulling directly downward on the cord for one second and releasing immediately, allowing three full seconds to elapse between pulls.

110. Q. If the discharge valve on the air-signal system is out of order, or leaking, on any car, how can you cut it out?

A. By closing the cock in the branch pipe leading from the train-signal pipe to the discharge valve; to do so the handle of this cock should be placed lengthwise with the pipe.

111. Q. How is the slack taken up so as to secure the proper adjustment of piston travel?

A. By means of the dead-truck lever, and if that is not sufficient, one or more holes must be taken up in the underneath connection and the adjustment then made by the dead-truck lever. Where automatic slack adjusters are applied to any car, such adjuster must be fully released before the slack is taken up elsewhere.

SPECIAL FOR INSPECTORS.

112. Q. Do you understand that no passenger train may be started out with any of the brakes cut out of service?

A. I do.

113. Q. Why is it important that no leaks should exist in the air brake service?

A. Because they would interfere with the proper working of the brakes and might cause serious damage.

114. Q. What must be done with the air brake or air-signal couplings when not united to other couplings on cars equipped with dummy couplings?

A. They must be secured in the dummy couplings so that the face of the dummy coupling will cover the opening of the hose coupling in order to prevent dust and dirt from entering the hose.

115. Q. If the air issues from the exhaust port of the quick-action triple valve when the brakes are off, what is the cause?

A. It is probably due to dirt on the rubber-seated emergency valve.

116. Q. How often must the cylinder and triple valves be examined, cleaned and lubricated?

A. As often as once every six months on passenger cars and once in twelve months on freight cars. The dates of the last cleaning and lubrication must be marked with white paint on the cylinders.

117. Q. What is the difference between the quick-action passenger and freight triple valve?

A. The passenger triple valves have larger ports and slide valves.

118. Q. How may a passenger triple valve be distinguished?

A. By having one exhaust outlet, or suitable lettering designating the class of service.

119. Q. How may a freight triple valve be distinguished?

A. By its two exhaust outlets, one being plugged.

120. Q. When should the graduating spring of the triple valve be replaced with a new one?

A. When it is worn or rusted out, or not of standard size.

121. Q. To what travel of piston must the brakes be adjusted?

A. Not less than six inches, and this adjustment must be made whenever the piston travel is found to exceed nine inches.

122. Q. How is the slack taken up so as to secure this adjustment?

A. By means of the dead-truck lever, and if that is not sufficient, one or more holes must be taken up in the underneath connection and the adjustment then made by the dead-truck lever. Where automatic slack adjusters are applied to any car, such adjuster must be fully released before the slack is taken up elsewhere.

123. Q. What are the different holes in the outer end of the cylinder levers for, and why must the connections be pinned to the proper hole for each car?

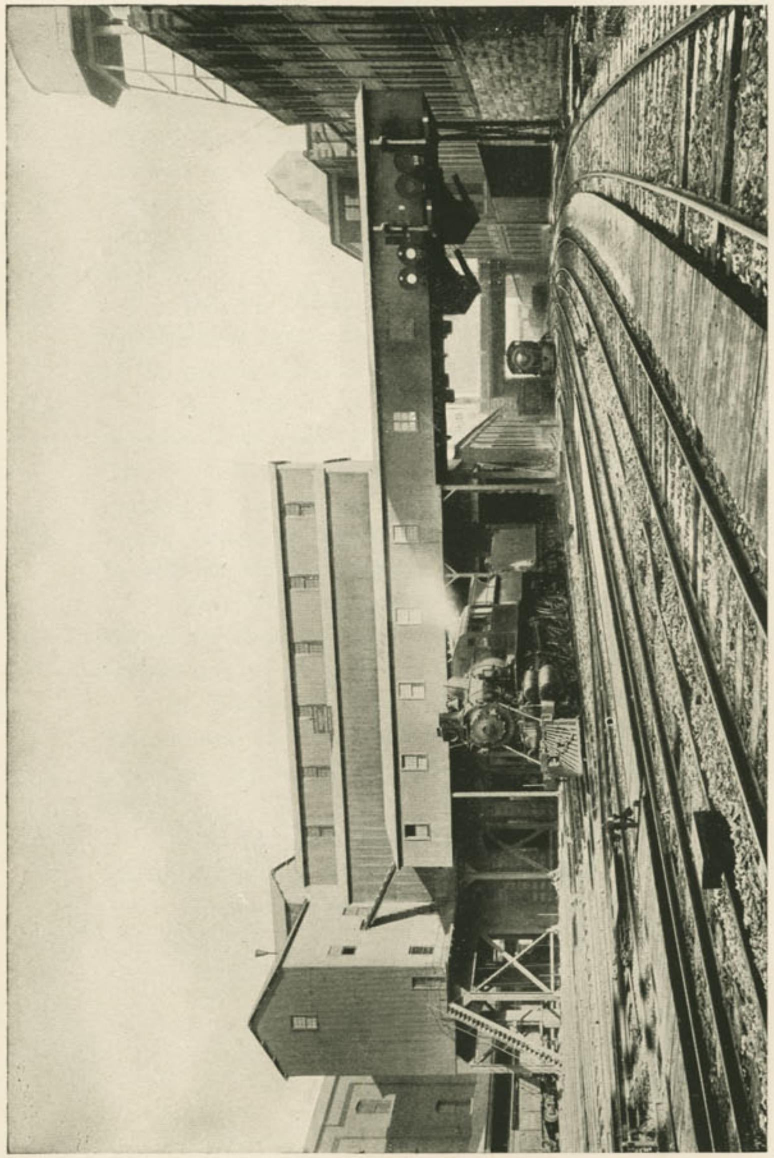
A. These holes are to enable the adjustment of the brake pressure to be made according to the weights of the different cars. The connection must be made to the proper hole in each case, according to the weight of the car, so as to give proper braking power, otherwise the brake will be inefficient, or the wheels may be slid under the cars.

124. Q. How many sizes of high speed brake-reducing valves are there in use, and how will it be known to which size of cylinders they should be connected?

A. There are three sizes, namely, one for 8-inch, one for 10-inch and 12-inch and a third for 14-inch and 16-inch cylinders, and they can be distinguished by the raised figures cast on their body.

125. Q. To what pressure must the high speed brake-reducing valve be adjusted on passenger equipment cars?

A. The authorized pressure.



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Hints on Locomotive Engineering in Catechism Form.

ACCIDENTS ON THE ROAD.

1. What is the first duty of the train crew in case of accident on the road?

A. When the train has been stopped, a flagman should always be sent out to protect the rear of the train, and on a single-track road a flagman should be sent out ahead when necessary, in order to fully protect the train. If the accident occurs on a double-track road, a flagman should be sent out to protect the rear of the train. If both tracks are fouled, a flagman should be sent out in both directions. Flagmen should be sent out regardless of whether the road is block signalled or not. If the accident is serious enough to require considerable time to make temporary repairs, or if outside assistance is required, a message to the train dispatcher should be sent from the nearest telegraph station without loss of time.

2. If a piston-rod breaks, what is the quickest way to effect temporary repairs?

A. The commonest form of piston-rod breakage is through the key-way, and this generally results in the breakage of the front cylinder cover. Disconnect the valve rod, place the valve in its central position, and clamp the valve stem so that the valve cannot move. Remove loose parts of cylinder head or any likely to fall into cylinder. Remove broken rod and piston, and take as much of train as can be pulled. If any part of train is left on the road, a rear flagman must be left to protect it.

3. Broken steam chest or steam chest cover?

A. If the cover or chest is only cracked, it may save time to continue the trip to the nearest station, even if a good deal of steam be lost; but if the break is serious, open smoke-box door, slack the bolts of the branch pipe lower joint and insert a piece of sheet iron in the joint, the flat portion of an old coal scoop will do. If a suitable piece of sheet iron cannot be obtained, take out the ball ring of the joint and insert a piece of board in its place, and tighten down. Disconnect valve rod, clamp valve in its central position, and oil cylinder through indicator plug holes, if there are any, or slack the front cylinder cover and pour in a quantity of oil and tighten up and proceed.

4. Broken valve yoke or stem?

A. Disconnect the valve rod, take up steam chest cover, block valve in central position by pieces of wood cut so as to reach valve from front and back walls of steam chest. If cylinders have been bored for indicator pipes, take out plugs and oil through holes. If not, slack off front cylinder cover and pour a quantity of oil through opening.

5. Broken side rod?

A. Remove broken parts of the rod, and take down corresponding sections on opposite side of engine. Care must be taken when disconnecting engines that have three or more driving wheels on one side to note the position of the knuckle pin in the side rod. The section of a side rod containing a knuckle pin can be left up only if the section ahead of, or back of, the knuckle pin can be left up. For example, if on a 4-6-0 engine where the knuckle pin is back of the main crank pin and the side rod broken in the back section, the side rod could be disconnected at the knuckle pin and the back section taken down on both sides. If the break occurred in the front section, the entire side rod on both sides must be taken down.

If the engine is what is sometimes called "tandem-connected," that is, if the main driving axle does not carry the eccentrics, it follows, as a matter of course, that if the section of the side rod which drives the wheels and axle carrying the eccentrics must be taken down, then the engine is helpless and must be towed in. In such case, both side rods must be taken down, both main rods disconnected, pistons shoved forward and blocked in the guides, allowing the body of the main rod to be connected to the crosshead and carried in the yoke. In blocking the crosshead, care must be taken to see that the crank pins of the forward drivers do not strike the stationary crosshead. Tie cylinder cocks open and close the lubricator.

6. Broken cylinder head?

A. If the front cylinder cover breaks, without flying to pieces, it may be saved by blocking with a heavy piece of wood against the buffer beam and tightening by wedge driven in between buffer beam and block, or tightening up may possibly be effected by the use of a small jack, secured in place with wire. If the head is badly shattered, proceed as directed in answer to question No. 2.

If the back head is broken, but not sufficiently to cause any danger of the guides getting out of line, it is safe to run with main rod up, watching closely for any signs of further breakage. If the back cover is broken so as to have caused damage to the guides, or if continuing to work steam in cylinder is likely to cause damage to the guides, etc., take down main rod, disconnect valve rod, place valve on the center, and clamp valve stem to hold it there.

7. Broken crank pin?

A. If main crank pin is broken, take down the side rods on both sides, and if engine is "tandem-connected," follow the procedure outlined in answer to question No. 5.

If eccentrics are on main axle, with main crank pin broken, take down side rods on both sides, push crosshead ahead and block it in the guides, taking care to see that crank pin of leading driver on the disabled side does not strike the crosshead, and run engine light on good side. If any other crank pin breaks except the main one, proceed as described in answer to question No. 5, and pull part of train.

8. Broken relief valve?

A. Take out the broken valve case, drive a wooden plug tightly in the base of the case to completely block the aperture, and screw the plugged relief valve case back into its place. If thread is stripped, plug the hole in chest with a wooden plug driven in tightly.

9. Broken valve rod gland?

A. If the gland has broken close to one stud, a wide washer slipped over the stud may cover the break and hold the gland tight. If the body of the gland is broken, wind a piece of wire around the barrel of the gland, and use the valve stem clamp which all engines are supposed to carry, having, in this case, bent the beak or part intended for the valve stem key-way, out of the way, or break it off.

If a stud has pulled out, change the studs, and both may hold until you get home. If the good stud will not hold, put it back where it belongs and try a rough bolt, with washers enough to bring pressure from the head on the gland.

10. Piston-rod gland?

A. If a lug has broken near a stud, put a wide washer on and tighten up. If the body of the gland is broken, wrap with wire, put some waste or canvas into the stuffing-box, and put a piece of board, notched on one edge for the piston-rod, over the gland and tighten up. If one stud has pulled out, put the notched board across the gland and tie each end with double strings of bell cord or wire and carried round the front end of the cylinder, and tighten the cords by twisting them. The twisting is accomplished by inserting a bolt or piece of stick between the strings and turning it round several times.

11. Broken crosshead?

A. With four-bar, or with Laird guide bars, push the piston ahead and block the crosshead by putting a piece of wood on the lower guide bar against the crosshead and guide bar block at the yoke and wrapping bell cord around guide and wood, so as to prevent the blocking working out. Disconnect the main rod at the butt end, and allow main rod to rest in yoke, take down strap and brasses, so that end of main rod will not be struck by revolving main crank pin. Disconnect the valve rod, clamp valve in central position, and run engine on one side.

If the guide bars are supported by the yoke at the center, block the crosshead at the back by placing the piece of wood between crosshead and front guide bar block, and wrap with bell cord as before. Clamp valve stem as before with valve in central position, and take down the main rod.

12. Broken crosshead gib?

A. If the engine is running forward the pressure of the crosshead will be against the top guide bar. If the lower gib is broken, take it out and substitute a flat piece of hard wood, well oiled, for the broken gib; cut the wood wide enough to cause the crosshead gib plates to grip it and hold it in place. If the top gib is broken, remove a bottom gib if possible and put it in on top of the crosshead, and the wooden gib below. If the bottom gib cannot be removed, put the wooden one in on top and proceed cautiously, taking care to see that the wooden gib is freely oiled.

If the gibs are held in place by the sides of the crosshead and are without gib plates, it will be necessary to nail or screw small strips of wood across the wooden gib at each end, in order to prevent the gib slipping out endwise. In this case the ends of the wooden gib must be allowed to project far enough to hold the strips. Care must be taken to see that there is sufficient clearance for the wooden gib at each end of the stroke.

13. Broken or bent guide yoke?

A. If this accident interferes with the alignment of the guide bars, the main rod must be taken down and crosshead blocked, as described in answer to question No. 11. The valve must be clamped in central position, and the engine run on one side.

14. Broken eccentric?

A. A broken eccentric disables the motion in so far as that particular eccentric is concerned, and the strap and rod belonging to it must be taken down. If it is the go-ahead eccentric which has failed and the engine is running forward, the back-up strap and rod may be taken down or not, but the valve rod must be disconnected and the valve must be clamped on its center. If cylinder is fitted for an indicator, remove plugs and oil through holes. If not, slack front cylinder cover, oil through opening. If the back-up eccentric is broken when engine is running forward, it is possible sometimes, after taking down strap and rod belonging to the broken eccentric, to drop the reverse lever down to the "corner" and keep it there, working the engine accordingly, with a block of wood in the link slot full length and wired in position to prevent link slipping horizontally on the block, and the bottom end of link secured with wire forward and back to prevent swinging.

15. Broken eccentric strap or rod?

A. If the go-ahead strap or rod breaks when the engine is running forward, proceed as outlined in answer to question No. 14.

16. Broken connecting rod?

A. Remove the broken parts and block the crosshead forward or back, as described in answer to question No. 11. Clamp the valve in its central position.

17. Broken rocker arm or rocker box?

A. If the box is broken, take it down, remove the rocker, valve rod and eccentric rods; treat as a case of one side being disabled and as outlined in answer to question No. 5 or 11.

If direct valve motion is used on the engine, take down transmission bar if eccentric straps and rods are not removed.

18. Broken or sprung link?

A. In case of broken link, take down link, eccentric strap and rods, clamp valve in its central position, and oil as described in answer to question No. 11.

If the link is sprung and if it is of the solid type, proceed as described above, but if the link is made up of four pieces, slack bolts at top and bottom of link and insert a washer or washers, and tighten up so as to widen the link-slot sufficiently to allow the link-block to work freely when link is raised, and proceed with train.

19. Broken link-block or link-block pin?

A. Remove broken parts, and proceed as outlined in answer to question No. 17.

20. Broken saddle pin or link lifter?

A. Remove broken parts. Place reverse lever in the corner. Fit a block of wood between bottom of link-block and bottom of link. Drive block in tightly, so as to completely fill link slot up and down, and wire it in position or clamp it in position with bolt through the wooden block, and with strap on each side of the link. The engine cannot be reversed from the cab in this condition, but may be reversed by removing wooden block, lifting link and putting in wooden block above link-block.

21. Disconnected or broken throttle rod?

A. What appears to be a broken or disconnected throttle rod may be a cocked valve, which will often be brought back to its seat if the rod be tapped. If the throttle be disconnected, so that the valve cannot be closed, reduce steam pressure down to a point where you can handle the train with reverse lever and brake, and take part of train.

If the throttle rod is broken or disconnected, so that the valve cannot be opened, arrange to be towed in without disconnecting any part of the engine.

22. Broken driving axle?

A. If the broken axle is the main driving axle, connecting and side rods on the disabled side must come down. The valve must be clamped in its central position and lubricator on that side closed. It is assumed that the driving wheel is found broken off by fracture of the axle close to the outside of the driving box, so that the wheel has to be thrown down clear of the engine. Jack up the axle on the broken side and slip a piece of wood between the under side of the spring saddle and the top of the frame, in order to take the weight off the broken axle. Take down driving cellar and block between axle and pedestal brace, so as not to carry weight of axle on edges of cellar. Use cellar packing on top of this block. Run engine very cautiously. If other than main axle is broken, block as above, and take down only the side rods on both sides, which should come down (see answer to question No. 5). If the engine has under hung springs, block between frame and top of axle-box. Chain end of equalizer to bottom rail of frame and take down spring under disabled axle.

If the trailing axle is broken, proceed as outlined above. Weight of rear of engine can be partly carried on tender. Jack up rear of engine, and chain a piece of track rail to lower bar of frame by two chains, one near broken axle and one near back of frame, and allowing end of rail to extend out under end-sill of tender, and secure end of rail to end-sill of tender by a chain. In this way the main drivers and front of tender will carry weight of engine, which will thus be taken off broken axle. Remove side rods as outlined in answer to question No. 5, and proceed cautiously with both main driving wheels working.

23. Broken reach-rod?

A. The engine can be run with reach-rod broken and links down so as to give valves full travel. If the engine is running forward and it becomes necessary to back up, lay a bar on top of frames, and, using a pair of small chains, lift the links, and chain the lifting arms up to the bar. In some classes of engines it may be possible to pass the bar over the frames and under the lifting arms. In running forward, if it is desired to "notch" up the links, raise them to the required point and chain lifting arms to bar across frames in the required position, or a pair of blocks may be put in each link-slot above the link-block and wired there, as outlined in answer to question No. 20.

24. Broken reverse lever?

A. Proceed in the manner outlined in answer to question No. 23.

25. Broken pin or bracket at bottom of reverse lever?

A. If the bracket is not broken, insert a temporary bolt in the holes of the bracket and reverse lever. If the bracket is broken so as to let bottom of reverse lever become loose, remove bracket and place bottom of reverse lever where it should be, and block from bottom of reverse lever to back of cab, also block from bottom of reverse lever to front of cab. It is advisable to cut both these pieces of wood a little too long, so as to make them lie at an angle with the cab floor and about a foot or so up at the back and front. By this means they may be securely wedged in position, and with a few blows from a hammer they will hold the bottom of the reverse lever approximately in its proper position.

26. Shackle-bar between engine and tender?

A. Remove broken bar and insert link of heavy chain in the shackle-bar pocket under the foot plate, and drop pin in place through the link of the chain. This will give two free ends of the chain, which should be carried back and secured to the body bolster of the tender. Take up slack if possible in the safety chains and have very little slack in the heavy chain, in order to cause as little jerking as possible when engine starts train. Run cautiously with part of train.

27. Broken shackle-bar pin?

A. Remove broken pin and remove king-pin from nearest flat car; chalk on car so that the loss of the king-pin may be known. Wedge top of borrowed king-pin with wood so that it cannot slip down. Start train carefully and run very cautiously with part of train. Remember, the fireman has to work practically between engine and tender, and good judgment and great care are required in making this repair.

28. Broken engine truck frames?

A. In case of a four-wheel truck where the frame is broken, jack up engine to take weight off the truck, then block on top of the truck equalizers with a couple of short rails, which pass from one side to the other and under the bolster. This will, when the engine is lowered, transfer the weight from the bolster directly to the top of the equalizers, and the engine may then be run carefully and slowly.

29. Broken engine truck bolster?

A. Remove broken bolster and proceed as outlined in answer to question No. 28; chain rails together to prevent their spreading, but with center casting resting on the short cross rails. The truck will not readily curve and great care must be exercised in running the engine. If short rail is not available, it is possible to chain up each end of the truck bolster to the truck plate, or to a rail resting across the truck frames.

30. Broken frame?

A. If the engine frame is broken in front of the main driving axle, disconnect valve rod and clamp valve in its central position. Disconnect main rod at butt end, block crosshead forward, shut off lubricator on disabled side, and bring engine in on one side.

If frame is broken back of main driving axle, take down side rods on both sides, with due reference to the position of the side rod knuckle, leaving up main rods and front section of side rods.

31. Broken engine truck spring hanger?

A. Remove broken hanger, and chain end of spring up to equalizer by small chain, passing round equalizer and under spring.

32. Broken engine truck spring?

A. Jack up engine and place two blocks on top of equalizer, over hanger pins and under engine truck frame. Lower engine and proceed carefully.

33. Broken engine truck axle or wheel?

A. If break in the axle occurs outside the axle box on a four-wheel truck, and is the back pair of the truck, chain axle up at broken end to engine frame, so that axle box and equalizer are supported by chain to engine frame. This will leave good wheel on other side on rail, and if broken end be chained up as high as it will go, the good wheel will be made to hug the rail. Run engine very cautiously. If front axle is broken, turn the truck if possible so broken axle will be at the rear and remove broken axle, chain truck frames and front of equalizer up to engine frame, and proceed with great caution.

34. Broken axle of pony truck?

A. Jack up front of engine and remove truck and block between forward driving boxes and frame, so that front driving springs do not carry any weight; chain front of truck equalizer up so as to keep it out of the way of catching on anything. Proceed cautiously and slowly, as the weight formerly borne by the pony truck now rests on the forward pair of driving wheels.

35. Broken cross equalizer of 2-6-0 or 2-8-0 engine?

A. Jack up engine and block on top of forward driving axle boxes and below frames. Thus take weight off forward driving springs. Place short rail over back end of truck equalizer and on top of engine frames. Chain back end of equalizer to the short rail, and see that rail is secured so it cannot shift off frames. If short rail cannot be had, when engine is jacked up, wedge front of truck equalizer securely between cylinder saddle and equalizer, and chain wooden block or wedge firmly in place. Instead of blocking on top of forward driving boxes, the front ends of both forward driving springs may be chained down to engine frames.

36. Broken driving spring stirrup or saddle?

A. Block axle box on top and below frame, or below spring and on top of frame.

37. Broken spring hanger?

A. Remove broken hanger and chain end of spring to engine frame, and block under end of equalizer thus freed.

38. Broken driving spring?

A. Remove broken spring. Block driving box on top and below frame, and block under end of equalizer thus freed. If underhung spring, remove spring, block on top of box and block end of freed equalizer or under end of adjacent spring.

39. Broken equalizer or post?

A. Block both boxes affected on top and below frame. Take down loose parts and run slowly, as journals are liable to heat.

40. Broken valve seat?

A. In many cases it is possible to work engine even with considerable loss of steam. If the valve seat is broken between the steam port and the outside of the seat, it is then impossible to prevent steam passing into one end of the cylinder. Disconnect main rod and push piston to that end of the cylinder to which the steam leakage would naturally force it. Block crosshead so as to hold piston in that position, place valve so that steam port adjacent to the breakage will be open and the exhaust closed by valve. Block valve in this position. This will keep cylinder full of steam. This can be done by disconnecting valve rod, putting key in valve stem, and cutting a piece of wood to fit between key and gland and securely tieing or wiring wood in place. Shut off lubricator on disabled side of engine and close and disconnect cylinder cocks. If the piston is blocked at the front end, the connecting rod may be left attached to the crosshead and carried in the guide yoke. If the piston must be blocked at the back end, take down connecting rod.

41. Broken lifting shaft?

A. Take down broken shaft, and proceed as in answer to question No. 23.

42. Key loose in frame splice or cylinder saddle?

A. If keys have slacked back, drive them in, and where necessary use a thin liner to secure them temporarily, the object being to insure against danger of bolts shearing.

43. Axle box stuck in jaws?

A. This generally is the result of driving journal becoming hot. The box in expanding holds fast between the shoe and wedge in the pedestal jaws. A good way to get the box loose again is to pull down hard on the wedge by means of the pedestal bolt which passes through the pedestal binder with a nut on the under side. Then run the driving wheel up on a piece of wood or iron laid on the rail, so that it will drive the box up. When the wheel comes off the piece of wood or iron, the box will probably pull the wedge down enough to completely loosen it. If the driving brass is broken and there is danger of further heating, it may be prevented by blocking on top of driving box and below frame, or block on top of frame and under spring saddle to relieve the pressure on the broken brass.

44. Broken grate bar?

A. If a grate bar is broken at one end, it may be possible to raise it up and block it as nearly as possible in place with a piece of iron resting on ash pan. A stone may be used for this purpose. If this cannot be done, clean fire off broken bar as well as possible, and throw in a few fish plates and move them with a poker so as to temporarily cover hole in grate. If grate bar has broken in the center and cannot be raised, the hole may be filled with a few stones or pieces of brick sufficiently to prevent the coal from falling into the ash pan.

45. Broken whistle stem?

A. Bank or deaden fire with fine wet coal, and fill boiler as full as possible, so that as steam blows off there will be enough water over the crown sheet to permit of steam being raised again without the necessity of filling the boiler. When steam pressure has been sufficiently reduced, take out broken whistle stand, and if it screws into dome cover, use any plug which will screw in or an angle cock from a car if it will fit. If the whistle stand bolts to dome-cap with a ball and socket joint, use piece of sheet rubber if convenient and piece of sheet iron in the joint, so as to block the opening and tighten whistle stem down in place. If none of these things can be done, a hard wood plug, driven tightly in and securely wired or clamped down to prevent it starting, may be used, but when running steam pressure should be kept as low as possible.

46. Burst flue?

A. This will probably mean a dead engine in a very short time. Draw the fire, and in very cold weather blow off water through blow-off cock. Take down hose bags and empty tender, and prepare engine to be towed in. It is not necessary to disconnect anything. Take out relief valves on steam chests and oil through openings.

47. Leaky flues?

A. If flues leak badly, bran or sawdust mixed with water in a bucket may be sucked up into injector through overflow. Too much bran will cause the boiler to foam, and when bran or sawdust has been introduced into the boiler it will be necessary to constantly open boiler gage cocks and gage glass drain cock to prevent their clogging, and in order to ascertain actual water level.

48. How can a piston valve be blocked in its central position?

A. A piston valve can be clamped in its central position in a manner similar to that of an ordinary D-slide valve, but in case no clamp is available both the steam chest covers should be removed and the valve placed in its central position, and two pieces of wood cut so that each will bear against the valve and the chest covers when put in position again. If the valve has inside admission it will not be necessary to make the cover joints steam-tight.

49. Guide bars broken?

A. In case the guide bars are broken or damaged in such a way that it is impossible to block the crosshead in them, the piston may be blocked at the back of the cylinder by taking off the front cylinder cover and pushing the piston to the back of the cylinder; hold it there by cutting a piece of board so that it will bear upon the piston and the cover when it is put back in place.

50. Broken smoke box front?

A. Take off broken casting and replace it with a series of boards placed one on top of the other, so that each board touches the one above it. Cut holes in the boards, so that the smoke box studs pass through the boards and tighten up with nuts. The smoke box cannot be made perfectly air-tight in this way, but it will serve as a temporary repair, so that engine may be run.

MISCELLANEOUS.

51. Can cylinder clearance be equalized if one piston-rod is slightly shorter than the other?

A. Yes: For it is known that when the piston is exactly in the center of its stroke the distance from the center of the wrist-pin to the center of the main driving axle is the length of the connecting rod. The length of the connecting rod can be varied by the use of liners at the butt end. The crosshead clearance will not be the same on both sides of the engine, nor will it be the same at each end of the stroke. Care must be taken to see that the piston does not strike the cylinder cover. The difference in the lengths of the two connecting rods will make no practical difference to the engine.

52. Is an engine likely to do itself more damage in slipping at high speed than at low speed?

A. At slow speed, when an engine slips, the revolutions of the driving wheels are more numerous, compared with the distance the engine moves over, than they are when it slips at high speed. At slow speed the driving wheels, so to speak, store up energy, which, when the wheels catch on the rails, is converted into work in the form of a severe jerk to the train or a bent side rod or broken pin. When the slip at high speed is caught by the rails, the number of revolutions not being relatively great, as far as the distance moved over is concerned, there is proportionally less accumulated energy to be transformed into work, and the jerk to the train is less and the danger of damage to the engine itself is less.

53. What causes an engine to slip after steam has been shut off?

A. The expression "slip of driving wheels" is generally taken to mean that the driving wheels are revolving faster than the speed of the engine would cause them to revolve. As a matter of fact, when the throttle has been closed there is nothing to make the wheels move faster than they should if the engine was being towed. The peculiar jarring sensation which usually accompanies this form of slip very closely resembles the effect produced by the slip caused under steam pressure, where the wheels revolve faster than the speed calls for, and one may be mistaken for the other. Bent crank pins or a twisted axle, or engine out of quarter may slightly retard the motion of the wheels when the steam has been shut off, and thus produce a sensation resembling that produced when the wheels spin round ahead of the speed.

54. What may cause the flange of one of the front driving wheels to cut?

A. If the engine has a front truck, the cutting may be caused by the truck center casting not being exactly in the center, or the engine truck spring on the cut flange side of the engine may be weak or partly broken. The truck will, therefore, be down on the defective side and should be levelled up. If the cause is the truck casting not being in the center, the remedy is to bring it to its proper place. The front driving axle may be out of tram with the main driving axle, and this can only be set right by bringing both axles into tram.

55. What is meant by galvanic action in a boiler?

A. Galvanic action is set up when two dissimilar metals are acted on by an acid and one of them is gradually dissolved. In a locomotive boiler a weak galvanic action is set up when certain kinds of impure water are used which contain a trace of acid. The action is made apparent when the iron tubes near the copper ferrules are eaten away. To prevent this action the acid must be neutralized.

56. Do main driving wheel tires wear faster than the others on the same engine?

A. The main driving tires often wear away faster than the others because they are subjected to the pressure of the main rod, which, when the engine is running forward, presses the wheel down against the rail. Sometimes the main driving wheels carry more weight than the other wheels if adjustment has not been accurately made.

57. Is there any particular substance used in making steam pipe joints?

A. The essential in all steam pipe joints is that the surfaces should be thoroughly clean and smooth and fit each other accurately; the tightness of the joint does not depend on the presence of any foreign substance. The joint is usually made with a brass ring, which is flat on the pipe side and concave on the cylinder-saddle side. Such rings are carefully ground on both faces, and a very thin coating of white lead and oil or black varnish may be used before tightening up, but neither is absolutely necessary.

The fit of the ring and the mechanical accuracy of the work is what the efficiency of the joint depends on.

58. What is the cause of occasional leaking of flues?

A. The chief cause of intermittent leaking of flues is rapid changes of temperature in the fire-box, caused, perhaps, by the too frequent opening of the fire door, or the heavy working of the engine and opening the door when steam is shut off, causing unequal contraction of flues and flue sheet.

59. What is the effect of reducing the throw of locomotive eccentrics?

A. Reducing the throw of eccentrics would, other things being equal, reduce valve travel. The throw of an eccentric cannot be altered by changing its position on the axle. If there is a rocker in the valve motion between the eccentric and the valve, the travel of the valve may be altered, independent of the throw of the eccentrics, by making one arm of the rocker longer than the other. Changing the distance between the center of the eccentric and the center of the axle is the only way to alter the throw of an eccentric.

60. How is the dead center found?

A. The way to find the dead center, or point in the stroke where the piston stands still, is to turn the main driving wheel so that the crosshead comes near but not at the end of its stroke, and the crank pin is somewhere above the horizontal center line through the main driving axle. Mark that position by center-punch marks, using a trammel reaching from the wheel to some fixed portion of the engine, such as the guide yoke. Mark the position of the crosshead by scribing a line on it and one of the guide bars. Now move the wheel around until the scribed line on crosshead and guide again coincide. Take the trammel and with one point in the center-punch mark on the yoke mark the tire. Divide the distance equally between the tire punch marks, and when the trammel point comes to this central punch mark, the crank will be on its dead center. Care must be taken in turning the wheel not to turn it back, if one or other point is accidentally overrun. The wheel must be moved so as to always push or pull the crosshead and piston. If the piston be pushed in one case and pulled in the other, any lost motion at the wrist pin or main crank pin will vitiate the result.

61. How can a leak in the dry pipe be distinguished from a leaky throttle?

A. When the throttle leaks, the steam which comes through is usually dry, but that from a leaking dry pipe joint is usually wet, owing to the dry pipe being nearer the water level in the boiler. To test this in the shop, fill the boiler up high enough to completely submerge the dry pipe, but not high enough to reach the throttle. If the dry pipe leaks, water will come through.

62. Is it easier to pull or push a train of given weight?

A. It is easier to pull a train over a portion of road than to push it over the same road. There are two reasons for this. The engine, if backing up when pushing the train, is more likely to slip than when running forward, because there is a tendency in turning the driving wheel by the action of the connecting rods to take some of the weight off the drivers and transfer it to the engine truck, but whether the engine backs or runs forward when pushing the train there is more flange friction caused by pushing a train than when pulling it. This may be illustrated by the behavior of a chain which can be readily pulled along in a straight line, but if pushed, even in an oiled groove, has a tendency to buckle and the links to skew as they rub along the sides of the groove. The cars of a pushed train act in much the same way, and extra flange friction is thereby developed.

63. Can an engine having 20x24-inch cylinder be made to pull a heavier load by having its cylinders changed to 22x28 inches, without altering its weight?

A. Theoretically, the increase of the cylinders, either in diameter or in stroke, or an increase in boiler pressure, will increase the tractive effort of the engine, and, for that matter, a decrease in the diameter of the driving wheels will produce a like result. If an engine has been properly designed in the first place, it is not advisable to do any of these things for the reason that the friction between the driving wheels and the rail must be taken into account. For dry clean rails the co-efficient of friction is about 0.25 of the weight on the drivers. In other words, if an engine has 100,000 pounds weight on its driving wheels, its maximum tractive effort ought not to exceed 25,000 pounds. If it does, the engine is likely to slip. The alteration of its cylinders, therefore, while increasing its calculated tractive effort, might have the practical effect of making the engine less efficient than it was by rendering it unduly slippery. The weight on the drivers is called the adhesive weight, and one-quarter of this is the practical frictional limit which should not be exceeded by the tractive effort.

64. Why is a throttle valve for a locomotive generally made with a double seat?

A. This is done for the purpose of approximately balancing the valve and rendering it easy to work. A throttle valve, as usually designed, has its upper disc a little larger in diameter than the lower one, so that the pressure acting on it, when shut, will tend to keep it shut and so avoid any accidental opening.

65. Why are some throttle valves hollow?

A. The throttle valves of most of the modern types of locomotives are made hollow, so that, whether open or shut, they will always have the metal surrounding the stem, or the inside walls in contact with steam. This is for the purpose of having the valve as hot as the throttle case, and consequently as much expanded as the case. In the older forms of throttle valves, where the top of the upper and the bottom of the lower disc only were in contact with steam when the valve was closed, the stem was comparatively cool and did not expand as much as the case, and there was, therefore, a tendency for the lower disc to be pulled slightly off its seat, which caused the valve to leak.

66. What amount of lead would be good practice for an engine hauling fast passenger trains over a hilly division, engine of the 4-6-0 type, 18x24-inch cylinders, 180 pounds pressure, 66-inch drivers, and adhesive weight about 92,500 pounds; total weight, 122,500 pounds?

A. About one-tenth of an inch lead would be good practice. If the trains pulled were light, the amount of lead might be slightly greater.

67. What would be the correct lead to give a 2-8-0 engine handling heavy freight trains over a fairly hilly division, cylinders 20x24, steam pressure 180 pounds, drivers 50 inches diameter, adhesive weight 111,500 pounds, total weight 129,500 pounds?

A. About one-sixteenth of an inch lead would be good practice.

68. How is the pressure on journals usually calculated?

A. The weight on a journal is usually computed as if it rested on an area made up of the length of the journal, multiplied by its diameter. A standard M. C. B. 3¾x7-inch journal has practically a weight sustaining area of 24.37 square inches, for the actual bearing is only 6½ inches long. If the journal load is 200 pounds per square inch, the journal carries in all 4,874 pounds.

69. What is meant by saying that an engine uses so many pounds of steam per horse power, say 45 pounds?

A. This expression refers to the steam used in producing one horse power. In this case it was the steam from 45 pounds of water, and the steam is here measured by weight and does not refer to pressure; 45 pounds of water turned into steam still weighs 45 pounds.

70. Why does a locomotive with lost motion in its driving boxes pound heavier on the left side than it does on the right side?

A. When the right crank pin leads, as it usually does on engines built in this country, the pull of the piston on the right crank pin on the top half revolution has been forward. While the right piston is traveling forward it is pulling the right driving box against the right front pedestal shoe. When the exhaust takes place and compresson begins just before reaching the forward quarter, the right driving box is pushed against the back shoe. At the same time the left crank pin is on the top quarter and is being pulled forward by the left piston, so that the left driving box is against the front shoe and by leverage, the right driving box is being pushed back and goes back without very heavy jar in any case, as soon as exhaust takes place. By the time steam pressure comes on the right piston on the forward quarter the box is solid on the back shoe. When the left crank pin comes near its forward quarter, the box is being held against the forward shoe by leverage from the right crank pin, in which the right driving box is the fulcrum. When steam is admitted on the left side, it drives the left box back suddenly to the left back shoe. These actions and reactions are repeated on the back quarter on both sides, and if there is any lost motion the left side develops a pound sooner than the right side.

71. Is it safe to run any distance when, by reason of some accident to the valve gear, the steam ports have to be covered?

A. Yes. As no steam or water of condensation enters the cylinder there is nothing to remove the lubricant. A little good oil introduced into the cylinder when the valve was placed in its central position ought to be sufficient for a considerable distance. If valve oil is not available, use black oil.

72. How is a piston-valve packing blow ascertained?

A. Place the engine on top or bottom quarter with reverse lever in the center and cylinder cocks open. In this position the valve has closed off all communication with the cylinder. When steam is admitted to the valve chamber, if the forward cylinder cock emits steam, it shows that the front piston valve packing rings are defective. If steam comes from the rear cylinder cock, the back piston packing rings are defective.

73. How to locate a cylinder packing blow in an engine with piston valves?

A. When testing cylinder packing, place engine so that right main crank pin shall be on the forward top eighth and left main pin will be on back top eighth. If, on opening the throttle, steam escapes from both the cylinder cocks of either side, it generally shows that on the side on which steam appears that piston has defective packing or that cylinder is cut, but it must be remembered that a defective valve bushing or defective piston valve would allow steam to escape in the same way. If, however, that piston valve has been proved all right, the piston packing in the cylinder is not steam-tight.

74. Does a piston-valve engine sound lame with defective packing rings?

A. If the piston valve is of the outside-admission type, the inner rings control the exhaust. Any defect in either of these rings would hasten the release at the defective end, and so cause the engine to sound lame. If the piston valve is of the inside-admission type, the outer rings govern the release, and any defect in either ring would manifest itself in lame beats from the exhaust.

75. What is the matter if a piston valve shows no blow during a standing test, yet blows at a certain point when the engine is working hard and is at slow speed?

A. In making the standing test a good valve will show no blows, as the ports are covered. The appearance of a heavy blow at some point when the engine is working hard, with full travel, indicates that the valve overtravels and passes off the valve seat. A bent lifting arm may cause this.

76. If a locomotive uses 5 pounds of coal per horse power per hour, what is the theoretical efficiency, assuming that a pound of coal contains 14,500 heat units?

A. The total number of heat units is $14{,}500\times5=72{,}500$. One horse power is equivalent to the raising of 33,000 pounds one foot in a minute. In one hour, or 60 minutes, the number of foot pounds would be 1,980,000. This divided by $778.3=2{,}543.9$ heat units per horse power per hour. Now divide that amount by the number of heat units contained in the 5 pounds of coal, viz.: $2{,}543\div72{,}500=0.035$, which is the theoretical efficiency of the engine.

77. What ingredients, and in what proportions, will give good metallic packing for valve stems and piston-rods?

A. The original formula used for U. S. metallic packing was, tin 100 parts, copper 9, antimony 6, total 115 parts. Or, to put it in percentage, tin 87 per cent, copper $7\frac{3}{4}$, and antimony $5\frac{1}{4}$. A reduction of antimony to 3 parts instead of 6 gives a softer alloy, which may be more serviceable under certain conditions. Some roads use a packing made of 80 parts lead, 12 of tin, 3 of phosphor tin, and 5 of antimony; total 100 parts. Others use 74 lead, 17 tin, 3 phosphor tin, and 6 of antimony; total 100.

78. In fastening block and tackle to an engine or car for the purpose of pulling either onto the track, should the three-pulley block or the two-pulley block be attached to the derailed car or engine?

A. The three-pulley block should be attached to the engine or car, as by that means there is one more subdivision of the rope to help increase the effective pull.

79. What is meant by latent heat?

A. Latent heat is the heat which is absorbed in the change of physical state, as when ice becomes water, or when water becomes steam. Latent heat has been defined as potential energy in the form of a change in the internal constitution of a substance produced by the absorption of heat without rise of temperature. Latent heat cannot be recorded by a thermometer. The latent heat of water is 143 thermal units. In other words, to melt one pound of ice a quantity of heat has been absorbed which would be capable of raising a pound of water through 143° F.

The latent heat of steam is 967 thermal units, and in order to convert one pound of water at 212° F. into steam at the same temperature an amount of heat has been absorbed capable of raising 967 pounds of water at 1° F.

80. What is about the proper allowance of oil for a heavy freight engine on through freight and on local freight?

A. Under usual road conditions, one pint of valve oil for 75 miles run and one pint of engine oil for 35 miles.

On local freight, one pint of valve oil for 60 miles and one pint of engine oil for 30 miles. On the basis of so much per 100 miles, the through freight would be $1\frac{1}{3}$ pints valve oil and 3 pints engine oil. Local freight, $1\frac{2}{3}$ pints valve oil and $3\frac{1}{3}$ pints engine oil.

81. What part of an eccentric usually experiences the most wear?

A. Generally the greatest wear is to be found on that part of the eccentric which is farthest from the center, owing to its being the part that pulls or pushes the strap.

82. What is meant by the term single-acting engine?

A. A single-acting engine is one in which steam acts on one and the same side of the piston each stroke. For example, in a vertical engine, if steam always and only acted on the under side of the piston during the up stroke, the engine would be a single-acting engine. Locomotives are not single-acting engines.

83. What is the water brake, which is sometimes spoken of as being applied to a locomotive?

A. The so-called water brake is the name given to the method of retarding the motion of an engine when drifting on long down grades. The arrangement consists of a $\frac{1}{4}$-inch pipe from the boiler in the cab, inserted below the water level and run forward to the exhaust passage in the cylinder saddle. When the engine is drifting forward, the method of retarding the motion is to open the cylinder cocks, place reverse lever in back gear, and then open the valve in the cab on the $\frac{1}{4}$-inch pipe. This allows a small stream of hot water to flow into the exhaust cavity below the cylinder saddle. A certain amount of this water is drawn into each cylinder at each stroke, and its stored up heat is sufficient to turn most of it into steam which lubricates the piston, and the pressure produced by compression is sufficient to apply a slight but constant check to the speed of the engine. The steam and water are blown out of the cylinder cocks at each stroke. There is no danger of the pressure becoming too great, as only a small quantity of water is drawn in by the pistons at each stroke and all is driven out on the return stroke. The proper name for it is the Le Chatelier back-pressure brake.

84. What is meant by the expression "water-bottom," as appplied to a locomotive tender?

A. A tank having what is called a water-bottom is one in which that portion which contains the water extends under and at the back of the fuel. The water-bottom is the flat extension, perhaps 12 or 18 inches deep, which forms the floor on which the fireman shovels the coal. In this kind of tank there is usually no water space at the sides of the fuel, as there is in the ordinary U-shaped tank.

85. When a steam engine indicator is not available, how can one find the mean effective pressure in a cylinder?

A. When the cut-off is known it is possible to get a good approximation of the mean effective pressure by multiplying the boiler pressure by the decimal fraction corresponding to the point of cut-off, as given in the following table:

For $\frac{1}{4}$	cut off,	multiply	by	0.597
" $\frac{1}{3}$	"	"	"	0.670
" $\frac{3}{8}$	"	"	"	0.743
" $\frac{1}{2}$	"	"	"	0.847
" $\frac{5}{8}$	"	"	"	0.917
" $\frac{2}{3}$	"	"	"	0.937
" $\frac{3}{4}$	"	"	"	0.966
" $\frac{7}{8}$	"	"	"	0.992

86. Should a compound engine be run as a simple or as a compound engine when drifting?

A. When drifting it is good practice to run the engine as a compound, with just throttle opening sufficient to overcome any excessive pounding due to the weight of the heavy low-pressure piston, often noticeable in a cross-compound. The effect of using very light throttle under these circumstances keeps up a pressure in the cylinders sufficient to prevent the smoke box gases from entering, and it helps to lubricate the cylinder. The reverse lever should not be put down to the corner. With the throttle slightly open it would be wasteful of steam to drop the reverse lever down to the corner, as the valves would then have full travel at increased speed. The object is to reduce the tendency to pound and preserve the lubricant in the cylinder.

87. What is the mean effective pressure in the cylinder?

A. This expression simply means average steam pressure during the stroke. In computing it from an indicator card it it usual to measure from the back-pressure line to the steam line, at intervals representing one inch of stroke, and set down the pressure for each inch of stroke. Taking the average of these gives the mean effective pressure for that stroke. The arbitrary rule adopted by the American Railway Master Mechanics' Association for estimating the M.E.P. in the cylinders for use in calculating locomotive tractive power at full stroke is 85 per cent of the boiler pressure.

88. What is good practice in the matter of side play between hubs and boxes of the driving wheels of a 2-6-0 engine?

A. Good practice would be to allow $\frac{3}{32}$ inch for cast iron driving wheels and $\frac{1}{8}$ inch if the hubs are babbitted. This is satisfactory if the main driving wheel tires are without flanges. The pony truck wheels should have from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch.

89. What is the amount of shrinkage which should be allowed for a locomotive driving tire on a cast iron wheel center?

A. The old rule for the smaller sized wheels, such as 28-inch, was $\frac{1}{100}$ inch for every foot of diameter. This is equivalent to a $\frac{1}{1200}$ of the diameter in inches as the shrinkage allowance. This allowance is not strictly followed for larger wheels. Some shops allow $\frac{1}{1000}$ of the diameter in inches for tires 56 to 78 inches where cast iron centers are used. For 78-inch tires on steel centers, particularly if the runs are not heavy, an allowance of $\frac{1}{900}$ of the diameter in inches is the rule followed.

90. What is the pressure shown on a steam gage?

A. A steam gage, such as is used on any ordinary boiler or locomotive engine, shows the pressure in pounds per square inch above that of the atmosphere. Atmospheric pressure at the sea level is 14.7 pounds per square inch. Absolute pressure is that above vacuum. Thus 100 pounds gage pressure equals 114.7 pounds absolute.

91. What effect has short valve travel as compared with long travel, cylinders being the same for each?

A. The valve with the short travel will move slower than the one with long travel, and will open the steam ports to a less amount, and will close more slowly but earlier than the longer travel valve.

92. Does long valve travel tend to retard or accelerate the speed of an engine?

A. It tends to accelerate the speed by giving freer entrance and exit to the steam.

93. When does compression begin in a cylinder?

A. Compression begins when the valve shuts off the flow of exhaust steam. This position of the valve is called the point of compression or point of exhaust closure.

94. What physical changes does water undergo in its change to ice and to steam?

A. Water freezes at 32° F. It contracts as the temperature decreases until it reaches 39.2° F, which is called the point of maximum density. As the temperature continues to sink below that point, water expands at the same rate as it contracted when above that temperature. When it turns to ice it expands about one-eleventh of its volume. This is why pipes are burst when ice is formed in them, and it is also the reason why ice floats in water. Water boils at 212° F. at the sea level under an atmospheric pressure of 14.7 pounds per square inch. The boiling point falls as the pressure decreases and rises as it increases. Under a pressure of only 10 pounds, water boils at 193.2° F. Under a gage pressure of 100 pounds, water boils at 337.5° F.

95. Is there a simple and practical way of getting the angular advance of the eccentrics of a locomotive?

A. Place the driving wheels on a track having a good plank floor between the rails. Set the right crank pin, for example, on the extreme forward quarter. The lap and lead of the valve are known, and suppose, when added together, that they equal one inch. The arms of the rocker are supposed to be of equal length. Hang a string having a pointed plumb bob at each end over the axle, and so lay it off on the floor. Place the go-ahead eccentric with the "bulge" uppermost. The exact position can be found by hanging the string over the eccentric and moving the eccentric until the plumb bob points are equal distances outside the lines representing the axle. Move the eccentric round toward the crank pin until the point of the plumb bob adjacent to the pin has moved one inch along the floor. The eccentric then has an angular advance equivalent to the linear advance of the valve. If the engine has indirect motion, this eccentric follows the crank pin and this position is correct. When settng the back-up eccentric, place it temporarily with the bulge hanging down, and move it toward the crank pin so that the plumb bob points move one inch over the floor. If the motion is direct, the same procedure should be followed, only the eccentrics should be reversed in vertical position and should be moved away from the pin in each case. Indirect motion using a rocker with both arms the same length, and both arms above or below the rocker shaft, will not make any difference in this method of finding the position of the eccentrics.

96. Does a locomotive slide valve travel faster or slower when the links are hooked up?

A. When the links are hooked up the valve travels slower, because its travel is shorter than when in full gear, and, as it only makes one excursion to and fro for every revolution of the wheel, it is moved more slowly when it has a shorter distance to cover.

97. In calculating the tractive power of a locomotive, is any allowance made for the internal friction of the engine itself?

A. The formula by which the tractive effort is calculated does not allow for the friction of the engine.

98. If the tractice power formula does not take into account any friction, what amount should be allowed?

A. Ten per cent of the power was formerly allowed for locomotive friction, but this is too low according to tests made at Purdue University with a Schenectady locomotive. In those tests the friction of the locomotive itself used up from 12 to 23 per cent of the power developed.

99. What is a 1° railroad curve?

A. A railroad curve is measured and spoken of as the segment of a circle. A 1° curve is a curve in which 100 feet is the distance which subtends an angle of 1 degree. In a 2° curve a chord of 100 feet subtends an angle of 2° at the center of the circle. In a 3° curve 100 feet subtends an angle of 3°, and so on for all degrees of curvature. A 1° curve, therefore, has a radius of 5,730 feet. A 2° curve has a radius of 2,865 feet. A 10° curve has a radius of 573 feet.

100. What are easement curves?

A. A railroad curve is dealt with as a segment of a circle, and straight track between curves is spoken of as a tangent. As a matter of fact, where straight track joins a curve, say, for example, where a tangent touches a 3° curve, the sudden change in direction would be too great for anything but low speeds, and the necessary rail elevation could not be properly attained at the exact point where curvature began; therefore, between the tangent and the curve proper there is introduced a curve of greater radius than the 3° curve, as the easement curve. It might be, in this case, a short 1° curve, so that the train would pass over the tangent, then over the short 1° curve with a gradual rise of the outer rail, and finally reach the 3° curve. It would pass off the 3° curve on to the short 1° curve and on to the tangent at the other end. In this case the short 1° curves would be called easement curves.

101. What is the difference between temperature and heat?

A. This can be best explained by stating the way in which heat and temperature are measured. Temperature is measured or recorded on a thermometer and is expressed as so many degrees, Fahrenheit or Centigrade, according to the thermometer used. Heat is measured in thermal units. One British thermal unit (B.T.U.) is the quantity of heat required to raise one pound of pure water (H_2O) from 39° to 40° F.

102. When steam is blown off a locomotive boiler, why does the water level sink?

A. Water in a boiler with a steam pressure of 200 pounds absolute is at a temperature of 381.7° F. As the pressure falls, by reason of steam being blown off, a portion of the heat stored up in the water is liberated and it turns some of the water into steam. At 100 pounds absolute pressure the water is at a temperature of 327.9° F. As the pressure goes down, the heat in the water has been turning more of it into steam, which is, of course, blown off, and when the pressure has been reduced to zero on the gage, or 14.7 pounds absolute, which is the pressure of one atmosphere, the water is reduced to a temperature of 212° F, and no more water turns to steam except by cooling and evaporation below the pressure of one atmosphere. When the operation of blowing off a boiler is begun, the injector should be put on for the double purpose of securing a high water level, so that the crown sheet will not be uncovered when all the steam has been blown off; and also for the purpose of reducing the temperature of the water by the addition of comparatively cool feed water, and so hastening the operation of blowing off.

103. What is the function of a by-pass valve on locomotive cylinders?

A. The function of a by-pass valve is to prevent back pressure, caused by the churning of air in the cylinders when the locomotive is drifting. The by-pass valves are made so that when steam is admitted to the cylinders the passage between the ends of the cylinder is tightly closed by the steam pressure causing the by-pass valves to shut, but when the engine is drifting they open and allow air to pass out from one side of the piston through the by-pass passage to the other side of the piston on one stroke and vice versa on the next. Air thus moves from before the piston and comes round behind it each stroke.

104. What is meant by the term cylinder clearance?

A. Cylinder clearance, as used in calculations concerning the efficiency of an engine, is the space between the piston, when at the end of its stroke, and the valve face. This is the volume made up of the space between the piston and the cylinder cover, and the steam passage between cylinder and valve face.

105. What is the difference between back pressure and compression?

A. Back pressure is the pressure of steam which resists the return of the piston on the side from which the steam is exhausting while the exhaust port is open. Compression is pressure caused by the squeezing of the exhaust steam remaining in the cylinder after the valve has closed the exhaust or outflow, prior to opening for the admission of live steam. Any excess of compression over and above what is needed for the best conditions of operation is also called back pressure.

106. What is the object of the crown sheet sloping toward the back, which may be seen in some engines?

A. When the engine is on a down grade, a sloping crown sheet tends to maintain a more even water level over it than if it were horizontal. The slope prevents the tendency to uncover the back of the crown sheet.

107. What are the essential qualities of good valve oil?

A. Valve oil, as supplied by the Galena Signal Oil Company, is made from a refined product of petroleum mixed with some good animal oils. The ingredients are selected with a view of making a compound to stand high temperature and yet retain its lubricating quality, and, at the same time, contain nothing which would cause corrosion.

108. What is Galena engine oil made from?

A. It is made from Franklin crude oil, which is a natural product of high lubricating quality. This is mixed with whale oil and red lead in certain proportions. These are combined in such a way that the red lead is held in solution in the oil and is thus capable of being carried to a journal by waste packing, and it tends to fill up the minute spaces on the surface of a journal bearing.

109. How should a two-cylinder compound be counterbalanced?

A. Each side should be balanced for itself alone, as a two-cylinder or cross-compound locomotive is really two engines, and the source of steam supply for either cylinder has nothing to do with the counterbalance.

110. Why does an engine equipped with piston valves often pound very noticeably when drifting?

A. When the engine is drifting the valve is moving as it does when steam is being used, and, where by-pass valves are not used, air is being pushed out into the exhaust. When the valve reverses its motion there comes a time when the valve completely closes the port through which the air is passing to the exhaust. This corresponds to the point of exhaust closure when steam is being used. With an ordinary D-slide valve, when drifting, the air can raise the valve off its seat, but with a piston valve the valve cannot lift and the sudden stoppage in the flow of air causes a slight amount of compression, and this is sufficient to take up the lost motion in the boxes or in either end of the main rod. The nearer the reverse lever is to the corner, the less will be the pound as the exhaust closure is late and the piston is near the end of its stroke, and consequently not moving as fast as when the exhaust closure takes place early, and there is less air compressed and the pound is less.

111. If the side rods of a 2-6-0 engine are in tram, is there any provision to enable the rod to lengthen when the main driving wheel drops down on low joint on the back?

A. There is no provision for the alteration in the length of the side rod in this case, except the usual amount of slackness in the fit of the side rod bearings, which is probably $\frac{1}{32}$ inch scant. When the main wheel comes down a low joint and the leading and trailing drivers are on slightly higher track, each of the sections of the side rods lie along the hypotenuse of a right-angled triangle,

whose base is along the straight line joining the leading and trailing crank pins. With rods perhaps 7 feet long, and main driver say $\frac{1}{4}$ inch lower than the others, the change in the length of the side rods would be so small that it may be safely disregarded. If an engine were fitted up so snug that it could not "give" slightly in various ways, it would run too hot to be of service on the road.

112. Why does air become hot when it is compressed and cool when it expands?

A. Air becomes hot when it is compressed because mechanical work is done upon it during the process of compression, as lead or any other substance becomes hot when it is hammered. This becomes apparent in the rise of temperature, just as a chip of steel heats when being cut off in a lathe. If a given volume of air be compressed to half its original volume without heating, if such a thing were possible, its pressure would be doubled, but in practice the pressure would be somewhat increased because the inevitable heating of the air tends to make it expand. Air in common with other gases expands $\frac{1}{490}$ of its volume for every increase of 1° F (it expands $\frac{1}{273}$ of its volume for each degree Centigrade). If air be heated by compression and allowed to cool and then expanded, it will draw heat from the walls of the containing vessel equal in amount to that which was caused by reason of its compression.

If a gas expands $\frac{1}{490}$ of its volume for each rise of 1° F, and shrinks by the same amount for every 1° F abstracted from it, then, theoretically, if a gas was cooled down through 490° F it would have no volume. This theoretical point, minus 490° F, is called the absolute zero of temperature. As a matter of fact, no gas can be made to lose its entire volume in this way, because before it reached so low a temperature some physical change would intervene. It would become liquid or otherwise depart from the theoretical rate of contraction.

113. Does turning off the outside of an eccentric alter its throw?

A. Turning off the outside edge of an eccentric, that is, the part which is enclosed in the strap, does not alter the throw of the eccentric. The throw of an eccentric is determined by the distance which the center of the eccentric is from the center of the axle, and, if a certain amount be taken off the "bulge" of an eccentric, an equal amount will be taken off the back; and, though the eccentric may be made smaller, its throw is not altered.

114. What is the angularity of the connecting rod?

A. The term "angularity," as applied to the connecting rod, can best be explained by following the crank pin through one revolution. When the crank pin is on the forward quarter the piston is at the forward end of the cylinder. When the pin comes to the bottom quarter it will be found that the piston and crosshead are not exactly in the center of their stroke; they have run a little beyond the vertical center line. This distance is greater, the shorter the connecting rod. By the time the crank pin reaches the back quarter the piston and crosshead have exactly completed their stroke. When the crank pin comes to the top quarter the piston and crosshead are a little back of the center of their stroke, in fact, they are where they were when the pin was on the bottom quarter. When the pin comes to the forward quarter, both crosshead and piston are at the end of their stroke. It will thus be seen that the piston travels more than half its stroke during the first quarter revolution of the wheel, and consequently less than half during the second quarter of the revolution of the wheel. During the third quarter it travels less than half its stroke, and more than half during the last quarter. It, therefore, appears that for the crosshead half strokes at the front of the cylinder the pin will describe less than an exact quarter circle, and for the two half strokes at the back of the cylinder the pin will describe more than a quarter circle.

This explanation must be somewhat modified when dealing with the position of the piston when the crank is on the top or bottom quarter in engines which have the center of the axle below, or above, the center line of cylinder.

115. What is meant by a steam gage being so many pounds "light" or "heavy?"

A. If the boiler is carrying 100 pounds pressure, as shown on a correct standard test steam gage, and, at the same time, the doubtful gage shows 95 pounds, then the doubtful gage is said to be 5 pounds "light." If, however, the gage in question registered 105 pounds, then it would be said to be 5 pounds "heavy." It might be better to use the words "weak" or "stiff" in the relative cases.

116. What is the physical condition of the water in a boiler when it is said to be foaming?

A. When steam bubbles form in pure, clean water, each small globule rises quickly to the surface, and instantly breaks away into the steam space without much "splashing" on the surface of the water. Foaming generally takes place in water which is more or less viscous or cohesive, as when soapy or oily. When steam is formed in water in this state, each bubble of steam, as it endeavors to free itself at the surface, is enveloped in a watery, greasy film like that of a soap bubble, and this film rises a certain distance above the surface before it breaks. When this action goes on to a very considerable extent, as it does in a boiler where large quantities of steam are being rapidly formed, the result is that the surface of the water becomes frothy and water is liable to be carried up into the throttle valve, as there is a strong current or up-rush of steam toward the throttle if it is open at the time. When the water in a boiler is foaming badly it is very difficult to ascertain the true water level, as the height shown in the water glass is unreliable, and the gage cocks do not give very satisfactory results. The throttle should be shut off when endeavoring to get some idea of the water level. Temporary relief may be had by filling the boiler pretty full and using the blow-off cock to blow off a gage of water. The boiler should be washed out as soon as possible and the tank thoroughly cleaned.

117. What is "priming?"

A. Priming is practicially frothing in clear water, and is caused where steam is being rapidly generated, and where the water level is high a certain amount is carried into the throttle. Priming is water being carried up in quantity with the steam as it rises from the surface. The water level can be ascertained by shutting off.

118. How are locomotive springs tempered?

A. Tempering of locomotive springs is usually done by having a large cast iron box filled with water, which is kept flowing out at one side and in at the other to keep it cool. Another cast iron box is filled with whale oil or other suitable mixture. This oil cistern is usually immersed to a certain depth in the water box. The spring plates are set each to its proper radius, and heated to redness and one at a time dipped in the oil bath and kept there until each comes down to a light or dark blue, according to the quality of the steel. The spring plate is then dipped into the water bath and cooled off.

119. What is the principle upon which the sight-feed lubricator works?

A. The sight-feed lubricator is pratically two separate chambers, placed one on top of the other. The upper one is the condenser and the lower one the oil chamber. The condenser is connected with the boiler by a small steam pipe. Steam, therefore, enters and condenses in the upper chamber, and the water of condensation passes down to the bottom of the oil chamber through a small pipe. The oil chamber having been previously filled with oil, the water of condensation being introduced at the bottom of the chamber forces the oil up, and, as it floats on top of the water, it rises readily. There is an upright pipe placed in the oil chamber, which opens close to the top and receives the oil as it is forced up. Oil having entered this pipe, passes down it inside the lubricator, and at the bottom of the upright pipe a branch leads off to the sight-feeds or glass tubes which are outside the oil chamber. The sight-feed glasses are also full of the water of condensation from the condenser. The ends of the branch pipes opening into the sight-feeds are fitted each with a nipple, from which drops of oil pass up into the water in the glasses, and float up to the top where they enter the long pipes (formerly called tallow pipes) which lead to the steam chests. Small choke nipples are placed in the tallow pipes close to the lubricator, and chokes or narrow openings are provided in the tallow pipes at the entrance to the steam chests. These are to prevent the fluctuations of pressure in the steam chest from drawing the oil out of the lubricator too rapidly. A glass tube like the water gage on a boiler shows the quantity of oil in the lubricator at any time.

120. What is the principle upon which an injector works?

A. Roughly speaking, an injector consists of a cylindrical brass case containing various tapered nozzles into which steam is introduced through one nozzle. The point of the first nozzle

partly enters a second nozzle, leaving an annular space around it, connected by pipes to the water supply, and through which water enters. This second nozzle is called the combining tube, because in it the jet of steam meets with and is condensed in the water. The combining tube terminates opposite the smaller end of a double cone nozzle called the delivery nozzle, but does not touch it by a space equal to about its own diameter at this end, leaving an open annular space which is connected to an overflow pipe. The other and larger end of the delivery nozzle is connected by pipes to the boiler, with proper valves to prevent return of the water. The combined jet of water and steam passes the overflow opening and is received by the delivery nozzle and pipes and carried to the boiler. The theory of the injector, and the reason why steam at a given pressure can force water into the boiler from which the steam was drawn and against its own pressure, is that the steam, moving at considerable velocity and being comparatively light, meeting the water which is flowing slowly and is much heavier, is thus able, while losing its own velocity, to impart a velocity to the water greater than it had before. By combining with the water it causes a heavier body (the water) to acquire sufficient momentum to raise the check valve and enter the boiler against the pressure of the steam.

121. What is a non-lifting injector?

A. A non-lifting injector is one which is placed below the level of the bottom of the tank, and is constantly filled by the flow, due to gravity. The water is forced from this level into the boiler.

122. What is a lifting injector?

A. A lifting injector is one which is placed above the level of the bottom of the tank or even above the water level, and the injector is filled by the operation of either an extra steam nozzle or by a special method of varying the area of the steam nozzle which then lifts the water up to the injector, from which it is forced into the boiler in the same manner as in the non-lifting injector.

123. What is the action of a lifting injector?

A. When steam is admitted to what is called the lifting nozzle of the injector, a partial vacuum is formed in the injector itself by the steam passing through and out of the overflow, and the water in the tank which is below the level of the injector rises to the injector by the weight of the atmosphere in obedience to natural law. The injector does not lift the water in the usual sense of those words. It takes away some of the air pressure from the surface, and the water in the tank which is below the level of the injector rises up to the injector level, just as water in a well rises in the pipe of a suction pump when the plunger has caused a partial vacuum in the pump.

124. What is the effect of long, narrow steam ports compared with shorter and wider ones?

A. Long, narrow ports of the same area as short, wide ones admit steam rapidly at the beginning of valve opening. Shorter and wider ports, while not giving as large an opening at the beginning, do not wire-draw as a rule and the exhaust is freer, but they require a longer valve travel to obtain this result. With a given travel of valve the width of port is fixed, and port length gives freedom.

125. What is the heat value of crude oil as fuel?

A. Fuel oil gives about from 19,000 to 20,000 British thermal units per pound, while very good coal properly burned gives in the neighborhood from 14,000 to 14,500 B.T.U. per pound. Many coals give only 13,500 B.T.U. The evaporative efficiency of coal is about 10 pounds of water per pound of coal from and at 212°. That of crude oil is about from 13 to 14 pounds of water per pound of oil. Fuel oil has a higher evaporative efficiency, of about 25 or 30 per cent.

126. What is a piston valve?

A. A piston valve is really like a spool with enlarged ends, each end having two or more packing rings. One of the rings at one end controls the flow of steam to the cylinder and the other controls the exhaust. The packing rings have the same functions as the steam and exhaust edges of the slide valve, as if a slide valve were bent backwards to a circular form. Piston valves are, of course, circular in form and work in a bushing, inserted in the steam chest or valve chamber. A piston valve differs from the ordinary D-slide valve only in form, not in function. It does not have any balance strips, as the balance is secured by reason of its form. No valve yoke is used with the piston valve; a straight

rod through the body of the valve is the valve stem and connection with the valve rod. A slide valve can lift from its seat when excessive pressure reaches it from below. This is not possible with a piston valve.

127. How are the smoke stack and exhaust pipe brought in line?

A. Level the smoke-box lengthwise and crosswise. Place the smoke stack or base on the smoke box and find the center of the opening by calipering. From the center so found suspend a plumb bob so that it just hangs over the center of the seat of the exhaust pipe, and fit and fix the base in that position. Adjust the smoke stack or the base so that the plum bob, when hung from the center of the top of the stack, is directly over the center of the exhaust seat. Secure the stack or base in this position.

128. How is the exhaust pipe placed in line with the stack?

A. The stack being in line with the exhaust pipe seat, the pipe may be placed on the seat which has been planed parallel with the cylinders and tested to insure its being level, and, as the smoke-box has been leveled lengthwise and crosswise, the plumb line may be dropped from the center of the stack, and the exhaust pipe adjusted so as to bring its center directly under the plumb bob. In the case of double nozzles, the plum bob must come exactly over the center of the division between the two openings.

129. What is the result of having bad joints about the smoke-box?

A. The result of a bad joint anywhere about the smoke-box, whereby it draws air, is a bad steaming engine. When the engine is working slowly, and the exhaust steam leaves the exhaust nozzle, it passes up in the form of a powerful jet and fills the stack and drives out a stackful of smoke-box gas. This gas has entered the smoke-box through the flues, and, when it is driven out, more rushes in to take its place, so that a strong though intermittent draft is applied to the fire. When the engine is working quickly the steam rushes up the center, and the smoke and gases are entrained up the sides of the stack by friction. If the smoke-box draws air from the outside, air will enter more readily than the gases from the fire-box, on account of the resistance through the fire and in the tubes, and, when the exhaust jet moves a stackful of gas, part of it is made up of air drawn in from the outside, and the draft on the fire is consequently weaker. The inflow of air from outside, making the draft weaker, also causes an accumulation of cinders in the smoke-box, and, as oxygen is contained in the air drawn in, the hot cinders soon catch fire owing to there being live sparks among them, and this state of affairs soon becomes evident by the excessive heating of the smoke-box plates and front.

130. What is the effect of a leaky steam pipe in the smoke-box?

A. This causes a bad steaming engine, as the escaping steam helps to fill the smoke-box and so diminishes the draft on the fire. The exhaust only removes a stackful of gas each time the jet shoots out, and if steam has leaked into the box it must be got rid of, and consequently not so much of the smoke-box gases can be removed at each exhaust, and the blast on the fire is weakened thereby. A leak of steam in the smoke-box can be distinguished from a smoke-box drawing air, from the fact that the leaking steam does not burn up the cinders in the smoke-box, though they accumulate in the box and lie in the flues and tend to restrict the draft.

131. What is good average evaporative performance for an engine per pound of coal?

A. This depends very largely on the quality of the coal used, but with good bituminous coal about from 7 to 8 pounds of water is evaporated per pound of coal under normal conditions. Hard coal evaporates about 6 to 7 pounds of water per pound of coal.

132. What effect does the size of a smoke stack produce?

A. Generally speaking, the enlargement of a smoke stack will give freer opportunity for the escape of the smoke-box gases, but the size of the stack is, after all, a matter found by experiment. A tall, narrow stack may have the same volume as a shorter one of larger diameter. Some railroads prefer the high, narrow stack, and others, where head room is an important consideration, use short stacks with an extension carried down into the smoke-box. If a stack is too large the draft will be feeble, as the jet of exhaust shoots through it without drawing out a complete stackful. If

the stack is too small the exhaust will choke, and the effect on the fire will be poor draft.

133. What is the principle of the pneumatic blow-off cock?

A. The pneumatic blow-off cock is constructed something like a check valve of a boiler; that is, there is a valve which prevents the escape of water, and this valve is held down on its seat by the pressure in the boiler. Against the outer side of this valve the stem of a small piston rests. The piston is enclosed in a cylinder, placed opposite the check valve, and the outer part of this cylinder is in communication with the main air reservoir, the pipe forming the connection having a cut-out valve on it placed in some convenient position. When air is admitted behind the small piston it is forced out, and its stem unseats the check valve and thereby enables the contents of the boiler to discharge. When the air pressure is cut off, the pressure in the boiler causes the check valve to reseat itself and so shut off the flow of water from the boiler. The seating of the check valve pushes back the stem and small piston to their normal positions.

134. How does a grease cup act?

A. The grease cup is filled full of grease, and the cover is screwed on and the plug screwed in sufficiently to subject the grease to some pressure. Part of the grease is thus forced through the small hole leading to the crank pin. As the grease is used, the pressure applied by the plug gradually diminishes, but even with very satisfactory lubrication some slight heat is developed which expands the grease sufficiently to keep up a small flow for a considerable length of time.

135. Does an engine with large driving wheels run faster than one with small drivers?

A. A locomotive with large driving wheels will pass over a greater distance with the same number of strokes than one with smaller wheels. In a sense, the engine with the smaller wheels may be said to run faster, but it does not travel as far in a given time. An engine having 80-inch driving wheels makes about 252 revolutions to the mile, while a 60-inch wheel turns 336 times in a mile. This is 84 revolutions more for the smaller wheel than for the larger, or about 31 per cent. If both engines ran the same distance in the same time, the smaller wheel engine would burn more coal and there would be considerable increase in piston speed for the engine with the smaller wheel.

136. What is the effect of a splitting-wedge or bridge in the single exhaust tip of an engine?

A. The splitting-wedge or bridge is sometimes put in as an expedient to cause an engine to steam better. The bridge sharpens up the exhaust, that is, it gives the steam more velocity, as the exhaust steam has to pass out of a nozzle diminished by the area of the bridge. The bridge has much the same effect as bushing the exhaust tip or applying one with smaller area of opening. The usual practice is to use an exhaust tip of suitable size without the bridge, as the presence of any obstruction in the nozzle tends to somewhat increase back pressure, and great care must be taken not to divide the jet so that part of it will strike the top of the smoke-box and miss the opening at the base of the stack.

137. If a locomotive stands with right crank pin on forward quarter and the reverse lever be moved from extreme forward to extreme back gear, how much will the valve move?

A. In the position described the engine is standing with valve open the full-gear lead amount. As the reverse lever is drawn back to the center the valve will open still further until the mid-gear lead position has been reached. As the reverse lever is moved to extreme back gear the valve will move back again to the same place it was, which is full-gear lead. The opening of the valve, or the lead, will be the same at each end of the stroke whether the reverse lever be full ahead or full back, if the valves have been set with the back motion similar to the forward.

138. Why are some engines made with center line of cylinders above the center line of the driving wheels, or sometimes with the cylinders inclined at an angle to the horizontal center line of the drivers?

A. This is sometimes done for the purpose of gaining space above the engine truck wheels, or for other reasons which may be of importance in a particular design, but the engine so built does not gain or lose in power, as this elevation of the cylinders above the center line of the wheels is usually but a few inches.

139. Why is it that some locomotive grates slope down toward the front end?

A. This is done in shallow fire-boxes for the purpose of giving as much space as possible above the fire and below the lower row of flues. In some engines the grates are level at the back of the box and slope forward from a point about half way along the box; others have a gradual slope from the back of the box to the front, but in any case the idea is to keep the lower flues sufficiently above the fire to prevent their becoming choked with cinders or coal when the engine is working. A locomotive grate should be placed as low as possible in the fire-box, provided it is sufficiently above the mud-ring to prevent the fire acting on the plate where it lies against the mud-ring.

140. How can a blow due to defective balance strip be distinguished from a blow from a leaky slide valve?

A. Place the engine with crank pin on the top quarter of the side to be experimented with, block the driving wheels, open the cylinder cocks, place the reverse lever in the center, and slightly open the throttle. With engine in this position the valve covers both ports. If steam blows out of either cylinder cock it proves that this side of the engine is defective. To determine whether it is a defective balance strip or a leaky valve, move the reverse lever a short distance on either side of the center notch, but not enough to make the valve uncover either port. If steam continues to blow from one cylinder cock, the valve or valve seat is cut on the end indicated by the blow from the cylinder cock. If, however, the blow is alternately from one cylinder cock and then from the other, the defect is in the balance strips, as live steam is passing into the balance area and down into the exhaust cavity, and, when the valve is moved to and fro, it brings first one steam port and then the other into communication with the exhaust cavity, and steam passes down the steam port thus exposed. There will, of course, be a greater amount of blow up the stack, whether the valve or the balance strip is defective.

141. What is the cause of the difference in the size of the drops of various kinds of oil?

A. Other things being equal, the oil having the greatest specific gravity the thicker it will be. The weight and thickness of an oil determines the size of the drops. Heavy, thick oil has less fluidity than light, thin oil, and breaks into drops less readily than thin oil. When fed through the small nozzle of a lubricator, the particles of heavy oil adhere to the nozzle for a longer time and form a larger drop before breaking away and floating up through the water. Light fluid oil adheres but slightly to the nozzle and breaks away after a small drop has been formed. The particles of heavy oil have more cohesion among themselves, and, when formed into drops, resist the tendency to break apart more than do the drops of lighter, thinner and more fluid oil. The size of the nozzle modifies the size of the oil drop. Wide, flat nozzles produce larger drops than thin, sharp nozzles do, as there is a larger surface for the oil to adhere to.

142. What is specific gravity?

A. When one says that the specific gravity of gold is 19, one means that gold is nineteen times heavier than an equal bulk of pure distilled water (H_2O) at a temperature of 39.2 Fahrenheit.

143. What are the principal causes of a boiler explosion?

A. Defective construction is one cause, and by this we mean not only bad original design, but also repairs which introduce conditions which are equivalent to bad design. Bad design may be defined as the construction of a boiler from plans and specifications which make parts inaccessible or do not provide for a sufficient factor of safety. Boilers should be so designed that their weakest part shall be, if possible, fully five times stronger than the internal pressure required to tear apart the weakest portions. Deterioration of the boiler may also bring about an explosion. Corrosion, accumulation of scale, pitting, extensive cracking, mud-burning, broken stay-bolts may so weaken the plates of a boiler as to cause an explosion. These defects may be allowed to develop through neglect, and for want of constant and intelligent inspection and proper repairs. Gradual deterioration of a boiler may be said to begin from the time it is put into service, just as wear takes a place in the parts of the machinery of an engine from the time it enters active service. Deterioration may be a slow process, but its effects are cumulative. Unremitting care must be bestowed upon a boiler

in regular service. Nowhere is the proverb more true that "Eternal vigilance is the price of safety" than it is in dealing with a locomotive boiler. Low water may also cause an explosion. If the water level is allowed to become so low that the crown sheet is uncovered, the sheet itself becomes very hot, and consequently soft enough to bag down between the crown stays. If the internal pressure is kept up, the sheet will eventually be pulled off the stay-bolts and the unsupported sheet will then very likely tear across a row of stay-bolt holes and violently discharge the contents of the boiler. Boilers exploded from this cause generally show evidence of the overheating by the color of the plates, and it is frequently possible to ascertain after the accident the level to which the water in the boiler had sunk at the time of the explosion.

144. When the contents of a boiler under steam pressure are suddenly discharged, why is the action so violent as to be termed an explosion?

A. This is caused by the almost instantaneous liberation of the heat stored in the water. The temperature of water forming steam under a pressure of 200 pounds absolute is 381.7° F. If the pressure be quickly removed, this stored up heat causes the water to flash into steam, and though to the eye of Science the process is no doubt gradual, yet it takes place with such rapidity and such force as to tear the boiler to pieces in the process and hurl the broken parts in all directions. An exploded boiler is generally left entirely destitute of water, and although none of the heat below 212° F had any part in the vaporization of the water, the powerful outrush of steam and water is usually sufficient to blow all the water out.

145. What is the mechanical energy stored in the form of heat in water at 200 pounds pressure?

A. Water at 200 pounds absolute pressure, or 185.3 pounds gage pressure, has a temperature of 381.7° F. It is, therefore, 169.7° F hotter than water at 212° F. Each pound of water, therefore, contains 169.7 British thermal units, ready to cause water to flash into steam. If the boiler contains 2,500 gallons of water, that amount will weight 25,000 pounds. The total heat units in 25,000 pounds of water is 4,242,500, and as each heat unit is equal to 778.3 foot-pounds, the total stored up energy in the water is equivalent to 3,301,937,750 foot-pounds. This amount of energy would be capable of lifting 100 tons more than $3\frac{1}{2}$ miles.

146. What are some of the causes which may prevent an injector from working?

A. If the strainers in the tank or the suction pipe become clogged, so that an insufficient supply of water reaches the injector, it will fail to work, because all the steam is then not condensed and the injector will blow back. If the injector draws air, the same result will be produced. These defects must be remedied by either cleaning out the strainer or the suction pipe, or by stopping the air leaks. If there are air leaks in the tender hose, wrapping it round with a wet cloth will often be found effectual. If the injector is coated with scale, so that the internal passage is clogged, the injector will not work properly. The interior parts cannot well be cleaned on the road, unless the obstruction is caused by the presence of some foreign body. If the feed water is too hot to condense all the steam, the injector will break. The temperature of the feed water must then be lowered by filling the tank at a water station, and, if necessary, letting a considerable quantity run out of the hose bags. If the boiler is priming badly, and steam laden with water reaches the injector, it will interfere with its proper working. Shutting the throttle will frequently remedy this trouble.

147. Is a movement of the water in the gage glass a sure sign that it registers the true water level in the boiler?

A. The movement of the water is not an infallible sign, though if the water in the glass remains stationary there is something wrong. If the opening into the boiler at the bottom of the glass is stopped up, the water will maintain a constant level. This level is utterly unreliable as an indication of the water level inside the boiler. If the bottom opening is free and the top clogged up, the water will still continue to rise and fall in the glass, but the indication as to the true water level will be quite untrustworthy. The gage glass should be frequently blown out from both top and bottom through the drain pipe at the bottom, and the try cocks used to check the indication given by the glass.

148. What is the duty of the man who lights up or starts a fire in an engine?

A. He should first ascertain the height of the water in the boiler. The indication given by the water glass is not sufficient. He should make certain by opening the lower try cock and observe the flow of water. If the engine is cold, the safest way is, if possible, to take out the stem of the lower try cock and observe the flow of water. Simply opening the try cock when the engine is cold may cause water lodged in the cock to drip out, and thus not indicate the water level in the boiler.

149. Why is it not advisable to sand one rail?

A. In case the engine slips with sand on only one rail, the driving wheels on that side may catch suddenly and the momentum of the moving wheels, rods, etc., on the other side may cause an excessive strain on the axle, which may bend it or break a crank pin.

150. If a water glass breaks, how should the valves in the mountings be shut off?

A. The person attempting to close the valves of a broken gage glass should protect himself with a coal scoop or a loose coat thrown over his head and should have a fireman's glove on his hand. The lower valve should be shut off first, as hot water is being blown from it, after which the top valve should be shut.

COMPOUND LOCOMOTIVES.

151. What will happen if the intercepting valve of a Richmond cross-compound sticks in the compound position?

A. When it is desired to start in the simple position with the intercepting valve stuck in the compound position, no steam can get to the low-pressure steam chest except from the high-pressure exhaust. If the engine has stopped with the high-pressure crank pin on the forward or back quarter, the engine will not start, as the high-pressure piston cannot move the pin and live steam cannot get to the low-pressure side. If the engine has stopped so that the high-pressure piston can move the engine, the low-pressure side will receive steam after one high-pressure exhaust. The engine itself may be started under these circumstances.

152. If the intercepting valve of a Richmond cross-compound sticks in the simple position, what will happen?

A. In this case the engine would start, but if it did not automatically become compound after a few revolutions the pressure in the receiver between the high-pressure piston and the closed intercepting valve would rise and eventually become equal on both sides of the high-pressure piston, and the emergency high-pressure exhaust valve would have to be opened in order to allow the high-pressure exhaust to pass directly to the atmosphere. The engine could then be run slowly as a simple engine with the emergency valve open.

153. What would happen if the emergency valve stuck open or shut on a Richmond cross-compound?

A. If the emergency valve stuck open, the engine could not be made to work compound, but would have to be run slowly as a simple engine. If the emergency valve stuck shut, the engine could not be changed back to simple after it had changed to compound.

154. If the reducing mechanism in the intercepting valve of a Richmond compound engine became deranged, so that live steam could enter the receiver, what should be done?

A. The intercepting valve should be removed. The emergency valve should be left in place, and the passage leading from the auxiliary steam pipe to the intercepting valve casing should be blocked, and the engine be thus rendered wholly a compound for the time. In starting, the high-pressure side will be the only one to receive steam. If there was simply a leak, so that steam got into the receiver, it would weaken the high-pressure side and strengthen the low-pressure side, probably to the point of causing the low-pressure relief valves to pop.

155. If the Richmond compound emergency valve and the intercepting and reducing mechanism became inoperative or broken, what should be done?

A. All parts of the intercepting valve and emergency valve should be removed and the passage for live steam from the auxiliary steam pipe to the intercepting valve should be blocked. The engine would then become simple, using only the high-pressure side. The low-pressure valve and piston would be lubricated by some steam passing to the low-pressure side.

156. If the by-pass valve on the low-pressure cylinder of a compound should become deranged or broken, so as to permit the passage of steam to both sides of the piston at the same time, what should be done?

A. Remove the by-pass valves and fill the central portion of the by-pass passage by a plug of wood. This can be held in position by two pieces of wood filling the distance between the by-pass caps and the plug of wood.

157. What can be done in case the shell of a Schenectady compound intercepting valve breaks?

A. If the shell is broken at the forward end, so that the reducing valve is left intact and only the end wall damaged, the whole valve should be pushed forward to the position in which it would be if the engine were working simple. In this position the reducing valve will shut off live steam coming from the auxiliary steam pipe to the low-pressure cylinder, and the engine may be run as a compound.

If the reducing valve end of the intercepting valve is broken, the bottom joint of the auxiliary steam pipe should be slacked off and a piece of sheet iron inserted so as to block the entrance of live steam on the low-pressure side, and the engine run as a compound.

158. What would happen if the starting valve of a Vauclain four-cylinder compound should become deranged?

A. It is not impossible to find a Vauclain four-cylinder compound running with the starting valve open, as the amount of steam which can get through at any speed is very small. If the valve is broken off, so that steam blows into the atmosphere, the ends of the equalizing pipes should be plugged and the plugs fastened so that they will not be blown out. The engine will then be worked as a compound, the low-pressure cylinders not receiving steam when starting until the first high-pressure exhaust has taken place.

159. In the Pittsburgh compound, does the intercepting valve work automatically?

A. No, it does not work automatically. As long as the reverse lever is kept in the corner, either in forward or back gear, the engine runs as a simple engine. When the reverse lever is put in the first or second notch from the corner, the engine becomes a compound, as the intercepting valve is controlled by the movement of the reverse lever. The movement of the intercepting valve causes the high-pressure exhaust to pass directly into the receiver. When this is done, the opening into the receiver, by which live steam from the reducing valve enters, is closed to reducing valve steam, and the pressure accumulating in the chamber behind the reducing valve, acting on the larger area of the valve, causes it to close, and holds it in that position until the movement of the intercepting valve again opens the receiver for the escape of steam from the chamber behind the reducing valve, and, by thus reducing the pressure behind it, permits it to open. The intercepting valve is on the high-pressure side of the engine.

160. How does the Baldwin two-cylinder compound, intercepting valve act?

A. The intercepting valve for the Baldwin two-cylinder compound is on the high-pressure side of the engine, and is not automatic in its action. It is, therefore, independent of receiver pressure, and is operated by steam pressure controlled by a valve in the cab. The valve is normally held in simple position by the pressure of a spring, and, when it is desired to "compound" the engine, steam is admitted behind a piston connected with the intercepting valve, and the movement of this piston counteracts the tension of the spring and places the valve in the "compound" position.

THE AIR BRAKE.

161. What was the original form of Westinghouse air brake?

A. It was called the straight air brake.

162. How did the straight air brake work?

A. There was an air pump on the engine which filled a reservoir also on the engine with compressed air, and when it was desired to apply the brakes a three-way cock on the engine was turned to permit the flow of compressed air from the reservoir through a continuous pipe under the tender and all the cars of the train. The pipe was connected between each vehicle by a rubber hose. This pipe fed the brake cylinders and moved a piston in each, which pulled the brake rods and levers as the hand brake had done. To release this brake, the three-way cock was turned so as to let the air out of the cylinders and brake pipe.

163. What improvement was made on this form of brake?

A. The automatic brake was devised. This consisted in a change of principle. In the Westinghouse automatic air brake the pump filled the main reservoir on the engine, the same as with the straight air brake; and a feed valve in the brake, acting as a reducing valve on it, constantly filled the brake pipe, as the pipe under the tender and cars was called. Compressed air was, therefore, always in the brake pipe when the brakes were off, and a reduction of pressure in the brake pipe set the brake. The bursting of a rubber hose between any of the cars, as when the train broke in two, would set the brakes. This was why the brake was called automatic.

164. How were the brake cylinders supplied with compressed air in the automatic brake?

A. Under each car an auxiliary reservoir was placed, and a triple valve governed the flow of air from the brake pipe to the auxiliary reservoir and from the auxiliary reservoir to the brake cylinder.

165. How did this triple valve operate?

A. The triple valve consisted of a piston operating a slide valve. When the brake was off, air flowed in from the brake pipe under the piston and pushed it to the end of its stroke, known as release and charging position, thus moving the slide valve so that it covered the port leading to the brake cylinder. Air under the triple piston held it in this position, and flowed by the piston through a small short groove in the triple cylinder. It then passed to the auxiliary reservoir, and filled it to a pressure of about 70 pounds.

166. How were these brakes applied?

A. When brakes were to be applied, the engineer let some of the air out of the brake pipe by means of the brake valve in the cab, and this caused the triple piston to move to the service application position where it blocked the groove, and the movement of the piston carried with it the slide valve and its movement uncovered the port leading to the brake cylinder, so that air from the auxiliary reservoir flowed into the brake cylinder and applied the brakes.

167. How were brakes released?

A. Brakes were released by restoring the air pressure to the brake pipe. This was done by moving the handle of the brake valve in the cab to release position, which made communication between the main reservoir on the engine and the brake pipe. The flow of stored-up air into the train pipe had the effect of moving all the triple pistons up again to their original positions, which enabled air to feed into the auxiliary reservoir. It covered the port leading to the brake cylinder by moving the slide valve, which also opened a passage for the escape to the atmosphere of the air imprisoned in the brake cylinder.

168. How were the various pressures regulated to insure release?

A. The air pump supplied 90 pounds pressure to the main reservoir, and the feed valve, which was really a reducing valve on the engineer's valve, permitted only 70 pounds pressure to be carried in the brake pipe and the auxiliary reservoir, and there was only atmospheric pressure in the brake cylinder. When only a few pounds pressure was let out of the brake pipe, the greater pressure in the auxiliary reservoir moved the triple pistons, and, the brake cylinders being empty, the flow of air from the auxiliary reservoir took place as soon as the passage to the brake pipe was cut off and that to the brake cylinder was opened. Filling the brake cylinder from the auxiliary reservoir reduced the pressure in the auxiliary reservoir to about that made in the brake pipe when the triples moved to lap position. When air at 90 pounds pressure from the main reservoir flowed through the train pipe it forcibly drove the triple pistons up to their release and charging positions, and the flow of air then continued from the highly charged brake pipe into the impoverished auxiliary reservoirs, while the brake cylinders discharged to the atmosphere, releasing the brake.

169. What was done when brake release was fully completed?

A. The engineer turned the handle of his brake valve to running position and cut off the direct flow of main reservoir pressure to the brake pipe, and the air pump meantime proceeded to restore the 90 pounds pressure to the main reservoir and the feed valve allowed air at 70 pounds pressure to flow continually into the brake pipe and auxiliary reservoirs.

170. How was the plain triple valve made sensitive?

A. The slide valve in the triple was fitted with what was called a graduating valve, and its operation was as follows: When the triple piston had moved down so as to open communication between the auxiliary reservoir and the brake cylinder, it opened a small port which was governed by a little valve called the graduating valve. The reduction of pressure in the auxiliary reservoir soon brought the pressure slightly below that of the air left in the train pipe (as the engineer reduced it but a few pounds in order to cause a brake application), and the triple piston began to move up again to the release position. A slight motion of the triple piston was sufficient to move the graduating valve which was in the slide valve, but not to move the slide valve itself. The slight movement of the graduating valve closed the small port leading to the brake cylinder, so that what air had entered it remained there, and the auxiliary reservoir pressure remained as it then was and the brake pipe pressure as it was. A further reduction of brake pipe pressure drew down the triple piston just sufficient to again open the graduating valve and permit a second flow of air from auxiliary to brake cylinder, making a stronger application of brakes. When the auxiliary pressure again fell a trifle below that of the brake pipe, the triple piston moved up enough to close the graduating valve and hold stationary the pressure in the auxiliary, brake cylinder, and brake pipe.

171. What did the quick-action brake do that the plain automatic brake had not done?

A. It enabled the brake to be used on long trains, in what is called the emergency application, and insured a rapid and positive action of the brake on each car.

172. Describe the emergency action of the plain triple valve.

A. When air was suddenly or quickly discharged from the brake pipe, the triple piston was carried down to the limit of its stroke and the slide valve was drawn clear of the port leading to the brake cylinder, and it thus opened wide that port. Air, therefore, passed quickly and directly through this larger port from the auxiliary reservoir to the brake cylinder. A quicker, though not a stronger, brake application was thus obtained.

173. How did this emergency application work on long trains?

A. The emergency action of the plain triple was not satisfactory on long trains, though the service application had proved to be quite satisfactory. On long trains the sudden application caused the brakes on the front cars to set first and the slack of the train to run in on the retarded front cars with such force as to do damage.

174. How was this defect remedied by the quick-action triple valve?

A. The quick-action triple is identical in action with the plain triple as far as service application is concerned, but it contained an emergency feature which enabled brakes to be set on the rear cars of long trains a few seconds later than on the front cars. The quick-action triple was provided with an emergency valve and a check valve which was interposed between the train pipe and the brake cylinder. This emergency valve was held shut by the pressure of air in the brake pipe. Above the emergency valve was a piston having a larger area than that of the emergency valve. When a sudden reduction of air in the brake pipe took place, the triple piston moved to the extreme end of its stroke and carried the slide valve past the opening to the brake cyinder, just as in the plain triple. A port in the slide valve in the quick-action triple was brought opposite a port leading to the upper side of the emergency piston. Pressure from the auxiliary was thus introduced on top of this piston and forced it down, and its movement unseated the emergency and check valve and so opened a large direct passage from the train pipe to the brake cylinder. Air from the train pipe was thus discharged into the brake cylinder and not only increased the pressure in the brake cylinder, but caused a sudden reduction of air in the

brake pipe of the next car behind, and so on throughout the train. The brakes on the last car of a 50-car train were set fully in 2½ seconds after the handle of the engineer's brake valve in the cab had been placed in the emergency position.

175. How does the emergency application secure a more powerful brake action than the service application?

A. In the service application, the gradual equalization of pressure between the auxiliary reservoir containing 70 pounds and the empty brake cylinder takes place when both contain air at about 50 pounds. This is the maximum brake power, and no further reduction of air pressure in the brake pipe can do more. When the emergency application is resorted to, the brake pipe pressure is rapidly discharged into brake cylinder, so that the brake cylinder contains air under some pressure just as the auxiliary reservoir begins to equalize with the brake cylinder, and under these circumstances the equalization is effected with a pressure of 60 pounds in the brake cylinder and auxiliary reservoir. The emergency application, therefore, sets the brakes quicker and tighter than the maximum service application.

176. How is the pressure in the brake cylinders applied to the brake rigging so as not to skid the wheels?

A. The levers, which with the rods, etc., form what is called the foundation brake gear, are proportioned so that the total pressure on the brake shoes on freight cars shall be about seventy per cent of the light weight of the car. For passenger cars (having two 4-wheel trucks) about ninety per cent of the light weight of the car is used. For driver brakes on engines about seventy-five per cent of the weight on the driving wheels is used, and for tenders, which are loaded practically all the time, about 100 per cent is used.

177. In proportioning the leverage for freight or passenger cars, tenders and engines, what pressure in the brake cylinders is the basis of the calculation?

A. Where plain triple valves are used, 50 pounds pressure in the brake cylinders is the figure employed in the calculation, and 60 pounds where quick-action triples are used.

178. In a brake cylinder, does piston travel affect the equalization of auxiliary reservoir and brake cylinder pressures?

A. Yes, long travel reduces the pressure in both auxiliary reservoir and brake cylinder below the amount which is considered normal and which is used in the calculation for leverage. Short piston travel keeps the equalization point above the normal. Other things being equal, the brakes set harder with short piston travel than they do with long piston travel. Cars with long piston travel, in a train with brakes fully applied, release before those having short travel because there is less pressure on top of the triple pistons.

179. If piston travel is very short, how will the brakes act?

A. If the piston travel is less than 2⅝ inches, the brakes will not remain set for the reason that in the brake cylinder wall there is a groove cut parallel to the axis of the cylinder. This is called the "leakage groove," and it is placed there to prevent the brake setting owing to a leaky triple valve. Air leaking in small quantity from the auxiliary reservoir through the triple valve to the brake cylinder might in time cause the brake to set, and the leakage groove is cut in the cylinder wall for the purpose of allowing this air to flow past the piston and escape to the atmosphere without setting the brake. The leakage groove thus prevents the gradual accumulation of air in the brake cylinder, but when a service application is made only a small quantity of air blows out through the leakage groove before the piston has moved over it and set the brake.

180. In ordinary air brake practice, what is considered the proper amount of piston travel?

A. Piston travel, to secure good results, should be between 5 and 8 inches. The most generally satisfactory piston travel is about 7 inches.

181. What is the usual method of adjusting piston travel?

A. This is generally done by taking up the slack in the brake rigging, and is accomplished by altering the position of the dead lever, which is the lever in the truck held stationary at the top with a pin. The top of the lever is held between the parallel sides of a yoke in which a series of holes have been drilled, and the pin

through the top of the lever can be put through any pair of holes to adjust the position of the dead lever.

182. Have the pressures in the brake cylinder been ascertained from actual practice for various lengths of piston travel?

A. A series of tests was made with a properly equipped freight train, and the results published in the Air Brake Men's 1896 proceedings. The figures in the following table are the average of several tests. The table is taken from that report:

Piston Travel and Resultant Cylinder Pressure.

Train pipe Reduction.	4	5	6	7	8	9	10	11
7	25	23	17½	13	10½	8		
10	49	43	34	29	23	19½	17	14
13	57	56	44	37½	33	29	24	20
16			54	47½	41½	35	29	24
19				51	47	40	36½	32
22					50	47½	44	39
25							47	45

183. Is there any method of automatically taking up the slack of the brake rigging?

A. The American slack adjuster is a device for automatically taking up the slack in the brake rigging and regulating piston travel. In the ordinary brake arrangement, one end of the floating cylinder lever is fastened to the back head of the brake cylinder. When the American slack adjuster is used, this end of this lever is attached to a crosshead, working in a pair of guides. The crosshead is moved backward or forward according as a ratchet wheel on a screw connected to it is revolved to the right or left. The farther the end of this lever is moved from the brake cylinder head the less slack there is in the rigging.

The method of operating the screw is automatic, and whether it moves or not depends on the brake cylinder piston travel. The end of the screw is fitted with a ratchet nut, and the pawl for turning this nut is attached to the stem of a small piston, which is in a cylinder carried at the end of the guide bars. The small cylinder communicates with the brake cylinder by a copper pipe which enters the side of the brake cylinder, so that a travel of the piston past this point permits air to enter the copper pipe, and moves the small piston. This pushes the pawl over one or more teeth of the ratchet nut, and when the brake cylinder pressure is released, air from the small cylinder flows back through the copper pipe to the brake cylinder and escapes to the atmosphere. A spring behind the small piston brings it back, and the pawl which is engaged with the ratchet nut also comes back and in so doing turns it through a small angle, thus rotating the adjuster nut and slightly moving the end of the floating cylinder or adjuster lever. When the small piston is back at the end of its return stroke, the end of the pawl strikes against a lug and is thrown out of engagement with the ratchet nut. Each movement of the ratchet nut slightly decreases the piston travel by taking up the slack in the brake rigging, though the adjuster remains inoperative when the cylinder piston does not pass the port leading to the adjuster cylinder.

184. Is there any arrangement whereby the train crew can apply the brake?

A. Yes, in each passenger car there is a valve with a lever handle which is attached to the end of a branch pipe which comes up from the brake pipe through the floor of the car. Opening this valve in any car permits air from the brake pipe to escape to the atmosphere, and so applies the brake to the whole train. When this valve is opened quickly and completely, an emergency application of the brake takes place.

185. In descending long grades where brakes must be set for considerable periods of time, how are the auxiliary reservoirs recharged so as to make up for losses occasioned by leaks from the brake cylinder or the brake pipe?

A. Retaining valves are used to gradually reduce and then hold a certain amount of pressure in the brake cylinders after the triples valves have been moved to release position. The retaining valve is placed at the end of a pipe which leads from the release port of the triple valve. The handle of the retaining valve is placed within reach of the train men. The valve consists essentially of a small cylinder or casing in which a weighted valve is so proportioned as to require a pressure of over 15 pounds to raise it. Ordinarily, the handle of the retaining valve is turned

to give free exhaust for air from the brake cylinder. When it is desired to use the retaining valve, as when the train is descending a long grade, the handles are turned to compel the exhaust from the brake cylinder to raise this weighted valve. Air which passes this valve reaches the atmosphere through a restricted opening $\frac{1}{16}$ inch in diameter, so that the time occupied in discharging brake cylinder pressure down to what it is intended to hold, by the weighted valve, will be lengthened. When the retaining valve is in operation, the engineer may release the brakes for the purpose of recharging the auxiliary reservoirs. Air from the brake cylinders passes out through the retaining valve, which, as its name implies, retains 15 pounds in the brake cylinders while the triple pistons are in the recharging position. Air at 50 pounds pressure in the brake cylinders requires about 25 seconds to blow down to 15 pounds through the retaining valve, and during this time the auxiliary reservoirs have been receiving a fresh supply of air from the brake pipe. The 15 pounds retained in the brake cylinder maintains a certain though reduced amount of brake-shoe pressure on the wheels, and thus prevents the wheels from becoming overheated, as well as prevents the train from attaining too high a speed while the recharging of the reservoirs is taking place. The brakes may be kept in this partial state of application until full pressure is restored in the auxiliary reservoirs or not, as occasion requires. When the train has descended the grade, the retaining valves are then cut out by the train crew and normal brake action is resumed.

186. How does the engineer manipulate the air brake?

A. By means of the engineer's brake valve. This valve, located in a convenient position in the cab, gives the engineer complete control of the flow of air from the main reservoir and to and from the brake pipe. There are five positions of the brake valve handle. The first is *full release position,* in which the unrestricted flow of air from the main reservoir to the brake pipe ensures the release of all brakes on the train. The second is the *running position,* which is maintained when the brakes are off and the brake pipe and the auxiliary reservoirs are being filled or are full. In this position the flow of air to the train overcomes the effect of small leaks. The third position is *lap.* In this position all ports in the brake valve are blanked. The fourth is *service* *position,* and is used when brakes are gradually applied as in regular service. The fifth position is the *emergency.* This is used when it is desired to suddenly and fully apply the brakes.

187. In making a service application, what reductions in brake pipe pressure should be made?

A. For the first application between 5 to 7 pounds is considered good practice. For a second application with long trains from 7 to 10 pounds is usually satisfactory, but the judgment of the engineer, knowing the road and the kind of stop to be made, must govern in each case. A total reduction of from 20 to 25 pounds will generally cause the full application of brakes.

188. When the brakes are fully set, what effect will emptying the brake pipe have?

A. After auxiliary reservoir and brake cylinder pressure have equalized, emptying the train pipe will not set the brakes any harder, and there is then the possibility that pressure from the auxiliary reservoir and brake cylinder may leak past the triple piston or the check valve into the brake pipe and so reduce brake power.

189. Why does a slight reduction by the engineer's brake valve constitute an equal reduction in pressure in the brake pipe of a long train?

A. Because the engineer's valve is so constructed that the engineer in making the reduction of pressure allows air to escape from a small reservoir holding compressed air at brake pipe pressure above the equalizing discharge piston and its valve. This valve will not reseat until the pressures on both sides of this discharge piston are equalized. It is, therefore, apparent that the engineer having made a certain reduction, the flow of air from the brake pipe will continue until it has been reduced by the amount which he discharged from above the equalizing discharge piston. A given reduction of brake pipe pressure at the front of the train insures that amount of reduction all through the brake pipe. It is, therefore, possible to set brakes throughout the entire train, and the surging of air in the brake pipe toward the front end, consequent on an exhaust from the front end, cannot release the head-end brakes while leaving the rear brakes applied.

190. How is compressed air supplied to the whole brake system?

A. By a steam pump or air compressor situated on the engine. The steam and air cylinders of this pump are placed one above the other, with pistons for each attached to the same piston-rod. The pump delivers compressed air direct to the pipe leading to the main reservoir and to the train pipe, but between the pump and the train the engineer's brake valve is interposed, in which a feed valve is located which keeps the pressure reaching the brake pipe 20 pounds lower than that in the main reservoir. The excess pressure in the main reservoir is for the purpose of insuring rapid and positive release of brakes.

191. How is the pressure in the main reservoir and the brake pipe maintained?

A. There is no safety or blow-off valve for air on the air brake system, and the pressure is maintained by the pump, which is automatically shut off when the requisite pressure has been reached and is automatically started when the pressure falls. There are two methods of pump governor connection as adopted by the Westinghouse Air Brake Company. With the more modern, or G. 6 brake valve, the pump governor air pipe is connected to the pipe carrying main reservoir pressure. The older style of brake valve D. 8, has the pump governor connected so as to receive brake pipe pressure.

192. What is the object of the more modern method of pump governor connection?

A. With the newer method of connection the pump will not stop until 90 pounds pressure is on the main reservoir, and that pressure cannot be had until the brake pipe has 70 pounds pressure. With the older method the pump simply maintained the required pressure in the brake pipe, and the excess pressure in the main reservoir was not necessarily there under these circumstances. In mountainous regions or on level roads handling exceptionally long trains, the pump governor is set for higher main reservoir pressure than 90 pounds.

193. What is the high-speed brake?

A. The high-speed brake is a method of using a higher brake pipe and auxiliary reservoir pressure than 70 pounds. It is intended for use on passenger trains, and it has been found that brake-shoes may be safely pressed against rapidly revolving wheels with a force sufficient to skid them if revolving at slow speeds.

194. How does the high-speed brake differ from the ordinary air brake?

A. A brake pipe and auxiliary reservoir pressure of 110 pounds is maintained, and a high-speed automatic reducing valve is attached with pipe leading to the brake cylinder, so that when air at 110 pounds auxiliary reservoir pressure is introduced into the brake cylinder the brakes set powerfully and the reducing valve begins to blow away air until it has reduced the brake cylinder pressure to 60 pounds. The auxiliary reservoir and brake cylinder pressures equalize in the high-speed brake at about 88 pounds. The exhaust port of the automatic high-speed reducing valve is triangular in shape, so that comparatively rapid or slower exhaust is obtained according to the degree of opening permitted. High train speed and emergency application requires longer time to blow down the pressure from 88 pounds to 60, while in service application the reducing valve prevents a higher pressure than 60 pounds building up in the brake cylinders.

195. What change in the quick-action equipment is necessary to transform it into the high-speed brake?

A. The brake cylinders must be equipped with the high-speed automatic reducing valve, and the engine must be equipped with a duplex pump governor and two train line governors or old style feed valves to provide for using either the higher or lower brake pipe pressures. Only one diaphragm portion of the pump governor and one train line feed valve is used at a time. They are arranged with cut-off cocks so that the high-speed brake may be used, or the ordinary quick-action brake may be used, as desired.

196. What is the air signal system?

A. The air signal system has replaced the bell-cord and cab-gong as a means of communication on passenger trains between train crew and enginemen. The signal system is a separate equipment from the air brake, consisting of a separate line of pipe under the engine and cars and separate hose connections, stop cocks, etc. The signal pipe is supplied with air from the main reservoir, but between main reservoir and signal pipe a reducing valve is interposed so that air at about 45 pounds pressure can enter the signal pipe, and it is kept at full pressure all the time. A small signal whistle is located in the cab, and between the whistle and the signal pipe a signal valve is placed, the opening and closing of which, by means of the movement of a diaphragm, causes the whistle to sound. The signal pipe passing under all the cars has an upright branch pipe carried in some convenient location, such as beside the door. This upright pipe terminates in a car-discharge valve, which is operated by a light cord carried from one end of the car to the other. The opening of the car-discharge valve in any vehicle on the train for a brief interval allows air to escape from the signal pipe to the atmosphere, and this causes a wave of reduced pressure to travel through the signal pipe to the whistle valve and allows the diaphragm to lift a moment and air under pressure to blow out of the whistle, causing a clear sound of short duration. The stop cock at the last hose connection on the rear car must be closed as in the brake system, with free communication all through the rest of the train along the signal pipe.

197. What is the high-pressure control?

A. It is a modification of the engine equipment designed for use on railroads having heavy grades and for handling heavily loaded cars on down grades with a large volume of empty car mileage made in the opposite direction. By using the duplex governor, 90 or 110 pounds pressure can be had on the main reservoir according as one is cut in and the other cut out, also by the use of one of two train line feed valves a pressure of 70 or 90 pounds can be had in the brake pipe and auxiliary reservoirs, according as either is cut in. The brake power for freight cars is about 70 per cent of the light weight of the car, but when the cars are fully loaded this percentage becomes considerably less, and 90 pounds per square inch may be used quite safely on the heavier train with an increase power about 25 per cent. When a train of heavily loaded cars has been taken down a long grade or handled over a hilly division under 90 pounds pressure in auxiliary reservoir and brake pipe, the engine on the return trip handling empties may be made to operate brakes under 70 pounds brake pipe pressure, with economy of steam and air and reduction of wear and tear, as well as securing safe and adequate brake power in each case.

198. What is the automatic and straight air equipment?

A. This is a separate equipment applied to the engine and tender, and is useful on switching engines in yards because a triple valve will not fully recharge an auxiliary reservoir between very frequent applications. On freight trains the straight air equipment affords a means of taking up the slack between the cars by bunching the train up against the engine, and on long down grades it helps to retard the motion of the train when brakes have been released, with or without retaining valves in operation, and while the recharging of the auxiliary reservoirs is in progress.

The straight air equipment is arranged so that air for the engine and tender brake cylinders is taken from the main reservoir and is passed through a reducing valve set at 45 pounds and through a straight air brake valve before reaching them. There is also interposed on the pipe line leading to the brake cylinders a double check valve, the function of which is, when the straight air is used, to prevent air from discharging through the triple valve exhaust port, and when the ordinary automatic brake is used it prevents air from the auxiliary reservoir escaping through the straight air valve. There is also a safety valve on the brake cylinder pipe, which operates to blow off any surplus pressure in the brake cylinders of engine and tender in case the reducing valve should have become in any way deranged and should permit too high a presssure. The straight air equipment may be used on engine and tender or the regular automatic brake may be used, as occasion demands.

199. What is the Westinghouse "E T" Equipment?

A. This is the engine and tender equipment by which brakes on the engine and tender may be applied or released independently of the train brakes, or the train brakes may be applied or released independently of the engine brakes, or both engine and train brakes may be operated together. This arrangement enables the engineer to handle long trains very successfully, as the engine brakes may be set while train brakes are released, thus preventing undue shock and reducing the danger of breaking in two. The alternation of brakes on engine and train is advantageous on long

down grades, as the engine and tender brake, when applied, retards the train while the auxiliary reservoirs are being recharged. The danger of overheating the tires is also very much reduced by this arrangement.

200. What is the object of a brake test before a train starts from a terminal, and how is it made?

A. The object of the test is to ascertain for a certainty that everything connected with the air-brake and air-signal systems is in working order before the train starts, so that defects may be remedied and that the enginemen and train crew may be sure that the brake is absolutely reliable. The inspection of a passenger train is begun from the rear, the inspector noticing that the rear angle cock is shut. The inspector then opens the car-discharge valve on the last car four times, which gives four blasts on the air signal whistle in the cab. This is the signal, when the train is standing, to apply brakes if they are not set, and it proves that the signal system is in working order. After brakes have been applied the inspector comes forward along the train and observes that the brakes on each car are properly set and that there is no excessive piston travel or bad leaks in the brake pipe or hose couplings. On reaching the engine, the inspector opens the car-discharge valve on the forward car four times, when testing a passenger train, which blows the signal whistle in the cab. The engineer then releases brakes and the inspector should inform the engineer that the test has proved satisfactory.

In testing a freight train, after brakes are set, one brakeman should walk along the ground examining piston travel and looking for leaks. The other should go over the top of the train, beginning at the front end, and turn up the handles of the retaining valves. When the brakemen reach the back end of the train, the engineer should be signalled to release brakes, and both brakemen should start forward again; the one on top of the train, after having waited at least twenty seconds, should turn down the handles of the retaining valves; if there is a blow of air from the retaining valve after the handle is turned down, it is evidence that the valve is working properly. The man on the ground should see if the brakes release properly as soon as the retainers are turned down. A strict account of the cars upon which the retainers and the brakes are defective should be taken and a report made to the engineer and conductor, and any further information concerning the brakes, which the brakemen have been able to gain during the inspection, should be given to engineer and conductor while there is time to remedy defects.

The safety of life and property depends upon the proper working of the air brakes, and in brake handling, as in all other operations connected with train movement, nothing should be left in doubt. In modern railroad service, with all its manifold responsibilities, the careless or incompetent person is a menace to safety, and among the faithful and intelligent army of railroad employees the Chancetaker has no legitimate place.

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