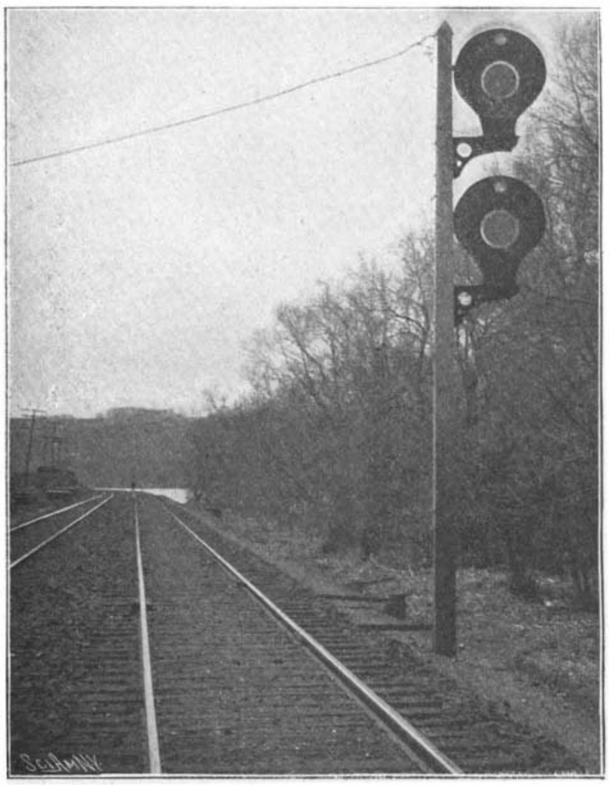
making a total engaged on track work and general labor connected therewith of 459,704 men. Carrying out our system of comparison with some standard of bulk, we have chosen the Park Row Building, New York, which has a total height of 390 feet. If this army of trackmen and laborers were combined in one typical giant, he would be some 385 feet in height and of proportionate weight and bulk. The next largest item is the machinists, of which there are 34,698, the carpenters, of which there are 48,946, and various other shopmen engaged in the repair and general maintenance of the rolling stock to the number of 120,550, making a total number of skilled and unskilled men in the railroad shops of 204,194. The next largest total is that of the station agents, baggage masters, porters, etc., there being 32,294 station agents and 94,847 baggage masters, porters, etc. Then follow the conductors and brakemen, 32,000 of the former and 84,493 of the latter. There are 92,458 enginemen and firemen, 45,292 of the former and 47,166 of the latter. Employed in the general offices of the various railroad companies, in performing the vast amount of clerical work required, there are 39,701 clerks, while sheltered under the same roof is a body of men upon whom as much as or more than any other in the whole army of railroad employes falls the responsibility of the safety of trains and passengers—the telegraph operators and dispatchers, of whom there are altogether 26,606. The smallest in number, but controlling the whole of this vast organization, are the general officers, presidents, vice-presidents, treasurers, secretaries, etc., of whom there are 4,780.



The upper disk is a red home signal; the lower is a distant signal, green. Both indicate that their respective sections are occupied.

Fig. 1.—Hall Automatic Block Signals on the Philadelphia and Reading Railroad.

MONEY VALUE.—Perhaps, after all, the most remarkable figures are those which show the total value of the railroad system of the United States, which expressed in figures is 13,308,029,032 dollars. If this sum were represented in ten-dollar gold pieces, and these pieces were set on edge, side by side, they would reach more than half way from New York to San Francisco, or 1,700 miles. Or were this coin melted and run into a single casting, it would form a column 15 feet in diameter and 259 feet in height.

Railroad Signals.

BLOCK AND INTERLOCKING SIGNALS.

BY B. B. ADAMS.

Signals have come during the last dozen years to be an important feature on many railroads, where, a short time ago, there were but scattered plants here and there. The great increase in traffic has necessitated the introduction of block signals to space fast trains; and at terminals, junctions and large yards interlocking signals are now necessary to celerity and safety, to say nothing of economy. Over 25,000 miles of American railroad are now worked by the block system, and the interlocking machines in yards and at crossings and drawbridges aggregate over 40,000 levers; and it may be remarked in passing that the next few years ought to witness the doubling of these figures. On about 4,000 miles of the 25,000 the signals are automatic, and the more recent installations of these signals embody numerous ingenious refinements in this class of machinery. There is a healthy rivalry between the makers of the different designs, so that within a hundred miles of New York one may see four or five different kinds of automatic signals. The automatic signal is a distinctively American development, the railroads of Europe having only recently begun to take an interest in it, and our illustration, Fig. 4, shows four signals in one of the latest installations—that on the Pennsylvania Railroad westward from Philadelphia. This is a four-track railroad, each track being used only for trains in a given direction.*

As the reader already knows, the essential feature of the automatic block signal is an electric current flowing through the rails of the track. The signal being at the entrance of a block section, which is, say, three-quarters of a mile long, the battery for the current is at the outgoing end; and when the rails of the track, throughout the section (and also the rails of side tracks and crossovers, so far as they foul the main track) are clear—not occupied by wheels at any point—the circuit of the battery is through the right-hand rail of the track to the electro-magnet at the signal, thence to the left-hand rail and by that back to the battery. This circuit being closed, the electro magnet at the signal is energized and holds the signal, through the medium of a stronger electro magnet, worked by a local battery, in the *all-clear* or go-ahead position. The entrance of a train short circuits the current through the wheels and axles, de-energizing the electro-magnet (relay); and the signal, by force of gravity, assumes the stop position, thus warning the next following train not to enter the section. The signal remains at "stop" until every pair of wheels has passed out of the section. The signals marked *A* 17 in the illustration Fig. 4 are for the two westbound tracks of a four-track railroad; those on the right-hand mast being for the right-hand or outer track, and those on the left-hand being for the inner track. The lower arm on each post is a distant or cautionary signal, informing the engineman of the position of the "home" or stop signal at the entrance of the next succeeding block section.* This provision is made for the purpose of avoiding loss of time during fogs, or whenever the engineman can not see a stop signal until he comes within a short distance of it. With the distant signal, he has notice about 4,000 feet before reaching a home signal whether or not he is to expect to a stopped by it; so that in spite of fog or darkness he may run as fast as he pleases,

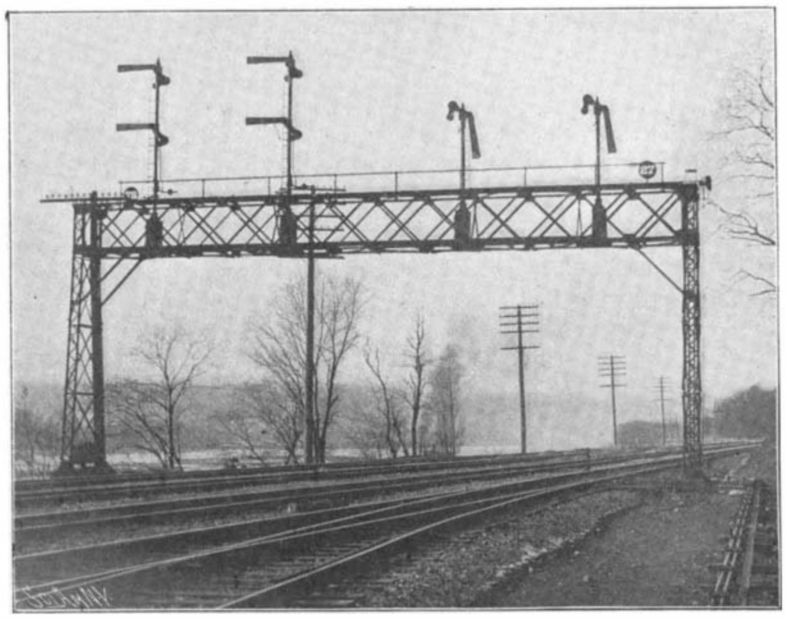


Fig. 2.—Grafton Three-position Automatic Block Signals on the Pittsburg, Fort Wayne and Chicago Railroad.

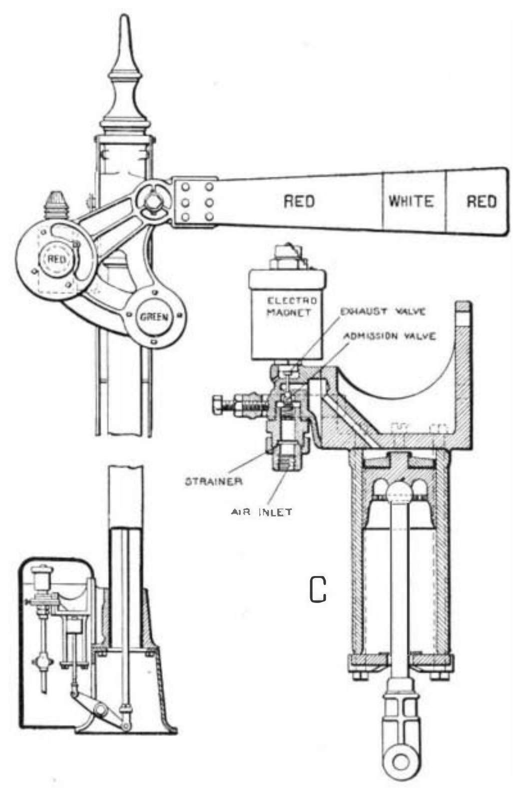


Fig. 3.—Details of Electro-Pneumatic Semaphore.

* The upper arm (home signal) on the right-hand mast is at "stop," protecting from following trains the train seen in the distance. The lower (distant) arm, being also horizontal, indicates that the home signal of the next succeeding block section may be expected to be found in the stop position. The arms on the left-hand mast are for the second track. Both of these indicate "all clear," showing that on that track the next two block sections are unoccupied. The signals at the extreme left of the photograph, which are for the two eastbound tracks, indicate that both those tracks are occupied in the section immediately ahead, and also in the one next beyond. The train on one of the tracks is seen in the illustration, the arm having assumed the stop position immediately after the first wheels of the engine passed the signal.

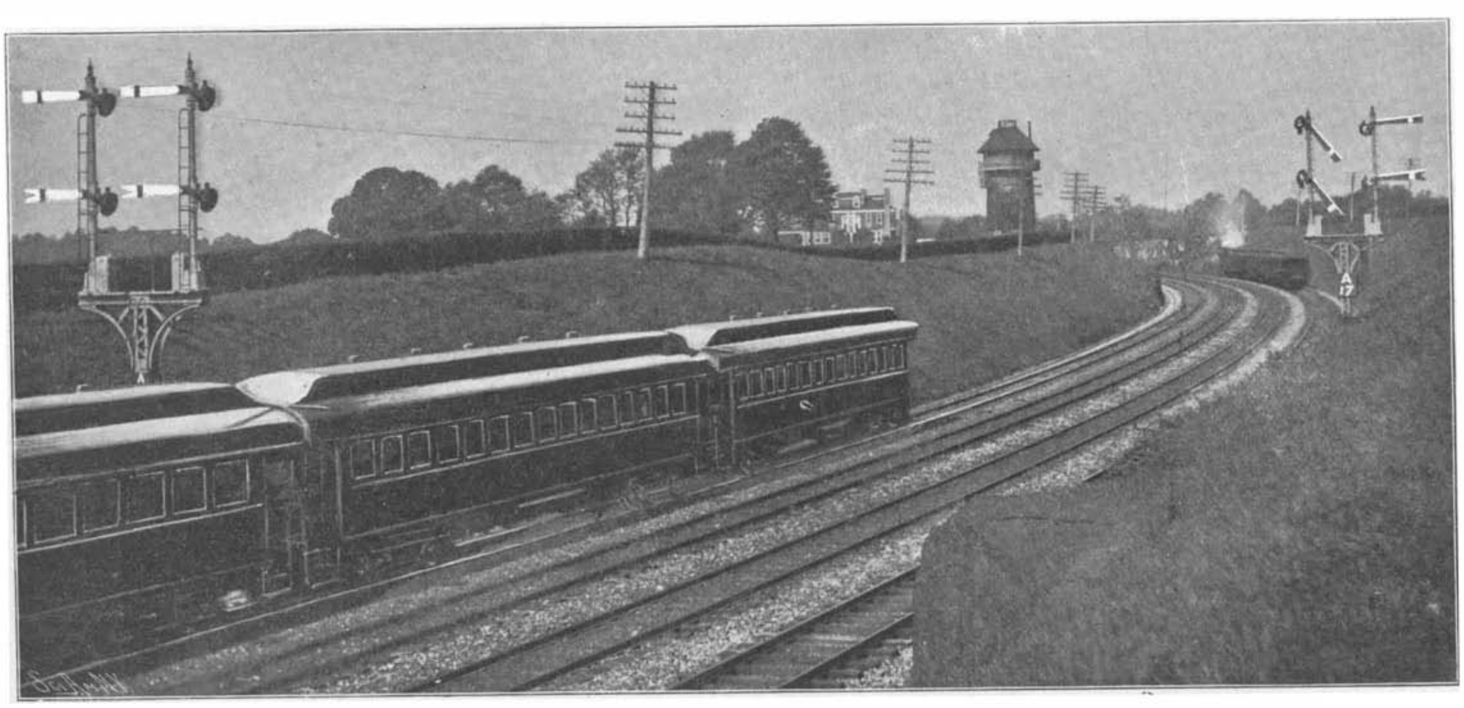


Fig. 4.—Westinghouse Electro-Pneumatic Semaphore Block Signals on the Pennsylvania Railroad.

BLOCK AND INTERLOCKING SIGNALS.

within a limit of a rate of speed which will permit him to stop within a distance of 4,000 feet. The distant signal is controlled by the movements of the corresponding "home" through the medium of a wire on poles; or, by means of a polarized relay, it can be controlled by the track circuit of the section between the home and its corresponding distant. This does away with the line wires and obviates certain disturbances by lightning.

Fig. 5.—Signal Cabin at the Grand Central Station, Chicago.

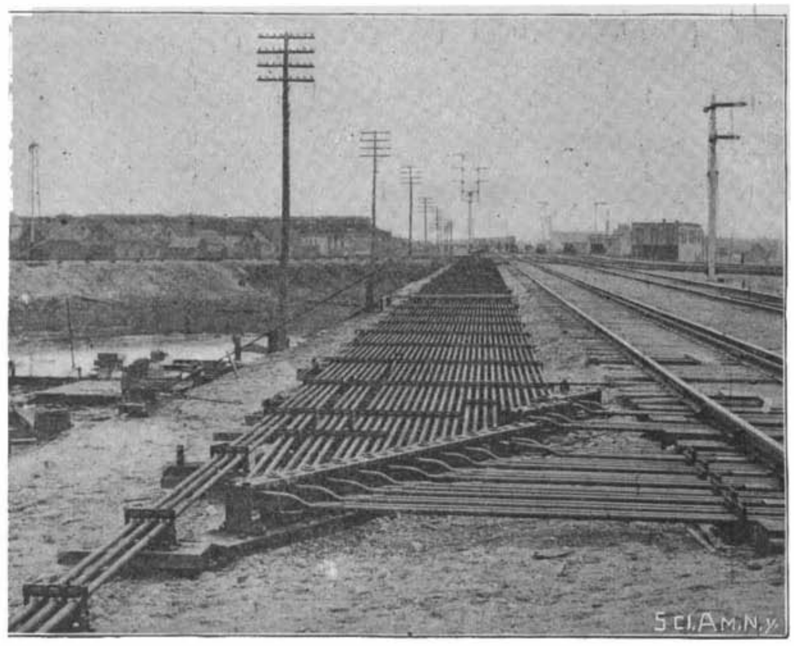
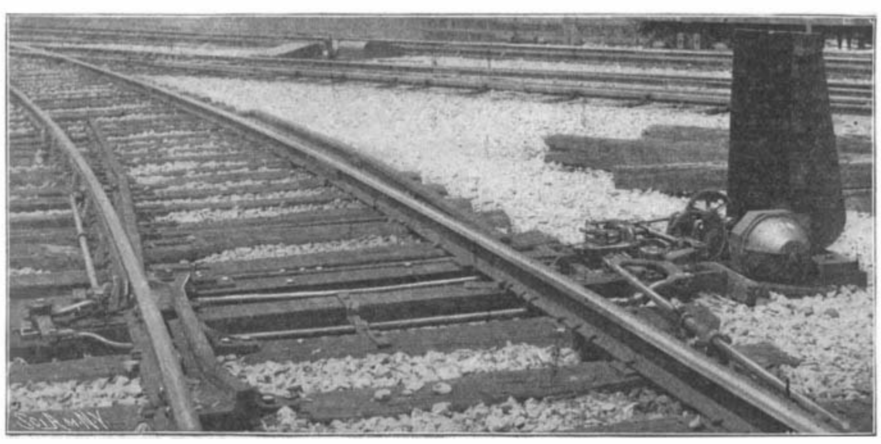


Fig. 6.—Connections from Cabin to Switches and Signals.

These signals are the Westinghouse electro-pneumatic; the power for moving the arm to the downward or all-clear position being compressed air, at about 70 pounds per square inch, acting through a cylinder fixed in an iron box at the foot of the mast. This cylinder is shown in section at *C*, Fig. 3. The pneumatic pressure is conveyed from a compressor to the several signals along the line, for a distance of 10 to 20 miles, by means of an iron pipe buried in the ground. As will be seen from the detail view, the air, entering the cylinder at its upper end, forces downward a piston which by its lever pushes up the signal rod (inside the cylindrical iron mast) and thereby moves the arm of the signal downward. On the release of the pressure from the cylinder, which occurs when a train enters the block section, the signal arm flies to the horizontal or stop position by gravity, the casting on its left-hand end, with the vertical rod within the post, furnisbing the weight to do this. An accidental failure of air would have the same effect, throwing the signal to the stop position, thus bringing to a stand any train which might come along, and compelling the engineman to report the cause of the failure, which the inspector then finds and removes. The construction of the electro-magnetic valve whereby the track circuit, when closed, keeps the cylinder *C* charged with air, will be understood from an inspection of the drawings. The de-energizing of this magnet, on the entrance of a train, is due to the fact that nearly all of the electric current flows from one rail to the other through the wheels and axles of the cars, as before explained. In Fig. 4 the lamps on the left-hand mast of signal *A* 17 show an uncolored ("white") light indicating at night "all clear." When the arm of a home signal assumes the horizontal or stop position a red glass comes in front of the light, giving the stop indication. On a number of prominent railroads the all-clear indication is now green instead of white; and in such cases the distant signal also shows green for all clear, while for the caution indication the distant is made to show, on some roads yellow, and on others a combination of red and green, a red light and a green light being fixed close together, side by side.



The switch in the illustration is a derailing switch. The detector bar is seen at the left of the left-hand rail.

Fig. 7.—Electric Motor for Switch.

The signal just described is the semaphore. This is the type most extensively used, because it is easily discernible under adverse conditions; but on a number of roads the disk is the favorite for automatic signals. Fig. 1 shows Hall automatic disk signals—a home and distant—on the Philadelphia & Reading. The Hall signal was the pioneer of its kind, and so well was it designed that those of the latest designs are substantially identical in their main features with those put up more than thirty years ago. The disk signal is worked wholly by the power of the electro-magnet, requiring no compressed air or other costly force. The disk, which is of silk or other light fabric, stretched on a ring, is balanced on a pivot and is controlled by the armature of the electro-magnet. In the engraving both disks are visible. The upper (home) indicating stop and the lower (distant) indicating caution. They remain in this position by force of gravity. The section of track covered by this home signal is now occupied by a train (beyond the curve). When this train clears the block section the energizing of the magnet lifts the disk so that it is concealed within the case, and its absence, showing the white interior of the case, indicates "all clear." As in all automatic signals, a failure of the electric current or the presence of a pair of wheels on the track within the section, withdrawing the current, will cause the stop signal to be displayed.

In Fig. 2 we see the three-position signal, which has found considerable favor during the past few years. In this arrangement the single arms serve both as home or positive signal and also as a distant or cautionary. For example, the one at the right, in the cut, when horizontal, indicates stop; when hanging downward at an angle of 45 deg. from the horizontal it indicates all clear for this section, but means also (the same as a distant signal) "be prepared to stop at the next signal;" when downward in a practically vertical position, as shown in the cut, it indicates all clear for its own section and also indicates (performing the function of the distant signal) all clear for the next succeeding block section.

These signals are worked by an electric motor fixed in the box at the foot of the post, a motor for each post. All of the motors along a stretch of 10 to 20 miles of line are actuated by energy from storage batteries, which are kept in wells sunk in the ground near the signal, and the batteries in turn are charged by a dynamo situated at a central point. The double copper feed-wire is strung on the telegraph poles. Signals moved by electric motors are now made by a number of different companies and are in use on half a dozen roads.

INTERLOCKING.

Block signals are noticed and appreciated by everybody, because their beneficent office in preventing collisions is at once understood; but interlocking is equally important in its sphere; and it is often a more direct money-saver. In a crowded yard the *concentration* of the switch and signal levers in one cabin saves innumerable steps and enables one man to do work formerly done by five or more; and the interlocking of one lever with any other lever in the same frame prevents this one man from becoming confused by the multiplicity of operations that he has to perform, and giving conflicting signals which would lead to a collision of trains; and the two—concentration and interlocking—are the advantages for which a railroad will spend from $25,000 to $200,000 at a large yard.

The most common form of interlocking is that in which the several switches are connected to levers in the cabin by rods (gas pipe) supported on rollers close to the ground. The levers moving these rods, perhaps twenty, fifty or a hundred in a single frame, are all mounted on the same axis. For signals (but not for switches) wires may take the place of the rods. The common types of interlocking are no doubt familiar to the reader. Fig. 6 shows a part of the "lead-out" and connections of a large plant in Chicago. Such large bodies of rods as that here shown are usually covered with wooden boxing, so that the yardmen will not stumble over them.

In crowded yards it often occurs that the space occupied by the signal rods is needed for tracks or buildings, and for this and other reasons compressed air and electricity have been introduced for working the switches and signals, the air pipes or electric wires being buried in the ground. The most familiar type of the power switch-and-signal machine is the electro-pneumatic, in which the functions are performed on the same general principles as with the block signals shown in Fig. 4; the signals of an interlocking plant being worked by pneumatic pressure as shown in Fig. 3. A cylinder for a switch is fixed horizontally on the sleepers at the side of the track. The completion of the movement of a switch is made to convey an electrical

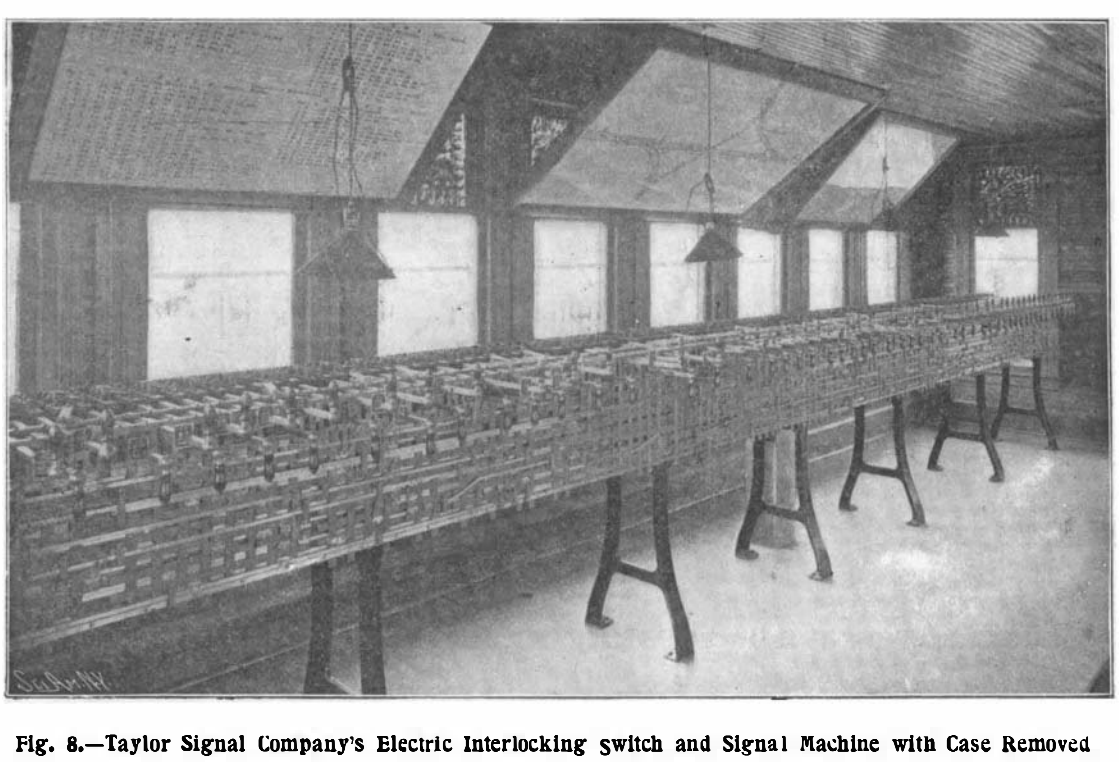


Fig. 8.—Taylor Signal Company's Electric Interlocking Switch and Signal Machine with Case Removed

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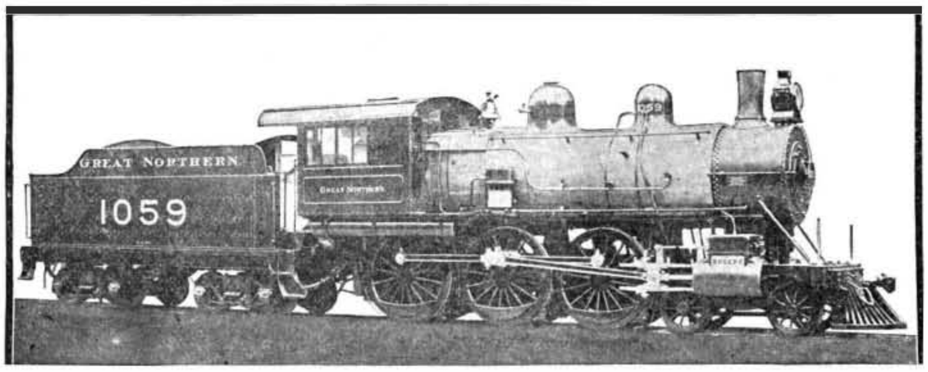

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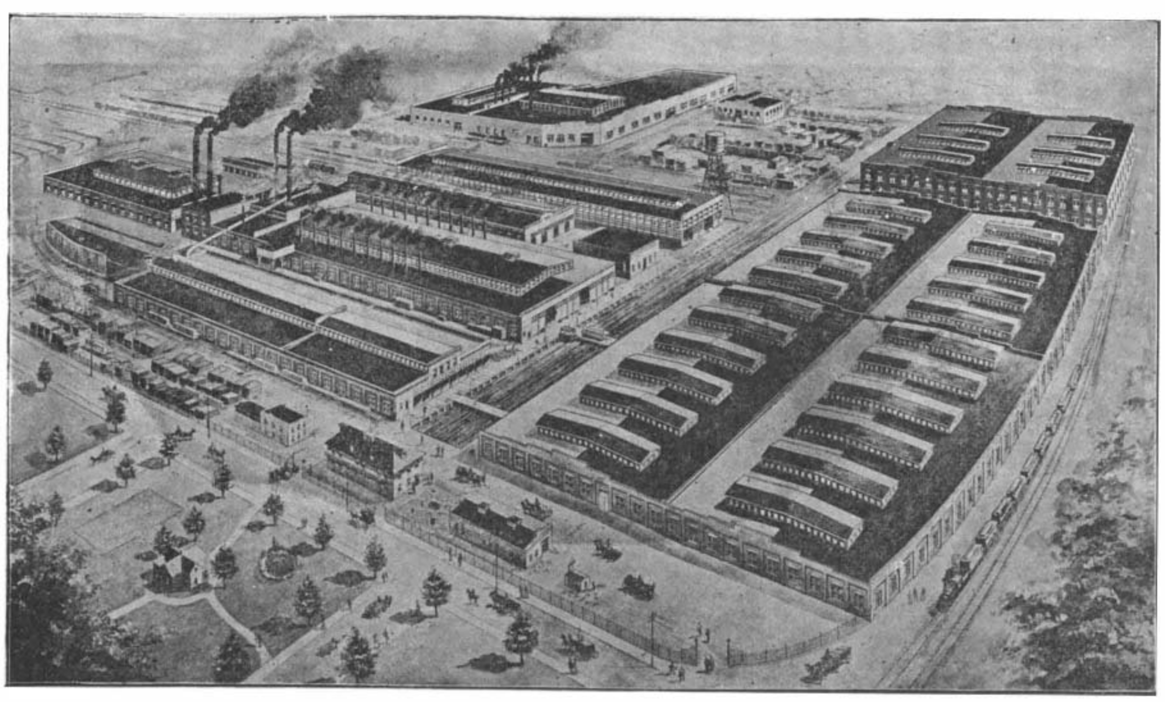

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"indication" to the cabin to insure that the go-ahead signal for that switch shall not be given prematurely. Besides the usual mechanical interlocking of one lever with another, the electro-pneumatic machine provides numerous additional safe-guards in the way of magnetic locks. With a power machine the work of the signalman is reduced from that of pulling levers, weighted with heavy loads, to the turning of the extremely light handles at the front of the machine. By these handles long horizontal rods are rotated on their axes, and these in their revolution close the electric circuits (thereby actuating the air valves) in proper sequence. The interlocking is effected by longitudinal and transverse rods at the top of the machine. In some machines a diagram of the yard is attached to the machine, and metal strips represent the tracks; and these are movable, so that every operation which takes place on the ground, by the act of the signalman, is repeated before his eyes in the cabin.

At the Grand Central station, in New York city, and at various other large yards, the switches and signals are worked by the low-pressure pneumatic system. With this no electric power is required, the electro-magnet at the operating cylinder being supplanted by a diaphragm valve. The air-valve—one at each signal cylinder and one at each end of each switch cylinder—is opened or closed by the movement of a circular flexible diaphragm, moved up or down a quarter of an inch, by air at a pressure of seven pounds per square inch conveyed in a half-inch pipe from the cabin.

In the operating pipes the pressure is 15 pounds per square inch. When a switch or signal is not in use, its operating pipes are under atmospheric pressure only. The interlocking is similar to that in other types of machine.

Fig. 5 shows the signal cabin containing a low-pressure ("all-air") switch and signal machine recently erected at the Harrison Street station, Chicago. The cabin is supported on the six metal columns, in the way shown, for the purpose of economizing ground room; one of the subordinate tracks of the yard occupying the space beneath the building. The air pipes, extending from the cabin to the ground and there branching to the various switches and signals, are seen in the center of the drawing.

The most recent development in the interlocking signal field is the "all-electric" system of the Taylor Signal Company, of Buffalo. In this system all the switches and signals are moved by small electric motors—a motor for each switch or signal; and the work of the signalman consists of opening or closing electric circuits. The interlocking is mechanical, as in the other types described, and is placed vertically on the front of the machine, as in the well-known Johnson type of mechanical interlocking. Extensive installations of this system have been made at Chicago, and in numerous other Western cities. Electric power is provided from a 60-volt storage battery, and as the current is required only while switches or signals are being moved, the consumption of power is small. A gasoline motor is usually used to run the generator to charge the storage battery. Fig. 7 shows a Taylor motor with the cover off. The connection at the right moves the detecter bar. The motor, through a suitable train of wheels, is made to revolve the large main gear one revolution for a single movement of the rails. The horizontal rod moving the rails receives its motion from a cam fixed to the main gear. When a switch movement is completed, the motor circuit is automatically broken and the motor at that moment is converted into a generator; and by its function as a generator, which lasts but a fraction of a second, it sends a current back to the cabin giving to the signalman the "indication" that the switch movement has been fully accomplished. For a single switch a 1 horse power motor is used, and for a signal a motor of 1-6 horse power. The dwarf signals (used for slow yard movements) are in the Taylor system moved by a pair of solenoids. The solenoids, fixed vertically at the bottom of the signal post, are energized by a current from the cabin and lift a vertical rod which forces the signal downward. In case of failure of any part, the rod is forced downward by a spring, throwing the signal arm up to the stop position.

COMPRESSED AIR AS A TRANSPORTATION AGENT.

BY WALDON FAWCETT.

With a more extensive use of compressed air for power purposes has come a corresponding broadening of the scope of its employment as a transportation agent, and indeed it has been conclusively proven that pneumatic traction has decided advantages over all other forms of mechanical haulage for a large variety of operations. Prominent among these are the various phases of underground haulage. For coal mines where there is danger from mine gas its utilization is almost essential, whereas the advantages which commend its employment in non-gaseous mines are almost as potent. A rather unique field has been opened by the introduction of compressed air locomotives in railway tunnels, where the smoke, vapor and gas from steam locomotives are objectionable.

For the ordinary compressed-air haulage plant there are five essential features, namely, the locomotives, constructed to carry stored-up energy in the shape of compressed air, a charging station, a stationary reservoir, usually consisting of one or more storage tanks in which the air is compressed, an air compressor capable of compressing any desired number of cubic feet per minute to any pressure desired, and power for operating the compressor, either steam or water power being applicable for this purpose. The compressed air locomotives now most generally used are made by the H. K. Porter Company, of Pittsburg, Pa.

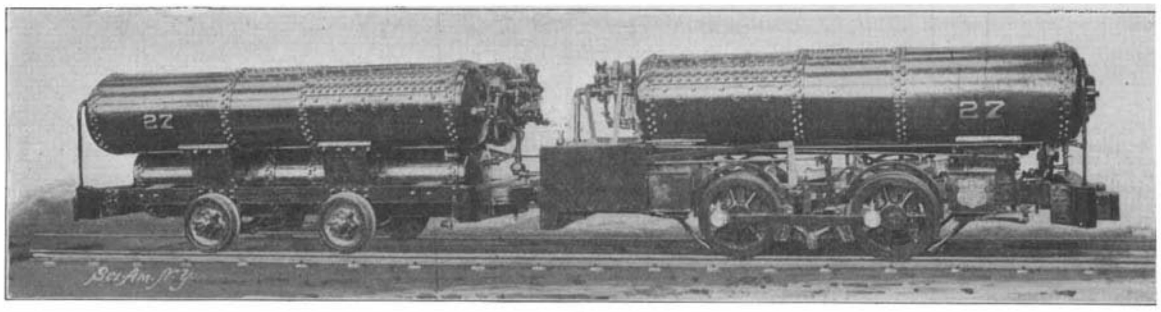
The general machinery of an air locomotive, cylinders, frames, wheels, etc., is usually very similar to that of a steam locomotive, save that the weight is greater, the bearings larger and the details of construction stronger than in a steam machine of the same power. The main points of difference are found in the fact that instead of the usual boiler with its fuel and water accessories for developing power, the air locomotive is equipped with one or more strongly constructed main storage tanks, which are charged with compressed air at high pressure, a combination regulator and automatic stop-valve and an auxiliary low-pressure reservoir in which the air is carried at a uniform working pressure for distribution to the cylinders. The cubic capacity and the pressure of air in the main storage tanks on a motor are determined, of course, by the amount of stored energy required by the length of the run which such a locomotive is to make and the weight of the train which it is called upon to draw. Not infrequently locomotives are built to carry an air pressure of 800 or 1,000 pounds, but relief valves make it impossible to charge the motor tanks to a higher pressure than is required. The initial storage pressure decreases, of course, while the locomotive is working. As illustrating the capabilities of the compressed air motors, it may be mentioned that there are in service in this country a few locomotives which are fitted with seamless steel tubes and carry a pressure of from 1,500 to 2,500 pounds per square inch.

The combination regulator and automatic stop-valve through which the high-pressure air passes from the main storage tank to the low-pressure or auxiliary reservoir is provided with mechanism which can be instantly adjusted for maintaining whatever pressure is found most economical in the operation of the motor. Ordinarily 140 pounds per square inch is satisfactory, but in case of an emergency, such as getting derailed cars on the track, the pressure may be increased by immediate adjustment to 150 or 160 pounds. Not only is the regulation of air between the high-pressure and low-pressure reservoirs automatic, but it is at all times uniform, the air being admitted as rapidly as it is needed and at the required pressure.

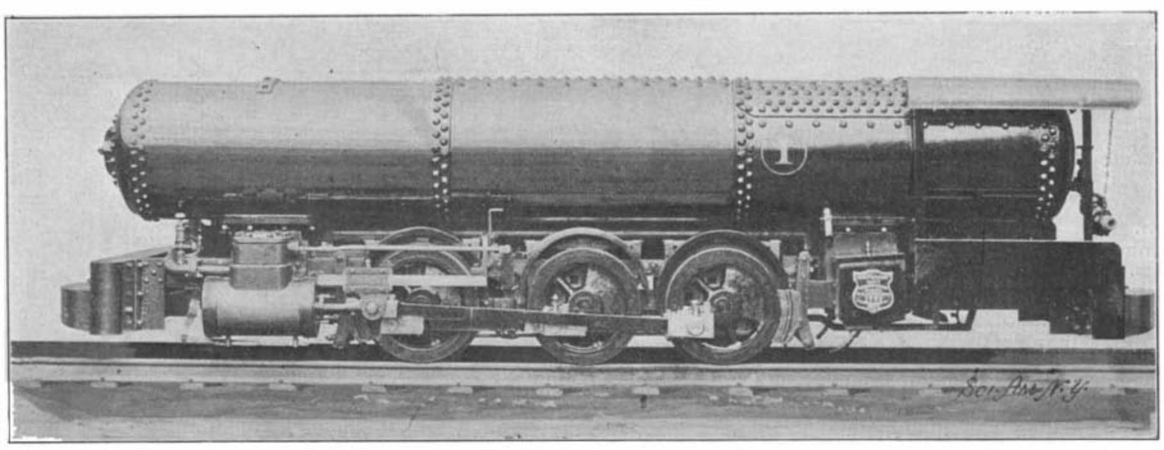
For charging the locomotive storage tanks previously referred to, there are provided the charging stations, which are connected with the stationary receiver or reservoir by a pipe. It is customary, when the reservoir or storage system is a pipe line, to have a charging station at each end of the line, so that the motor may take a charge of air at the end of each single trip or each round trip as required. Air locomotives may be charged either direct or by a reservoir. However, direct charging is very wasteful, and consequently the method most generally accepted involves the use of the stationary reservoir.

The reservoir for a compressed-air transportation line usually consists of either a pipe line or one or more storage tanks of construction similar to the locomotive storage tank, although usually designed to carry a somewhat higher pressure. By means of the reservoir system the compressor may be kept in nearly continuous operation at a fairly uniform speed. By an automatic system of governing the compressor, when the work is light, slows down in speed, whereas when the demand for air increases, the speed is quickly brought up to the required capacity.

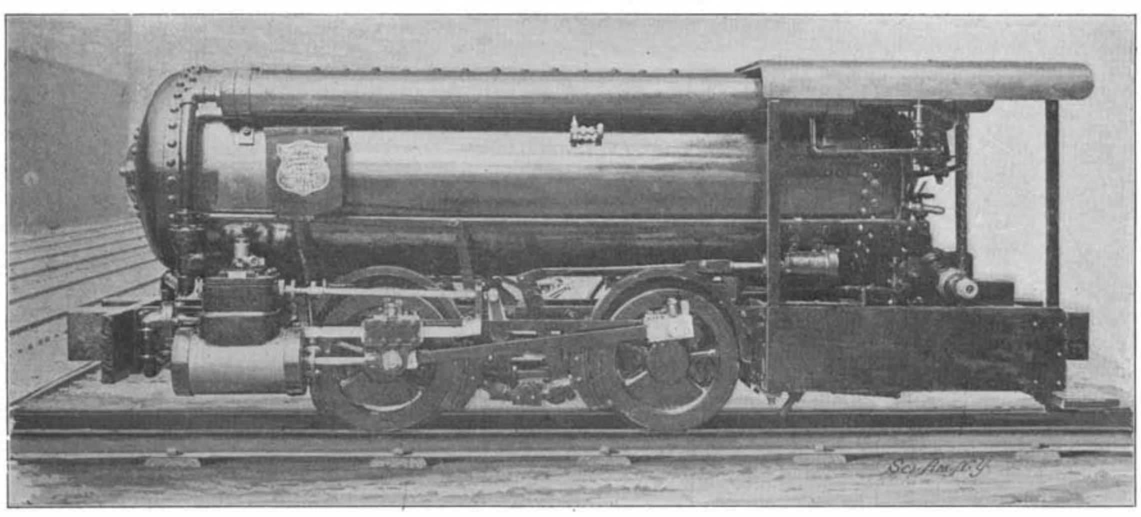
In a pneumatic street car the storage reservoirs are carried on the car trucks and occupy the space under the seats. The operating, brake and controller stands on the platform are very similar to the corresponding stands on an electric car. In the operation of the car, the air leaving the storage tank on the car passes through a reduction valve, where the pressure is reduced from 2,000 pounds to a working pressure of 150 pounds. It then passes into and through the water in the heater, where it takes up the moisture and heat of which it was robbed after compression and before the air was permitted to enter the station storage tanks. This is the principle that was employed on the cars experimented with on the Metropolitan system, New York. In ordinary service an air car weighing somewhat less than 10 tons will consume 400 cubic feet of free air per car mile, and in some classes of service the consumption is double that.



Pneumatic Locomotive.



Locomotive Driven by Compressed Air.



A Compressed Air Locomotive.

COMPRESSED AIR AS A TRANSPORTATION AGENT.