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REPORT

OF THE

INTERSTATE COMMERCE COMMISSION

ON

BLOCK-SIGNAL SYSTEMS

AND APPLIANCES FOR THE AUTOMATIC CONTROL OF RAILWAY TRAINS

UNDER PUBLIC JOINT RESOLUTION NO. 46
APPROVED JUNE 30, 1906

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THE INTERSTATE COMMERCE COMMISSION.

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EDWARD A. MOSELEY, Secretary.

INTERSTATE COMMERCE COMMISSION,
Washington, February 23, 1907.

SIR: The Interstate Commerce Commission has the honor to transmit herewith a report of its investigation concerning block-signal systems and appliances for the automatic control of railway trains under Public Resolution No. 46, approved June 30, 1906, entitled "Joint resolution directing the Interstate Commerce Commission to investigate and report on block-signal systems and appliances for the automatic control of trains."

Very respectfully,

MARTIN A. KNAPP,
Chairman.

The PRESIDENT OF THE SENATE OF THE UNITED STATES.

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REPORT OF THE INTERSTATE COMMERCE COMMISSION ON BLOCK-SIGNAL SYSTEMS AND APPLIANCES FOR THE AUTOMATIC CONTROL OF RAILWAY TRAINS.

To the Senate and House of Representatives:

The Interstate Commerce Commission respectfully reports as follows:

By joint resolution of Congress, offered by Hon. James R. Mann, of Illinois, approved June 30, 1906, the Commission was directed to investigate and report on the use of and necessity for block-signal systems and appliances for the automatic control of railway trains in the United States. The Commission was further directed, in transmitting its report to Congress, to recommend such legislation as to the Commission seems advisable.

In compliance with the terms of this resolution, the Commission has conducted an investigation, the main features of which were:

(1) An order issued on August 24, 1906, calling upon all railroad companies in the United States for certain information. A copy of this order appears in the Appendix.

(2) A supplementary circular to the fifty or more roads now using block signals, designed to elicit information as to the main features of their practice.

(3) Further investigation of a personal nature on certain roads concerning details of practice.

(4) Inquiry into and the preparation of descriptions of signal apparatus of different kinds in use on American railroads, embodying data from manufacturers and railroad companies; and

(5) Inquiry into the methods for stopping trains in the event of failure of an employee, for any cause, to obey a signal indication.

Acting under the authority of the resolution the Commission employed Messrs. B. B. Adams and C. C. Anthony as experts, and the technical part of this work has been principally performed by them.

Mr. Adams has for twenty years been one of the editors of the Railroad Gazette, and is recognized as an authority on signaling. He has had long experience in railroad work in America, and has made a close study of the railroad practice in England. He is the author of the Block System (1901), a book describing American practice in block signaling and interlocking, and was for two years secretary of the Railway Signal Association, a national organization of signal engineers.

Mr. Anthony is supervisor of signals of the Pennsylvania Railroad. He has been with that company eleven years, and before that was for two years on the New York Central. On these two roads are found nearly all of the signal appliances which have received general approval in America, and in their use all of the difficult problems of signaling have been presented. In dealing with these problems Mr. Anthony has had a prominent place. He is one of the leading members of the Railway Signal Association.

Information has also been gathered concerning the number of miles of railroad worked by the block system, the methods employed, the kinds of apparatus in use, the relative merits of different methods and different devices, the economy of the block system, and its value as a safeguard for lives and property. Besides the block signals in use a number of block-signal devices not yet put in use, but designed to afford more complete protection against collision than is afforded by the usual appliances, have been inquired into.

Before proceeding to consider this information in detail, it seems proper that a short résumé of the history of the block system on American railroads should be given.

HISTORY.

The term "block system" is used to designate the method or process whereby, by the use of the telegraph, telephone, or electric bells, or by automatic apparatus, each train on a railroad is forbidden to pass a certain point (the entrance of a block section) until the last preceding train on the same track has passed beyond a certain point farther on (the end of that section). No train enters a block section except and until its engineman sees on the signal post an "all right" signal.

Without the block system, protection from rear collisions depends on the maintenance of a time interval at stations and on elaborate instructions for the use and observance of red flags (or lanterns), torpedoes, and fusees, which instructions are often hard to enforce.

Protection from butting collisions (on single-track lines) depends on the exercise, on the part of enginemen and conductors, of most intelligent and unceasing vigilance in the observance and execution of intricate rules and written orders, and on the exercise of the utmost care by the train dispatcher, who, by the use of the telegraph, regulates the movements of those trains—on the more important single-track roads a large proportion of the whole—for which the time-table does not prescribe meeting points, which includes all trains when running behind time.

With automatic signals, the passage of the wheels of the train along the track actuates and controls the signals. No signalman is required, and the signals may be fixed anywhere along the line, not necessarily at stations.

The block system as first used in this country, and as now used on thousands of miles of railroad—that is, the "telegraph" block system—is very simple. The agent or operator at a given station sees that a signal indicating "stop," one for trains in each direction, is displayed so as to be seen by the engineman of any train approaching and running in that direction; and this signal is displayed continuously until the attendant operator or signalman has been informed from the next station beyond that the last preceding train on that track has arrived at the said next station, and has either passed on or has been set off on a siding, clear of the main track. This stop signal may be a very simple device so that, with properly instructed station attendants, the necessary first cost of the system is very small.

The introduction of the block system has been slow because under favorable circumstances the old system has done well. With a sufficiently long-time interval between trains at each station, and with rigidly enforced regulations concerning rates of speed and for "flagging back" in case of delay (every delay shortens the time interval between the delayed train and the one following it), trains may be run with a considerable degree of safety by time-table alone, and it is not necessary to have all of the stations constantly manned by a telegrapher. This being so, American railroads, most of them with stations not very near together, were reluctant to increase their expenses even a moderate percentage. With stations far apart, the block system would have required, especially at night, when the small stations were ordinarily closed, many additional telegraphers. The Pennsylvania Railroad was for years the only road using man-operated block signals.[a]

Not until about 1885 was the manual system used systematically elsewhere, except on a few miles of the New York Central and Hudson River, where the "controlled manual" block system was introduced, from England, about 1882.

Automatic block signals were invented in America and have been developed on American railroads. Although man-operated block signals had been used for some years on English railroads, with their denser traffic, more frequent stations, and lower expenses for attendants, automatic block signals found more pronounced favor in this country; and the Eastern Railroad of Massachusetts (now the Boston and Maine) had 16 miles of its line near Boston equipped with automatic signals in 1871. Other New England roads followed, so that by 1878 there were automatic signals on a considerable mileage in the vicinity of Boston. In the next year, 1879, the track circuit, a radical improvement, was introduced on 10 miles of the Fitchburg Railroad, near Boston; and from that time automatic signals made steady though rather slow progress. Though there was not in this system the cost of additional station attendants, as in nonautomatic block signals, the cost of installation of apparatus and fixtures was high, as was also the cost of inspection and maintenance; therefore, only companies enjoying a heavy and profitable traffic deemed it wise to equip their lines with automatic signals.

Except on a few lines, block signals were introduced where the dense traffic compelled an improvement on the old system. For many years some roads which had made considerable investment in automatic block signals continued to maintain their time-interval rules, keeping the signals as an auxiliary protection. On a few roads, however, far seeing and discriminating managers who saw that the potential value

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[a] The first block signaling in America appears to have been on the line between Kensington (Philadelphia), Pa., and Trenton, N. J., in 1863 or 1864. This statement is based on the testimony of the late Robert Stewart, who was superintendent of telegraph of that road at or about that time. The space interval was adopted after the occurrence of a disastrous rear collision of eastbound extra trains at night carrying soldiers from the seat of war to New York and New England. The block system was extended northward from Trenton to New Brunswick some time in 1864. The earliest date of which an authentic record has been found is November 12, 1869, which appears on a circular issued by F. Wolcott Jackson, general superintendent of the New Jersey Railroad (Jersey City to New Brunswick), and dated at Jersey City, N. J., giving the rules under which the space interval was to be maintained. The circular is signed also by R. Stewart, superintendent of telegraph. The block system was put in effect from Frankford Junction westward to Mantau (West Philadelphia) in 1870. In 1872 the Pennsylvania Railroad took control of all these lines, and at that time a length of 90 miles was being worked by the block system. In a statement made by Mr. Ashbel Welsh, in 1866, he speaks of the block system as having been in use for a year between Jersey City and New Brunswick. The block signals consisted of banners in boxes, some of which have been in use until within a few years and may be familiar to the reader. The box stood on a post, and red flannel banners were dropped in front of a white surface or white light for the stop indication. On some of the boxes there were hoods to prevent impairment of the engineman's view by the rays of the sun reflected from the glass which covered the opening in the front of the box and protected the banner from the weather.

of the space-interval principle was greater than appeared from the cold calculations based on volume of traffic and on the earnings or expenses for single years, introduced the telegraph block system on lines where the volume of traffic did not compel its introduction. That is to say, the trains were not so frequent as to require a shortening of the time interval to increase the capacity of the road. Some of these managers were, indeed, impelled to make this change because of large expenses due to the damages caused by collisions.

One of the most significant things in connection with the progress of the block system during the past few years has been its use on long lines of single-track railroad. On lines of this kind its use is now so general that the propriety of adopting the system for lines of any grade may be looked upon as a generally accepted principle. There are not wanting managers who had delayed the introduction of the system until it could be shown by statistics that the added expense would be warranted and have found such statistics only in connection with a long list of killed and injured passengers, the victims of a collision.

MILEAGE OF RAILROAD WORKED BY THE BLOCK SYSTEM.

The length of railroad in the United States on which trains are run under the block system, as shown by reports made in September, 1906, in response to the order of the Commission, is 48,743.2 miles. The items making up this total are shown in the table which appears in the Appendix. A length of 6,826.9 miles is shown as being equipped with automatic block signals, and a length of 41,916.3 miles as worked by manual signals; and these are further subdivided into single-track lines, double track, etc. Of the lines worked manually, 911.8 miles, on seven different roads, are equipped with controlled manual apparatus; that is to say, the signal levers have electric locks providing interlocked control from station to station. This electrically controlled apparatus is substantially all to be found on double-track lines. A less complete "control" apparatus is in use on 915.7 miles of single-track lines, belonging to four companies. Another method of electrical control, the electric train staff, adapted for the protection of trains on single-track lines, is in use on 179.3 miles of road, belonging to thirteen different companies.

A number of important companies have made considerable extensions to their block-signaled lines during the year 1906. Comparing the totals now reported with those appearing in a table published by the Railroad Gazette in January, 1906, the following increases appear:

	Miles.
Atlantic Coast Line	152
Central of New Jersey	97
Chesapeake and Ohio	135
Cleveland, Cincinnati, Chicago and St. Louis	205
Delaware and Hudson	101
Delaware, Lackawanna and Western	38
Erie	72
Great Northern	176
Hocking Valley	31
Illinois Central	146
Lake Shore and Michigan Southern	1,137
Lehigh Valley	46
Long Island	13
Louisville and Nashville	374
Michigan Central	630
Mobile and Ohio	24
New York Central and Hudson River	279
Norfolk and Western	490
Oregon Railroad and Navigation Company	77
Philadelphia and Reading	19
Pennsylvania (including controlled lines east of Pittsburg)	468
Southern Railway	101
Southern Pacific and controlled lines	374
St. Louis and San Francisco	38
Union Pacific	88

In a number of cases the mileage now reported is less than that which appears in the Railroad Gazette's table of a year ago, although the statistics shown in that table were said to be based on official information from the several railroads. Some of these discrepancies are accounted for by the fact that in the Commission's statistics subsidiary companies are shown separately; others appear to have been due to incorrect reports made to the Gazette. In two or three cases railroads then reported that on all of their lines not completely block signaled, passenger trains were protected according to the space-interval principle, by supervision from the train dispatchers' offices, and this mileage, suitably explained, was included in the Gazette's table; but these roads did not make any such claim in the reports which they sent to the Commission.

It will be seen that nearly all of what are called the great railroads of the country are represented in the Commission's table, showing that on the broad question of the merit and adaptability of the block system the views of the officers of these roads are in substantial agreement. With two or three exceptions, all companies doing what may be called a heavy passenger business are represented here. On twenty-nine roads which have no block signals (all but five of them operating, each, less than 500 miles of line) the passenger traffic is comparatively light. Only two of these reported for the year ending June 30, 1905, passenger earnings of over $2,500 per mile.

This showing of block signals in use on nearly 50,000 miles of railroad lines indicates a marked advance over the conditions which existed in this country in 1890. As before observed, the block-system principle was recommended by railroad men of advanced ideas more than forty years ago, but up to 1890 such recommendations had little influence on general railway practice. The fact that some railroads introduced the block system because of density of traffic, others because of abnormal collision records and alarming damage bills, and still others because of a clear discernment of the value of the principle, makes it impossible to clearly connect causes and results in trying to estimate the reasons for the progress of the block system, or to form an opinion as to the prospects at the present time of further progress.

COST OF THE BLOCK SYSTEM.

Like many other items in the operation of a railroad, the cost of the block system is a somewhat indefinite quantity. Few roads have introduced the system in such a way as to keep its cost separate from other expenses. Except on a new line, the significant item is the excess of cost above what was paid for train protection under the old system. Usually the first cost of introducing the telegraph block system is confined to one additional telegraph wire, say $30 per mile, and a signal, say $75 or less, at each station. On many lines the train-order signal already in use for train dispatching has been made to serve satisfactorily as a block signal. The real financial burden, if any there be, is in the additional telegraph operators required, making a permanent increase in the pay rolls. On one road on which the telegraph operators already in service managed the block signals, the increased expense for wages of operators (for additional operators) was less than 5 per cent. There are numerous examples similar to this. The cost of an additional telegraph wire is too small to receive special consideration.

On the other hand, a road which erects signal cabins specially for block signals, and employs signalmen independent of its existing telegraph service, will expend $500 each for the cabins and from $1,200 to $1,500 yearly for wages, fuel, and maintenance at each. With block stations 3 miles apart, these items would thus aggregate $16,666 and $40,000 to $50,000, respectively, for 100 miles of line. Whether the stations are 3 miles apart, or more or less, depends, of course, on the volume of traffic and the required frequency of trains; so that no universal rule can be laid down.

The cost of the electric apparatus for "controlled manual" has been looked upon by most roads as unwarranted. Only roads with heavy earnings are using it. The "average" road acts on the theory that with competent signalmen the "control" is unnecessary. The justification of this position depends on the results; and results may not be visible until after a term of years, for the reason that signalmen not fully competent may work for years without causing a collision.

In considering the installation of automatic block signals, the first financial question is the original cost of the signals, apparatus, fittings, and appliances. The cost of maintenance, while a considerable item, is decidedly smaller than the cost of operation of the nonautomatic systems, in which the item of wages is large. Automatic block signals have involved expenditures of from $1,500 to $3,000 a mile of double-track road, the precise figure varying according to the type of signal the number of outlying switches to be connected, and the frequency of the signals or length of the block sections. The maintenance of these signals costs variously from $75 to $125 per signal per year. Until within two or three years automatic signals have not been introduced except on lines of considerable traffic, where the necessity for running the passenger trains closely following one another was considered pressing. One important exception to this statement is the case of the Cincinnati, New Orleans and Texas Pacific Railway, which has used these signals on its single-track line for long distances for ten years or more. At the present time this road has about 300 miles of single track alone equipped with automatic signals. During the past year or two the Southern Pacific has taken similar action—has ordered automatic block signals for hundreds of miles of single-track lines.

That but few other roads have adopted automatic signals except on very short lengths of single-track line—the reason that the two roads just mentioned are exceptional—appears to be based on the fact that for single-track lines the automatic system does not afford all of the safeguards that are needed. Nothwithstanding a full equipment of signals it is necessary to continue in force the time-table rules regarding the meeting of trains and train dispatchers' authority and oversight to provide for the meeting of extra trains and of regular trains when behind time.

One or two companies have introduced automatic signals on single-track lines where the telegraph block system has been in use and is continued in use. This is to facilitate movements where it is necessary that a considerable number of trains, usually freight trains, must follow one another in the same direction at short intervals. The telegraph block system is worked with facility only between meeting points; that is to say, between block stations fixed at the sidetracks where trains can meet and pass. These are usually 3 miles or more apart, while by the introduction of the automatic signals provision can be made for the protection of trains running in the same direction much less than 3 miles apart.

Where trains are so frequent that a time interval of five minutes or more can not be tolerated, the automatic system is now generally deemed the only suitable system, because where trains must follow one another as closely as once in five minutes the block signals must be not over 2 miles apart; and with this interval the cost of the manual block system would be very high.

From a humanitarian standpoint the block system is to be regarded simply as a safeguard against collisions of trains, but it is much more than that, for it is an effective means of increasing the capacity of a railroad. On lines where the traffic is dense or even moderately active, the use of the block system permits the running of trains near together at full speed. The running of successive trains within two minutes of one another may be safely permitted under a properly operated block system; whereas, in the operation of lines where the block system is not used, it is necessary to maintain a time interval of from five to ten minutes between trains except where the speed is very low, as in the case of some freight trains. The block system thus increases the capacity of the road and serves, in some degree, to postpone the day when additional main tracks must be built at great expense. This is a fact that must be taken into consideration in any proper estimate of cost.

SAFETY.

The broad question of the safety of the block system needs no discussion, but it will be proper to consider somewhat more in detail the relative merits of the different systems, considering each by itself and in comparison with the other systems. It is obvious that the system generally, whether telegraph or automatic, is safer than the time interval and dispatcher system, because fewer collisions occur under it. Nearly all of the large railroad companies have adopted it to a considerable extent, and they are putting it in use on additional lines year by year. Whatever may be their conclusion as to the precise measure of economy, they do this avowedly to promote the safety of the lives and limbs of passengers and trainmen.

The block system provides that each engineman may, with perfect safety, start and run his train by the sole authority of a visible signal, fixed on a post at the side of the road, which gives him the exclusive right to the track for a given distance (to the next block signal) without limitation as to the time to be spent in getting there, or the speed. The system provides all necessary security against collision, with no question about the importance of the train, or the priority of any other train. So far as safety is concerned, all trains are of the same class.

Without the block system, the right of a train to proceed depends on the class of the train as regards other trains: on the time, as shown in the time-table, and on the vigilance of the engineman in seeing that the preceding train is out of his way. Under the block system these otherwise vital features become matters merely of convenience or expediency. With no block system rear collisions are provided against by flag or lantern signal, but the failure of this safeguard is notorious. It fails both from the negligence of flagmen to carry out or display the signal, and of enginemen to heed it when it is given. On a single-track line, in addition to these uncertainties, the men in charge of trains have the burden of considering their rights as against trains coming from the opposite direction, which are of two or more different classes, and the superiority of which as related to their train may vary from hour to hour, or may be varied by telegraphic orders from the train dispatcher at any stage of the train's journey. Butting collisions due to confusion in these things—to mistakes in reading the time-table, to wrong telegraphic orders, to nondelivery of orders, to forgetting orders, and other blunders—are as notorious as are rear collisions from flagmen's failures.

On either double track or single track we have on the one hand (in the block system) fixed signals, situated at known locations, few and simple requirements, and few men to share the responsibility of any given operation. On the other hand, we have in the old system, signals (as flags), not fixed but to be encountered at unexpected places, or no signals at all, compelling dependence on the time-tables, watches, and confusing rules of superiority. Responsibility is divided among a larger number of men.

It is therefore not necessary to be acquainted with the details of railroad working to decide which must be the safer method of operation.

The engineman who makes a mistake under the block system usually finds himself condemned by all competent critics, with little paliation, because the problem under which he breaks down has been simplified to the last degree; whereas mistakes made under the other system (forgetfulness, mistakes in reading poor handwriting, errors in adding and substracting hours and minutes, neglect of some rule that rarely affects him) are of a kind that enlist sympathy by reason of the general appreciation of the great difficulty of surely avoiding such mistakes three hundred and sixty-five days in the year, one year after another.

Every railroad company finds evidence of the superiority of the block system in the record of collisions, regardless of all theoretical arguments. A few roads have informed the Commission that by the introduction of the block system their expenses for collisions have been reduced. One makes the definite statement that this reduction—1906 compared with 1896—was 45 per cent, notwithstanding a great increase in the volume of traffic, which increases the dangers. It is undoubtedly true that but for the use of permissive blocking for freight trains a part of the time, which involves a virtual suspension of the block system, this percentage of saving would have been much larger.

There is no escape, therefore, from the conclusion that the block system is the best known instrumentality for the prevention of collisions, notwithstanding the imperfections which have been shown in the results of its operation, and that the highest standard, both of the public requirement and of expert railroad opinion, calls for its general use. The most progressive railroads are using the system extensively and are extending it, and their signal engineers and operating officers are constantly striving to make it more perfect.

Considering now the question of safety more particularly and looking at each method of signaling by itself, we will take first the "controlled manual." For the reason that comparative statistics of safety are not to be had in authentic and lucid form, the question of safety must be decided in all of the systems largely by a critical examination of the apparatus, the principles of the system, and the methods of administration.

THE CONTROLLED MANUAL.[a]

This system is the safest known. All signal operations are made by regular attendants in the signal cabins, and the man (A) giving a clear signal must always have the cooperation of the one (B) at the other end of the block section. The movement of the train itself also checks the operation of A. In some few installations the last-named safeguard—that depending on the movement of the train—is made constant during the passage of a train through the whole length of the block section by having a track circuit throughout the section. This secures the advantage both of human attendants and of the self-acting machinery of the automatic block system. There can be no question that in this system false clear signals due either to errors of signalmen or faults of apparatus are fewer than in the telegraph block system or in the automatic system; though it is fair to say that, because of its mechanical refinements (deemed an extravagant expense because of the infrequency of the errors that it is designed to prevent), the controlled manual in its complete form has not come into extensive use.[b] For this reason the superiority of this system can not be compared with that of the others on a satisfactory basis.

Errors of enginemen are probably neither more nor less frequent with this system than with the telegraph block system, though there are no available statistics on the point.

THE TELEGRAPH BLOCK SYSTEM.

Faults of apparatus are in this system too rare to merit attention in this place. The question of safety as compared with the other system hinges on the efficiency of the signalman. Considering the controlled manual system as the standard, this system is inferior by reason of the chance that a signalman will give a wrong signal because his error or neglect is not invariably checked by any other person, nor by any electrical machinery. Looking at the accident records compiled by the Commission for the last two years, July 1, 1904, to July 1, 1906, it appears that of the 160 rear and butting collisions which were deemed "prominent" and entered in Class A (persons killed, 507; injured, 2,597) 13 occurred under the telegraph block system.[c]

All of these are charged to the negligence or misconduct of signalmen, and none primarily to faults of enginemen, though in one case an engineman disobeyed a rule designed to provide against signalmen's neglect. In the same two years seven collisions in Class A on lines worked under the automatic block system were reported as all due to

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[a] There are in use on two or three roads incomplete "controlled manual" signal machines which to not come within the description here outlined. They cost less and they provide against only a part of the dangers.

[b] We are now considering only methods in general use on interstate railroads doing a general passenger and freight business. Automatic stops, included in the general system, and designed to shut off the motive power and apply the brakes of a train, are in use on city passenger lines in New York, Boston, and London, where the traffic is very dense, but have not been adopted elsewhere.

[c] See list in Appendix.

misconduct or neglect of enginemen. These figures tend to indicate that in its feature of monitorship the telegraph block system has a marked advantage. The presence of the attendant at or near the signals keeps the engineman wide awake and attentive to the signal indications. The causes of the signalmen's errors in these 13 cases are various. Inexperience and culpable neglect—the latter apparently a grave moral defect—are the two most prominent.

Without the fuller statement of facts which an inquiry on the spot would furnish, a closer analysis of this accident list can not be made; but there can be no question that the number recorded (13) is far smaller than would have been the case had the block system not been in use.

In aiming to define or even to discuss a standard of perfect safety, human fallibility can not be ignored, as the mysteries of the "personal equation" have never been fathomed. However, should the "control" apparatus be regarded absolutely necessary in manual block signals, the record of the British railroads must be considered. Most of their lines have no "control," yet the records show that collisions are rare. Again the introduction of machinery to check the errors if men can not be fairly accepted as a justification of neglect to use any well-known means of preventing human errors by wise selection and adequate discipline. The British Government inspectors have discussed "control" but have never formally recommended it, or given any decided opinion in favor of its general use.

The facts of the accident records justify a strong presumption that American signalmen are not so carefully selected nor so well trained as those of England. The average signalman in America is young, and has had, probably from six months to two years instruction—not systematic training—under another signalman, whose superiority to the student is due entirely to what he has learned by experience and not at all to methodical and authoritative instruction. The average block signalman in England, on the contrary, has served as such from five to twenty-five years and has been through a long course in a signal cabin as "booking boy," or as assistant, before being trusted with full charge of the block signals. This difference in personnel of the signalmen of the two countries undoubtedly explains in large measure the nearer approach to perfection of the block signal service in England. The fact that youth and inexperience are factors in our "failures in block working" has been repeatedly illustrated in the accident records, as given in the quarterly bulletins. A more searching study of this feature of the practice in this country would involve detailed inquiries in many places. So long as the telegraph block system is worked anywhere with a higher degree of safety than on American railroads, the practice of American roads to the extent of such superiority must be declared deficient. The Commission knows of no American who has made an extended examination of the men and methods in English signal cabins, nor of any Englishman who has studied the practice in America, but such brief and partial studies as have been made confirm what is here said.

THE AUTOMATIC BLOCK SYSTEM.

The basic block-signal principle applies to the automatic and the non-automatic alike. Considering the distinctive features of the automatic, we have to deal primarily with the behavior of apparatus and fixtures instead of with the acts of men. A number of railroads have records showing only one dangerous failure of apparatus in millions of movements. These railroads are the busiest in the country, and these signals have been in use from five to twenty years. Faults of apparatus, where developed, have been diligently investigated, and constant progress has been made; the manufacturers of signals and signal apparatus cooperate with the railroads in seeking perfection, even at great expense.

Nearly all of the larger roads operating the busiest lines show by their acts that they deem the automatic system preferable to the non-automatic. One prominent road, the Pennsylvania, is constantly introducing the automatic on its lines of heavy traffic in place of the telegraph block system. The automatic signals have thus already superseded the telegraph block system on lines where the latter had been in use twenty-five or thirty years. Errors of enginemen constitute the most prominent fault in the automatic system. Faults of apparatus are considered under another head.

DEFICIENCIES OF THE BLOCK SYSTEM.

The complete space interval system is sufficient for all demands of any possible train movement. The time interval is partial. It has to be bolstered up by the red-flag system, and the flag has to be bolstered by the torpedo. But we must recognize all known deficiencies of the block or space system and thus avoid cherishing extravagant expectations of perfection.

Under the telegraph block system an operator may omit to record the passage of a train or to advise the next block station; he may clear the signal for a certain track without first looking out of the window to see if the track is not obstructed near his cabin by another train. Unless the standard of selection and discipline is high, moral faults come in, such as allowing inexperienced persons to perform responsible duties, or going to sleep with signals in the clear position. (Signals when not in use are to be left in the stop position, which provides against danger from a sleeping operator; violation of this rule is therefore to be classed as a moral fault.

An element of weakness in the system as worked on many railroads is found in the long hours of service. A great majority of the signalmen on American railroads are required to be on duty twelve hours out of the twenty-four, and seven days in the week. This is a practice which must be a violation of true economy, except possibly in cases where the work is very easy and hours off are freely granted. Most men who are of sufficient intelligence and moral character to make thoroughly satisfactory block signalmen will naturally seek a respite occasionally from such a confining routine, and if they can not accomplish this without securing a substitute at their own expense they are under constant temptation to "change off"—the day man working for the nightman and the nightman for the day. If they can do this they work more than twelve hours without adequate intermission, which, in such delicate work, is a reprehensible practice.

Errors of enginemen, though rare under the telegraph block system, must be recognized. In spite of the monitorship of the signalmen, enginemen do sometimes run past stop signals. These errors occur usually in the night or in a dense fog, but in probably 99 per cent of such cases the engine runs beyond the signal only a short distance. Against this chance of collision there is a rule requiring the signalmen to forbid the starting of a train from A to B until the last preceding train has passed some distance beyond the signal at B, say 300 feet. These errors of enginemen are mostly due to allowing enginemen to run in districts with which they are not thoroughly familiar or to lax discipline.

The faults of automatic signals are largely nondangerous—that is to say, they may cause a failure of a signal and thus delay one or more trains, but involve nothing worse than delay. To recount these faults would be chiefly a technical essay showing how well the signal engineers and designers have succeeded in eliminating faults and perfecting the system. By successive improvements, following the lessons of experience, failures of batteries, breakage or crosses of wires, and other mishaps have been so controlled that they always set or retain the signal in the stop or danger position.

Dangerous failures of apparatus are those which cause a signal to indicate "proceed" when the block section is not clear. When a train enters a block section, the block-signal arm indicates "proceed." By the passage of the train over the rails, it is caused to move at once into the position to indicate "stop" to the next following train. This is accomplished by the reduction of the force of the electric current flowing through an electro-magnet. This allows the armature of the magnet to drop through the space of a small fraction of an inch. If the armature should fail to move freely in its bearings, or if, in consequence of lightning or some other foreign electric current, the magnet should continue to exert its attractive force, or if the small space should be closed (in freezing weather) by condensed moisture or any substance forming an electrical conductor, the signal would continue to indicate "proceed," and this would permit a second train to enter the block section already occupied by the first one. If then the first train should be unexpectedly stopped, there would be a collision unless (*a*) the engineman of the following train should see the rear car in time to stop, or (*b*) the flagman of the train that had stopped should get off and go back and signal the oncoming train. As to the engineman, he might be prevented from seeing ahead by a curve in the line, or by fog or falling snow; and flagmen, from various causes, often fail to perform their duty. If trains follow one another at very short intervals and at high speed, a flagman may be unable to stop a following train even when doing his best. Knowing that the block signals are almost perfect, he will shirk the task as unnecessary, unless his devotion to duty is of the highest grade. The rules specifically require the flag protection (with both automatic and man-operated block signals) and thus theoretically provide against collision from any failure or wrong indication of the block signals, but the coincident failure of both the block-signal protection and the flag protection must be recognized.

At the same time it is fair to observe that these dangerous failures of automatic block signals are exceedingly rare. Collisions by reason of them are still more rare. One company reports that in a period of five years certain automatic block signals were operated 19,000,000 times, with only two dangerous failures. Other companies could give reports nearly as good, probably; but many of the roads say they have no satisfactory records.

The faults of enginemen respecting signals are largely susceptible of correction by rigid discipline. The more progressive roads have introduced "surprise checking," by which if an engineman has fallen into the careless and dangerous habit of assuming that a signal will be all right, and thus approach it at such high speed that he can not stop when it is against him, he is detected and called to account. This is done by sending out inspectors to put the signal in the stop position when, so far as safety is concerned, it might be in the proceed position. There can be little doubt that of the seven collisions before referred to, most or all would have been prevented or greatly mitigated if this means of enforcing discipline had been in use.

On some single-track roads, where the telegraph block system has been introduced on the cheapest scale, a deficiency in the protection of train movements at the smaller stations appears also in another feature, namely, the use of a single signal opposite the telegraph office in place of two signals, one at the approach to the station yard and the other at the outgoing end of it. This single signal being used to stop trains which must, for convenience, stop with the engine several hundred feet beyond the signal violates the fundamental principle that the stop required by a stop signal must be either exactly at the signal or at some point short of it. While, with this single-signal arrangement, and with switches not interlocked, the block system is incomplete, the fact remains that by suitably modifying regulations and by good discipline, the block system still serves well in its chief function, the important and essential one of preventing collisions between stations.

Before leaving this branch of the subject, mention should be made of the necessity for interlocking. While many of the more important trunk lines are measurably well equipped with both block signals and interlocking signals, which may be called twin safety devices, there are many hundreds of miles on which the block system is used with a fair degree of success, although the interlocking is not complete.

The term "interlocking" is used to designate the arrangement of switches and signals at junctions and crossings by which the attendant is prevented from giving conflicting signals—from permitting trains on two or more converging or crossing lines to come into collision with one another and from giving any signal to pass over a switch until the switch is in a safe position. The signals are the same in appearance as block signals, but in their construction provision has to be made for indicating to a train not only that it may proceed but over which of two or more diverging tracks it is to proceed. If the switch at a junction or cross over is not suitably interlocked with signals, and with distant signals when necessary, the safe passage of trains past such switch depends on rigid adherence to regulations, and on the vigilance of the engineman; and if such a switch is situated within the limits of a block section, the block system is to that extent imperfect. The same is true of a crossing, where one railroad crosses another at grade.

If there are not suitable interlocked signals, which are made a part of the block-signal system, the signals of the block system give only a conditional right to proceed. Likewise a drawbridge, if not interlocked with the block signals, constitutes a break in the block system, which is not provided for except by modifying provisions in the rules under which the block system is worked. There are many lines on which there are both crossings and drawbridges, as well as numerous switches, which are not suitably equipped. At a drawbridge or a crossing in this condition, trains are required to come to a stop, thus providing against wrong movements by putting a rigid limit to the speed of all trains.

On roads where the side-track switches are not interlocked, which is the case at many of the smaller stations on some lines, the safety of trains as regards the danger of misplaced switches depends on the old rules and on a vigilant lookout on the part of the engineman. On such lines the block system is useful mainly in preventing collisions on the open road between stations.

LOCOMOTIVE CAB SIGNALS AND APPLIANCES FOR THE AUTOMATIC CONTROL OF TRAINS.

In addition to the several block-signal systems described, appliances for giving the signal indications in the locomotive cab and for automatically stopping trains when there is danger ahead have been used or tried to a limited extent.

LOCOMOTIVE CAB SIGNALS.

A locomotive cab signal was in use for some time (1902–1906) on the Harlem Line, partly in tunnel, in Park avenue, New York City. It is by this line that the trains of the New York Central and Hudson River and the New York, New Haven and Hartford railroads enter New York City.

In this system the signal indications are given by colored electric lights in the cab. The circuits of the lamps are controlled by a relay similar to that used on the track circuit. At certain predetermined points along the line the circuit that includes the winding of the electro magnet of the relay comes into connection through the wheels of the engine and the rails of the track with an outside controlling circuit which in turn is controlled by the track relays or equivalent devices for the next block section ahead. As the train passes each of these points, if the block ahead is clear, the circuit of the relay on the engine remains unbroken and the lamp indicating "clear block," which has been burning since the last point for the actuation of the relay was passed, continues to burn, but if the block ahead is occupied the relay circuit is broken, the lamp indicating clear is extinguished, and the lamp indicating stop is lighted.

As applied on the Harlem Line the system was worked as an adjunct to the ordinary roadside block signals already in service. It is understood, however, to be designed for use without other signals, as a complete system in itself.

AUTOMATIC STOPS.

Automatic stops are in use on the Boston Elevated Railroad and on the express tracks of the New York City subway. Neither of these lines is interstate, but the applications are of interest as illustrating the practical working of automatic stops, although their use on steam railroads would unquestionably be attended with many serious difficulties not met with under the special conditions of city rapid transit lines. The devices used are practically the same on both of the lines named.

An arm or trip is placed alongside of the rail and arranged so that it lies below the top of the rail when the signal is clear and is raised above the top of the rail when the signal indicates stop. The trip, like the signals, is operated electro-pneumatically. On the cars are valves in the brake pipes having levers projecting downward so as to come in contact with the trips when the latter are raised. The striking of a valve lever against a trip opens the valve, allows the air to escape from the main brake pipe and so, by the regular working of the automatic air brake, cause the application of the brakes on all the cars and the stopping of the train.

Another automatic stop was used on the elevated railroad at the World's Fair, Chicago, and for several years on two of the elevated roads in Chicago; it was also tried to a limited extent on a few standard railroads. This device included a trip and an air valve in the brake pipe, but the design was quite different from that mentioned in the preceding paragraph, and was made with more particular reference to the conditions on standard steam railroads.

A system that may be regarded as a modification of the automatic stop, and which has been tried by a few railroads, uses an electric circuit, completed through a contact device placed near the rail, to actuate the mechanism which shuts off the steam on the locomotive and applies the brakes of the whole train. With this system, however, it is in the power of the engineman to open the throttle and release the brakes as soon as the device has operated; so that he can prevent the train from stopping or can regulate the speed so as to make the stop at any desired point. Thus the apparatus performs the function of calling to his duty an inattentive engineman, while yet not causing excessively sudden or unnecessary stops.

Automatic stops, except those of the class last mentioned, act independently of the engineman and bring the train to a stop before they can be released. They are therefore in the nature of emergency appliances, intended to stop a train before it reaches a point of danger if the engineman fails to do this himself. Obviously the automatic stop must act at such a distance from the actual point of danger that the train can be brought to a stop by the brakes before reaching that point. And if, in the ordinary course of operation, the engineman is to bring the train to a stop before the automatic device can come into action, the stopping point must be arbitrarily moved back, and the signal erected, at the point where the trip or contact for the automatic stop is placed. Ordinarily, then, the engineman will stop at a point (the "home" or stop signal is its new location) a safe stopping distance away from the place where the stop signal is usually located; but if, for any reason, he fails to do so, the train will still be automatically stopped short of the point beyond which it can not safely run.

The automatic stop that can be released at once by the engineman does not necessarily require any change in the location of the signals. The actuating device would naturally be placed at the distant signal (the signal set 100 or 200 rods back as a warning that the stop signal is being approached). In case the engineman should fail to do anything himself toward stopping the train, the automatic appliance would make the stop short of the home signal; but if the engineman is in possession of his faculties and is attending to the running of the train when the distant signal is reached, he can prevent an emergency stop and bring his train up to the home signal exactly as he could if the automatic stop was not there. A disadvantage of this is that the stopping device does not guard against miscalculation or the result of unforeseen conditions that may make it impossible for the engineman to stop as he intends. It is fully effective only in case he is asleep or dead, or for any other reason fails to act when he passes the distant signal. But by the use of a proper recording device, used in connection with the stop to check the action of the engineman, this disadvantage may be in a measure overcome.

It seems clear, then, that an automatic stop to provide for all contingencies should be absolute, and in that case, as already pointed out, there must always be a section of "dead" track in the rear of every danger point, or with automatic block signals moving trains must be practically one block farther apart than they need be under present actual practice. This means a very decided reduction in the capacity of the road; that is, the number of trains that can be moved over it in a given time—a condition that in extreme cases would necessitate a costly increase of track facilities. It is this serious loss in capacity of the road and, in addition, inconveniences that would result from stopping trains at a distance from the proper stopping points, with many practical difficulties in the application and operation of automatic stops, that has prevented any use in ordinary railroad service outside the experimental field of an appliance so desirable theoretically.

It is undeniable that collisions on our railroads could be reduced to an exceedingly small number by the efficient management of block signals as now used, including well-known, well-tested, and generally approved safeguards; it is also unquestionable that an efficient automatic stop would prevent that last small percentage of such accidents as are due to the engineman falling dead at his post, and other like causes.

OTHER APPLIANCES.

A considerable number of inventions, embodying cab signals, automatic stops, and combinations of the two, have been brought to the attention of the Commission. Most of these indicate on the part of their inventors entire lack of familiarity either with the practical conditions of railroad operation or with the present state of the art of signaling. Many violate a universally accepted principle that, in the electrical control of signal appliances, the closing of the electric circuit should be necessary for the display of the clear signal, while the breaking of the circuit, intentional or accidental, should result in the stop indication of the signal. Many appear to have merit, but in the absence of actual continued use, or even extended trial on any standard steam railroads, no very definite opinion concerning their practicability can be formed.

SIGNALING ON ELECTRIC RAILWAYS.

On electric roads, other than standard steam roads on which electric traction has been installed, the development of block signaling has been on quite different lines from those followed in steam road practice. Station attendants are, of course, generally lacking, and, without them, the means of cheaply operating a simple manual block system has not been available.

Interurban roads of moderate length and attaining moderately high speeds have at first been operated without signals of any kind; dependence has been placed upon the time-table for the meeting of cars on single track, and when this has failed, by reason of certain cars losing time, it seems to have been deemed reasonably safe, in view of the low speeds and generally good view, to leave it to the motormen and conductors to use their own judgment in making passing places. This way of operating has naturally, however, proved unsatisfactory, and the next step has generally been to place electric-lamp signals at the passing places and to operate these signals by electric switches thrown by the conductors or motormen. With these simple appliances it is possible for the men in charge of a car, on passing a siding, to signal the movement of their car to the next siding against a car moving in the opposite direction.

Electric lamps have been used very generally in signals for electric roads, for day as well as night indications, because of the ample supply of current to operate them and their simplicity, as compared with signals having moving parts and requiring motors of some kind to move them. Lights, however, can hardly make as effective day signals for high speed movements as do semaphores or even disks.

The track circuit has hardly been considered as a means for the automatic control of signals on electric roads of ordinary character, because of the special and expensive construction necessary to make the track circuit reliably operative in connection with the heavy current from the car motors which must also traverse the rails.

Automatic-signal systems have been used on such roads to a limited extent. These generally make use of contact devices touched or moved by the trolley. The brief electrical impulses given by these devices as the cars pass actuate the signal-setting and signal-clearing mechanism. To insure that the first car going out of a block shall not clear the signals when one or more following cars are still in the block a counting device is used. This is set forward one point by each car entering the block and reversed a point by each car passing out; it therefore comes back to its normal position, permitting the signal to clear, only when as many cars have passed out of the block as have entered in succession. While counting devices may give quite satisfactory results on electric roads running single cars and having few irregular movements, it is plain that they would be practically useless under the complicated conditions imposed by freight traffic.

The automatic block systems for electric roads violate an important principle in that the stop-signal indication is given by the closing of an electric circuit. The objection to this is somewhat lessened by the provision of a more or less positive indication to the motorman that the stop signal has been displayed; in the absence of such indication the motorman is required to proceed carefully through the block. But in this and other respects these systems fall below the standards of automatic signaling, as generally recognized by signal engineers and all competent authorities on the subject.

CONCLUSIONS AND RECOMMENDATIONS.

Under questions 7, 8 and 9, in its order of August 24, the Commission sought to obtain information from railroad officials concerning the economy of the block system, the extent to which it had reduced the number or cost of collisions, and how far it had increased the capacity of their lines.

The answers to these questions have not been, in all respects, entirely satisfactory. Many railroad officials have freely expressed themselves in favor of the block system, and the manager of one of the most important systems of railroad in the country, on which automatic block signals of the latest type have been installed very extensively within the past few years, declares unequivocally that the investment which his company has made in this direction is one of the best that it has made in any department. A great many managers, however, appear reluctant to make positive statements with respect to the actual results attained from the operation of the block system on their lines.

It appears that the block system has been introduced from mixed motives. One road, for example, will incur the added expense of several hundred dollars per mile per year because it has been mulcted a considerable sum for damages in a collision of passenger trains; another will introduce the system because of numerous lesser collisions of freight trains, causing much loss and showing the likelihood of greater loss. Another will emphasize the feature of reputation, knowing that passengers will feel safer under a scientific system and this feeling will influence their patronage. If a competing line already has block signals this argument may be forced on a manager. Another manager, particularly sensitive to the reputation of his road, will be influenced by the effect on his subordinates and on his own peace of mind. They all breathe more freely after getting rid of the anxieties incident to the time interval and flagging system.

The salient facts shown in the statements which have been received from carriers are that—

(1) Fifty of the principal railroads of the country have introduced and are using the block system on their important lines, though with considerable difference in details of apparatus and methods of operation.

(2) The telegraph block system is operated at moderate expense, with a great improvement in safety as compared with former methods of train control.

(3) Automatic block signals, almost universally looked upon in this country as the highest exemplification of the art, have been and are being developed with great energy and skill and liberal expenditures of money.

(4) Automatic signals are superseding the telegraph block system to some extent, and seem destined to do so increasingly in the future.

(5) Thirty roads of considerable length and importance have not yet adopted block signals of any kind.

(6) The block system has proved decidedly profitable even on lines where the signal equipment is not complete, this being accomplished by careful adherence to modifying rules making provisions against the deficiencies of the block system and by the continuance of the train dispatching regulations which were used before the block system was adopted.

It is proper to add that all of the railroads continue in force their rule requiring that when a train is unexpectedly detained a flagman shall go back with a red flag or lantern to stop any following train, though, as the accident records show, flagmen have repeatedly failed to stop trains that have wrongfully passed block signals.

The main facts which have been elicited concerning the present policies of the railroads of the country in respect to block signaling are:

(1) The principal railroads use the block system on their lines of heaviest traffic, and most of them report that it is economical.

(2) Many of these roads use it also on lines of light traffic, and some are rapidly extending it.

(3) All railroad officers deem the system an improvement over any other method of guarding against collisions. In other words, they consider it a means of safety.

(4) Many say that it has reduced the number and cost of collisions.

Those who do not testify on this last point simply plead ignorance, saying that their records are imperfect. One reason why some of the roads do not keep records of the results of the block signal system is, no doubt, that they are convinced that as a means of safety it is an improvement over the old system without statistical proof. Another is that its benefits consist partly in an amelioration of unfavorable conditions which can not be definitely compared one period of time with another. It is probable that one reason why records are withheld on the plea of incompleteness or slight inaccuracies, is that they show the prevalence of permissive blocking, or other practices not generally approved.

The various conditions under which the different block signal methods are used may be observed by considering briefly the practice on typical roads, as follows:

The "controlled manual" system is used on the four-track lines of the New York Central and Hudson River and the New York, New Haven and Hartford. These are the principal examples of this system in the United States. It is, of course, equally adapted to two-track lines. The electric train staff, which is a type of controlled manual apparatus, is used on 100 miles of a single-track division of the Southern Pacific, and on short sections of other roads. The train staff is universally approved as a safety device, but its failure to secure more general recognition appears to be due to a general feeling that the controlled manual apparatus which is used on double-track lines is perfectly adapted to single-track work, and is superior to the staff in that trains need not be stopped or slackened for the purpose of delivering the staff.

The telegraph block system, the cheapest method in use, is found on four-track sections of the Pennsylvania Railroad (though according to the present policy of the road these signals will in the near future be supplanted by automatic signals); it is used on double-track lines by the Baltimore and Ohio, the Pennsylvania, the Chicago, Burlington and Quincy, the Chicago, Milwaukee and St. Paul, the Chicago and Northwestern, the Erie, the New York Central lines, the Philadelphia and Reading, and a number of roads of less importance than these. The telegraph block system is used extensively on single-track lines of the Atchison, Topeka and Santa Fe, the Bessemer and Lake Erie, the Chesapeake and Ohio, the Chicago and Alton, the Chicago Great Western, the Lehigh Valley, the Norfolk and Western, the Northern Pacific, the Southern, the St. Louis and San Francisco, and on the lines just mentioned as using it on double track.

The automatic block system is in use on the four-track lines of the Boston and Albany, the Boston and Maine, the Central of New Jersey, the Pennsylvania, the Philadelphia and Reading, and the Pittsburg and Lake Erie. It is in use on double-track lines of these roads and of the Baltimore and Ohio, the Chicago and Alton, the Chicago and Eastern Illinois, the Chicago and Northwestern, the Delaware, Lackawanna and Western, the Illinois Central, the Lehigh Valley, the New York Central lines, the New York, New Haven and Hartford, the New York, Ontario and Western, the Southern Pacific, the Union Pacific, and on short sections of fourteen other roads. It is used on single-track lines of the Chicago and Alton, the Cincinnati, New Orleans and Texas Pacific, the Delaware and Hudson, the Missouri Pacific, the Oregon Short Line, the Oregon Railroad and Navigation Company, the Southern Pacific and the Union Pacific, and on short sections of four other roads.

With regard to the telegraph block system, most of the roads using it show records of long continued immunity from collision, but the 13 collisions which are referred to in this report, details concerning which are given in the Appendix, with others occurring more recently and still fresh in the public mind, compel us to recognize that the system is not perfect.

The only reason specifically formulated by any railway manager for not introducing the block system is financial inability, except in the case of lines on which the passenger business is extremely light. Looking at the policies of some roads as they are known, and at others in the only way in which they can be interpreted in the light of facts, it is quite clear that, generally speaking, the roads which have been dilatory in adopting the block system or in extending its use have simply pursued that temporizing policy which postpones appropriation of money until necessity will permit of no further postponement. An appropriation for the erection of block signals or for the expense of maintaining them is not viewed with favor, because railroads operating without such signals have, in many cases, made fair records for a long time. It is true that important railroads have carried thousands of passengers for many years, with no block system, without fatally injuring a single one of them in a collision. Such a record is justly regarded with pride, but a single collision ten years hence, which is an admitted possibility, would extinguish the pride and becloud the record of the past.

Many important roads have introduced the telegraph block system with the expenditure of very little money, simply by establishing a few new telegraph offices. There are also cases where a road, which has apparently held the view that the block system is impracticable by reason of its cost, has quickly changed its policy after the occurrence of a collision on its own line. It is true that roads which introduce the block system without increasing their telegraph facilities usually find themselves obliged, for a part of the time at least, to run freight trains under permissive blocking (which, strictly speaking, is not block signaling at all), but the action of such roads is significant because it marks decided progress. Their imperfect system protects passenger trains and it educates trainmen to the need of a space interval for all trains.

A number of prominent roads which have shown enterprise in safeguarding their more important lines by means of block signals are continuing the old methods on other lines. A disastrous collision in the State of Indiana in November affords a striking illustration of this fact. A few roads which enjoy ample prosperity have as yet done little or nothing in providing block signals.

The present investigation has been conducted for the purpose of setting forth the actual facts under present practices, affording the best guide as to what can or should be done to improve the safety of travel on the railroads of the United States. The conclusions reached confirm the views which have been heretofore expressed by the Commission in its annual reports for the years 1903, 1904, and 1905. In its report for the year 1903 the Commission presented the draft of a bill similar to the one introduced in the House by the Hon. John J. Esch, of Wisconsin, which provides for the introduction of the block-signal system and also for the exercise of supervisory power by the Commission through the employment of suitable agents and inspectors.

Supervision is necessary, not only to insure that the specific requirements of the law are complied with, but also because of differences in methods of construction and operation and in the standards of perfection and safety on different roads where the block-signal system is already in use. This point was not especially emphasized by the Commission at the time the bill was laid before Congress, but the present investigation has more clearly emphasized the need of such supervision. The differences of practice, etc., are reflected in the results of operation. In reporting the faults of signals, the errors in operation, different companies make widely different showings. This is a vital matter, in which the function of the Government in securing publicity is a particularly useful one, and in which no authority other than the Government can act efficiently. To investigate accidents, as is done in England and to some extent by State commissions in this country, may be called an indirect method of securing information as to the efficiency with which safeguards to life and property are administered. To investigate signals and signal practice directly, without regard to accidents, would be a more direct method of promoting safety. Accidents should be investigated, for they increase so rapidly year after year that the record is looked upon as a reproach upon our American system of railroad management; but it is even more logical and reasonable to investigate signal practice, for, as regards the worst class of accidents, namely, collisions, investigation and regulation which look to prevention are chiefly of value. Investigation to this end is needed under four heads, namely:

(1) The telegraph block system on the larger roads (mainly double track) as regards the personnel and the routine, the use or nonuse of distant signals, and the practice of permissive block signaling.

(2) The telegraph block system on single track lines and minor roads as regards the personnel, the routine, distant signals and permissive signaling, and also as regards the use of time rules and dispatchers' orders to make up for incompleteness in the block signaling arrangements.

(3) The automatic block system should be investigated on all roads with respect to the efficiency of the apparatus and of the methods of inspection and care and the integrity of the records of signal operations in respect to their completeness.

(4) The automatic block system on single-track lines should be investigated with respect to the features named in the foregoing para-

graph, and also as regards the use simultaneously with the block signals of dispatchers' orders and other measures designed to prevent collisions irrespective of the block-signal system.

If legislative enactment should not require the early introduction of the block system on all railroads, Government inquiry should be pursued with a view to determine the necessity for its installation on particular lines or parts of lines on which it is not now in use. The principal and, indeed, the only argument against the enactment of a compulsory block-signal law, is that a large number of railroads are now making fair progress in the extension of block signals without compulsion. Certainly the roads which come within this class can have no fault to find with such a mild measure of compulsion as that provided for in the bill proposed by the Commission; while as to roads which have taken no action, some compulsion should be employed to require them to bring their service up to a proper standard within a reasonable time.

The question of the need of apparatus for automatic control of trains is a somewhat difficult one. Collisions occur occasionally under both the telegraph and automatic block systems, which an efficient automatic stopping apparatus might prevent. The locomotive engineman has most exacting duties. An individual runner may be far above the average in mental poise and moral character and yet may fail in vigilance or in judgment occasionally, and such failure may mean disaster. Again, the individual engineman may be efficient in a high degree, and yet the efficiency of a force of enginemen as a whole may be unsatisfactory. The engineer performs such an innumerable succession of important acts on every trip that, even with an infinitesimal percentage of failures, the forty or fifty thousand engineers of the United States may still be chargeable within the course of a year with a large aggregate of fatal and nonfatal injuries. Anything less than perfection is cause, at least, for investigation, if not for decided dissatisfaction.

Every great accident due to an engineman's fault is followed by a strong public demand for the introduction of automatic train stopping devices. As previously shown in this report, such devices used to a limited extent, though not on interstate roads, seem to have given a fairly good account of themselves, but these records do not justify the Commission in making any recommendation as to their use or nonuse without a more thorough and complete investigation.

The limited extent to which devices of this character have been used makes it practically impossible for the Commission to obtain anything more than theoretical and technical knowledge concerning them. It is therefore apparent to the Commission that Congress can not be furnished with much further information concerning these appliances, which would appear extremely valuable theoretically, without extensive tests conducted by officials of the Government and at Government expense. For this reason and because the resolution under which this inquiry has been made does not confer authority to make such tests, the Commission, on January 3, 1907, addressed a communication to Congress recommending that supplemental legislation be enacted authorizing the Commission or some other official body to supervise and conduct experimental tests of such safety devices as appear to be meritorious, and that an appropriation be made sufficient to secure the most competent experts and defray the other expenses incident to such a project. The

Commission can only repeat this recommendation, believing that such experimental tests would be of great value in determining the direction which legislation not now recommended should take in seeking to add to the safety of railway operations.

The recommendations of the Commission for immediate or early legislation are summarized as follows:

(1) That the use of the block system should be enforced on the passenger lines of the country in general, according to the provisions of a bill in substance like the one submitted to the Congress by the Commission in December, 1903, except that the time to be allowed for final compliance with its compulsory features should be made three or four years from the present.

(2) That with or without the passage of a law requiring the use of block signals there should be a law authorizing an official investigation of train accidents, and providing for the employment of competent men to perform the duties imposed by such an enactment.

(3) That investigation by official tests of automatic appliances for the control of railway trains should be authorized in accordance with the Commission's recommendation of January 3, 1907, with an appropriation of sufficient amount to conduct such tests in a proper manner.

Recently a disastrous collision occurred in the District of Columbia (at Terra Cotta station on the Baltimore and Ohio Railroad, December 30, 1906) in which 43 passengers and other persons were killed. This collision occurred on a line equipped with block signals. It was the subject of much discussion in the press and elsewhere, and the circumstances attending it were such that the whole question of the management of railroad trains when running at high speed was brought prominently before the public, including the comparisonof the block system with other methods. The Commission therefore instituted an inquiry into the case, as well as into another collision which occurred in November on the Southern Railway, causing the death of Mr. Samuel Spencer, the president of that railway. These inquiries are not yet completed, but these accidents are referred to here simply for the purpose of observing that consideration of them has not been omitted. The investigations have proceeded far enough to show that the fault in these cases is not to be charged to the signal system in use, but to laxity in the methods of operating it. Collisions from the same or similar causes have occurred many times before, and these causes have had full consideration in the present report. As has been observed in the annual reports of the Commission to Congress, the block-signal system remains superior to any other system, both theoretically and by the test of actual experience, after all due weight has been given to the records of failures in the running of trains under it. It is the intention of the Commission to submit a further report covering these matters and other questions that have not been fully treated herein.

Answering specifically the questions (not hereinbefore answered) which are embodied in the Senate resolution of January 29, 1907:

The length of time that would be required to put in operation the telegraph block system would depend on the facility with which telegraph operators could be trained to act as signalmen, and, in most cases, on the ability of manufacturers (railroad shops or independent concerns) to provide and erect the signals and apparatus. As these questions have to be decided in each case on the special conditions of that case, a general answer could not be made; but a period of from one to three years would undoubtedly be fair. For the installation of automatic signals a longer time should be allowed in the present state of manufacturing business with all shops overworked, a much longer time, because the apparatus is delicate and costly, requiring time and extensive facilities for manufacture. The Commission has not recommended the specific requirement by law of any particular kind of signals, and it is not believed that the introduction of automatic signals should be made compulsory at the present time.

The record of the number of deaths by accident, which is called for by the last paragraph of the resolution, will be found in the Appendix.

All experience has shown that, generally speaking, the number of deaths is reduced by the adoption of automatic block signals as compared with operation without block signals, but no ratio has been computed, for the reason that on nearly every railroad conditions are constantly changing, making comparisons uninstructive; and, obviously, it is impossible to estimate what would have been the number of fatal accidents on a block-signaled railroad if it had not been block signaled.

Employees in connection with the dispatching and moving of trains and the operation of block signals should also work under such conditions only as will promote in them the best mental, physical, and moral conditions attainable in the service. The rules of operation by which they are to be governed should be, as far as possible, uniform and absolutely explicit, and free from ambiguities and confusion. There can be no doubt that many of the recent great disasters are traceable to defective service due to nonobservance of these essentials.

A comparison of the results (freedom from fatal accidents of automatic block signals with nonautomatic) can not be made with any degree of accuracy for the reasons just mentioned, and because the nonautomatic system is worked under varying conditions. In certain imperfect comparisons which have been made, the automatic system has appeared to be superior, but the nonautomatic was at a disadvantage, because it was worked without certain safeguards.

All of which is respectfully submitted.

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Washington, D. C., *February 23, 1907.*

APPENDIX.

CONTENTS.

GLOSSARY.

Block system: Any method of maintaining an interval of *space* between trains moving on a railroad. Primarily the term refers to the spacing of trains moving (on the same track) in the same direction; but in practice it is used, on single-track lines, both for this purpose and for the protection from each other of trains moving in opposite directions toward each other.

Telegraph block system: A block system in which the block signals at a block station are worked by an attendant on information conveyed to him from the other block stations by the Morse telegraph. In some cases telephones or electric bells are used instead of the telegraph.

Manual block system: Another name for the telegraph block system.

Controlled manual block system: A manual block system with electric bells (not the telegraph), in which the signal apparatus at one end of a block section is electrically locked with that at the other end in such a way that to display a "proceed" signal to permit a train to enter the section the signal men at the two block stations, the entering end and the outgoing end, must act together.

Electric train staff: A form of the controlled manual block system for controlling train movements on single track.

Lock-and-block: Another name for the controlled manual system.

Block station: A place from which manual block signals are operated. On important lines the block station is generally a "tower," that is, a two-story building, with the signal levers and telegraph instruments in the second story.

Automatic block system: A block system in which the signals are worked by power, without an attendant, the power being controlled by the passage of a train into, through, and out of a block section. The kinds of power used are electro-magnets, actuated by primary or storage batteries; weights and clockwork; compressed air; carbonic-acid gas; and electric motors worked by primary or storage batteries, or by electric current conveyed by line wire from a generator station. A train (or car) sets a signal to indicate "stop" by the effect which the car wheels have on an electric current flowing through the rails of the track.

Permissive block signaling: Permitting a train to enter a block section before the preceding train has vacated it. In such cases the second train is required to run as slowly as may be necessary to avoid striking the train ahead; that is to say, the engineman, duly considering the speed at which he is moving, must, in case of a curve in the road, or when snow is falling, or a fog prevails, or there is any obstruction to his view, see that the track ahead is clear far enough to permit of stopping short of any obstruction. He must not depend on receiving any warning from a flagman or otherwise as to the whereabouts of the preceding train.

Space-interval system: The block system.

Time-interval system: The rules under which trains are run where there is no block system. To obviate the danger of rear collisions in consequence of unexpected delays to trains between stations the attendant at each station sees that a prescribed interval, usually five, seven, or ten minutes, is maintained between trains. This interval is intended to allow time enough for the protection of a delayed train by sending back a flagman to warn any following train.

Rear collision: A collision in which a train (or engine) collides with a train, car, or engine ahead of it, headed in the same direction as itself.

Butting collision: A collision between meeting trains—trains moving toward each other on the same track.

Torpedo: An explosive cap, the size of a small watch, fastened on the top of a rail of the track, to be exploded by the pressure of the first wheel of an approaching engine or train. The detonation indicates "stop." Torpedoes are used when, by reason of fog, snow, darkness, or other cause, a visible stop signal, such as a flag or light, may not be seen by the engineman.

Fusee: A chemical fire light, like a roman candle, giving a bright light—red or green—as a stop or slow signal. The fusee is thrown off the rear of a train as a warning to any following train. Its stick has a sharp point, and it can be thrown so as to stand upright. It is the only practicable stop signal in use which can be effectively given at will from a moving train.

Train dispatcher: The officer who supervises the movement of the trains on a given division of railroad, sending telegraphic orders to the conductors and enginemen of trains for which the time-table does not give full authority. On a single-track line he must by this means adjust the relative rights of opposing regular trains when one or both is behind time, and those of all extra trains.

Semaphore signal: The most common form of fixed signal used on railroads. It is a movable arm about 4 feet long pivoted at one end to a post from 20 feet to 30 feet high. The arm in a horizontal position always indicates "stop." (See description in Appendix.)

Train-order signal: A fixed signal—semaphore or other—used at telegraph offices to indicate to a train that it must stop there to receive a telegraphic order affecting its right to the road.

Automatic stop: A mechanical appliance to be used as, or in connection with, a block signal on a railroad to stop a train (or car) by cutting off its motive power, or setting its brakes, or both.

Fixed signal: A signal fixed in a certain location, as distinguished from a signal, such as a hand flag or hand lantern, which is carried about from place to place.

Home signal: A fixed signal, as at the entrance of a block section, which, when it indicates "stop," requires an approaching train to stop before passing the signal.

Distant signal: A fixed signal used primarily to indicate to a train that it must stop at another signal—a home signal—a certain distance beyond. When a distant signal indicates "proceed," it means that the stop signal to which it is related will be found in the "proceed" position. The distant signal, by its indication—"caution" or "proceed"—gives to the engineman a preliminary warning of what indication he may expect to receive from the "home signal" and thus often obviates a reduction of speed.

ACCIDENTS.

Below are given two lists of accidents. The first of these is a tabular statement showing a striking comparison between the casualties to employees in collisions and derailments on the railroads of Great Britain, where the absolute block system is nearly or quite universal, and casualties to the same classes on the railroads of the United States, where far the greater part of the freight train mileage is worked without the absolute block system—and much of it on roads having no block signals at all for any class of trains.

The second statement is a summary of collisions reported during two years as occurring on block-signaled lines in the United States. From this it will be seen that practically all of the collisions on lines worked by the manual or telegraph block system were due to errors or neglect of signalmen, while all of those in the list occurring on lines equipped with automatic block signals were due to errors of enginemen.

It will be seen that the proportion of casualties to numbers employed on the English roads, as shown in the table, is very small as compared with the proportion on the American roads. For a long succession of years the official reports, published by the British Board of Trade, summarizing casualties reported by the railroads of the United Kingdom, have shown the total deaths of employees from both collisions and derailments per million employees at only about one-fortieth of the aggregate from the same causes in this country—a truly startling comparison.

Employees killed and injured in collisions and derailments.

	1905.				1904.			
	Killed.		Injured.		Killed.		Injured.	
	Number.	Proportion.[a]	Number.	Proportion.[a]	Number.	Proportion.[a]	Number.	Proportion.[a]
UNITED STATES.								
Train mileage	....	....	....	....		975,000,000		
Collisions	410	....	3,618	....	464	47.59	3,700	379.49
Derailments	305	....	1,497	....	285	29.23	1,739	178.36
Collisions and derailments	715	....	5,565	....	749	76.82	5,439	557.85
GREAT BRITAIN (UNITED KINGDOM).								
Train mileage	....	....	....	....		397,000,000		
Collisions and derailments	6	....	112	....	7	1.76	114	28.72

	1903.				1902.			
	Killed.		Injured.		Killed.		Injured.	
	Number.	Proportion.[a]	Number.	Proportion.[a]	Number.	Proportion.[a]	Number.	Proportion.[a]
UNITED STATES.								
Train mileage		951,000,000				905,000,000		
Collisions	561	58.99	3,781	397.58	425	46.96	3,065	338.67
Derailments	264	27.76	1,714	180.23	229	25.30	1,380	152.49
Collisions and derailments	825	86.75	5,494	577.81	654	72.27	4,445	491.16
GREAT BRITAIN (UNITED KINGDOM).								
Train mileage		394,000,000				400,000,000		
Collisions and derailments	9	2.29	146	37.06	4	1.00	110	27.50

[a] Number per hundred million train miles.

The list of collisions on block-signaled American lines follows:

In the two years from July 1, 1904, to July 1, 1906, there were reported in the United States 4,783 rear and butting collisions of trains; of these 160, killing 460 persons and injuring 2,408, were of sufficient importance to be specially mentioned in the accident bulletins. Of these 160, 13 occurred on lines worked by the telegraph block system. The following is a condensed statement of the causes of these 13, taken from the bulletins:

1. Rear collision of passenger trains; 16 persons killed, 52 injured. The signalman at B took the chance of permitting the signalman at A to give a clear signal before he had put his own signal at stop behind the preceding train, which was detained only 470 feet beyond B, in sight of the signalman, and was run into by the next train.

2. Rear collision of freight trains; 2 persons injured. A signalman fell asleep and failed to put his signal in the stop position after the passage of the leading train. Second train had reached his station on a permissive signal.

3. Rear collision of freight trains; 1 person killed and 2 injured. Signalman gave a clear signal when the block section was not clear; gross negligence.

4. Butting collision, passenger train and yard train; 19 persons injured. Signalman permitted a yard engine to occupy main track on the assumption that passenger train would approach with speed under control. Gross negligence.

5. A signalman turned a freight train into a sidetrack, forgetting an engine which was standing on the sidetrack.

6. Butting collision of freight trains; 4 persons killed, 3 injured. Confused and careless conduct by the two signalmen, one 19 years old, the other 21 years old, and both of only six months' experience. In this case there was electrical locking between two signal stations, but not the full "controlled manual" system.

7. Rear collision of passenger and freight trains; 2 persons injured. Misunderstanding between operators.

8. Rear collision of freight trains; 2 persons injured. Mistake of signalman who had been in service at this place only five days; two years' experience elsewhere.

9. Rear collision, a passenger train and a freight train. Mistake of signalman who had been in the service only two weeks.

10. Butting collision, passenger and freight; 4 persons killed, 18 injured. Signalman, three years in the service, formerly a brakeman, went to sleep, leaving his signal in the clear position. (This and item 2 are to be classed as gross negligence. Usually in cases of this kind there is a moral delinquency and frequently collusion between operators. The rules require that when a signalman withdraws his attention from a signal it must be left in the stop position, and they also forbid the operator at the outgoing end of a block section to telegraph back "all clear" to the entering end except when he has his signal in the stop position.)

11. Rear collision, passenger and freight; 40 persons injured. Signalman went off duty without giving proper information to the man who relieved him.

12. Rear collision, near station, passenger train ran into work train. The passenger train should have been diverted from track No. 4 to track No. 3. The primary error was the omission to put the block signal promptly in the stop position immediately after the passage of the work train, both trains being under the control of a single signalman at the time.

13. Carelessness in giving permissive signals, a passenger train and two empty engines being allowed in the same block at the same time.

In the same two years Class A contained notes of seven collisions (all rear collisions) occurring on lines equipped with automatic block signals. All of these were due to enginemen passing signals indicating stop.

1. Rear collision of passenger trains; 7 persons killed, 14 injured. Engineman, experienced, ran past two block signals set against him. Gross negligence. There is no indication that he did not see the signals except possibly that one was obscured by smoke, though the engineman knew undoubtedly that he had passed it while it was obscured.

2. Rear collision of freight trains; 3 persons killed, 2 injured. Occurred at 2 a. m. Engineman asleep. Had been on duty twelve hours thirty minutes.

3. Rear collision of freight trains; engineman asleep. Brakeman on engine failed to keep a lookout. These men had been on duty sixteen hours forty-five minutes, with an intermission of two hours.

4. Butting collision of freight trains; no explanation.

5. Rear collision of freight trains; engineman on duty fourteen hours, with three hours' intermission. This engineman had been in the service only fifteen days.

6. Rear collision of freight trains; no explanation of engineman's negligence. A brakeman was riding on the engine and might have seen the signal and stopped the train.

7. Rear collision, passenger and freight; no explanation.

BLOCK SYSTEMS.

The several methods of block signaling or block working may be divided into three classes:

First. That in which the signals themselves are operated manually, by signalmen, in accordance with information transmitted from one signalman to another.

Second. That in which the signals work automatically; that is, signalmen are not required and the signals, moved by any suitable power, are so controlled electrically as to indicate stop or proceed in accordance with the presence or absence of trains in the blocks or of other conditions, such as open switches, affecting the safe movement of trains.

Third. That in which the signals are operated manually but are so controlled by electrical devices that a signalman is prevented from setting a signal to allow a train to enter the block until the signalman at the other end of that block cooperates with him to release the controlling device. This form of the block system may and usually does include, either construction such that a train must pass out of the block before the releasing can be effected, or means by which the presence of a train in the block makes it impossible to give a clear signal.

Before the details of these three classes of the modes of block signaling are taken up, the signals themselves, which are, of course, common to all three, and the track circuit, which is the foundation of the systems of the second class and plays an important part in some of those in the third, will first be described.

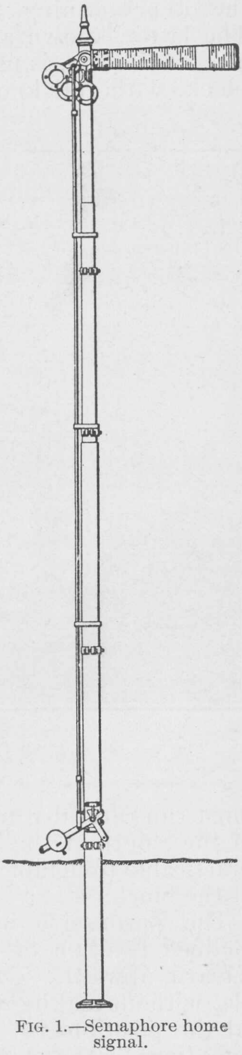

FIG. 1.—Semaphore home signal.

THE SEMAPHORE.

The signal most generally used in all these systems is of the semaphore type, fig. 1. The semaphore signal was developed from the semaphore used for the transmission of messages before the invention of the electric telegraph. It consists of a vertical post or mast 20 to 30 feet high, near the top of which is pivoted a movable arm nearly 1 foot in width and 4 or 5 feet long. The semaphore is placed at the right of the track and the arm projects to the right of the mast, as viewed from an approaching train that is to be governed by its indications. Where there are several parallel tracks the signals may be placed on a light bridge spanning the tracks and either a little to the right of, or exactly over, their respective tracks. (See fig. 2.)

By day the necessary signal indications for the government of the enginemen are given by the positions of the arm. The arm horizontal, which may have a fancied resemblance to a bar opposing the passage of a train, means stop; an inclined position means proceed. In block signaling it is found to be necessary or desirable to give two different "proceed" indications—one meaning "proceed, block is clear," and the other meaning "proceed, looking out for a train in the block." The latter, known as the caution, or perhaps preferably the permissive, indication, is used to permit a train to proceed into an occupied block, with full knowledge, on the part of the engineman, that he

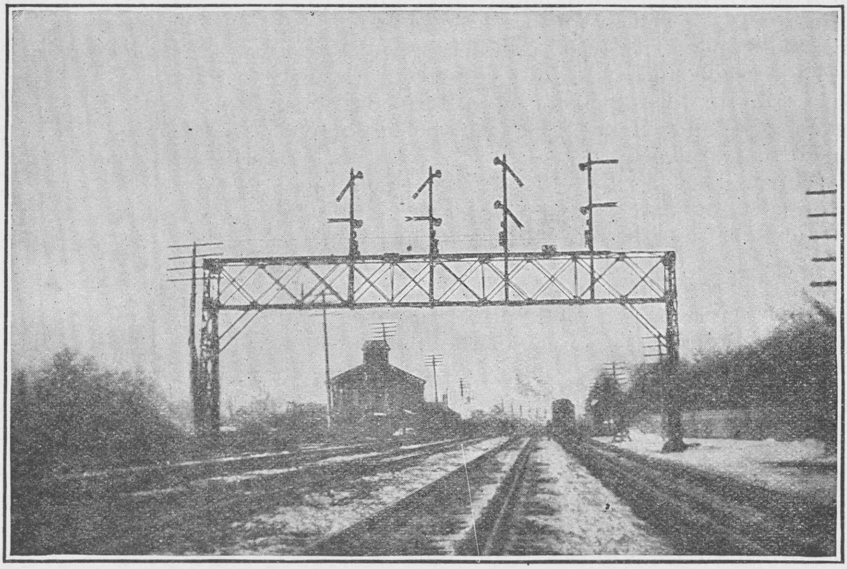

FIG. 2.—Signal bridge with electro-pneumatic automatic block signals.

must run carefully and look out for a train ahead, where, on account of the length of the block or the frequency of trains, it is not always practicable to detain one train until the preceding train has passed out of the block.

The permissive indication is usually given by an intermediate inclined position of the arm; on some roads it is given by inclining the arm upward. To make the three indications as distinct as possible, without making the arm work both above and below the horizontal the positions 90° and 45° from the horizontal, fig. 3, are used on some lines for the "block clear" and permissive indications, respectively.

Home and distant signals.—The signals, figs. 1 and 3, distinguished by the square ends of the arms, are known as home signals, because they are usually located at or near the places from which they are operated. The home signal marks the point at which trains may be required to stop. and, when indicating stop, must not be passed by a train except in the case of a signal located in front of a station; it is usual to allow trains to move a short distance past such a signal in order to stop at the station platform.

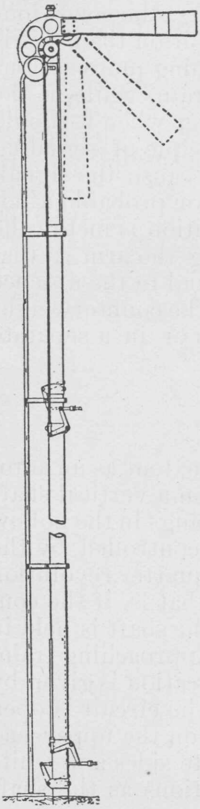

FIG. 3.—Three position 90° Semaphore.

To give the enginemen preliminary information as to the indications of the home signal, so that they may have no difficulty in stopping before passing it when it indicates stop, and may proceed at unchecked speed when it is clear, a distant signal is used. The distant signal is distinguished by a notch in the end of the arm, fig. 4. The horizontal position of the arm does not call for a stop at the signal, but cautions the engineman to be prepared to stop at the home signal; the inclined position of the arm is an indication that the home signal is clear.

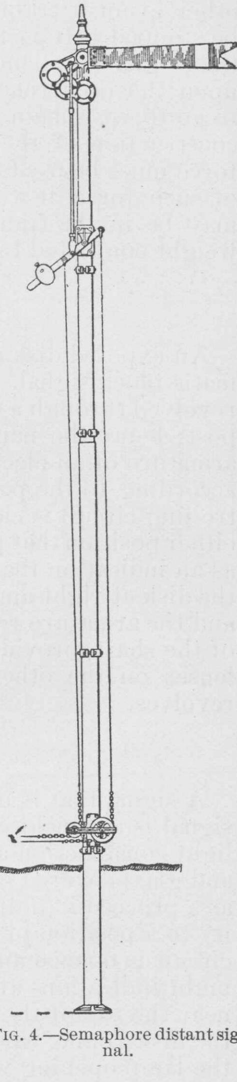

FIG. 4.—Semaphore distant signal.

Night signals—At night the indications are given by colored lights. An extension of the arm to the left of the center on which it works forms a frame in which one or more colored glasses are held. With the movement of the arm these glasses move in front of a lamp and give a red light when the arm is horizontal, commonly a green light for the permissive indication, and, by uncovering the lens of the lamp altogether, permit the white light to appear for the "block clear" indication. The distant signal also shows a white light when clear, but, although its aspect by day when indicating "prepare to stop at the home sig. nal," is quite different from that of the home signal giving the permissive indication; it is common practice to use lights of the same color, green, for these two indications at night. This is mainly because of the difficulty in obtaining lights of a sufficient number of different colors and of the necessary degree of visibility. The semaphore arm is moved by a lever in the station or signalman's cabin, connected to the arm by means of rods or gas pipe or, in the case of a signal at a considerable distance, by means of wires. Semaphores are also operated, especially when used for automatic signals, by electric motors, fluid pressure, or other suitable power, electrically controlled.

Counterweighting.—It is obvious that a signal must be liable to failure in the performance of its functions, due to breaking or sticking of some part of its mechanism or of the operating means. A moment's thought will make it clear that, when a failure occurs, the conditions will be much better if the signal stays in the stop position than if it is left in the clear position. For, in the first case, nothing more serious should result than the unnecessary stopping of a train, while in the other event a train may proceed and run into danger when it should be stopped. It is therefore a well-established principle of signaling that signal appliances should be so designed as to cause the signal, upon the occurrence of failures of the most usual or probable kind, to go to, or remain in, the stop position. This condition is met in the construction of the semaphore by counterweighting the arm so that force must be used to bring it to the clear position, and in the absence of such force, it will take the horizontal position. The counterweight may be in the frame that holds the colored glasses or in a separate weight connected to the rod below the arm.

CLOCK-WORK SIGNALS.

An exposed disk signal (fig. 5) is used to a limited extent as an automatic block signal. The disk or target is mounted on a vertical shaft revolved through a train of wheels by a weight that hangs in the hollow post; hence the name clock-work signal. Detents controlled by the armature of an electro-magnet hold the shaft at any quarter revolution according to the position of the magnet armature; that is, if the controlling circuit is closed and the armature attracted the shaft is held in either position that presents the disk edgewise to an approaching train, as an indication that the block is clear; the stop indication is given by the disk at right angles to its former position, when the circuit is open and the armature released. At night a lamp placed on the upper end of the shaft, provided with red lenses on two opposite sides and white lenses on the other sides, gives the proper indications as the shaft revolves.

INCLOSED-DISK SIGNALS.

A signal that is used to a much greater extent than the clockwork signal is the inclosed-disk signal, fig. 6. The disk, which is of very light construction and protected from wind and weather by the case and glass-covered opening, is easily swung to one side of the opening, as a proceed indication, by an electro-magnet and is returned by gravity to a position in front of the opening, as a stop indication, when the circuit is opened and the magnet ceases to attract its armature. The night indications are given by a lamp placed behind the small opening near the top of the case; a ring attached to a bar that forms part of the disk frame, carries the colored glass which is brought in front of the lamp opening when the disk covers the large opening below.

The disk signal has the merit of simplicity and cheapness both in first cost and maintenance. For this reason, and also perhaps because it is felt that automatic signals should differ in form from other signals, disk signals are in favor for automatic blocking on a few roads.

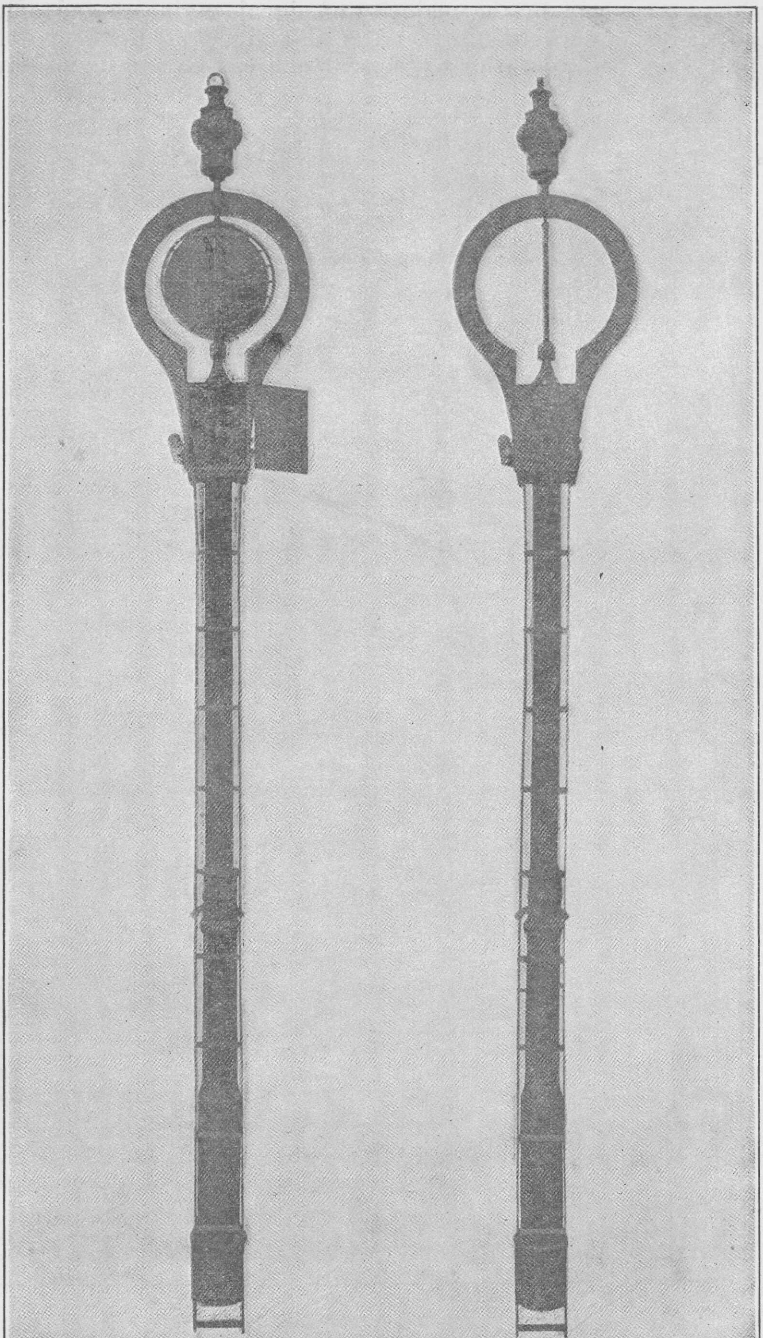

FIG. 5.—Clock-work signal.

It is, however, held by the majority of signal engineers and officers in the operating department, that the disk signal is, in the point of visibility, decidedly inferior to the semaphore. Except under favor-

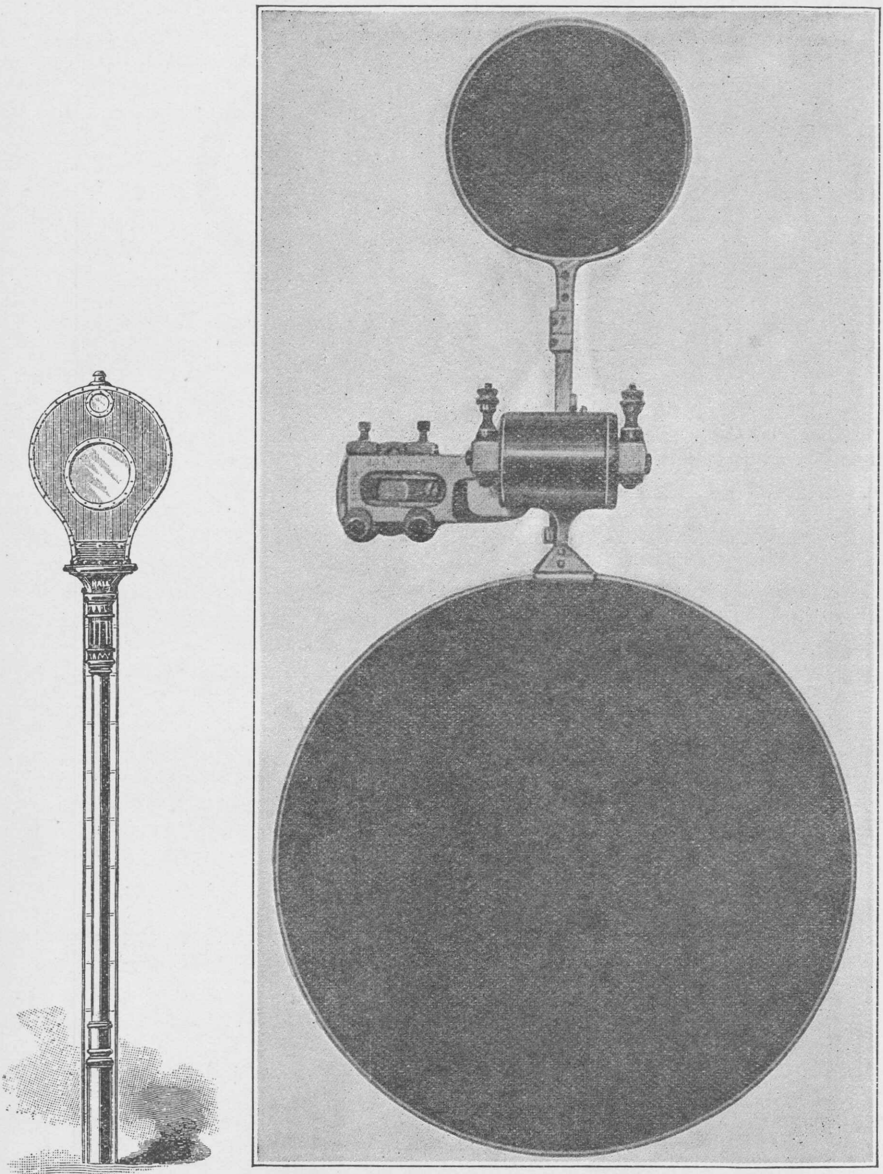

FIG. 6.—Inclosed-disk signal.

able conditions as to light, it is difficult to see clearly at any considerable distance whether or not the disk is in front of the opening; at times sunlight is reflected from the glass in such a way that the disk can not be seen; in winter snow sometimes sticks to the glass and obscures the indication.

The clockwork signal, while at a disadvantage as compared with the inclosed disk on account of a somewhat complicated mechanism and in having moving parts exposed to the weather, is little better in respect to visibility; it is still much inferior to the semaphore on account of the small size of the disk or target.

Many clock-work and inclosed disk signals were installed during the early years of automatic signaling, because they were then the only signals that could be had at a cost that could be considered by most railroads. But since the development of automatic semaphores, successful in operation and reasonable in cost, the use of signals of the other two types has extended much more slowly, as it is generally agreed that, in distinctiveness and in the clearness with which its different aspects can be perceived at a distance, the semaphore surpasses all of the numerous other types and forms of signals that have been tried and used since railroads began to require fixed signals.

THE TRACK CIRCUIT.

The track circuit, used for the control of automatic block signals and also to actuate the releasing devices in the controlled manual system is illustrated in fig. 7. The two lines of rails form the conductors for the electric current. At each end of the track-circuit section the rails are insulated from the adjoining rails by insulating rail splices, so that the flow of current is confined to the desired limits. To guard against interruptions on account of poor metallic contact at the rail splices within the circuit, bond wires, riveted to the ends of the adjoining rails, are provided at every joint.

The two terminals of a battery B are connected by wires to the opposite rails at one end of the section. The ends of the winding on an electo-magnet R are similarly connected at the other end. The opposite rails are imperfectly insulated from each other by the ties and ballast, but while a certain amount of the current is wasted by "leaking" across from one line of rails to the other, a sufficient quantity flows from the battery through one line of rails, through the wire of the instrument, and back through the other line of rails to the battery, to energize the magnet and produce the desired effect. The practicable length of the track circuit is limited by this "leakage" of current, but there is usually no difficulty with sections one-half to three-fourths of a mile in length, and, under favorable conditions, lengths of 1 mile or more are worked successfully.

The wheels and axles of a train, by making a good metallic connection between the opposite rails, form a "short circuit" or "shunt," through which passes nearly all the current given out by the battery. The flow of current in the wire of the instrume nt R is thus practically cut-off and the magnet is deenergized. The breaking of a rail or of any other part of the electrical conductors of course has the same effect on the instrument. As the available current is small, the instrument R, known as a track relay, is usually of delicate construction. It does not operate or mechanically actuate the signal, but merely serves, by means of contacts attached to its armature, to complete, when the track circuit is clear, or interrupt, when the track is occu-

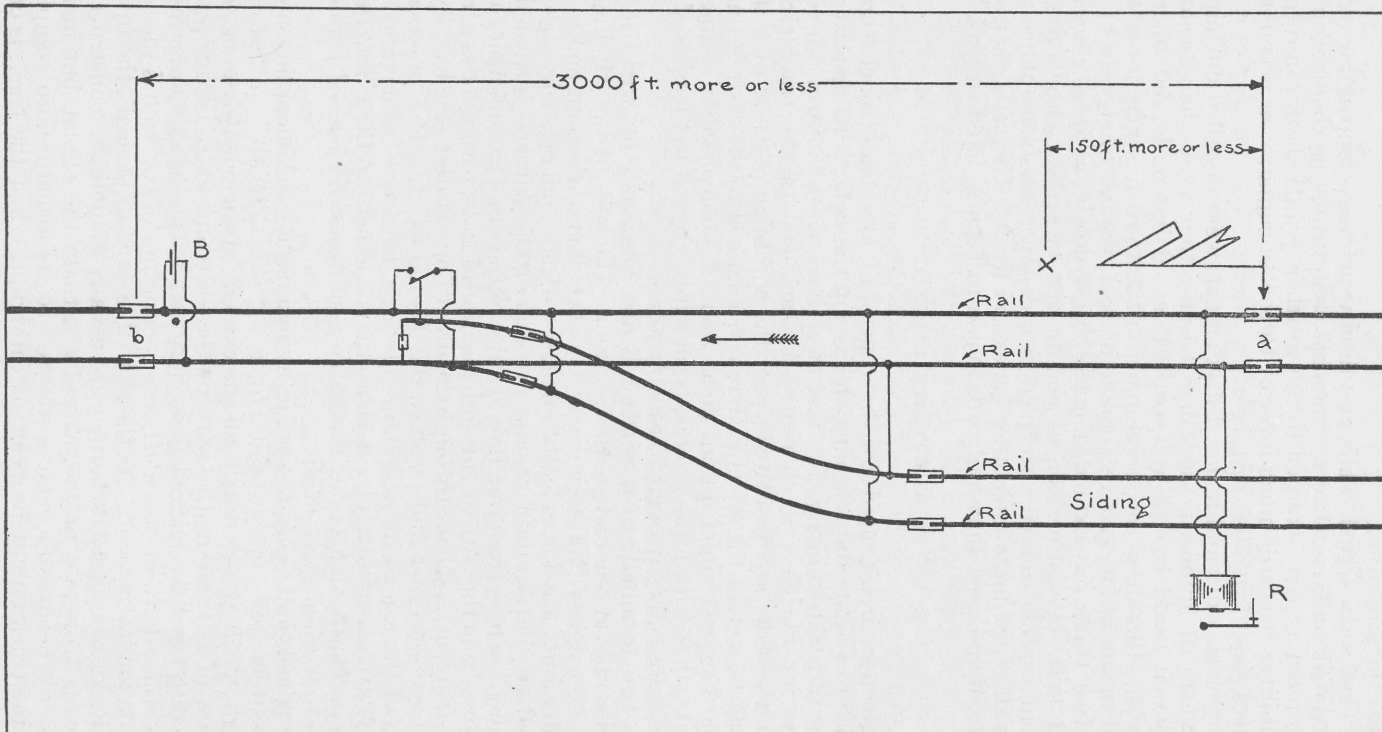

FIG. 7.—Diagram of track circuit.

pied by a train, one or more other circuits directly controlling the signals.

Failures.—In addition to the most usual failures common to all electrical circuits, due to broken conductors, loose connections and similar causes, the track circuit is especially subject to failures on account of increased leakage resulting from bad-track conditions or wet weather. Failures from these causes are "on the safe side," that is, they cause the signals to indicate stop when the block is clear. With proper construction and maintenance, however, the frequency of such failures is not so great as to interfere with the usefulness of the track circuit.

Dangerous failures of the track circuit are probably not more numerous than similar failures of the other circuits and devices connected with automatic signals; and, as records and experience show, the total of such failures is relatively very small. But they have unquestionably increased in number with the extension of electric railroads in the vicinity of steam roads using track circuits. The stray return currents of electric roads find their way through the earth to the rails of steam roads, and when of considerable strength or under certain combinations of circumstances, cause the magnets of track relays to be energized when trains are on the circuits. One method of securing at least partial protection against failures from this cause consists of connecting a second relay at the end of the track circuit at which the battery is connected, which may be deenergized by a train even though the relay at the other end of the circuit should be energized by stray currents.

THE TELEGRAPH BLOCK SYSTEM.

In simple manual block working any convenient means of communication may be used. With electric bells the necessary inquiries and information may be sent from one man to another by means of a code consisting of various numbers of taps or rings and combinations of numbers separated by pauses. The telephone serves still better or might supplement the bells by furnishing the means for explanations not provided for in the bell code. The Morse telegraph is most extensively employed, however, because its use in railroad working in America preceded the adoption of the block system and, when any line has undertaken block working, the telegraph has been already available; hence the general name, "telegraph block system."

Both the appliances and the working of the telegraph block system are very simple. At each block station there are erected signals to govern movements of trains in each direction (or a signal for movement in the proper direction on each track, where there are more than two main tracks). Each signal may give two indications, "stop" and "proceed, block is clear," or three indications, "stop," "proceed, block is clear," and "proceed, block is occupied by a preceding train," according to the conditions or method of operation. (See fig. 8, where the right-hand arm indicates "stop" and the left hand, "proceed, block is clear;" and fig. 9, in which the right-hand arm indicates "proceed, block is occupied by a preceding train.") Where the traffic is moderate the signals are usually erected at the regular stations and operated by telegraph operators who perform other duties at those stations. If some of the distances between stations are inconveniently great, or if other special conditions make it necessary, additional block stations may be opened. Where traffic is heavy and the operators' full time will be taken up with the block signal work, separate buildings may be provided for the signalmen and placed with more particular reference to the most suitable lengths of blocks or to the location of junctions, yards, etc.

Signals.—Signals like those shown in figs. 8 and 9, having on the same post signal arms governing trains in both directions, are used to a considerable extent on account of the simplicity of the connections and the low cost, and their use is regarded as allowable practice; but they are objectionable because the signal for one track is necessarily on the left hand (wrong) side and, in fact, over beyond the adjoining track, and also because it is occasionally necessary for trains to pass stop signals in order to get up to station platforms or reach sidings. A much better arrangement is to erect a separate post for each track and locate it in advance of the station so that there will ordinarily be no occasion for trains to move beyond stop signals.

For the sake of economy the telegraph block system has been installed to a great extent without distant signals. Where trains are at all frequent and the speeds of some trains are high, the absence of distant signals is a serious weakness in any signal system, for the reason that trains must either lose time by approaching carefully all home signals that can not be seen at an ample distance, or must take chances by keeping up their speed at the risk of passing a signal if it is found to be in the stop position. If discipline is good, however, and trains are not allowed to overrun stop signals, the lack of distant signals is not necessarily a dangerous condition.

Permissive blocking.—Obviously, if but one train at a time were to be allowed in a block, and a considerable number of trains were to be moved over a given line each day, or the movement of several trains in a short space of time without delay were to be provided for, short blocks would be necessary. Short blocks, however, mean large cost for operation, on account of the large number of signalmen that must be kept on duty. In practice, therefore, the length of block must be greater than the ideal length, which would permit the given train movement with only one train in each block, and must be a practicable length, governed by the possible expenditure for block operation, or fixed, in many cases, by the necessity of combining the block stations with the regular stations. With these longer blocks some of the trains must be admitted to blocks occupied by preceding trains—the method of operation known as permissive blocking—since, under this method, a train is permitted, with due warning, to enter a block that is not clear.

The usual practice is to allow freight trains, and in many cases passenger trains, to enter blocks occupied by freight trains, but to allow no train to enter a block occupied by a passenger train except by special order, naming the train ahead to be looked out for. Where freight traffic is heavy the permissive movements are regularly made on a third indication of the block signal, already mentioned, meaning "Proceed; block is occupied by a preceding train." Where traffic is lighter absolute blocking (that is, allowing but one train at a time in a block) may be the rule and permissive movements are then made only in special cases by order of the train dispatcher.

Operation.—In operating the telegraph block system each signalman keeps a train record, on which he notes the passage of each train

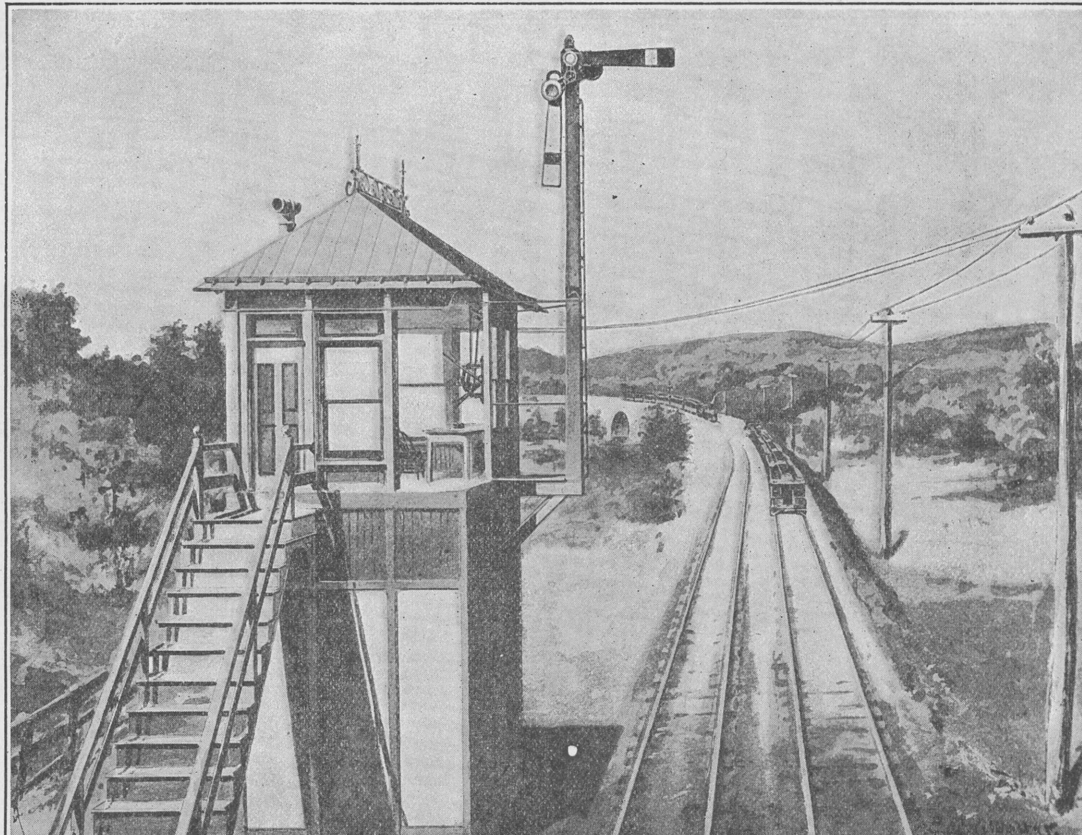

Fig. 8.—Telegraph block signals—stop and clear indications.

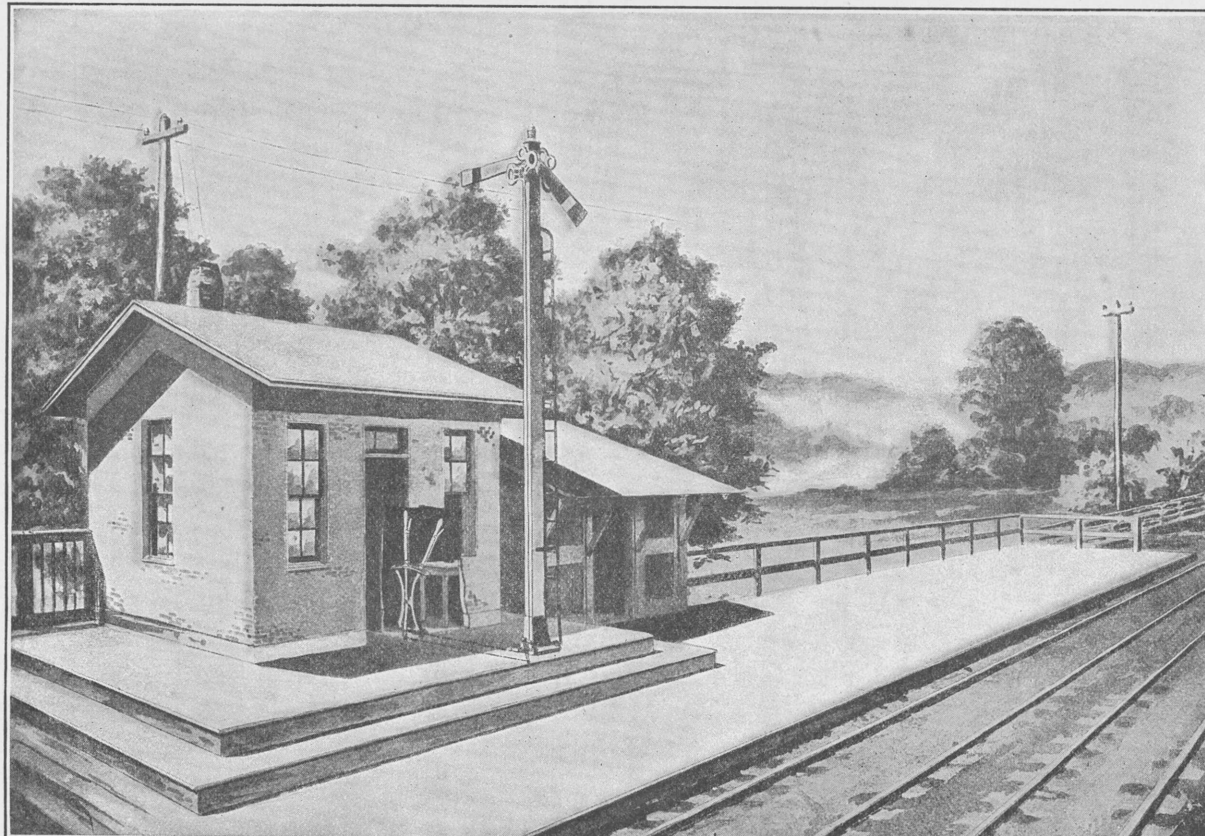

FIG. 9.—Telegraph block system—permissive indication.

and the information he receives from the signalmen at the neighboring stations as to the approach of trains or their passage out of the block ahead. In the simplest manner of operation the signalman, when he is informed that a train is approaching, if his record shows that the block ahead is clear, clears his signal for the train to proceed. When the train passes his station he notifies the signalman ahead and reports to the signalman in the other direction that the train is out of the block that it has just left. The signalman ahead clears his signal for the next block, if that block is clear, and the signalman in the rear is free to admit the next train that may approach. If, after one freight train has been admitted to the block, a following train approaches before the first has passed out of the block, the signalman, where permissive blocking is regularly carried on, simply sets his signal in a position to permit the train to proceed and indicate to the engineman that the block is occupied.

Under a more elaborate method of operation the signalman may consult the signalman in advance—that is, go through a form of asking his permission—each time before admitting a train to the block. This practice serves as a check on possible mistakes of the signalman, who, if he depended on his own record or memory, might some time admit a train in error when the block was not clear. This method is necessarily followed on single track, where the purpose is to prevent trains, through possible misunderstanding, from meeting between block stations, as well as to prevent one train from overtaking another.

The only appliances required for block working, as above described, aside from the signals, are a telegraph line and a set of telegraph instruments at each station. The line used for block communication is usually cut into sections, each taking in three or four stations.

Rules.—The following rules, extracted from a typical code, prescribe the operations of the signalmen in the routine block-signal work:

SIGNALMEN.

311A. The normal indication of home and advance block signals is "Stop."

311B. The normal indication of distant block signals is "Caution."

312. Signals must be operated carefully and with a uniform movement. If a signal fails to work properly its operation must be discontinued and the signal secured, so as to give the normal indication until repaired.

313. Signalmen must observe, as far as practicable, whether the indication of the signals corresponds with the position of the levers.

314. Signalmen must not make nor permit any unauthorized alterations or additions to the apparatus.

315. A block record must be kept at each block station.

316. The prescribed telegraph signals are as follows:

1. Display stop signal. Answer by S D or 5.
2. Block clear. Answer by 13.
3. Block wanted. Answer by 2 or 5.
4. Train has entered block. Answer by 13.
5. Block is not clear.
7. Train following.
8. Opening block station. Answer by numbers of trains in the extended block with time each train entered the block.
9. Closing block station. Answer by "13" after receiving transfer of the records of trains which are in the extended block.
13. I understand.
71. Train following, display "Stop" signal. Answer by S D.

S D. Stop signal is displayed.

317A. Rule 317A is for absolute block for following and opposing movements on the same track.

To admit a train to a block the signalman must examine the block record, and if the block is clear, will give "1 for No. 2" to the next block station in advance. The signalman receiving this signal, if the block is clear, must display the "Stop" signal to opposing trains, and reply "S D for No. 2." If the block is not clear, he must reply "5 of No. 7." The signalman at the entrance of the block must then display the proper signal indication to the train to be admitted.

A train must not be admitted to a block unless it is clear, except as provided in Rule 331 or by special order.

317B. Rule 317B is for absolute block for opposing movements and permissive block for following movements on the same track.

To admit a train to a block the signalman must examine the block record, and if the block is clear, will give "1 for No. 1" to the next block station in advance. The signalman receiving this signal, if the block is clear, must display the "stop" signal to opposing trains and reply "S D for No. 1." If the block is not clear, he must reply "5 of No. 4." The signalman at the entrance of the block must then display the proper signal indication to the train to be admitted.

A train must not be admitted to a block which is occupied by a passenger train, except as provided in Rule 331 or by special order.

To permit a train to follow a freight train into a block, the signalman must give "71 for Ex. 195 East" to the next block station in advance, to which the reply "5 of Ex. 187 East, S D for Ex. 195 East" must be made. The approaching train will then be admitted to the block under "Caution" signal or with caution card (Form B).

318A. Rule 318A is for absolute block for following movements only.

To admit a train to a block the signalman must examine the block record, and if the block is clear will display the proper signal indication to the train to be admitted, reporting its movement as per Rule 319.

A train must not be admitted to a block unless it is clear, except as provided in Rule 331 or by special order.

318B. Rule 318B is for permissive block for following movements only.

To admit a train to a block the signalman must examine the block record, and if the block is clear will display the proper signal indication to the train to be admitted, reporting its movement as per Rule 319.

A train must not be admitted to a block which is occupied by a passenger train, except as provided in Rule 331 or by special order.

A train may be permitted to follow a freight train into a block under "Caution" signal or with caution card (Form B).

319. When a train enters a block the signalman must report the train and the time to the next block station in advance, and when the train has passed the home block signal and the signalman has seen the markers, he must display the "Stop" signal, and when the rear of the train has passed 300 feet beyond the home block signal he must report the train and the time to the next block station in the rear.

This information must be entered on the block records.

320. Unless otherwise provided, signalmen must not give "1" or "3" until they have received "4" from the block station in the rear.

325. When a train takes a siding the signalman must know that it is clear of the block before giving "2" or displaying a "Clear" signal for that block.

The signalman must obtain control of the block before permitting trains at starting and junction points, or on sidings, to enter the block.

326. To permit a train to cross over or return, the signalman must examine the block record, and if all the blocks affected are clear of approaching trains he will arrange with the signalman at the next block station on either side to protect the movement, and when the proper signals have been displayed permission may be given. Until the block is clear no train must be admitted in the direction of the cross-over switches except under "Caution" signal or with caution card (Form B). All cross-over movements must be entered on the block records.

331. If from the failure of telegraph line or other cause a signalman be unable to communicate with the next block station in advance, he must stop every train approaching in that direction. Should no cause for detaining the train be known, it may then be permitted to proceed, using a "Caution" signal or a caution card (Form D).

FORM B.

.... Company.

CAUTION CARD.

.... Block Station, ... M. .... 190..

To Conductor and Engineman: Train No. .... on .... track.

Block is not clear. You may proceed with caution, expecting to find track obstructed.

....
Signalman.

Conductors and enginemen receiving this card properly filled out and signed by the signalman may proceed with the train under control, prepared to stop short of any obstruction in the block.

....
Superintendent.

FORM D.

.... Company.

CAUTION CARD.

.... Block Staton, ... M. .... 190..

To Conductor and Engineman: Train No. .... on .... track.

Bell circuits and telegraph line have failed. You may proceed with caution, expecting to find track obstructed.

....
Signalman.

Conductors and enginemen receiving this card properly filled out and signed by the signalman may proceed with the train under control, prepared to stop short of any obstruction in the block.

....
Superintendent.

Details of operation.—Referring to the diagram (fig. 10) which shows several arrangements of signals at three block stations, A, B, and C, if a train moving east is approaching A, the signalman there will, if the block is clear, display the "Proceed" indication at A (Rule 318). As the train passes his station A reports it by telegraphic numeral, 4, to B (Rule 319). When the whole train has passed the signal, as shown by the presence of the "marker" flags or lamps carried on the last car, A returns his signal to the stop position. The train having been reported by A, B performs the same operations as to block, B C, and, when the rear of the train is 300 feet beyond his signal, B, which has been returned to the stop position, reports the block clear of that train by "2" telegraphed to A. If permissive blocking is practiced, in the case of one freight train following another, each train admitted to an occupied block (by the proper signal indication or by caution card—Rule 318B) is reported in the block by A, for example, and clear of the block by B, when it passes his signal; when his block record shows that all trains admitted have been reported clear, A may clear his signal for the next train that approaches.

If a train is to cross from the westward to the eastward track just west of C, it is the duty of C (Rule 326) not to permit the train to cross if a westward train is approaching in the block B C; if, however, that block is clear, he must arrange with B to protect the train about to cross over exactly as he would protect an eastward train that had entered the block at his station.

Single track block.—On single track line trains are governed, with relation to trains moving in the opposite direction, by the time-table and the telegraphic orders of the dispatcher. But mistakes, resulting in collision, are occasionally made, and it is obvious that the block system can readily give to each train the protection of signals against trains coming toward it, and so afford a safeguard that will be likely to prevent disastrous results in case of mistake or forgetfulness as to the rights of trains. All that is necessary is that A, for example, before admitting a train to the block on single track, should make sure (Rule 317) that B has not previously admitted a train in the opposite direction which has not come through the block, and that B understands that a train is to be admitted at A, and will keep his signal for that block in the stop position against trains moving in the opposite direction until the train arrives at B. Where there is a passing siding within a block, say between A and B, and, on account of the expense, it is found to be impracticable to maintain an additional block station at such siding, the rule must, of course, be temporarily suspended when it is necessary to let trains leave A and B at about the same time to meet at that siding. In such cases, however, the trains are warned by the caution cards issued to them that the situation is exceptional.

Closing stations at night.—On some lines where trains, more especially passenger trains, are fewer at night than in the daytime, day signalmen only are on duty at certain block stations. On most railroads these stations are closed and reopened in accordance with the following rules:

338. To open a block station the signalman must give "8" to the next block station in each direction, and record the trains that are in the extended block. He must then display the normal signal indication, and notify the block station in each direction that the station is open.

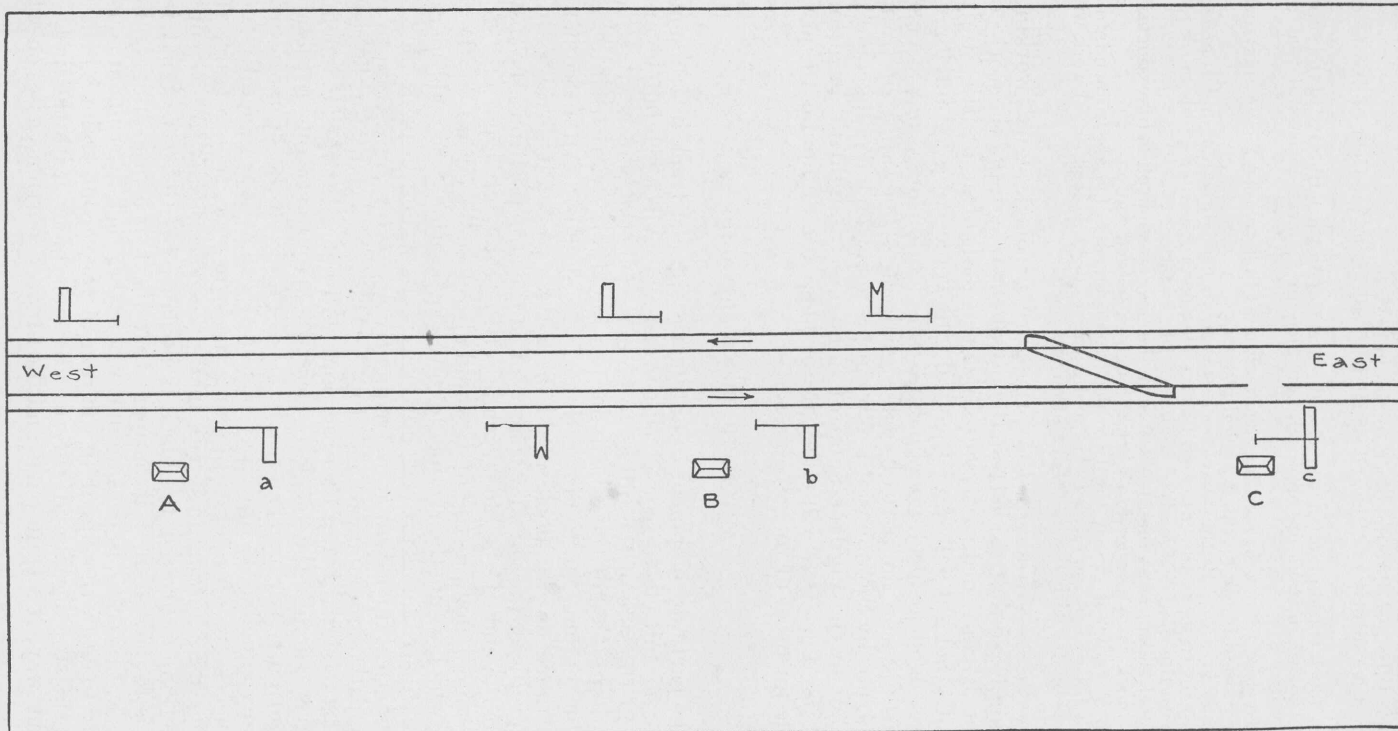

FIG. 10.—Diagram of telegraph block system.

When trains, which were in the extended block when the station was opened, and which had passed his station before it was opened, clear the block in advance, he must repeat the record to the block station in the rear.

He must not display the "clear" signal until all trains are clear of the block in advance.

339. A block station must not be closed, except upon the authority of the superintendent; nor when trains are approaching which are to meet or pass at that block station.

340. To close a block station the signalman must first obtain "2" for trains which he has admitted to the blocks in each direction.

He must give "9" to the next block station in each direction, and transfer the records of the trains in the extended block. He must then enter on his block record "13," with the time it is received from each block station.

The block signals must then be secured in the clear position, all lights extinguished, and the block wires arranged to work through the closed station.

While a station is closed the two blocks on each side of it are thrown into one; that is, if B is closed the block is AC, and A carries on the block signal work with C exactly as he did with B when that station was open.

Signalmen.—Although the procedure in block-signal working is very simple, so that, aside from the use of the telegraph, the work could be done by any ordinarily intelligent person after a little study, a moment's thought will show the vital importance of good intelligence, coolness, a clear head, good habits, conscientiousness, and a sense of responsibility on the part of each signalman. The safety of trains is secured, not by the doing of a few simple acts which a child could perform, but by the vigilant habit of mind and thoughtful attention to each thing done that will eliminate or keep at a minimum the always possible mistakes of forgetfulness.

AUTOMATIC BLOCK SIGNALS.

In the early development of automatic signals, track instruments—that is, circuit-closing or circuit-breaking devices having levers so placed at the side of the rail as to be moved by the wheels or actuated by the depression of the rails under passing trains—were used to a considerable extent for the operation of the signals. An instrument at the entrance of the block would, as a train passed it, break a circuit and thereby set the signal at that point in the stop position; the instrument at the end of the block, while setting the next signal at "stop," in the same manner as the first, would also close the circuit for the first signal, which would then return to the clear position. Signals operated by track instruments proved, however, to be wrong in principle.

In practical operation it is frequently necessary for a train to pass an automatic signal indicating "stop." This is especially for the reason that, if the signal is out of order and will not clear for an indefinite time even though the block is clear, it is impracticable to detain a train until a repair man can reach the spot and put the signal in order. Since any signal at "stop" may be out of order, it is generally found to be necessary to operate under a uniform rule that a train, after stopping at an automatic signal, may proceed carefully to the point of obstruction or through the block if no cause for the stop-signal indication is found. But if it happens that there is a preceding train in the block, this train, in passing out, where the track instrument is used, is likely to clear the signal in the rear of the second train, which has passed the stop signal and entered the same block with the first. In the same way, if a train parts and the forward portion passes on while the rear portion remains in the block, the signal that should protect the rear will be cleared.

Track-circuit control.—The track circuit is free from the imperfections of the track instrument; it holds the signal at "stop" so long as a car or even a pair of wheels remains on the rails of the circuit, and also, without any added complication, provides for the automatic clearing of the signal when the main track is cleared by a train taking a siding in the block (and after the switch has been set for the main track) and for setting the signal at "stop" and maintaining that indication when a switch is opened when a train enters the main track from a siding, and even when a train backs into the block at the outgoing end. As a result the track circuit is now universally used for the control of automatic signals on steam roads.

Arrangement of signals.—In the typical installation of automatic block signals, each block is of the length of one track circuit—from half a mile to 1 mile. At the entrance to the block a home signal is placed and, lower down on the same post, the distant signal for the home signal at the entrance to the next block. (See fig. 2.) The separate distant arm may, however, be dispensed with and the home signal made three-position; the home arm horizontal then indicates stop, at 45° it indicates that the block at the entrance of which it is placed is clear but the next home signal is in stop position, and the vertical position indicates that the block is clear and the next signal in a position (45° or vertical) indicating that its block is also clear. Longer blocks, with the signals controlled by two or more consecutive track circuits, are used to some extent. As distant signals more than 1 mile from their home signals would be farther than is necessary to insure safe stopping of trains and would impose an extra burden on the enginemen's memory, it is usual, where the blocks are much more than 1 mile long, to have separate distant signals within the blocks. Fig. 11 shows diagrammatically both short and long automatic blocks.

Switches.—Switches in the blocks control the track or signal circuits by means of simple circuit controlling devices; so long as a switch is not set for the main track the signal for the block in which it is located indicates stop. In addition the side-track rails extending to the point of safe clearance from the main track, are connected with the track circuit so that if cars are left dangerously near the main track the signal is held in the stop position (see fig. 7).

While the automatic signals give the proper indication if a switch is left open and afford protection to a train that enters the main track from a siding, there is still the possibility that a switch may be set for the siding and a train may start to enter the main track after another train has passed the signal controlled by that switch and before it has arrived at the switch. To meet this contingency electric indicators are, on some roads, placed at the switches and arranged to show the approach of a train from a point some distance in the rear of the nearest signal. It is also provided by rule that a switch must not be moved when a train is approaching, and that, after a switch has been set for the siding (and the signal thereby set at "stop"), the train shall not move from the siding to the main track until a certain time has elapsed, so that any train that may be approaching without the knowledge of the trainmen at the switch, may have time to arrive if it has already passed the signal. The dependence of these provisions upon observance of rules and the difficulty of insuring that such rules shall always

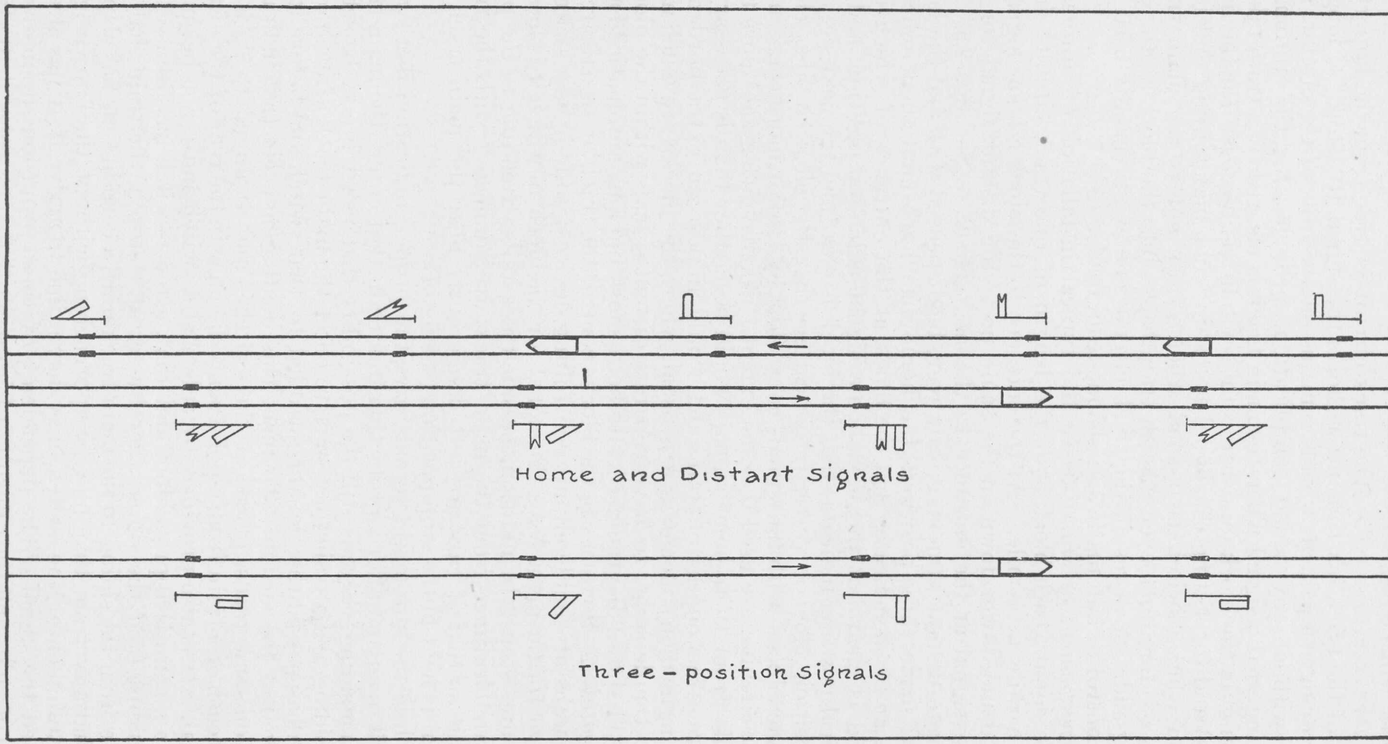

FIG. 11.—Diagram of automatic block system.

be strictly observed, emphasize the importance of interlocking, which will be touched upon later.

Automatic signals on single track.—Automatic signals have been used on single-track roads much less extensively than on double track. Two difficulties are met with in applying automatic signals on single track, which have doubtless prevented their more extended use on such lines. To make the signals efficient in preventing collisions between trains running in opposite directions—in cases of forgetfulness on the part of trainmen, or mistakes in or misunderstanding of orders, the controlling circuits must be more extended and complicated than are those on double track; that is, each of 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 always 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 by certain roads.

Signals.—Clockwork and inclosed disk signals, as still used on a few roads for automatic block signals, have already been described. Automatic semaphores are worked by compressed air controlled by electro-magnetically operated valves and supplied by a pipe line laid along the tracks from compressors usually located at water-supply stations; by compressed carbonic-acid gas supplied from portable cylinders delivered and connected to the various signals from time to time, and, like the compressed air, controlled by electro-magnetic valves; and by small electric motors connected by gearing to the operating mechanism and supplied with current from primary batteries or from storage cells. The storage cells may be charged on line circuits from generator stations located at suitable intervals or by primary batteries, or may be handled as portable batteries, taken to the generator stations for charging and returned, charged, to the signals. Storage batteries are also used on some lines to furnish current for the operation of electro-pneumatic signals and for the track circuits. The signals shown in fig. 2 are electro-pneumatic. Fig. 12 is an electric motor signal; the electro-gas signal is similar in appearance.

Automatic signals on electric railroads.—Automatic signals controlled by track circuits are used on a few electric railroads equipped for heavy service. Alternating current is used in the track circuits to render the relays unresponsive to the traction current flowing through the rails. The resulting increase of cost and complexity is considerable, but the signals and mechanism, other than appliances connected with the track circuits, are not materially different from those used on steam roads.

Automatic signals with automatic stops.—In the New York subway and on the Boston elevated railroad automatic train-stopping devices are used. As applied in the subway each trip for the automatic stop remains "set" until the train that operated it has passed far enough in advance, so that any following train that might overrun the trip would certainly be brought to a stop before colliding with the train protected by that trip. This is accomplished by making the length of block a little greater than the distance in which a train can be stopped, and so arranging the circuits that each signal remains in stop position, and the corresponding trip "set" until a train protected by it passes out of the next block ahead; that is, a train always has at "stop" in its rear not only the signal at the entrance to the block in which it is at the moment, but also the next signal back of that, and has never less than one block of clear track behind it in which a following train will be automatically stopped if it is not sooner stopped by its motorman.

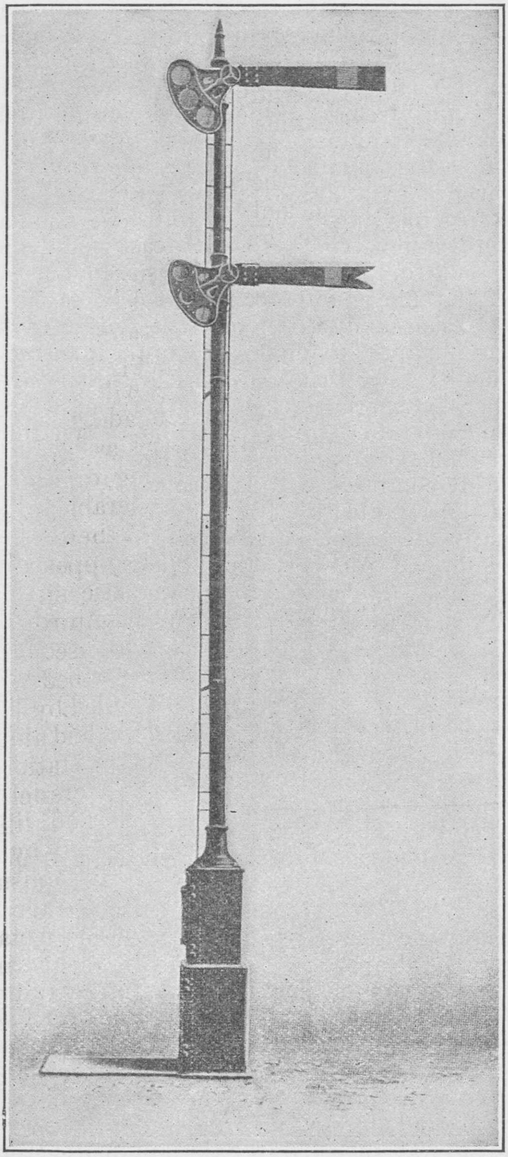

FIG. 12.—Electric-motor semaphore.

The effect of this on the train movement is shown by the upper diagram, fig. 13, where it is seen that, of two trains in motion, the second must be a little more than three blocks in the rear of the first if it is to find each distant signal clear, as it should if it is to continue running at full speed. With the ordinary arrangement of signals, as shown by the lower diagram, the second train could be one block farther advanced; or, the spacing of trains must be nearly one-half greater when the extra interval of one block is used, and the capacity of the road is proportionately reduced. Of course it is hardly necessary to say that the almost absolute safety secured justifies the use of the automatic stops and increased train interval in view of the density and character of the traffic and the peculiar conditions in the subway.

False clear signals.—While it is possible for an automatic signal or its controlling devices to become deranged in such a way as to indicate a clear block when the block is occupied by a train, the records show that, with proper construction and maintenance, such failures are very rare. Since they do occur, however, some railroad officers feel that the signals should be subject to constant inspection—that some

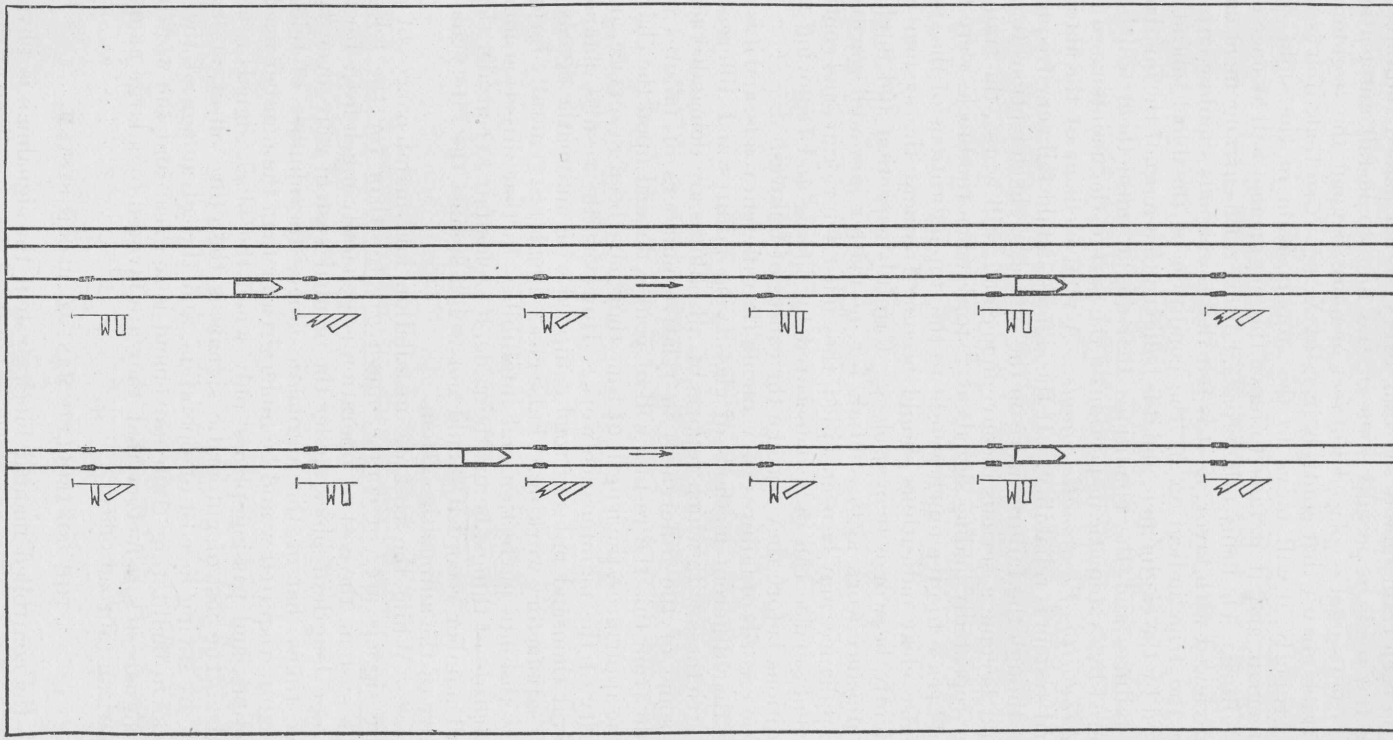

FIG. 13.—Diagram of automatic signals in New York subway.

one on each train should see that every signal passed indicates stop. On a few roads, especially some of the first to install automatic signals, each signal is placed 150 feet or more beyond the beginning of the track circuit that controls it, as at X, fig. 7, so that, if it is working properly, it will move to the stop position in the sight of the engineman, and if it fails to move the engineman will at once detect the failure. On many other roads, however, this arrangement has not been viewed with favor, as it is felt that the signals should continue to give the true indication of the condition of the block ahead until passed by the enginemen, and it is believed that most of the few dangerous failures and the conditions that might cause them will be discovered by systematic inspection on the part of the maintenance force.

Reliability of automatic signals.—A vital element of the automatic signal system is reliability. If the signals should fail very frequently, even though the failures were on the safe side, the detentions to trains would become a serious inconvenience and, still worse, the trainmen, after repeatedly finding signals at "stop" when the blocks were clear, would cease to give much weight to the stop indications of the signals. If false clear indications should become frequent the system would evidently be worse than useless. Careful inspection and intelligent maintenance work are essential; for, no matter how well constructed the appliances may be as installed, they must deteriorate, and continued efficient service can only be secured by finding and removing faulty conditions before they become the causes of failures.

The records of failures vary among the different roads, and it is probable that different methods of classifying failures and differences in the strictness with which reports of all failures are demanded account for some of the differences in relative numbers of failures given. Aside from this the results will of course depend upon the character of the appliances, the length of time they have been in service, and the quality of the maintenance work. However, the results obtained on several thousand miles of road equipped with automatic signals show very satisfactory working. False clear signals are generally rare; and, since absolute perfection and infallibility in that direction must, in the nature of things, be unattainable, it seems fair to consider that the small number recorded should not weigh against the safety and reliability of the automatic system.

Cost.—While the cost of installation and maintenance of automatic signals are, of course, much greater than for the telegraph block system, the cost of operation is generally much less; for if the average length of block under the manual system were even two or three times that of the automatic blocks the number of telegraph operators required would be much greater than the number needed at junctions and passing places only when the block signals are automatic. The cost of automatic signals is therefore offset, at least in part, by saving in cost of operation, and the advantage of the short blocks in facilitating train movement is so great and the working of the signals so satisfactory that they are favored by a large number of American railroad officers.

THE CONTROLLED MANUAL BLOCK SYSTEM.

In the controlled manual block system the signalman is physically prevented from clearing his signal unless the signalman at the other end of the block manipulates his apparatus so as to close an electric circuit and electrically release the signal. Thus each signalman is forced to consult or ask permission of the signalman in advance before clearing his signal.

To guard against possible mistakes of both signalmen at the same time an automatic locking and releasing device, actuated by the passage of trains, is added to the apparatus by which the signalman releases the signal at the entrance to the block in his rear. This is so arranged that each time the apparatus is operated to give a release it automatically becomes locked against a repetition of the operation until a train, having come through the block, passes that block station and by acting upon a device depressed by the wheels or by passing onto and off a track circuit releases the lock. The result is that, even though the signalman should make a mistake and attempt to release while a train was in the block, he would be unable to do so until the train had passed his station.

Appliances.—The appliances required in addition to the signals and means of communication are an electrical block instrument by which the signalman at B, for example, closes the circuit to unlock the lever at A; a lock on the signal lever, sometimes combined with the block instrument; line wires from station to station, and either a track instrument operated by the wheels of passing trains or a track circuit, by which the trains effect the releasing of the block instrument as they pass out of the block. Additional appliances sometimes used are electric "slots" or tripping devices on the signals by which the signals are automatically returned to the stop position when trains pass, and "continuous track-circuiting"—that is, the connection of the track throughout the entire length of the block into one or more track circuits arranged to keep one of the releasing circuits open, or inoperative, and so prevent the clearing of the signal, so long as a single car or engine is on the rails included in such track circuits.

Operation.—One form of block instrument is shown by fig. 14. With this machine B unlocks A's lever by pulling the lower knob outward and immediately letting it return to its original position, in which it then becomes locked against a repetition of the operation. At the same time the word "Free," previously visible, disappears from the rectangular opening in the case and the word "Locked," indicating that the operating knob is locked, as just stated, takes its place. The unlocking of the lever at A is shown by the inclined position of the indicator arm in A's instrument, seen at the round opening near the top of the case. The signal at A is then cleared.

When the train enters the block at A, the words "Train in block" automatically appear at the rectangular opening in B's instrument. B then gets his own lever for the next block unlocked by C and clears his signal for Block B C. While B's instrument continues in the condition in which the words "Train in block" are displayed, the unlocking circuit is open and the operating knob remains locked so that, after A's signal has been returned to, and become locked in, the stop position, in the rear of the train, it is impossible for B to repeat the unlocking and allow that signal to be cleared again until the train has passed out of the block.

When the train passes B, its wheels actuate the automatic release; to insure, however, that the signal at B shall be returned to the stop position for the protection of the train between B and C, before a following train is admitted to the block A B, the circuits are so arranged that the releasing is not completed until B's signal has been so placed. When this has been done and the train, by passing onto and off the releasing track circuit, has caused the track relay to open and close again (so that the releasing is delayed until the last car has passed), the word "Free" reappears and it is again possible to draw out the operating knob for the purpose of unlocking A's lever.

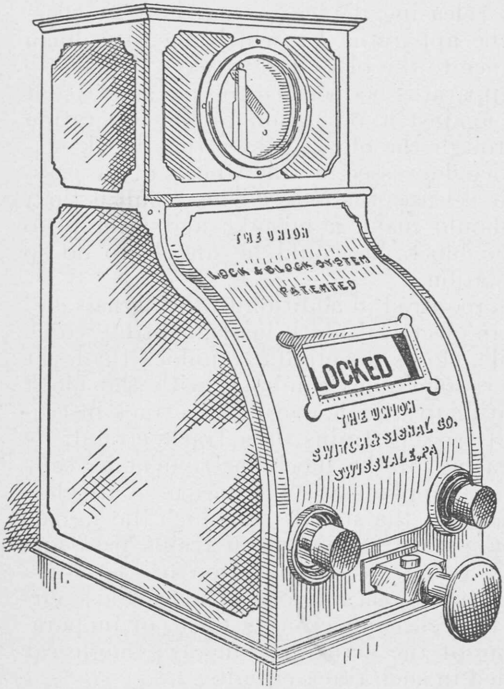

FIG. 14.—Controlled manual block instrument—Exterior.

The procedure in operating the controlled manual system is nearly the same as it is for the telegraph block system. A signalman, however, can not clear his signal in accordance with Rule 318, but must ask for "an unlock;" when an unlock is asked for, if the block is clear, it must be given by the proper manipulation of the block instrument. It is common practice to use electric bells for the ordinary communications in the working of the system.

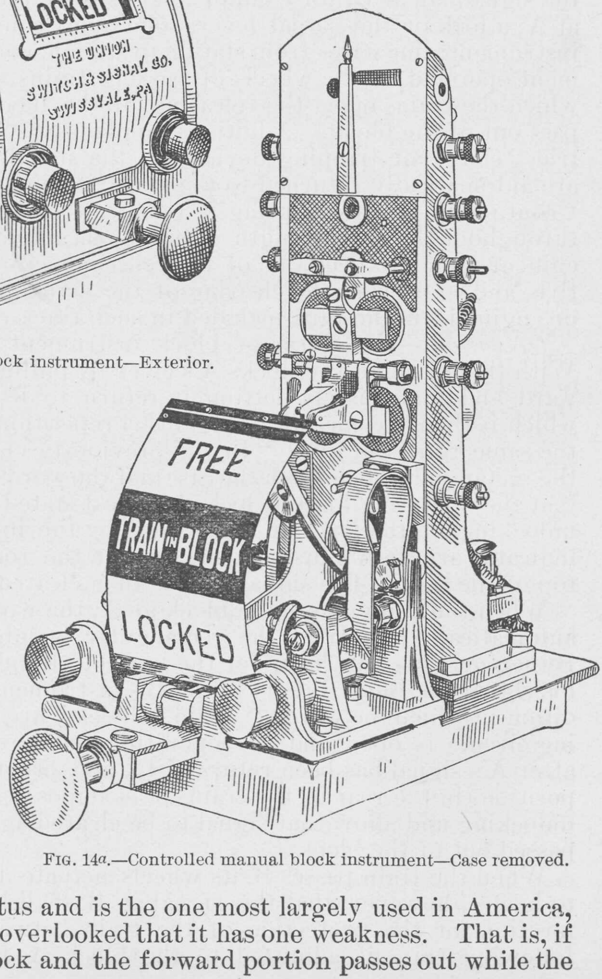

FIG. 14*a*.—Controlled manual block instrument—Case removed.

Imperfection.—Although this is an accepted form of controlled manual apparatus and is the one most largely used in America, the fact should not be overlooked that it has one weakness. That is, if a train parts in the block and the forward portion passes out while the rear stops in the block, or if a train is admitted to a block occupied by a preceding train (and this is sometimes necessary in the case of a train stalled or otherwise detained for an unusual time), the one train or portion of a parted train, in passing out of the block, will release the instrument while the block is still occupied; and precisely to the degree in which the signalmen may have fallen into the habit of depending upon the controlling devices, will there be danger of their giving a clear signal in such a case. Obviously, this condition would be common if permissive blocking were carried on. Of course this weakness can be removed by the addition of track circuits taking in the whole length of each block so that, as in the case of automatic signals, a clear signal can not be given so long as there is a single car in the block. But, on account of the considerable addition to the cost and the increased difficulty of maintenance, continuous track circuits have generally not been installed.

Merits of the system.—With continuous track circuits and all signals arranged to be automatically returned to the stop position the controlled manual should unquestionably be characterized as the ideal block system. It would be a combination of the telegraph and automatic systems, and each should check the faults of the other; a dangerous condition could hardly arise except through the coincidence of a failure of the controlling devices to prevent the clearing of a signal and, at the same time, an attempt on the part of one or both signalmen, through forgetfulness, to clear the signal improperly. Such a coincidence should be a very remote contingency.

The ideal condition is not usually attained, as one or both of the safeguards mentioned are commonly omitted. Even so, installation and maintenance are both costly. At the same time there is, in comparison with the telegraph block system, no such saving in cost of operation as an installation of automatic signals may effect. On the contrary, since the blocking should be absolute if the full advantage is to be derived from the controlled manual system, there must, in general, be a tendency to shorten the blocks and so increase the operating cost. While the controlled manual system is preferred by some railroad officers and the actual installations, without all the possible safeguards, seem to have made excellent records, it appears that a much greater number of officials are fully satisfied with automatic signals.

THE ELECTRIC TRAIN STAFF.

A form of the controlled manual block system for controlling train movements on single track, known as the electric train staff system, is in use to some extent. Under this system each train passing through a block is required to carry from one end of the block to the other a small iron rod, called a train staff, as a visible evidence of its right to occupy that block; and no train is allowed to be in a block without having in its possession a staff for that block. Originally there was but one staff for each block, which bore the names of the stations at the ends of the block as the means of distinguishing it from the staffs belonging to the adjoining blocks. Evidently if, after one train had moved from A to B and left the staff at B, a second train moving in the same direction should arrive at A, the staff would be at the wrong end of the block, and the train could not proceed until a train in the opposite direction had returned the staff to A.

Operation.—The electric staff system meets the requirements of practical working by providing several staffs for each block, which are normally secured, part at one end of the block and part at the other, in electric staff instruments so arranged that it is impossible to have more than one staff out at a time. When all the staffs are in, A, with the cooperation of B to unlock his instrument, can remove one staff, and vice versa; but the removal of one staff so affects the electric circuit that neither instrument can again be unlocked until that staff has been placed in the instrument at the other end of the block or returned to the instrument from which it was removed. Thus the staff is the key to the block, the possession of which by a train prevents the admission of any other train at either end of the block.

To provide for permissive blocking, which is likely to be necessary where the blocks are long, a special staff is supplied. One of several removable portions of this staff can be delivered to each of several trains that have to pass through the block permissively; the last train of the series takes the staff with the unused parts, and this, when combined with the parts delivered by the preceding trains (and only when thus complete), can be inserted in the staff machine to make possible the removal of a staff for the movement of a train in the opposite direction.

The signal levers are usually provided with locks which can be released only by the use of the staff as a key. The signals may also have electric "slots" by which they are automatically returned to the stop position as trains pass.

INTERLOCKING.

The plan, fig. 15, shows the arrangement of tracks at the junction of a double-track branch with a double-track main line, including a crossover to provide for movements from any track to any other and the signals required for complete signaling and interlocking at such a junction. Each switch is provided with a lock to secure it in its safe positions and detect, by failing to lock, any failure of the switch to move to a safe position.

To prevent the unlocking of a switch while a train is passing over it, each lock has connected to it a bar of flat iron supported along the side of the rail in such a way that it is raised above the top of the rail at each movement of the lock and checks the complete movement of the lock if such raising is prevented by contact with the wheels of a train.

The interlocking machine.—Each switch (or two switches forming a cross over), each lock (or two locks on adjacent switches), and each signal is operated by one of a group of levers assembled in the interlocking cabin or "tower." Nineteen levers are required for the plant illustrated and, allowing, as is customary, several unused spaces in the machine for additional levers that may be needed for future extension of the plant, a machine of twenty-four levers is used. The levers are so mechanically interconnected that they can be moved only in a certain order and the movement of one lever will prevent the movement of certain others. Thus, distant signal lever No. 1 can be moved to clear its signal only when levers Nos. 2 and 5 have been moved to clear those signals, for which No. 1 is the distant signal; No. 3 can be moved only after the movement of Nos. 4 and 5. Signal No. 2 can be

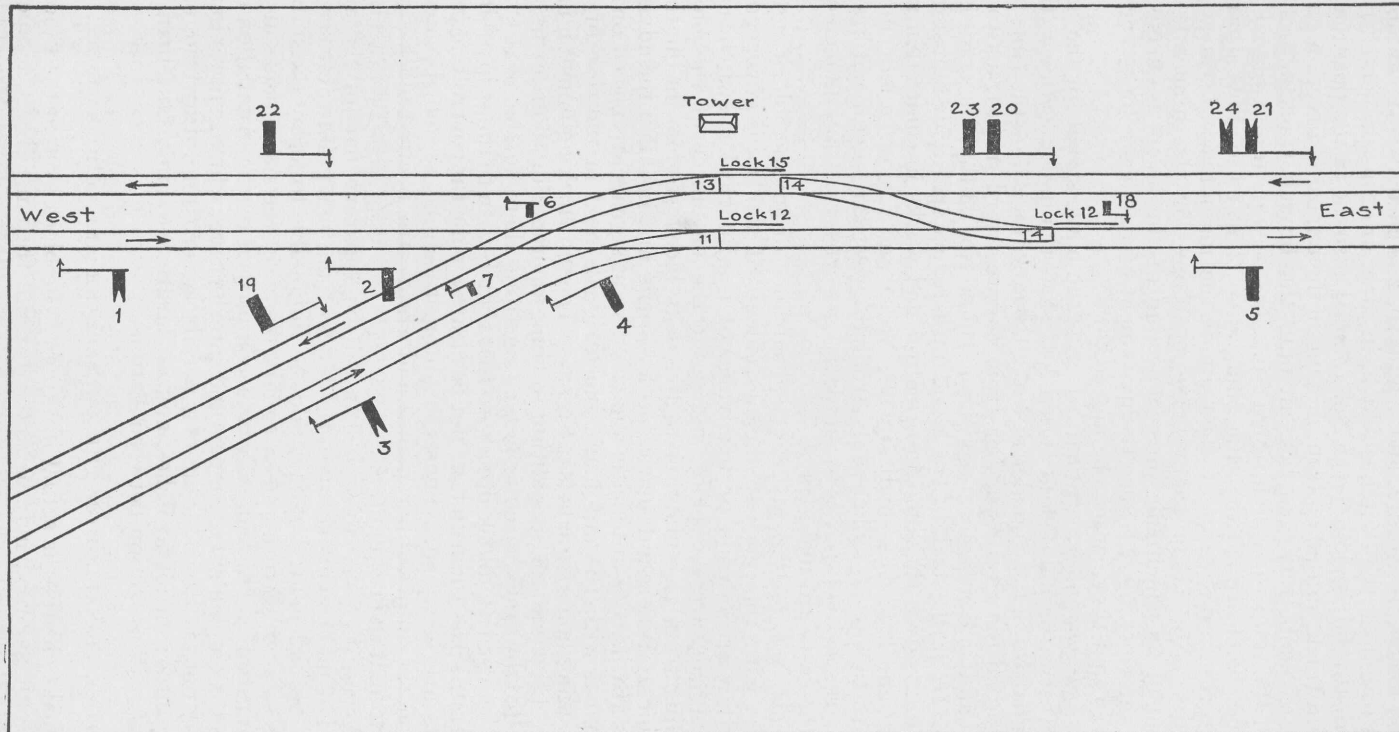

FIG. 15.—Diagram of tracks and signals at interlocking plant.

cleared only when switches Nos. 11 and 14 are set for the main track east and locked by No. 12, and while No. 2 is clear No. 12 can not be moved to unlock the switches which, in turn, are thus prevented from being disturbed; switch lever No. 13 must also be in the position for the main track, so that no train moving in the opposite direction on the westward main track can be sent onto the branch track across the path of the train for which signal No. 2 has been cleared. Signal No. 4 can not be cleared at the same time as No. 2, so as to allow a branch train to run into the side of the train on the main track, because No. 4 requires No. 11 in the reverse position—for the branch. The mechanism by which this interconnection of the levers is effected is called interlocking, because the movement of one lever locks certain others so that they can not be moved.

Interlocking signals.—Signal No. 23 is the home signal for the main track westward, and distant signal No. 24 works in connection with it and signal No. 22. Signal arm No. 20, below No. 23, on the same post is the signal for a train passing from the westward main track to the branch and indicates by its position below No. 23 that the train is to diverge from the straight track and must reduce speed; distant signal-arm No. 21 gives the same information and works in connection with Nos. 20 and 19. The small signals, Nos. 6 and 7, govern movements eastward to any possible points from the westward main and branch tracks, respectively; No. 18 similarly governs westward movements from the eastward main track.

Signals Nos. 5, 19, and 22, called advance or advance block signals because, with reference to the movements of the trains governed by them, they are beyond or in advance of the interlocked switches and home signals, are the block signals at the entrances of the blocks extending from the junction to the next block stations in the three directions. Where automatic block signals are installed the advance signals are usually automatic and the distant signals are placed on the same posts with the automatic block signals next in the rear of the interlocking home signals (see Fig. 2). The interlocking home signals, Nos. 2, 4, 20, and 23, in addition to being operated by their levers, are controlled by track circuits extending from them to the next ("advance") automatic block signals, so that they return to the stop position when trains pass them and can not be cleared while the controlling track circuits are occupied. Thus the automatic-signal system is carried through the interlocking plants and trains are insured block-signal protection at every point.

Importance of interlocking.—It will be apparent that for the mere control of movements through the blocks from this point three signals would be sufficient; but it would be impossible to locate those three signals so as to govern and safeguard properly the movements at the junction itself. This can only be accomplished by the installation of a complete complement of signals and interlocking, which, as previously pointed out, is desirable at every railroad crossing, drawbridge, or important group of switches, and is hardly less important than the block signal protection between stations.

BLOCK SIGNALING ON THE CHESAPEAKE AND OHIO RAILWAY.

To make clearer the actual working of the block system the practice on a particular road may be taken for illustration. The Chesapeake and Ohio Railway has been selected as a road that has maintained block working on lines of both heavy and light traffic, double and single track, for many years; in fact this road was one of the first, after the Pennsylvania, to adopt the block system, and it has continued and extended the use of block signals with very satisfactory results.

It has not, however, found it necessary to use elaborate or expensive appliances on the greater part of the line or to provide a much greater operating force than would be required for the station and train-order work if the block system were not in service. A further reason for taking this road as an example is, therefore, that it affords a good illustration of the possibility of securing satisfactory results from the use of the block system with a small expenditure of money.

Signals having arms for movements in both directions on the same post are used to a great extent at simple block stations. On the busier double-track lines, however, there are interlocking plants at many of the passing sidings and other important points. Certain block sections on one of the single-track divisions, in which there are tunnels, are provided with a simple form of controlled manual block apparatus. On some of the double-track lines there are single-track tunnels. At these points there are interlockings for the switches at the double-track endings, and the short sections of single track are worked by the electric train staff system which is absolute; that is, no provision is made for permissive movement of trains going in the same direction.

Rules.—The following are the principal rules governing the routine block-signal work on this road:

301. Block signals, unless otherwise provided, do not affect the rights of trains under the time-table or train rules; nor dispense with the use or the observance of other signals whenever and wherever they may be required.

302. The normal indication of home block signals is "stop."

306. A register is required at each block station. It must be examined before a train is admitted to a block.

A train passed by another train at a block station must be reentered upon the register.

The last train leaving must be the last recorded.

307. When notice is received of an approaching train, the signalman receiving it will notify the signalman in advance, ascertain if the block is clear and the "stop" signal displayed (using signal "17" for westbound trains); and signal "18" for eastbound trains); and after arranging with that signalman for the train, display "clear" signal to allow it to enter the block.

When a train enters a block the signalman will report it to the signalman in advance, and when the rear of a train has passed the block signal and the markers are seen, the signalman will display signal in "stop" position, and when the train has passed 300 feet within the block, report to the signalman in the rear that the train is clear of that block. When the block is clear, the home (and distant) signal shall be cleared sufficiently in advance of approaching trains to avoid delay.

308. If a train takes the siding at a block station, the signalman must know that it is clear of main track before reporting block clear or giving "clear" signal to a train moving in opposite direction.

311. When it is necessary to allow a train to follow another into a block, the signalman will issue caution card (Form B) when authorized by the train dispatcher or by Rule 319. A train shall not be allowed to enter a block occupied by a passenger train, except as provided in Rule 319 or by special order.

314. When necessary for a train to cross over at a block station where there are two running tracks, the signalman must first ascertain if the block to the rear on the opposite track is clear; if so, arrange with signalman at the entrance of that block to display "stop" signal before allowing movement to be made.

316. When necessary for a train that has been reported "clear" to back into a block, the signalman must first ascertain if block is clear before allowing movement to be made.

319. If from failure of telegraph line or other cause a signalman is unable to communicate with the next block station, he will stop trains moving in that direction, give to each written notice of the trouble, deliver caution cards allowing a train to

follow ten minutes behind a freight train and twenty minutes behind a passenger train.

331. Trains may pass a block station which displays a "clear" signal, but must not pass a "stop" signal unless caution card (Form B) is received, or it is necessary to do so in order to clear the main track for a superior train.

336. A train having cleared a block must not back into or within 300 feet of such block without permission of the signalman.

337. At block stations where there are two running tracks a train must not cross over without permission of signalman, in addition to protecting train as per Rule 99.

340. At a block station where the signalman is absent or incapacitated so that instructions can not be obtained, a train shall wait ten minutes and then proceed with caution to the next block station, where the conductor must report accordingly to the train dispatcher.

343. When approaching a block station, the engineman and fireman will announce to each other the indication of the signals.

Rule 99, referred to in Rule 337, reads as follows:

99. When a train stops or is delayed, under circumstances in which it may be overtaken by another, the flagman must go back immediately with stop signals a sufficient distance to insure full protection. When recalled, he may return to his train, first placing two torpedoes on the rail when the conditions require it.

The front of the train must be protected in the same way, when necessary, by the front brakeman or fireman.

Block station records.—The form of block register used at each station has spaces for a very complete record of each operation connected with the movement of a train through the blocks on either side of that station. The several entries forming the record of one train are made in one column in the order of the train's movement. By noting, in the case of either block, whether or not all the spaces are filled in the last column containing entries, it can be seen at a glance whether the block is clear or occupied. If one train is passed at a station by another going in the same direction, its record for the block in advance is made in the next column beyond that for the train that passed it, so that the last column used correctly shows the condition of the block. In addition, a transfer book is provided in which the signalmen enter, with the signatures of both, the positions of the signals and the train orders on hand when one man is relieved by the other at the end of his time on duty.

Absolute and permissive block.—Absolute blocking is maintained as far as possible. On the busiest portions of the road permissive blocking has proved to be necessary and, at some block stations, provision has been made for giving permissive signal indications; this is done chiefly in the case of freight trains ascending heavy grades. But on the lines of lighter traffic the exceptions to the absolute rule are said to be very few; and this is the case where the blocks are 8 to 10 miles long, and they are even longer on some branches having the lightest traffic. In some cases on single track there are passing sidings in these long blocks, and it is occasionally necessary to let two freight trains moving in opposite directions enter the block to meet and pass at such a siding. The trains are then, however, given telegraphic train orders providing for their meeting at that siding and, in addition, caution cards for their entrance into the block; so that the chances of the men on either train forgetting the meeting point are reduced to a minimum.

CERTAIN IMPROVEMENTS IN SIGNALING.

Among the improvements in signaling now in contemplation or in course of adoption special mention may be made, in conclusion, of the use of green lights instead of white for the proceed or "all clear" indication and semaphores giving their indications by positions of the arms above instead of below the horizontal.

The use of green lights for clear is now the practice on a number of important roads and is approved by many railroad officers and by the great majority of signal experts. The purpose of the improvement is, by taking a distinctive color for the clear indication, to eliminate the possibility that a stop or caution indication may be converted into "all

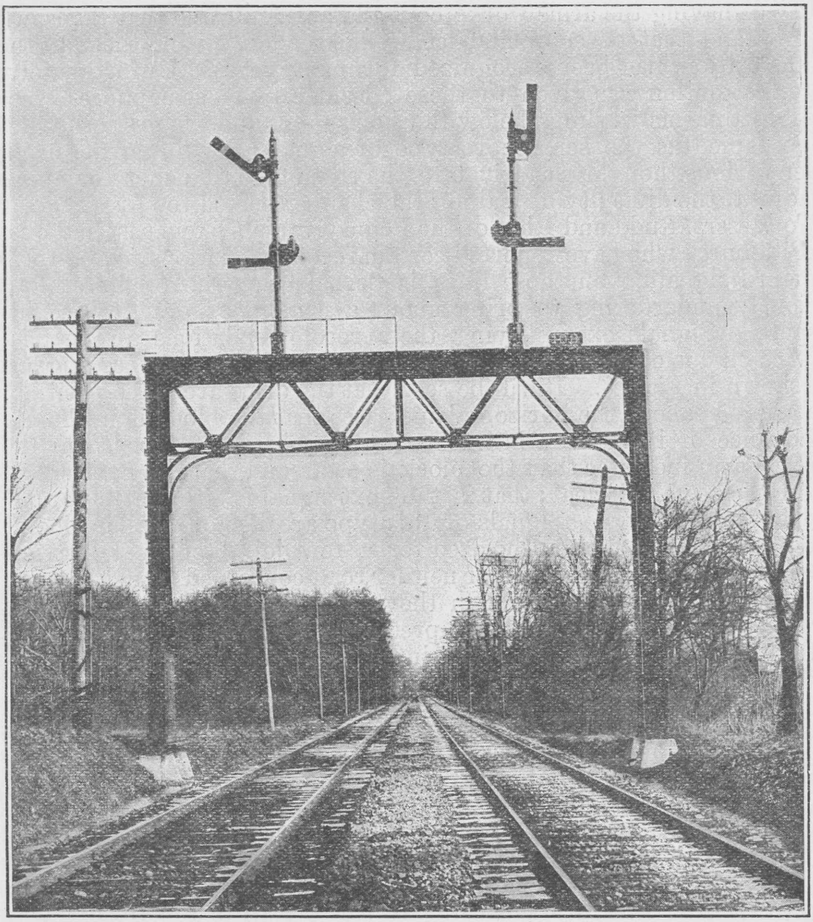

FIG. 16.—Three-position upper-quadrant semaphores.

clear" by the mere breaking of a colored glass, and at the same time to remove the recognized danger that one of the many lights in the streets and houses of cities and towns may be mistaken for the clear indication of a signal on which the light is out and which may at the time be giving a contrary indication.

The belief that the dangers are very remote, the expense of making the change and the difficulty of obtaining a good third color for the night caution indication have delayed this improvement. A glass giving a distinctive yellow-colored light has, however, been produced and one or two roads are using a green and a red light side by side. There can be little doubt that the other obstacles will give way before the growing conviction that the danger must be recognized and that the change ought to be made.

The semaphore arm working below the horizontal requires a counterweight to bring it back to the horizontal position when the operating force is removed, and this must be sufficient to overbalance the weight of any possible accumulation of snow or ice on the arm. The desirability of having the arms work above the horizontal, so that their own weight and that of snow and ice would tend to bring them to the stop position, has been recognized for many years. Unfortunately, before attention was given to these considerations, semaphores were made with arms working below the horizontal, and the first examples were copied as the semaphore type of signal grew in favor, until, when serious thought was given to the advantage of using the upper quadrant, the difficulty of making the change seemed too great.

To Messrs. Rudd and Rhea of the Pennsylvania system east and west of Pittsburg, who have reported certain recommendations for uniform standard signaling on those lines, is perhaps due the credit of first seriously undertaking to bring about a change of practice in this respect. Signals exemplifying their recommendations are in trial service on one division of the Pennsylvania road; two of these signals are shown in Fig. 16. It will be seen that the arms are three-position; the arm 45° above the horizontal indicates that the block immediately in advance of it is clear, but the next signal is in stop position; the vertical arm indicates that the block is clear and that the next signal also indicates block clear; that is, the next signal is either at 45° or 90° above the horizontal. Signals of this type are also on trial on one or two other lines and are authorized for a few joint terminal districts where the standard signaling of neither road concerned would be satisfactory to the other. Although they are warmly favored by many signal experts, it is impossible to predict as yet whether these signals will ultimately displace those now in service.

LAWS RELATING TO BLOCK SIGNALING.

Following are the British and the Massachusets laws, now in force, bearing upon the installation of block signals. It should be explained that the British board of trade is a Government institution and has from the first had a far more complete and detailed control of railroad matters along certain lines than has any governmental agency in this country. The order of the board of trade under this law went into effect in 1890. The Massachusetts law was passed in 1906.

British Law.

REGULATION OF RAILWAYS, 1889.

(52 and 53 Vict. Cap. 57. An act to amend the regulation of railways acts, and for other purposes. August 30, 1889.)

1. The board of trade may from time to time order a railway company to do, within a time limited by the order and subject to any exceptions or modifications allowed by the order, any of the following things:

(*a*) To adopt the block system on all or any of their railways open for the public conveyance of passengers.

(*b*) To provide for the interlocking of points and signals on or in connection with all or any of such railways.

In making any order under this section the board of trade shall have regard to the nature and extent of the traffic on the railway, and shall, before making any such order, hear any company or person whom the board of trade may consider entitled to be heard.

2. If default is made in compliance with any order made by the board of trade in pursuance of the last foregoing section, the railway and canal commission may, on the application of the board of trade, enjoin obedience to the order, and thereupon the order may be enforced as if it were made by the commission for the purpose of carrying into effect any of the provisions of the acts under which the commission have jurisdiction. (52 and 53 Vict., ch. 57 i; 52 and 53 Vict., cap. 57.)

3. Whenever any railway company shall be ordered by the board of trade to provide any appliances, or execute any works, or incur any expenditure under the provisions of this act which would properly be chargeable to capital account, it shall be lawful for such company to furnish to the board of trade an estimate of the cost of providing such appliances, executing such works, and carrying out such order generally, and thereupon the board of trade shall, upon the application of the company, fix and determine the amount which would properly be capital expenditure.

Massachusetts Law.

Section 1. The board of railroad commissioners may from time to time require railroad companies to install and maintain at such places upon the railroad premises as it shall designate, such block or other signals or devices as it shall approve for the purpose of safeguarding public travel.

Sec. 2. The supreme judicial court shall have jurisdiction in equity to enforce compliance with any order issued by the board under the preceding section.

PUBLIC RESOLUTION NO. 46.

Public Resolution—No. 46.—Joint Resolution Directing the Interstate Commerce Commission to investigate and report on block signal systems and appliances for the automatic control of railway trains.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Interstate Commerce Commission be, and it is hereby, directed to investigate and report on the use of and necessity for block signal systems and appliances for the automatic control of railway trains in the United States. For this purpose the Commission is authorized to employ persons who are familiar with the subject, and may use such of its own employees as are necessary to make a thorough examination into the matter.

In transmitting its report to the Congress the Commission shall recommend such legislation as to the Commission seems advisable.

To carry out and give effect to the provisions of this resolution the Commission shall have power to issue subpœnas, administer oaths, examine witnesses, require the production of books and papers, and receive depositions taken before any proper officer in any State or Territory of the United States.

Approved, June 30, 1906.

ACCIDENT STATISTICS.

[From the Interstate Commerce Commission's Report on Statistics of Railways in the United States for the year ending June 30, 1905.]

Comparative summary of railway accidents for the years ending June 30, 1900, to 1905, inclusive.

Year.	Employees.		Passengers.		Other persons.		Total.	
	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.
1905	3,361	66,833	537	10,457	5,805	8,718	9,703	86,008
1904	3,632	67,067	441	9,111	5,973	7,977	10,046	84,155
1903	3,606	60,481	355	8,231	5,879	7,841	9,840	76,553
1902	2,969	50,524	345	6,683	5,274	7,455	8,588	64,662
1901	2,675	41,142	282	4,988	5,498	7,209	8,455	53,339
1900	2,550	39,643	249	4,128	5,066	6,549	7,865	50,320

From the Interstate Commerce Commission's Accident Bulletin No. 20.

TABLE A.—*Summary of casualties to persons, year ending June 30, 1906.*

	Passengers (a and b).		Persons carried under agreement, etc. (bb).		Total (a, b, and bb).		Trainmen.		Trainmen in yards.	
	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.
Collisions	89	3,596	31	409	120	4,005	331	2,348	53	669
Derailments	48	2,341	12	315	60	2,656	220	1,385	17	209
Miscellaneous train accidents, including locomotive boiler explosions	0	86	2	31	2	117	61	1,036	5	215
Total train accidents	137	6,023	45	755	182	6,778	612	4,769	75	1,093
Coupling or uncoupling	....	....	....	....	....	....	101	1,060	65	695
While doing other work about trains or while attending switches	....	....	....	....	....	....	75	7,303	42	2,871
Coming in contact with overhead bridges, structures at side of track, etc	7	30	1	16	8	46	80	753	27	280
Falling from cars or engines or while getting on or off	140	1,962	4	65	144	2,027	295	4,436	98	2,252
Other causes	66	2,118	18	216	84	2,334	197	591	93	394
Total (other than train accidents)	213	4,110	23	297	236	4,407	748	14,143	325	6,492
Total all classes	350	10,133	68	1,052	418	11,185	1,360	18,912	400	7,585

	Yard trainmen (switching crews).		Other employees.		Total employees.		Total all persons.	
	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.	Killed.	Injured.
Collisions	43	429	57	463	484	3,909	604	7,914
Derailments	27	232	49	290	313	2,116	373	4,772
Miscellaneous train accidents, including locomotive boiler explosions	10	103	6	104	82	1,458	84	1,575
Total train accidents	80	764	112	857	879	7,483	1,061	14,261
Coupling or uncoupling	130	1,646	15	102	311	3,503	311	3,503
While doing other work about trains or while attending switches	55	2,735	96	2,945	268	15,854	268	15,854
Coming in contact with overhead bridges, structures at side of track, etc.	16	402	9	62	132	1,497	140	1,543
Falling from cars or engines, or while getting on or off	175	3,156	145	1,409	713	11,253	857	13,280
Other causes	119	363	1,095	14,586	1,504	15,934	1,588	18,268
Total (other than train accidents)	495	8,302	1,360	19,104	2,928	48,041	3,164	52,448
Total all classes	575	9,066	1,472	19,961	3,807	55,524	4,225	66,709

NOTE.—This table covers only passengers and employees actually on duty, and does not include the class of "other persons" covered by the annual statistical reports.

ORDER OF THE COMMISSION.

At a general session of the Interstate Commerce Commission, held at its office in Washington, D. C., on the 24th day of August, A. D. 1906.

Present: Hon. Judson C. Clements, Hon. Francis M. Cockrell, Hon. Franklin K. Lane, Commissioners.

The question of compliance with Public Resolution No. 46, as follows, being under consideration:

Public Resolution No. 46.—Joint resolution directing the Interstate Commerce Commission to investigate and report on block signal systems and appliances for the automatic control of railway trains.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Interstate Commerce Commission be, and it is hereby, directed to investigate and report on the use of and necessity for block signal systems and appliances for the automatic control of railway trains in the United States. For this purpose the Commission is authorized to employ persons who are familiar with the subject, and may use such of its own employees as are necessary to make a thorough examination into the matter.

In transmitting its report to the Congress the Commission shall recommend such legislation as to the Commission seems advisable.

To carry out and give effect to the provisions of this resolution the Commission shall have power to issue subpœnas, administer oaths, examine witnesses, require the production of books and papers, and receive depositions taken before any proper officer in any State or Territory of the United States.

Approved, June 30, 1906.

It is ordered, That the information called for below be furnished the Commission by all carriers subject to the act to regulate commerce not later than the 1st day of October, 1906.

1. Does your company run trains under the block system, either (*a*) the "telegraph block system" (in principle as described in the code of the American Railway Association), or (*b*) the manual controlled block system, or (*c*) the electric train-staff system, or (*d*) the automatic block system.

2. Give the number of miles of road worked by any or all such systems: (*a*) Single-track railroad, (*b*) double-track railroad, (*c*) three-track railroad, (*d*) four-track railroad, (*e*) railroad consisting of more than four tracks.

Give total number of miles of road operated by your company on which passenger trains are regularly run, and the percentage of such mileage worked by block signals. (Note: In the case of one or two signals, as at a station or curve, or of one or two sections equipped with automatic block signals, on a line where the time-interval rules are in force, the line is not to be counted as worked by the block system.)

3. Do you use any appliance by which trains can be stopped, regardless of the action of the engineman or motorman? If so, give a brief description of such appliance.

4. Furnish a copy of the code of rules prescribed for the government of employees in the movement of trains under the block system, including not only those rules which correspond to the rules prescribed by the American Railway Association, but any additions to or modifications of such rules. Describe any marked difference between your practice and that prescribed by the said association.

5. Give the number of railroad crossings on your block-signaled lines, as follows: (*a*) Number of crossings of other railroads using steam locomotives, (*b*) number of crossings of electric railroads, (*c*) number of each (*a*) and (*b*) equipped with interlocked signals.

State whether there is interlocking the crossing signals with the block signals.

In case of any crossings not equipped with interlocking signals, explain what provision is made for the prevention of crossing collisions.

If, on lines worked by the block system, there are drawbridges not interlocked with the block signals, explain what provision is made for safety at the draw.

6. Give a brief account of all lines on which block sections more than 4 miles in length are operated.

(*a*) Name of division or district.

(*b*) Whether operated as long block sections at all times or only a part of the time; if only a part, say at what times.

(*c*) Furnish a list of such sections, giving length of each block section in miles (or miles and tenths).

7. Do you consider the block system economical, aside from its use as a protection to lives and limbs of passengers and employees?

8. To what extent has the use of the block system reduced the number or cost of collisions on your road?

9. To what extent has it increased the capacity of your lines (particular lines or divisions may be specified), measured by the number of trains that can be run per hour?

(*a*) On single-track railroad.

(*b*) On lines where each track is ordinarily used by trains all running in the same direction.

A true copy.

EDW. A. MOSELEY, *Secretary.*

BLOCK SIGNALS ON THE RAILROADS OF THE UNITED STATES.

Table showing for each company the aggregate length of its lines or parts of lines on which the block system is in use, September, 1906. Companies not appearing in the list have reported that no block signals are in use on their lines.

[For footnotes to all references, see page 77.]

Names of railroads.	Automatic block signals.					Nonautomatic block signals.[a]					Total, all kinds.	Total miles operated by company (passenger lines).	Per cent operated under block system.
	Single track.	Double track.	Three track.	Four track.	Total automatic.	Single track.	Double track.	Three track.	Four track.	Total nonautomatic.			
Alabama Great Southern	29.5				29.5	2.0				2.0	31.5	291.1	11.0
Ann Arbor						1.4				1.4	1.4	292.0	
Atchison, Topeka and Santa Fe		18.2			18.2	965.6 S 18.8	227.0			1,211.4	1,229.6	5,043.0	23.3
Atlanta and West Point							4.8			4.8	4.8	87.0	5.5
Atlantic City. (Included in Philadelphia and Reading.)													
Atlantic Coast Line[b]						431.7	64.5			496.2	496.2	3,981.8	12.5
Baltimore and Ohio		102.4			102.4	308.4	373.5	3.0	8.5	693.4	795.8	2,960 7	26.8
Cleveland, Lorain and Wheeling						12.0	2.8			14.8	14.8	135.0	11.0
Baltimore and Ohio Southwestern							24.0		3.0	27.0	27.0	981.0	2.4
Baltimore and Sparrows Point							3.2			3.2	3.2	4.9	65.3
Bessemer and Lake Erie						135.3	61.2			196.5	196.5	198.7	98.9
Boston and Albany		164.7		16.0	180.7						180.7	377.5	48.0
Boston and Maine		62.0	.5	2.1	64.6		108.0 C 4.8			112.8	177.4	2,238.6	8.0
Buffalo, Rochester and Pittsburg[c]						322 6	106.9			429.5	429.5	429.5	100.0
Central of Georgia						52.6	10.0			62.6	62.6	1,853.0	3.3
Central of New Jersey		258.6		32.8	291.4						291.4	584.0	50.0
Chesapeake and Ohio						890.9 S 9.2	237.6 C 166.2			1,303.9	1,003.9	1,549.1	84.2
Chicago and Alton	159.9	103.5			263.4	S 14.1 341.2	41.2			396.5	659.9	937.0	70.0
Chicago, Burlington and Quincy		20.3		7.1	27.4	777.5 S 1.3	488.0	17.1		1,243.9	1,271.3	8,876.7	93.6
Chicago, Burlington and Quincy (see notes).						[d] 2,932.5 [e] 4,107.1				7,039.6	7,039.6		
Chicago and Eastern Illinois	2.0	101.6			103.6	C 135.7				135.7	239.3	793.3	30.0
Chicago Great Western		4.8			4.8	288.7	7.9			296.6	301.4	714.2	42.0
Chicago, Indiana and Southern		2.0			2.0	21.5				21.5	23.5	328.0	7.2
Chicago, Milwaukee and St. Paul		32.2			32.2	S 7.5 C 1.0 2,157.0	355.7			2,521.2	2,553.4	7,180.0	35.6
Chicago and Northwestern		404.7	8.5	6.0	419.2	2,871.2	378.6			3,249.8	3,669.0	7,479.7	49.0
Chicago Terminal Transfer		3.0			3.0						3.0	37.0	81.0

Chicago, Rock Island and Pacific		9.3			9.3	S 4.7	69.5			74.2	83.5	6,490.0	1.3
Chicago and Western Indiana		7.5			7.5		C 19.8			19.8	27.3	27.3	100.0
Chicago, St. Paul, Minneapolis and Omaha	1.2				1.2	629.0	29.9			658.9	660.1	1,655.8	40.0
Cincinnati, Hamilton and Dayton						76.0	25.0			101.0	101.0	1,038.2	10.0
Cincinnati, New Orleans and Texas Pacific	303.2	16.4			319.6	C 5.9 S 5.5				11.4	331.0	335.0	99.0
Cleveland, Cincinnati, Chicago and St. Louis						795.7	263.0			1,058.7	1,058.7	1,887.1	56.0
Cumberland Valley						22.3				22.3	22.3	163.2	13.7
Delaware and Hudson	123.0	86.0	1.5	8.5	219.0						219.0	820.9	27.0
Delaware, Lackawanna and Western	3.0	428.0		4.1	435.1						435.1	927.6	47.0
Erie				6.8	6.8	768.4	665.8 C 14.3		C 24.0	1,472.5	1,479.3	2,381.1	62.1
Galveston, Harrisburg and San Antonio	7.0				7.0	S 2.0				2.0	9.0	1,329.7	
Great Northern						S 3.5 172.5				176.0	176.0	5,230.8	3.4
Hocking Valley						76.9				76.9	76.9	338.5	22.7
Illinois Central	5.4	227.5		5.2 f 8.4	246.5	C 758.7 5.1				763.8	1,010.3	4,459.1	22.7
Kentucky and Indiana Bridge and Railroad Co						8.0	2.1			10.1	10.1	10.1	100.0
Lackawanna and Wyoming Valley						S 2.2	1.2			3.4	3.4	23.0	15.0
Lake Erie and Western						18.6				18.6	18.6	686.0	2.7
Lake Shore and Michigan Southern		131.5	46.5	118.9	296.9	1,134.4	222.2	18.9	5.2	1,380.7	1,677.6	1,677.6	100.0
Lehigh Valley	31.3	401.8	36.1		469.2	690.0 S 6.2	54.2			750.4	1,219.6	1,147.3	g 100.0
Long Island	2.6	62.2			64.8		C 14.1 15.1		C 1.2 2.7	15.3 17.8	97.9	392.0	22.0
Louisville and Nashville						342.7	31.1			373.8	373.8	4,011.0	9.3
Maine Central	13.1				13.1						13.1	807.5	1.6
Michigan Central		272.0			272.0	938.7				938.7	1,210.7	1,309.9	92.4
Missouri Pacific	42.5	17.2			59.7						59.7	3,492.5	1.7
St. Louis, Iron Mountain and Southern	28.8	5.7			34.5						34.5	2,459.1	1.4
Mobile and Ohio		2.3			2.3	50.7				50.7	53.0	926.0	5.7
Morgan's Louisiana and Texas Louisiana Western Iberia and Vermilion	123.0				123.0						123.0	552.6	22.3
Nashville, Chattanooga and St. Louis						94.2	8.6			102.8	102.8	1,226.0	8.5
Newburgh and South Shore						3.0	2.0			5.0	5.0	(h)	
New York Central and Hudson River		112.2		7.1	119.3	1,814.3 C 1.2	356.0 C 153.3		C 281.4	2,606.2	2,725.5	2,941.3	92.5
St. Lawrence and Adirondack						10.2				10.2	10.2	10.2	100.0
New York, New Haven and Hartford	27.0	199.2			226.2	159.9	53.8 C 156.1		C 70.6	440.4	666.6	1,900.0	35.0
New York, Ontario and Western	13.7	74.7			88.4						88.4	492.8	17.5
New York, Susquehanna and Western							19.6			19.6	19.6	205.0	1.0
New York and Long Branch		38.0			38.0						38.0	38.0	100.0
Norfolk and Western						1,446.0	218.0			1,664.0	1,664.0	1,825.0	92.0
Northern Central						290.9	127.8		17.4	436.1	436.1	437.1	99.7
Northern Pacific		14.8			14.8	961.7	98.1			1,059.8	1,074.6	5,352.4	20.0

Table showing for each company the aggregate length of its lines or parts of lines on which the block system is in use September, 1906. Companies not appearing in the list have reported that no block signals are in use on their lines—Continued.

Names of railroads.	Automatic block signals.					Nonautomatic block signals.					Total, all kinds.	Total miles operated by company (passenger lines).	Per cent operated under block system.
	Single track.	Double track.	Three track.	Four track.	Total automatic.	Single track.	Double track.	Three track.	Four track.	Total nonautomatic.			
North Shore		10.0			10.0						10.0	95.0	10.0
Oregon Short Line	35.9				35.9						35.9	1,092.8	3.3
Oregon Railroad and Navigation Co	188.0				188.0						188.0	*i* 828.0	22.7
Pennsylvania Railroad *j*		49.5		191.5	241.0	531.5	652.0	23.3	192.8	1,399.6	1,640.6	3,191.5	51.4
Pennsylvania Company	23.0	5.0	11.0	18.0	57.0	232.0	616.0	20.0	25.0	893.0	950.0	1,334.0	71.3
Pittsburg, Cincinnati, Chicago and St. Louis		5.0		2.0	7.0	526.0	435.0	7.0		968.0	975.0	1,393.0	70.0
Peoria and Eastern							5.2			5.2	5.2	342.6	1.5
Peoria and Pekin Union							7.5			7.5	7.5	15.4	48.7
Philadelphia and Reading *k*	13.7	352.6	35.0	11.7	413.0	206.6 C .8 S 3.6	139.8			350.8	763.8	1,166.9	65.5
Philadelphia, Baltimore and Washington		11.0	20.4		31.4		124.6		40.5	165.1	196.5	657.1	30.0
Pittsburg and Lake Erie		105.8	8.7	26.3	140.8	27.0				27.0	167.8	167.8	100.0
Richmond, Fredericksburg and Potomac						9.8	77.9			87.7	87.7	87.7	100.0
Seaboard Air Line						155.0				155.0	155.0	2,330.0	6.6
Southern						1,062.7	77.8			1,140.5	1,140.5	*l* 6,397.5	18.0
Southern Pacific:													
Pacific System	369.4	50.3			419.7	20.0 S 97.0				117.0	536.7	4,330.0	12.4
East of Sparks	216.1				216.1						216.1	1,006.7	21.5
Lines in Oregon													
St. Louis Merchants' Bridge Terminal		8.5			8.5		1.1			1.1	9.6	8.4	*m* 100.0
St. Louis and San Francisco	5.0	3.0			8.0	346.0 S 3.7 C 2.0	27.0			378.7	386.7	4,055.9	9.5
Staten Island Rapid Transit		9.2			9.2						9.2	9.2	100.0
Terminal Railroad Association of St. Louis		6.1 *n* 1.2			7.3		C 1.0 .6	.6	*o* 1.3	3.5	10.8	11.2	97.0
Texas and New Orleans	41.0				41.0						41.0	438.6	9.0
Union (Pittsburg)		1.0			1.0	3.2	1.8			5.0	6.0		
Union Pacific:													
East of Green River	104.7	45.1			149.8						149.8	2,751.9	5.5
West of Green River	115.2				115.2						115.2	203.6	56.6
Vandalia						219.6	18.9			238.5	238.5	804.9	29.6
Wabash *p*		7.2			7.2	1,965.9	71.6			2,037.5	2,044.7	2,044.7	
Wabash-Pittsburg Terminal		4.8			4.8						4.8	59.9	8.0

Washington Southern						3.6	28.9			32.5	32.5	32.5	100.0
West Jersey and Seashore		84.3	9.9		94.2	47.8	28.4			76.2	170.4	321.6	53.0
Wisconsin Central							6.1			6.1	6.1	838.8	
Yazoo and Mississippi Valley	4.2				4.2	C 15.4				15.4	19.6	1,239.1	1.6
Total q	2,032.4	4,143.9	178.1	472.5	6,826.9	33,585.1	7,567.7	89.9	673.6	41,916.3	48,743.2	143,615.8	

a All items under nonautomatic represent the telegraph block system unless otherwise indicated by "C," meaning controlled manual, or "S," meaning electric train staff.

b On all but 26 miles the block signals protect from rear, but not for butting, collisions.

c Buffalo, Rochester, and Pittsburg: Block signals used only for protection of rear of passenger trains and snow plows.

d Chicago, Burlington and Quincy: 2,932.5 miles for protection of passenger trains only.

e Chicago, Burlington and Quincy: 4,107.1 miles for protection of passenger trains, but not throughout the twenty-four hours of the day.

f More than four tracks.

g Lehigh Valley: Block signals on 72.3 miles not used by passenger trains (29.3 miles double track and 43.0 miles single track).

h All freight.

i Excluding lines on which but one train is run.

j Pennsylvania Railroad: Item 191.5 miles includes 1.8 miles of line having more than four tracks; item 192.8 miles includes 1 mile of line having more than four tracks.

k Including Atlantic City Railroad; North East Pennsylvania Railroad; Perkiomen Railroad; Philadelphia, Newtown and New York Railway, and Reading and Columbia Railroad.

l Excluding 391 miles on which only one train crew is in service.

m St. Louis Merchants' Bridge Terminal: Block signals on 1.2 miles of freight lines.

n Caution signals.

o Four-track and six-track.

p Wabash Railroad: Item 1865.9 miles includes 763 miles of line on which block signals are used only for protection of rear of passenger trains.

q The items representing lines on which the use of the block system is partial (Buffalo, Rochester and Pittsburgh; Chicago, Burlington and Quincy; Wabash) aggregate 8,232.1 miles.