U. S. Railroad Administration. Automatic Train Control Committee.
Report.

ANNUAL REPORT

OF

WALKER D. HINES DIRECTOR GENERAL OF RAILROADS

1919

AUTOMATIC TRAIN CONTROL COMMITTEE

A. M. BURT, Chairman

WASHINGTON
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PERSONNEL OF THE COMMITTEE.

A. M. BURT, Chairman------Assistant Director, Division of Operation, United States Railroad Administration.

W. P. BORLAND--------------Chief, Bureau of Safety, Interstate Commerce Commission.

C. E. DENNEY-------------- Assistant Federal Manager, New York, Chicago & St. Louis Railroad.

H. S. BALLIET---------------Assistant Terminal Manager, Grand Central Terminal, New York City.

HENRY BARTLETT------------Chief Mechanical Engineer, Boston & Maine Railroad.

J. H. GUMBES---------------General Superintendent, Pennsylvania Railroad.

R. W. BELL------------------General Superintendent of Motive Power Illinois Central Railroad.

Mr. C. A. Morse, chief engineer, Chicago, Rock Island & Pacific Railroad, who was, at the time of the creation of this committee, Assistant Director, Division of Operation, United States Railroad Administration, was appointed at that time chairman of the committee. On June 1, 1919, Mr. Morse resigned as Assistant Director and from the chairmanship of the committee, and Mr. A. M. Burt, his successor as Assistant Director, was appointed in his stead.

CONTENTS.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *December 31, 1919.*

DEAR SIR: I have the honor to submit herewith the report of the Automatic Train Control Committee of the United States Railroad Administration for the year 1919.

Sincerely,

A. M. BURT,
Chairman.

TO WALKER D. HINES,
Director General of Railroads.

ANNUAL REPORT AUTOMATIC TRAIN CONTROL COMMITTEE.

INTRODUCTION.

The Automatic Train Control Committee was created by Circular No. 25, dated January 14, 1919, issued by C. R. Gray, Director of the Division of Operation, United States Railroad Administration, with the approval of Walker D. Hines, Director General of Railroads.

The committee's instructions, as given in the circular, were as follows:

"The committee will proceed at once to make a study of, and report upon, the automatic train control devices now undergoing test upon various lines of railroad or available for test, with their recommendations for the installation and further practical test of any devices now or during their investigation made available for that purpose, which they may consider practicable and reasonably conforming to the purposes to be accomplished.

"The report of the committee will include their recommendations upon the requisites of automatic train control and their conclusions upon the mechanical or economic features of such of the devices as the committee may find available for practical use."

OUTLINE OF WORK DONE BY THE COMMITTEE.

The committee held its first meeting in Washington on January 23, 1919, and since that time 14 meetings of the full committee have been held. In addition to these meetings of the full committee, 17 subcommittee meetings have been held.

To enable the committee to become familiar with train-control devices undergoing test it became necessary to arrange for inspections of such devices wherever tests were being conducted. To accomplish this end the committee has made investigations and inspections of devices actually installed and operated, either as test installations or in actual service, at the following places: Baltimore, Md.; Boston, Mass.; Charlottesville, Va.; Chicago, Ill.; Danville, Ill.; Indianapolis, Ind.; Millbury, Mass.; New York, N. Y.; Oroville, Calif.; Philadelphia, Pa.; Pottstown, Pa.; San Francisco, Calif., Spokane, Wash.; Virginia, Minn.; Waltham, Mass.

Train control devices not undergoing road test, but which were presented to the committee's notice in laboratory form, were examined at the following points: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; Indianapolis, Ind.; Newark, N. J.; New York, N. Y.; Philadelphia, Pa.; Pittsburgh, Pa.; Rochester, N. Y.; Scranton, Pa.; Spokane, Wash.; Swissvale, Pa.

Thirty-seven devices were inspected as above outlined.

In addition to this work, plans and specifications of 300 train-control devices were examined by the committee.

The relation of automatic train control to operating conditions has been very fully discussed and all the elements of the problem have been thoroughly considered. The committee has been especially careful to give full consideration to all devices that have in any manner been brought to its attention, and has endeavored, through its inspections, the consideration of plans received and its discussions, to obtain a comprehensive knowledge of the state of the art as it at present exists in this country.

The following definitions and requisites for automatic train control were adopted by the committee:

DEFINITION OF AUTOMATIC TRAIN CONTROL.

An installation so arranged that its operation automatically results in either one or the other or both of the following conditions:

First. The application of the brakes until the train has been brought to a stop.

Second. The application of the brakes when the speed of the train exceeds a prescribed rate and continued until the speed has been reduced to a predetermined rate.

REQUISITES FOR THE DESIGN AND CONSTRUCTION OF AUTOMATIC TRAIN-CONTROL DEVICES.

1. The apparatus so constructed as to operate in connection with a system of fixed, block, or interlocking signals, and so interconnected with the fixed signal system as to perform its intended function:

(*a*) In event of failure of the engineman to obey the fixed signal indications, and

(*b*) So far as possible, when the fixed signal fails to indicate a condition requiring an application of the brakes.

2. The apparatus so constructed that it will perform its intended function if an essential part fails or is removed; or a break, cross, ground, or failure of energy occurs in electric circuits when used.

3. The apparatus so constructed as to make indications of the fixed signal depend upon the operation of the track element of the train-control device.

4. The apparatus so constructed that proper operative relation between those parts along the roadway and those on the train will be assured under all conditions of speed, weather, wear, oscillation, and shock.

5. The apparatus so constructed as to prevent the release of the brakes after automatic application until the train has been brought to a stop, or its speed has been reduced to a predetermined rate, or the obstruction or other condition that caused the brake application has been removed.

6. The train apparatus so constructed that, when operated, it will make an application of the brakes sufficient to stop the train or control its speed.

7. The apparatus so constructed as not to interfere with the application of the brakes by the engineman's brake valve or to impair the efficiency of the air brake.

8. The apparatus so constructed that it may be applied so as to be operative when the engine is running forward or backward.

9. The apparatus so constructed that when two or more engines are coupled together, or a pusher is used, it can be made operative only on the engine from which the brakes are controlled.

10. The apparatus so constructed that it will operate under all weather conditions which permit train movements.

11. The apparatus so constructed as to conform to established clearances for equipment and structures.

12. The apparatus so constructed and installed that it will not constitute a source of danger to trainmen, other employees, or passengers.

GENERAL CONSIDERATIONS.

The use of automatic train control has been generally advocated in the public press for the past decade or more, and especially after each collision involving serious injuries and loss of life, occurring on tracks protected by block signals, where employees have failed properly to perform their duties. It is obvious that on lines where all the generally accepted means for the protection of trains are in use, and collisions still occur due to the failure of the human element, additional safeguards must be provided if such accidents are to be avoided. In considering additional safeguards that may be adopted for the prevention of collisions it is necessary to analyze briefly the circumstances under which such accidents occur and undertake to arrive at a conclusion as to the possibilities and limitations of any preventive measures which may be available.

The purpose of a block system generally is to provide a proper space interval between trains to protect against rear-end collisions in the assigned direction of traffic, and against both rear-end and head-on collisions on track signaled for movements in both directions. On roads where track circuit controlled block signals are installed it is evident that, if the rules are obeyed and the indications of the fixed signals along the roadway are at all times observed, understood and obeyed, accidents such as the signal system is designed to prevent can not occur, except in the unusual event of a signal failing to indicate an unsafe condition when such a condition exists.

Generally speaking, therefore, on tracks fully equipped with modern track circuit controlled block signals, train collisions can occur only as the result of one of the following causes:

1. Failure of brakes.
2. Failure of signals to perform their functions.
3. Failure of employees to comply with rules or orders.
4. Failure of employees to observe, understand, or obey signal indications.

Train-control devices will not prevent collisions due to brake failures which are infrequent and comprise only a small percentage of such accidents.

Failure of signals to perform their functions is a comparatively rare occurrence. Track circuit controlled block signal systems are so designed that when any part fails the signal should display the stop indication. In some cases of failure, however, the signal indicates "proceed" even though it should indicate "caution" or "stop." Such failures, known as "false clear" failures, contain a serious element of danger, but their infrequency makes the possibility of collisions from this cause exceedingly remote.

Collisions due to failure of employees to comply with rules or orders are a large proportion of the total number reported and many of these could not have been prevented by an automatic train-control device.

Automatic train-control devices may be expected to prevent only such accidents as are due to the failure of employees to observe, understand, and obey signal indications. Failure to see or understand signals may be due to smoke, fog, snow, absence of the night signal indications, complexity in the scheme of indication, unfamiliarity of the engineman with the route over which the train is running, the diversion of his attention or his physical incapacity, etc. Failure to obey signal indications that are seen and understood are rare and include only those cases where enginemen in their anxiety to make time take chances, or where they use poor judgment in the interpretation of rules, which permit them to exercise some discretion. Statistics show that most of the collisions which have occurred on tracks protected by track circuit-controlled signals are due to the causes above enumerated.

There appears to be a popular misconception as to the number of fatalities that might be prevented by automatic train-control devices. Statistics show that train collisions have been the cause of less than 6 per cent of the fatalities to persons, other than trespassers, occurring on the railroads of the United States in the five and one-half years ending December 31, 1918.

Records of the Interstate Commerce Commission show the fatalities to nontrespassers on railroads of the United States from July 1, 1913, to December 31, 1918, inclusive, as follows:

	Year ending June 30—						Six months ending Dec. 31, 1916.		Year ending Dec. 31—			
	1914		1915		1916				1917		1918	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Collisions	271	5.61	121	3.42	233	5.16	141	4.95	364	6.23	499	8.27
Derailments	262	5.42	180	5.08	194	4.29	91	3.18	176	3.01	290	4.81
Other train accidents	18	.38	21	.60	38	.84	18	.64	151	2.58	168	2.78
Train service accidents (including highway crossing accidents)	3,871	80.13	2,872	81.20	3,566	78.95	2,355	82.54	4,633	79.28	4,485	74.37
Nontrain service accidents (industrial, etc.)	409	8.46	343	9.70	486	10.76	248	8.69	520	8.90	589	9.77
Total	4,831	100.00	3,537	100.00	4,517	100.00	2,853	100.00	5,844	100.00	6,031	100.00

NOTE.—On account of change in the ending of the fiscal year from June 30 to Dec. 31, in 1916, the figures for the last 6 months of 1916 are shown separately.

The foregoing facts, however, should not be taken as minimizing the seriousness of the situation, and in considering them weight should be given to the further fact that many of the victims of train collisions are passengers who do not contribute by their negligence to the accidents and are entitled to the largest measure of protection that is reasonably possible; nevertheless, the limitations of automatic train-control devices, even the most complete and dependable that may be developed, should be clearly understood. All fatalities resulting from train collisions averaged per year from July 31, 1913, to December 31, 1918, inclusive, 296, or 5.6 per cent of the fatalities to nontrespassers on the railroads of the United States, and of this number many resulted from collisions occurring on yard tracks or at other places where they would not have been prevented by an automatic train-control device.

The cost of an automatic train-control system is an undetermined item which involves not only the original expense of installation but also the cost of maintenance and the effect of its operation upon the capacity of existing facilities. If a device materially reduces the capacity of a railroad, its installation where heavy traffic is handled may necessitate further expenditure for additional running tracks. A device to satisfactorily meet such conditions must therefore be one which will interfere as little as possible with the capacity of a railroad, and this requirement may necessitate the addition of speed-control apparatus at an increased cost for its installation and maintenance.

The question of installing automatic train-control systems in such a manner that the normal operation of trains will not be interfered with is one of the most difficult problems to be solved. The primary function of a block-signal system is to maintain a definite space interval between moving trains, but in addition thereto it enables trains to be moved safely without delay, as by giving an engineman information that the track ahead of his train is clear for a definite distance, he is enabled to proceed with confidence at the highest rate of speed which can be maintained with safety. Train movements are thus greatly facilitated, and this fact is so important and fundamental that on multiple-track roads of heavy traffic it is well recognized that to handle the volume of traffic now being moved would be impossible without the use of automatic block signals, unless additional running tracks were provided. Fundamentally, therefore, track circuit controlled automatic block signals, in addition to providing greater safety of train operation, add to the capacity of a railroad as do additional running tracks. In imposing automatic train control upon such a system this fact must be clearly borne in mind and in correcting unsafe conditions due to the failure of the human element the fundamental feature of the signal system itself, as above outlined, must not be unnecessarily impaired.

There are other problems in connection with this subject, some of the most important being those of reliability, clearance, and interchangeability. These and other questions involved are considered later in this report.

It must not be assumed that this brief statement of general considerations with regard to the use of automatic train-control devices is anything more than an attempt to indicate some of the difficulties of the subject.

THE TRAIN-CONTROL PROBLEM.

Automatic train control is popularly regarded as a penacea for railroad accidents. Persons who are not familiar with railroad operating requirements generally fail to understand fully the factors which must be taken into account in the practical use of train-control devices. On this account a comprehensive statement of the questions involved from the standpoints of construction, maintenance, and operation is desirable.

Briefly stated, the problem is to provide some appliance to furnish protection against accidents when employees disregard signal indications or, so far as possible, when signals improperly indicate proceed. The problem comprises two main elements, one of which consists in reproducing upon a moving train, either by mechanical or electrical means, a correct indication of the condition of the track ahead; the other requires proper means for controlling the train in obedience to the indication given. The first element necessitates the use of suitable mechanism along the roadside, while the second requires the use of suitable mechanism installed upon the train, both of which must properly correlate and function interdependently. Important factors entering into the problem are:

(*a*) Reliability in operation.

(*b*) Inspection, maintenance, and test to insure efficiency.

(*c*) Clearance—Relation between parts of the device and obstructions on the roadside or train.

(*d*) Capacity—The effect upon the traffic handled over a given section of railroad.

(*e*) Interchangeability as between different devices on track used by railroads jointly.

(*f*) Correlation with track circuit controlled block signaling and air brake apparatus.

RELIABILITY.

It is obvious that an automatic train-control device must be reliable in operation; that is, it must respond with certainty to all the conditions under which it should act, and should remain inert at all times when conditions are such that a train may proceed with safety. If the device fails to act when the danger it is designed to guard against is present, its intended function can not be performed, and if it acts frequently when there is no danger the interference with operation becomes serious and the device itself becomes discredited, the device must of necessity be exposed to all climatic conditions and must function properly during the most severe weather. It must also be protected from damage, the roadside mechanism from being torn out by objects dragging from passing trains, and the train-carried mechanism from being struck by foreign obstacles on the roadside.

INSPECTION, MAINTENANCE, AND TEST.

Even the best designed apparatus, installed in the most substantial manner, will fail if not properly inspected and maintained. Proper inspection and maintenance of automatic train-control devices will be more difficult than the inspection and maintenance of track circuit controlled signals, for the reason that part of the apparatus will be located on the roadside and another part upon the train. The roadside apparatus will naturally be looked after by the maintainers who keep the signals in order, while the condition of the train-carried apparatus will be looked after by the mechanical forces in enginehouses and shops. While it is quite possible to have these two sets of maintainers subject to a single supervision, it will nevertheless be a difficult matter to correlate the results of the necessarily divided inspection and maintenance so as to determine with certainty the cause of failures which are reported to have occurred. This difficulty arises from the fact that it will often be impracticable to bring the train apparatus and the roadside apparatus at a particular location into operative relation with one another for test purposes.

To a certain extent also the amount of inspection and maintenance required by the signal system itself will be increased by the use of an automatic train-control device, as by its imposition upon the signal system certain elements will be added to the latter, and these will require careful attention.

In view of the emergency nature of an automatic train-control device it may be assumed that under ordinary operating conditions it will very infrequently be called upon to perform its intended function. It is important, therefore, in order that the device may not become inoperative through disuse, that its condition be disclosed by means of frequent and regular tests.

CLEARANCE.

The location of automatic train-control apparatus on train or roadside requires detailed study in an effort to secure satisfactory operation. Clearances are materially affected by tunnels, bridges, station platforms, track pans, grade and highway crossings, etc.

An analysis of train-control devices places them in two general classes:

(*a*) *Contact.*—Those that depend for their operation on the physical contact of an element carried on the train with an element at a fixed location on the roadside.

(*b*) *Noncontact.*—Those that depend for their operation on an electrical or magnetic impulse without physical contact between the roadside and train elements.

A large part of the development has been in devices of the contact class. Many troublesome clearance problems enter into the solution of their application and use. If the roadside elements are located between the rails they are likely to be torn out by objects dragging from moving trains. The most practicable location appears to be a short distance outside of the rail and near its level, but even here there are some serious difficulties. Snowplows and ballast spreaders work to the level of the rails and a track element extending above the rail within their range will interfere with such equipment. These difficulties, while perhaps not insurmountable, will be, on some roads, quite serious and must be met. It is evident that part of the track element must be placed above the rail level, as it is impossible to operate any part of the train element below that level for the reason that in such location it would be torn off by coming in contact with switch rails, crossing planks, and other obstructions.

With the noncontact devices the clearance difficulties are very materially reduced and evidently this fact has been one of the leading causes for the development work that has been and is now being done with this class of devices.

CAPACITY.

As previously pointed out, a properly operated automatic block-signal system adds to the capacity of a railroad by increasing the freedom and flexibility of train movements over it. This condition should not be unduly interfered with by the use of an automatic train-control device. It is apparent, however, that if such a device is to act to stop a train only in the occurrence of those emergencies caused by the failure of employees to obey signal indications, the automatic brake application must be made a sufficient distance away from the actual point of danger to bring the train to a stop before reaching that point, under the most unfavorable conditions. This involves the necessity of providing maximum braking distance for all trains equal to that required for any train on the road.

This can not be done without decreasing the track capacity, and on congested railroads is therefore a matter for serious consideration. To overcome these difficulties permissive features have been installed to enable the engineman to nullify the brake application and speed-control apparatus is being developed.

INTERCHANGEABILITY.

The joint use of a track by two or more railroads is frequent throughout the United States and essential in many cases to economical operation. This practice, as well as the joint use of terminal facilities, has been extended during the past two years, and will, without doubt, become more general. It is necessary, therefore, that train-control devices shall be so designed that the engine equipment of the various lines will properly function with the roadside apparatus on tracks used jointly.

Detouring in case of accidents makes it necessary for the trains of one company to move over the tracks of another. Such movements are handled by a qualified employee of the owning road in connection with the crew of the detouring road. Due to the comparative infrequency of and the safeguards thrown around such movements it would not appear necessary that the train-control apparatus should be so designed as to be operative in all cases on the engine of the detouring road, but the equipment detoured must conform with the clearance requirements on the road used.

It is therefore highly desirable, and in certain localities necessary, that a train-control device for practical use shall not restrict the free operation of the trains of several roads over the same track.

CORRELATION WITH ELECTRICALLY CONTROLLED BLOCK SIGNALING AND AIR-BRAKE APPARATUS.

The use of electrically controlled block signals has resulted in materially increasing the safety and efficiency of train operation and it is essential that train-control apparatus shall be so designed that it may be superimposed upon the block signal system and not interfere with the performance of the signals.

It is also essential that the engine apparatus of automatic train-control devices shall be adapted to use with the present air brake system and shall not interfere with its practical operation.

The committee, as a result of its investigations, has prepared the following classification of automatic train-control devices, based on the character of control, on the general method of communication between the roadside and train and on the type of device used in securing the desired result. Most devices readily fall into a single classification, although a few are found with characteristics of two types. In the present stage of development the dividing line between the different types is not always well defined. The characteristics of the various types, with a brief description of their main distinguishing features, are given as far as it is possible to state them from our knowledge of the art as it exists.

ANALYSIS AND DESCRIPTION OF THE DIFFERENT TYPES.

CLASSIFICATION OF TRAIN-CONTROL DEVICES.

Character of control.	Class of device.	Types of device.
I. Intermittent	A. Contact	1. Plain mechanical trip. Ground or overhead. 2. Electrically controlled mechanical trip. Ground or overhead. 3. Intermittent electrical contact.
	B. Track rail contact	1. Insulated truck with short track circuit section.
	C. Noncontact	1. Induction. 2. Inert roadside element. 3. Nonmagnetic rail.
II. Continuous	A. Contact	1. Third rail or special conductor.
	B. Noncontact	1. Induction. 2. Wireless.

Speed control or cab signals may be applied to most of the above types.

INTERMITTENT CHARACTER, CONTACT CLASS (I–A).

The distinguishing feature of automatic train-control devices of the intermittent character is that the indication is transmitted to the train from the roadside apparatus only at definite points. The indication thus received continues as the controlling factor in the operation of the train until the next indication point is reached, when it may be continued or changed, depending on the indications there received. Normally the indication on the train is not changed while it is between any two indication points.

Control of the intermittent character may be either of the contact or noncontact class, depending on whether or not physical contact is required between the roadside and train apparatus.

All intermittent contact types have the following characteristics in common:

1. Control of the train apparatus by the roadside apparatus is through mechanical means.

2. Impact shocks between the train and roadside apparatus with trains moving at high speed are severe.

3. Where electrical energy is required for their operation the amount is relatively small.

4. If the train apparatus is not properly located the operation of the device is liable to be interfered with by oscillation.

5. Being composed largely of mechanical elements its maintenance is comparatively simple.

6. When electrical elements are used they are similar to those generally found in signal installations.

7. Since effective contact requires an overlapping of train and roadside apparatus, clearance lines are interfered with, resulting in a possibility of the train apparatus being damaged or unnecessarily operated by obstructions along the right of way or the roadside apparatus being struck and deranged by train-carried obstructions.

INTERMITTENT CHARACTER, TRACK RAIL CONTACT CLASS (I–B).

This class requires no special contact element on either the roadside or train, but uses the running rails of the track in lieu of a roadside contact element and wheels of the engine in lieu of a train-contact element. It has no characteristics common to other types of devices.

INTERMITTENT CHARACTER, NONCONTACT CLASS (I–C).

Since the development of the intermittent noncontact types has been comparatively recent, the characteristics (which are largely ascertained by experience) are not as well determined as with the contact types. The following characteristics, however, are common:

1. Control of the train apparatus by the roadside apparatus becomes effective when the two parts are in proper inductive or magnetic relation.
2. Considerable "air gap" is necessary as compared with devices commonly used in railroad signaling.
3. There being no overlapping of train and roadside apparatus, the different elements can be kept within established clearance lines.
4. Improper operative conditions of roadside apparatus can not be readily detected.

CONTINUOUS CHARACTER, BOTH CLASSES (II–A AND II–B).

Some effort has been made to develop train-control devices of the continuous character, both of the contact and noncontact class. These are designed to give an immediate indication on the train of any change in operating conditions. As only a few devices have reached the stage of practical development no common characteristics can be stated, and such individual characteristics as have been determined are given later in the consideration of the individual types.

PLAIN MECHANICAL TRIP TYPE (I–A–1).

The plain mechanical trip type has a train element which functions with the contact element of the roadside apparatus. The roadside apparatus may be placed either at the track level or at some point above it. The train contacting element either directly controls the brake-application valve or is mechanically connected thereto. The roadside contact element is movable so that it may be brought into range of the train element when a stop is to be produced. This operation is purely mechanical and the controlling mechanism is remote from the roadside element. The roadside contact element may be a movable trip making momentary contact with the train contact element or it may be a movable trip rail.

The characteristics of this type are well known, since it represents the earliest development in the art. Its limitations, however, have restricted its use. The chief characteristics of this type, in addition to those previously noted as common to its character and class, are as follows:

1. Generally speaking, mechanical connections are positive in their action.

2. The removal of essential parts is not readily detected.

3. Long mechanical connections may be required. These are generally impracticable.

4. With the roadside element located much above the track level there is danger of injury to passengers and to employees whose duties require them to ride on the sides or tops of cars.

5. The roadside apparatus and the train apparatus are only in operative relation when a stop is to be produced by the device.

Electrically Controlled Mechanical Trip Type (I–A–2).

In the electrically controlled mechanical trip type the roadside apparatus is controlled electrically, though the trip element itself may be operated by some other power, such as compressed air. The train apparatus may be of the same character as that used in the plain mechanical trip type and may be similarly located, or it may be electrically controlled so that when a circuit is broken by the contact of the train and the roadside apparatus the brakes are applied.

The chief characteristics, in addition to those already noted as common to its character and class, are as follows:

1. The power by which it is controlled permits the roadside apparatus to be placed a suitable distance from the point at which a stop is to be made.

2. The roadside apparatus may be readily interconnected with the signal system.

3. Electrical elements may be confined to the roadside apparatus where they can readily be maintained.

4. The breakage or removal of certain essential parts can not readily be detected.

5. In exposed locations there is danger that the trip element will be frozen in nonstop position.

Intermittent Electrical Contact Type (I–A–3).

The distinguishing feature of the intermittent electrical contact type, commonly known as the "ramp" type, consists in the train apparatus being put into operative condition at every indication point. This result may be attained by direct operation of the contact elements themselves or through electrical circuits controlled by the contact element. A necessary sequence is that the train apparatus must be retained in the proceed position, if the block is clear, by a circuit maintained through contact with the roadside element while passing over it. The length of the ramp may vary considerably, depending on the results to be accomplished while the train element is in contact with it. The ramp is generally placed outside of and parallel with the running rail.

This type has received relatively the greatest development, and a number of devices have been installed and tested, two now being in service operation on steam roads. There is a very little difference between the devices of this type and this is chiefly in the design of details. In some devices the ramp is energized by a roadside battery. The control is through circuits similar to those used in an automatic signal system. In other devices the ramp is not energized by a roadside battery but energy is supplied from a source on the train, the ramp in this case forming part of a circuit between the train apparatus and the signal controlling apparatus. The distinguishing feature of all these devices is a holding circuit for energizing the train element. This is a "stick" circuit so that when the train element is once deenergized it can not be again energized unless it be restored mechanically, or by means of a secondary circuit through the ramp or by a release switch. In all cases the train circuit will be broken when the contact shoe passes over a ramp.

As extensive tests of this type have been made its characteristics are well defined. In addition to those before noted as common to its character and class, the following characteristics are known.

1. The train circuit is broken every time a ramp is passed; a valuable self-checking feature is thus provided.

2. Few electrical elements are required on the train.

3. Electrical contact between the ramp and the train element is subject to interference by snow, ice, sleet, frost, or other insulating materials.

4. To secure effective electrical contact considerable pressure is required between the train contact element and the ramp.

Insulated Truck, with Short Track Circuit Section, Type (I-B-1).

This type requires insulation between a truck and the engine or tender and short track circuit sections located at the indication points. In some devices the insulated joints in the two rails must be exactly opposite while in others one joint must be located a given distance ahead of the other. The circuit controlling the train relay is completed from the insulated truck through the wheels and running rails to the other part of the engine. When an indication point is reached the circuit through the rails is interrupted by the insulated joints unless the joint is electrically bridged by means of a loop circuit through the signal relay. No roadside battery is required for the operation of the engine apparatus. Some devices of this type have been tested to a limited extent. The principal characteristics are as follows:

1. No roadside apparatus involving clearance problems is required.
2. No contact element is required on the engine.
3. Check circuits are necessary to detect failures of insulation.
4. Insulations that are sufficient for track circuit purposes may not withstand voltages required on the engine.
5. A definite location of insulated joints is required.
6. Unbonded joints on sidings or in yards may produce a stop.
7. Poor contact between wheels and rails, due to sand or rust, will produce an unnecessary stop.
8. The short track circuit section must be incorporated in the signal control circuits.

Induction Type (I–C–1).

In this type both permanent and electromagnets are used in the roadside apparatus. The field of the permanent magnet is present to cause the train apparatus to act except when conditions are proper for the train to proceed, in which case the field of the permanent magnet is deflected or neutralized by the electromagnet. The electromagnet is energized by a separate battery through one of the relays of the usual signal system. The magnets employed in the roadside apparatus are placed between the running rails of the track, as this location better meets the clearance requirements of operation.

In principle the train element may be either a duplicate of the track element or a receiving element of suitable form, through which the train controlling apparatus is made operative.

As but one device of this type has been tested in service, comparatively little information is available concerning the practicability of its operating features.

The chief characteristics of this type, in addition to those already noted as common to its character and class, are as follows:

1. Safe operation depends on the reliability of permanent magnets.
2. Generally speaking, clearance conditions require the permanent magnets to be placed between the running rails of the track.
3. The electrical energy required to energize the electromagnet used as a neutralizing element may prove to be excessive.
4. With a normal clear scheme of automatic stop control short track circuit sections may be necessary at each indication point to conserve current.

5. On account of the location of the roadside element between the rails, and the necessity for its protection against damage, the difficulty of track maintenance at roadside element locations will be increased.

6. Due to the small amount of energy transmitted through the necessary air gap between the roadside and train elements, any parts on the train that are to be operated by the magnetic field of the roadside magnets must possess low inertia.

Induction Type with Inert Roadside Element (I–C–2).

This type employs a fixed and inert roadside element, which may be placed either between or outside of the running rails of the track, to reduce the flow of current in a coil on the train. This reduction in the flow of current causes the brake controlling relay on the train to open, thus applying the train brakes. No extensive road tests of this type of device have thus far been conducted, and it is practically in the laboratory stage of development.

In addition to those before noted as common to its character and class, the following characteristics are known:

1. No magnetic or electromagnetic energy is required at the roadside element location.

2. The roadside apparatus may be readily installed at desirable points.

3. The reduction of current flow produced on the train apparatus by the inert roadside element is similar in its action to a shunt circuit.

4. The train apparatus may be influenced by metals on the roadbed.

5. Where the track element is connected with the signal system it may be rendered inoperative by short circuit between connections.

Induction Type, Nonmagnetic Rail (I–C–3).

This type makes use of a rail of nonmagnetic material, such as manganese steel, inserted in the track at indication points. Only very limited tests of this type have been conducted and its characteristics have not been fully determined. In addition to those before noted as common to its character and class, the following characteristics are known:

1. No roadside apparatus in which clearance problems are involved is required.

2. Interference may exist when passing over manganese frogs and crossings.

3. Introduction of rails of special material will be to some extent objectionable.

Continuous Electrical Contact Type (II–A–1).

This type employs a continuous conductor. When placed at the track level the conductor is usually in the form of a rail of lighter section than the running rails of the track. In some devices of this type the track rails are utilized as conductors. In normal operation the train contact element must remain in constant engagement with the roadside contact element. The train apparatus may be of the same kind as that used in the intermittent electrical contact type. The chief characteristics, in addition to those already noted as common to its character and class, are as follows:

1. The use of a continuous conductor renders it possible to use current at a higher voltage than is generally feasible with other contact-type devices.
2. Contact must be maintained with the roadside conductor.
3. Special construction will be required at highway and railway crossings, crossovers, turnouts, etc., to avoid breaks in the continuous conductor.
4. Frost and dirt may cause interference with contact.
5. Introduction of special conductors along the roadside will be objectionable.

Induction Type (II–B–1).

This type employs either the running rails of the track or special conductors on the roadside. Some of the roadside and train elements required are dissimilar to those used in other types, such as the alternating current track circuit and apparatus to amplify the current transmitted to the train.

The following are the chief characteristics of the type so far as known:

1. Energy required in the roadside apparatus is comparatively small in amount.
2. No roadside apparatus which interferes with clearance requirements is necessary.
3. Operation of the device is based directly on the track circuit.
4. The amplifying element proposed has not been subjected to service tests and its reliability for the purpose intended has, therefore, not yet been determined.
5. So far as known, this type requires the use of alternating current in the track rails.
6. Its operation may be affected by location of insulated joints.

Wireless Type (II–B–2).

Some progress has been made in developing new methods of applying the wireless principle to the operation of an automatic train-control device. Practically all the work accomplished in this line has been of a laboratory nature and definite information as to the results attained is not available. The chief characteristics of this type are as follows:

1. A continuous conductor is required along the roadside.
2. Different frequencies are required for different tracks or directions.
3. Special apparatus is required to produce current.

DESCRIPTION OF DEVICES EXAMINED.

The devices examined by the committee are briefly described below. The devices in this list are arranged according to type, and those in service or that have been installed for test purposes are not separated from those that were examined by the committee in shop or laboratory.

Plain Mechanical Trip Type (I–A–1).

Installed on the United Railways & Electric Co. of Baltimore. Inspected September 3, 1919. The contact is made above the roof of the car and the roadside apparatus is operated mechanically from levers in an interlocking plant. The only place where this stop is in use on this company's tracks is at a drawbridge, roadside apparatus being used on each side of the draw span. One hundred and fifty overhead trolley type cars, such as are commonly used on city lines, are equipped with train apparatus. The device has been in service since May, 1918, and is reported to have given good service.

Electrically Controlled Mechanical Trip Type (I–A–2).

AUTOMATIC CONTROL COMPANY.

Inspected July 11, 1919, in the office of the company at Indianapolis, Ind. Apparatus of full size was used for demonstration purposes. The roadside apparatus includes a movable trip rail operated by an electric motor. The train contact element is operated by the roadside element when a stop is to be produced, making a brake application. Contact elements are placed on each side of the rear end of the tender to provide for forward or backward movement. A proceed valve or release switch when operated manually permits the train to pass a trip rail in the stop position. No speed control elements are included.

Clifford Automatic Train Stop Co.

Inspected July 23, 1919, in the company's shop at Scranton, Pa. Apparatus of full size was used for demonstration purposes. The roadside apparatus included a movable trip rail, designed to be operated by an electric motor, operating directly on a valve in the train contact member. Speed control features were included whereby brake applications would be made at approach signals unless neutralized by the engineman by proper operation of the brake valve.

KEY ROUTE, OAKLAND, CALIF.

Inspected May 5 and 7, 1919. This device is of the electrically controlled mechanical trip type. The contact is made above the roof of the car and the roadside apparatus is operated either by a separate motor or mechanical connection to the signal arm. Roadside apparatus for 113 stops is in service on the terminal interlocking plant and on 3.4 miles of double track on the pier leading to the ferry terminal, 91 cars being equipped with the train apparatus. No speed control features are used. Provision is made so that the roadside trip arm may be moved from the stop to the proceed position by the train crew, from the ground, when necessary to pass a signal in the stop position, after this operation the trip arm assuming the stop position as soon as released.

KINSMAN DEVICES.

Six installations of this device were inspected as follows:

	Date of inspection.	Number of stops.	Number of cars.	Mileage.
New York Municipal Railway Corporation	June 4, 1919	569	....	....
Interborough Rapid Transit Co	June 5, 1919	1,813	4,010	56.0
Hudson & Manhattan Railroad	June 6, 1919	290	286	26.0
Pennsylvania Tunnel & Terminal Co	......do......	52	376	7.0
Philadelphia Rapid Transit Co	Sept. 4, 1919	136	215	7.5
Boston Elevated Railway Co	Sept. 8, 1919	207	424	19.0

All of these installations have electrically controlled roadside apparatus, the trip arm being operated electrically or pneumatically. In some cases the trip arms are located between the running rails, but in most cases they are outside of the rails. On the New York Municipal, Interborough, and Hudson & Manhattan speed control features are used in connection with the signal installation, time limit relays being used to define the time allowed for a train to run a definite distance. Provision is made so that the roadside trip arm may be moved from the stop to the proceed position by the train crew, from the ground, when necessary to pass a signal in the stop position. After this operation the trip arm assumes the stop position as soon as released. This type has given satisfaction under the special conditions existing in subways and on elevated lines.

NEVENS-WALLACE TRAIN CONTROL CO.

Inspected September 8, 1919. Roadside apparatus was installed at one location at Waltham, Mass., on the Boston & Maine Railroad, and one engine equipped for development and demonstration purposes. The roadside trip arm is operated by an electric motor controlled through the automatic signal circuits. The train apparatus is operated by direct contact of the train trip arm with the roadside trip arm. No electrical circuits are used in connection with the train apparatus. A centrifugal governor controls the train apparatus so that when the speed is at or below a predetermined rate the engineman can prevent an automatic application of the brakes or release them when they had been applied automatically.

WILLSON-WRIGHT SAFETY APPLIANCE CO.

Inspected May 1, 1919. This device is of the electrically controlled mechanical trip type. The contact is made above the roof of the car by contact with a glass tube on the car, and the roadside apparatus is operated by mechanical connection to the signal arm. Roadside apparatus is installed for 24 stops, on 29 miles of single track of the Washington Water Power Co.'s electric lines, Spokane, Wash. No speed control is used. Provision is made so that the roadside trip arm may be moved from the stop to the proceed position by the train crew from the ground when necessary to pass a signal in the stop position. After this operation the trip arm assumes the stop position as soon as released.

Intermittent Electrical Contact Type (I–A–3).

AMERICAN RAILWAY SIGNALS CO.

Inspected July 26, 1919, at the laboratory of Thomas E. Clark, Detroit, Mich. This is the device formerly known as the Julian-Beggs. The parts of the apparatus that were examined, with the exception of the engine relay, had been used experimentally on the Cincinnati, New Orleans & Texas Pacific Railroad. Proceed, caution, or stop indications were provided for by means of a three-position relay controlling the train apparatus. The three-position relay is controlled by the polarity of current on the ramp. A centrifugal governor was provided for speed control. A circuit reverser, operated in connection with the centrifugal governor, depends for reversal upon a specified movement of the engine and provides for change in circuits to permit engine running backward. Cab indicator lights were provided.

AMERICAN TRAIN CONTROL CO.

Inspected April 15 and 16, 1919, on the Chesapeake & Ohio Railroad between Charlottesville and Gordonsville, Va. The device is in use on 21 miles of single track and 32 engines are equipped. Automatic block, color light signals, and train control were installed at the same time. Ramps are located in pairs in advance of the signal, the right-hand ramp being used for the stop and the left-hand for the approach indication for the next block. No speed-control features are used but approach indication is provided.

CASALE SAFETY DEVICE CO.

Inspected July 28, 1919, on the Chicago, Rock Island & Pacific Railroad, near Blue Island, Ill. One ramp was installed and one engine equipped. A three-position relay controls the train apparatus to provide proceed, caution, or stop indications. The three-position relay is controlled by the polarity of current on the ramp. A centrifugal governor provides speed control that prevents exceeding a predetermined speed after receiving a brake application at the approach signal.

GENERAL RAILWAY SIGNAL CO.

Inspected July 24, 1919, at the shops of the company in Rochester, N. Y. This apparatus was part of that used in an extensive test installation on the New York Municipal Railways at Brooklyn, N. Y. Special ramps were used to regulate the speed control feature. Depending on the local conditions existing, different speeds were permitted which were automatically adjusted by the ramps. A centrifugal governor operated the necessary circuit closers that control the circuits through the different devices. The device is designed so that no automatic application of the brakes will be produced as long as the speed of the train is controlled in accordance with the signal indications.

GENERAL SAFETY APPLIANCE CO.

Inspected May 2, 1919. A temporary ramp and one engine was fitted up on the Spokane International Railroad. The contact shoe was bow shaped and not of the vertical lifting type. No special features were exhibited which differed from the general type. No speed control features were provided.

GOLLOS RAILWAY SIGNAL CO. OF AMERICA.

Inspected March 21, 1919, in the office of the company at Chicago. This device was tested by the Bureau of Safety, Interstate Commerce Commission, on the Chicago, Burlington & Quincy Railroad, in 1916. Speed-control features were included and as exhibited required two centrifugal governors. Two different voltages are used on the ramp to give proceed and caution indications.

INTERNATIONAL SIGNAL CO.

Inspected June 6, 1919, in the company's office at New York, N. Y. The apparatus examined had been used experimentally on the New York, New Haven & Hartford Railroad. The air valve on the engine was worked by direct contact between the engine shoe and the ramp. Speed-control features were used that would permit the engineman to release the brake when the speed had been reduced to a predetermined rate.

MILLER TRAIN CONTROL CORPORATION.

Inspected March 17, 20, 21, and 22, 1919. Apparatus exhibited in Chicago was inspected and an inspection made of the installation on the Chicago & Eastern Illinois Railroad at Danville, Ill. This installation is on 106 miles of automatic-signaled double track and 73 engines are equipped. The engine air valve is operated by direct contact between the shoe and the ramp. No speed control is provided.

ORCUTT AUTOMATIC TRAIN CONTROL CO.

Inspected September 9, 1919. This device was installed experimentally on the Millbury branch of the Boston & Albany Railroad. Multiple ramps on the roadside and a number of shoes on the engine were used. One rail only was divided into blocks, the other being continuous. The current was provided from the engine and the circuit was completed through the ramps, line wires, relays, and running rails. Cab indicators were used, but no speed-control features were provided.

SHADLE AUTOMATIC TRAIN SIGNAL CO.

Inspected July 11, 1919. Three ramps were installed on the Cincinnati, Indianapolis & Western Railroad near Indianapolis, Ind., and were connected with the automatic signal system. One engine was equipped. Speed-control features were included and were controlled by a specially wound generator driven from the axle, which was designed to close the circuit to the brake valve at a certain speed, permitting a deenergized ramp to be passed, if circuit controllers were operated by the engineman and fireman at the same time.

SIMMEN AUTOMATIC RAILWAY SIGNAL CO.

Inspections were made of the installation on the Mesaba Railroad at Virginia, Minn., March 24, 1919, and on the Indianapolis & Cincinnati Traction Co., July 21, 1919. This device gives control of trains from a central point by the use of cab signals. No stop features are included and no speed-control devices are used. Both installations examined were on single-track electric lines. Ramps for one direction are energized with one polarity from a central battery and ramps for the other direction by the opposite polarity, depending on the position of the control switch. Apparatus is also installed in the central station which automatically records the time of the passing of cars over the ramps.

THAYER AUTOMATIC SIGNAL & TRAIN CONTROL CO.

An examination was made of plans and some apparatus of this company at Spokane, Wash., on May 2, 1919. Speed-control apparatus and one of the air valves, all the apparatus constructed, were examined.

TRAIN CONTROL APPLIANCE CO.

This apparatus, known as the Bulla device, was inspected March 17 and 20, 1919, in the Coliseum at Chicago. The roadside apparatus consisted of a brush with which the engine shoe makes contact. The roadside circuits are so designed that when a stop is to be made the engine circuits are shunted when the shoe makes contact with the brush. No speed control features were included.

B. F. WOODING.

Certain parts of this device were examined in New York, N. Y., on September 6, 1919. This device is of the same type as that tested on the Delaware, Lackawanna & Western Railroad by the Bureau of Safety, Interstate Commerce Commission, in 1917. The ramp is of special design, having two hinged leaves that are forced apart by the shoe or knife contact on the engine. At the same time the shoe is forced downward in a vertical plane, operating the contacts of the engine. Speed control is provided by a special cam on the engine, operated in accordance with the speed of the train when the engine shoe engages the ramp.

Insulated Truck, with Short Track Circuit Section, Type (I–B–1).

SAFETY BLOCK SIGNAL CO.

Inspected September 4, 1919, at Philadelphia, Pa. This apparatus had been installed experimentally on the Huntingdon & Broad Top Mountain Railroad. The apparatus examined comprised only an air valve and a throttle-closing device which had been on an engine for about two years, although only in service six months. As installed both tender trucks were insulated but no detector circuit was used to show a failure of the insulation. No speed control features were provided.

INDUCTION TYPE (I-C-1).

M-V ALL-WEATHER TRAIN CONTROLLER CO.

Inspected November 1, 1919, at the company's shop in Newark, N. J. Electromagnets for the roadside apparatus are energized as the train approaches and they act on the collecting coils of the train apparatus to allow the train to proceed. To provide time for the engine apparatus to act, a group of magnets must be placed at each indication point. A train occupying the block shunts the energizing battery of the roadside coils in the rear so that a following train would be stopped. Speed control is provided.

NATIONAL SAFETY APPLIANCE CO.

Inspected May 5 and 6, 1919, at the company's shop at San Francisco, Calif., and at the road installation at Oroville, Calif. Three roadside magnets were installed at Oroville, on the Western Pacific Railroad, and one engine equipped. The roadside apparatus consists of a permanent magnet with neutralizing coils to give a proceed indication. The train apparatus includes a permanent magnet that is influenced when it passes over the unneutralized field of the roadside apparatus. No speed control is provided.

SPRAGUE SAFETY CONTROL AND SIGNAL CORPORATION.

Inspected June 3, July 7, and September 10, 1919, at the company's laboratory in New York, N. Y. Permanent magnets are used on the roadside to produce approach and stop indications, and electromagnets to reset the train apparatus. Neutralizing coils are used to deflect the magnetic field of the permanent magnets when conditions are proper to proceed. The train apparatus includes pole pieces that attract an armature to break the train holding circuit when passing over the unneutralized field of a permanent magnet. Speed control, based upon the speed of the train and the braking effort, is provided. The device is designed so that no automatic application of the brakes will be produced as long as the speed of the train is controlled in accordance with the signal indications.

INERT ROADSIDE ELEMENT TYPE (I-C-2).

GENERAL RAILWAY SIGNAL CO.

Inspected July 23 and September 29, 1919, at the laboratory of the company in Rochester, N. Y. The roadside apparatus consists of coils arranged around a U-shaped laminated core. The terminals of the coils are joined through contact of relays in the signal circuit. The train apparatus consists of similar coils designed to pass directly over the roadside coils. The current in the train coils is greatly reduced when the train coils come within range of the roadside coils, if the terminals of the latter are not joined. An electron amplifier is used to vary the current in a circuit of the train apparatus to produce the results desired. No battery is required for the roadside apparatus. No speed control features were used.

Nonmagnetic Rail Type (I–C–3).

AUSTEN H. FOX.

Inspected June 7, 1919, in the laboratory of the Fox-Lenderoth Co. in New York, N. Y. This apparatus is now in process of development. Only the engine collecting device was examined. This device uses nonmagnetic rails at indication points. No speed control was provided.

Induction Type (II–B–1).

PITTSBURGH TRAIN CONTROL CO.

Inspected July 10, 1919, at the company's laboratory in Pittsburgh, Pa. The induced field around the rails of an alternating current track circuit is used to produce the proceed indication. Train collecting coils are constantly within range of this field and are connected to an electron tube amplifier to control the train apparatus. The stop indication is produced by the absence of alternating current in the track circuit. This is accomplished between the approach and stop signals by changing the character of the track circuit from an alternating current to a direct current circuit and between the stop signal and the obstruction due to the absence of track circuit current. A manually operated valve is provided so that the engineman may assume control of the train at any time or may prevent an automatic application of the brakes. No speed control is provided.

UNION SWITCH & SIGNAL CO.

Inspected July 8, 1919, at the company's shop, Swissvale, Pa. The operation depends on induced fields around the running rails in which alternating current for the regular track circuit, and in addition an alternating current in the same direction in both rails, with a line wire return, are used. Two pairs of collecting coils are carried on the train so as to always be in range of the induced fields. One pair of coils picks up current due to the field created by the track circuit current and the other pair picks up current due to the field created by the rail-line wire circuit. Each pair of coils is connected to an electron tube amplifier, the secondary circuits of which control a three position, two element, alternating current relay. The polarity of either of the two roadside circuits may be reversed to provide approach and proceed indications. The absence of current in either or both circuits produces a stop indication. The device is designed so that no automatic application of the brakes will be produced as long as the speed of the train is controlled in accordance with the signal indications. A centrifugal governor controls air valves to provide speed control.

Wireless Type (II-B-2).

THOMAS E. CLARK.

Inspected July 26, 1919, at his laboratory in Detroit, Mich. This wireless device is in the experimental stage.

Combination Insulated Truck and Inert Roadside Element Types (I-B-1 and I-C-2).

SCHWEYER ELECTRIC & MANUFACTURING CO.

Inspected September 5, 1919. A test installation was located on the Colebrookdale Branch of the Philadelphia & Reading Railroad. Six indication points were installed. They were controlled in different ways through the track circuit, by switch in the station or by circuit controllers on signals. The roadside apparatus consisted of a laminated steel element to cooperate with the train apparatus to produce a stop, and a short track section, controlled through the signal circuits, to work in connection with insulated parts of the engine to give a proceed indication. The train apparatus consisted of a choke coil supplied with alternating current from a generator on the train and also the necessary control relays and valves. Speed control was provided.

Combination Plain Mechanical Trip and Induction Types (I-A-1 and I-C-1).

RICHARDS-FORD TRAIN CONTROL CO.

Inspected September 3, 1919, at the office of the company, Baltimore, Md. A ramp is used to produce a stop by opening the circuit for the train apparatus. The circuit for controlling the train apparatus is maintained by the cooperation of the armature on the train relay and the roadside magnet, if the conditions are proper to proceed. Two ramps, located different distances from the running rails, are used to give the approach and the stop indication. The only apparatus constructed was the train pick-up relay and the indication magnet. No speed control was provided.

GENERAL DISCUSSION.

A congressional enactment in 1906 directed the Interstate Commerce Commission to investigate and report upon the subject of automatic train control. In compliance with this legislation the commission on February 23, 1907, submitted a report to Congress in which it was recommended that official tests of automatic appliances for the control of railway trains, conducted at Government expense, be authorized by Congress. This recommendation was favorably acted upon, and in the appropriation act of March 4, 1907, an item of $50,000 was provided for that purpose. This authorization and the appropriation making it effective was extended and continued by the sundry civil act of May 27, 1908, since which date the commission has continuously conducted examinations and tests of train-control devices of various types and made reports setting forth the results thereof. Coincident with the work of the Interstate Commerce Commission, investigations and tests have been conducted by a number of railroad companies, and this committee has had the benefit of much of the information gained from both Government and railroad sources.

The installation of automatic train control appears feasible—assuming that a type to satisfactorily meet the operating conditions will be fully developed—to protect trains moving with the established direction traffic on main tracks, but it is doubtful if a device can be developed to protect all movements in the large terminals without restricting train movements to a prohibitive degree. The necessity for automatic train control must be developed in each individual case.

As automatic train control is most necessary for the protection of high-speed trains, the apparatus must be suitable, with reasonable maintenance, to operate efficiently on such trains at the highest permissible speed and must not restrict the operation of the engine over any track which it may use. The brake application as made by the train-control device must be such as to safely bring the trains of various classes to a stop without endangering the controlled train or trains on adjacent tracks more than would occur if the brakes were applied by the engineman.

The fact that automatic train-stop devices of the electrically controlled mechanical trip type are operated with a high degree of success on certain underground and elevated tracks can not be regarded as conclusive evidence that such devices, or devices of other types intended to accomplish similar results, would be practical for use on tracks in the open country, subject to entirely dissimilar operating conditions. On the tracks where these devices are in successful use trains run are for passenger service and their equipment is uniform in character; they are moved at comparatively moderate speeds; clearance conditions are uniform, and there are no weather conditions present to interfere with proper operation. On roads in the open county, on the other hand, the equipment of trains is not uniform, and the variation in train speeds is great; there is also great variation in the length and weight of trains, so that the breaking effort required varies widely between trains of different make-up. Clearance and weather conditions on tracks in the open country also present difficult problems which are not present on underground and elevated tracks.

The committee believes that any comprehensive study of automatic train control must begin with the block system, as the principle of the block system is fundamental to the subject and must be the foundation of any automatic train-control system. The term "block system" covers any means for maintaining an interval of space between trains as distinguished from establishing an interval of time between trains at specified points. The signals used in the block system on the railroads of this country indicate the condition of the blocks governed and convey certain information to employees responsible for the safe movement of trains. An automatic train-control device is not a substitute for the block system, but is merely a means for compelling observance of the rules and practices prescribed for its operation, thus insuring that the block system, or space-interval method of train operation, will be observed.

The superiority of the block system as compared with other methods of train operation is generally recognized. It is in use on practically one hundred thousand miles of railroad line, including the busiest railroads or the busiest parts of practically all railroads in this country. Notwithstanding the fact that accidents occur on block signaled roads, the use of the block system is beyond question attended by a material increase in the safety of train operation and travel. The first step, therefore, which should be taken on lines which are not operated under the block system, in order to meet the need for more complete train protection, is not experimentation with or the adoption of some form of train-control device but the adoption of the block system itself, concerning which the results of years of experience in practical service on thousands of miles of railroad are available, firmly establishing its functions and value.

The amount of apparatus required and the rules and practices necessary to be followed to render the block system adequate for any railroad depend upon traffic and operating conditions. On many lines where traffic is light a simple form of manual block system with the enforcement of proper rules is adequate; on busy lines an automatic block signal system, together with the enforcement of proper rules and practices, is necessary to economically provide protection for train movements, and the proper field for the use of automatic train-control devices is in connection with this latter class. The consideration of automatic train-control devices should be confined to this field, and any pressure or clamor for the introduction and use of such devices should not be permitted to divert attention from or obstruct progress in the vastly more important field of extending the use of the block system and instituting improvements in block signal apparatus and practices already in use. Constant progress and development is required to keep pace with traffic needs.

Limiting the consideration of automatic train-control devices to their proper field of usefulness in connection with automatic signals, however, should not be construed as minimizing the importance of possible value of such devices. The practical development of automatic train-control devices and their use to supplement existing automatic block signals for the purpose of compelling obedience to signal indications is highly desirable.

The use of train-stopping devices on lines where trains are run on close headway will require the use of some form of speed-control apparatus in order to maintain the required capacity. The need of speed control is recognized, but little progress has been made in meeting the requirements. Some of the conditions under which speed control may be used are the following:

1. To prevent a predetermined speed being exceeded regardless of track conditions.

2. To permit a train to proceed at a predetermined low speed after having been stopped by an automatic brake application.

3. To permit a train to pass a brake application point at a predetermined speed without receiving an automatic brake application.

4. To permit a train to pass an approach indication point without an automatic brake application providing the engineman properly observes the approach indication.

5. To permit a train to proceed without an automatic application of the brakes as long as the speed of the train is controlled in accordance with the signal indications.

In a considerable number of the tests of automatic train-control devices which have been conducted during the past several years the apparatus tested has been far less substantial and rugged in construction than modern signal and interlocking apparatus in common use, notwithstanding that the operating conditions and requirements are, generally speaking, more severe for train-control than for signal devices. In some cases also the installations tested were only temporary, and the apparatus was not so constructed and installed that successful operation for a considerable period of time could reasonably be expected. Many of these devices have been developed and tested by persons who were not familiar with signal apparatus in common use nor with many of the problems which are encountered in the application of these devices to railroad operating conditions. The development of signal apparatus and interlocking devices has been comparatively slow process, during which countless devices have been proposed, many of them tested and used in actual service, and a comparatively small percentage retained in their original form. It follows that the development of automatic train-control devices will probably be along similar lines.

Generally speaking, it may be said that the tests which have thus far been conducted have demonstrated that the functions of automatic train-control devices are possible of accomplishment under actual service conditions. But while these functions may be accomplished under the conditions existing at comparatively isolated locations, with the high degree of maintenance ordinarily given to test installations of this character, it is an entirely different problem, and a far more complex one, to apply these devices to the various operating conditions encountered in railroad service, and to accomplish these functions day and night, year in and year out, on a large number of trains and on several hundred miles of a busy railroad. From a practical standpoint, automatic train-control devices are still in the development stage, and many problems in connection with their practical application remain to be solved.

Development of automatic train-control devices by individual enterprises must of necessity be extremely slow, and it is believed that the time has come when more active cooperation should be undertaken by the railroads. To accomplish this task a systematic study of the problem must be continued, available engineering talent must be utilized to design and construct apparatus suitable for the purpose intended, apply it to meet various operating conditions, and conduct experiments on a more comprehensive scale than has been done in the past.

CONCLUSIONS.

The committee has reached the following conclusions:

1. That the relative merits of the various types of automatic train control can not be determined until further tests have been made.

2. That more extended service tests, including complete records of performance are necessary before a decision can be reached on the availability for general practical use of any of the devices that have been brought to the attention of the committee.

3. That on a large part of the railroad mileage in the United States, with a given amount of money available for protection purposes, a greater degree of safety can be obtained by installing block signals than by installing automatic train control devices.

4. That on lines of heavy traffic, fully equipped with automatic block signals, the use of train control devices is desirable.

5. That complying with its instructions and without implying indorsement, the committee finds the following devices available for further test:

American Railway Signals Co	Intermittent electrical contact type.
American Train Control Co	Do.
Automatic Control Co	Electrically controlled mechanical trip type.
Casale Safety Device Co	Intermittent electrical contact type.
Clifford Automatic Train Stop Co	Electrically controlled mechanical trip type.
General Railway Signal Co	Intermittent electrical contact type.
Do	Inert roadside element.
International Signal Co	Intermittent electrical contact type.
Miller Train Control Corporation	Do.
National Safety Appliance Co	Induction type.
Nevens-Wallace Train Control Co	Electrically controlled mechanical trip type.
Schweyer Electric & Mfg. Co	Inert roadside element.
Shadle Automatic Train Signal Co	Intermittent electrical contact type.
Sprague Safety Control & Signal Corporation	Induction type.
Union Switch & Signal Co	Continuous induction type.
Wooding, B. F	Intermittent electrical contact type.
Willson-Wright Safety Appliance Co	Electrically controlled mechanical trip type.

6. That it does not appear necessary to make tests of all of the devices of a type to determine the availability of that type for general practical use.

7. That a committee on automatic train control should be continued.

RECOMMENDATIONS.

The committee therefore submits the following recommendations:

1. That this or a similar committee be continued to the end of Federal control, extending the present provisions for the employment of a permanent staff.

2. That at the termination of Federal control the work of this committee be continued under the American Railroad Association. On account of the importance of the subject the work should be done by a special committee, having the same standing as a section of the association. The Bureau of Safety of the Interstate Commerce Commission should, as now, have representation on this committee. This committee should include in its work:

(*a*) Analysis of the reports of train accidents now made to the Interstate Commerce Commission.

(*b*) Authorization of tests to be undertaken and such supervision of them, in cooperation with the Interstate Commerce Commission, as may be necessary.

3. That arrangements be made by the Railroad Administration or after the termination of Federal control by the American Railroad Association, for the further practical test, under rules that may be adopted by the committee, of such devices as may be available for that purpose. Such tests should include in form prescribed by the committee:

(*a*) Record of performance.

(*b*) Record of installation cost, separated between roadside and train apparatus, and into unit costs.

(*c*) Record of cost of modifications of the existing signal system to accommodate the test installation.

(*d*) Record of direct operation and maintenance costs.

The committee has been efficiently aided in its work by its secretary, Mr. G. E. Ellis, and its signal engineer, Mr. E. L. Adams. It also wishes to express its appreciation of the hearty cooperation received from railroad officers and the proprietors and inventors of the devices examined.

Respectfully submitted:

A. M. BURT, *Chairman.*
H. S. BALLIET,
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NOVEMBER 29, 1919.

Mr. Bartlett, being absent in Europe, was unable to sign this report.

To Mr. W. T. TYLER,
Director of Operation.

DEFINITIONS OF TERMS USED IN THIS REPORT.

Advance (in advance of):

The space beyond the point referred to relative to an approaching train.

Amplifier (see Audion):

A device in which the current in one circuit is increased by the change in characteristics in another circuit connected to the device.

Apparatus:

The group of elements carried on the train or placed on the roadside.

Audion (see Pliotron):

A glass tube or bulb resembling an incandescent lamp from which the air has been exhausted. The tube contains three elements, a filament, a plate, and a grid with terminals for connection to outside circuits. The device is intended to change the amount, or characteristic, of a current flowing through the plate filament circuit as the potential of the grid is changed. The filament must be heated to incandescence before current will flow in plate-filament circuit. The potential on the grid is supplied from another source and as this potential changes the current in the plate-filament circuit changes.

Circuit, holding (see Holding circuit).

Circuit, normal closed:

A circuit arranged so that its continuity is normally unbroken or so that a condition, such as a break, a cross, or a failure of source of power that would prevent the proper operation of the controlled device, would be self-evident by producing the result for which the apparatus was designed.

Circuit, normal open:

A circuit arranged so that its continuity is normally broken at one or more points, and so that a condition, such as a break, a cross, or a failure of source of power that would prevent the proper operation of the controlled device, would not be self-evident by producing the result for which the apparatus was designed.

Circuit, pick-up:

A circuit that is completed either by the closing of a manually operated circuit controller or by cooperation between a train element and roadside element to restore the train apparatus to the proceed position or to hold it in the proceed position when passing a signaling point.

Circuit, "stick" (see Stick relay):

The control circuit for a stick relay.

Collecting coils:

Coils of wire carried as a part of the train apparatus and in which current is induced by currents or magnetism in the roadside element.

Device:

The combination of the apparatus on the train and that on the roadside necessary to produce an automatic stop at one location.

Electron amplifier (see Amplifier).

Element:

One of the parts that make up the train or roadside apparatus.

Holding circuit:

The circuit that holds the train apparatus in the "proceed" position.

Main reservoir cut-off (see Nonrelease valve).

Mechanism:

An element, either of the roadside or train apparatus, having moving parts.

Nonrelease valve:

A valve designed to shut off the supply if air from the main reservoir to the train brake pipe when an automatic application of the brakes is made, thereby preventing the release of brakes through the engineman's brake valve until the purpose of the automatic application has been accomplished.

Pliotron (see Audion):

A device having practically the same characteristics as the Audion and used for similar purposes.

Polarized relay:

A relay having an armature that moves or rotates in one direction or the other, dependent on the direction of current in its coils. The relay may be operated by either direct or alternating current. A three-position relay is a polarized relay. A permanent magnet in proper relation to an electromagnet may be used in direct current types.

Ramp:

A metal bar with an inclined upper surface fixed on the roadside in permanent relation to the track to lift the vertically moving part of the shoe and, when necessary, to form a part of the pick-up circuit.

Rear (in rear of):

The space before passing the point referred to relative to an approaching train.

Release button or switch:

A manually operated button or switch, the operation of which will permit the release of the brakes after an automatic stop has been made.

Shoe:

The element of the train apparatus that includes the contact piece, circuit controllers, air valves, etc., that control the train apparatus when in contact with, or within the influence of, the roadside element. The shoe is generally carried on the frame of the engine or tender truck.

Speed control:

A device to control the automatic application of the brakes, dependent on the speed of the engine. It may or may not require the cooperation of the engineman to make it effective.

Stick relay:

A relay that is held energized through one of its own contacts so that when its holding circuit is opened an auxiliary pick-up circuit must be closed to restore the normal operation.

System, train control:

A number of installations of the device to provide control over a certain section of track, the different groups of apparatus being properly interconnected, mechanically or electrically, to produce the desired result.

Three-position relay (see Polarized relay).

Trip arm:

A movable rod or arm carried on the train or located on the roadside and intended to cooperate with a corresponding element on the roadside or the train, respectively, to produce a stop when conditions require it.

Trip rail:

A movable rail or ramp located on the roadside and capable of being moved into or out of position to engage the proper element of the train apparatus, dependent on whether a stop is to be produced or not.

APPENDIX I.

Plans and Devices Examined.

The committee examined 37 devices in various stages of development as described in the body of the report. All types except one were represented and these were distributed among the various types as follows:

Plain mechanical trip	1
Electrically controlled mechanical trip	10
Intermittent electrical contact	15
Insulated truck with short track circuit section	1
Intermittent induction	3
Inert roadside element	1
Nonmagnetic rail	1
Continuous electrical contact	0
Continuous induction	2
Wireless	1
Combined insulated engine and inert roadside element	1
Combined plain mechanical trip and intermittent induction	1

Of the above list, 14 possessed some speed control features as part of the device and 23 were without such features. Defects, classed as "open circuit," due to either the requirement of the application of energy to produce a brake application or to the possibility that essential parts might be removed or broken without producing a stop, existed in 6 devices.

Generally the governors used in those devices exhibiting speed control features have been of the centrifugal ball type, driven from an axle of the engine by belts of various kinds or by rigid connections. The method of transmission is obviously an important part of such a device and presents difficulties, some of which are due to the limited space available for the location of the speed control apparatus. One device examined took into consideration, in its speed control apparatus, the braking effect which would be produced by the engineman's handling of the train. Some purely electrical speed control apparatus has been examined, but none which has been subjected to any extensive tests. One device depended for its speed control on the impact between the engine contact element and the roadside contact element, as related to the speed of the train in reference to the rate of inclination of the roadside contact element to the track.

The use of amplifiers in the form of audions or pliotrons, designed to increase or modify the electrical energy in the train apparatus by the influence of the roadside element in noncontact types, is indicated in three devices. In each of the devices the amplifier is used in a different manner but they are all in the experimental stage and no tests under operating conditions have been made.

As stated in the report, more or less complete plans of 300 devices have been examined in addition to the plans of those that were inspected. These were divided among the various types as follows:

Plain mechanical trip	135
Electrically controlled mechanical trip	31
Intermittent electrical contact	63
Insulated truck with short track circuit section	9
Intermittent induction	4
Inert roadside element	0
Nonmagnetic rail	2
Continuous electrical contact	40
Continuous induction	2
Wireless	1
Combined intermittent induction and intermittent electrical contact	1
Combined nonmagnetic rail and intermittent electrical contact	1
Unclassified	11

The following is a list of all devices, plans of which were examined, arranged alphabetically:

Adkins, W. H	Continuous electrical contact.
Adler, Charles	Do.
Aird, W. S	Plain mechanical trip.
Allard, Andrew J	Intermittent electrical contact.
Allen, Dwight	Do.
American Railway Signals Co	Do.
American Signal Co	Insulated truck with short track circuit section.
American Train Control Co	Intermittent electrical contact.
Amick, P. A	Do.
Anderson, Joseph E	Continuous induction.
Annendt, J. C	Intermittent electrical contact.
Austin, William	Plain mechanical trip.
Automatic Control Co	Electrically controlled mechanical trip.
Automatic Electric Railway Block Signal Co.	Plain mechanical trip. Intermittent electrical contact.
Automatic Railway Appliance Co	Plain mechanical trip.
Backus, William E	Intermittent electrical contact.
Baldwin, C. W	Plain mechanical trip.
Barry, Garrett J	Do.
Battaglino, Joseph	Intermittent electrical contact.
Baum, F. J	Special.
Beaver, Thomas	Continuous electrical contact.
Bedrossian, Archie	Plain mechanical trip.
Begin, A. F	Insulated truck with short track circuit section.
Benedict, G. W	Plain mechanical trip.
Berger, A. C	Intermittent electrical contact.
Bess, Elijah	Plain mechanical trip.
Betz, Harry D	Wireless.
Bogart, Harry	Plain mechanical trip.
Bond, Harry M	Do.
Bostwick, F. F	See National Safety Appliance Co.
Bouillet, E	Continuous electrical contact.
Boulade, Jean	Intermittent electrical contact.
Bower, A. L	Plain mechanical trip.
Do	Intermittent electrical contact.
Bowersock, H. T	Plain mechanical trip.

Brew, T. A	Continuous electrical contact.
Brinson, Joseph G	Plain mechanical trip.
Brookins, Andrew J	Intermittent electrical contact.
Brosey, A. J	Do.
Brosvik, B. B	Special.
Brothers, George J	Plain mechanical trip.
Brownell, George W	Do.
Brubaker, J. L	Do.
Buck, J. G	Do.
Buell Signal & Train Control Co., Inc	Insulated truck with short track circuit section.
Buhl, C. R. H	Intermittent electrical contact.
Bulla, M. B	*See* Train Control Appliance Co.
Burbridge, H. J	Plain mechanical trip.
Button, F. E	Intermittent electrical contact.
Cabrera, Jose	Continuous electrical contact.
Carlisle, Bert	Special.
Carlisle, Howard	Continuous electrical contact.
Casale Safety Device Co	Intermittent electrical contact.
Casselman, J. B	Electrically controlled mechanical trip.
Cave, Elmore	Plain mechanical trip.
Chaloner, T. T	Do.
Chandler, J. L	Continuous electrical contact.
Clapp, Clark E	Plain mechanical trip.
Clark, Irving L	Do.
Clarke, Lee R	Do.
Clark, Thomas E	Wireless.
Clifford Automatic Train Stop Co	Electrically controlled mechanical trip.
Codire, P. F	Plain mechanical trip.
Coker, J. R	Intermittent electrical contact.
Conte, A. M	Plain mechanical trip.
Cooper, Bernard	Do.
Cornet, A. E	Do.
Coulombe, Arthur	Do.
Coulombe, O. J	Do.
Courtright, W. R	Do.
Crawford, John S	Do.
Crossland, D. W	Do.
Crossley, William	Do.
Currier, W. S	Do.
Curtis, C. J	Special.
Custer, John	Continuous electrical contact.
Dally, W. P	Insulated truck with short track circuit section.
Dansberry, William H	Plain mechanical trip.
Da Silva, Raul Ribeiro	Do.
Do	Electrically controlled mechanical trip.
Dawson, J. V	Plain mechanical trip.
De Ford, J. W	Do.
Dennette, Frederick	Electrically controlled mechanical trip.
Dettmer, J	Plain mechanical trip.
Devos, Charles	Do.
D'Narvarte, Juan	Do.
Dodge, A. Y	Intermittent electrical contact.
Doran, J. J	Plain mechanical trip.
Drake, George Alexander	Continuous electrical contact.
Drawbaugh, I. P	Plain mechanical trip.
Dungan, Ernest E	Continuous electrical contact.
Do	Intermittent electrical contact.
Eickhoff, Fred H	Do.
Electrical Automatic Railroad Safety Signal Co.	Do.
English, A. J	Plain mechanical trip.
Esworthy, J. W	Intermittent electrical contact.
Faufata, Namaka L	Do.
Fay, Bernard	Plain mechanical trip.
Filiberto, Nicola	Continuous electrical contact.
Do	Electrically controlled mechanical trip.

Finnigan, George P	Intermittent induction.
Fish, Edwin A	Plain mechanical trip.
Fockerynski, Joseph V	Continuous electrical contact.
Fox, Austen H	Nonmagnetic rail.
Frame, John	Plain mechanical trip.
Friedly, E. R	Do.
Fry, Walter	Do.
Fulks, M. R	Do.
Fuller, R. E. Co	Do.
Do	Do.
Do	Continuous electrical contact.
Gadeholt, Bjorn	Special.
Gainer, A. L	Plain mechanical trip.
Garrison, G. B	Do.
General Railway Signal Co	Intermittent electrical contact.
Do	Inert roadside element.
General Safety Appliance Co	Combined intermittent induction and intermittent electrical contact.
Gerlach, George W	Intermittent electrical contact.
Ghent & Webler	Plain mechanical trip.
Gibbons, W. A	Do.
Giles, William E	Insulated truck with short track circuit section.
Gilkeson & James	Plain mechanical trip.
Gladish, W. J	Electrically controlled mechanical trip.
Golles Railway Signal Co. of America.	Intermittent electrical contact.
Goodpasture, Charles H	Plain mechanical trip.
Gorsuch, E. W	Intermittent electrical contact.
Goveia, Ervin M	Plain mechanical trip.
Gramm, John A	Do.
Gray-Thurber	*See* Pittsburgh Train Control Co.
Gumm, G. J	Plain mechanical trip.
Guthner, Albert L	Do.
Hanna, Jacob	Continuous electrical contact.
Hardy, J. O	Plain mechanical trip.
Hawkins, Hubert C	Electrically controlled mechanical trip.
Heald, Leonard	Special.
Heales, George	Plain mechanical trip.
Heath, Frank	Electrically controlled mechanical trip.
Hedges, I. W. and R. F	Plain mechanical trip.
Hellman, Lui F	Do.
Hennessy, D. E	Intermittent electrical contact.
Henry, F. G	Continuous electrical contact.
Hermance Machine Co	Intermittent electrical contact.
Hickman, Harry	Do.
Higgins, W. J	Intermittent induction.
Hitselberger, L	Plain mechanical trip.
Hochstein, A. P	Do.
Hoffman, James L	Continuous electrical contact.
Hole, C. C	Electrically controlled mechanical trip.
Hollinger, A	Continuous electrical contact.
Holt, John	Do.
Horchler, William	Plain mechanical trip.
Horne, L. W	Nonmagnetic rail.
Howard, C. L	Plain mechanical trip.
Huber-Williamson	*See* Pittsburgh Train Control Co.
Hudson, Frederick F	Intermittent electrical contact.
Hudson Signal Sales Co	Continuous electrical contact.
Industrial Appliances, Ltd	Plain mechanical trip.
Inman E. R	Continuous electrical contact.
International Automatic Signal Co	Insulation truck with short track circuit section.
International Signal Co	Intermittent electrical contact.
Jenke, Carl F	Plain mechanical trip.
Jensen, S	Do.
Johnson, Arnold O	Continuous electrical contact.

Johnson, Jeremiah	Intermittent electrical contact.
Johnson, W. H	Plain mechanical trip.
Joly, Cezaire	Do.
Josephson, A	Intermittent induction.
Julien-Beggs Signal Co	*See* American Railway Signals Co.
Kamiske, C. G	Plain mechanical trip.
Karl, William, and Karl H	Intermittent electrical contact.
Kern. John D	Do.
Khouhesserian, Hagop H	Do.
Knight Brothers	Plain mechanical trip.
Koch, George	Do.
Kogler, Peter J	Do.
Kohlback, Henry F. W	Special.
Krummel, William R	Plain mechanical trip.
Labit, G. E	Do.
Lawson, Clarence	Do.
Leach, F. I	Do.
Lenz, Charles S	Electrical controlled mechanical trip.
Leon, F	Plain mechanical trip.
Littleton, A. S.	Continuous electrical contact.
Lodge, H	Insulated truck with short track circuit section.
Loughridge, M. H	Intermittent electrical control.
Lumb, Charles F	Plain mechanical trip.
Lutschg, Fred M	Intermittent electrical contact.
Macfarlane Communications Corporation.	Continuous electrical contact.
Mahoad, Homer F	Intermittent electrical contact.
Mainardi Brothers	Continuous electrical contact.
Mansfield, W. Thomas	Plain mechanical trip.
Martell, Stephen	Electrically controlled mechanical trip.
Mathis, Paul Neree	Plain mechanical trip.
Matthias, B. F	Do.
Maxey, John	Do.
McArthur, T. W	Continuous electrical contact.
McCollom, William R	Electrically controlled mechanical trip.
McIntyre, M. J	Plain mechanical trip.
McKay, Richard F	Intermittent electrical contact.
Mendonca, J. C	Special.
Merryweather, James	Plain mechanical trip.
Milde, Franz	Do.
Miller, R. L	Electrically controlled mechanical trip.
Miller Train Control Corp	Intermittent electrical contact.
Miner, J. R	Plain mechanical trip.
Mitchener, John Edward	Do.
Moore, John M	Do.
Morgan, C. W	Do.
Morgan, D. L	Intermittent electrical contact.
Morgan, J. A	Do.
Morgan, W. D. L	Plain mechanical trip.
Moulton, Richard L	Do.
Murphy, Albert C	Do.
Murphy, James P	Intermittent electrical contact.
Musy, Felix M	Electrically controlled mechanical trip.
Do	Intermittent electrical contact.
M-V All-Weather Train Controller Co	Intermittent induction.
National Safety Appliance Co	Do.
Nead, William S	Intermittent electrical contact.
Neely, S. L	Continuous electrical contact.
Nein, W. C	Intermittent induction.
Nelson, Buell C	Continuous electrical contact.
Nevens-Wallace Train Control Co	Electrically controlled mechanical trip.
Newton, D. C	Intermittent electrical contact.
Newton & Lindeman	Do.
Do	Do.
O'Connor, Charles J	Plain mechanical trip.

Oetting, O. W. A	Nonmagnetic rail.
Oliver, Nathan A	Plain mechanical trip.
Orcutt Automatic Train Control Co	Intermittent electrical contact.
Pate, M. M	Electrically controlled mechanical trip.
Patterson, W. C	Intermittent electrical contact.
Patterson, Warren C	Plain mechanical trip.
Pilger, George J	Do.
Pittsburgh Train Control Co	Insulated truck with short track circuit section.
Do	Intermittent electrical contact.
Do	Continuous induction.
Pond, Albert D	Electrically controlled mechanical trip.
Powell, John H	Do.
Prouty, E	Plain mechanical trip.
Putnam, A. G	Electrically controlled mechanical trip.
Quackenbush, William C	Intermittent electrical contact.
Query, Joseph O	Plain mechanical trip.
Quinn, P. J	Intermittent electrical contact.
Ramapo Iron Works	Electrically controlled mechanical trip.
Raymond Manufacturing Co	Intermittent electrical contact.
Reedy, M. W	Plain mechanical trip.
Reger, Kent	Special.
Reichman Bros	Intermittent electrical contact.
Reliostop	*See* Industrial Appliances (Ltd.).
Richards-Ford Train Control Co	Combined plain mechanical trip and intermittent induction.
Rideout, William A	Intermittent electrical contact.
Roberts, C. H	Continuous electrical contact.
Robinson, Peter J	Intermittent electrical contact.
Robinson, William	Continuous electrical contact.
Rockefeller, Arthur A	Plain mechanical trip.
Rodehaver, H. B	Continuous electrical contact.
Ruf, Henry C	Intermittent electrical contact.
Russ, Frank A	Plain mechanical trip.
Safety Block Signal Co	Insulated truck with short track circuit section.
Safety Signal Co	Electrically controlled mechanical trip.
Sammons, Thomas	Continuous electrical contact.
Samuels, John	Intermittent electrical contact.
Schaefer, John	Electrically controlled mechanical trip.
Scheidt, Henry C., jr	Plain mechanical trip.
Schmidtke, C. W	Do.
Schneider, George	Do.
Schneider, Peter	Electrically controlled mechanical trip.
Schneider, William	Do.
Schultz, Emil H	Continuous electrical contact.
Schutte, Frederick A	Do.
Schweyer Electric & Manufacturing Co.	Combined inert roadside element and insulated truck with short track circuit section.
Scott, J. J	Plain mechanical trip.
Seeley, Enridge P	Do.
Shadle Automatic Train Signal Co	Intermittent electrical contact.
Shelton, R. M	Continuous electrical contact.
Silvene, Tony	Intermittent electrical contact.
Simmen Automatic Railway Signal Co.	Do.
Simms, Amos Hoffman	Electrically controlled mechanical trip.
Sindeband, M. L	Continuous induction.
Sketchley, F. A	Electrically controlled mechanical trip.
Skinner, J. H	Continuous electrical contact.
Slattery, Martin F	Plain mechanical trip.
Slingland, Leonard	Do.
Smith, A. E	Do.
Smith, Sidney Guy	Continuous electrical contact.
Sparhawk, Frank O	Plain mechanical trip.
Sparks, John G	Do.

Sprague Safety Control and Signal Corporation.	Intermittent induction.
Stafford, E. C	Intermittent electrical contact.
St. Clair, Frank	Plain mechanical trip.
Stebbins, H. O	Intermittent electrical contact.
Steele, Franklin, jr	Plain mechanical trip.
Stiegelmeyer, Edward	*See* Automatic Control Co.
Streit, Melville V	Continuous electrical contact.
Sullivan, J. Herbert	Intermittent electrical contact.
Taylor, A. G	Continuous electrical contact.
Thayer Automatic Signal & Train Control Co.	Intermittent electrical contact.
Thomas, C. P	Do.
Thomas, Charles P	Plain mechanical trip.
Do	Electrically controlled mechanical trip.
Thomas, M. E	Do.
Thompson Automatic Signal Co	Insulated truck with short track circuit section.
Todd, Robert H	Continuous electrical contact.
Toxey, Elliott	Intermittent electrical contact.
Do	Electrically controlled mechanical trip.
Train Control Appliance Co	Intermittent electrical contact.
Troyer & Hochstetler	Plain mechanical trip.
Tubman, S. A	Electrically controlled mechanical trip.
Turner, C. C	Intermittent electrical contact.
Union Switch & Signal Co	Continuous induction.
Vigliano, Joseph	Intermittent electrical contact.
Wade, Frank K	Do.
Walker, James L	Plain mechanical trip.
Walsh, William E	Do.
Walton, Frank A	Intermittent electrical contact.
Warne, Alfred Ernest	Plain mechanical trip.
Warthen Automatic Stop and Cab Signal Co.	Intermittent electrical contact.
Welch, W. H	Electrically controlled mechanical trip.
Whalen, E. V	Plain mechanical trip.
Wilbur, J. F	Do.
Williams, H. J	Intermittent electrical contact.
Wililams, William L	Special.
Williams, William	Plain mechanical trip.
Willson-Wright Safety Appliance Co	Electrically controlled mechanical trip.
Wilson, George	Plain mechanical trip.
Wilson, Henry W	Do.
Wintsch, Max Th	Combined intermittent electrical contact and nonmagnetic rail.
Do	Intermittent electrical contact.
Wooding, B. F	Do.
Worden, Aden M	Special.
Wulff, E. H	Plain mechanical trip.
Youngen, S. I	Do.
Zettel, Louie A	Do.
Zwickle, John	Do.

APPENDIX II.

Bibliography.

American Railway Association:
Report on Automatic Train Stops—
Railway and Engineering Review, July 19, 1913.
Railway Age Gazette, May 29, 1914.
Reports of Joint Committee on Automatic Train Stops: April 21, 1913; October 20, 1913; April 20, 1914; November 10, 1914—
Proceedings of the American Railway Association 1913–1915.

American Railway Engineering Association:
Automatic Train Control.
American Railway Engineering Association Bulletin, February, 1919.

Angus, A. R.:
New System of Automatic Signaling and Automatic Train Stop, by O. O. Burge—
Railway and Engineering Review, August 17, 1912.

Bailey, Henry E.:
Automatic Train Stops—
Railway and Engineering Review, February 27, 1909.
Block Signals and Safety Stops—
Railway and Engineering Review, February 19, 1910.

Belnap, H. W.:
Report on Automatic Train Control—
Railway Review, Jannary 13, 1917.

Biddle:
Biddle's Automatic Train Control—
Railway Gazette, June 22, 1917.

Blair, H. Avery:
The Perry-Prentice Wireless Signaling System—
International Railway Congress Bulletin, August, 1909.

Block Signal and Train Control Board:
Rowell-Potter Safety Stop—
Second Annual Report, 1909.
Harrington Train Control and Alarm—
Third Annual Report, 1910.
Lacroix Train Control System—
Fourth Annual Report, 1911.
Block Signals and Automatic Control—
Railway Library, 1911.
Conclusions and Recommendations, December 6, 1911.
Final Report, June 29, 1912—
Annual Reports of the Interstate Commerce Commission.

Bostwick, F. F.:
Cab Signals and Automatic Stops at Oroville—
Railway Age Gazette, November 26, 1915.

Brownell:
Brownell's Automatic Stop—
Railway Age Gazette, October 1, 1915.
A New Type of Automatic Railroad Stop—
Scientific American, August 28, 1915.

Buell, Joseph W.:
Analysis of Railway Signaling and Presentation of a Plan for Better Safeguarding Railway Travel. (Washington, D. C., 1907.)
The Buell Cab Signal System. (Washington, D. C., 1905.)
Buell's Cab Signal and Automatic Train Stop—
Railway Age Gazette, November 12, 1915.

Burge, O. O.:
New System of Automatic Signaling and Automatic Train Stop Invented by A. R. Augus—
Railway and Engineering Review, August 17, 1912.

Canadian Engineer, February 23, 1911:
Prentice Wireless Train Control. Illustration of devices recently tried on the Canadian Pacific Railroad.

Carlyle, S. S.:
Making Collisions Impossible—
Technical World, October, 1909.

Carson-Burgess:
Carson-Burgess Cab Signal and Automatic Train Stop—
Railway and Engineering Review, March 30, 1912.

Carter, Charles F.:
When the Engineer Forgets—
Technical World, March, 1913.

Cary, Harold:
Hands Off the Throttle—
Technical World, October, 1915.

Cassier's Magazine:
May, 1911—
The Harrington Safety Stop.

Central Railway Club Proceedings:
May, 1912—
Prentice Wireless Train Control.

Chatfield, C. E.:
Cost of Automatic Train Control—
Railway Review, October 21, 1916.

Coleman, F. C.:
Automatic Wireless Train Control—
Scientific American, December 5, 1913.

Dammond, William H.:
Cab Signals and Train Stops—
Railway News, March 7 and 21, 1914.

Dayton, Thaddens S.:
The Wreckless Railroad—
Harper's Weekly, February 22, 1912.

Dearden, W. H.:
Safety in Railroads—
Harper's Weekly, October 18, 1913.
Incentive to Invention—
Outlook, July 26, 1913.

Detroit:
The Detroit Automatic Train Control—
Railway Gazette, September 26, 1913.

Edison Monthly:
May, 1913—
Train Control—The MacDonald System.

Electric Journal:
October, 1913—
Automatic Control of Trains, by L. V. Lewis.

Electric Review and Western Electrician:
February 7, 1914—
Electric Automatic Railway Signaling System Used in England.

Electric Traction:
November, 1916—
Norfolk Automatic Car Stop Installation.

Elliott, W. H.:
An Expert's Experience With Automatic Stops—
Railroad Gazette, March 6, 1903.
Automatic Train Control.
Railway and Engineering Review, November 28, 1908.

Engineer (London):
January 16, 1914—
Automatic Train Control on the Great Western Railway.
August 29, 1913—
Automatic Wireless Train Control. (Prentice System.)
March 9, 1917—
Railway Collisions at Wigan and Kirkbridge.
July 20, 1917—
Description of the General Electric Railway System of Automatic Train Control for Westinghouse Brake.
Engineering.
July 13, 1906—
The Raymond Phillips System of Train Control.
Engineering News.
Vol. 71, 1914—
Automatic Train Stop or Train Control Systems.
January 30, 1913—
British Opinion on Railway Automatic Stops, by H. Raynor Wilson.
March 6, 1913—
Collision in a London Subway. Failure of an Automatic Stop.
October 8, 1914—
Train Stops on the Chicago & Eastern Illinois Railroad.
Farnsworth, F. L.:
Mechanical Brains for Engines.
Railroad Man's Magazine. October, 1917.
Gollos:
Developments in the Gollos Automatic Train Control.
Railway Age Gazette, March 21, 1916.
Gollos Automatic Stop.
Railway Age Gazette, August 6, 1915.
Test of Automatic Stop System.
Railway Review, August 7, 1915.
Test of Gollos Automatic Train Stop, Chicago Great Western Railroad.
Railway and Engineering Review, October 26, 1912.
Report on Automatic Train Control System by Interstate Commerce Commission.
House Document 1192, 64th Congress, 1st Session.
Gradenwitz, Alfred:
An Automatic Railway Stop—
Scientific American. January 8, 1910.
Gray-Thurber:
Gray-Thurber System of Automatic Train Control as Applied to an Automatic Signal System—
Railway Engineering and Maintenance of Way, November, 1914.
Illustrated Lecture on Train Control delivered before Brotherhood of Locomotive Firemen and Enginemen, June 18, 1913, at Washington, D. C., by Guy P. Thurber.
The Conservation of Human Life in Steam and Electric Railroad Travel—
Official Proceedings of Railway Club of Pittsburgh, February 24, 1911.
Track Insulation Stops the Trains in this Automatic Control System—
Popular Science Monthly, March, 1918.
Report of the Chief of the Division of Safety, Interstate Commerce Commission, for 1914—
House Document 1482, 63d Congress, 3d Session.
Report of the Chief of the Division of Safety, Interstate Commerce Commission, for 1915.
Harper's Weekly:
February 22, 1912—
The Wreckless Railroad, by Thaddeus S. Dayton.
October 18, 1913—
Safety in Railroads, by W. H. Dearden.
Harrington:
Automatic Train Stopping Devices—
Cassier's Magazine, May, 1911.
The Harrington Safety Stop—
Harrington Automatic Train Stop.
Railway Age Gazette, May 5, 1911.
Mechanical Trip Automatic Stops—
Railway Age Gazette, May 19, 1911.
The Harrington Train Control and Alarm—
Third Annual Report of the Block Signal and Train Control Board, 1910.
Hendrick, Calvin W.:
A Railroad Adopts the Automatic Stop. Adoption of the Jones System by the Maryland & Pennsylvania Railroad—
Scientific American, September 20, 1913.
Horne & Crane:
Horne & Crane's Automatic Stop—
Railway Age Gazette, October 9, 1914.
Hudson & Manhattan Tunnel Signals and Automatic Train Stops:
Railroad Gazette, March 6, 1908.
Hunting, Gardner:
Railroad Trains Guard Each Other. Mac Donald System of Train Control—
Technical World, September, 1913.
Illustrated World:
December, 1915—
Stopping Trains from the Dispatcher's Office, by Stanley B. Lowe.
International Railway Congress Bulletin:
August, 1909—
The Perry-Prentice Wireless Signaling System, by H. Avery Blair.
Interstate Commerce Commission:
Report on Block Signal Systems and Appliances for the Automatic Control of Railway Trains. Washington, 1907.
59th Congress, 2d Session, Senate Doc. 342.
Report of the Chief of the Division of Safety, 1914—
Report of Test of the Automatic Train Control System of the American Train Control Company, Baltimore, Maryland—
63d Congress, 3d Session, House Doc. 1541.
Report of the Chief of the Division of Safety, 1915—
Report on Test of the Automatic Train Control System of the Gollos Railway Signal Company, which was conducted from August 10 to October 1, 1915, and from February 26 to March 31, 1916—
64th Congress, 1st Session, House Doc. 1192.
Report of Tests of the Wooding Train Control System Conducted by the Division of Safety, on the Delaware, Lackawanna & Western Railroad, January to April, 1917—
65th Congress, 1st Session, House Doc. 251.
Annual Report on Automatic Train Control—
Railway Gazette, May 25, 1917.
Iron Trail:
November, 1905—
A Remedy for Railroad Accidents, by B. C. Rowell. Rowell-Potter Safety Stop.
Jones, E. E.:
Automatic Signal and Automatic Stops on High Speed Electric Railways—
Pacific Railway Club Proceedings, August, 1917.
A Railroad Adops the Automatic Stop, by Calvin W. Hendrick—
Scientific American, September 20, 1913.
The Jones System of Automatic Train Control—
Railway and Engineering Review, March 1, 1913.

Jones, E. E.—Continued.
- Interstate Commerce Commission Report of Test of the Automatic Train Control System of the American Train Control Co., Baltimore, Md.—
  - 63d Congress, 3d session, House Doc. 1541.

Julian-Beggs:
- Automatic Speed Control. The Julian-Beggs Automatic Speed Control Apparatus—
  - Railway Age Gazette, March 16, 1915.
- Improved Julian-Beggs Train Control—
  - Railway Age Gazette, March 21, 1916.
- The Julian-Beggs Automatic Stop and Train Control System—
  - Railway Review, May 26, 1917.
- Julian Train Control and Automatic Stop—
  - Railway Gazette, November 12, 1915.
- The Julian Train Control and Automatic Stop. A description of the demonstration made on the Queen & Crescent and of the equipment required—
  - Railway Age Gazette, June 25, 1915.
- Cab Signals and Automatic Stops, by Stephen Smith—
  - Richmond Railroad Club Proceedings, May 15, 1916.
- Julian-Beggs System—
  - Address and Explanation of Julian-Beggs Automatic Stop and Train Control System.
    - Cincinnati Railway Club Proceedings, February, 1917.
- Test of the Julian-Beggs Train Control Signal System—
  - Railway Review, May 27, 1916.

Kinsman:
- The Kinsman Block System—
  - Railroad Gazette, June 8, 1894.
- Signals and Automatic Train Stops in the Hudson & Manhattan Tunnel—
  - Railroad Gazette, March 6, 1908.
- The Kinsman System—
  - Signals and Automatic Train Stops in the Hudson Tunnels—
    - Railway and Engineering Review, March 14, 1908.

Lacroix System:
- Making Collisions Impossible, by S. S. Carlyle—
  - Technical World. October, 1909.
- To Prevent Train Wrecks, by Robert H. Moulton—
  - Technical World, January, 1913.
- Seeking an Invention to Prevent Railroad Collisions. Interstate Commerce Commission makes test on Staten Island of Young Texan's Device—
  - New York Times, April 23, 1911.
- Lacroix Train Control System—
  - Block Signal and Train Control Board, Fourth Annual Report, 1911.

Lewis, L. V.:
- The Automatic Control of Trains. Explains the problem of automatic train control and reviews the devices brought into use, discussing features of the automatic stop—
  - Electric Journal, October, 1913.

Literary Digest (editorial):
- January 18, 1913—
  - Mr. Mellen's $10,000 prize. (Offered for a perfect automatic train control.)
- September 20, 1913—
  - The Necessary Engineer.
- January 2, 1915—
  - Comment under title "A Train Stop that Works."
- April 28, 1917—
  - The Coming of the Automatic Stop. From an editorial in the Railway Age Gazette, March 9, 1917, on the Mount Union collision.

Locomotive Firemen and Enginemen's Magazine:
- December, 1911—
  - Demonstration of the Miller Train Control System.
- July, 1916—
  - The Miller Train Control, by O. G. Tripp.

Lowe, Stanley B.:
- Stopping Trains from the Dispatcher's Office—
  - Illustrated World, December, 1915.

MacDonald System:
- Railroad Trains Guard Each Other, by Gardner Hunting—
  - Technical World, September, 1913.
- Train Control—
  - Edison Monthly, May, 1913.

MacIntosh, J.:
- Is the Safety Stop Practicable? Wireless System Successfully Tested on Canadian Pacific—
  - Railroad Man's Magazine, April, 1913.

McChord, C. C.:
- Commissioner McChord on Westport Derailment. Long crossovers demanded for all high speed trains. Railway called to account for neglecting automatic stop—
  - Railway Age Gazette, December 13, 1913.

McHenry, F.:
- The Automatic Railroad Stop—
  - Scientific American, August 23, 1913.

Mellen, Charles S.:
- The Truth, No. 3. (The Interstate Commerce Commission and Automatic Train Stops)—
  - Wall Street Journal, December 16, 1912.
- Mr. Mellen's $10.000 Prize. (Offered for a perfect automatic train control.)—
  - Literary Digest, January 18, 1913.
- Mellen's Price. (Offered for an automatic safety stop.)—
  - New York, New Haven & Hartford Railroad News, July, 1913.

Miller Train Control:
- An Automatic Train Control—
  - Railroad Man's Magazine, July, 1916.
- Automatic Train Stops on the Chicago & Eastern Illinois—
  - Railway Age Gazette, November 27, 1914.
- A Train Stop That Works—
  - Literary Digest, January 2, 1915.
- A Train Control That Works, by Joe Mitchell Chapple—
  - National Magazine, July, 1916.
- Demonstration of the Miller Train Control System—
  - Locomotive Firemen and Enginemen's Magazine, December, 1911.
- The Most Important Invention of the Times, by Elbert Hubbard—
  - East Aurora, N. Y., 1894.
- The Miller Automatic Train Stop—
  - Railway Age Gazette, June 5, 1914,
- The Miller Train Control. What it is and What it is Doing. The Train Control Securities Co.—
  - Washington, D. C., 1916.

Miller:
- Recent Developments in the Miller Train Control—
  - Railway Gazette, July 28, 1916.
- Train Stops on the Chicago & Eastern Illinois Railroad—
  - Engineering News, October 8, 1914.
- The Miller Train Control, by O. G. Tripp—
  - Locomotive Firemen and Enginemen's Magazine, July, 1916.

Moulton, Robert H.:
- To Prevent Train Wrecks—
  - Technical World, January, 1913.

National Magazine:
July, 1916—
A Train Control That Works, by Joe Mitchell Chapple.

New York, New Haven & Hartford Railroad's Automatic Stop Prize—
Conditions That Must Be Observed in the Competition for the $10,000 Award—
Scientific American, January 18, 1913.
Automatic Stop Competition—
Scientific American, March 29, 1913.
New York, New Haven & Hartford Railroad Company's Automatc Stop—
Scientific American, July 19, 1913.

New York, New Haven & Hartford Railroad News:
July, 1913—
President Mellen's Prize. (Offered for an automatic safety stop.)

New York Times:
April 23, 1911—
Seeking an Invention to Prevent Railroad Collisions. Interstate Commerce Commission Makes Test on Staten Island of Young Texan's Device.

Outlook:
July 26, 1913—
Incentive to Invention, by W. H. Dearden.

Pacific Railway Club Proceedings:
August, 1917—
Automatic Signaling and Automatic Stops on High Speed Electric Railways, by E. E. Jones.

Patterson:
System of Electric Cab Signals and Automatic Stop, Patented by Frederick Patterson to Prevent Collisions—
South African Railway Magazine, July, 1912.

Peabody, J. A.:
Automatic Control of Trains. Showing particularly the effect of automatic devices on the capacity of a road—
Signal Engineer, 1913.

Phillips:
Phillips Automatic Train Stop—
Railroad Gazette, May 31, 1907.
The Raymond Phillips System of Train Control. Brief illustrated description of this automatic train control system—
Engineering, July 13, 1906.

Prentice:
Automatic Wireless Train Control. Diagram and description of the Prentice System—
Engineer (London) August 29, 1913.
The Perry-Prentice Wireless Signaling System, by H. Avery Blair—
International Railway Congress Bulletin, August, 1909.
Automatic Wireless Train Control, by F. C. Coleman. Prentice System—
Scientific American, December 5, 1913.
Is the Safety Stop Practicable? Wireless system successfully tested on Canadian Pacific. By J. MacIntosh—
Railroadman's Magazine, April, 1913.
Wireless Train Control, by Frank W. Prentice—
Central Railway Club Official Proceedings, May, 1912.
Prentice System of Wireless Train Control on the Canadian Pacific Railroad—
Railway and Locomotive Engineering, February, 1911.
The Prentice Wireless System of Automatic Train Control—
Railway News, August 23, 1913.
Prentice Wireless Train Control. Illustrated description of this invention for the automatic control of trains which has recently been tried on the Canadian Pacific Railroad—
Canadian Engineer, February 23, 1911.
Prentice Wireless Train Control—
Railway Age Gazette, June 23, 1911.

Railroadman's Magazine:
April, 1913—
Is the Safety Stop Practicable? Wireless system successfully tested on Canadian Pacific, by J. MacIntosh.
October, 1917—
Mechanical Brains for Engines, by F. L. Farnsworth.
July, 1916—
An Automatic Train Control. The Miller Train Control.

Railroad Trainman:
July, 1913—
The Automatic Stop.

Railroad Gazette:
June 8, 1894—
The Kinsman Block System.
August 10, 1894—
Rowell-Potter Automatic Signals on the Chicago & South Side.
March 6, 1903—
A Discussion of the Inherent Difficulties in the Working of the Automatic Stop That Make Its Use Objectionable, by W. H. Elliott.
May 31, 1907—
Phillips Automatic Train Stop.
March 6, 1908—
Signals and Automatic Train Stops in the Hudson & Manhattan Tunnel.

Railroad Age Gazette:
October 9, 1908—
Automatic Stops and Cab Signals.

Railway Age Gazette:
January 28, 1910—
The Rowell-Potter Safety Stop.
May 5, 1911—
Harrington Automatic Train Stop.
May 19, 1911—
Mechanical Trip Automatic Stops.
June 16, 1911—
Waldron's Automatic Stop, by J. M. Waldron. A paper read before the Railway Signal Association, New York, June 14, 1911.
June 23, 1911—
Prentice Wireless Train Control.
August 30, 1912—
Automatic Train Control.
September 20, 1912—
Summary of information concerning the principal automatic stops in use, with notes on some of the more recent experiments.
September 27, 1912—
Automatic Stop or Cab Signal.
December 27, 1912—
Automatic Stop Experiment on the Lackawanna.
March 7, 1913—
The Effect of Block Signals and Automatic Stops on Accidents, by A. G. Shaver.
June 6, 1913—
The Automatic Train Control Problem. Some of the difficulties encountered in adapting automatic devices to miscellaneous railroad service, by A. H. Rudd.
April 11, 1913—
October 10, 1913—
Automatic Stops and Audible Signals.
December 13, 1913—
Commissioner McChord on Westport Derailment. Long crossovers demanded for all high speed trains. Railway called to account for neglecting automatic stop.
May 29, 1914—
A. R. A. Report on Automatic Train Stops.
June 5, 1914—
The Miller Automatic Train Stop.
July 10, 17, 24, 1914—
The Automatic Train Stop, I, II, III.
October 9, 1914—
Horne & Crane's Automatic Stop.
November 27, 1914—
Automatic Train Stops on the Chicago & Eastern Illinois.

Railway Age Gazette—Continued.
March 16, 1915—
The Julian-Beggs Automatic Speed Control Apparatus.
April 30, 1915—
Two recent accidents at Devon and Ilford, and the necessity for automatic train control.
June 25, 1915—
The Julian Train Control and Automatic Stop. A description of the demonstration made on the Queen & Crescent and of the equipment required.
August 6, 1915—
The Gollos Automatic Stop.
October 1, 1915—
Brownell's Automatic Stop.
October 8, 1915—
Cab Signals and Automatic Stops on the Western Pacific.
October 29, 1915—
Signal System and Automatic Stop on the Western Pacific at Oroville, Calif., criticized by M. Tainer.
November 12, 1915—
Buell's Cab Signal and Automatic Train Stop, by Joseph W. Buell.
November 26, 1915—
The Cab Signals and Automatic Stops at Oroville, by F. F. Bostwick.
March 21, 1916—
Developments in the Gollos Automatic Train Control.
March 21, 1916—
Improved Julian-Beggs Train Control.
April 13, 1917—
The Webb Automatic Train Stop. An automatic stop which tests its own integrity at every contact point and reports audibly to enginemen.
September 14, 1917—
Wooding's Automatic Train Stop. A spring-supported contact rail, made movable to break ice.
November 9, 1917—
Wooding's Automatic Stop.
July 19, 1918—
The Automatic Stop.

Railway Gazette (London):
September 26, 1913—
The Detroit Automatic Train Control.
November 12, 1915—
Julian Train Control and Automatic Stop.
July 28, 1916—
Recent Developments in the Miller Train Control.
October 6, 1916—
Car Signals and Automatic Stops on the Western Pacific Railroad.
November 17, 1916—
The Warmineter Collision and Automatic Train Control.
March 30, 1917—
The Board of Trade and Automatic Train Control.
May 18, 1917—
More Thoughts on Automatic Train Control.
May 25, 1917—
Interstate Commerce Commission's Annual Report on Automatic Train Control, 1917.
June 22, 1917—
Biddle's Automatic Train Control.
January 26, 1917—
Automatic Train Control Again.
August 3, 1917—
Automatic Train Control, Great Eastern Railway.
November 2, 1917—
Wooding's Automatic Train Stop.

Railway and Engineering Review.
March 15, 1902—
Rowell-Potter Safety Stop and Block Signals on the Chicago, Milwaukee & St. Paul Railway.

Railway and Engineering Review—Contd.
April 7, 1906—
Address on Safety Appliances, by B. C. Rowell.
January 18, 1908—
Automatic Stops and Cab Signals.
March 14, 1908—
Signals and Automatic Train Stops in the Hudson Tunnels.
October 17, 1908—
Report of Railway Signal Association Committee VI for year 1908—Automatic Stops and Cab Signals.
November 7, 1908—
December 19, 1908—
Automatic Train Control, by George W. Ristine.
November 28, 1908—
Automatic Train Control, by W. H. Elliott.
December 26, 1908—
Trial of the Rowell-Potter Block Signals and Automatic Stop.
February 27, 1909—
Automatic Train Stops, by Henry E. Bailey.
May 1, 1909—
Official Inspection of Rowell-Potter Automatic Train Control Apparatus.
October 16, 1909—
1909 Report of Railway Signal Association Committee VI — Automatic Stops and Cab Signals.
February 19, 1910—
Block Signals and Safety Stops, by Henry E. Bailey.
October 15, 1910—
1910 Report of Railway Signal Association Committee VI—Automatic Stops and Cab Signals.
June 17, 1911—
Automatic Train Control.
June 24, 1911—
Automatic Stop Device, Interborough Rapid Transt Co., by J. M. Waldron.
July 22, 1911—
Automatic Safety Device Effective.
October 28, 1911—
1911 Report of Railway Signal Association Committee VI—Automatic Stops and Cab Signals.
March 30, 1912—
Carson-Burgess Cab Signal and Automatic Train Stop.
August 17, 1912—
New System of Automatic Signaling and Automatic Train Stop, by O. O. Burge. Invention of A. R. Angus.
October 26, 1912—
Test of the Gollos Automatic Train Stop, Chicago Great Western Railway.
January 4, 1913—
Automatic Control of Trains, by B. C. Rowell.
February 8, 1913—
The Automatic Stop. Arguments Based on False Assumption.
March 1, 1913—
The Jones System of Automatic Train Control.
Failure of an Automatic Stop on an English Railway.
July 19, 1913—
A. R. A. Report on Automatic Train Stops.

Railway and Locomotive Engineering.
February, 1911—
Prentice System of Wireless Train Control on the Canadian Pacific Railroad.
May, 1917—
Wooding Automatic Stop Signal and Speed Control. Description of the Apparatus.
December, 1917—
Automatic Signals and the Automatic Stop.

Railway Engineer:
June, 1915—
General Discussion and Review of Automatic Train Control.
Railway Engineering and Maintenance of Way:
November, 1914—
Gray-Thurber System of Automatic Train Control as Applied to an Automatic Signal System.
February, 1916—
Principles and Operation of Speed Control Mechanism. Automatic Brake Application if Stop Indication is Overrun.
Railway Master Mechanic:
November, 1915—
The Automatic Stop Signal.
Railway News:
August 23, 1913—
The Prentice "Wireless" System of Automatic Train Control.
March 7, 1914—
March 21, 1914—
Cab Signals and Train Stops, by William H. Dammond.
January 2, 1915—
Signaling on Railway Trains in Motion, by W. Willox.
Railway Record:
November 23, 1912—
Automatic Train Control Safety Stop. Sketch of Development of Appliance. Estimated Cost of Equipping Existing Railway with this Device.
Railway Review:
August 7, 1915—
Test of Gollos Automatic Stop System.
April 22, 1916—
Automatic Stops.
May 27, 1916—
Test of the Julian-Beggs Train Control Signal System.
July 1, 1916—
Progress with Automatic Train Control.
September 9, 1916—
Cost of Installation of Automatic Train Control in Connection with Automatic Block Signals, by A. G. Shaver.
October 21, 1916—
Cost of Automatic Train Control, by C. E. Chatfield.
February 17, 1917—
The Future of the Automatic Stop.
April 14, 1917—
British Report on Automatic Train Control.
April 21, 1917—
Trials of Automatic Train Control.
May 26, 1917—
The Julian-Beggs Automatic Stop and Train Control System.
March 9, 1918—
The Ruthven Electromagnetic Control System.
October 5, 1918—
Automatic Stops Again Recommended.
July 13, 1918—
The Need of Development of Automatic Train Stops.
January 18, 1919—
Train Control and Automatic Stop, by W. I. Steel. Opinion of an Engineer on the Chesapeake & Ohio.
January 18, 1919—
A National Automatic Train Control Board.
Railway Signal Association:
1908 Report of Committee VI—Automatic Stops and Cab Signals—
Proceedings of the Railway Signal Association, 1908.
Railway and Engineering Review, October 17, 1908.
Railway Age Gazette, October 23, 1908.
1909 Report of Committee VI—Automatic Stops and Cab Signals—
Proceedings of the Railway Signal Association, 1909.
Railway Signal Association—Continued.
1909 Railway and Engineering Review, October 16, 1909.
1910 Report of Committee VI—Automatic Stops and Cab Signals—
Proceedings of the Railway Signal Association, 1910.
Railway and Engineering Review, October 15, 1910.
1911 Report of Committee VI—Automatic Stops and Cab Signals—
Proceedings of the Railway Signal Association, 1911.
Railway and Engineering Review, October 28, 1911.
Developments of Automatic Train Control Devices—
Journal of the Railway Signal Association, twenty-third year, March, 1918.
Railway Signal Engineer:
May, 1917—
New Haven Tests Webb Automatic Stop.
December, 1918—
The Shadle Automatic Train Signal and Stop.
May, 1917—
The High Cost of Stopping Trains.
Ristine, George W.:
Attitude of Railroads to the Automatic Stop—
Scientific American, January 25, 1913.
Automatic Train Control—
Railway and Engineering Review November 7, 1908.
Railway and Engineering Review, December 19, 1908.
Rowell-Potter Safety Stop:
Block Signals and Safety Stops, by Henry E. Bailey.
Railway and Engineering Review, February 19, 1910.
Official Inspection of Rowell-Potter Automatic Train Control Apparatus.
Railway and Engineering Review, May 1, 1909.
The Rowell-Potter Safety Stop—
Railway Age Gazette, January 28, 1910.
Rowell-Potter Automatic Signals on the Chicago & South Side—
Railroad Gazette, August 10, 1894.
Rowell-Potter Safety Stop and Block Signals on the C. M. & St. P. Railway—
Railway and Engineering Review, March 15, 1902.
Trial of the Rowell-Potter Block Signals and Automatic Stop—
Railway and Engineering Review, December 26, 1908.
The Rowell-Potter Safety Stop—
2nd Annual Report of the Block Signal and Train Control Board, 1909.
Rowell, B. C.:
Automatic Control of Trains—
Railway and Engineering Review, January 4, 1913.
The Automatic Stop. Arguments Based on False Assumption—
Railway and Engineering Review, February 8, 1913.
A Remedy for Railroad Accidents. Rowell-Potter Safety Stop—
Iron Trail, November, 1905.
Address on Safety Appliances—
Railway and Engineering Review April 7, 1906.
Rudd, A. H.:
The Automatic Train Control Problem. Some of the difficulties encountered in adapting automatic devices to miscellaneous railroad service.
Train Dispatcher's Bulletin, July, 1913.
Railway Age Gazette, June 6, 1913.
Truth Concerning Automatic Stops—
Signal Engineer, June, 1913.
A Safety Automatic Train Stop—
Scientific American, May 3, 1913.

Rudd, A. H.—Continued.
Discussion of the Fourth Annual Report of the Board on Automatic Train Control—
Scientific American, January 18, 1913.
The Need of an Automatic Stop—
Scientific American, June 21, 1913.
Ruthven:
The Ruthven Electromagnetic Control System—
Railway Review, March 9, 1918.
Schweyer:
Schweyer's Automatic Train Stop—
Railway Age, June 21, 1918.
Scientific American:
January 8, 1910—
An Automatic Railway Stop adopted provisionally by the German Railroad Admiuistration. By Alfred Gradenwitz.
July 20, 1912—
Human Fallibility and the Automatic Stop.
December 28, 1912—
The Automatic Railroad Stop.
January 18, 1913—
A Successful Automatic Train Stop. A device which saves the train, reports disregard of signals, thereby stiffens discipline.
January 18, 1913—
Discussion of the Fourth Annual Report of the Block Signal and Train Control Board.
January 18, 1913—
Conditions that Must Be Observed in the Competition for the New York, New Haven & Hartford Railway's Automatic Stop Prize.
January 25, 1913—
Attitude of Railroads to the Automatic Stop, by George W. Ristine.
February 15, 1913—
Ideal Automatic Train Control, by Maximilian Weis.
March 29, 1913:
New Haven Railroad Automatic Stop Competition.
May 3, 1913—
A Safety Automatic Train Stop.
June 21, 1913—
The Need of an Automatic Stop.
July 19, 1913—
The Competition for the New York, New Haven & Hartford Railroad Company's Automatic Stop.
August 23, 1913—
The Automatic Railroad Stop, by F. McHenry.
September 20, 1913—
Adoption of the Jones System by the Maryland & Pennsylvania Railroad, by Calvin W. Hendrick.
December 5, 1913—
Automatic Wireless Train Control, by F. C. Coleman. Prentice System.
February 28, 1914—
Requirements of the Automatic Train Stop.
August 28, 1915—
A New Type of Automatic Railroad Stop. (Brownell.)
December 29, 1917—
Train Control; Automatic Brake Operation.
Shaver, A. G.:
The Effect of Block Signals and Automatic Stops on Accidents—
Railway Age Gazette, March 7, 1913.
Cost of Installation of Automatic Train Control in Connection with Automatic Block Signals—
Railway Review, September 9, 1916.
Shadle:
The Shadle Automatic Train Signal and Stop—
Railway Signal Engineer, December, 1918.
Signal Engineer:
1913. Vol. 6—
Truth Concerning Automatic Stops, by A. H. Rudd.
June, 1913—
Automatic Control of Trains, by J. A. Peabody. Showing particularly the effect of automatic devices on the capacity of a road.
September, 1914—
Automatic Train Stops in France.
May, 1915—
1915 Report of the Chief of the Division of Safety, Interstate Commerce Commission.
Smith, Stephen:
Cab Signals and Automatic Stops. Julian-Beggs System—
Richmond Railroad Club Proceedings, May 15, 1916.
Address and Explanation of Julian-Beggs Automatic Stop and Train Control System—
Cincinnati Railway Club Proceedings, February, 1917.
South African Railway Magazine:
July, 1912—
System of Electric Cab Signals and Automatic Stops to Prevent Collisions, patented by Frederick Patterson.
Technical World:
October, 1909—
Making Collisions Impossible, by S. S. Carlyle. The Lacroix Cab Signal and Automatic Stop.
January, 1913—
To Prevent Train Wrecks, by Robert H. Moulton.
March, 1913—
When the Engineer Forgets, by Charles F. Carter.
September, 1913—
Railroad Trains Guard Each Other. MacDonald System of Train Control. By Gardner Hunting.
October, 1915—
Hands Off the Throttle, by Harold Cary.
Tainer M.:
Signal System and Automatic Stop on the Western Pacific at Oroville, Calif., Criticised—
Railway Age Gazette, October 29, 1915.
The Train Control Securities Company:
The Miller Train Control—what it is and what it is doing—
Washington, D. C., 1916.
Times Engineering Supplement:
March 30, 1917—
Automatic Train Control.
Tripp, O. G.:
The Miller Train Control—
Locomotive Firemen and Enginemen's Magazine, July, 1916.
Waldron, J. M.:
Waldron's Automatic Stop. A paper read before the Railway Signal Association, New York, June 14, 1911—
Railway Age Gazette, June 16, 1911.
Automatic Stop Device, Interborough Rapid Transit Company—
Railway and Engineering Review, June 24, 1911.
Wall Street Journal:
December 16, 1912—
The Truth No. 3. (The Interstate Commerce Commission and Automatic Train Stops.) By Charles S. Mellen.
Webb:
New Haven Tests Webb Automatic Stop—
Railway Signal Engineer, May, 1917.
The Webb Automatic Train Stop. An automatic stop which tests its own integrity at every contact point and reports audibly to enginemen—
Railway Age Gazette, April 13, 1917.

Weis, Maxmilian:
Ideal Automatic Train Control—
Scientific American, February 15, 1913.
Willox, W.:
Signaling on Railway Trains in Motion—
Railway News, January 2, 1915.
Wilson, H. Raynor:
British Opinion on Railway Automatic Stops—
Engineering News, January 30, 1913.
Collision in a London Subway. Failure of an Automatic Stop. Railway and Engineering Review, February 22, 1913—
Engineering News, March 6, 1913.
Wooding:
Report of tests of the Wooding train control system conducted by the Division of Safety, on the Delaware, Lackawanna & Western Railroad, January to April, 1917.
House Document 251, 65th Congress, 1st Session.
Wooding—Continued.
Report of tests of the Wooding train control system, etc.—Continued.
Railway Signal Engineer, October, 1917.
Wooding's Automatic Stop:
Railway Age Gazette, November 9, 1917.
Wooding's Automatic Stop Signal and Speed Control. Description of the Apparatus—
Railway and Locomotive Engineering, May, 1917.
Wooding's Automatic Train Stop. A spring-supported contact rail made movable to break ice—
Railway Age Gazette, September 14, 1917.
Wooding's Automatic Train Stop—
Railway Gazette, November 2, 1917.
Work, Leonard:
The Future of the Automatic Stop—
Railway Review, February 17, 1917.

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