FIRST ANNUAL REPORT OF THE BLOCK SIGNAL AND TRAIN CONTROL BOARD TO THE INTERSTATE COMMERCE COMMISSION

This board was appointed on July 10, 1907, and organized on July 12. The doings of the board during the year 1907 were made the subject of an informal report to the commission November 21, 1907.

The duties of the board, as defined by its instructions from the commission and the acts of Congress under which its appointment was authorized embrace the investigation of (*a*) block signals, (*b*) automatic stops and cab signals, and (*c*) other devices designed to promote the safety of railroad operation. According to the terms of the law the board may investigate the "use of" and the "need for" devices which come within these definitions and may test devices and appliances which are presented to it "in completed shape * * * without cost to the government."

The two subjects first mentioned (*a* and *b*) were investigated by the commission before the appointment of this board, and the report on the subject made by the commission to Congress February 23, 1907, may be looked upon as a preface or explanatory introduction to the work of this board. In that report the commission gave a succinct account of the state of the art of block signaling in the United States at that time and recommended the enactment by Congress of legislation looking to the gradual compulsory adoption of the block system on all passenger lines, except those traversed by less than six trains each way weekly. This recommendation made by the commission in 1907 (a repetition of recommendations made in former years) was indorsed by this board in its informal report of one year ago.

Block signals, both automatic and nonautomatic, have already been intelligently developed in this country, and the time of the board has therefore been devoted mainly to automatic stops and cab signals, which have not been so fully developed. Up to November 21, 1907, the date of our former report, about 250 plans of inventions in this field had been received, and fifty-five of these had been examined. Nearly all of these inventions were found to possess little or no merit, the inventors being apparently unfamiliar with the needs of the railroad service as well as ignorant of the state of the art. The makers of those automatic stops and cab signals which are in regular use have taken no special pains to bring their apparatus to the attention of the board, though they have offered to furnish any information which we may ask for.

Within the past twelve months a further large number of descriptions of inventions, alleged inventions, or propositions has been received and they have been dealt with as shown in the statement given below.

The authority to investigate devices other than block signals, automatic stops, and cab signals was granted by Congress May 27, 1908, and as yet has been exercised only in a small number of cases, none of which calls for notice in this report.

The present status of the work of the board may therefore be said to be as follows:

Plans and specifications of 371 devices have been examined to date. Of these, 248 relate to block signal, cab signal, or automatic train stopping devices, while 124 relate to other devices designed to promote the safety of railway operation, as defined by the provisions of the Sundry Civil Appropriation Act of the first session of the Sixtieth Congress.

Of the 371 files placed under examination, 184 have been reported on, and 187 are still in course of examination.

Of the 184 files reported on, 168 are signal and train stopping devices, and 16 are other railway safety devices.

Of the 187 files still in course of examination, 80 are signal and train stopping devices, and 107 are other safety devices.

Of the 184 files reported on, 12 signal and train stopping devices have been considered to possess sufficient merit to warrant the board in saying that if the proprietors should install the same on a railroad under practical working conditions the board would examine the installations with a view to determining whether tests should be conducted at government expense. Of these 12 devices, 4 are now being installed, 1 of these being reported ready for test, and the board is advised that the installation of 4 others will be begun in the near future.

It has been necessary to spend much time on some of the most ill-considered inventions, for in rejecting a device or plan, cherished by its originator as promising great benefits to mankind and vouched for by patent experts as unique, it is necessary to marshal the reasons for our action in the most logical and forcible manner. Such inventors often are exceedingly persistent, and some of them, sorely disappointed at the unfavorable decision of the board, return again and again.

STATISTICS.

Under an order issued by the commission on November 18, 1907, the board gathered and compiled statistics showing the milage of railroad operated by the block system in the United States as of January 1, 1908, together with information as to the kinds of apparatus used for automatic block signaling and of the methods employed in the working of the non-automatic block system, and these were published by the commission in pamphlet form in April last. By direction of the board, the secretary has distributed 1,500 copies of this pamphlet. Under an order which has just been issued by the commission, it is proposed to compile similar statistics as of January 1, 1909. These statistics give no information concerning automatic stops, because until within a few months there have been none of these in use on railroads which are subject to federal authority in this matter. (Automatic stops are in use on the Hudson and Manhattan tunnel between New York, N. Y., and Hoboken, N. J.) No information is given concerning cab signals, because none of these are in regular use in this country.

The work of the board during the past twelve months has been pursued along the same lines as before, but in addition to investigations in this country two members of the board, in March last, visited England, France, and Belgium, to secure information concerning the use of cab signals in those countries.

To expedite the work of the board three technical assistants have been employed to aid the members in digesting descriptions with a view to reaching decisions on all important matters at the earliest possible date.

PROCEDURE.

Inventions and propositions brought before the board are dealt with in accordance with the procedure prescribed last year and referred to in our former report. It is required that each invention be suitably described, with drawings if necessary, and as a rule these drawings and descriptions must be examined and passed upon by the board before the question of testing a device will be taken up, and before hearings or interviews will be given. When the plan of a device has been examined and the thing described is held to have merit, the board, if satisfied that a test would be of value or interest to the public, advises the proprietor that if an installation, made by himself, when tested by himself, confirms the favorable impressions given by the plans, the board will undertake a test on behalf of the government. As the commission has already been informed, the American Railway Association has co-operated with the board in securing the use of tracks for testing automatic stops and cab signals.

In carrying out the intent of the legislation under which it acts, which requires investigation of the use of and necessity for apparatus and systems for the promotion of safety in railway operation, the board not only examines plans, descriptions, models, or installations of devices submitted to it, but makes such observation and inspection, through its members or employes, regarding the use of existing appliances, systems, and operating methods as may enable it to determine the necessity for other appliances, systems, or methods than those now in use.

The principal appliances or systems, the use of and necessity for which have been considered by the board up to the present time, are the following:

1. Automatic stops.
2. Cab signals.
3. The telegraph block system.
4. The controlled manual block system.
5. Automatic block system.
6. Other railroad appliances and systems.

1. *Automatic stops.*—This term is used to define devices for stopping railroad trains by means independent of the engineman or motorman. The class may be divided as follows:

(*a*) Contact devices, mechanical, on or near the ground. At a fixed point, as at the entrance to a block section, a lever on the engine or a car of a train, coming in contact with apparatus fixed on the roadway, actuates levers, valves, etc., on the vehicle. No electrical apparatus is used.

(*b*) Contact rail devices for conveying an electric impulse from a fixed point on the roadway to an electrical apparatus on the vehicle. A rail (or rails) fixed at the signaling point, or in a suitable relation to it (but not continuous throughout the length of the block section), comes in contact with a metallic brush or other conductor on the vehicle.

(*c*) Ground devices embracing both of the foregoing features.

(*d*) Devices for making contact overhead, as, for example, from a signal post to apparatus fixed on the roof of the cab of a locomotive, mechanical, electrical, or both.

(*e*) Devices making no contact, the impulse on the vehicle being produced by magnetic or electric induction.

2. *Cab signals.*—These may be classified, *a, b, c, d, e,* the same as automatic stops, the difference being that automatic stops are designed to shut off steam or cut off electric power and apply the power brakes, or both, while a cab signal is designed only to ring a bell or sound a whistle or show a light for the information and guidance of the engineman or motorman, these audible and visual signals being given in his cab.

3. *Telegraph block system.*—With this system three principal methods of communication are used: *a,* Morse telegraph; *b,* telephone, and *c,* electric bells (with code). While in the operation of most systems of this kind communication between the signalmen at both ends of the block is prescribed to admit a train to the block, systems are in use on the Erie and on the Northern Pacific in which the operations of the block signalmen are actively participated in by the train dispatcher, who supervises the movement of trains under the block-signal rules throughout a division or subdivision of a railroad.

4. *Controlled manual block system.*—In this system, which is further described under a separate heading, four principal methods of control are used: *a,* block instruments without track circuits; *b,* block instruments with track circuits or track instruments at each block station; *c,* block instruments with track circuits throughout the length of each block section; and *d,* the electric train staff.

5. *Automatic block systems.*—In practically all such systems in use in this country the operations of the signals are controlled entirely by the action of the train upon track circuits throughout the length of each block section or by certain conditions affecting the use of the block, such as the continuity of the track rails and the position of switches. In such systems the signals proper are classified as follows: *a,* exposed-disk or clockwork signals; *b,* inclosed-disk signals; *c,* electro-pneumatic semaphore signals; *d,* electric-motor semaphore signals; *e,* electro-gas semaphore signals; *f,* "light" signals; and *g,* other types. Such systems comprise a considerable amount of other apparatus, such as relays, circuit controllers, generators, compressors, motors, batteries, and a large number of other electrical and mechanical devices.

6. *Other railroad appliances and systems.*—This class includes the following devices: *a,* roadway and structures, including rails, ties, switches, rail fastenings and other track appliances, bridges, and other structures and permanent way appliances; *b,* equipment, including locomotive, motor and car structures and machinery, such as trucks, wheels, car steps and platforms, brakes and brake rigging, draft rigging, car couplers, hose couplers, and car appurtenances; *c,* train signals; and *d,* operating systems and methods.

AUTOMATIC STOPS AND CAB SIGNALS.

The automatic stops and cab signals now in use are few in number and do not call for extensive investigation, for their characteristics are known. Most of them are installed in situations free from the troubles incident to frost, snowstorms, and certain other adverse conditions which prevail on railroads generally.

Carrying out what we believe to be the purpose of the resolution of Congress, the object kept in view by this board in this matter is the securing of accurate information concerning the usefulness and efficiency of automatic stops in general railroad service. Experience with stops in subways or in other places not exposed to snow, rain, and frost does not afford the lessons sought, and therefore the board is devoting its attention chiefly to such devices as are offered for test in unprotected situations during the winter season. Experience on city passenger railroads is unsatisfactory also because of the absence of some of the conditions which must be met on ordinary railroads; such as irregularity in the length of trains and differences in design of engines and cars; also because in consequence of the very heavy traffic on those lines very frequent inspection is practicable. On ordinary railroads such highly efficient inspection would probably be excessively costly.

Automatic stops.—The principal automatic stop devices which have had our attention are as follows: The mechanical trip devices used in connection with electro-pneumatic block systems in use on the Boston Elevated, the Interborough Rapid Transit of New York City (subway), the Philadelphia Rapid Transit, and the underground lines in London, England. Mechanical trip train stops of the same general design, but worked by electric motors rather than by compressed air, are in use on the Hudson and Manhattan tunnel under the Hudson River between New York, N. Y., and Hoboken, N. J. The officers of these roads are unanimous in their testimony as to the satisfactory operation of the stops, and there have been occasions when but for the action of the automatic stop collisions would have occurred in consequence of neglect on the part of the motormen.

Two experimental installations of automatic stops have been made recently, one of the mechanical trip type, with certain modifications, by the Rowell-Potter Safety Stop Company, on the Chicago, Burlington & Quincy Railroad near Chicago (described in The Signal Engineer for December, 1908), and one of the intermittent contact rail type, with a normally closed engine circuit, by the Simmen Automatic Railway Signal Company, of Los Angeles, on the Atchison, Topeka & Santa Fe Railroad in southern California.

The Rowell-Potter Company has been before the public for fifteen years or more and devices made by it have been in use in past years to some extent, notably by the elevated roads of Chicago, but the apparatus now installed on the Chicago, Burlington & Quincy has been tried but a short time, and the board is not yet prepared to report on it. The Simmen devices include a system of remote control of a number of signals in a block system from a central point such as a dispatcher's office. This installation also has been in use but a short time, and no detailed investigation of it has been made.

The board has made a partial test of the Perry-Prentice cab-signal and train-stop device as recently installed experimentally on the line of the Suburban Railroad Company of Chicago. This system forms, so far as known, the first application of the use of the Hertzian waves to railroad signaling. It makes use of "wireless" communication between a line wire strung along the track and apparatus in the engine cab. A coherer is included in a normally closed engine circuit, which circuit is broken if the particles of metal in the coherer cease to be held in cohesion by the action of the Hertzian oscillations emanating from the aerial conductor extending through the block.

Cab Signals.—While, as previously noted, a number of installations of automatic train stops have been made on certain city railroads in this country, none of these installations provide for a visible or an audible signal indication on the vehicle. The automatic stops are used in connection with fixed visual signals only, it being generally assumed by the officers of these roads that it is unnecessary to supplement the indication of the fixed signals with any indication on the vehicle, and that the motorman, guided by the fixed signal indications, will properly control his train under all conditions except those which incapacitate him for proper action, in which event the automatic stop will come into play and control the movement of the train.

On the other hand, the European idea seems to be that if a sufficiently clear and reliable indication is given to the engineman he can be depended upon properly to control his train; and therefore automatic stopping devices are not favored. Most of the descriptions of automatic train-stop devices submitted, however, provide for the use of a cab signal; and some cab-signal devices have been presented which do not include the use of an automatic train stop. The immediate problem in either of these devices is to produce certain effects on apparatus carried on the vehicle by the existence of certain conditions upon the track, and if the apparatus or system provides a proper means for carrying out this object the means are equally available for the control of an automatic train-stop or cab-signal or other device of that character fixed on the vehicle.

The only cab signals which have been used regularly for any considerable length of time are: (1) That used on the Northern Railroad of France; and (2) that on the North-eastern Railroad of England. That on the Northern of France is an electric contact apparatus (class 2 *b*). It is used in connection with fixed manual visual signals throughout the lines of that company, over 2,400 miles in extent, and has been so used on most of those lines for twenty years. A whistle is sounded in the cab of the locomotive when a fixed distant (visual) signal is passed at "caution." The system can not be approved, however, because the electric apparatus is arranged on the open-circuit principle. As the silence of the whistle in the cab indicates a clear track, any derangement of the apparatus, for example the accidental breakage of a wire, would produce a false clear indication. The apparatus being arranged on this principle, there is no way of knowing with exactness how well it has served its purpose, for it may have been out of order an unknown number of times without being promptly discovered.

The board has communicated with the officers of the Northern Railroad of France, but their experience is relatively of little value as throwing light on the problems which have to be met in this country, because of the open-circuit feature and because in the climate of France the apparatus is not subject to severe weather conditions.

The cab signal on the Northeastern of England is a mechanical arrangement (class 2 *a*) and it has been in limited use for ten years. Like the electric device just mentioned, however, it gives no warning of its own failure, and therefore the records of its service are of little value as throwing light on the degree of perfection with which it has worked.

A cab signal combining the functions of both classes—2 *a* and 2 *b*—but operated on the closed-circuit principle, is in use on the Great Western Railway of England, where it has been in regular service on a short branch line for over a year. This apparatus gives proceed indications as well as caution indications, and the Board of Trade has permitted the abandonment of the fixed distant block signals where this system is in use.

A cab signal actuated by magnetic induction was tried on the Manchester, Sheffield & Lincolnshire several years ago, and with good results, but the experiment was given up because, in consequence of the number of foreign locomotives running over the line, the company concluded that no cab signal of any kind would be desirable.

It will be observed that automatic stops are in use in America, but not elsewhere, except on the London underground lines. Cab signals, on the other hand, are in use in England and France, but not at all in America.

Comparison of automatic stops and cab signals.—In considering the characteristics and use of automatic stops as compared with cab signals, we have the following facts:

1. Automatic stops have been adopted for regular service only on city railroads which carry a heavy traffic and are worked by electric power. Their lines are in tunnels protected from snow, or on elevated structures where snow does not accumulate in troublesome quantities. Motormen do not have a companion or monitor in the cab with them, as does the engineman of a steam locomotive, and there is therefore a stronger argument for an automatic stop. Being worked under exacting conditions, these city roads are very efficiently inspected.

2. The Northern of France uses cab signals, but it does not get from them the full benefit of which they are capable, and therefore France must be left out of the account.

3. Leaving out facts 1 and 2, both automatic stops and cab signals are to be looked upon as still in the experimental stage, although they have been proposed for many years. Cab signals have been tried in many places, but all of the experiments have been short-lived, except that on the North Eastern of England. British railroad officers naturally prefer a cab signal, because, with the high efficiency of their locomotive runners, they do not feel the need of an automatic stop. They have more trouble from fog than is experienced in America, and therefore feel a more definite need of a cab signal for use as a convenience in ordinary working, regardless of the question of safety. In America both cab signals and automatic stops have been proposed as safety devices purely, and on the assumption that the vigilance of enginemen and motormen can not be improved to the point of insuring a satisfactory degree of safety while using only the present visual signals.

TELEGRAPH BLOCK SYSTEM.

In connection with the falling off in freight traffic throughout the country since the beginning of the depression in business in October, 1907, some roads have carried their economies so far as to discontinue the use of the block system where it had been regularly maintained for some years; and this expedient is reported to have been adopted on two single-track lines where the controlled manual system (without track circuits) had been in use several years. Again, on lines where the block system is still maintained a part of the block stations have been closed to save the expense of maintaining signalmen both night and day. In still other cases a part of the block stations on a line have been put under new schedules under which they are closed a part of the time; as, for example, an office will be closed eight hours out of twenty-four, thus saving the expense of one signalman. In some cases an office will be kept open in the daytime and not at night, while perhaps at the next station no signalman will be found on duty in the daytime, but one will be on duty at night. Other odd arrangementments or hours have been introduced. These irregularities have been introduced not alone because of the depression in business, but also because of the law enacted by Congress March 4, 1907, limiting the hours of service of block signalmen, which increases the expense. As business improves the block system will be restored probably; but this making of extensive changes in the methods of train operation by so many roads emphasizes the importance of the bill which was before the last Congress to authorize the Interstate Commerce Commission to secure full information regularly concerning this department of railroad operation. This feature of the bill introduced by Hon. J. J. Esch, of Wisconsin, in the last session of the Fifty-ninth Congress is no less important than that making the use of the block system compulsory.

As was remarked in the report of the Commission on the block system in February, 1907, many block signalmen in America are young and lacking in training and experience. This has been indicated in the records of railroad accidents, this deficiency being a cause of disastrous collisions. This fault in the personnel of railroad operation has not been so conspicuous during the past year as it was during the heavy traffic of 1905-1907, because, first, the diminished number of trains has made the work of the signalmen simpler and easier, and, second, the same cause has made possible the improvement of the block-signal service by eliminating the less competent signalmen. This improvement in the personnel has not been universal, however, and the board has information of instances here and there of signalmen whose incompetence was manifest, and in some of these cases there has been evidence of excessive use of intoxicants. The information the board has gained as the result of the investigation it has conducted along these lines justifies the continuance of this investigation.

While on the subject of the personnel of telegraph offices it is proper to observe that the difference in habits, capacity, and training of signalmen on the railroads of Great Britain as compared with those of American roads, which was referred to in the above-mentioned report, was confirmed by the observations of members of this board in England and Scotland last spring.

Under the head of the telegraph block system, mention should be made of the superiority of the block telegraph instruments used in England—which are modifications of the well-known needle telegraph—as compared with the communicating methods used with the simple manual or telegraph block system in this country. With the needle system the receiving instrument gives a visual as well as an audible signal, and the visual part, by the position in which it remains after each operation, serves as a constant indication before the signalman's eyes of what the last operation was.

A modification of the telegraph block system has lately been introduced on the Northern Pacific railway—single track—which merits attention. This is the simple telegraph block system, but each operation by the signalman—or, rather, the series of operations by which a signalman assures himself that a block section is unoccupied, and then gives the proceed signal to a train—is carried out under the immediate supervision of the train dispatcher, all the block-signal stations of a district being on a single wire connected with the dispatcher's office. This system is commonly called the "A B C" system. A train is admitted to a block section only on a signal in which the dispatcher and two block signalmen have co-operated, thus greatly reducing the chances of error. The operations are further safeguarded by requiring each train to stop at every station, unless the signalman both displays a clear signal and delivers written cards to the enginemen and the conductor. (By means of large hoops, these cards are delivered to trains passing at twenty-five miles an hour and faster.) By the employment of these safeguards, provision against collisions of trains is so fully secured that the officers of the road have felt warranted in the discontinuance of the rule requiring all meeting orders to be written out, telegraphed, repeated, and receipted for. This writing and repeating process is so slow that it causes many delays to trains.

On some divisions of the Northern Pacific the freight trains are now run over the road in 20 to 25 per cent less time than formerly. This not only effects an economy for the road, but also enables the trainmen to earn more wages per hour. The arrangement of meeting points without using the full written and repeated telegraphic orders is equally practicable with the electric train staff, and the same saving in time is accomplished. This is shown by the results on those parts of the Southern Pacific and the Atchison, Topeka & Santa Fe where the train staff is used. The difference in the Northern Pacific practice as compared with the use of the staff system is that the method under which the dispatcher co-operates with the signalman may be introduced on any line, no matter how light its traffic, and with but little preparation; and the cost of the electric staff apparatus, which is considerable, is saved. On the other hand, the number of dispatchers may have to be increased, and the maintenance of the discipline necessary to make the three-man block signaling operation satisfactorily free from liability to error is probably more of a task than the maintenance of the same degree of safety by means of the electric staff, which is a highly efficient "controlled manual" apparatus for single-track lines. As a preventive of false clear block signals, this apparatus theoretically should be superior to any number of co-operating men.

The term "telegraph block system," as used on American railroads, is applied to all man-operated systems not fitted with electric control of levers, and includes lines where the telephone is the means of communication. Telephones have been used to a limited extent for several years for sending train orders. They have lately been introduced quite extensively in block signaling, however, as was shown by the block-signal statistics published by the commission in the present year.

Theoretically, telephones are as safe and as convenient as the long-used Morse telegraph, and the experience of many roads for the last year or two has confirmed this theory. We touch upon this subject in this place merely to make reply to the query, voiced in several places, whether the change in apparatus and methods has involved any lessening of safety. The only serious question that has ever been raised concerning the safety of telephones is in regard to the liability of indistinct transmission of syllables and words. In the Morse telegraph or any other system this contingency must be provided for, and with the telephone, as with the telegraph, mistakes are guarded against by good training and discipline, and by repeating back all communications.

CONTROLLED MANUAL BLOCK SYSTEM.

Within the last four years controlled manual apparatus without track circuits has been introduced extensively on single-track lines of the Illinois Central, the Chicago, Burlington & Quincy (described in The Signal Engineer for November, 1908), and the Chicago & Eastern Illinois railroads, and the electric train staff, embodying similar principles, has been put in use on 100 miles of the Southern Pacific.

As a safety device, the controlled manual system is already well understood and well developed, so that the investigation of it cannot be looked upon as calling for special attention on the part of this board; but these extensive installations on single-track lines are in some respects new departures in American railroad practice, and a study for the purpose of comparing these with each other and with other systems may be desirable at a later date.

AUTOMATIC BLOCK SIGNALS.

As shown by the statistics which have been published by the Commission, the railroads of the country made comparatively rapid progress in automatic signaling for several years up to the end of 1907. Since then only a few important new installations have been begun; but within the past month the St. Louis & San Francisco gave an order for the equipment of 712 miles of its single-track lines, and the Southern Pacific is resuming work on some of the installations which were suspended a year ago.

The extensive installation on the New York Central & Hudson River in and near New York City of automatic block signals adapted for use in connection with railroad tracks, the rails of which are traversed by powerful electric currents used with electric propulsion of trains, constitutes one of the notable instances of progress in the signaling art.

LACK OF KNOWLEDGE OF THE ART.

Of the hundreds of descriptions and plans of devices or systems for the promotion of safety in railroad operation examined by the board, so few possess any merit that it is evident that a large proportion of the inventors or proprietors of such devices are entirely unfamiliar with the conditions to be met in railroading, the development of safety appliances, the state of the art of signaling, and often with well-known natural laws. This is manifested in three forms:

(1) In devices which, no matter how well designed or constructed, would be dangerous or of little or no value.

(2) In devices or systems which, no matter how well the details of design and construction were carried out, are fundamentally wrong in principle.

(3) In devices or systems which, while theoretically useful and workable, are designed without regard to the well-known properties of materials or a consideration of the quantitative values of the forces and velocities involved.

Dangerous devices.—As an example of the first class, may be cited the highway crossing gate designed to be closed automatically by the approach of a train. It is obvious that such a device, no matter how perfect in operation, would be unsafe to use, as the gates would descend or close when the train was within a given distance of the crossing, irrespective of whether or not pedestrians or vehicles were on the crossing, thus preventing their escape from the very danger that the invention is intended to avert. Other inventions of substantially the same class are those for the automatic throwing of switches by train approach, especially those intended to restore to the main track position, by the passage of the train itself, a switch that has been maliciously or carelessly left set for a siding or turn-out.

The board believes that switches, being movable portions of the track, are so subject to obstruction of their proper movement by foreign substances, such as stones, lumps of coal, snow, ice, bolts, nuts, and other parts dropped from cars or locomotives, that they should not be operated except by an attendant, for the reason that such attendant can detect abnormal or unsafe conditions which would prevent the proper operation of the switch. These conditions cannot be detected by automatic apparatus controlled by approaching trains except under conditions where the throwing of the switch, the locking of the switch, the releasing of the signal, the clearing of the signal, together with the necessary approach and detector locking, are all interdependent and occur in proper sequence. Even with such refinement, it is considered doubtful if the reliability of operation of such devices would be sufficient to warrant their use in practice unless in special or unusual cases.

Devices wrong in principle.—The most typical devices of the second class referred to, namely, those that are wrong in principle, are signals that require the application of power to move them to the position to indicate "stop," and assume the "proceed" position by gravity or whenever the application of power to them ceases. Within this class falls also the large number of electrical appliances designed to operate on the so-called open-circuit principle. In these, the presence of electric current in the operating devices is required to give a "stop" indication or apply the brakes or accomplish the purpose for which the device is designed; whereas it is evident that all such appliances should be constructed on a principle directly opposite, namely, the closed-circuit principle, so that if the current supply should fail, or a wire should break or become disconnected, or a short circuit or a cross should occur, the "stop" indication would be displayed or the brake applied, or other purpose of the design carried out. In other words, all devices or systems must be to the highest degree self-checking of their own failures, so as to render them as nearly as possible incapable of falsely indicating safety when danger exists, or if used in train control, incapable of permitting a train to proceed when it should be stopped. This principle is fundamental, and no devices or system designed on the contrary or open-circuit principle can be approved.

Impracticable devices.—In the third class, or impracticable devices, we find many where it is intended to operate signals or mechanical trip train stops through the medium of cables or rods several thousand feet or a mile or more in length, attached to treadles or other trips which are intended to be depressed or moved by engagement with some part of another moving engine or train, little idea evidently being entertained by the inventor as to the inertia of the parts, the effects of impact, the elasticity and strength of the materials employed, or the conditions due to accumulation of snow, ice, or sand.

Reliability.—Next to safety, reliability is the most important feature in safety appliances. By this is meant infrequency of failure of the device or system to respond to all the conditions under which it should act. For example, if a signal device indicates a clear track when the track is obstructed, it is an unsafe device. If it indicates danger when there is no danger, it is not reliable; and such unreliability soon becomes a source of danger, for if a signal, for example, frequently indicates "stop" when the conditions are all right for the train to proceed, its "stop" indication soon becomes discredited as a true indication of danger and may come in time to be disregarded even when correctly given, and hence lead to disaster.

Contact devices.—Many devices or systems have been examined in which contact plates or rails are included in electric circuits carrying current which either continuously or intermittently is intended to be picked up by a contact brush or shoe on the moving vehicle. While a number of such systems are designed on theoretically correct principles, the practicability of making or maintaining a reliable contact can be determined only from long-continued experiment with various forms of roadway and vehicle contacts under such conditions of speed, vibration, clearance, shock, snow and ice as exist in actual railroad working in all localities and at all times of the year. In considering any closed circuit arrangement which makes use of a continuous contact rail, it must be borne in mind that a momentary loss of contact which might occur from very slight accidental circumstances might in an automatic train-stop device cause an emergency application of the brakes while running at high speed. This makes the reliability of such schemes extremely doubtful.

Equipment and structure clearances.—Inventors or designers of cab signals and automatic train stops often disregard the very definite relations that must necessarily exist between the dimensions of cars and engines and those of platforms, bridges, tunnels, road crossings and other structures along the roadway. It should be remembered, for example, that the location of end ladders on freight cars must be definite and reasonably uniform, in order to make their use safe for trainmen. Yet many devices of the overhead type are presented, by the use of which freight trainmen would undoubtedly be subject to more danger than the use of the devices would prevent. The question of equipment and structure clearances should be carefully studied by all who approach this problem.

Continuous track circuit.—A number of block signal systems have been presented for the board's consideration which involve the use of much complicated apparatus and would doubtless cost as much to install and maintain as the best-known systems now in use, and yet lack the very desirable protection afforded by the use of continuous track circuits with their ability to detect broken or removed rails. This is a protective feature free to be used by anyone as far as patent rights are concerned, and it is especially desirable in view of the relatively poor quality of most of the steel rails now on the market.

WORK OF VARIOUS RAILROAD ASSOCIATIONS.

Most worthy of commendation, as tending to promote the safety of railroad operation, is the work that is being carried on by the various technical associations of railroad officers, notably the recent work of the Bureau of Explosives of the American Railway Association, and the efforts of that association to secure better specifications for steel rails; the joint work of the American Railway Engineering and Maintenance of Way Association, and the Railway Signal Association, tending toward the adoption of a uniform system of railroad signaling, and the work of the latter association on specifications for automatic block signals and power and mechanical interlocking.

In addition to the work mentioned above, the Railway Signal Association during the last year has had the question of automatic train stops and cab signals under consideration by a committee which presented a report at the annual meeting of the association at Washington in October. This report, in addition to reviewing briefly the history of experimental installations of such devices in this country and describing various systems, submitted for adoption by the association a list of requisite of installation to which automatic stop and cab signal systems should conform to be considered safe and reliable in operation. These requisites, as amended at the annual meeting referred to and submitted to letter ballot of the Railway Signal Association, are as follows:

Railway Signal Association's proposed requests of installation for automatic stop and cab signals.—1. Apparatus and circuits so constructed that a failure of any essential part will cause the display of a stop signal indication and also the working of the automatic stopping device. The automatic stop device should be possible of arrangement so that it will not be operative or effective when the speed of the train is less than five miles per hour.

2. The train control feature must be applicable for use with the absolute or the permissive operation. With either system the release of the stopping device must be within the control of the engineman or trainman, but only after the speed of the train has been reduced to five miles per hour or less.

3. The automatic stopping device must be operative only in the direction of traffic, except in connection with signals governing reverse movements.

4. The system must be operative under all weather conditions.

5. The system where track circuits are used must be adaptable for use with a block system using track circuits.

6. The system must give protection against a broken rail, the ends of which have separated, or where a rail or section of a rail has been removed from the track.

7. The parts on the moving train must not extend beyond the maximum clearance lines, and the parts on the ground must not extend within the maximum clearance lines, except for a space of two feet above the top of the rail, within which distance the parts must clear the maximum equipment line.

8. An overlap equal to the braking distance for the maximum permissible speed must be provided for automatic stopping devices.

9. Emergency application of the brakes should be made only when a home or dwarf signal has been run by, when indicating stop. If the system is arranged to cause an application of the brakes when a train passes a distant signal that is indicating caution, the application of the brakes must not occur if the home signal is indicating proceed, or if the speed of the train is being controlled so that the train will be stopped before passing the home signal.

10. The circuits must be arranged to allow two or more engines to be used with one train, or to allow one train to push another train without having the automatic stop applied at each home signal, or to require the speed to be reduced to five miles per hour when passing a home signal that is indicating proceed.

11. The automatic stop must be adaptable for use with electric traction systems using direct or alternating current for train operation.

12. The automatic stop and cab signal should be considered only as adjuncts to be a fixed signal system. (NOTE.—This is on account of the impossibility of properly checking the work of the engineman if a cab signal or automatic stop is used without a fixed signal, and also from the necessity of informing the engineman of the exact commencement of the block and the point at which the indication received in the cab shall become effective.)

At the time of compiling this report the results of the letter ballot of the signal association on these requisites have not been published. It is understood that the committee of the Railway Signal Association considers these requisites as desirable for ordinary surface railroads and that they are not presented as suitable for urban railways, in subways, or upon elevated structures.

While, as noted above, this list of requisites has not been formally adopted by the Railway Signal Association, and while the board is not prepared to discuss the proposed requirements in detail on the basis of its present knowledge, it feels that they should have the careful consideration of all who are interested in this subject.

While the action of the American Railway Association in restricting the freedom of action of the voluntary technical associations composed of officers and employes of the railroads forming this association may result in a greater harmony and economy of effort by the technical associations themselves, such restrictions will hardly tend, unless exercised with greatest care, to increase the effectiveness of the associations in the promotion of the safety of railway operation.

CORRESPONDENCE.

General.—The secretary of the board has received 3,375 letters relating to various devices that have been presented for examination. In connection with this work, and the work of securing reports of block signal mileage, 4,500 letters have been written.

The following printed matter has been distributed:

Circular letters	700
Public resolution No. 46 and appropriation act, Fifty-ninth Congress	700
Form B. S. 1	700
Sundry civil act, Sixtieth Congress	300

The board has conducted correspondence relating to 709 devices, of which number 335 are signals and train stops, and 374 are other railway safety devices.

Complaints.—No small portion of the correspondence of the board has had to do with complaints and demands for an investigation of alleged suppressions of important inventions by powerful corporations and associations, to the serious detriment of the public interest and great pecuniary harm to individuals. The nature of the charges made indicates a necessity for investigation to determine whether they are justified in fact, it being considered equally important, from the standpoint of the public, to establish definitely that such accusations are untrue as that they are true.

There appears to be a very general belief that the inventor without means or influence cannot get his inventions considered by railroad officials, and in consequence appeals by such inventors to the government for aid to secure what is believed to be his rights have been both frequent and insistent.

The legislation under which the board acts, while providing the machinery for investigating the use of and necessity for block-signal systems and appliances for the automatic control of railroad trains and other appliances or systems designed to promote the safety of railroad operation, does not provide for the investigation of alleged suppressions of inventions, although it does indirectly aid the inventor without means or influence to get his invention considered when it has been found to possess sufficient merit to warrant a favorable report by this board.

It is believed to be in line with good public policy to provide means to satisfy the insistent demands for just treatment of the inventor, if such means do not already exist, and if they do, then to point out the way to make such means available and effective so as to satisfy the reasonable demands of the complainants.

Protests.—Another fruitful source of correspondence has been the protests of inventors on whose apparatus the board has felt obliged to report adversely, and it is interesting to note that not infrequently the most vigorous protests come from those whose devices have been found to possess a minimum of merit. This is largely due, it is believed, to a lack of knowledge of the technical requirements of modern railroad operation. In a number of instances the inventor, on having the faults of his system pointed out, has attempted to correct them and has then resubmitted his plans with corrections for further consideration. In a few instances this has led to a favorable report. It is believed that should inventors of railroad safety appliances avail themselves of the knowledge and experience of those skilled in the art, a much larger proportion of devices would be found to comply with practical railroad requirements.

In a few instances where, on account of fundamental faults in a system, the board has reported unfavorably, the inventor or proprietor has insisted on a practical test of his device notwithstanding, claiming the right to such a test under the appropriation act accompanying the joint resolution under which the board was created. The policy of the board in such cases was defined by the commission in a case referred to it for consideration at the December (1907) meeting of the board, the decision being as follows:

If * * * satisfied * * * that this plan or method of train control to prevent accidents is inherently defective and could not on that account be prudently adopted, we are of the opinion that you are justified in declining to expend the time and money which a test would involve. A device which in the end must be rejected as fundamentally deficient would not seem to require a test for the purpose of demonstrating its lack of practical utility.

Reports.—The board has felt it to be necessary in considering devices to be particularly careful in reporting on the same not to mislead or unduly to encourage the inventor or proprietor, who, if encouraged, might enlist capital in a venture the results of which are likely to prove fruitless. At the same time, the board has aimed to encourage the development of promising devices when it is believed that a test of the same would add materially to our present knowledge and aid in determining the availability of different features for practical use.

Among the more recent developments which are engaging the attention of those interested in the subject of railway signaling are alternating current track circuits for electric roads, working without the use of insulated joints or inductive bonds, the transmission of signal indications by Hertzian waves or other oscillatory impulses, and the production of effects upon moving vehicles as the result of conditions existing upon the track by magnetic or inductive effects without mechanical or electrical contact, involving even such principles as the non-magnetic properties of manganese steel rails.

The board desires to acknowledge the courtesy of those railroads which are in no way subject to the jurisdiction of the Interstate Commerce Commission, but have furnished the board with information and assistance in conducting its inquiries.

Respectfully submitted.

M. E. Cooley, *Chairman;*
Azel Ames,
F. G. Ewald,
B. B. Adams,
Block Signal and Train Control Board.

APPENDIX A.

Report of Committee on Investigation of European Train-Control Devices and Railway Signal Practice.

November 17, 1908.

Block Signal and Train Control Board,
Interstate Commerce Commission,
Washington, D. C.

Sirs: Your committee, appointed January 31, 1908, to go abroad for the purpose of investigating block-signal systems, railroad signals and practices, and devices for the automatic control of railway trains upon European railways, has the honor to submit herewith its report consisting of the following:

Part I, a narrative account of the trip, showing the persons and places visited and the devices and systems examined.

Part II, detailed reports upon the principal devices or systems examined, as follows:

(1) Raven mechanical trip cab signal, Northeastern Railway of England.

(2) Raven electric cab signal, Northeastern Railway of England.

(3) Bounevialle and Smith cab signal, South Eastern and Chatham Railway of England.

(4) Great Western cab signal, Great Western Railway of England.

(5) "Crocodile" cab signal system of the Northern Railroad of France.

(6) Manual block signaling system.

Part III, appendices and exhibits covering various items of information, as follows:

(A) Block signals, various.
(B) Interlocking.
(C) Roadway, track, and structures.
(D) Drawbridge protection.
(E) Equipment.
(F) Fog signaling.
(G) Miscellaneous methods and appliances for the promotion of safety on British railways.
(H) The railway department of the British Board of Trade.

* * *

PART II.

General.—This part of the report covers the manual block system as worked on most British railroads, and certain installations, more or less experimental, of cab signals seen in operation by the committee. Numerous devices for the display of signals on the engine cab have been invented in Great Britain and on the Continent, and a part of them have been experimentally tried, but the only ones in actual use in Great Britain at the time of the committee's visit, so far as known, are those described in this portion of the report, namely, the Raven mechanical cab signal and the Raven electric cab signal on the North Eastern Railway, the Bounevialle and Smith cab signal on the South Eastern and Chatham Railway, and the cab signal being tried on the Great Western Railway. The only installation of this character on the Continent of which the committee had knowledge and believed worthy of examination is the so-called Crocodile cab signal system in use on the Chemin de Fer du Nord, France.

In considering the various cab signal devices that have been tried on the European, and especially British railroads, it is important to bear in mind the operating conditions which have led the railways to undertake experiments with such devices to a far greater extent than has ever been done in the United States. It is safe to say that the primary cause of the interest in cab signaling in Great Britain is fog. Few persons who have not experienced the dense fogs which are encountered in England during the winter months can appreciate their density (in many cases largely increased by soft coal smoke) nor the extent to which their prevalence interferes with business, especially railroad transportation. It is perhaps sufficient to state that on one railroad in England as high as £5,000 has been paid out in extra fogmen's wages alone in three weeks. The general manager of the Lancashire and Yorkshire, which carries the densest freight traffic in England, stated that there were times every winter when every goods train on his road had to go in on a sidetrack and remain there for as much as eight days solely on account of the density of the fog. The fog often continues so long that no attempt is made to operate more than the passenger trains; and those are run with great difficulty and a greatly reduced speed. On some roads having a large suburban passenger service, notably the Great Eastern Railway, a special fog time-table is printed and posted, and goes into effect immediately upon the occurrence of fog.

The above described conditions will be seen to afford ample reason for British railroads paying very considerable attention to any methods or devices that will overcome the difficulty of operating the railroads at times when the fixed signals along the roadway are obscured by fog or snow. It must be remembered, too, that practically every mile of main track in England is block signaled, and that on many of the lines the traffic is very dense, requiring the use of very short blocks, so that fixed signals are much more frequent on British roads than is generally the case in America. Furthermore, the movement of trains on British railroads is controlled entirely by the indications of the fixed signals. Except in cases of serious accidents or obstructions flagging is hardly practiced at all, each train depending wholly upon the fixed signals for protection against following trains. While the English roads have shown considerable interest in the development of cab signals as being the means most likely to insure the display of a proper indication to the enginemen when the view of the fixed signals is obscured, they have given very little consideration to the question of automatic train control. The reason for this is that most British railroad officials believe that their enginemen are so thoroughly trained and so competent and reliable that all they require for the proper control of their trains is the necessary instructions or information in the form of a signal indication; and that any means whereby the control of the train movement is taken out of the hands of the enginemen is not only unnecessary but undesirable. (For description of fog-signaling apparatus and methods see Part III, section F.)

1. RAVEN MECHANICAL TRIP CAB SIGNAL.

The earliest and simplest type of cab signal to be used on British railways to any extent is the mechanical trip device designed by Mr. Raven, assistant mechanical superintendent of the Northeastern Railway, and installed on a considerable portion of that company's line.

The system comprises an air whistle on the engine, the valve for which is provided with a handle so arranged on the vehicle with respect to the track as to engage a T-shaped mechanical trip pivotally mounted on a shaft extending between the ties and under the rails when this trip is raised by the rotation of the shaft into position to engage the handle and open the valve on the engine. The trip device is, in common with all British cab signals, used only in connection with the distant signal, it being the theory of English fog-signaling practice that the audible indication should be given at the distant signal in order that ample distance may be allowed to enable the train to come to a stop at the home signal after having received the warning indication at the distant signal.

The principal mechanical feature of Mr. Raven's trip device is that the trip is not rigidly held in operative or tripping position by solid connectons through the signal in connection with which it operates, but is counterweighted toward the operative position and operates the handle of the engine valve, not by being rigidly held, but through the valve handle not being held strongly enough in its closed position to overcome the inertia of the ground trip, which to a certain extent is actually moved or depressed by engagement with the valve handle.

While this form of trip is commonly used with the ordinary manual block signals, it is also employed in connection with one of the few automatic block-signal installations in Great Britain, namely, the installation of the Hall electro-gas normal danger automatic block signals on the ten and one-half miles of double track between Alne and Thirsk on the Northeastern Railway. In this installation iron shutes, somewhat in the nature of a battery shute, are used to contain the counterweight, which is connected by a flexible cable in such a manner as to hold the trip normally in operative position, the trip being drawn down to the inoperative position by means of a continuation of the cable referred to, which passes over a sheave or pulley in the base of the signal mechanism case and connects to a lever which is directly operated by the up and down rod of the distant arm of the signal.

The valve handle above referred to as forming a part of the engine device is not acted upon directly by the mechanical trip, but is operated by a vertical rod connected to a special striking piece which, through the medium of the vertical rod and bell cranks, operates the whistle valve, an arrangement also being provided to cause the whistle to blow continuously if the striking piece is carried away by the impact of engagement with the ground trip or through any other cause. The method of operation of the ground trip through the medium of a slotted segment worked by a shaft which is rotated by the pull of the wire cable constitutes an ingenious method of taking care of the shock due to the impact of the parts.

Since this device was put into service regular fogmen have not been employed at distant signals in the territory covered by the installation. The Northeastern Railway is, however, not installing any more of these devices, for the reason that the Board of Trade now insist that all cab signals shall give a positive clear indication as well as a caution indication, in order that any derangement of the apparatus which would tend to cause a failure to display a caution indication shall be detected by the absence of the display of the clear or proceed indication.

While the Raven mechanical trip cab signal has been in use over a considerable mileage of the Northeastern for over three years, it is felt not to have had a very severe test under fast moving traffic, for the reason that as the trip operates only when a signal is passed while in the caution position, a very small percentage of the actual train movements require the movement of the trip. No further installations of this device are being made by the Northeastern Railway, though that company is experimenting with Mr. Raven's electric cab signal. The signal engineer of the road stated that one man on the division spent all his time in the maintenance and adjustment of these devices.

2. RAVEN ELECTRIC CAB SIGNAL.

The Raven electric cab signal as installed between Durham and Newcastle on the Northeastern Railway on about fourteen miles of track has been fully described in a paper read by Mr. J. Pigg before the Institution of Electrical Engineers, London, December, 1907. A very complete synopsis of Mr. Pigg's paper, with descriptions and illustrations, appeared in the Railroad Gazette of February 21, 1908.

It is a cab signal system in which, through the medium of circuit controllers operated in connection with the fixed signals along the roadway, current is supplied to various contact rails located along the roadway and collected by brushes or other collectors mounted on the engine and used to actuate a signaling device in the locomotive cab. In this system an audible warning is intended to be given whenever a train approaches a signaling point, irrespective of whether the route is clear or not, this audible indication being intended primarily as a marker of location. If the way is clear and the signals governing the block or route are pulled off, the warning indication is only momentary, but if the signals are not clear, the audible warning continues and visible indications of the fact are displayed on the indicator in the cab. The system provides for the installation, if desired, of additional contact bars between the first warning point and the signal, so that the engineman may, by counting the number of warning impulses given by the bell, know the location of his train with respect to the next signaling point ahead. In addition to the long contact rails or ramps from which current is collected by brushes suspended beneath the engine, the ramps being located in the center of the track, there are additional short contacts in the form of long, thin springs intended to engage a rotary switch mounted on an arm secured to the forward portion of the engine frame. This rotary switch is contained in a small wheel, and rotation of the switch for making or breaking the proper circuit is accomplished by the rolling of this wheel upon these contact springs. The system is adaptable to the use with it of a recording apparatus whereby a graphical record of its operations may be obtained on a strip or tape of paper driven by a clockwork mechanism, this and the marking mechanism being under the control of the signal apparatus.

It is not the intention in this report to go into a detailed description of the apparatus or circuits employed, such information being readily obtained by reference to the articles above quoted.

The electric circuits used in this system are complicated, as are the controlling and indicating devices. The arrangement of the wiring is primarily on the open-circuit principle, protection against the undesirable features of such an arrangement being provided by a separate system of circuits and an indicating device known as a "failure detector," this portion of the system working on the closed-circuit principle. While it may be that certain forms of electric contact devices will in time be developed which may be suitable for use in signaling or train-control systems, under the climatic conditions obtaining on most American railroads, it is very doubtful if devices of the type used in this system, particularly the auxiliary spring contacts, could be maintained in satisfactory operating condition during a considerable portion of the year in the colder regions of this country.

3. BOUNEVIALLE AND SMITH CAB SIGNAL.

The committee had no knowledge before arriving in England of the experiments being made on the Norwood Loop line of the South Eastern and Chatham Railway with the Bounevialle and Smith cab signal, but an opportunity was afforded by the proprietors of the device and the railroad company for an examination.

It is a cab-signal system designed primarily for fog-signaling work and intended to be used as an adjunct to the ordinary fixed, visual home and distant signals of a manual block system or an interlocking plant. This installation was fully described in The Electrician, London, December 20, 1907, but, so far as known to the committee, has not been described in the American technical press.

In each block or interlocking station where this system is used a battery is provided, one side of which is grounded and from the other side of which wires lead through circuit controllers operated by the home signal and distant signal levers for each track out of the cabin and along the roadway to contact rails or ramps about fifty yards long, mounted in pairs and placed between the running rails slightly in the rear of the signals, the visual indication of which is intended to be repeated in the engine cab. The cab signal comprises miniature semaphores operated by magnets, together with electric lights, these being connected by a proper wiring to contactors somewhat in the form of pendulums suspended beneath the engine in such position as to engage the contact rails or ramps. Two of these are provided on each engine in such position as to engage the two rails of the distant ramp, placed slightly to one side of the center of the track, and two others to engage the two rails of the home ramp, which rails are placed slightly to the other side of the center of the track. The four pendulum contacts are intended by contact with the ramp rails to pick up the four following indications: Distant signal on, "caution"; distant signal off, "proceed"; home signal on, "stop"; home signal off, "proceed," the current from the battery in the signal cabin being switched to either the on or the off rail of a ramp by the movement of the signal lever. Normally the pendulums hang nearly vertical, and the engine apparatus is de-energized.

Upon the engagement of the pendulums with the inclined end of a ramp, the pendulums are thrown upward and backward, and by this motion operate a mechanical bell to call the engineman's attention to the fact that his engine is about to pass over a ramp. The pendulums, from their own weight and assisted by the springs, rub upon the contact rails as the train passes over the ramp, it being the intention that one or the other of the pendulums of a pair will pick up current from whichever of the two rails is energized, and thus complete the proper circuit from the ramp through the pendulum (which is insulated from the rest of the engine), through the proper signal magnet in the cab and the proper incandescent lamp, thence through the engine frame and wheels to the rails and the earth, the circuit being completed through the earth back to the negative side of the battery in the cabin. A telephone is provided in the cabin and on the engine cab, so that communication may be had between the signalman and the engine driver whenever the engine is standing over a ramp.

It will be noted that while the engine is running through any block or over a portion of the track not covered by the ramps, the two semaphore cab signals are indicating caution and stop, respectively, and all indicating lamps are out; also, that the presence of current in the circuit is required not only for the proceed indications, but for the caution and stop indications while passing over the ramps. The wiring is thus seen to be on the open-circuit principle, and the only protection against failure to receive a stop or caution indication at a signaling point in case of a failure of battery or the breakage of a wire or a failure of the pendulums to make contact, is through the action of the mechanically operated bell calling the attention of the engineman to the fact that he has reached a ramp.

From the nature of the ramps and engine contacts it is believed that this device would be particularly susceptible to interference from snow and ice, and hence subject to dangerous failures, the only warning of which is the audible one of the mechanical gong.

4. GREAT WESTERN RAILWAY CAB SIGNAL.

This system is installed on twenty-two miles of the Fairford branch of the Great Western Railway, which branch is a single track operated under the electric train staff system with fixed home signals, the cab signal being used as a substitute for the distant signals. It represents the attempt of the Great Western to find some reliable method of overcoming the climatic conditions met in its territory, and was designed by Messrs. Jacobs, Insell, Newton and Bowden, all of the company's staff, and has been developed at Reading under the direction of Mr. A. T. Blackall, the company's signal engineer.

The system provides for a battery in each cabin, one side of which is grounded and from the other side of which a wire leads through a circuit controller which is closed only by the pulling off or a clearing of a lever in the cabin corresponding to the distant signal lever. This wire is carried on the pole line along the roadway to a contact rail or ramp placed midway between the running rails at any desired distance from the home signal, being located approximately in the position where a fixed distance signal would be placed if used. The ramp consists of an inverted T section, insulated from supporting chairs by wooden blocks, the inverted T forming a type of construction offering little surface for the accumulation of snow or ice. The engine equipment consists of a battery from which current is normally supplied to a magnet, the circuit including a switch mounted on one end of a contact shoe beneath the engine in such manner that when the engine is not passing over a ramp the contact shoe is normally in position to close this switch, thus keeping the controlling magnet on the engine normally energized on closed circuit. When the contact shoe mounted beneath the engine engages the incline of the ramp or contact rail, the shoe is raised from its normal position, this movement accomplishing two purposes, first, to break the normally closed engine circuit, and, second, by making electrical contact with the ramp to pick up current therefrom to energize another controlling magnet on the engine, should the ramp be energized from the battery in the signal cabin by the closing of the contact controlled by the proper lever, this circuit being completed through the grounding of one side of the engine-controlling magnet just mentioned.

It will be seen from this arrangement of apparatus and circuits that normally the clear signal is maintained upon the engine while running, and that if the conditions are right for the train to proceed the caution indication will be suppressed at the distant signaling point. In order, however, to give a positive proceed signal instead of simply suppressing the caution signal at this point, a polarized relay is provided for the control of the clear indication, which indication consists of the ringing of a bell. In the circuit of the second engine magnet, previously described, is one winding of the polarized relay. When the current is picked up from the ramp, it will, in addition to energizing the engine magnet referred to, also energize the polarized relay, the armature of which will close a local circuit embracing an electric bell and the battery therefor. The second winding of the polarized relay is for the purpose of keeping the local bell circuit closed so that the bell may continue to ring from its local battery after the shoe has passed off the ramp and until the bell circuit is momentarily opened by the engineman operating a break push button. In the circuit of the engine-controlled magnet, first described above, namely, the magnet which is energized from the engine battery itself, is a device controlled by a steam-operated valve so arranged as to open the circuit when the boiler pressure falls to about 20 pounds, insuring the automatic disconnection of the main engine battery in order to prevent the waste of current when the engine is not in running condition. The engine-controlled magnet referred to is used for the control of an air-whistle valve, which sounds the caution indication whenever the engine circuit is broken.

All the apparatus appears to be well designed and the system is exceedingly simple. It is, of course, correctly designed from the electrical standpoint, being not only on the closed-circuit principle, but having the source of energy of the external circuit located in the cabin instead of on the engine, which provides protection against crosses and grounds. For the climatic conditions under which it has to operate, and for the purpose intended, namely, to take the place of a fixed distant signal, it has served its purpose so well in an experimental installation that the railway department of the Board of Trade has given the Great Western Railway permission to take out of service entirely the fixed distant signals on the Fairford Branch where this cab signal is used. It is proposed to make an installation on the main line near Reading, using the cab-signal system in addition to the fixed distant signals, in order to further develop the details of the device under high-speed conditions, the intention being to continue the use of fixed distant signals, irrespective of how satisfactorily the cab-signal device is found to be, so long as any engines unequipped with the device are run over the road.

The principles embodied in the design of this system and a number of its details are believed to be of such merit that the board is arranging a test of an American system designed on practically the same lines.

5. "CROCODILE" CAB-SIGNAL SYSTEM IN FRANCE.

The Northern Railway of France (Chemin de Fer du Nord) is block-signaled throughout and all switches in its main tracks are interlocked with fixed signals. At block stations home and distant signals are used, and in connection with practically every distant signal on the road a form of electric contact rail cab signal is applied. These installations, from the shape of the ramp and its incline, are known as "crocodiles."

In each engine cab there is an air whistle controlled by an electro-pneumatic valve, one terminal of which is connected to ground through the engine frame, the other terminal being connected to a contact brush suspended beneath the engine and insulated therefrom. At each distant signal is located a battery, generally installed in a concrete battery shelter erected above ground, and one terminal of the battery is connected to ground. From the other terminal of the battery a wire is carried through a circuit controller which is closed when the distant signal is in the caution position, thence by the pole line to a point about 50 meters in rear of the distant signal where it is connected to the crocodile or contact rail.

From this it is readily seen that when the distant signal assumes the caution position, current from the battery is switched on to the line and thence to the crocodile or contact rail and thence picked up by the locomotive shoe and carried to the electro-pneumatic whistle valve, from which point the circuit is completed through ground back to the battery. The remarkable feature of this device is that while this signal provides no proceed indication, and is obviously constructed on the open-circuit principle, and being so arranged that failure to make contact, failure of the battery, or the breakage of a wire would prevent the display of a caution signal on the cab, 2,000 or more of these installations are in use on this railroad and many of them have been in service fully fifteen years.

6. MANUAL BLOCK-SIGNALING SYSTEM.

Signal apparatus.—There are few automatic block signals in Europe. While there are small installations on double or four track lines in Great Britain and on the Continent, and while some form of the controlled manual block system, notably the Sykes, is used to some extent in England, and the Siemens & Halske system on the Continent, practically all of the English roads use the manual block system.

This simple system of block signaling has been developed to the highest extent in England, and it will be proper to say a word concerning it.

It must be borne in mind that on a considerable proportion of British railways trains are both fast and frequent, yet a comparison of the train accidents occurring under the manual block system in England and in the United States can not but compel the belief that the system has reached a higher degree of perfection in England than in this country.

All of the principal English lines are double track, and on those which carry heavy traffic the blocks are so short that in a good share of the territory the distant signal for one cabin is mounted on the same post as the home signal of the cabin in the rear. The distant signals are practically all mechanically operated semaphores connected to the lever by a single connection, the wire usually consisting of a light galvanized stranded cable. For the home signals both pipe and wire connections are used.

The cabins as a rule are of brick, solidly constructed, and maintained with scrupulous neatness. A square-ended semaphore blade is used for home signals and a fishtail blade, painted red like the home blade, is used for the distant signal. A feature of the indications of these signals peculiar to British lines is that the night indications of both home and distant signals are alike—that is, the proceed indication is a green light and the night caution indication of the distant and the night stop indication of the home consist each of a single red light. On some four-track lines a ring or other distinguishing mark is added to the blades of signals on the outer tracks to distinguish them from the signals which apply to the inner tracks. The ordinary mechanical locking frames, the signals, and their connections constitute about all the apparatus that is used.

Communication apparatus.—Communication from cabin to cabin is had by means of an electric-bell system used in connection with the needle telegraph and to some extent with telephones. The use of the needle telegraph, or its equivalent in the shape of a visual indicator operated in connection with the bell circuits, undoubtedly contributes greatly to the successful operation of the system as compared with a system operated entirely by the Morse telegraph, the reason being that with a visible indication, such as that given by the indicator or the needle telegraph, a record is constantly before the eye of the signalman showing the last operation of the communication system. With the use of the Morse telegraph the audible signal of the sounder must, of course, be written down by the signalman on his train sheet or block report to obtain a record of the operation of any portion of the system. Substantially the same forms of block records are kept on the English railroads as in this country.

While bell codes are used in America to a greater or less extent, particularly in connection with controlled manual block-signal systems, they are not, as a rule, used for conveying such a large amount of information as is transmitted by the English block-signal bell codes. These are very complete in their signals for classifying the kind of train to be moved and the nature of the movement to be made.

Rules.—The rules governing the manual block working are, in general, much like those of American railroads, perhaps the most notable exception in detail working being the blocking back at stations or junctions. The rules for these movements prescribe that at a junction no train on one line is permitted to pass the block station in the rear of the one located at the junction while a conflicting movement is being made on the other line. In the same manner at certain stations one unoccupied block must intervene between the station block and any approaching train whenever a train is standing in the station. These are often suspended, however.

Signalmen.—As a rule, the English block signalman is probably no more intelligent than the American block signalman, but he is probably much better trained and under a stricter personal supervision. Passenger stations are so frequent on English roads that most block stations are under the jurisdiction of some stationmaster, and by far the greater percentage of signalmen are recruited from the ranks of the station porters. A smaller number are promoted from the track forces which furnish most of the fog signalmen, these men forming an important part of the personnel in English railroad operation during the winter months. (A more detailed description of the fog-signaling methods is given in Part III, section F.). Suffice it to say here that the more intelligent trackmen (or plate layers, as they are called) are employed in times of fog and snow at the block stations, and thus have an opportunity to acquire a knowledge of the block system. When a man has served as a plate layer or station porter for a sufficient length of time to become familiar with the general working of the road in his vicinity, and a vacancy occurs in the grade of signalman, he may be selected as a candidate for the post. If so, he is trained under a signalman at the designated cabin for a month, and at the end of that period is orally examined on his knowledge of the rules by the inspector, who, if the examination is satisfactory, fills out a competency certificate. The applicant is generally examined further by the assistant district superintendent who, if the examination is satisfactory, approves the certificate, and the man then appears before the district superintendent, who looks him over and may question him further, and if he is satisfied he signs the applicant's certificate. Should the applicant fail to pass the examination at the appointed time, he may be given another chance or be sent back to his former position at the discretion of the district superintendent. The method of selection and examination here described is that in use on the London and North Western. It is in substance the same on other lines.

If a man is transferred from one cabin to another, his period of training varies from about a week at the new cabin, if it is of practically the same class as his former post, to a fortnight if the new cabin is a more complicated one. Each man is examined not only as to his knowledge of his apparatus and the block-signal rules but in the local working conditions, and it should be noted that the British signalman not only has to perform the functions of signalmen but in addition practically acts as train dispatcher for the blocks controlled from his cabin, for the very good reason that there is no such official as the train dispatcher nor anyone corresponding to him on British railroads.

The traffic conditions on most roads in England vary very little from year to year, as compared with conditions on American roads where new industries are constantly springing up and new lines of traffic of varying volume are being constantly developed. Most of the English lines run through territory already developed and the traffic demands of which are so well known that it is relatively easy to predict within reasonably close limits, from past experience, the nature and volume of the traffic on any division at any given time. On this account a much greater proportion of British freight trains, and in fact all trains can be, or at least are, run on schedule than is the case in this country. In fact very few trains except work trains are run without a schedule, the extra or special train movements for any month, or even for a single week, being scheduled in monthly or weekly supplements to the working time-tables.

The block signalman is required to be familiar with all these special train movements, and as all schedules are, especially in bad weather, subject to derangement, he must be familiar with a very large number of special rules governing the precedence of delayed trains, there being no dispatcher to give him orders on such matters. In fact on some roads there is provided a book of "train margins," in which is set forth in detail the precedence of the various trains when they or other trains are late at junctions or other important points. As an example of this method of handling train movement under the block-signal rules, it may be noted that the special trains carrying passengers from the ports of arrival of American steamers to London are scheduled to use a given time between given points. The leaving time of such special trains from the steamship docks is, of course, variable and the actual leaving time is telegraphed to the principal stations on the line when the train leaves the port. On the basis of this actual leaving time and the published speed schedule the signalmen at junction points throughout the line must make their own arrangements for handling the branch and main line trains with as little delay as possible to either.

Probably the training in the conduct of such movements as those described above assists very materially in connection with the careful and voluminous instructions given to these men and the constant personal supervision to which they are subjected in making them the thoroughly competent and reliable signalmen that they are.

The system of inspection to which they are subject begins with that of the station master, who on some roads is required to make a daily inspection of the cabins under his jurisdiction and certify thereto upon the block report. District inspectors are so employed, who are supposed to visit each cabin about once a week, inspect the records and the work of the men, noting their visit on the block reports. Assistant district superintendents make frequent inspection, and on one road, at least, an inspector from headquarters visits each cabin once a year, and in addition to conducting an inspection examines the signalmen orally on the rules and special instructions. On most roads a premium or bonus is paid to signalmen for correct working of the block system, amounting to from £2 to £6 per year. Practically all roads have pension systems for their employes, largely supported, however, by the employes themselves.

As an example of the number of men engaged in signal operation, it may be noted that the Great Western employs 3,200 signalmen on 2,600 miles of territory.

The closing of a block station for a part of the day or night is common, the wires being switched through. In closing a block station the signals are cleared and usually the lights extinguished, though if the office is to be again opened before daylight they are left burning. An office, say, Station B, may be cut out, the wires being connected through from A to C, if in time of sudden fog B has difficulty in securing fogmen for his signals.

The general impression obtained from an observation of the working of the English manual block system is one of admiration for the men, methods, system of training, and conditions that make possible the high degree of safety and celerity with which a great volume of fast and dense traffic is handled by its use.

PART III.

This part of the report contains miscellaneous data collected by the committee while pursuing the main purpose of its investigation, and comprises brief notes in regard to devices or systems that have to do with the safety of railway operation.

A. Controlled Manual Block System.

While the English roads evidently have, as a whole, the best of signalmen, a number of companies have nevertheless introduced electric-control apparatus by which the men at the opposite end of a block must co-operate in giving a clear signal. Whether from a knowledge of errors which have occurred but which have caused no collisions and have not been made public, or from the desire to provide all possible safeguards, regardless of the smallness of the percentage of errors occurring when these refinements of safety are not employed, or from an inclination to satisfy a real or fancied demand on the part of the public, these roads have taken action which indicates that the past records, good as they have been, are not entirely satisfactory. Among the roads which have done this are the London and South Western, the Great Northern and the Northeastern.

The Southeastern and Chatham Railway and the London, Brighton and South Coast Railway have had a controlled manual block system in use for a long time. Almost all single-track lines in Great Britain are worked by the staff system, this being a fully developed electric system giving a high degree of protection through electric control exercised over the manual operation of the block signals. The Caledonian Railway on its Callander and Oban line has for several years used a high-speed electric staff and tablet system, which is still satisfactorily operated, though it is ascertained that most of the trains stop at all stations, the tablets being exchanged by hand. On some of the lines, however, where faster trains are run, the device for catching and delivering the tablets at speed is in successful use.

Automatic block signaling.—Some installations of automatic block signals exist in Europe, particularly those of the Hall inclosed disk type used in France, but the only automatic block-signal installations examined were those of the Hall normal danger electro-gas automatic signals on the ten and one-half miles of double track between Alne and Thirsk on the Northeastern Railway, and the low-pressure pneumatic installation on the London and Southwestern four-track line in the suburban territory outside London.

These installations cover the only important or extensive use of the continuous electric track circuit on British steam surface roads. To one familiar with the rapid increase in the use of the track circuit for signal control in America it is remarkable to note the slight extent to which it is used in Great Britain. The chief properties of value in an electric track circuit are the ability to detect by its use the presence of a single car or even a single truck or pair of wheels upon the circuit, or a broken or removed rail in the circuit, and the control of signals by the position of switches in the block.

The percentage of broken rails on English railroads is small as compared with that on American roads. The question of switch protection is probably of equal moment in the two countries. On the other hand, however, while in American practice continuous brakes are used on by far the greater proportion of cars in all freight trains, scarcely any continuous brakes are used on goods equipment in Great Britain. The use of continuous brakes by causing an application of the brakes whenever adjacent cars are separated, as by the train breaking in two, constitutes a considerable safeguard in block-signal operation by insuring the detection of the accidental or unauthorized separation of vehicles from a train, and hence the detection of vehicles that might be left in a block after the main portion of the train has passed out of the block. The nonuse of continuous brakes on British freight trains would seem to constitute a good argument for the use of track circuits in the signaling of British railways. Investigation of the subject, however, shows that numerous difficulties which are not encountered in American practice beset English railway officers in the use of track circuits, as follows:

1. The very light weight of a considerable portion of the English goods wagons. Most of these cars have a capacity of from 7 to 10 tons, though the number of wagons of 20-tons capacity is being increased.

2. The brakes on English goods wagons are seldom applied except while the vehicle is standing on a siding or being shunted in a yard, the ordinary service braking of the train being accomplished by the use of the engine brakes and the brake in the guards' van on the rear of the train. In the common type of English goods wagon the brake is applied through a long lever, the trainmen generally standing upon the lever in order to apply the brake. As a rule, brakes are used on one side of the car or wagon only. This infrequent braking of goods-wagon wheels permits the formation of a sort of glaze upon the tires which is so low in conductivity that the pressure of the wheels upon the rails is hardly sufficient to reliably shunt the track-battery current of a track circuit away from its relay.

3. The use of Monsell wheels. These wheels have wood centers, and in order to form a shunt upon the track circuit the wheel tires must be specially bonded to the axles.

4. The use of cast-iron wheels with steel tires, making poor electrical contact between the tire and the wheel center.

When the Northeastern Railway installed its automatic block system it was found that the contact between the wheel and the tire was often insufficient to secure a proper shunt, and the railway company found it necessary to bond the tires of all goods-wagon wheels to the wheel centers to secure proper electrical contact.

5. The inward canting of rails to correspond with the coning of the wheel treads.

Almost all British rail is supported in cast-iron chairs which are given such a slope as to cant the head of the rail inward at an angle to correspond with the coning of the wheel treads, which is generally one in twenty, though some roads use one in ten. This, of course, causes a larger bearing area between wheel and rail with proportionately less concentration of load, thus diminishing the probability of good electrical contact.

6. Whether from the chemical composition of English rail or from some other properties of it or from atmospheric or other conditions the rail heads in use appear to acquire a sort of film or glaze, which is a poor conductor. While the cause of this condition is not definitely known, its existence is vouched for by British signal officers of repute.

On the underground electric railways in London, including the Baker Street and Waterloo, the Great Northern, Piccadilly, and Brompton, the Hampstead Tube, and the District Railway, there are over 500 automatic block signals in use, mechanical-trip automatic train stops being used in these installations. All of these roads use direct-current propulsion, and the track circuit used for signaling is of the polarized, direct-current type, a factor in the use of such track circuits in connection with a direct-current propulsion system being the use of the fourth rail in the track for the propulsion-return circuit, the two running rails not being used for this purpose and the third rail being used for the propulsion feeder. This arrangement is installed on account of the British Board of Trade regulation which requires that when the running rails of an electric railway are used for propulsion return the drop must be restricted to ten volts, the requirement being made in order to prevent electrolysis of water pipes and other metal conduits or structures laid underground. The electric railways in London find it cheaper to install a separate insulated return rail than to restrict the drop in the return circuit in compliance with the Board of Trade regulation.

On the Liverpool and Southport electric line of the Lancashire and Yorkshire Railway a number of semi-automatic high semaphore signals are used, operated by solenoids, using the 600-volt current from the third rail. While they are in daily service and working reasonably well, the railroad officers do not consider them a particularly desirable form of electric signal. These signals are controlled by track instruments called treadle bars, which are mounted inside the running rails in such a position as to be depressed by the wheel flanges, this movement being used for the operation of circuit controllers.

The treadle bar and other forms of track instruments are used to a considerable extent in Great Britain and on the Continent in connection with controlled manual block systems and for the control of indicators and annunciators at interlocking plants, and in fact for a great many purposes where in America a track circuit would be used. There is, of course, scarcely any comparison between what can be accomplished by treadle bars as compared with track circuits, either from the standpoint of reliability or economy, under American conditions, and while, for the reasons previously stated, the use of the track circuit has met with but little favor in Great Britain, its use is increasing, and it is believed by those familiar with British signaling conditions that this increase will be considerable in the next few years.

B. Interlocking.

The protection of switches on most European railways is much more complete than in America, as practically all main-track switches are interlocked with fixed signals. By far the greater proportion of the interlocking is mechanical, though both in Great Britain and on the Continent power interlocking has come prominently to the front in the last few years, not by any means, however, to so great an extent as it has in America. In Europe there is a marked tendency to use mechanical interlocking machines at much larger plants than would be mechanically interlocked on American roads. The mechanical interlocking used in the United States is of British origin, but appears to have developed faster in improvement of details than has the English practice.

Notable features of British mechanical interlocking machines are the small amount of preliminary latch locking used and the heavy and substantial construction of the locking bars and tappets. Some British signal engineers claim that there is no advantage in preliminary latch locking, but to the American observer it would appear that the reason it is not used is principally because many of the machines are so large and the locking bars so long and so heavy that it would be exceedingly difficult for a signalman to operate a lever latch which was provided with a latch spring sufficiently powerful to drive the locking bars.

As previously noted, almost all distant signals are operated with a single connection, a small galvanized stranded cable being used. As noted in the portion of this report dealing with the manual block system in Great Britain, the night indication of the distant signal in the caution position is identical with the night indication of the home signal in the stop position, namely, a single red light. In a number of other respects the indications differ from those used in America, particularly as regards the indications for route signaling. The practice in this respect in Great Britain and to a considerable extent on the Continent is to display each signal arm denoting a diverging route upon a separate mast or post rather than to display the arms one above the other on the same post. For example, a single diverging route is indicated usually in America by a two-arm post, the upper arm governing the main route and the lower arm the diverging route, whereas the European practice is to use a bracket post with a single arm displayed on each mast or doll, these being arranged upon the main bracket post in the same relation as are the tracks that they govern. The Belgian State Railways formerly used the American method for indicating diverging routes, but have recently changed from the one-pole, two-arm type to the English practice, using a separate post or doll for each track, mounted upon a bracket mast or, as the French and Belgians call it, a "chandelier" or candlestick.

"Calling-on" arms are frequently employed to permit switching movements to be made past a signal at the entrance of a section of track which is not clear.

On the Belgian State Railways the proceed indication is given by the upward inclination of the semaphore arm. On the Northern Railway of France distant block signals are in the form of a circular disk; home block signals are semaphores of the skeleton type with enlarged rounded ends; distant signals for interlocking plants are square or lozenge-shaped metal banners, the former being used when the signal is located 800 meters or more from the home signal, and the latter form when on account of view or other conditions it is necessary to locate the distant signal at a less distance from the home, and the home interlocking signals are in the form of a square. Disk and square banners have the disadvantage that in the proceed position they are turned edgeways to an approaching train, the proceed indication being given simply by the absence of the caution or stop indication. On this railway diverging routes are signaled by pointed or fishtail arms in addition to the square banner home signal.

Lattice cantilever brackets are frequently used to support home signals in such a manner as to bring them over the tracks to which they refer. Very large wire compensators, mounted in heavy cast-iron frames, are placed at the middle point of most distant signal wire lines, the distant signal being operated by a single stranded cable. These compensators are used for distances as great as two miles.

Both inside and outside detector bars are in use. Some roads are using solid rods for cross leads instead of pipe, and a few roads use channel-iron sections for switch lock and signal connections instead of pipe. At least one road in Great Britain uses separate facing point locks for each point of a pair of switch points.

In power interlocking little advance is being made in Great Britain along electrical lines, with the exception of a few isolated examples of electric systems. The only type in extensive use is the Crewe system on the London and North Western. This system of power electric interlocking was designed by officers of the road, and the apparatus is all manufactured, as is all signaling and interlocking apparatus used on this road, in its own shops. The system is relatively simple and rugged in construction, though each individual lever, with its contacts, connections and indication magnet and fittings, occupies much more space, particularly in a vertical direction, than is the case in American machines.

Current is supplied at about 230 volts potential. The switch motors take about two amperes in starting light and about ten when carrying the full load of the switch points. The signals, which are of the solenoid type, require about three amperes for clearing and hold clear on one-half ampere. At Crewe Station which is an important and complicated junction, single-arm semaphore signals are used for the diverging routes, provided with a route indicator in the shape of a stationary rectangular board constructed on the principle of slatted signs to display a very large letter to indicate the route, such as M for Manchester, H, for Holyhead, etc.

The tappet locking of these machines is arranged in two and even three banks, the tappets being crank driven from vertical rods operated from miniature levers of the mechanical interlocking machine type arranged one above the other. These rods also operate heavy carbon contact blocks for the control of the circuits operating the various functions, and are in turn controlled by indication latches of the hook form having horizontal magnets. All parts of the switch machines except the motors run in oil. Battery indication is used and there are no considerable refinements of circuits or protective devices for cross and ground protection, at least not to anything like the same extent as in America.

A considerable number of low-pressure pneumatic interlocking machines have been installed in Great Britain and a number on the Continent, and in some of the installations, notably on the Northern Railway, of France, route levers rather than function levers have been used; that is, instead of having a lever for each switch or crossover, and a lever for each signal, one lever is provided for each route through the plant, the apparatus being so arranged that when the lever for a given route is reversed the various switches in that route will be successively set, locked and indicated, the proper signal clearing upon the return of the last indication, denoting the complete setting up and locking of the route.

Two notable installations of power interlocking in Great Britain are the electro-pneumatic plants recently installed at Newcastle-on-Tyne for the Northeastern Railway, the south box of this station containing 211 levers, and the new plant at the Glasgow Central Station on the Caledonian Railway, which, so far as known, is the largest power interlocking machine in the world. It contains 374 spaces.

At the Newcastle plant selection is freely used, as on machines of this type in the United States. There appears to be a considerable difference of opinion among British signal officers as to the use of this expedient. In the Newcastle installation the track circuit is used extensivey for operating an illuminated track diagram or indicator to denote the presence of trains on the various track sections, though it is to be noted that these track circuits control visual indications only and are not used for the control of electric locks on the interlocking machine levers.

A new electric interlocking system is being developed by Mr. Arthur H. Johnson, signal and telegraph superintendent of the London and South Western, in which an electric motor drives a rotary paddle in oil to force the oil into a cylinder, the piston of which operates a lock and switch movement. The return indication in this system is of the alternating current type, in which a small A. C. motor is provided for each lever. This drives a ball governor of ingenious design for tripping the indication latch.

The switches and signals of the large interlocking at the Antwerp Station of the Belgian State Railways are controlled by a Siemens & Halske electric interlocking plant, a considerable number of which are in use on the Continent. At the time of the committee's visit, however, this plant was undergoing extensive alterations on account of track changes, so that little opportunity was provided to study its working.

At Cabin No. 11, of the Chemin de Fer du Nord, in Paris, is a hydraulic interlocking plant, constructed entirely upon the route-lever principle, and known as the Autocombiner. This machine is constructed on the following principles: If there are two main tracks, A and B, which serve four yard tracks, 1, 2, 3 and 4, the machine would contain two rows of four levers each, and if, for example, it were desired to set the switches and signals to move a train from main track A to yard track 3, the lever in horizontal row A and vertical column 3 would be operated. In the same manner, if it were desired to move a train from yard track 4 to main track B, the lever at the intersection of column 4 and row B would be operated. This indication locking of this machine is hydraulic and of the successive or series type.

Electric indicators and repeaters are extensively used at British interlocking plants and are of substantial construction, though the development of relays and other electric accessories has not advanced to the extent found in American practice. Chiefly on account of the relatively small number of such devices used, very little attention is paid to high insulation or to protection against lightning, which does not appear to be a particularly troublesome factor in signaling on British lines.

A novel piece of apparatus is an electric signal repeater, chiefly used for fog-signaling purposes, designed by Mr. Arthur H. Johnson, of the London and South Western. The magnets, and in fact, all working parts of this repeater, are mounted in a glass bath which is filled with refined petroleum, affording additional insulation protection as well as preventing rust. The glass being of good quality and the miniature semaphore arm of the repeater being placed quite close to the glass, the visibility of the indication is not at all impaired by the immersion in oil. This repeater is used at Waterloo Station, London, one mounted in a wooden box at each fogman's station. The cover of the box operates a switch so that current from the battery is not thrown on to the apparatus until the cover of the box is opened.

An examination of various forms of signal lamps and signal glass encourages the belief that such devices are much more highly developed in the United States than in Europe.

C. Roadway, Track and Structures.

The roadway, track and structures of the British, French and Belgian roads are of the most substantial character, no expense being spared to secure easy grade and alignment of roadbed. Stone ballast is the rule in Great Britain and on all the better roads on the Continent, and bridges and buildings are constructed in the most permanent manner.

A number of forms of track structure have been used in Great Britain in the past, but the tendency has been toward the development of a type of track now practically uniform throughout the country. Just as American track construction has tended toward the T-rail and driven-spike construction, with staggered joints, so has the English practice gravitated toward the bullhead type of rail secured in cast-iron chairs by wooden wedges driven on the outside, the joints, which are of the suspended type, being laid square. Much less uniformity is manifested on the continental roads where types of track construction are numerous and vary from the British practice to the American. While several methods of securing the cast-iron chairs to the ties are used in England, the preferred method seems to be to bolt the chair to the tie by two bolts with the nuts on top. Many roads still use lag screws, round spikes and wooden treenails for this purpose.

The only advantage of the bullhead type of rail appears to be in the symmetry of its cross section, which tends to equalize the initial stress incident to manufacture. This type was originally designed with the idea of reversing the rail in the chair when the top surface had become worn, but this is not done to any extent at the present time, as it is found that the bottom head wears at its bearing surfaces on the chairs sufficiently to produce an undesirable roughness if the rail is turned.

Ties in Great Britain are generally 5 inches thick, creosoted, and sometimes are made of jarrow or other tropical hard woods.

On the Belgian State railways the standard angle bar is a 6-bolt suspended joint, 4 lag screws being used to fasten the bars to the ties. The Northern Railway of France uses a 4-bolt suspended joint with the nuts on the inside of the rail, the ballast on the outside being graded nearly up to the top of the rail.

A number of roads formerly drove the wooden keys or wedges on the inside of the rail, but this has been almost universally abandoned in favor of driving the wedges on the outside, as by having the wooden keys or wedges between the rail and the chair less shock is brought upon the latter, thus reducing very considerably the number of chair breakages. Tie plates are used to some extent in France. The London and North Western Railway uses a felt pad under each chair, and a 4-bolt suspended joint, the chair being secured to the sleeper by 2 lag screws with wooden ferrules and 2 round spikes without ferrules. The track of this railroad, as a whole, was the finest that we saw, though the Great Western and portions of the London and South Western compared most favorably in appearance and in riding qualities with it and with the best American tracks.

An interesting feature of English track layouts is the large number of rigid frogs employed, easy curvature frequently being obtained by the use of separate and direct connections between tracks separated by intervening tracks, rather than by the use of simple crossovers, as is the general practice in America. Switchstand construction is not highly developed for the reason that all main track switches are interlocked.

Switches are all of the point type, and the general practice is to cut out the stock rails about three-sixteenths of an inch to permit the use of a reasonably thick switch point and still preserve smooth riding qualities. On the Belgian State railways a number of cast-steel switch points were observed, and it was noted that both driven and screw track spikes were used.

Owing to the absence of pilots on locomotives, guard rails projecting as high as 2 inches above the running rails are often used, particularly with crossing frogs, on the French and Belgian roads. For the protection of employes required to be put upon the track the Northern Railway of France paints its switch fittings, the ends of guard rails, and other obstructions which might trip a man walking on the track, with whitewash, frequently renewed, to enable them to be readily located at night.

A noticeable feature upon the French railways was the use of translucent ground-glass signs, one being placed about 1,200 meters in the rear of the distant signal at every point where a route diverges, bearing the word "Bifur," an abbreviation of bifurcation. The signs of this type are also used to indicate the ends of the stub tracks, displaying in large characters the words" Voie d'impasse," bumping posts also being indicated by the same type of sign with the words "Heurtoir d'impasse." These same ground-glass signs with black numerals are used to indicate the permissible speed in kilometers per hour wherever slow signals are required, a plain white board with a white light being used to denote that full speed may be resumed. These translucent signs are illuminated at night.

The Northern Railway of France, like the roads of England, runs left-handed.

Most standpipes used for supplying the water to locomotives do not use an arm extending over the track, but are provided with large-sized leather or canvas hose to reach from the standpipe to the tender, a method involving less danger than our swinging water cranes, though it would doubtless be much more difficult to keep in proper condition during the very cold weather experienced in this country. It was noted that in England iron baskets mounted on tripods and carrying live coals were provided at water columns, these evidently furnishing sufficient heat to prevent the flexible hose from becoming clogged with ice. The London and North Western uses track tanks, the water scoops of the locomotives commonly being operated mechanically rather than by compressed air.

D. Drawbridge Protection.

The only drawbridges inspected were those at Naburn and Selby on the Northeastern Railway. At both of these points plate girder swing spans carry the two main tracks of this railway over streams having a considerable water traffic. The spans are mounted on tubular piers and turned by rack and pinion gearing, driven by three-cylinder hydraulic engines of the oscillating cylinder type, the pressure being derived from steam-driven compressors located on the shore and transmitted through pipes having valves and couplings at the shore end of the span, and required to be disconnected for turning the bridge. A sufficient accumulation of pressure for two or three turnings is stored in accumulators under each draw span. The turning, end raising, and wedge withdrawing mechanisms are mechanically interlocked with each other, and with a lever electrically locked from the signal cabins on each side of the bridge. Mechanical bridge couplers for the interlocking pipe connections, as well as electric bridge couplers for the line circuits, are provided and interlocked with the wedges, or rather, "resting blocks" (which are not wedge-shaped, but parallel faced), to prevent the coupling up of the pipe or wire connections until these "resting blocks" are in place. The same practice in the operation of the block system is followed at these draw-bridges as at junction points, namely, blocking back, i. e., not permitting trains to pass the second cabin in the rear of the bridge when the draw is open. Probably no one requirement of the board of trade has done so much to prevent accidents at junctions and draw-bridges as this one, which establishes what may be called an overlap at such points. With the exception that no track circuit is provided nor any means of carrying the wheel load from the bridge rails to the shore rails, either in the form of miter-rails or sliding joint bars, the protection is quite complete. All of the foregoing applies strictly to Selby.

At Naburn mercury contact treadles were being put in at the approaches and Sykes detector bars at the home signals to afford somewhat the same measure of protection as would be afforded by track circuit. At Naburn, also, a device is installed whereby in case of failure of the electrical apparatus of the block system a key could be carried from one cabin to the other for releasing the apparatus so as to permit working to continue until repairs are made. In the electrical protection being installed at Naburn and at some other places, the use was noted of relays in which permanent magnets are used, normally tending to pull the relay contacts open, while electro-magnets are used to offset the pull in the permanent ones, closing the contacts. It is claimed that these relays are more efficient than the ordinary neutral type, and that the pick up and release points are brought considerably closer together. A feature of interest in the construction of the drawbridges at Naburn and Selby was the fact that the floors had no ties, the rails being carried on longitudinal stringers which rest on the floor beams, the only other flooring being one of the transverse strips of plate about one-half inch thick by 6 inches wide, no provision being made for carrying any derailed wheels over the bridge. The construction appeared to be such that a derailed vehicle would be likely to damage the bridge.

E. Equipment.

The weights of European locomotives, passenger and freight cars have increased somewhat during the last few years though to a much less extent than in America. The standard of maintenance on most roads is high, considerable attention being paid to smartness of appearance. The increase in weight of locomotives has increased the length, and the later large locomotives are generally provided with a forward truck or bogy. The use of passenger coaches of the corridor type has materially increased some of the comforts of traveling. There are practically no box cars on British railroads and comparatively few on the Continent, practically all freight being carried in short, open cars of the gondola type, goods that would be damaged by wet weather being covered by tarpaulins. While a considerable number of 40-ton cars have been built for the export coal trade and a considerable number of 20-ton cars are in use, the larger part of merchandise freight continues to be handled in cars of from 7 to 12 tons capacity. British commercial methods, under which retailers, as a rule, carry very small stocks, which they replenish with great frequency, continue to provide a great field of usefulness for the small car. By far the greater percentage of freight cars, or goods wagons, as they are called, are of the 4-wheel type, using a link and hook coupler and side sill buffers, a lever brake to be operated by hand or foot or the weight of the body, the brake lever being placed on one side of the wagon only. Continuous brakes are rarely found on goods equipment and automatic couplers on neither passenger nor goods cars.

In making up trains or in switching work trainmen are supposed to use a wooden stick with a steel hook on the end for making couplings and picking up the end of the link of the three links of chain attached to the coupling of one car and engaging one of the three links with the coupling hook on the adjacent car. Couplings are frequently made without the use of a stick. It is not necessary to make the coupling until the cars have come to a stop. The usual form of coupling on passenger coaches consists of a wrought-iron or steel draw-bar with a hook end, the hooks of two adjacent cars being connected by a steel turn-buckle, the right and left handed screw of the turn-buckle having a lever pivoted to its center portion, the end of this lever being enlarged into a ball of metal 3 or 4 inches in diameter, so that once the turn-buckle is sufficiently tightened the weight of the ball on the end of the lever will prevent the turn-buckle from unscrewing. The use of these turn-buckle couplers together with the side sill buffers adds considerably to the solidity and riding qualities of the train, though the type of construction is not well adapted to very sharp curvature. A considerable agitation is now taking place, particularly by railroad employes, in favor of what is termed the "either side brake," it being considered by the advocates of this arrangement that it is very desirable to have a brake lever on both sides of every goods wagon, so that in switching operations these wagons may be braked without the necessity of brakemen having to cross the track or go between moving vehicles to get to that side of the wagon which is provided with a brake lever. Of the continuous brakes in use the larger percentage are of the vacuum type, though the Westinghouse air brake is used to a considerable extent in Great Britain and on the Continent. All British railroads and the Northern Railway of France as well as some other continental roads run left-handed and the engineman drives on the left-hand side of the cab, a noticeable feature of the engine control being that most throttle valves are operated by a screw rather than by a push-and-pull lever, and the same is true to even a greater extent of locomotive reversing gear. The use of the bell is unknown on British locomotives, the whistle alone being used for giving warning signals.

F. Fog Signaling.

The impetus that has been given to the design of cab signals in Great Britain on account of the prevalence of fog in that country has been mentioned in this report and attention called to the fact that such fogs are at times so severe as to entirely prostrate the freight traffic of a large railway for several days. The method of fog signaling used in Great Brtain is to supplement to as great an extent as possible all visual signal indications by audible ones. It is hardly possible for one who has not seen British fogs to realize the density or the effect upon traffic of the continuance for several days or a week of fogs so dense that pedestrians frequently become lost in a familiar locality. Of necessity British railroad companies must have a very complete organization for handling traffic in times of snow and fog. The fog signalmen or fogmen, as they are called, are generally detailed from the track forces. Lists of the names and addresses of these men and their fog stations are posted in the signal cabins and careful arrangements made for promptly notifying them when their services are needed, both day and night, and for relieving them or subsisting them while on duty. Fog signalmen are provided with hand lamps and with a supply of detonators or torpedoes for use as audible signals. On most roads a small shanty containing either a fireplace or provided with a strap iron basket for a coal fire is located at or near each distant signal and is used as a fogman's station. The duty of the fogman at each distant signal is to place an explosive cap or detonator upon the rail whenever the distant signal is at caution and to remove it from the rails whenever the distant signal is cleared. Fogmen detailed at the block stations operate detonators in connection with home and starting signals and assist the signalmen in giving information or instructions to trains.

In many cases where one fogman has to serve more than one distant signalman and for that purpose would be required to cross running tracks, and hence be likely to be struck by trains, mechanical torpedo placers are used, consisting of a single or multiple torpedo holder and connections for operating it from a small lever stand near the track, enabling the fog signalman to place from one to four torpedoes successively upon the rails of one or more tracks by operating the levers mounted in the lever stand. In some localities miniature signal masts and arms, copies of the actual signals used for controlling train movement, are mounted near the base of the full-sized signals, the arms on the models being connected by wires with those of the actual signals thus serving as repeaters. The fog at times is so dense that the position of the working arms cannot be seen, and it is necessary for the fogman to be guided by the operation of the model in placing his torpedoes upon the rail. A single-shot torpedo placer operated by the signal itself was observed on the Belgian State Railway. On the Northern Railway of France a number of torpedo placers were seen, one in particular, which was used in connnection with the home signal of an interlocking plant, being so designed as to be operative only for movement with the current of traffic, a treadle being provided which upon being struck by the wheel of a car or engine making a reverse movement would remove the torpedo from the rail, so that it would not be exploded by a vehicle moving in the reverse direction. Various magazine torpedo machines have been developed in Great Britain, probably the one most used being the Clayton fogging machine. This consists of a portable cast-iron box or magazine containing a number of detonators designed to be kept in the signal cabins and taken out by the fog men to their various stations when they report for duty. It is mounted upon the fixed portion of each device, which is located close to the rail and worked through pipe connections from a lever stand. In one of the cuts showing a typical signal bridge carrying low-pressure pneumatic automatic block signals on the London and South Western Railway an installation of this machine is shown, together with the connections and the cabins from which the machines are operated by the fogmen. The North-eastern Railway of England abandons its automatic block during fog and falls back upon its manual block, the operating officers appearing to believe that they can better do without the track-circuit protection in such cases than without the verbal information given by the signalmen for each train movement.