understood that either of these would instantly respond to every vibration; but by the introduction of an auxiliary spring, at the end of the tube, this is absolutely prevented, and the perfected gauge is the result.

VALVE THAT MEANS SAFETY.

The second device, the "safety valve," is a valve which opens automatically to relieve the boiler of the excess of steam pressure. When boilers were first used to generate steam the danger of over-pressure was soon, and often fatally, demonstrated; therefore, a lever, on which was attached a weight, the latter so adjusted that, when a certain pressure existed in a boiler the valve would automatically open, thus relieving the boiler of the excess of steam pressure, and closing when the boiler was relieved, was devised. It was discovered, when the earlier locomotives were built, that this "ball and lever" safety valve could not be used thereon, owing to their jarring, vibratory motion, and, so, many devices were tried, in order that one might be found which could be successfully applied. Spring loaded valves were tried without success, the trouble with them being that, when these valves opened out to the excess pressure of the boilers, they would stay open and not "seat," automatically, when the pressure had fallen to the "popping" point, the point just below that at which they are opened. This difficulty was finally overcome by George W. Richardson, who devised a spring loaded safety valve fitted with an adjustable ring, which formed a "huddling" chamber—chamber where the steam is collected—above the valve seat, so that, when the pressure in the boiler was sufficient to raise the valve from its seat, the steam pressure was exerted upon an increased area in the huddling chamber, thus causing the valve to raise further from its seat and give the required relief; and when, by this action, the boiler was relieved, this "Richardson Spring Loaded Safety Valve" would promptly seat within two or three pounds of the pressure at which it would "blow"—emit steam. Richardson not only made this spring loaded pop safety valve—in "plain United States," a safety valve in which a large area is suddenly opened for the discharge of steam—a success, but he made it possible to use a spring loaded safety valve on a locomotive. (The Consolidated Pop Safety Valve is the successor of the Richardson safety valve, it may be explained.) While various improvements have been made in construction, the valves are all operated upon the principle laid down by Richardson.

In the earlier safety valves the escaping steam caused a great deal of noise; the makers, realizing this, began fitting their safety valves—for locomotives—with "mufflers," devices to render noiseless the escape of steam, and to-day a railroad engine fitted with Consolidated Locomotive Pop Safety Valves will relieve the largest and most powerful locomotive boiler carrying the highest steam pressure while standing in a station, without annoyance to passengers or bystanders.

FEEDING WATER TO BOILER.

The third device is the inspirator, a variety of injector for steam boilers, in which a jet of steam raises the water from the tender and supplies it to another steam jet, which delivers it under pressure to the boiler. Locomotives were originally fitted with pumps, which were attached to and operated from the "cross head." It was possible to use these pumps with those locomotives, for they were run at slow speed; but as speed increased it was found impossible to operate them. With the invention of the injector this problem was solved. The early injectors—as originally designed by Giffard—were operated under then conditions of steam pressures, but as the steam pressure was still further increased, to meet more modern demands, it became necessary to have an improved form. In 1876 John Hancock, of Boston, conceived the idea of the double injector, which he called the Hancock Inspirator, and which comprises a set of tubes, or nozzles, which lifts or draws the water from the tender, and delivers it to a second set, which, in turn, forces the water into the boiler, as described. This inspirator will operate from the lowest to the highest steam pressure, and is capable of feeding water into the boiler under any and all conditions—under light or heavy service, with high or low steam pressure.

Many difficulties have been experienced with high speed locomotives in securing the proper appliances to be used in connection with these inspirators, particularly check valves—valves through which the water can pass only one way; the failure of these to operate properly would cause the inspirator to fail—and unless the latter is able to do its work the engineer is forced to stop his engine. The Hancock Inspirator Company has brought out many forms of safety check valves, and other devices, that have completely obviated this. With its present inspirator—and its auxiliary devices—proper "water feeding," for locomotives, has been made possible.

WHY "THE MACHINE NATION."

It is interesting to note that the steam gauge, the coil spring safety valve and the inspirator, or injector—the devices which largely make that terrible embodiment of explosive power, the present locomotive, possible and safe to handle—were all invented in Boston, that greater centre of manufacturing, and, also, that the plants that first turned them out have remained in New England to this day.

It is said that the class of workmen employed in these different plants—the which are now all owned and controlled by the great Manning, Maxwell & Moore corporation—is very high; and that, during the long lives of these three manufacturing concerns, there has never been the slightest trouble between the employes and their employers. Also that many of the employes of the Hancock Inspirator Company have sons who have gone to different technical colleges, and that some of them are themselves graduates of such institutions as the Boston School of Technology; and that this, too, is true of the workmen at the plants of the Consolidated Safety Valve Company and the Ashcroft Manufacturing Company, at Bridgeport, Conn. It may be remarked that it is just such conditions as these that have had most to do with our wearing of the championship colors in the manufacturing field.

THE AUTOMATIC TRAIN STOP.

Regarding the automatic train-stop: It has, for many years, been recognized that it would be advantageous to have some attachment connected with the danger signal in such a way that a train should be stopped automatically in case the engineer ran past it. The many objections to the use of such an attachment, in general railroad service, have, up to the present time, prevented its adoption, except in a few very special cases. These objections to its general use remain as strong as ever in the minds of the great majority of intelligent and discriminating railroad officials. In certain cases, where the tracks are well protected from weather, etc., and where the traffic is only of one sort and the conditions of its movement are simple and uniform, it has been found practicable to use an automatic stop by which brakes are arbitrarily applied without the intervention of the motorman or engineer in case the danger signal is passed. It may be added that the gradual extension of these stops into a wider field is a matter receiving earnest attention from railroad officials, and that it is quite possible that experiments will be made with them on the steam railroads; but up to the present time their use has been confined to three or four roads of heavy traffic operated entirely by electricity, and on the tracks of which it is possible to give the mechanism the necessary protection.

The outcry for the instant installation—on all the roads of the country—of "stop" and block signal systems has probably been more insistent than for any of the other safeguards; and these, too, have been made in utter ignorance of the situation in that field. The fact that it has only been installed upon about one-fifth of the railroad mileage of the country is largely due to the fact that block signalling has not been tried out like the air brake, the automatic coupler and the heating methods, and that it is to-day in a state of rapid evolution; for which reason it is not to be wondered at that the railroads have gone about its adoption slowly and cautiously. Indeed, to the suggested legislation on the subject, the objection that any attempt at specific legal restrictions, or requirements, would be based on transitory conditions, and often, probably, on mechanical errors, has been urged by the maker of the system most extensively used in this country. He might have added another, viz., such legislation; this would likely inspire with pernicious activity an array of irresponsible producers of impracticable devices—similar to the army of tinsmiths who for so long a time hindered the true development of the acetylene gas generator, and made life a burden to the competent and adequately equipped makers thereof—which would work an injury to the entire safety appliance trade, to the roads and to the public generally. The latter does not seem to understand that accidents cost the roads more, as regards property loss, than any one else; that they, together with the most thoroughly experienced and equipped manufacturers, instantly bring to bear upon them, in order to prevent their recurrence, the best professional talent and the highest technical skill the whole world can produce, as is shown elsewhere in this article.

It may be well to reinforce this statement with the opinion, expressed by one prominent in the management of the concern which turns out perhaps the best known safety appliance in the world to the effect that, "Existing laws on the subject—those in relation to the train brake, automatic coupler and safety car heating—are all right, for the few laggards should very properly be coerced; but we should not dare legislate anything which has not been proven on to the roads." He is also authority for the statement that "The roads are very diligent in installing approved safety appliances." The conviction, then, must impress itself that in railroad safeguards, for whatever improvement—at least, in the present fields of endeavor—is to be expected, we must look to those great establishments, those foster brothers of the vast railroad corporations, that—through a process of co-evolution—have almost become part and parcel of them; that have gained under their ægis all there is of practical insight into the physical needs and limitations of the roads, and that are in possession of all there is of technical knowledge and mechanical skill, of the plants for utilizing such resources to the fullest, and of the data, derived from extended practical experience, innumerable experiments and exhaustive tests, and which go to make up the authentic history of the art—in other words, that have the general and qualitative equipment in men, machinery and means that fit them, and above all others, for their several missions. Nor does this mean that the "door of opportunity" is to be closed to other aspirants—far from it, for the broadminded men at the helms of these concerns are ever ready to listen to and encourage the real inventor, as they also are to afford the meritorious invention the chance that may lead to its adoption. This, however, is well known, as is also the fact that they are the possessors of the peculiar all-round mechanical equipment, and of the other especial facilities and resources, which will best give form to the invention and insure for it proper and satisfactory tests. How well known all this is may be gathered from the statement of one of these principals, who has spent many years winnowing the grain of effective from the husks of abortive invention, saying: "It is my principle never to turn down an inventor arbitrarily, without giving his invention as reasonable consideration as limitations of time and skill will permit," he plaintively deprecates the fact that "I make myself a great nuisance to our engineers in that way, and have caused them to waste

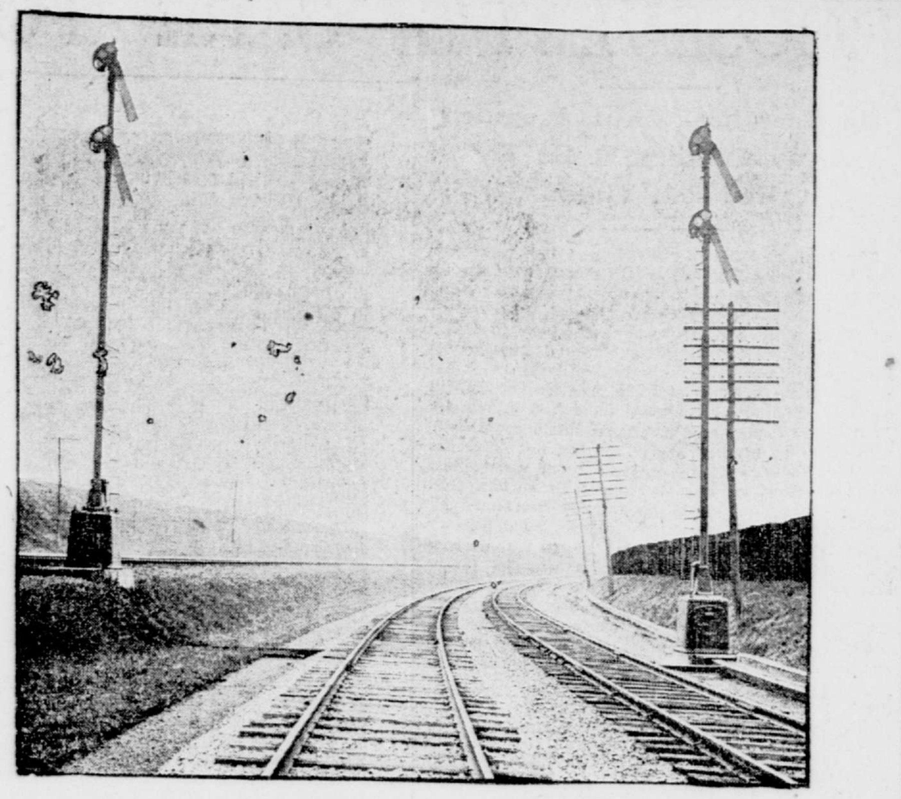


FIG. 2—"AUTO SIGNALS OF THE ELECTRO-PNEUMATIC TYPE."

many hours by such examinations." It may be added that, contrary to popular belief, these establishments are not merely huge manufacturing plants; they are largely "experiment stations."

THE POWER TRAIN-BRAKE.

The methods of the Westinghouse Air Brake Company, the big plant of which employs about thirty-five hundred men, aptly illustrate the foregoing. It is located in the town of Wilmerding, which has a population of approximately ten thousand, largely made up of the employes of the air brake company. Its staff of experts is said to practically include every one who is most familiar with the subject of brakes in this country; it has done nearly all of the brake business, at least 75 per cent of the brakes in use in this country being of the Westinghouse type; all in use here are built upon standards prescribed by the Master Car Builders' Association and based upon the performance of the Westinghouse brakes; and this company has been the source of every real improvement and advance made in the art of power braking. As a result of these peculiar conditions it can be safely said that every brake invention of merit is submitted to the Westinghouse Air Brake Company, and is acquired by them if it possesses any intrinsic merit or the possibility of future development. It, therefore, seems safe to assume that the Westinghouse company must be regarded as the source of continued advance in the art of train braking. The following will give an idea of the vast and increasing popularity of its product:

STATEMENT SHOWING NUMBER OF WESTINGHOUSE PASSENGER AND FREIGHT BRAKES SUPPLIED UP TO DECEMBER 31, 1896, AND EACH YEAR SINCE.

	Freight.	Passenger.	Total.
To December 31, 1896	486,825	48,302	535,127
1897	91,792	552	92,344
1898	168,447	967	169,414
1899	193,486	1,484	194,970
1900	163,368	1,452	164,820
1901	147,821	2,184	150,005
1902	171,451	2,730	174,181
1903	113,402	2,894	115,296
1904	68,695	1,524	70,219
1905	161,656	2,038	163,694
1906	192,283	2,118	194,401
Totals	1,959,226	66,245	2,025,471

It should be explained that none of the safety devices and appliances, as they are in use to-day, sprang "full panoplied" into existence; for example, while the "Westinghouse air brake" is known wherever a rail has been laid, few may be aware of the fact that, though in certain essentials it is the same device with which George Westinghouse revolutionized train operation, nearly forty years ago—it was first used on the Pittsburg & St. Louis ("Panhandle") Railroad, on the "accommodation" between Pittsburg and Steubenville, in the year of its invention, 1869—it is as far ahead of the original as are the wonderful achievements of the locomotive builders of to-day of the first railroad engine. Nevertheless, the performances of that first air brake were so satisfactory that its introduction in the passenger service of the various railroads almost immediately followed.

The ceaseless vigilance, the patient endeavor, the amount of technical skill and knowledge, as well as the high purpose, brought to bear upon the evolution of the safety appliance are strikingly shown in the history of the Westinghouse brake; and it will well repay reading, if only for the reassurance, the sense of security in travel that the mere knowing of such an ever present protection will impart.

Since its organization the Westinghouse Air Brake Company has employed a large corps of inspectors, the sole duty of which has been to observe the brakes in actual service, and to co-operate with the railroads in securing the best possible care for and performance of brake apparatus. One of its duties is to personally investigate every reported brake failure of any importance; and, in this connection, it may be said that such a thing as a failure of the brake mechanism to perform its intended functions is almost unknown—at most, failures are so few that they may not be intelligently expressed by percentage, nor can those associated with it from its introduction recall a dozen instances—in fact, the railroad men no longer give credence to statements of that character, that are sometimes made by employes in excuse for their own dereliction. (The reader must not imagine that the brake apparatus is in any way responsible for the class of accidents so frequently reported, of late, as attributable to the "falling brake beam," for it has nothing to do with the latter, which is a part of the car structure proper.) The information obtained through this system has been the greatest aid in identifying the need for, and in the perfecting of, new brake devices.

THE EARLIER AIR BRAKES.

First came the "straight air," which had on the locomotive its compressor and reservoir, from which the air was forced, at the will of the engineers, through the "train (conducting) pipe" of each car and through the lengths of hose that coupled it from car to car, to apply the brake-shoes. Its shortcomings were that, the perishable rubber hose was likely to burst, and so render it inoperative; and that, in the case of a parted train, the half to rearward of the point of separation was left without braking power.

The men employed to set brakes by hand were highly efficient, but the air brake, when introduced, could stop a train in one-third the distance required by the best of them. In addition to contributing a greater element of safety, it materially facilitated the movement of passenger trains, for it placed their entire control, both with respect to starting and stopping, and, for the first time, in the hands of the engineers.

Then followed (1873) the "automatic brake," which, in addition to having a main reservoir on the locomotive, had an auxiliary storage reservoir on each car; it also reversed the actuating process of the "straight air," in that the train pipe was kept filled with air and applied the brakes when the air was permitted to escape, or when it escaped through "parting" accident to train. It was quicker and more efficient than the "straight air"; could be operated on either section of a parted train, and put the possible application of the brakes in the hands of train crew, and passengers, instead of leaving the entire brake control with the engineer.

"AUTOMATIC" ON FREIGHT TRAINS.

The successful performance of the automatic brake, on passenger trains, suggested to some of the Rocky Mountain railroads the advantages that would be derived by its use on freight trains, particularly on account of the very heavy gradients of the many miles over which their traffic was moved. At this period—about 1883, or 1884—there was practically no interchange of freight cars in transcontinental traffic, all freight being transferred from the cars of Eastern lines to those running to the Pacific Coast. This rendered it possible to make a practical determination as to the availability and economy of using the automatic air brake in such service; and the early experiments were so highly satisfactory that, by 1886, it practically controlled, in place of hand brakes, all of the freight traffic of the Trans-Missouri railroads.

The rapid increase of railway traffic at this period drew attention to this successful experiment, and resulted in the gradual creation of a sentiment that it would be highly advantageous to control all freight trains by power brakes. While, however, their operation on the Pacific roads was so satisfactory, many believed the conditions of the latter peculiar to them, and that before determining upon some standard of apparatus—the which was essential to its general employment—experiments should be made to determine whether or not the air brakes as then operated were the best that could be devised. The matter was placed in the hands of the Master Car Builders' Association for examination and tests, and under its auspices were made what are known as "the Burlington trials," in which the automatic air brake and several other types were thoroughly tested, in order to determine which of all the various plans proposed was the most satisfactory, and which—if any—they would be justified in recommending as standard for general use.

Of the various brakes tested, the performance of the automatic air brake, such as was used on the Pacific Coast, was by far the most satisfactory; but the committee reported that even it did not meet all of the essential requirements of the entire country's freight service. As a matter of fact, the experiments of the Western roads had been upon trains of from twenty to thirty cars, while the tests at Burlington were made with those of fifty cars, which then represented the maximum length used in freight service. In these tests the performance of the automatic was entirely satisfactory for all ordinary service, but when applied in emergency the forward brakes went on so much more quickly, and with so much greater force, than those upon the rear of the train as to cause highly objectionable, and, under certain conditions, destructive shocks—the rear portion, weakly braked, running into the front portion. The committee, therefore, recommended that further tests be made, to give the inventors opportunity to overcome the defects—then revealed for the first time—in connection with long train operations, and arranged to test the improvements the following year.

THE QUICK ACTION AUTOMATIC.

As a result of the 1886 Burlington experiments, what is known as the Quick Action Automatic Brake was invented, by means of which the rapidity of serial action in emergency applications—as compared with the automatic brake—was greatly increased, so that the difference of time of application between the first and last car of a fifty-car train was so slight as to entirely eliminate objectionable shocks and collisions. A material gain in power was coincidently obtained.

The distinctive feature of operative difference between the quick-acting brake and the automatic brake resides wholly in "emergency application"—the application that is made to produce the quickest possible stop. With the automatic brake this is accomplished by the quickest possible reduction of pressure in the train pipe, which is made by opening wide (upon the locomotive) the communication between train pipe and atmosphere, thus permitting the air in the train pipe finally to become completely exhausted. It will, however, be obvious that on a train of fifty cars—nearly one-third of a mile long—it will take considerable time to discharge all of the air from such length of pipe, with consequent tardy brake application; and this was the objection to the automatic brake in emergency applications under such conditions. This difficulty was overcome in the quick action automatic.

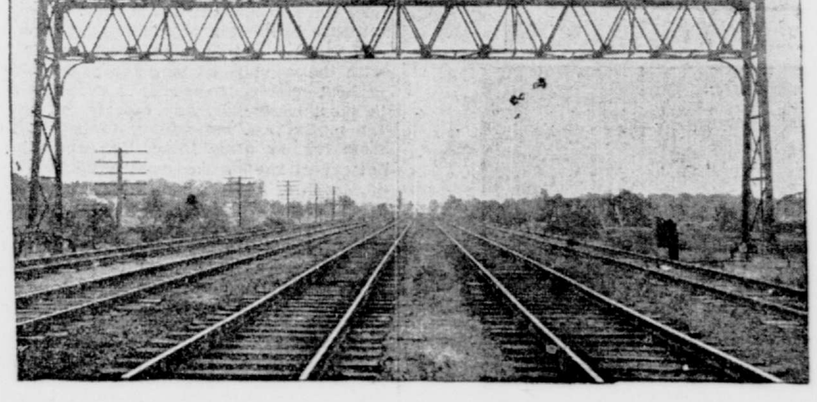


FIG. 3—"AUTO SIGNALS, CONTROLLING FOUR TRACKS, AS PLACED ON A BRIDGE."

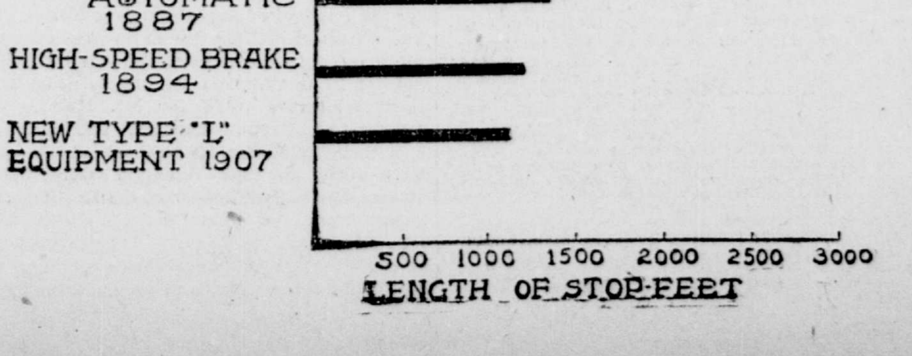
About the time these experiments had been going on, there had been finally perfected the type of automatic car-coupler now known as the "Master Car Builder's Standard," and the one that is universally used by all railroads. It was a marked improvement upon the "link and pin" type heretofore employed, both because of its greater strength and of its automatic character, which materially reduced liability of accidents to trainmen in their operation. At this date (1884), there was a great and humane call for improved coupling and brake appliances, to prevent the great loss of life and the many injuries to employes resulting from braking and coupling trains by hand; but it was obvious that, to make any practical headway in the desired direction, a general agreement was required among all railroads as to certain essential features to be standardized, for, to become useful and effective, these devices must necessarily be capable of interchangeability in mode of operation, and largely so as to construction. As there is no common ownership of railway equipment, it was not an easy matter to propose a form of such construction that would be universally acceptable. Finally, however, the testimony in favor of the automatic coupling and the quick acting brake became so pronounced that the use of them was generally accepted as a solution of the problems for which they were intended; and, as a direct result of these practical demonstrations, the important legislation known as the Safety Appliance act, was enacted, by the Congress, in 1893. It required the use, by all the railroads in the country, of automatic air brakes, and of automatic car couplers, of types that will interchange with each other. It should be noted that this legislation did not precede, but followed, the practical recognition, by railroads, of the necessity for these devices; and, also, that it was made effective only by virtue of the fact that the railroads were sufficiently broad minded, and self-interested, to take such action as would make this elemental act efficient—by providing certain standards for adoption. Reasonable time was given by the government for the application of these safety devices, and, at this date, practically all of the freight cars of this country are now supplied with automatic couplers and quick acting air brakes, the latter being of the standard type determined by the Burlington experiments.

THE HIGH SPEED BRAKE.

The greater efficiency of the quick acting brake, as compared with the automatic, led to its very general application to the passenger equipment of the country, and it remained the standard for that service up to within a few years, at which time there was perfected, and applied to passenger equipment, the High Speed Brake. As its name indicates, this was the outgrowth—and its first application was made to some—of the especially high speed trains which came in vogue with the advent of the Empire State Express. The necessity for something of this kind is apparent when it is remembered that—not double, but—four times the distance is required in which to stop a train at forty miles, as compared with twenty miles an hour, with the same braking force. In other words, the distance in which a train can be stopped is as the square of the speed, and not directly as the speed.

Speaking in general terms, the increased efficiency of this high speed brake as compared with the quick acting brake was from 20 per cent to 25 per cent. Within the last few years this type has been fitted to all of the fast passenger trains, and many roads use it upon all passenger equipment.

CHART SHOWING APPROXIMATELY THE REDUCTION OF DISTANCE REQUIRED IN WHICH TO STOP A TRAIN OF LOCOMOTIVE AND SIX CARS FROM A SPEED OF 60 MILES PER HOUR SINCE THE INTRODUCTION OF THE WESTINGHOUSE AIR BRAKE. "PLUS" MEANS DISTANCE INDEFINITE.



THE QUICK SERVICE BRAKE.

It will be remembered that the improvement in the automatic brake which led to its general adoption on freight trains was wholly confined to the "emergency application" feature, the other functions of the brake, such as are most frequently used in regular service, being satisfactorily performed in the same manner as by the first automatic type. It will also be recalled that the basis of a satisfactory performance for a freight brake was the experiments with the fifty-car trains (at Burlington), which at that time were considered to represent the maximum length. The improved condition of the railroads and the great increase in the power of locomotives have, however, led to the operation of much longer and heavier trains, so that now seventy, eighty and even one hundred cars are not infrequently found to be advantageously employed. With this lengthening the limitations of the automatic brake, in service work, were found; and it became apparent that some improvement in the direction of securing rapid serial application there, as well as in emergency applications, was a necessity of satisfactory brake operation. After a series of expensive experiments with long trains, in actual service, extending over a period of two years, there was finally perfected the latest form, which is called the Quick Service Brake, because of its capacity for rapid serial application in both "service" and "emergency applications." The result is obtained by substantially the means described in connection with quick acting brakes; with the new device brakes can be applied, in "service," more quickly on a hundred-car train than upon a fifty-car train with the automatic type, and the brakes are also applied with substantially equal force on the first and last cars of a long train—which was not the case with the automatic brake, those upon the front portion being applied with somewhat greater force than those upon the rear.

As already stated, changes in brake apparatus must be made without injury to the large investment made in the brakes with which all of the passenger and freight cars of this country—England and the Continent have brakes on but few of the latter, though they use them on practically all of the former—are fitted; this new improvement meets this requirement. Brakes of this kind can be converted to the new type at a comparatively moderate cost, when they require general repairs. In regular service work the new brake will stop a long train in about half the distance required with brakes now generally used; and, with it, there is a marked reduction in the consumption of air.

NEW BRAKE YET UNNAMED.

As a result of these expensive experiments, there has also been designed a new type of passenger car brake, as yet unchristened, which has an (approximately) increased efficiency of 15 per cent., as compared with the high speed brake, together with features of flexible operation that will add very material smoothness and ease of stoppage.

While the successive named styles of air brake described represent what may be termed the well defined cycles, a host of minor advances have marked its gradual evolution; a fact that is emphasized by the two thousand or more patents that cover "the Westinghouse." It is said to cost the roads about $125 to equip (with it) a passenger and $30 a freight car, but as the power train-brake eliminates at least 50 per cent. on the first, and 25 per cent. on the latter, of the train crew required in the days of the hand brake, the expense is more than offset; though, of course, this is the least consideration, for the vast saving of life, limb, and property would make it cheap at any price. One such achievement as the following, however simply told, will indelibly fix that conviction; and, therefore, it is given, without any attempt at heightening its effect—the happening is sufficiently hair-raising in itself—through word painting, and in the straightforward language of the formal report:

A WESTINGHOUSE BRAKE FEAT.

"Relative to the accident to one of the important express trains of the Jersey Central on August 4, I am handing you herewith a pencil sketch showing the bridge on which the derailment occurred. The train in question ordinarily consists of an engine and three cars, but on the date of the accident it was handling an extra baggage car, also an extra parlor car. It left Atlantic City on time at 8:30 a. m. and was due in New York three hours later. The distance of 135.4 miles between the former point and Jersey City is made in two hours and forty-nine minutes, making five regular station stops, two flag stops and frequently a number of deadhead stops for bridges, etc., which will give you an idea of the running time of this train. After stopping at Elizabethport on the day in question to unload passengers and baggage, the train proceeded, a few minutes late. It was running on track No. 1 over the Newark Bay Bridge, and just after crossing the draw, which is near the centre of the bridge and over thirty feet of water, it ran through an open switch, which had just been installed with a view of extending track No. 4 to a point adjacent to the draw. The new track had been partially laid, but was not connected with track No. 3. The engine and first car went off the ends of the uncompleted track, the engine and tender turned over and were submerged in about fifteen feet of water below, killing the engineer and also carrying the fireman into the water, but he escaped with but little injury. One end of the baggage car, which was loaded with a freak animal, went into the water and rested on the submerged engine and tender, the rear of the car remaining on the bridge, which was about fifteen feet above the water. The front trucks of the first car, which was a combination loaded with passengers and baggage, went off the track, but fortunately did not leave the bridge. The rear trucks of this car were almost off the ends of the rail when the train stopped. It is believed that the combination car could have been pushed into the bay by hand, and that any reduction in retardation to the cars or any increase in speed of the same at the time the brakes were set would have resulted in a serious loss of life and destruction of property. The superiority of the brakes in use on this train undoubtedly was the only thing that saved it from total destruction."

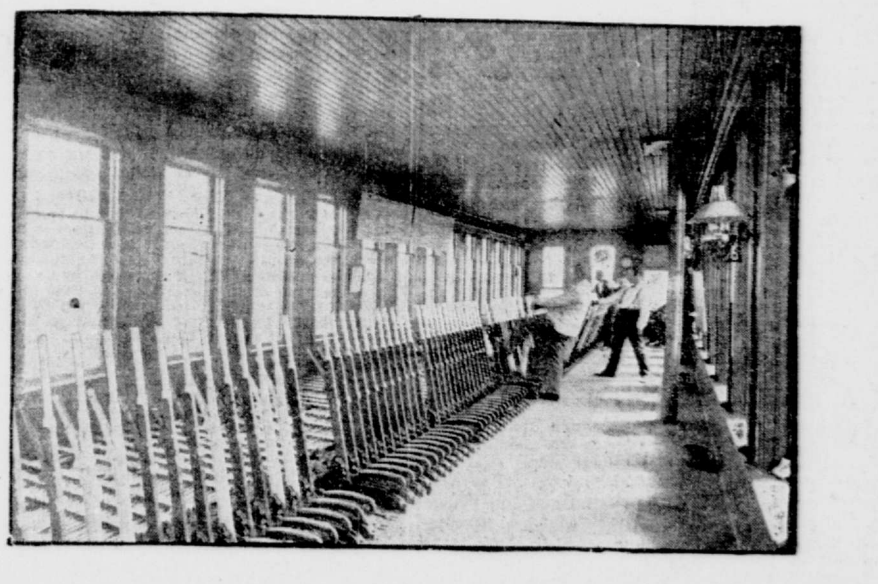


FIG 4—"ELECTRO-PNEUMATIC INTERLOCKING MACHINE CONTROLLING SWITCH AND SIGNALS."

A FRICTION DRAFT GEAR.

While upon the subject of the achievements of the Westinghouse Air Brake Company it may be well to give brief mention to certain other of its productions that enter the field of safety appliances and devices—briefly, for the reason that space for a more extended discussion of them is wanting and not because of any lack of importance in them.

Among these is the Westinghouse Friction Draft Gear, a device to be used in the place of the springs that are commonly employed in draft appliances on railway cars. The advantage of this mechanism is that it has more than double the yielding capacity of the ordinary spring, but is almost entirely without reactive effect. The reactive effect of springs in draft gear is a prolific source of parted trains, which are known to be the cause of many of the most costly and disastrous accidents. By the introduction of friction draft gear the heavy shocks and strains—every traveller must have wondered how anything made by man could possibly withstand such terrific jerks and impacts—to which long trains are subjected, owing to the powerful locomotives, are greatly reduced, with all the attendant benefits that go with this improvement. This device has been standard upon the Pennsylvania Railroad for several years, and they now have many thousand cars fitted with it. As a practical result of its application there has been almost an entire cessation of the parted trains, with their accompanying wrecks, that were so frequent before the friction draft gear was introduced.

It may be remarked that the parting of trains is one of the most frequent and dreaded causes of accidents. If it results in a self-collision—especially of a freight train—a mass of debris is deposited on adjoining tracks and often causes the wreck of the first passenger train coming along, as in the case of the terrible disaster at Harrisburg some time ago. It also causes delay which, through the throwing out of schedules, is another fruitful source of accidents.

The Pennsylvania people esteem this gear, as a device for saving property and preventing accidents, as scarcely less valuable than the quick acting air brake. "It is proper to remark, just here, that to this great company is really owed a vast debt of gratitude by the public for the share it has had in the development of the Westinghouse air brake, and, indeed, to its liberal and enlightened policy of sparing no expense or trouble to lend a helping hand to the inventors and manufacturers whose mission it is to afford protection to life, limb and property in railroad transportation. Although the Westinghouse people are well equipped with tracks for initial and experimental trials, it is only under the conditions of actual traffic that the really practical tests can be made, and the most significant data obtained; and through its readiness at all times to afford such opportunity the Pennsylvania has proved itself their invaluable ally."

The Westinghouse company also invented and introduced the train air signal as a substitute for the bell cord for communication between train and locomotive. This has proved a most efficient signalling device, and has been in regular service for nearly thirty years.

Within the last few years there has been gradually introduced upon passenger trains, by this company, what is known as an automatic slack adjuster, by which the wear of the brake shoes is automatically compensated for and the performance of the brake made much more uniform.

THE QUESTION OF SPEED.

The charge of "too fast schedules" is not easily disposed of, for it opens up a very broad field of discussion, and is a matter upon which even the experts are not agreed. And yet it might be summarily answered with the statement that a similar outcry was made, about three-quarters of a century ago, against "the tremendous speed" of twenty miles an hour—it was denounced by the press of that day as "flying in the face of Providence!"; that speed greater than that at which, in the worst of the recent disasters, the trains are now known to have been running, has been common for years past on the roads on which they occurred, as it has been on others of the great railroad systems; that high authority has claimed that no speed we are now running at is beyond present engineering ability to make safe, and that it is held, by those familiar with the record, that there have been as many accidents to slow as to fast trains, but that this charge brings up the further complaints against railroad managements that they jeopardize the travelling public by experimentation, and by speeding over construction and with equipments not originally built and provided for such fast time, the defense to the first of which is that only the practical tests under the regular traffic conditions can be considered conclusive, those on trial tracks, and under pre-arranged conditions, affording valuable suggestions, it is true, but not, in their last analysis, being sufficiently exhaustive to be reckoned entirely satisfactory and conclusive, and that, but for such "experimentation," we should be at the stage where the performances of the Stourbridge Lion were the wonder of the world; and to the second of which the defense is that it is not founded on fact, for whatever shortcomings there may be are due merely to the incompleteness of the expert attainment of the day. As regards the construction provision one expert, it is proper to say, does call attention to what he considers a serious omission. He says, "We have higher and heavier rails, and higher speed and heavier locomotives, but there has been absolutely no change in the ties themselves"—he believes that the latter "should have knee braces, every other one," and adds that "they are not very expensive."

Perhaps, however, the real answer is to be found in the remorseless demand, on the part of the public, for speed; the up-to-date merchant is pretty apt to keep in stock the goods, in his line, his customers want. It should be remarked in this connection, however, that it is contended by no small number of transportation experts that the ceaseless and unwise nagging, for their assumed failure to move passengers and goods with sufficient rapidity, has been very disturbing to all classes of the operating forces of the roads, and has had much to do with the frequency of accidents of late. As one has expressed it, "it has made their fingers all thumbs."

ON ORGANIZATION AND DISCIPLINE.

It is possible to discuss with more assurance the charges of "non-enforcement of discipline," or at least to present more generally accepted reasons therefor. And it must be acknowledged that these divide the blame pretty equally between the railroad managements and those under them. One, which has been advanced, in an article which appeared in "The Outlook" some time since, by an ex-army officer, a graduate of West Point, who has served an apprenticeship on the railroads, in every grade of the operating department, from brakeman to superintendent, and who is now engaged as an operating expert in the examination of various railways, and as an editorial writer for a technical journal, is that the "five thousand general and five thousand subordinate officers" are insufficient to enforce strict discipline "among the, approximately, million and a half railway employes in the United States." Said he: "Railroads have much in common with military organizations. They can learn from the accumulated experience of centuries of army existence. Thus, a regiment of twelve hundred men has from forty to fifty officers, or one for every twenty-four to thirty men." The other is voiced by "The Railway Age," which attributes the low condition of discipline, in part, ". . . to the growth of a certain trade union idea, which would demand employment for any man, whether he was worthy or not; for instance," it continues, "an engineer was recently discharged for drunkenness, but his union persisted in the demand for a reinstatement, despite his fault. An equally noteworthy element leading to the lax condition of discipline is the tremendous demand for labor, in consequence of which many of them are no longer anxious lest they should lose their jobs; they have grown indifferent, have lost their sense of duty, and have also lost respect for authority."

Another specialist does "not think that either the comparatively small officering or the union is to blame for slack discipline," but that "the real cause is the great difficulty the roads experience in getting a sufficiency of skilled labor, and in keeping it—which necessitates a certain amount of coddling." Somewhat different is the contention of an official high in the management of one of the greatest manufacturing industries in the country—a concern, too, that is closely allied with, and draws its revenue chiefly from, the railroads—who holds that, "while the unions are in a great measure, at fault, it may be regarded as certain that wherever there is lax discipline, the officials may not be excused from responsibility."

"The Outlook" of last February, placing the blame for the frequency of railroad accidents "with some of the great financial powers controlling the railway," quoted from the speech of a "distinguished officer"—made several years since, before the American Railway Association—the declaration that "an impending calamity lay in the drifting of the control from the hands of the professional and technical men into the hands of those financiers who regard railways not so much as transportation machines as opportunities for speculators to make money." This same officer, however, said later, in the course of the same speech, that "some of the great financiers who have taken control of the railroads see this danger clearly, and try to build up the power and ability of the technical staff." And he has very lately, in deploring the fact that "discipline has sunk to a condition below anything that has existed since I have been watching railroads," expressed the opinion that this low state of discipline is "very little a question of shiftlessness on the part of superintendents and other officers, but very greatly a matter of demoralization, due to the trade union idea," and, also, to the fact that railroad labor "has been taught that it is a downtrodden and oppressed body, and that all corporations and their officers are wicked," adding that "the whole tone of certain members of the newspaper press and of certain occupants of pulpits has been to breed insubordination and a chronic sense of grievance." All of which, in so far as it portrays the lack of discipline in railway labor, adds emphasis, by the way, to a recent utterance of The Tribune to the effect that "employes often risk their own lives, and those of others, by carelessness, or a wilful disregard of regulations with which they have long been familiar."

THE BLOCK SIGNAL SYSTEM.

Perhaps that disregard is not more often or more dangerously exhibited than in the non-observance of signals. An operating expert, quoted earlier, has pointed out that, "while block signals are accomplishing a great deal—perhaps more than any other one factor—the most elaborate devices for the safe operation of railways are as naught, if the men using them are not properly trained and handled. The morale of the service is the point on which railway managers fix their attention." From all accounts, this morale is not up to the mark, and, as this authority has further stated, "too often a lax discipline winks at disregard of signals in order to make fast time." Now, block signalling is a positive method, and leaves nothing to the engineer's discretion, as will be shown in the description, which is given below to enable the reader the better to form his judgments of the many and diverse statements and suggestions which have appeared in the public prints of late, as well of the argument here made concerning it; the rules and regulations governing it are the result of long and exhaustive study and experiment, and of hard won experience, as the brief sketch of its history and gradual development, also presented, will demonstrate, and to deviate from them, in any way, is simply to court the very disasters that have been the most significant guide posts to point the way to present approved practice.

Before describing the evolution of railway signalling it may be well to define the block system, which, in some form or other, it has always been designed to serve. By "block system" is meant the separating of trains by space intervals, and the earliest method of achieving this was that used for many years throughout America—i. e., the determination of space by the lapse of time between trains. That method is still in use to a considerable extent. It must be patent to the reader that if space can be maintained between trains there can be no collisions.

In a recent publication of the Interstate Commerce Commission it is stated that "the first block signalling in America appears to have been on the line between Kensington (Philadelphia), Penn., and Trenton, N. J., in 1863 or 1864." It goes on to say that "the space interval was adopted after the occurrence of a disastrous rear end collision of eastbound extra trains, at night, carrying soldiers from the seat of war to New York and New England." From that it seems to have been gradually extended northward over a few lines that, eventually, were taken over by the Pennsylvania Railroad; at that time, in 1872, a length of ninety miles was being worked by the block system. There is nothing to be gained by following it step by step as it made its way throughout the country, for, though that would doubtless be interesting, it will be more instructive to study the development of signalling itself, the simple elementary form of which is the "telegraphic block." Operators at two consecutive stations, or signal cabins, or whatever it may be on a railroad, communicate with each other by wire, using the Morse alphabet, or conventional Bell signals; one operator admits a train to a block when the other operator informs him that the train last admitted has gone out. This is crude and subject to many causes of failure.

THE CONTROLLED MANUAL SIGNAL.

The next step forward was by the use of what is called indiscriminately "controlled manual signals" or a "lock and block system," in which the signal at one block tower, or station, is locked in position, and can be released only by an electric impulse from the tower in advance. This, of course, necessitates the concurrent action of the two operators, and clears away some of the chances of error. A further improvement, however, was the use of an electric circuit, in the rails, for a short section, at either end of the block. When a train enters a block, and the signal is put at danger behind it, that signal cannot be unlocked until two things have happened at the other end of the block, viz.: The train must have passed out of the block, and so over the insulated track section there; and, also, the operator at that end of the block must have performed some act which will send an electric impulse back, and so join in unlocking the signal at the first block station. In this way very good and satisfactory, but not complete, protection is had; for the reason that it is possible for a part of the train to pass out of the block, and release the block instrument, and yet leave a portion of itself still standing in the block. This sort of accident can be provided against only by the vigilance of the operator; he should not release the signal at the entrance to the block until he has assured himself that the train passing out has carried its proper "markers" to show that it is completely out. Carelessness in this respect sometimes leads to accidents against which the automatic signals offer more complete protection.

THE AUTOMATIC BLOCK SIGNAL.

In automatic signalling the signals are "set" and "cleared" by the movement of trains, irrespective of operators. Theoretically—that is, so far as signals are concerned—with this method, it would be possible to start a train, say, from Jersey City, and let it go to Philadelphia, without the intervention of either operators or train dispatchers; for the signals ahead of it would automatically announce the fact, to the engineer, that the blocks ahead were clear, or were occupied, while signals automatically "set" behind the train would protect it in that direction. Obviously, dispatchers and operators are necessary for other purposes; but on a line of railroad with automatic block signals, the greater part of the signals are at places where there are no operators, and are, therefore, entirely out of the control of such. These signals go to "stop" or "danger" (the horizontal position of the semaphore blade) by gravity; that is, they are so counter weighted that they will always stand at "danger" or unless they are actually pulled to "clear" or held at the latter position by the action of some external power. In fact, it is a fundamental principle, in all correct signalling, that the semaphore shall be so counterbalanced that it will go to the danger position in case of broken connections, derangement of mechanism or interruption of control.

THE ELECTRO-PNEUMATIC SYSTEM.

The automatic signal is moved to the clear position by compressed air or electricity. In the electro-pneumatic system, as used on the Pennsylvania Railroad, the Long Island Railroad, the New York subway, to some extent on the New York Central, on the Central Railroad of New Jersey, and on several other roads, the signal is cleared by admitting compressed air to a cylinder, the pressure of the air in that cylinder moving the piston from one end of the cylinder to the other, precisely as a piston is moved in the cylinder of a steam engine. When the air is discharged from that cylinder, the counterweight again carries the signal to its danger position. Air is supplied from a central compressing station, and is carried to pipes along the line of the railroad. Branch pipes lead to the individual cylinders of the signals. The air is allowed to pass from these pipes to the working cylinders through valves, which valves are controlled by electricity. An electric current is constantly flowing through the rail, and this is part of the automatic control. When that electric circuit through rails is complete and flowing around its normal course, the air valve is held open, and air flows from the pipes into the signal cylinders, and the signals are thus held clear. The instant that a pair of wheels passes into the block, this flow of current is short-circuited; and, instead of passing around its complete course, it passes across from rail to rail through the wheels and axle, and thus, the magnet pulling the valve open being de-energized, the valve closes, the air is shut off from the signal cylinder, and the signal goes to danger. It follows that anything which interrupts the circuit in an automatic block section will cause the signal to go to danger; thus, automatic signals with complete track circuits detect broken rails and open switches, and so offer a degree of protection which cannot be obtained by any other signal system.

"AUTOMATIC" BY ELECTRICITY.

The automatic signal worked entirely by electricity involves the same general principles of operation as the electro-pneumatic signal. This kind of signal has recently come into very great use. The Union Switch and Signal Company has put out about 23,000 signals of this class. The first one was put in service only ten years ago, and half of the total number sold were during the last year, which shows the immense rapidity with which this system of signalling is extending. In the case of the automatic electric semaphore signal, the control by the track circuit is precisely the same as in the case of the electro-pneumatic signal, but the operation of clearing the signal is performed by a little electric motor placed in a case at the base of the signal pole. The uninterrupted flow of electricity through the track circuit causes the signal to be held clear. If the circuit is broken, certain magnets in the signal mechanism are de-energized, and the signal goes to the danger position by gravity.

EXPLANATION OF SIGNAL PICTURES.

Figure 1 shows electro-pneumatic signals. The signals carrying a letter "A" as a marker are automatic signals, controlled by track circuits,