American Railway Signaling Principles and Practices

CHAPTER III

Principles and Economic Phase of Signaling

Published by the Signal Section, A. R. A.
30 Vesey Street, New York, N. Y.

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PRINCIPLES AND ECONOMIC PHASE OF SIGNALING

PRINCIPLES OF RAILWAY SIGNALING

The purpose of railway signals is the transmitting of information to employees in charge of the operation of trains.

Safety was undoubtedly the original purpose for which signals were installed and the fundamental principles were centered around this original purpose, although in actual application it is impracticable to separate the principles pertaining to safety from those pertaining to facility of train movement, and since they are so interrelated they will be stated without regard to either safety of train movement or the facilitation thereof.

The principles are submitted as fundamentals of fixed signaling regardless of whether they be of the semaphore, color light, position light or color position light type. They do not refer to construction details, which details may properly be covered by specifications prepared, or in the course of preparation, by the Signal Section, American Railway Association.

Modern signaling is developed from three fundamental indications which were approved by the American Railway Association in 1910:

1. Stop
2. Caution
3. Proceed

To these were added two other indications:

4. Proceed at slow speed
5. Proceed at medium speed

These indications modified to meet present day operating conditions are published in the Standard Code of the American Railway Association, adopted January 17, 1928.

The principles of railway signaling as they relate to design, construction and installation of signal systems and to train operation are as follows:

Design and Construction

Reliability
Uniformity
Expansive capabilities
Simplicity
Selectivity
Distinctiveness
Limitation

Reliability: The design, construction and installation of all parts must be with reliability in mind so that both safety and facility of train movement may be obtained.

Uniformity: To avoid confusion in the engineman's mind and possible delay to trains, uniformity in aspects and indications is necessary.

Expansive capabilities: Light traffic and simplicity in track layout requires a less elaborate signal system than does heavy traffic and more complicated track layouts; however, the signaling for the light traffic or the simple track layout should, for economic reasons, be capable of expansion to provide for increasing traffic to the ultimate capacity of the railway.

Simplicity: Physical and weather conditions at times make the reading of signal indications by enginemen difficult. For these reasons simplicity is an important factor in the design and construction of a signal system.

Selectivity: Different speeds are required at different locations, and on various routes, orders also are involved. A signal system should give definite information as to permissible speeds and orders transmitted or to be delivered.

Distinctiveness: Signal systems being of different kinds, the signals used in each system should be distinctive either in design or marking so that they can be readily classified.

Limitation: By limitation is meant the restriction imposed by the indication given by the signal such as stop at next signal, pass next signal at medium speed, proceed at restrictive speed, etc. Limitations as transmitted by the signal indications should be readily understandable for safe movement of trains.

Installation

Location
Stopping distance
Confliction
Protection
Visibility

Location: Signals should, as far as practicable, be located:

1. To the right of and adjoining the track to which they refer.
2. Back of fouling points.
3. So as to protect conflicting train movements.

Stopping distance: Signals should be spaced at least stopping distance apart, or, where not so spaced, an equivalent stopping distance provided by two or more restrictive indications approaching signals requiring such indication.

Confliction: Confliction, one signal with another, or with some outside object of similar shape or color must be guarded against.

Protection: The protection desired must be given careful consideration and the installation made in conformity with the recommended practices of the Signal Section, A.R.A.

Visibility: From an operating standpoint, visibility is important. Signals should be located so as to give the greatest possible view to enginemen on approaching trains.

Requisites and adjuncts.

Requisites and adjuncts, applicable to the installation of interlocking systems, automatic block signal systems and centralized traffic control systems, have been promulgated by the Signal Section, A.R.A. They are as follows:

Interlocking System

Requisites.

1. The apparatus so constructed and circuits so arranged that the failure of any part of the system, affecting the safety of train operation, shall cause all signals affected to give the most restrictive indications which conditions require.

2. Signals of prescribed form, the indications given by positions, by lights of prescribed color, or by both.

3. Signals located preferably to the right of and adjoining the track to which they refer.

4. Approach and home signals spaced at least stopping distance apart, or where not so spaced, an equivalent stopping distance provided by two or more restrictive indications approaching the home signals when their indications require the giving of such restrictive indications.

5. Approach or other restrictive indications approaching signals giving indications more restrictive than Approach, except where not required because of speed restrictions.

6. Track circuits throughout the limits of the interlocking plant.

7. Switch control for power-operated signals governing movements over a switch and corresponding interlocking units so signals can give indication to proceed only when such units are in proper position.

8. Mechanical locking to insure predetermined order of lever movement, or circuits to insure proper correlation of the units of the interlocking plant.

9. Signals, operated manually by signalman, controlled semi-automatically where such signals form a part of an automatic block signal system, and co-operatively by the signalman and control operator where such signals form a part of a centralized traffic control system.

10. Approach or time locking with automatic or manual release.

11. Section or route locking.

12. Facing point locks, or switch-and-lock movements, for mechanically-operated switches, and corresponding interlocking units.

13. At manually-operated interlockings power switch operating and locking mechanism provided with means to indicate that switch or corresponding interlocking unit has completed its movement and is locked. At automatic interlockings circuits to insure proper correlation of the units of the interlocking plant.

14. Indication lock or the equivalent for power-operated signals at manually-operated interlockings.

Adjuncts.

1. Track diagram at manually-operated interlocking plants on which is indicated the occupancy of track sections.

2. Approach annunciators.

3. Section release locking.

Automatic Block Signal System

Requisites.

1. The apparatus so constructed and circuits so arranged that the failure of any part of the system, affecting the safety of train operation, shall cause all signals affected to give the most restrictive indications which conditions require.

2. Signals of prescribed form, the indications given by positions, by lights of prescribed color, or by both.

3. Signals located preferably to the right of and adjoining the track to which they refer.

4. Signals spaced at least stopping distance apart or, where not so spaced, an equivalent stopping distance provided by two or more restrictive indications approaching signals requiring such indications.

5. Approach or other restrictive indications approaching signals giving indications more restrictive than Approach, except where not required because of speed restrictions.

6. Continuous track circuits on main track and on other tracks where medium speed is permitted.

7. Signals automatically controlled by track circuits, and in addition at interlockings, where such signals form a part of the block signal system, manually by signalman.

8. Switch control for signals governing movements over a switch so that signals can give an indication to proceed only when such switches are in proper position.

9. Means for establishing, maintaining, and changing direction of traffic on tracks signaled in both directions, or signals so controlled that proper restrictive indications are provided to protect against opposing movements.

Adjuncts.

1. Means of communication at points where trains may clear.
2. Switch indicators.
3. Take siding indicators.
4. Leave siding indicators.
5. Grade signals.
6. Approach annunciators.

Centralized Traffic Control System

Requisites.

1. The apparatus so constructed and circuits so arranged that the failure of any part of the system, affecting the safety of train operation, shall cause all signals affected to give the most restrictive indications which conditions require.

2. Signals of prescribed form, the indications given by positions, by lights of prescribed color, or by both.

3. Signals located preferably to the right of and adjoining the track to which they refer.

4. Signals spaced at least stopping distance apart or, where not so spaced, an equivalent stopping distance provided by two or more restrictive indications approaching signals requiring such indications.

5. Approach or other restrictive indications approaching signals giving indications more restrictive than Approach, except where not required because of speed restrictions.

6. Continuous track circuits on main track and on other tracks where medium speed is permitted.

7. Signals automatically controlled by track circuits, and in addition at controlled points manually by control operator, and at non-automatic interlockings cooperatively by signalman and control operator.

8. Signals at a controlled point so interconnected that they cannot be cleared for opposing or conflicting movements.

9. Signals at a controlled point so interconnected that they cannot be cleared unless the signal at the next controlled point governing opposing movement indicates Stop.

10. Circuits of signals at controlled points provided with stick feature, such stick feature being effective or non-effective at the will of the operator and which when effective will necessitate again reversing the control lever, or equivalent, in order that signal may again clear.

11. Switch control for signals governing movements over a switch so that signals can give an indication to proceed only when switch is in proper position.

12. Approach or time locking with automatic or manual release.

13. Section or route locking.

14. Means for establishing, maintaining, and changing direction of traffic.

15. Means of communication between control station and points where trains may clear.

16. Switches, if operated from control station by power mechanism, equipped with means for hand operation.

17. Switches operated by switch stand, if electrically locked in normal position, operative only after unlock has been given, the unlock to cause signals protecting such switches to give the most restrictive indication the condition requires.

18. Track diagram on which is indicated occupancy of track sections at controlled point.

19. OS indication on control machine for each main track at each controlled point.

20. Indication on control machine that switch has completed its movement and is locked.

Adjuncts.

1. Automatic block signals between controlled points.
2. Continuous track circuits on sidings.
3. Indications at control station to indicate occupancy of track sections between controlled points.
4. OS indication provided with stick circuit.

5. Signals at automatic interlockings within the limits of centralized traffic control territory controlled by control operator.

6. Electric locks on hand-operated switches.

7. Take siding indicators.

8. Leave siding indicators.

9. OS indications on control machine in addition to those for controlled points.

10. Indications on control machine to repeat position of the signals and/or switches at controlled points.

11. Recording traingraph.

Train Operation

Train order system.

This method of directing trains is a time interval method and provides authority for the movement of regular trains subject to the rules. Under normal operation when trains conform to the time-table schedules there is no delay, but if the schedules are interrupted or extra trains are run, it then becomes necessary to issue orders to authorize train movements. The amount of delay time will depend upon the number of open train order offices, the type of train order issued ("19" or "31") and the number of train movements involved. Due to the fact that a "31" order requires the signature of the conductor, resulting in train delays, the use of "31" orders has been greatly restricted in recent years.

A train order signal is required at each office where orders are to be delivered, the signal normally being displayed in the Clear position, indicating "no order," until the dispatcher is ready to have the operator issue orders for trains. On some roads the train order signal is normally at Stop and is cleared, if there are no orders, in view of the approaching train. Freight and passenger train movements, and "meets" as well as "passes" are made on time-table and train order instructions. In the time interval method of directing train movements, the safety of train operation is dependent upon the exact observance of the many rules governing train operation not only in the operating book of rules adopted by each railroad, but also the special instructions in the time-table or otherwise.

Manual and controlled manual block system.

In the manual block system of directing train movements, a manual block signal, normally at Stop, is used for spacing trains between block offices; the train order signal, previously referred to, is sometimes used as the manual block signal. Freight and passenger trains may be permitted to follow one another into a block, although on most railroads an absolute block is maintained for passenger trains. In the latter case it is essential to have shorter block sections and sufficient offices to expedite traffic without delays. Manual block operation is a slower method of protecting train movements than the train order system. Railroads adopted this system in an endeavor, even at the expense of additional block offices, to surround train operation with greater safety, particularly passenger trains, than is possible in the time interval method. On light traffic lines, block lengths of 5 to 7 miles do not cause excessive delays, but with a traffic density of 20 or more trains per day, the use of an absolute block for passenger trains, which permits only one train in the 5 or 7 mile block section, results in considerable delay time.

The manual block system is operated by rules without electrical or mechanical check on the block operator. The controlled manual block system is operated with electrical and mechanical check on the block operator and a signal cannot be displayed to admit a train into a block without the cooperation of the block operators at each end of the block.

Train staff system.

The train staff system (used in England as early as 1840) operates on the principle that to pass safely over a section of track, every train should have in its possession a tangible right to do so in the form of a metal bar or staff which gives authority for the train to proceed. This type of system requires a staff machine at each end of the block, which machines are so interconnected that but one staff can be removed from a machine and must be replaced in either machine before another staff can be removed, except that some installations are provided with a permissive staff authorizing a following movement into a block at permissive speed. The system may be operated with or without track circuits.

Automatic block system.

With the train order, manual block or staff system the safe operation of the system is more or less dependent upon the human agency. With the automatic block system the train automatically operates the signal that protects it.

The fundamental element of the automatic block system is the continuous track circuit which provides an economical and safe method of maintaining a space interval between following and opposing train movements. The space interval or block may vary in length from a few hundred feet to two or more miles, the average length being about one mile.

In the non-automatic systems the block section lengths are, as a rule, influenced by the labor costs of operation and not by the traffic requirements, but in the automatic block system the block lengths are arranged to meet the operating requirements and therefore greater facility of operation is provided.

Interlocking.

The Standard Code defines Interlocking as: An arrangement of switch, lock and/or signal appliances so interconnected that their movements must succeed each other in a predetermined order. Its use was largely influenced by considerations of economy. It was soon recognized as a necessity in the large passenger terminals because the cost of switchmen to operate hand-throw switches became excessive and the possibility of collisions due to fog, bad weather conditions and the delays necessary to guard against accidents, often placed serious limitations on traffic. Interlockings were also found advantageous at yards, junctions, crossings and other points.

Centralized traffic control.

Centralized traffic control is a method of train operation by signal indication which makes it economically possible to greatly extend the territory controlled from one station. This system of train operation is considered by many to be among the outstanding developments in the railway field and its wide use as a means of handling trains is predicted because of the economies in operation which it affords. It not only affords direct economies in transportation, but it makes possible a more extensive use of track facilities.

Centralized traffic control basically involves the control of signals and switches governing the use of a series of consecutive blocks from a central point and provides for the movement of trains by authority of the signals so controlled. Most installations include the control and operation of switches because of additional advantages which come about through the elimination of train stops. A few installations in light traffic territory have been made where signals only are controlled, the switches remaining hand-operated.

Systems of Signaling in Service

General.

Basically all signal systems now in service on the various railroads are arranged to meet, as nearly as possible, the conditions set forth in the principles. The details of application, however, are different in a number of instances, and, in order that the student may have a clearer conception of the arrangements, three general schemes of signaling now in service will be explained.

The three schemes are generally known as one-arm, two-arm and three-arm signaling. For convenience semaphore symbols are used, the indications of which are given by positions of arms and color of lights. With light signals the indications are given by color, the position of lights, or both.

One-arm signaling.

In one-arm signaling the number of aspects that can be displayed is necessarily limited, but where used these aspects are considered sufficient to take care of all requirements. The three indications used are Stop, Proceed at Restricted Speed, and Proceed, illustrated in Fig. 1. All reduced speed movements for whatever purpose are controlled by the indication Proceed at Restricted Speed.

It is sometimes desirable or necessary to provide additional indications, such as Stop; then Proceed, permissive signal aspect in manual block territory, etc. This is usually accomplished by the addition of (1) number or letter plate, or (2) marker light, or (3) shape of arm, or (4) combination of these distinguishing features.

Two-arm signaling.

Additional aspects are available in two-arm signaling over the one-arm system, but these are generally used at interlockings where diverging moves are made, also at approach signals at interlockings. At other points or territory, such as at manual block stations, automatic signal territory, etc., one arm is all that is necessary, qualified frequently by a marker light or other distinguishing feature. The aspects and indications usually displayed at interlockings where two-arm signaling is used are shown in Fig. 2.

Those generally displayed as manual block signals and their approach signals are shown in Fig. 3. It will be noted that certain of the aspects in Fig. 3 are the same as shown in Figs. 1 and 2, so that in order to make a distinction between them due to the different indications, one of four conditions is usually provided: (1) letter plate, or (2) marker light, or (3) shape of arm, or (4) combination of these distinguishing features.

Figure 4 shows the aspects and indications generally displayed by automatic signals and the same qualifying features as mentioned under manual block signals are also usually used.

Three-arm signaling.

This system is likewise generally used at interlockings where it is considered desirable to provide more than one indication for the government of train movements over various routes or at various speeds. Usually the top arm is used to govern movements over the high-speed route, the second arm over the medium-speed route, and the third arm over all of the restricted or slow-speed routes. Each arm can be made to operate in three positions and indicate the position of the signal in advance. Should the track arrangement at an interlocking be such as to not permit movements at high or medium speed, to obtain uniformity the three-arm signal is used, but the arm corresponding with the non-permissible speed is made inoperative.

The aspects and indications available under the three-arm system of signaling are shown in Fig. 5. Usually the bottom arm is shorter than the other two.

The aspects and indications of manual block and automatic signals used by railroads employing the three-arm system of signaling are usually the same as shown in Figs. 3 and 4.

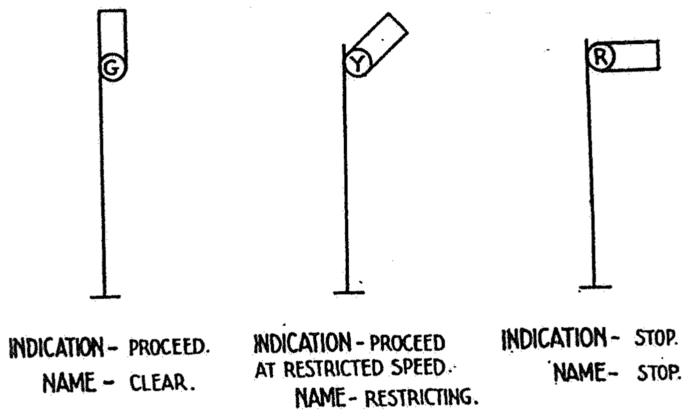


Fig. 1.
Aspects and Indications of One-Arm Signaling.

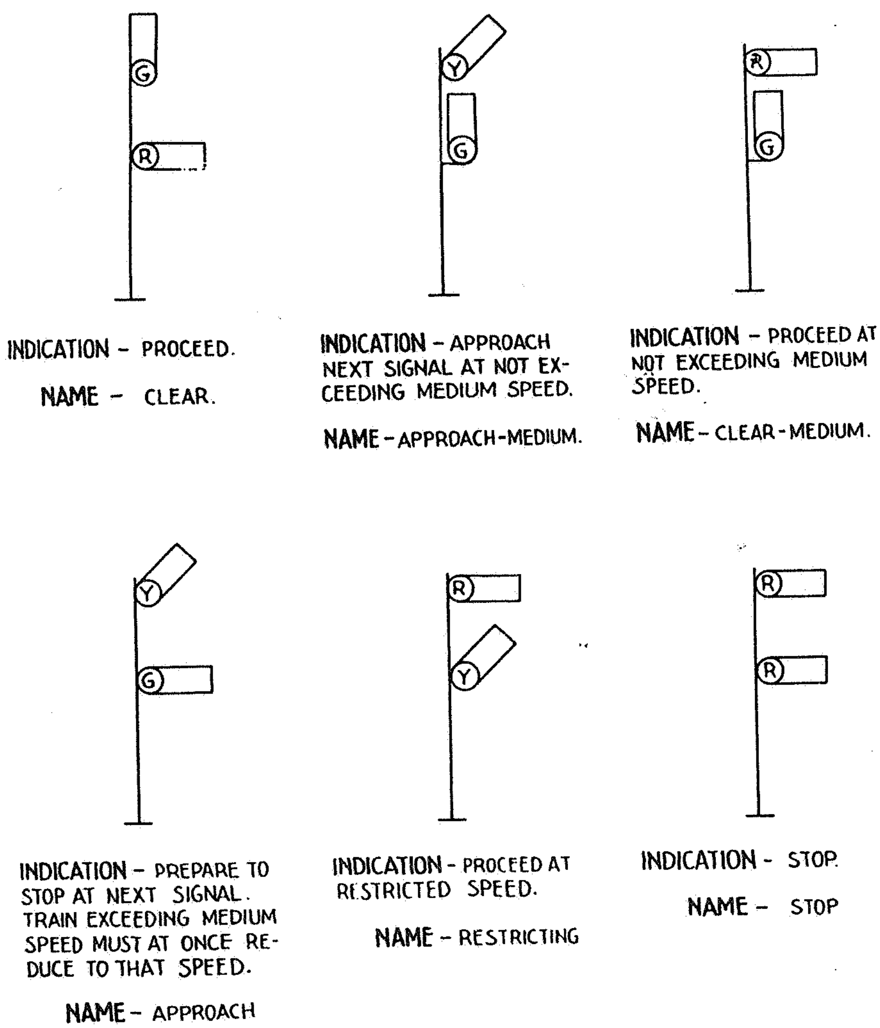


Fig. 2.
Aspects and Indications of Two-Arm Signaling at Interlockings.

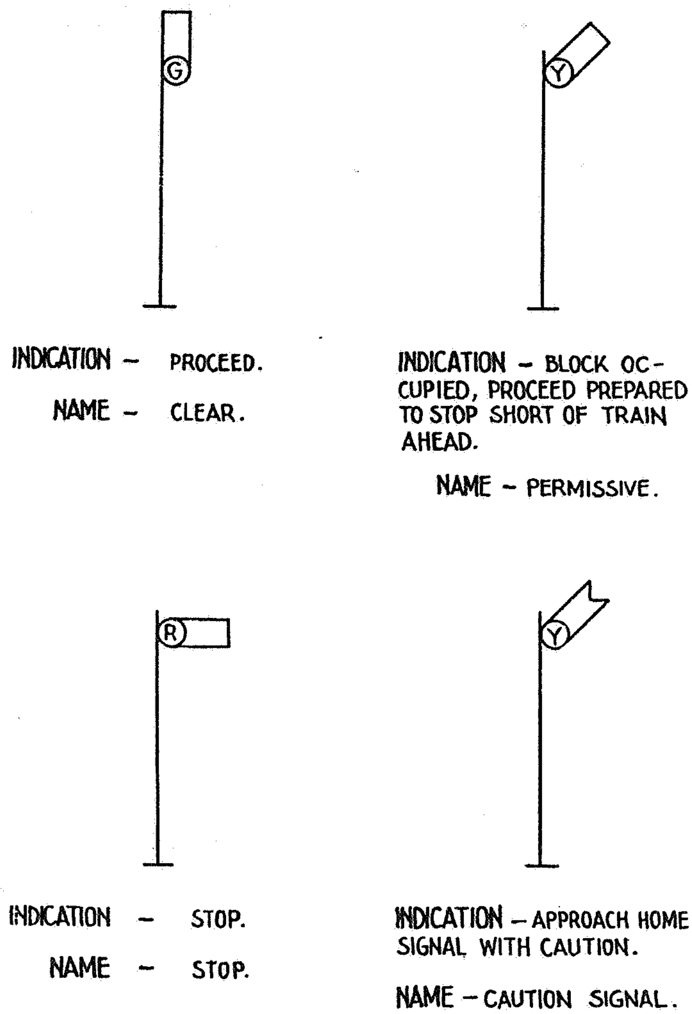


Fig. 3.
Aspects and Indications of Manual Block and Distant Signals.

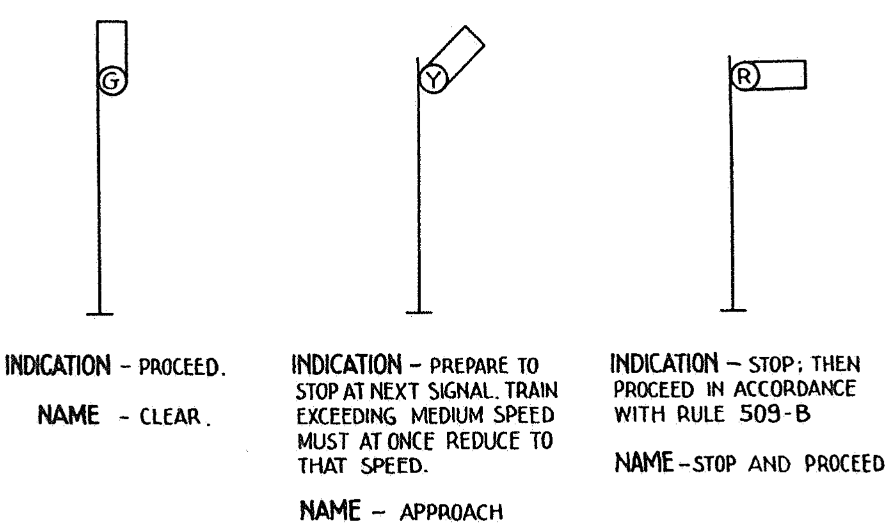


Fig. 4.
Aspects and Indications of Automatic Signals.

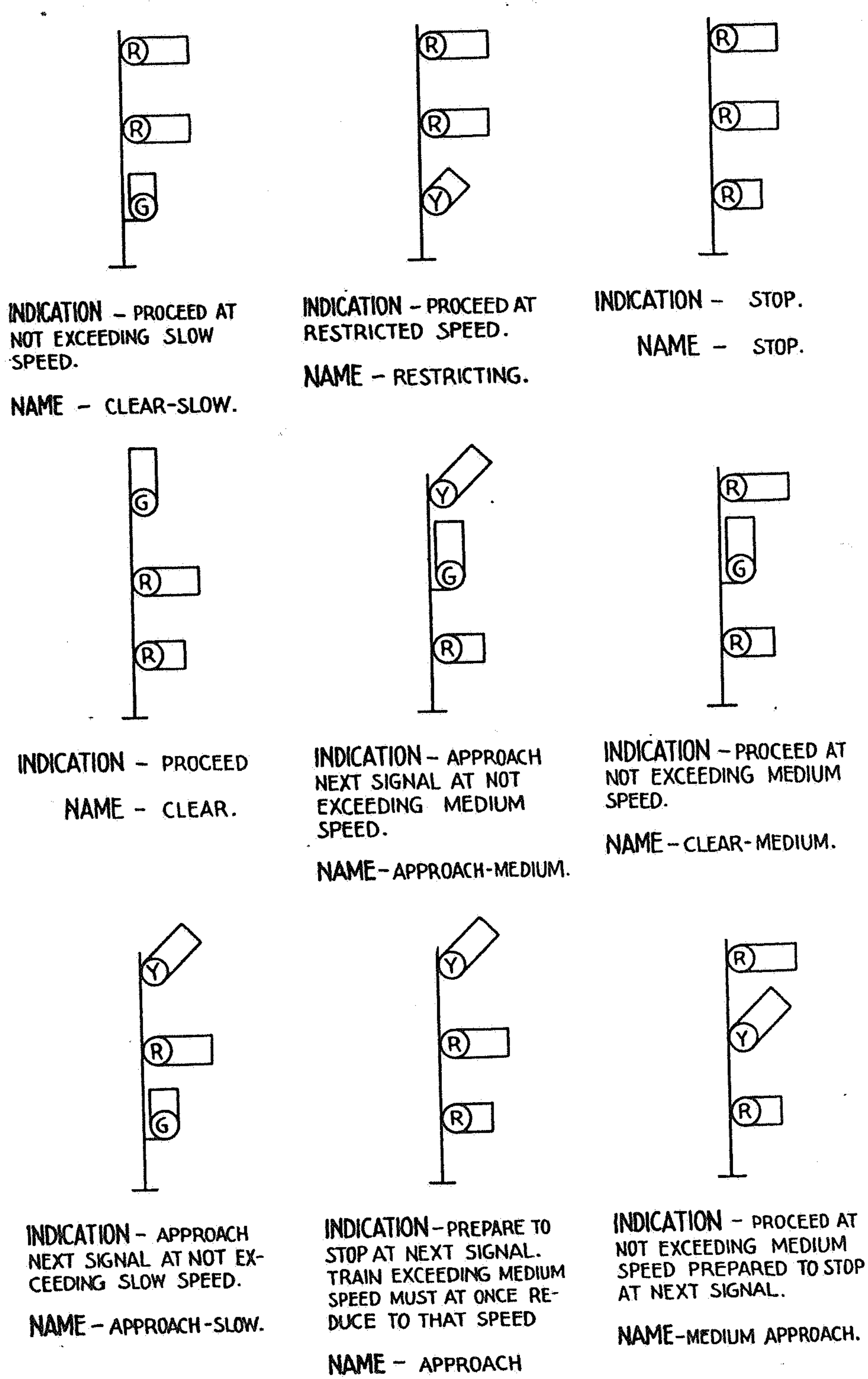


Fig. 5.

Aspects and Indications of Three-Arm Signaling at Interlockings.

Certain railroads have adopted as their standard either the color light, position light, or color position light signals, and their system is arranged accordingly, the aspects and indications of each type of signal agreeing in general principles to those explained under one, two and three-arm signaling. Chapter II—Symbols, Aspects and Indications explains in detail the aspects and indications displayed by the different types of signals, as well as the various systems in effect, and it is recommended that the student study Chapter II carefully in order to obtain complete information of all details regarding any particular system and type of signal.

No specific mention has so far been made of dwarf signals; however, the aspects and indications displayed by them may be the same as those displayed by the high signals.

Cab signals and cab indicators.

A detailed description of the aspects and indications of cab signals and cab indicators is given in Chapter II.

ECONOMICS OF RAILWAY SIGNALING

Introduction

The purpose of this portion of the chapter is to present, in summary form, data showing the economic results actually accomplished by modern signal systems and to suggest methods for determining the probable economic benefits to be derived from proposed installations. Its 29 tables and references to about 200 published articles, amplify the summaries.

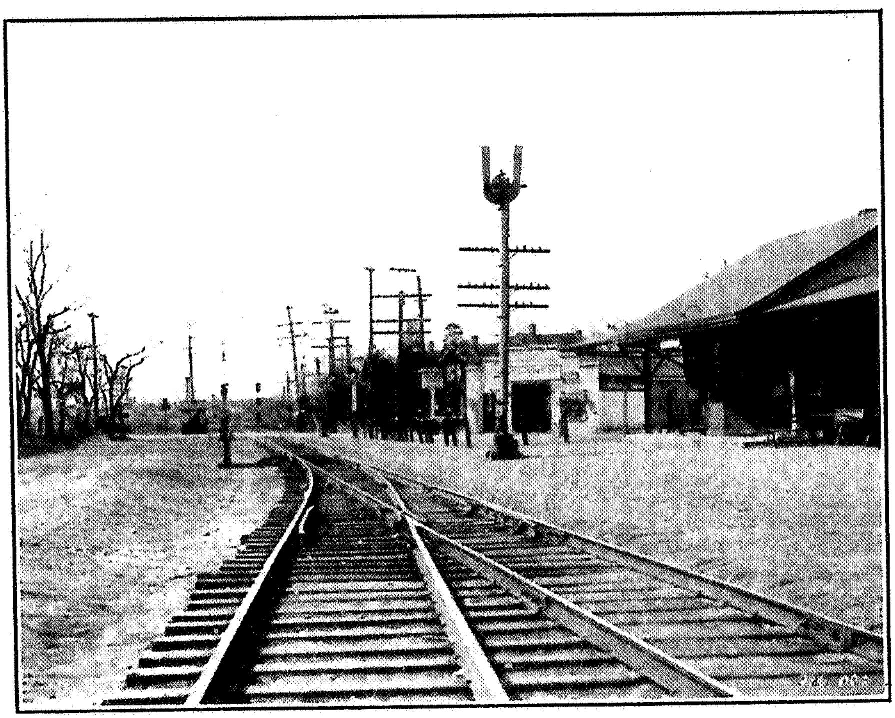
In the early days little attention was paid to the economic phase of railway signaling, as installations were made primarily for the increased safety of train operation. At present, the safety of operation is generally taken for granted and signaling is often justified solely by the resultant saving in operating expenses. The insurance value of a system of automatic signals, interlocking, or other signaling devices, is recognized as having a real economic value, although it is not often included in an economic statement.

The development of railway signaling has been steady from the time when automatic block signaling and mechanical interlocking were the two main branches to the present time when refinement of apparatus and inventive genius have made possible many new applications of the basic principles. Recent developments such as remote control, automatic interlocking, automatic train control, continuous cab signals, centralized traffic control and car retarders have given impetus to railway signaling. These later developments have for the most part been designed for the promotion of transportation efficiency, increased safety and economy. It is logical that the additional cost of a proposed signal system over and above the basic requirements of safety should be justified by saving in operating expenses or through saving in capital costs because of the greater capacity and operating facility.

Economics of railway signaling involves the determination of the financial and business reasons for the expenditure. It may also involve a comparative analysis of the proposed signaling and alternative improvements so that it can be shown whether signaling is the most desirable solution for facilitating the movement of traffic and increasing the capacity of the railway.

Saving more costly improvements.

Railway signaling offers a means of improving operating performance by providing facilities for the more intensive utilization of existing trackage, generally at a lower unit operating cost and a lower unit fixed cost than could be achieved by other types of improvements and therefore gives more increased capacity and facility of operation with a higher return on the investment. As traffic growth is ordinarily at a slow steady rate, it is generally more economical to provide for greater utilization of existing facilities than to provide huge sums for additional capacity which could not be utilized because the traffic would not be great enough for a number of years to bring about a suitable saving on the additional capital expenditure.



Train Order Signal on Central Railroad of New Jersey.

Signaling apparatus is of such a type that it may be used to advantage even if changes are made in the original track layout. For example, if a single-track line equipped with automatic signals is later double tracked, the signaling apparatus may be relocated to fit the new track arrangement. Practically every signal installation contains an assemblage of certain basic apparatus which is largely interchangeable with that of other signal installations on the railroad and therefore signaling may be economically applied to a relatively temporary traffic situation as well as to a situation which promises to be more permanent.

A modern signal system will frequently provide the additional capacity needed to handle a seasonal peak traffic of relatively short duration in the most economical manner because the capacity required is furnished at the lowest possible capital investment. Such a system will not only reduce the investment required to handle this traffic expeditiously, but will also bring about sufficiently improved operation during the periods of normal traffic throughout the balance of the year to make an attractive operating saving even at the periods of minimum traffic density. Modern signal systems do not require traffic at or near peak densities in order to justify the expenditure, although the rates of saving increase rapidly with increased traffic.

Block stations.

In the train order and manual block methods of directing train movements the number of block stations may be increased or decreased as traffic varies seasonally and the cost of operation may be made somewhat proportional to the traffic density. The first cost and the maintenance expense is low although the cost of operation is high due to the wages of the operators and the train delay due to inflexibility of the system in handling increases in business. Generally, the block stations, operated one or more tricks per day depending upon traffic conditions, are 2 to 5 miles apart although blocks of 7 to 10 miles are used in some cases while, during light traffic periods, blocks of 20 to 40 miles are not unusual.

The cost of operation per block station per year varies with the number of operators on duty per day and generally averaged in 1930 about $2,000 for each operator, or about $6,000 for three tricks. This amount includes not only the wages but also the heat, light, and other expenses incident to maintaining and operating the block stations. As traffic increases and more blocks are added, the cost of the manual block method of directing train movements increases. It is therefore desirable to compare the cost of operation with the alternate methods of automatic block or operation by signal indication, as to economy and increased safety. An increasing mileage of these latter methods of directing train movements is being installed as shown by the statistics of the Interstate Commerce Commission Bureau of Safety. According to these reports, the total track miles of automatic and non-automatic block increased from about 86,000 in 1910 to 150,000 in 1931, while the track miles of manual block decreased from about 62,000 in 1910 to about 56,000 in 1931.

On the following pages will be found the various applications of signaling in the field of railway transportation and the economic and other advantages actually accomplished by automatic block signals, interlockings, train operation by signal indication, remote control, centralized traffic control, car retarders, and highway crossing protection.

Automatic Block Signal System

The economy of train operation in an automatic block system results from a decreased number of operators and from providing facilities for several times the number of trains in the same track length with block protection and less train delays. The increased safety of train operation and the operating benefits obtained account for the steady increase in track mileage of automatic block signals in the United States from about 23,800 in 1910, to over 94,000 in 1931.

The first cost of automatic block signals on 13 railways, as reported in returns to the Interstate Commerce Commission questionnaire* of July 22, 1927, is shown in Table I.

TABLE I

Cost of Automatic Block Signals

Railway	Type of signals**	D. C. or A. C.	S. T. or D. T.	Road miles	Cost per track mile
A. T. & S. F.	3 CL	A. C	D. T.	229.75	$2,898
B. & O.	4 CPL	D. C.	D. T.	106.0	2,782
I. C.	3 CLO	D. C.	S. T.	108.98	3,005
L. A. & S. L.	3 CLO	D. C.	S. T.	130.0	3,038
L. & N.	3 UQSA	D. C.	S. T.	137.4	3,687
M.-K.-T.	3 UQSO	D. C.	S. T.	209.6	2,930
M. P.	3 CLO	D. C.	S. T.	391.1	3,822
N. C. & St. L.	3 CLA	D. C.	S. T.	83.7	3,308
N. Y. C. (E.)	3 CL	D. C.	D. T.	64.2	3,569
N. Y. C. & St. L.	3 CL	D. C.	D. T.	9.9	2,070
N. P.	3 CLA	D. C.	S. T.	33.93	2,532
O. S. L.	2 LQSO	D. C.	S. T.	44.6	2,864
S. P.	2 LQSO	D. C.	S. T.	145.9	2,461

** Abbreviations:

3 CL —3 color, light signal
3 CLA —3 color, light signal, APB system
3 CLO —3 color, light signal, overlap system
4 CPL —4 color, position light signal
2 LQSO—2 position, lower quadrant, semaphore signal, overlap system
3 UQSA—3 position, upper quadrant, semaphore signal, APB system
3 UQSO—3 position, upper quadrant, semaphore signal, overlap system

The variation in these cost figures per mile of track is due to the difference in the track and signal layouts, traffic conditions, pole line and power conditions, local operating conditions, amount of interlocking changes and additions, amount of highway grade crossing protection and date of installation, and shows the impossibility of using an average cost value per mile of automatic block signals unless the requisites of installation are known.

Data of 11 installations of automatic block signals on 7 railways are shown in Tables II and III.

* *Railway Signaling*, April 1928, pp. 142 and 143.

TABLE II

Automatic Block Signal Installations

Railway	Location	Miles of road	track	Avg. no. trains per day Frt.	Pass.	Pub. ref.†
C. C. C. & St. L.	Crestline-Berea	63.2	126.4	20	30	1
C. C. C. & St. L.	Cincinnati-Greensburg	58.3	116.6	18	16	2
A.R.E.A. report	Section A-C	42.0	42.0	18	8	3
A.R.E.A. report	Section A-E	66.0	66.0	15.8	10.2	4
A.R.E.A. report	Section A-B	48.0	48.0	28	28	5
N. & W.	Portsmouth-Cincinnati	100.0	100.0	10	8	6
S. A. L.	Richmond-Norlina	98.4	98.4	15	18	7
S. A. L.	Norlina-Raleigh	87.7	87.7	16	18	7
S. A. L.	Raleigh-Hamlet	96.1	96.1	15.4	18	7
Signal Section, A.R.A. report	Division "E"	148.2	157.1	22	12	8
W. M.	Hagerstown-Cumberland	79.0	97.2	7	....	9

† For publication references, see p. 75.

In 8 of these installations the automatic block signals replaced manual block while in the other 3 installations "31" orders were eliminated and "19" orders used when the automatic block system was installed.

TABLE III

Operating Advantages of Automatic Block Signaling

Railway	Frt. train hrs. saved per year	Frt. train speed m. p. h. Before	After	Per cent increase in speed	Time saved per frt.	Per cent saving or improvement
C. C. C. & St. L.	9,050	13.0	16.7	28	1.08 to 1.38 hrs.	45.5
C. C. C. & St. L.	2,579 EB	17.09	20.03	17	18 to	18.0
	WB	16.19	17.66	9	30 mins.	
A.R.E.A. report	3,395	12.25	14.41	18	31 mins.	37.2*
A.R.E.A. report	6,035	12.0	14.9	24	64 mins.	51.6*
A.R.E.A. report	4,259	13.6	15.3	12	25 mins.	35*
N. & W.	6,744	11.3	14.2	25	104 mins.	Saved $2,900 per month
S. A. L.	5,252	14.8	17.1	15	52 mins.	13.4
S. A. L.	3,484	20.6	24.3	18	39 mins.	14.4
S. A. L.	4,628	11.8	13.4	13	56 mins.	10.2
Signal Section, A.R.A. report	13,399	10.2	11.4	12	100 mins.	16.6
W. M.	10,844	6.2	9.6	55	272 mins.	Overtime hours reduced 92%

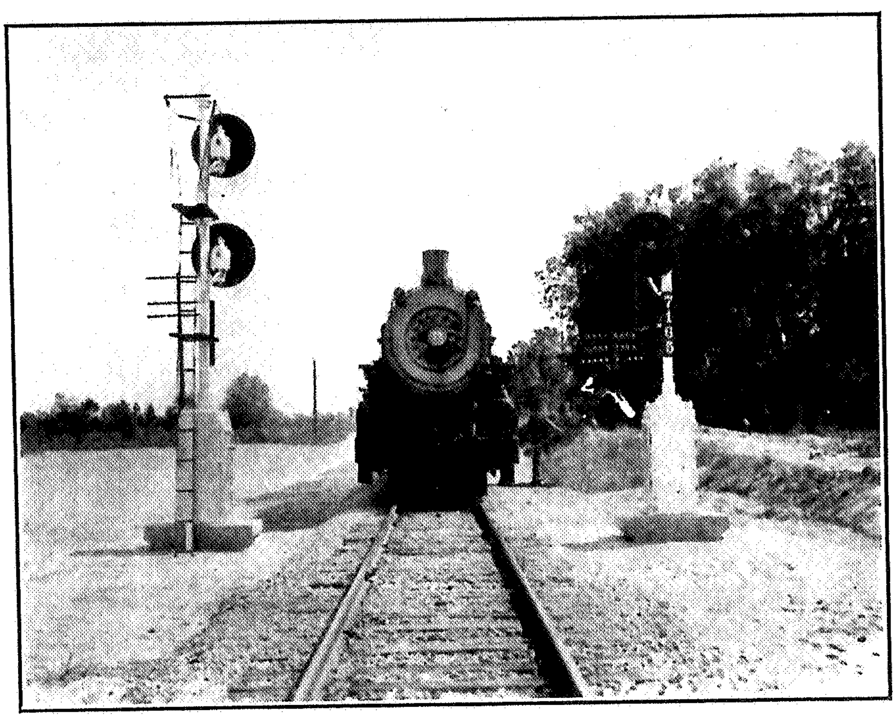
Note.—Per cent saving is after deducting interest, maintenance and operating charges.

* Per cent increased capacity.

In 6 of these installations the automatic block signals showed saving of 10.2 to 45.5 per cent, above all charges, with a traffic of 33 to 50 trains per day. Even railways with a light traffic of 7 to 18 trains per day found that this method of directing trains reduced overtime and showed improved economic results.

On the two C. C. C. & St. L. (Table III) installations there was an increase in speed of 9 to 28 per cent resulting in increased gross ton miles per train hour. No credit was taken for a saving in per diem or for a saving in repairs to equipment due to the decreased number of train stops or for the improvement in passenger train performance.

On Section A-C (Table II), before the installation of automatic block signals, all trains were operated by time-table and train orders. All meets were by "31" orders. Trains were spaced by 10-minute intervals. After the automatic block signals were installed, the "31" orders were eliminated and "19" orders only were issued, saving an average of 55 "31" orders per day. This resulted in eliminating 20,075 stops per year, at an estimated average of 7½ minutes per stop (2,000 ton trains at a speed of 15 miles per hour), which equals 2,509 train hours of the total 3,395 train hours estimated saving per year.



Automatic Block Signals on Atlantic Coast Line Railroad.

On Section A-E (Table II), there was a reduction of 80 stops per day on account of eliminating "31" orders, saving 29,200 stops per year, at an estimated average of 7 minutes per stop (1,500 ton trains at an average speed of 15 miles per hour), which accounts for 3,407 train hours of the total 6,035 train hours estimated saving per year. In both of these studies there were only slight variations in the number of "19" orders issued before and after the automatic block signals were installed.

On the N. & W. installation (Table III), "31" orders were used for all movements involving the protection of passenger trains or to restrict the movements of all trains while "19" orders were used for advancing trains. With automatic block signals, "19" orders were used exclusively, saving an average of 18 minutes for each stop previously made for delivery of "31" orders to heavy coal trains. When a freight train was given a permissive order to follow another freight train into a block under the old system, the engineman of the second train did not know how far ahead the other train was. As a result it became necessary for the second train to proceed at slow speed prepared to stop within range of vision. Under such circumstances, considerable time was lost and the block was occupied longer than necessary. With the same number of trains operated on the two days compared, there were 30 meets under manual block compared with 16 meets with automatic block signals. The number of times that trains were stopped for meets or orders was reduced from 70 to 36 while the average stop was reduced from 18 to 6.3 minutes.

An editorial in *Railway Age,* Aug. 4, 1928, p. 205, relative to "Using '19' Orders with Safety" states:

"With the increasing traffic on many single track lines, officers have been forced to seek methods that will reduce delays and increase track capacity. The adoption of the Form 19 order, and the unlimited use of the caution card to permit following trains in the same block, will often secure the desired result, as long as there are no errors in the handling of orders. The Norfolk and Western did not choose to take any chances on its single track division from Cincinnati, Ohio, to Portsmouth, but, when the manual block system failed to provide the capacity and average speed desired, a system of automatic signals was installed, and with this protection against accidents in case of an error in the handling of train orders, the Form 31 was superseded by the Form 19 for directing train movements. This is one of the most clean-cut illustrations of the benefits of automatic signals that it has been our opportunity to present for some time. It should be of interest to those roads that are facing the problem of increasing the capacity of single track lines with safety."

The three installations on the S. A. L. (Table II) are of interest because of the 282.2 mile length and the careful study made of the train operation before and after the automatic block signals were placed in service. Under manual block the average distance between block stations was 4.2 miles while the average distance between automatic block signals was 1.8 miles. Two of the divisions in 1928 had 100 per cent on time operation of all passenger and carded or manifest trains which was unheard of prior to the installation of the automatic block signals. There was an improvement in the time of passenger and express trains but no claim for economy was included in the total saving.

The large saving in freight train time and overtime hours on the W. M. (Table III) with a light traffic of 7 trains per day was due to the successful operation of 7,000 ton trains in "turn-around" service and the elimination of stops for "31" orders following the automatic block signal installation.

Increased safety of automatic block signals.

While very little data is available showing the reduction in the cost of accidents following the installation of automatic block signals, the reports of two railways taken from the records of the Signal Section, A.R.A., are of interest. In the S. A. L. report (Table II), the reduced cost of accidents, average for 10 years, on three divisions on 282.2 miles of road, following the installation of the automatic block signals, amounted to $58,072 per year, or an average of about $206 per mile of road per year. This cost not only included property damage but all claim settlements.

This report further stated: "We do know instances where signals prevented trains leaving stations before arrival of trains they had momentarily overlooked; also trains stopped account of broken rails."

On another railway the reduced cost of accidents, average for 5 years, effected by automatic block signals on a single-track division was estimated at $190 per mile of road per year.

It is evident that the reduced cost of accidents following an installation of automatic block signals may be an appreciable item and will vary with the methods of previous train operation, traffic conditions, open or mountainous territory, amount of obscured view, curves or tangent track conditions, and other local factors peculiar to each installation. The reduction in the cost of accidents alone will sometimes offset the cost of maintenance and operation of the automatic block signals.

Automatic block signals will show increased safety of train operation and also intangible saving by providing the following:

1. Protection against accidents due to track being occupied, open switch points, cars fouling main track, derails out of normal position, broken rails and, in some cases, slides.
2. An approach indication, facilitating train operation at meeting and passing points.
3. Improved service to the shippers and traveling public.
4. Increased railway capacity.
5. Postponement of more costly alternative improvements.
6. Easing of the mental strain on dispatchers, enginemen, trainmen, signalmen and others.
7. An advertising value.

The value of these intangible saving and operating benefits which should be credited to the automatic block system cannot always be ascertained but it is obvious that they are of economic importance.

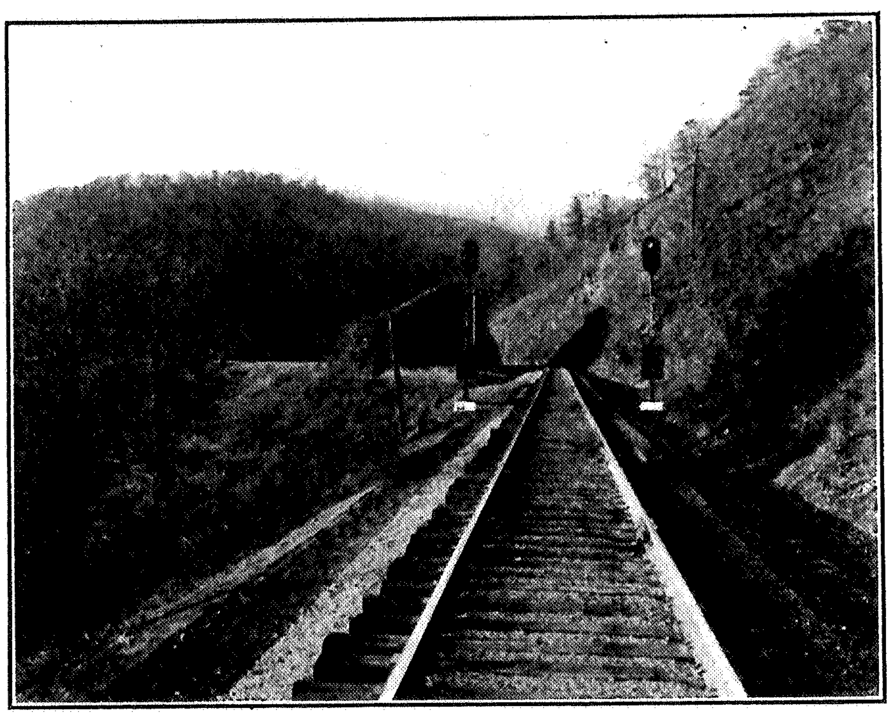
The Signal Section, A.R.A. conclusion and findings on Automatic Block Signals are as follows:

Conclusion

Automatic block signals are recommended as an economic means to be considered for reducing operating expenses by increasing track capacity and improving train operation where manual block, train staff or time interval spacing of trains is in use.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.



Automatic Block Signals on Southern Railway.

Interlocking

The earliest interlocking plants were of the mechanical type but in later years the power type has been more often used. The approximate number of the various types of plants in the United States from 1884 to 1930 is shown in Table IV.

TABLE IV

Interlocking Plants in United States

Year	Mechanical	Electro-mechanical	Pneumatic	Electro-pneumatic	Electric	All other types	Total all types	Total working levers
1884	131	......	9	......	....	4	144	2,219
1902	2,121	......	13	64	18	10	2,226	39,977
1916	4,921	297	31	469	758	....	6,476	152,515
1925	5,273	466	31	630	930	....	7,330	172,375
1930	5,520	737	....	740	1,136	....	8,133	184,420

Note.—Table from *Railway Engineering and Maintenance Cyclopedia*, 1926, p. 773, with estimated additions.

The improvements in train operation following the installation of 9 interlockings on 8 railways are shown in Table V.

In addition to the 6,000 train stops saved per year at Delavan (Table V), there were over 29,400 train stops eliminated at Lynchburg, and over 20,000 train stops eliminated at Lakeland Junction interlocking.

The Signal Section, A.R.A. conclusion and findings on Manually-Operated Interlockings are as follows:

Conclusion

Manually-operated interlocking is recommended as an economic means to be considered for reducing operating expenses and expediting traffic.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

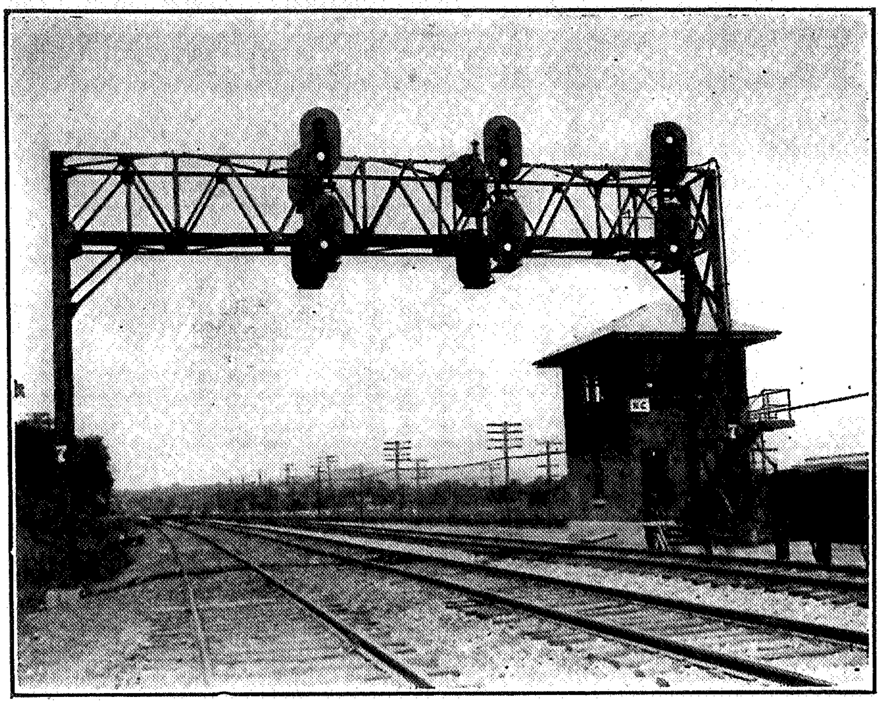
TABLE V

Operating Advantages of Interlocking Installations

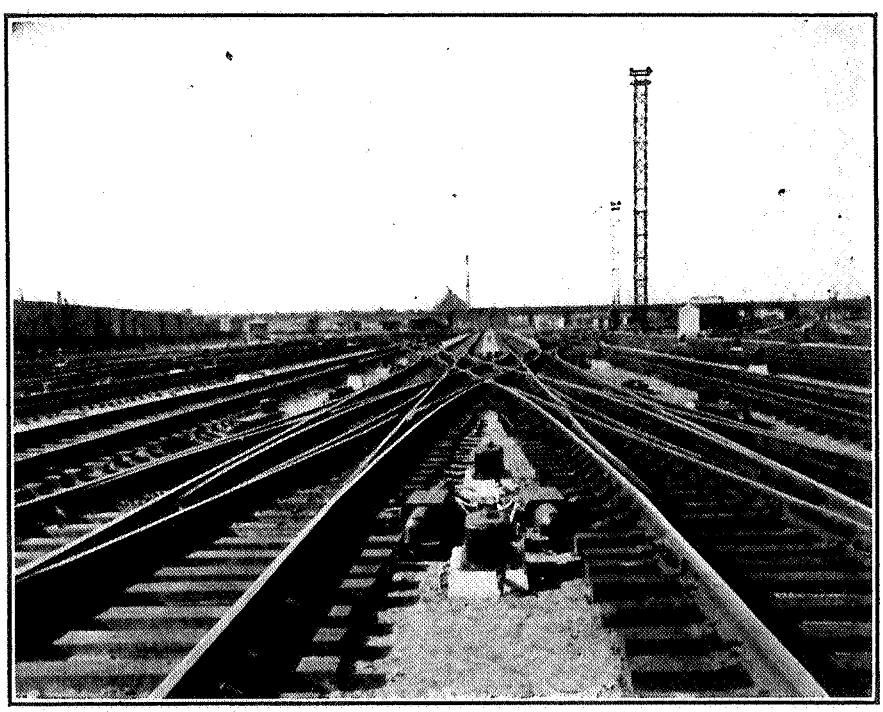
Railway	Location	In service	Layout	Type machine	Lever size	Trains per day	Cost	Saving per year	Per cent saving	Pub. ref.**
C. & A.	Delavan, Ill.	1929	Crossing	Mech.	24	30	$27,000	Saves 6,000 train stops yearly.		10
C. & O.	Lynchburg, Va.	1925	Crossing	E. P.	23	93	32,182*	$14,101*	43.8	11
C. & O.	Russell, Ky.	1925	Yard	E. P.	24	100	14,500	13,709	94.5	12
C. St. P. M. & O.	Lakeland Jct., Minn.	1931	Crossing	Elec.	7	27	13,000	10,000	77	13
D. & H.	Albany, N. Y.	1930	Junction	Elec.	4	100	8,242	5,500	67	14
I. U. T.	Indianapolis, Ind.	1931	Terminal	E. P.	111	200	360,000	Exceeds interest, depreciation and operating expenses.		15
N. P.	Tacoma, Wash.	1929	Junction	Mech.	32	75	32,000	7,000	21.8	16
N. Y. C.	E. E. Gibson Yd., Ind.	1927	Yard	Elec.	30	500	57,200	12,858	22.5	1
P. & L. E.	Becks Run, Pa.	1929	Yard	Elec.	38	60	96,343	87,450	90.7	17

* Reporting road only.

** For publication references, see p. 75.



Interlocking Signals on Chesapeake & Ohio Railway.



Interlocking on Boston & Maine Railroad.

Consolidation of interlockings.

In recent years there has been a tendency to consolidate interlockings in order to reduce operating expenses and centralize the direction of train movements. Examples of this practice and the operating and economic results of 15 installations on 6 railways are shown in Table VI.

The Signal Section, A.R.A. conclusion and findings on Consolidation of Interlockings are as follows:

Conclusion

Consolidation of interlockings is recommended as an economic means to be considered for reducing operating expenses and avoiding the expense of duplicate buildings.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

Automatic Interlockings

Automatically controlled signals and other signaling devices for the protection of train movements over railway grade crossings and at other relatively simple layouts have come into considerable prominence during the past ten years, 243* installations being made on 40 railways in 34 states between the years 1925 and 1930. These installations operate upon the approach of a train and have been called "automatic interlockings."**

This type of signaling not only eliminates the necessity for attendants for operation of the interlocking levers, but also the interlocking machine, other interlocking appliances, the interlocking station and other buildings, and in addition saves the yearly cost of maintaining and operating these facilities. The first installations were brought about by the necessity for providing an economic means of eliminating statutory stops for non-interlocked railway grade crossings where either or both of the crossing lines had a traffic of only a few trains per day. The present practice is to install these plants even when there is heavy traffic or part-time manual control is desirable on account of local operating conditions. They have been installed for automatic signal protection of gauntlet tracks over bridges and through tunnels, and at junctions of branch lines with main lines.

The operating advantages on 18 installations of automatic interlockings on 14 railways are shown in Tables VII and VIII.

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* As of December 31, 1931, there were 305 automatic interlocking plants in service and an average of 6.789 trains using these plants daily.

** For complete automatic interlocking report see Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, pp. 58–65, 449–455.

TABLE VI

Advantages of Consolidation of Interlockings

Railway	Location	In service	No. plants	Type machine	Lever size	Trains per day	Cost	Saving per year	Per cent saving	Pub. ref.*
A. T. & S. F.	Galveston, Tex.	1928	3	E. P.	87	135	$35,000	$14,000	40.0	18
B. & M.	Salem, Mass.	1928	2	E. M.	12	170	37,200	6,102	16.5	19
C. B. & Q.	Lincoln, Neb.	1930	2	Elec.	88	54	153,430	24,667	16.0	20
C. B. & Q.	Lincoln, Neb.	1929	2	Elec.	4	24	20,525	4,363	21.2	21
N. C. & St. L.	Howell, Ga.	1928	2	Elec.	107	480	10,057	4,995	49.6	22
N. Y. C.	Stanley, Ohio	1928	2	Elec.	152	180	211,000	39,424	18.7	23
P. R. R.	Aspinwall, Pa.	1923	3	E. P.	51	150	203,000	36,691	18.0	24
P. R. R.	Birdsboro, Pa.	1929	3	Elec.	20	36	59,139	14,253	24.1	25
P. R. R.	Bullis Mills, N. Y.	1929	3	Elec.	7	30	24,142	10,799	44.7	26
P. R. R.	Crosscut, Pa.	1929	2	E. M.	4	46	14,202	5,206	36.6	27
P. R. R.	Denholm, Pa.	1929	4	E. M.	6	33	35,366	10,580	29.9	28
P. R. R.	Enola, Pa.	1930	2	Elec.	5	95	17,000	5,331	31.3	29
P. R. R.	Kouts, Ind.	1930	2	Elec.	6	60	24,802	5,890	23.7	30
P. R. R.	Laurel Hill, Pa.	1929	2	E. M.	59	78	13,927	5,862	42.0	31
P. R. R.	New Portage, Pa.	1929	2	E. M.	32	25	5,649	5,726	101.0	32
Total			36				$864,439	$193,889		
Average per installation							57,629	12,926	22.4	

* For publication references, see p. 75.

TABLE VII

Automatic Interlockings

Railway	Location	In service	Type layout	Trains per day	Remarks	Pub. ref.*
A. T. & S. F.	Camp, Okla.	1929	S. T. Crossing	15	Replaced mechanical plant	33
A. T. & S. F.	Lost Springs, Kans.	1929	S. T. Crossing	28	Includes 4 sidings	33
A. T. & S. F.	Marion, Kans.	1929	S. T. Crossing	28	Simple layout	33
B. & O. C. T.	Hammond, Ind.	1930	Gauntlet	20	Tracks over bridge	34
B. R. T.	Brooklyn, N. Y.	1923	End of D. T.	335	Automatic power switch	35
C. & A.	Streator, Ill.	1929	S. T. Crossing	22	Simple layout	36
C. & E. I.	Sullivan, Ind.	1928	S. T. Crossing	50	Two interchange tracks	37
C. G. W.	Waverly, Ia.	1927	S. T. Crossing	16	One interchange track	38
C. M. St. P. & P.	22 plants	1921–28	S. T.-D. T. Crossings	20	Various layouts	39
C. R. I. & P.	Laurens, Ia.	1926	S. T. Crossing	12	Simple layout	40
C. R. I. & P.	Pleasant Hills, Mo.	1929	S. T. Crossing	29	Replaced 25 year plant	41
L. & N.	Nashville, Tenn.	1929	Gauntlet	40	Tracks over bridge	42
M. & St. L.	3 plants in Iowa	1930	S. T. Crossings	32	Interchange tracks and sidings	43
N. Y. C.	Raisin Center, Mich.	1927	S. T.-D. T. Crossing	38	Replaced 20-year plant	44
G. N.	Wayzata, Minn.	1927	D. T. Jct.	25	3 power switches	45
G. N.	Barnesville, Minn.	1929	S. T. Jct.	16	2 power switches	46
T. & O. C.	Charleston, W. Va.	1919	Gauntlet	30	Tracks over bridge	47
Wabash	Steubenville, Ind.	1929	S. T. Crossing	28	Replaced 30-year plant	48

* For publication references, see p. 75.

TABLE VIII

Economic Advantages of Automatic Interlocking

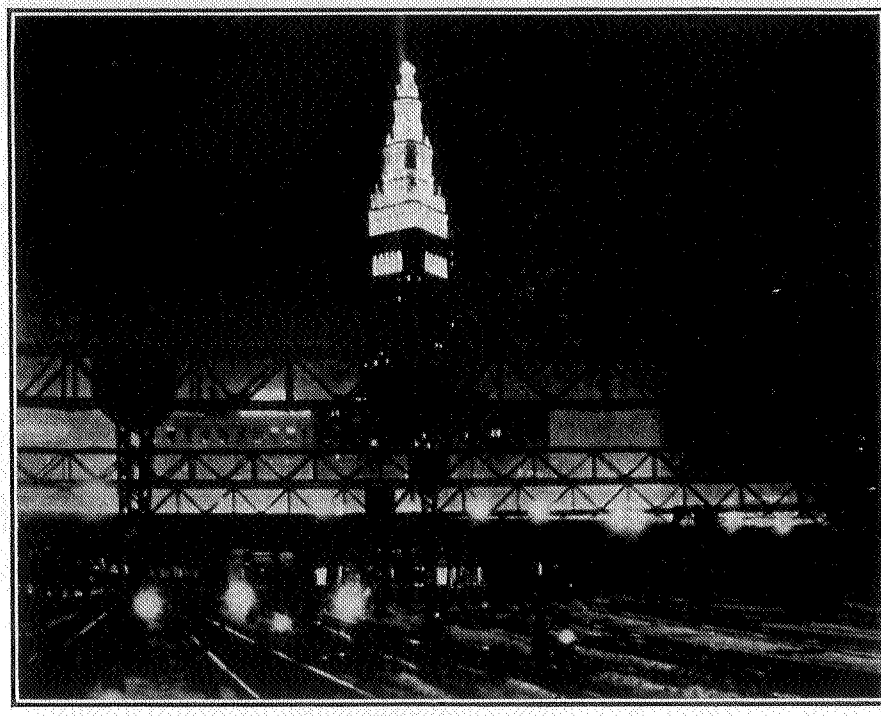
Railway	Cost	Saving per year	Per cent saving	Remarks
A. T. & S. F.	$6,866	$4,898	71	Released three levermen.
A. T. & S. F.	13,277	16,864	127	Eliminated over 9,280 train stops annually.
A. T. & S. F.	8,703	15,088	173	Eliminated over 8,240 train stops annually.
B. & O. C. T.	2,800	5,551	198	Released three switch tenders.
B. R. T.	2,300	4,300	187	Released three levermen.
C. & A.	10,487	3,000	28.6	Eliminated 8,000 train stops annually.
C. & E. I.	11,600	12,000	103	Eliminated 18,000 train stops annually.
C. G. W.	6,500	5,000	77	Replaced 16-lever mechanical plant.
C. M. St. P. & P.	6,000†	4,200†	70	Eliminated thousands of train stops annually.
C. R. I. & P.	5,000	4,500	90	Released three levermen.
C. R. I. & P.	5,500	4,500	82	Released three levermen.
L. & N.	3,846	5,000	130	Replaced desk lever interlocking.
M. & St. L.	10,000†	5,333†	53	Eliminated thousands of train stops annually.
N. Y. C.	11,560	2,181*	18.9	Released three levermen.
G. N.	11,118	5,000	45	Replaced mechanical plant and released three levermen.
G. N.	5,800	2,310	39.8	Eliminated train stops at junction.
T. & O. C.	1,650	8,145	493	Released six flagmen.
Wabash	18,334	5,000	27	Released three levermen.

The costs of installation show a wide spread. This can be accounted for by the difference in the types of installation and the fact that in some cases the installation replaced existing interlocking facilities. The saving at an automatic interlocking is high when installed at a simple crossing layout where no protection was previously provided and all trains are required by State law to stop or on a gauntlet track where switch tenders, flagmen, or levermen are eliminated. On the C. M. St. P. & P. it was only necessary to eliminate two train stops per day and on the A. T. & S. F. it was found that a time saving of 14 minutes per day would pay the annual charges for an automatic interlocking.**

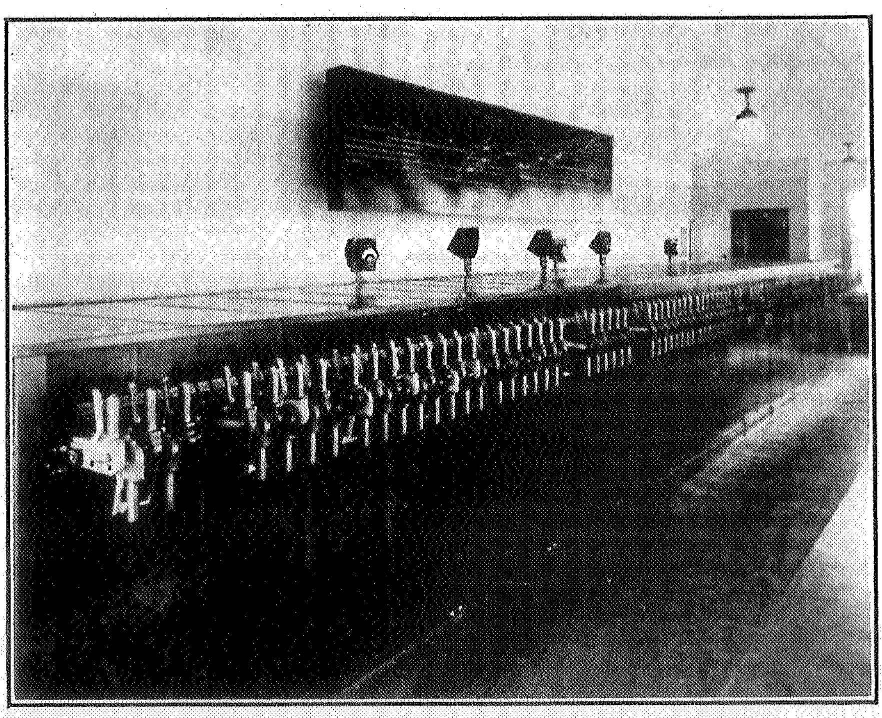
† Average per plant.

* Reporting road only.

** For detail list of eighteen advantages of automatic interlocking, see Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 59.



Interlocking at Cleveland Union Terminal.



Interlocking Machine on Toronto Terminals Railway.

In addition to the 18 installations (Tables VII and VIII), a summary of the average saving made at 22 automatic interlockings installed at non-protected crossings on 6 railways, is as follows:

1. Average total saving per year	$7,552
2. Maintenance, operation and interest per year	818
3. Average net saving per year	6,734
4. Average total cost of installation	7,089
5. Annual return on investment over and above interest charges, per cent	95

A summary of the average saving made at 11 automatic interlockings replacing manually-controlled interlockings on 5 railways, is as follows:

1. Average reduction in wages per year	$2,756
2. Annual cost of maintenance, operation and interest on interlocking plants replaced	1,113
3. Total annual saving	3,869
4. Annual charges of automatic plants	590
5. Annual net saving	3,279
6. Average total cost of installation	5,864
7. Annual return on investment over and above interest charges, per cent	55.9

The above figures cover cost and saving of reporting road only.

Summary of the Saving Effected by Automatic Interlockings

Installations	Cost of installation	Net saving per annum	Annual return on total cost*
18 installations on 14 railways	$141,341	$112,870	80%
22 installations on 6 railways at non-protected crossings**	155,934	148,140	95%
11 installations on 5 railways replacing manually-controlled plants	64,501	36,071	56%
Total, 51 installations	$361,776	$297,081	82%
Average per installation	7,094	5,825	82%

The Signal Section, A.R.A. conclusion and findings on Automatic Interlockings are as follows:

Conclusion

Automatic interlockings replacing manually-operated plants at railroad grade crossings, gauntlets, or junctions, or replacing non-interlocked arrangements is recommended as an economic means to be considered for reducing operating expenses and expediting traffic.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

* Over and above 6 per cent interest charges.

** 90,740 train stops eliminated per year.

Train Operation by Signal Indication

The first installation of train operation by signal indication was made in 1882. In 1931 there were 230 installations on 47 railways. The mileage* of these installations is as follows:

Number of tracks	Miles of road	Miles of track
Single track	1,206.9	1,206.9
Double track	902.5	1,805.0
Three tracks	234.1	696.7
Four tracks	98.0	392.0
Five tracks	0.8	4.0
Total	2,442.3	4,104.6

Installations of this kind have been due to the desire to improve railway operation by:

1. Reducing delays caused by:
   (a) Fleeting of trains causing congestion of traffic during certain periods of the day.
   (b) Congestion on grades.
   (c) Congested sections of track, affecting train operation over entire divisions.
   (d) Train stops entering and leaving sidings.
   (e) Meeting of trains.
   (f) Interference with yard switching.
   (g) Interference with roadway repairs and renewals.
   (h) Operation of trains by "31" orders, manual block and other methods of directing trains.
2. Providing:
   (a) Increased capacity and facilitating traffic in terminal and suburban areas.
   (b) Postponement of additional track facilities.
   (c) A higher per cent of "on-time" performance.
   (d) Faster schedules for competitive traffic.
   (e) Improved train operation through tunnels, gauntlets and other congested sections.
   (f) Signaling for rush hour traffic conditions at a minimum expenditure.
   (g) Modern signaling for larger motive power and increased train loading.
   (h) Economical train operation.
   (i) Increased safety of train operation.

* A.R.E.A. Proceedings, Vol. 31, pp. 1040, 1058 and additions to November 1931 A.R.E.A. Proceedings, Vol. 33, pp. 510, 514.

Train operation by signal indication is applicable to a variety of track and operating conditions for expediting traffic. While a large percentage of the installations have been made on single and double track lines, it has also been installed on three, four and five track lines. Examples of installations are shown in Table IX.

TABLE IX

Types of Installations

S. T. sections	Road miles
B. & O.	89.2
C. of Ga.	23.6
C. & O.	5.0
C. C. C. & St. L.	97.0
M.-K.-T.	5.0
M. P.	50.1
N. C. & St. L.	13.5
N. Y. N. H. & H.	13.2
P. R. R.	8.0

D. T. sections	Road miles
A. T. & S. F.	187.9
B. & M.	6.5
C. P.	7.6
C. & O.	28.0
C. B. & Q.	72.5
C. M. St. P. & P. / C. R. I. & P.	37.7
D. & R. G. W.	25.0
Erie	9.5
I. C.	21.0
M. P.	32.0
P. R. R.	8.3

Center track of 3 tracks	Road miles
B. & O.	24.3
C. & O.	6.0
C. & N. W.	13.5
C. B. & Q.	12.1
D. L. & W.	9.1
I. C.	26.0
P. R. R.	6.8

3-track section	Road miles
C. & O.	21.0

4-track section	Road miles
C. R. R. of N. J.	2.9
C. & O.	1.0
C. B. & Q.	12.3
D. L. & W.	1.3
Erie	2.2
N. Y. C.	5.0

5-track section	Road miles
D. L. & W.	0.8

Tunnel applications

B. & M., Hoosac Tunnel, Mass.
C. P., Glacier, B. C., Can.
D. L. & W., Hoboken, N. J.
Erie, Jersey City, N. J.
N. Y. C., Grand Central Terminal
P. R. R., Pennsylvania Terminal

Installed with new tracks

C. & O., Cincinnati, Ohio, 3.6 miles of 2 and 4 tracks
C. M. St. P. & P., C. R. I. & P., Polo, Mo., 37.7 miles of 2 tracks
M. P., HD Jct., Mo., 32.0 miles of 2 tracks

Eliminated congested sections

B. & M., Hoosac Tunnel—North Adams, Mass.
C. of Ga., Terra Cotta—Carman, Ga.
C. & O., Cheviot—Brighton, Ohio.
C. C. C. & St. L., Terre Haute, Ind.—Pana, Ill.
M. P., Leeds, Mo.—Osawatomie, Kans.
N. C. & St. L., Cowan—Sherwood, Tenn.

TABLE IX—Continued

Postponed expenditures for additional trackage

A. T. & S. F., Fort Madison, Ia.—Pequot, Ill.
A. T. & S. F., Holliday—Olathe, Kans.
B. & O., Millers—Orleans Road, W. Va.
C. of Ga., Terra Cotta—Carman, Ga.
C. C. C. & St. L., Terre Haute, Ind.—Pana, Ill.
D. L. & W., West End—Milburn, N. J.
I. C., Otto—Gilman, Ill.
M. P., Leeds, Mo.—Osawatomie, Kans.
N. Y. N. H. & H., Highland—Maybrook, N. Y.
P. R. R., Spruce Creek—Tyrone Forge, Pa.

These installations are on sections of lines on which, with few exceptions, there is heavy traffic movement. On ten of the installations, the greater capacity deferred the necessity of providing additional trackage, thus effecting substantial savings in both construction and maintenance costs, and made it possible to utilize the existing trackage to a greater capacity for a smaller investment.

The cost of installations depends on whether automatic block signals and track work are included, the signaling required at interlocking plants, signaling practice on each railroad, and local conditions.

Twenty-six examples of the operating and economic advantages of train operation by signal indication on single and multiple track lines of 20 railways are shown in Table X.

The Signal Section, A.R.A. conclusion and findings on Train Operation by Signal Indication are as follows:

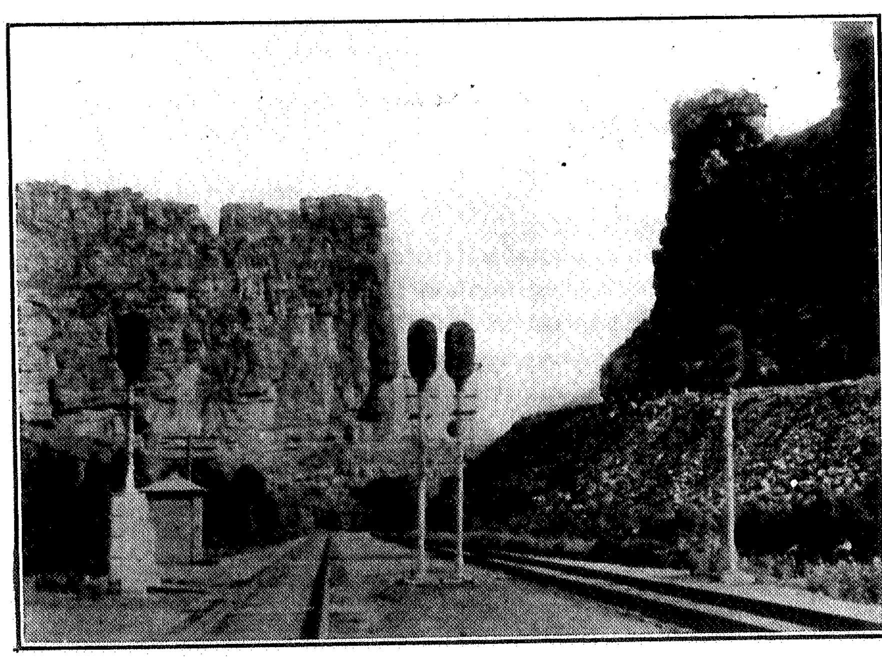
Conclusion

The operation of trains by signal indication on single or multiple track lines is recommended as an economic method to be given consideration for the possible postponement of expenditures for additional trackage and reducing operating expenses by relieving congestion, increasing track capacity, improving train operation and eliminating written train orders.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

Signals in Electrified Territory on Delaware, Lackawanna & Western Railroad.



Signals on Denver & Rio Grande Western Railroad.

TABLE X

Train Operation by Signal Indication Installations

Railway	Location	In service	Road miles	Track miles	Trains per day	Annual saving	Per cent on investment	Pub. ref.*
A. T. & S. F.	Fort Madison, Ia.—Pequot, Ill.	1927	175.7	351.4	60	----	----	49
	Reduced delays and increased train loading. Increased capacity 30 to 35 per cent. Discontinued siding extensions. Greatly facilitates heavy track work.							
A. T. & S. F.	Holliday—Olathe, Kans.	1931	12.2	24.4	34	----	----	50
	Tonnage trains saved 9 min. in 12.2 miles. Eliminated delays due to 0.6 grade. Increased track capacity and deferred third track. Time saving made on reduced number of trains per day as compared with previous operation.							
B. & O.	Millers—Orleans Road, W. Va.	1914	24.3	24.3	27	----	----	51
	Materially increased track capacity. Postponed fourth track.							
B. & O.	Rosemont — Parkersburg, W. Va.	1929	89.2	89.2	40	----	----	52
	Reduced train orders 1,000 per month. Eliminated train stops at sidings. Facilitated train operation.							
B. & M.	Hoosac Tunnel—North Adams, Mass.	1928	6.5	14.5	65	----	----	53
	Eliminated congested section of division and staff operation for reverse traffic through 5 mile tunnel. Electric operation and "fleeting" of trains caused congestion adjacent to tunnel.							
B. & M.	North Chelmsford—Ayer, Mass.	1929	13.5	27.0	57	$37,847	----	54
	Reduced delays at meeting points, bunching of trains, yard engine interference, and increased track capacity.							
C. P.	Glacier, B. C., Can.	1929	7.6	15.2	28	----	----	55
	Unique system of automatic operation expedites traffic through 5 mile tunnel.							

* For publication references, see p. 75.

TABLE X—Continued

Railway	Location	In service	Road miles	Track miles	Trains per day	Annual saving	Per cent on investment	Pub. ref.*
C. of Ga.	Carman — Terra Cotta, Ga.	1927	23.6	23.6	52	$20,264	21	56
	Eliminated congested section. Postponed second track. Estimated maximum capacity 80 trains per day.							
C. & O.	Cheviot—Brighton, Ohio	1928	5.0	5.0	47	$26,209	101	57
	Eliminated absolute block of 4.5 miles on 1.91 per cent grade, reducing delays and greatly facilitating traffic.							
C. & O.	Cincinnati, Ohio—Covington, Ky.	1929	3.6	9.2	178	----	----	58
	Reverse traffic over double track Ohio River Bridge and a mile section of four track eliminates delays and facilitates traffic.							
C. & O.	Scott—DK Cabin, W. Va.	1923	28.0	56.0	80	$6,228	34.6	59
	Reduced delays and facilitated traffic.							
C. & N. W.	Des Plaines—Barrington, Ill.	1930	13.5	13.5	120	----	----	60
	Eliminated delays, reduced schedules 3 to 5 min., increased on-time performance and provided increased capacity on three-track line.							
C. M. St. P. & P. / C. R. I. & P.	Polo—Birmingham, Mo.	1931	37.7	75.4	36	----	----	61
	Either direction signaling on new single and double track line facilitates train operation.							
C. C. C. & St. L.	Terre Haute, Ind.—Pana, Ill.	1928	97.0	98.5	34	----	----	62
	Eliminated congested section on this division. Reduced time 45 min. on EB and 15 min. on WB freights. Postponed double track and increased capacity 15 per cent.							
D. L. & W.	West End—Milburn, N. J.	1923	15.3	15.3	260	----	----	63
	Expedited trains and improved on-time performance.							

* For publication references, see p. 75.

TABLE X—Continued

Railway	Location	In service	Road miles	Track miles	Trains per day	Annual saving	Per cent on investment	Pub. ref.*
D. & R. G. W.	Helper—Colton, Utah	1929	25.0	50.0	49	----	----	64
	Eliminated delays on 2.4 per cent grade, expedited train movements and increased track capacity.							
Erie	Tusten—Lackawaxen, N. Y.	1931	9.5	19.0	42	----	----	65
	Reduced delays, expedited preference trains and increased track capacity with highly satisfactory operation.							
I. C.	Otto—Gilman, Ill.	1924	21.0	42.0	60	----	----	66
	Saved 9 to 24 min. per freight train, postponed the building of extra tracks and effected saving in operation.							
M.-K.-T.	Muskogee—Wybark, Okla.	1925	5.0	5.0	36	$4,500	----	67
	Facilitates train movements between junction point and terminal.							
M. P.	HD Jct.—Valley Park, Mo.	1931	32.0	64.0	40	----	----	68
	Running trains in either direction on either track is a decided operating advantage. Sidings are seldom used.							
M. P.	Leeds, Mo.—Osawatomie, Kans.	1925	50.1	50.1	36	----	----	69
	Increased average train speed 22.6 per cent and GTM per train hour 20.9 per cent. Reduced train hours and increased efficiency of train operation.							

* For publication references, see p. 75.

TABLE X—Concluded

Railway	Location	In service	Road miles	Track miles	Trains per day	Annual saving	Per cent on investment	Pub. ref.*
N. C. & St. L.	Cowan—Sherwood, Tenn.	1911	13.5	16.0	40	$33,653	----	70
	Relieved traffic congestion, increased track capacity.							
N. Y. C.	Grand Central—Mott Haven, N. Y.	1931	5.0	20.0	850	----	----	71
	Reduced delays at Mott Haven Jct. and in running time of trains into Grand Central Terminal. Increased track capacity for rush hour train movements.							
N. Y. N. H. & H.	Highland—Maybrook, N. Y.	1909	13.2	13.2	46	----	----	72
	Reduced freight train hours and overtime. Deferred double track.							
P. R. R.	Louisville Bridge, Ky.	1882	8.0	10.5	87	----	----	73
	Successful 50 year operation reduced delays, eliminated train orders and facilitated traffic.							
P. R. R.	Spruce Creek—Tyrone Forge, Pa.	1913	6.8	6.8	35	----	----	74
	Increased capacity 25 per cent, reduced congestion and postponed fourth track.							

* For publication references, see p. 75.

Remote Control

Remote control is used to advantage where switches are located some distance from a station, at an end of double track, junction, railroad crossing at grade, or at entrance to a yard where an operator at a nearby station can control the position of the switches and/or signals in such a way as to allow trains to proceed without stopping or reducing speed below that specified in the rules.

While outlying switches may be operated manually by trainmen, switchmen or by other designated employees, without signal protection the remote control method shows the lowest annual cost of operation. The economic value of operating outlying switches by the remote control method is dependent upon the cost of stopping and starting the trains that could pass over controlled switches without stopping. It becomes economically advantageous to remote control an outlying switch when the cost of stopping and starting the trains or the payroll saving is greater than the fixed and operating charges accruing from the installation.

The number* of remote control switches and signals in service at the end of specified years is shown in Table XI.

TABLE XI

Remote Control Switches and Signals

Year	Number control points	Number single switches	Number crossover switches	Number of signals Semaphore	Light
1929	376	449	136	1,122	980
1930	367	460	211	991	1,364
1931	396	493	200	1,065	1,468

A comparative study** of 5 different schemes of operating a facing point switch 5,000 feet from an existing station, based on the detail estimates of one railway in 1923, is shown in Table XII.

TABLE XII

Methods of Operating a Facing Point Switch

Scheme	Switch operated by	With	Total First cost	Total Annual cost
I	Trainmen	No signals	0	$7,300
II	Switchmen	One distant signal	$1,806	5,467
III	Switchmen	One home and distant signal	3,356	5,976
IV	Mechanical interlocking	Five signals	7,308	7,182
V	Remote control	Five signals	11,191	2,397

* Reports of the Director of Bureau of Safety, I. C. C. Tabulation of Statistics.

** Signal Section, A.R.A. 1923 Proceedings, Vol. XXI, pp. 145–155.

Table XII shows the first cost and the annual cost of operation of each scheme and indicates that the advisability of installing either schemes II, III, IV or V, based upon the saving that would accrue from the investment, is entirely dependent upon the cost of operation under scheme I. The costs will vary with different railways depending upon local conditions.

Remote control has been applied to a variety of track layouts and operating conditions for expediting traffic. Typical examples of how the system has been successfully applied are as follows:

Remote control of manual block signals.

The C. C. C. & St. L. has five installations of manual block stations remotely controlled which serve to direct train movements and report the passing of trains, thereby saving the expense of operators at such points, all of which are located at outlying sidings. The first installation was made on a single-track line at Horace, Ind., in 1927, the manual block signals being controlled from Greensburg, 7 miles away, saving the expense of a three-trick block station at Horace. About 18 trains are operated in this territory per day.*

A similar installation of remotely controlled signals replacing a two-trick manual block station was made on a double-track line at Campbell, Ill., on the N. Y. C., 5½ miles north of Danville, Ill., in 1930. About 20 trains per day are operated over this territory.**

The C. & O. placed in service, in 1930, a remote control system of combined manual and controlled manual block train operation between Old Town and Nelsonville Yard Office, Ohio, a distance of 11.4 miles, of which 3.2 miles is double track. Before this change was made there was a three-trick office at East Clayton, the operators handling the switch at the end of double track and blocking trains to the next manual block office. Under the new signaling, the operator at Nelsonville Yard Office controls the signals at the end of double track and blocks trains to the next open block station.†

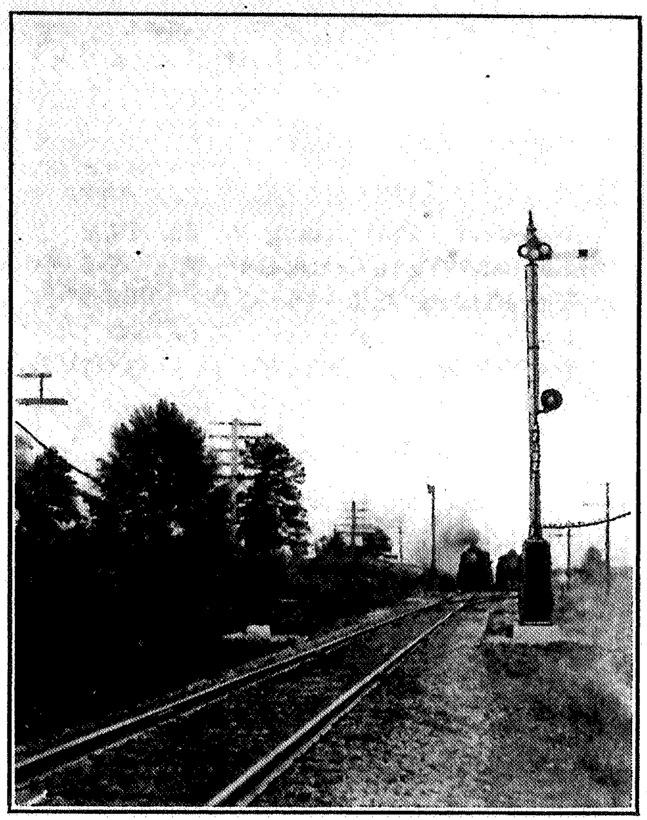
Remote control of end of double track.

- C. of Ga., Americus, Ga.
- C. of Ga., Griffin, Ga.
- C. & O., Balcony Falls, Va.
- C. & O., East Clayton, Ohio
- C. B. & Q., Concord, Ill.
- C. G. W., Rice, Ill.
- N. C. & St. L., Stevenson, Ala.
- N. & W., N. Roanoke, Va.

Remote control of junction interlocking.

- C. & N. W., Chaldron, Nebr.
- C. & N. W., Green Bay, Wis.

* *Railway Signaling*, April 1929, p. 137.
** *Railway Signaling*, September 1930, p. 327.
† Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 27.



Remotely-Controlled Switch on Central of Georgia Railway.

Remote control of crossing interlocking.
C. B. & Q., Lincoln, Nebr.
M. C., Rochester Jct., Mich.

Remote control of end of siding.
T. & O. C., Centerburg, Ohio

Other remote control installations are shown in Table XIII.

TABLE XIII

Remote Control Installations

Railway	Location	Track miles	No. remote switches	Pub. ref.*
B. & O.	Rosemont—Parkersburg, W. Va.	89.2	56	52
C. of Ga.	Carman—Terra Cotta, Ga.	23.6	2	56
C. C. C. & St. L.	Terre Haute, Ind.—Pana, Ill.	98.5	16	62
M. P.	Leeds, Mo.—Osawatomie, Kans.	50.1	12	69
S. P.	Bena—Tehachapi, Calif.	32.7	11	76

Time Saved per Train Stop

The time saved per train stop eliminated at an outlying switch location will vary with the train load, grade and other local conditions. The average time saved per freight train stop eliminated in a number of reports is shown in Table XIV.

TABLE XIV

Time Saved per Freight Train Stop

Railway	Average minutes saved per freight train stop	Pub. ref.*
C. & O.	10.0	77
C. & O.**	14.1	78
C. C. C. & St. L.	5.5–8.0	62
I. C.**	9.0	79
17 roads	5–19.4, av. 13.24	80
11 roads	7–27.6, av. 10.4	81
6 roads	6–19.25, av. 10.4	82
T. & O. C.	8.0	83
T. & P.	15.0	84

While the time saved per freight train stop eliminated averaged 11.9 minutes in the 39 cases shown in Table XIV, the time saved per passenger train stop eliminated varied from 2 to 5 minutes.

* For publication references, see p. 75.
** Based on dynamometer car tests.

The cost of remote control will vary with the type and amount of signaling depending on local conditions. The average cost on a large number of installations varied as shown in Table XV.

TABLE XV

Cost of Remote Control

Number of remote control switches	Total cost	Cost per power switch	Pub. ref.*
126	$510,602	4,052	80
17	86,784	5,105	81
473	2,822,077	5,966	85

The economic advantages and the actual cost of 14 remote control installations are shown in Table XVI.

The saving made by remote control installations is due to:

1. Reduction in delay time due to train stops eliminated.
2. Reduction in cost of train operation.
3. Reduction in cost of maintaining and operating block or interlocking stations.
4. Increased safety of train operation.
5. Increased track capacity.
6. Increased on-time performance.
7. Deferring more expensive alternative improvements.

The Signal Section, A.R.A. conclusion and findings on Remote Control are as follows:

Conclusion

The use of remote control for outlying signals and/or switches is recommended as an economic means to be considered for reducing operating expenses and expediting traffic.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

Centralized Traffic Control

In 1932, thirty railways of the United States and Canada were using centralized traffic control for directing train movements at from one to eleven locations and are securing operating economies and advantages impossible to attain with other methods of dispatching trains. Since the first application of this system in 1927, there have been 65 installations and more are under construction.

* For publication references, see p. 75.

TABLE XVI

Economic Advantages of Remote Control

Railway	Location	Year	Type layout	No. sws.	Type machine	Trains per day	Total cost	Annual saving per year	Annual saving per cent	Pub. ref.†
C. of Ga.	Americus, Ga.	1926	End DT	4	T. L.*	37	$10,425	$3,756	36.0	86
C. of Ga.	Americus, Ga.	1930	End DT	4	T. L.	27	404	2,418	591.0	86
C. of Ga.	Griffin, Ga.	1929	End DT	4	T. L.	35	16,306	3,997	24.5	87
C. & O.	Balcony Falls, Va.	1925	End DT	1	T. L.	24	11,607	8,370	72.1	77
C. & O.	East Clayton, Ohio	1930	End DT	1	T. L.	13	14,570	4,774	32.7	75
C. & N. W.	Chaldron, Nebr.	1929	Jct.	1	C. T. C.	26	37,200	14,465	38.9	88
C. & N. W.	Green Bay, Wis.	1929	Jct.	4	C. T. C.	32	27,500	31,855	115.8	89
C. B. & Q.	Concord, Ill.	1928	Ends DT	2	C. T. C.	26	26,000	7,128	27.4	90
C. B. & Q.	Lincoln, Nebr.	1929	Crossing	5	C. T. C.	28	17,664	4,396	24.9	91
C. G. W.	Rice, Ill.	1931	Ends DT	2	C. T. C.	24	18,000	7,000	38.9	92
M. C.	Rochester Jct., Mich.	1930	Crossing	....	P. B.**	22	17,900	5,000	27.9	93
N. C. & St. L.	Stevenson, Ala.	1923	End DT	1	T. L.	24	6,277	8,894	141.7	94
N. & W.	N. Roanoke, Va.	1928	Ends DT	2	C. T. C.	16	15,000	4,400	29.3	95
T. & O. C.	Centerburg, Ohio	1922	End Sdg.	1	T. L.	20	5,100	4,712	92.4	83
	Total 14 installations						$223,953	$111,165	....	
	Average per installation						15,997	7,940	49.6	

* T.L. — Table lever
** P.B. — Push button
† For publication references, see p. 75.

This system of train operation is considered by many to be among the outstanding recent developments in the railway field and its wide use as a means of handling trains is predicted because of the economies in operation which it affords.

Centralized traffic control makes operation by the signal indication method available to all kinds of railway operating conditions. The advantages of this method of operation are many. The time element in the transmission of orders is practically eliminated and results in more efficient dispatching. Direct control of each train movement is made possible without dependence upon a system of control involving intermediate operators for the delivery of orders. The train order in the signal indication method is given by the signal to the engineman.

Application of centralized traffic control.

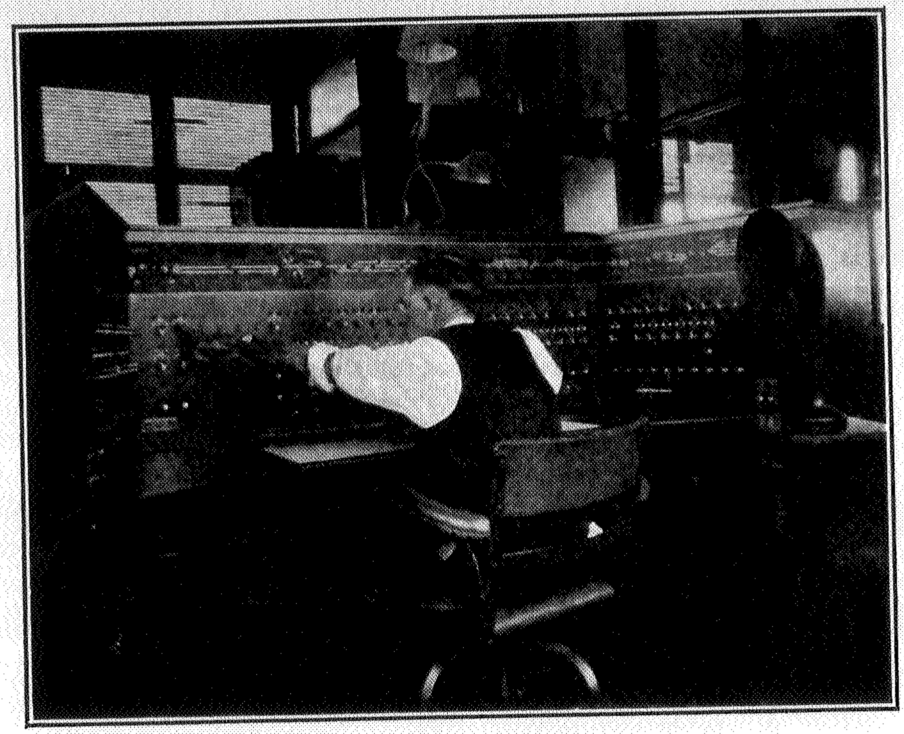
Typical examples of the application of the system are:

Congested locations	Single-track sections	Double-track sections	Interlocking plants eliminated	Replaced staff system
B. & G.	A. T. & S. F.	B. & M.	B. & M.	C. P.
B. & M.	B. & O.	C. B. & Q.	C. R. R. of N. J.	C. G. W.
C. P.	C. B. & Q.	C. M. St. P. & P.	C. B. & Q.	P. & I.
C. B. & Q.	D. & R. G. W.	C. R. I. & P.	D. & H.	
D. & R. G. W.	M. P.	Erie	I. C.	
T. & N. O.	N. Y. C.	I. C.	M. P.	
	P. R. R.	M. P.	P. & P. U.	
	P. M.	P. R. R.		
	S. P.	T. & P.		
	Wabash			

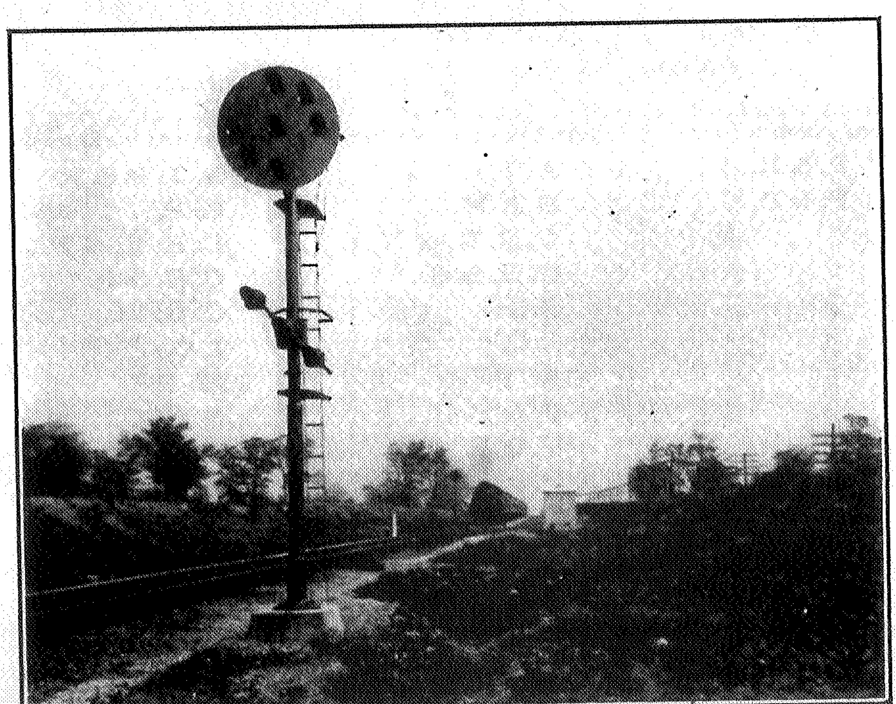
Terminal roads with many junction points	Either direction signaling on double track	Sections where C. T. C. postponed additional trackage
P. & I.	A. T. & S. F.	A. T. & S. F.
P. & P. U.	B. & M.	C. P.
	C. R. R. of N. J.	C. R. R. of N. J.
	C. B. & Q.	C. B. & Q.
	Erie	C. G. W.
	I. C.	I. C.
	M. P.	M. P.
	P. & P. U.	N. Y. C.
	T. & P.	P. R. R.
		P. M.
		S. P.
		T. & P.
		Wabash

These 13 installations totaling 332 miles postponed second tracking and center sidings at a cost, based largely on railroad estimates, of approximately $18,888,500 and at a cost of $1,908,750 for annual charges.*

* A.R.E.A. Proceedings, Vol. 33, p. 514.



Centralized Traffic Control Machine on Baltimore & Ohio Railroad.



Centralized Traffic Control Location on Pennsylvania Railroad.

Centralized traffic control installations on various railways, and their mileage with other details, are shown in Table XVII.

TABLE XVII

Centralized Traffic Control Installations—1932

Railway	No. of installations	Miles of Road	Miles of Track	Power switches	Signals	"OS" points
A. T. & S. F.	4	60.0	86.5	34	72	76
B. & O.	3	107.4	112.4	56	232	101
B. & G.	1	16.0	16.0	2	49	15
B. & M.	11	200.3	362.0	254	578	241
C. N.	1	9.5	15.2	7	11	10
C. P.	1	9.0	9.0	2	18	4
C. R. R. of N. J.	1	4.9	19.6	4	9	6
C. & N. W.	2	8.5	8.5	5	20	9
C. B. & Q.	8	82.0	109.0	69	184	76
C. G. W.	1	1.6	1.6	2	6	2
C. M. St. P. & P., C. R. I. & P.	1	37.7	75.4	11	24	14
C. R. I. & P.	1	20.7	31.1	4	16	17
C. C. C. & St. L.	1	5.0	10.0	8	20	10
D. & H.	1	12.3	18.0	6	47	22
D. & R. G. W.	2	39.0	41.5	14	69	26
Erie	1	9.5	19.0	4	9	5
I. C.	2	19.2	34.2	11	66	10
L. V.	1	11.2	11.2	2	8	2
M. P.	4	99.0	143.5	49	243	70
N. Y. C.	1	40.2	43.5	32	102	32
N. Y. N. H. & H.	1	4.0	12.0	2	9	6
N. & W.	1	8.5	8.5	1	8	4
P. & I.	1	15.0	15.0	13	30	15
P. R. R.	4	58.0	86.0	25	63	50
P. & P. U.	1	7.1	14.9	20	37	17
P. M.	1	20.0	20.0	8	33	11
S. P.	1	39.7	42.3	24	101	29
T. & N. O.	2	23.0	23.0	10	37	14
T. & P.	4	84.3	164.4	32	197	24
Wabash	1	37.0	37.0	15	65	35
Total...............	65	1,089.6	1,590.3	726	2,363	953

Typical examples of costs of centralized traffic control installations are shown in Table XVIII.

TABLE XVIII

Costs of Centralized Traffic Control Installations

Railway	Location	No. C.T.C. switches	Miles of Road	Miles of Track	Approximate Total cost	Approximate Cost per mile of track	Remarks
B. & M.	Three installations	235	143.7	263.0	$2,608,000	$9,910	Includes track and interlocking changes.
C. P.	Medicine Hat—Dunmore, Alberta	2	9.0	9.0	57,600	6,400	Replaced staff system.
C. B. & Q.	Steward Jct.—Flag Center, Ill.	14	9.0	18.0	65,810	3,650	Existing automatic signals.
C. B. & Q.	Red Oak—Balfour, Ia.	20	25.5	28.0	100,000	3,700	Existing automatic signals.
C. B. & Q.	Waverly—Greenwood, Nebr.	5	12.0	19.0	31,500	1,650	Existing automatic signals.
I. C.	Otto—Ashkum, Ill.	10	11.5	23.0	35,000	1,520	Existing signaling.
M. P.	Edgewater Jct.—Atchison, Kans.	28	43.0	43.0	430,000	10,000	Three interlockings consolidated.
N. Y. C.	Stanley—Berwick, Ohio	32	40.2	43.5	455,000	10,460	Replaced manual block.
P. & I.	Metropolis, Ill.—Paducah, Ky.	13	15.0	15.0	130,000	8,660	Replaced manual block and staff system.
P. R. R.	Ben Davis—Almeda, Ind.	12	33.0	36.0	178,750	4,960	Replaced manual block.
P. & P. U.	Peoria—N. Pekin, Ill.	20	7.1	14.9	96,700	6,530	Four interlockings consolidated.
P. M.	Mt. Morris—Bridgeport, Mich.	8	20.0	20.0	106,000	5,300	Replaced manual block.
Wabash	State Line—Lafayette, Ind.	15	37.0	37.0	162,000	4,380	Existing overlap signals.
	Total	414	406.0	569.4	$4,456,360	....	
	Average per mile of track					$7,830	

Table XVIII indicates that the costs will vary considerably depending upon:

1. Whether C.T.C. includes new automatic block signals.
2. Charges for signaling replaced and/or retired.
3. Charges for track facilities.
4. The concentration of signaling due to interlocking plants.
5. Signaling practice of each particular road.
6. Distance of control point from territory (not important on large installations but forms larger part on small installations).

The freight train time saving on 10 centralized traffic control installations is shown in Table XIX.

The improvements in train operation following the installation of centralized traffic control on 33 installations on 23 railways are shown in Table XX.

Among the advantages of centralized traffic control may be mentioned the following:

1. Increases safety of train operation.
2. Reduces train stops, meeting and passing trains.
3. Increases freight train average speed and decreases freight train hours.
4. In many cases permits increased train loading because of removing restriction imposed by grades at entrance points to sidings due to power operation of switches or because elimination of delays permits greater loading and maintenance of schedules.
5. Provides greater productivity in gross ton miles per train hour because of increased speed and tonnage.
6. Reduces written train orders.
7. Reduces cost of operation.
8. Provides increased track capacity and a greater utilization of existing facilities thereby conserving capital which would otherwise be required for more costly methods of increasing the capacity of the railway.
9. Provides facilities for instantly directing train movements as required.

The Signal Section, A.R.A. conclusion and findings on Centralized Traffic Control are as follows:

Conclusion

Centralized traffic control for single or multiple track operation is recommended as an economic means to be considered for postponing capital expenditure for additional trackage and reducing operating expenses by relieving congestion, increasing track capacity, improving train operation, eliminating written train orders and providing facilities for instantly directing train movements as required.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

TABLE XIX

Freight Train Time Saving on Centralized Traffic Control Installations

Railway	Location	Freight trains per day	Average freight train speed m. p. h. Before	After	Average time per trip—freights Before	After	Saved	Per cent time saved	Minutes saved per frt. train mile
A. T. & S. F.	Holliday—Olathe, Kans.	14	16.3	20.3	45m	36m	9m	20.0	0.74
C. P.	Medicine Hat—Dunmore, Alta.	10	12.9	18.0	42m	30m	12m	28.6	1.33
C. B. & Q.	Red Oak—Balfour, Ia.	11.6	14.4	17.5	112.4m	93m	19.4m	17.2	0.72
D. & R. G. W.	Provo—Midvale, Utah	24	15.8	21.5	120m	88.4m	31.6m	26.3	1.0
M. P.	Edgewater—Atchison, Kans.	12	13.7	20.2	184.2m	124.8m	59.4m	32.2	1.4
N. Y. C.	Stanley—Berwick, Ohio	19.3	8.7	11.8	276m	204m	72m	26.0	1.8
P. & I.	Metropolis—Paducah, Ky.	29.5	12.0	15.5	38.4m	29.3m	9.1m	23.7	1.20
P. M.	Mt. Morris — Bridgeport, Mich.	16.5	20.22	25.53	58.82m	46.58m	12.24m	20.8	0.61
P. R. R.	Ben Davis—Almeda, Ind.	11	16.325	30.59	106.8m	57m	49.8m	47.0	1.7
S. P.	Stockton—Brighton, Calif.	18.7	12.8	21.1	173.5m	105m	68.5m	39.8	1.85
	Total for 10 installations							281.6	12.35
	Average per installation							28.1	1.2

In addition to the time saving, there was an increase in tonnage on five of these installations varying from 1 to 16 per cent.

TABLE XX

Operating Advantages of Centralized Traffic Control Installations

Railway	Location	Year	Track miles	Trains per day	Operators released	Per cent on investment	Pub. ref.*
A. T. & S. F.	Dodge City—Kingsley, Kans.	1930	44.0	42	11	....	96
	Trains expedited on busy single-track section. Delays and overtime reduced.						
A. T. & S. F.	Holliday—Olathe, Kans.	1931	24.4	34	....	....	50
	Either direction signaling on double track saves 9 minutes per freight train. Postponed third track.						
B. & O.	Gilkeson—Wheeling, W. Va.	1931	43.7	20	16	....	97
	Freight train time reduced 20 to 60 minutes, overtime reduced, safety increased and increased track capacity.						
B. & O.	North Lima—Roachton, Ohio	1931	56.0	45	14	....	98
	Eliminated 46,355 train stops per year, increased traffic capacity, increased the safety of train operation and reduced operating expenses due to a reduction in overtime of train crews and closing of manual block offices.						
B. & G.	Arthur Jct.—Bingham, Utah	1929	16.0	50	9	....	99
	Materially reduced delays to 5,400 ton trains on 2.5 per cent grade.						
B. & M.	Dover, N. H.—Rigby, Me.	1931	112.4	56	....	....	100
	Increased flexibility of train operation by either direction running on 44.8 miles double-track line, reduced operating expenses, increased track capacity sufficient to enable abandonment of 33.9 mile parallel single-track line except in emergency.						
B. & M.	Hoosac Tunnel—E. Fitchburg, Mass.	1931	157	36	....	....	101
	Either direction operation on two and three tracks expedites traffic on grades, reduces delays, facilitates switching movements and increases track capacity.						
B. & M.	Lynn—Swampscott, Mass.	1930	9.6	140	9	....	102
	More flexible operation provided by consolidating two interlockings and eliminating hand-operated switches. Delays reduced and traffic expedited at two junctions.						

* For publication references, see p. 75.

TABLE XX—Continued

Railway	Location	Year	Track miles	Trains per day	Operators released	Per cent on investment	Pub. ref.*
B. & M.	North Chelmsford—Ayer, Mass.	1929	27.0	57	Annual saving $37,847		54
	Reduced delays at meeting points, bunching of trains, yard engine interference, and increased track capacity by either direction operation.						
B. & M.	Winchester—Wilmington, Mass.	1930	34.0	104	9	----	103
	Either direction signaling on two-track suburban territory facilitates train operation. Three interlockings, installed in 1885, consolidated. Includes four junctions and provides increased traffic capacity.						
C. P.	Medicine Hat—Dunmore, Alta.	1928	9.0	30	----	47	104
	Saved 12 minutes on EB freight trains, provided quicker turn-around service, replaced staff system and postponed 7 miles of second track. Reduced delays adjacent to terminal.						
C. R. R. of N. J.	North Branch—Whitehouse, N. J.	1930	19.6	50	3	----	105
	Consolidated interlockings with either direction signaling on one track, expedites traffic and postpones four tracking of two-track line.						
C. B. & Q.	Steward Jct.—Flag Center, Ill.	1929	18.0	35	6	12.7	106
	Either direction signaling on double-track facilitates train operation. Two interlockings consolidated at junction points.						
C. B. & Q.	Red Oak—Balfour, Ia.	1930	28.0	45	10	19	107
	Power operation of siding switches on grades permits heavier tonnage trains to save over nineteen minutes on busy single-track line. Postponed double track. Two interlockings consolidated.						
C. B. & Q.	Waverly—Greenwood, Nebr.	1929	19.0	40	----	20	108
	Eliminated hand operation of switches at ends of double track. Postponed second track.						
C. M. St. P. & P. } C. R. I. & P. }	Lawson—Moseby, Mo.	1931	22.0	40	----	----	61
	Operation of a low grade single-track freight line with a single-track freight and passenger line expedites train movements.						

* For publication references, see p. 75.

TABLE XX—Continued

Railway	Location	Year	Track miles	Trains per day	Operators released	Per cent on investment	Pub. ref.*
D. & H.	Lanesboro, Pa.—Center Village, N. Y.	1930	19.3	34	9	....	109
	Four small interlockings consolidated, train stops eliminated, traffic expedited and operating expenses reduced.						
D. & R. G. W.	Deen—Tennessee Pass, Colo.	1928	9.0	44	3	....	110
	Train operation by signal indication on 3 per cent mountain grade expedites train movements, increased average train speed and GTM per train hour, and reduces time on helper movements.						
D. & R. G. W.	Provo—Midvale, Utah	1929	32.0	30	....	....	111
	Reduced time of tonnage freight trains one minute per mile and reduced overtime.						
Erie	Tusten—Lackawaxen, N. Y.	1931	19.0	42	3	....	65
	Reduced delays, expedited preference trains and increased track capacity.						
I. C.	Clinton—Kenney, Ill.	1929	11.2	30	3	30	112
	Train operation by signal indication expedites train movements and eliminates one telegraph office.						
I. C.	Otto—Ashkum, Ill.	1930	23.0	60	6	31	113
	Operating expenses reduced $11,000 per year by consolidation of three interlocking plants. Third track postponed.						
M. P.	Edgewater Jct.—Atchison, Kans.	1930	43.0	60	16	18	114
	Eliminated three interlockings, freight train time reduced 59.4 minutes, speed increased 47 per cent, GTM per train hour increased 57 per cent. Postponed second track.						
M. P.	HD Jct.—Rose Hill, Mo.	1931	62.5	30	....	....	68
	Either direction signaling on new double-track line facilitates train operation.						
N. Y. C.	Stanley—Berwick, Ohio	1927	43.5	34	18	24	115
	Freight train speed increased 36 per cent, GTM per train hour increased 39 per cent. Postponed second track costing $2,000,000.						

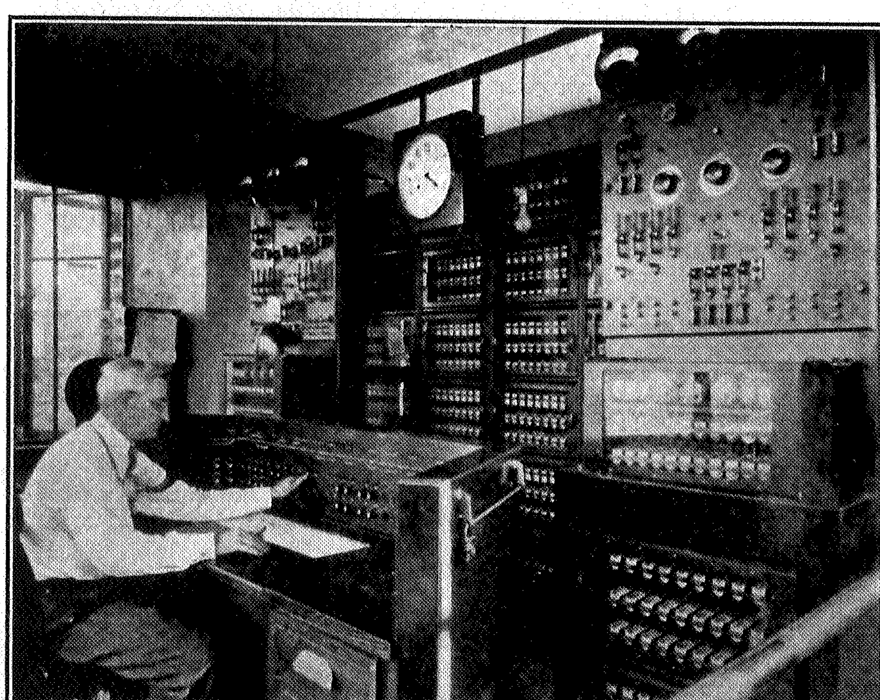
* For publication references, see p. 75.

TABLE XX—Concluded

Railway	Location	Year	Track miles	Trains per day	Operators released	Per cent on investment	Pub. ref.*
P. & I.	Metropolis, Ill.—Paducah, Ky.	1929	15.0	64	12	24.2	116
	Short connecting freight line speeds traffic by reducing delays and stops at five junction points. Manual block and staff systems previously in service.						
P. R. R.	Ben Davis—Almeda, Ind.	1930	36.0	30	12	28	117
	Train hours reduced 49 per cent, GT per train increased 1 per cent, freight train speed increased 87 per cent, GTM per train hour increased 89 per cent, track capacity increased. Second track postponed.						
P. & P. U.	Peoria—N. Pekin, Ill.	1931	14.8	163	14	20	118
	Either direction signaling on double track and consolidation of four interlockings reduces operating expenses.						
P. M.	Mt. Morris—Bridgeport, Mich.	1928	20.0	28	5	22	119
	Freight train speed increased 26 per cent, time per freight train reduced 21 per cent, train loading increased, track capacity increased and second track postponed with reduction in operating expenses.						
S. P.	Stockton—Brighton, Calif.	1929	43.0	46	7	----	120
	EB freight trains reduced running time 67 minutes and WB freight 70 minutes over division, delays reduced, track capacity increased and second track postponed. Ninety per cent of meets are non-stop.						
T. & N. O.	Beeville—Skidmore, Tex.	1930	11.0	42	----	----	121
	Delays reduced, traffic expedited and track capacity increased.						
T. & P.	Addis—Edgards, La.	1929	107.8	40	----	----	122
	Either direction signaling controlled from three stations eliminates necessity for center siding.						
Wabash	State Line—LaFayette, Ind.	1931	37.0	19	8	18	123
	Train stops and train hours reduced, freight train speed increased, block stations eliminated and second track postponed. Control machine is 93 miles from farthest controlled switch.						

* For publication references, see p. 75.

Centralized Traffic Control Machine on New York Central Railroad.



Centralized Traffic Control Machine on Baltimore & Ohio Railroad.

Car Retarders

Originally all freight cars were classified in flat switching yards, but in order to reduce switch engine hours and speed up operation, hump or gravity yards were installed in many places so that after a car was pushed over the top of the hump by the switch engine, it would accelerate down the hump by gravity to the classification tracks, each car or cut of cars being ridden by a car rider to control speed of car. Switchmen were used to operate the classification yard switches. The next move for effecting economies was the application of power-operated switches whereby one operator replaced a number of switchmen. The latest improvement at hump yards permits a few operators, controlling car retarders, to do the work formerly requiring a large number of car riders.

The car retarder is an arrangement of brake shoes located along and parallel to the rails. These shoes, operated by power, are forced against the inside and outside faces of the car wheels to reduce the speed of the car. The car retarder system includes the retarders, the power-operated switches, control machines, power supply, and sometimes power-operated skate placing mechanisms at the hump end of each classification track for stopping cars in emergency. The number and location of car retarders and operating stations depends upon the track layout and profile at each yard. In general, however, the first retarder is near the summit of the hump; others are at intervals along the leads. The car retarder operators also operate the switches of the classification tracks, judge the speed of the cars, retard them when necessary by means of the car retarders, and, if necessary, operate the skate machines.

In 1932 there were 37 car retarder installations in service. The details of these installations by 21 railways or companies are shown in Table XXI.

The economies effected by the installation of car retarders depend upon the capacity of the yard, the amount of business handled and the distribution of business throughout the day. The operating advantages reported on 21 installations on 16 railways are shown in Table XXII.

In addition to the saving shown in Table XXII, there are other operating advantages and economies realized, such as:

1. Possibility of keeping a yard in operation under severe weather conditions.

2. Elimination of tracks, motor cars and concrete subways for returning riders to the hump or the utilization of such tracks for additional classification tracks.

3. Increases the capacity of the hump, as all delays caused by waiting for riders to return to the hump are removed.

TABLE XXI

Details of Car Retarder Installations

Railway or company	Installations	Classification tracks	Control stations	Retarders	Switches	Skates	Track circuits
B. & M.	3	113	6	56	109	0	0
Carnegie Steel Co.	1	1	0	1	0	0	0
C. R. R. of N. J.	1	24	3	21	23	24	0
C. & O.	1	21	3	21	25	21	23
C. & N. W.	1	59	3	30	58	0	0
C. B. & Q.	1	49	3	20	52	0	50
C. C. C. & St. L.	1	30	2	24	29	0	29
Commonwealth Edison Co.	1	4	1	1	0	0	0
Erie	1	24	2	17	24	0	24
I. C.	3	137	13	251	143	135	0
I. H. B.	3	90	12	170	95	0	0
L. V.	3	70	5	45	68	70	68
M. C.	1	31	2	17	35	31	35
N. Y. C.	6	172	16	125	172	111	172
N. Y. N. H. & H.	4	145	10	106	146	24	122
N. & W.	1	36	2	37	44	37	5
P. R. R.	1	34	3	25	33	34	33
R. F. & P.	1	46	2	27	48	46	11
State Line Gen. Co.	1	5	1	4	4	0	0
T. & P.	1	32	2	21	38	32	0
Waukegan Gen. Co.	1	2	1	1	1	0	0
Total	37	1,125	92	1,020	1,147	565	572

4. Reduces damage to lading and equipment.

5. Practically eliminates personal injuries.

6. Permits faster freight schedules and better connections.

7. Permits clearing the receiving yard in a shorter time resulting in an increased capacity of the yard, without providing additional receiving tracks.

8. Permits reduction in motive power.

9. Increases car miles per car day and reduces per diem.

10. Eliminates the problem of securing car riders.

11. Provides increased flexibility of operation for meeting varying traffic conditions.

12. Permits classifications at one central point rather than at several locations.

13. Has proven of economic advantage at low traffic density.

14. Reduces engine and crew hours.

The Signal Section, A.R.A. conclusion and findings on Car Retarders are as follows:

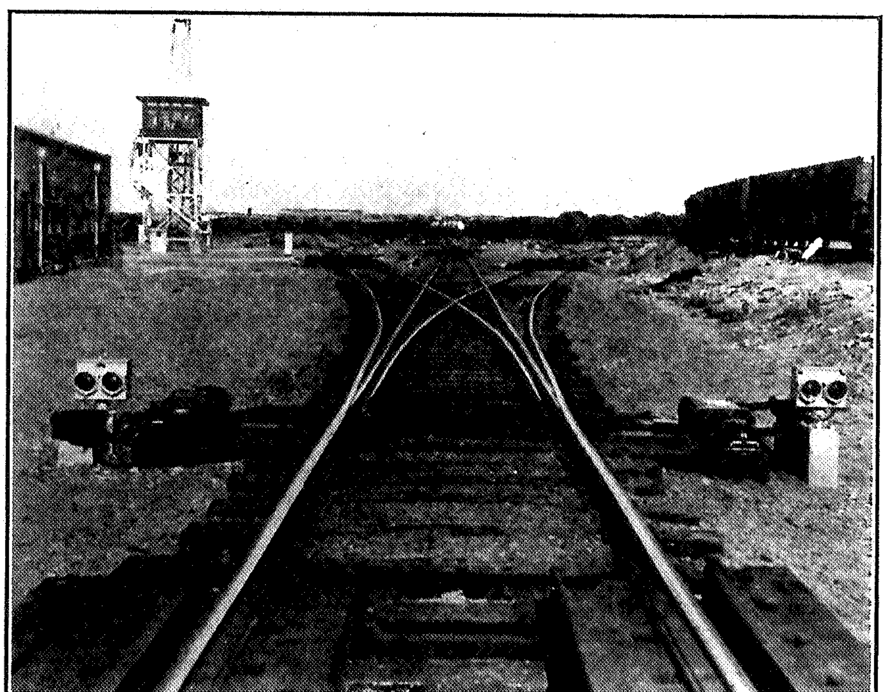
Conclusion

Car retarders are recommended as an economic means to be considered for improving service to shippers and reducing operating expenses by reducing motive power expense, increasing car capacity, reducing delays and personal injuries, reducing damages to equipment and lading, and consolidating classification yards.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

Car Retarder Installation on New York, New Haven & Hartford Railroad.



Car Retarder Installation on Texas & Pacific Railway.

TABLE XXII

Advantages of Car Retarder Installations

Railway	Location	In service	Cars per day	Pub. ref.*
B. & M.	Mechanicville, N. Y.	1927	1,200	124
	Decreased yard costs 40 per cent; cut time of cars in receiving yard 50 per cent. Net annual saving in excess of 50 per cent on investment.			
B. & M.	Mystic Yards, Boston, Mass.	1927	2,150	125
	The car retarder equipped yards effected a large saving in switching costs at Boston Terminal.			
C. R. R. of N. J.	Allentown, Pa.	1927	1,000	126
	Saved approximately 40 cents per car not including engine terminal repairs, hostling, etc., on account of reduced hours.			
C. & O.	Russell, Ky.	1929	2,750	127
	Operating expenses reduced approximately 40 per cent per year on the investment. Operating costs reduced 25 cents per car.			
C. & N. W.	Proviso, Ill.	1929	2,500	128
	Materially expedited traffic at busy Chicago Terminal.			
C. B. & Q.	Galesburg, Ill.	1932	3,500	129
	Operating costs reduced 28.6 cents per car. Reduced classification work at many other terminals.			
C. C. C. & St. L.	Sharonville, Ohio	1929	1,150	130
	Saved average of 54 minutes per car classified and 25 cents per car in classification costs. Annual saving approximately 40 per cent on investment.			
Erie	Marion, Ohio	1931	1,400	131
	Operating costs reduced 40 cents per car. Reduced amount of classification work at other yards. Saving approximately 30 per cent on investment.			
I. C.	Markham Yard, Ill.	1926	2,500	132
	Two retarder yards saved 24.8 per cent of original investment cost per year, and provide better operation and service.			
I. C.	E. St. Louis, Ill.	1926	1,500	133
	Reduced yard cost 27.5 per cent.			
I. H. B.	Gibson, Ind.	1924	1,600	134
	Saved 32.9 cents per car handled in first year of operation.			

* For publication references, see p. 75.

TABLE XXII—Concluded

Railway	Location	In service	Cars per day	Pub. ref.*
I. H. B.	Blue Island, Ill.	1926	2,760	135
	In addition to the actual saving that without question is effected in cost of classifying cars at Blue Island by use of the retarder, we must add the saving that would be necessary for a larger facility to handle the peak business if car rider operation were in use.			
M. C.	W. Detroit, Mich.	1930	1,125	136
	Approximate annual saving of $145,000 brought about by retarder operation. Increase of 14 per cent in number of cars humped per hour.			
N. Y. C.	Selkirk, N. Y.	1928	1,800	137
	Capacity of yard increased 50 per cent by the installation of retarders, which will permit additional saving with any increase in business.			
N. Y. C.	Stanley, Ohio	1931	1,000	138
	New yard designed for car retarder operation to handle northward lake coal traffic.			
N. Y. C.	Toledo, Ohio	1929	500	139
	Car retarders at coal handling docks facilitated operation and brought about saving.			
N. Y. N. H. & H.	Hartford, Conn.	1926	1,350	140
	Saved 13 cents per car in direct costs of classification.			
N. & W.	Portsmouth, Ohio	1928	1,800	141
	Cost per car handled reduced 10 cents. Damage to cars and lading reduced 40 per cent. Three-trick operation made profitable because of lower labor cost.			
P. R. R.	Pitcairn, Pa.	1929	1,400	142
	Net saving of $153,000 per year. Increased capacity of hump makes possible to handle business formerly requiring three-trick operation in two tricks.			
R. F. & P.	Potomac Yard, Va.	1930	1,300	143
	Facilitated movement of perishable freight and reduced operating cost 10.69 cents per car.			
T. & P.	Fort Worth, Tex.	1928	1,500	144
	New retarder equipped yard afforded greatly improved facilities for handling freight car classification. Reduced flat switching at other yards.			

* For publication references, see p. 75.

Highway Grade Crossing Protection

Prior to the advent of the automobile, the protection of highway grade crossings with railways was generally confined to the installation of warning signs indicating the location of the crossings except at the more heavily traveled crossings where watchmen, gates, or bells were installed to indicate the approach of trains. However, the rapid development of improved highways and the increasing automobile registration has introduced new problems. The greater automobile traffic at night and in the early morning hours has greatly increased the cost of watchmen and gatemen for continuous service and resulted in excessive costs of operation and maintenance. The rapid increase in the number of highway crossings where it has become necessary to provide warning of the approach of trains and the necessity for economy led to the development of automatic crossing devices which can be installed at a minimum cost and which have a low yearly maintenance cost as compared with the previous types of protection. These relatively economical devices can be more widely used than more expensive means of protection, thereby reducing the hazards of accidents at the maximum number of crossings.

The tendency since about 1926 has been toward the use of the flashing light signal which has become the standard on the majority of the steam railways in the United States, although the wig-wag is standard in some of the western states and in Canada. Flashing light crossing signals have also been installed in England, Belgium, France, South Africa, New Zealand, Australia, Uruguay, Peru, Brazil and Japan.

A summarized statement* of the various types of protection at highway grade crossings on Class I steam railways in the United States for 7 years is shown in Table XXIII.

TABLE XXIII

Types of Protection at Highway Grade Crossings

Type of protection	1925	1926	1927	1928	1929	1930	1931
Gates	6,320	6,170	5,957	5,707	5,456	5,007	4,902
Watchmen	7,907	7,765	7,554	7,297	7,037	6,714	6,430
Signals	13,014	13,992	15,213	16,211	17,697	18,566	19,720
Total protected crossings	27,241	27,927	28,724	29,215	30,190	30,287	31,052
Fixed signs	202,324	202,620	203,817	205,933	208,154	205,734	202,446
Otherwise unprotected	4,068	4,611	3,742	4,941	4,465	4,652	4,519
Grand total	233,633	235,158	236,283	240,089	242,809	240,673	238,017

Of the 31,052 protected crossings in 1931 (about 13 per cent of the total number of all crossings) the number equipped with gates, watchmen, and signals, is shown in Table XXIV.

* *Railway Age*, November 22, 1930, p. 1094, and November 14, 1931, p. 737.

TABLE XXIV

Crossings Equipped with Gates, Watchmen and Signals

Type	Number	Total
Gates, with or without other protection operated 24 hours per day	2,919	
Gates, with or without other protection operated less than 24 hours per day	1,983	4,902
Watchmen, alone or with protection other than gates, on duty 24 hours per day	1,216	
Watchmen, alone or with protection other than gates, on duty less than 24 hours per day	5,214	6,430
Both audible and visible signals, without other protection	9,857	
Audible signals, only	3,792	
Visible signals, only	6,071	19,720
Total protected crossings		31,052

In addition to providing more economical protection, automatic highway grade crossing signals provide more efficient protection than the type replaced, and provides 24-hour protection whereas, in many cases, the protection replaced was only for a portion of the day. In certain cases auto-manually controlled signals have been used and in other cases manual control has made it possible to make substantial saving in operating expenses.

Table XXV* shows the relative costs of maintaining various types of highway grade crossing protection and indicates that the annual cost of protecting one crossing with watchmen or gates manually-controlled would be sufficient to maintain about seven crossings with automatic devices.

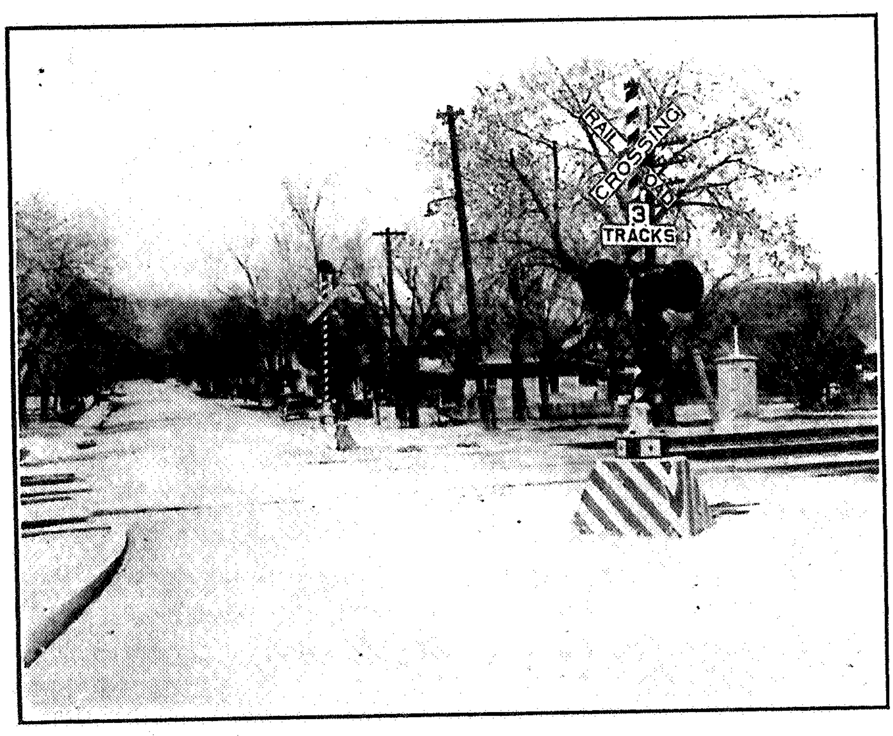
TABLE XXV

Cost of Highway Grade Crossing Protection

Type of protection	No. of railroads reporting	Annual Depreciation	Annual Interest 5.5%	Annual maintenance and operation	Total annual cost	Annual cost capitalized at 5.5%
Watchmen	8	$8.24	$9.54	$2,851.23	$2,869.01	$52,000.00
Gates	11	86.59	95.10	3,069.65	3,251.34	59,000.00
Flashing lights	10	93.09	105.27	256.30	454.66	8,300.00
Wig-wags	7	90.32	106.96	245.20	442.48	8,000.00
Special fixed signs	4	1.71	1.53	9.44	12.68	250.00

* A.R.E.A. Proceedings, Vol. 30, p. 503.

Highway Grade Crossing Signal Installation on Erie Railroad.



Highway Grade Crossing Signal Installation on Denver & Rio Grande Western Railroad.

In considering the economics of highway grade crossing protection, no attempt is made to evaluate the safety features in dollars. The relative advantages of one type of protection over another in dollar costs is considered rather than the question as to whether protection is required. The railway does not in all cases have the final word as to the type of protection to be installed but in many cases can choose between several alternatives. It is, of course, to the interest of the public and the railway to provide the most economical solution to the highway traffic problem. Ordinarily, however, it will be found that the use of automatic crossing signals will provide the most desirable protection even at points where traffic conditions are unusual.

Table XXVI shows the economies effected by several installations of flashing light or wig-wag signals replacing more expensive types of protection. Some are operated automatically, some auto-manually and others manually from one or more centralized points.

TABLE XXVI

Economy of Highway Grade Crossing Protection

Railway and location	Number of crossings	Annual saving	Annual return per cent	Pub. ref.*
Signal Section, A.R.A. report	42	$71,058	99.8	145
B. & L. E., Greenville, Pa.	5	3,000	15.6	146
C. & N. W., Elgin, Ill.	25	9,213	72.8	147
C. M. St. P. & P., Oconomowoc, Wis.	6	4,758	33.4	148
I. U. T., Indianapolis, Ind.	23	15,984	33.3	149
L. & N., E. St. Louis, Ill.	6	10,187	113.3	150
M.-K.-T., Clinton, Mo.	11	3,300	28.7	151
P. R. R., Kokomo, Ind.	13	10,000	31.7	147
Wabash, Wabash, Ind.	13	7,800	40.0	152

Most of the installations shown in Table XXVI have provided increased protection for the complete 24 hour period instead of a portion of the day. The saving shown is not on the basis of what it would cost to provide equivalent protection under the old method for 24 hours each day at each crossing, but represents only the difference between the cost of the protection furnished during the period previous to the installation, and the cost during a like period subsequent to the installation.

The Signal Section, A.R.A. conclusion and findings on Highway Grade Crossing Protection are as follows:

Conclusion

Replacing manual by automatic, auto-manual, or centralized control highway grade crossing protection is recommended as an economic means for reducing operating expenses.

*For publication references, see p. 75.

Findings

First cost, economy of installation and the return on the expenditure will vary with local conditions.

Economic Studies

Determination of the value of saving in operating expenses.

The saving in operating expenses which are brought about by a modern signal installation are in three different classes of varying degrees of tangibility. It is obvious that the lines of demarcation between the tangible, quasi-tangible and purely intangible saving cannot be sharply drawn because items considered in each group will vary with conditions and the method of analysis.

In the following three groups the various classes of saving are indicated with some examples of each group:

1. Direct or tangible saving which will result in less actual dollars paid out and which can be measured with a fair degree of accuracy on the basis of time saved by the substitution of modern signaling for the previous type of operation.

   (a) Wages:

   1. Of employees made available for other service.

   2. Of train and engine men where overtime hours are reduced by speeding up train movements.

   (b) Maintenance and operating expenses on discontinued units.

   (c) Fuel, water, lubricants and other supplies for locomotives saved by reduction in number of stops and slow-downs.

   (d) Train mile saving due to increased tonnage per train and operation of fewer trains.

   (e) Capital and operating charges saved by doing the same work with less locomotives and/or cars. This item would be tangible only if the saving per train and the number of trains make possible a quicker round trip and actually released or deferred purchase of equipment.

   (f) Capital saving from substitution of modern signaling for some other improvement, such as increasing existing facilities, where the new signaling provides sufficient additional capacity to handle the anticipated increased traffic.

2. Indirect but real saving which is more dependent upon opinion as to the amount applicable to the train hours saved, such as:

   (a) Per diem on freight cars.

   (b) Train supplies and expenses.

   (c) Locomotive repairs.

   (d) Car repairs.

   (e) Locomotive and car depreciation, retirements and interest, when conditions are not as in item 1-e.

   (f) Enginehouse expenses. If less locomotives including hostler engines are operated as a result of locomotives being released, this becomes a tangible saving.

3. The more intangible saving which, because of the irregular recurrence of the causes bringing them about and the varying intensity of the expense involved or for other reasons, cannot always be forecast.

(a) The insurance value of the installation in the prevention of accidents. If a direct comparison of "before" and "after" operation is available, this becomes a tangible saving.

(b) The effect of better service to the shippers.

(c) Saving in loss and damage accounts.

(d) Easing of the mental strain on dispatchers, enginemen, trainmen, trackmen, signalmen, and others.

Primarily a study of the economies to be effected by an installation of railway signaling depends upon careful selection and handling of the basic test data upon which the saving in time and the improvements in operating performance are based. The final results of the study may be shown in terms of the value of the train hours or train miles saved, a comparison of the gross ton mile costs or in such other manner as the study may require.

The general procedure in determining the probable time saving of a proposed installation should be as follows:

1. Selection of period in past performance which will approximate expected density.
2. Selection of sample data—days of varying traffic densities representative of conditions obtained with different numbers of trains per day. A small number of days may be used for an approximate estimate but a larger number should be used where greater accuracy is required.
3. Redispatching selected days by the graphical method to show probable improved performance with the new signaling.
4. Translation to annual basis of the data of the sample days to find the probable number of train hours saved per year under the improved system.

After determining the probable time saving which will be made with the proposed installation, the results may be translated to a dollar basis by using the unit train hour and train stop values applicable to the particular installation, or by determining the actual saving in wages, fuel, etc. The results of the study may, in some instances, be expressed in terms of the comparative costs per 1,000 gross ton miles, which method has been used particularly in connection with studies of "before and after" performance on installations which have been in service for some time. In those cases where the improved signaling has been definitely responsible for increased tonnage per train and the result is a smaller number of trains required to move a given tonnage, the train miles eliminated may be definitely valued and will constitute an important part of the saving from the installation.

In economic studies of signal installations there are several factors upon which a value must be placed, such as the train hour and train stop, interest and the cost of maintenance and operation. These values are essential to determine the annual profit or loss upon the proposed expenditure.

Train hour value.

The value of the saved train hour has been a subject of discussion and many different values have been used in economic reports. These variations in values are often justified due to the fact that the actual value of a saved train hour has a much wider range than the cost of producing a train hour. The saved train hour value varies depending upon the class of power, number of locomotives per train, overtime wages, fuel, water, per diem, enginehouse expense, locomotive repairs, interest and depreciation, local operating conditions, and locations of the carriers in each of the various operating regions of the country.

Examples of a number of saved train hour values are shown in Table XXVII.

TABLE XXVII

Train Hour Values

Railway	Value	Remarks	Pub. ref.*
Signal Section, A.R.A. report	$24.98	Average for freight trains of all railways for year 1923	155
A. T. & S. F.	20.00	Automatic interlocking report	33
C. & O. System	20.89	Average for freight trains first seven months of 1927	157
C. & O.	18.00	Either direction report	158
C. C. C. & St. L.	15.98	Overtime rate. Automatic signal report	1
C. C. C. & St. L.	10.32	Straight time rate. Automatic signal report	1
N. Y. C. System	38.86	Double-headed freight trains	153
N. Y. C.	25.00	Freight and passenger trains. Either direction report	154
N. Y. C. System	24.94	One engine freight train	153
N. Y. C.	10.00	Light engine. Interlocking report	11
N. & S.	12.05	Average for yard engine, year 1927	159
P. R. R.	16.12	Consolidated interlocking report	24
S. A. L.	18.00	Automatic signal report	7
U. P.	24.00	Freight trains. Spring switch report	156
W. M.	24.00	Freight trains. Automatic signal report	9

* For publication references, see p. 75.

The actual cost of producing the average freight train hour, exclusive of per diem on cars, on the North and South Railroad* for the year 1927 was $20.02 as shown in Table XXVIII.

TABLE XXVIII

Cost of Freight Train Hour on North and South Railroad

System data (for freight service only)		Total or average
1. Train miles		14,311,135
2. Locomotive miles		16,078,742
3. Train hours		1,271,460
4. Average tractive power		68,272
5. Train miles per locomotive mile (1 ÷ 2)		0.89
	Total cost	Cost per train hour
6. Wages, train and engine men	$9,005,357.00	$7.08
7. Fuel	3,528,609.00	2.78
8. Water	365,489.00	0.28
9. Lubricants	153,733.00	0.12
10. Other supplies	82,055.00	0.06
11. Enginehouse expenses	1,101,825.00	0.87
12. Train supplies and expenses	1,110,346.00	0.87
13. Locomotive repairs	7,289,978.00	5.74
14. Locomotive depreciation	961,321.00	0.76
15. Locomotive retirements	20,253.00	0.02
16. Interest on locomotive investment	1,833,084.00	1.44
17. Total, including wages	$25,452,050.00	$20.02
18. Total, excluding wages	16,446,693.00	12.94

The report further states: "Items 1 to 15 are of record usually in report to the Interstate Commerce Commission. * * * It should be remembered that the figures for a system include all classes of service and all the varying conditions that may exist on widely separated portions of a large system."

An editorial in the *Railway Age*, June 1, 1929, p. 1266, refers to the train hour value as follows:

"When considering the authorization of expenditures for equipment or improvements to reduce operating costs or to facilitate train operation, one basis for estimating the economics to be effected is the number of train hours of delay eliminated. The Signal Section of the A.R.A. made a study of train hour costs in 1924, as a result of which it set up a tentative figure of $24.98 as the average out-of-pocket cost for a train delay hour. In discussing this

* A.R.E A. Proceedings, Vol. 30, p. 829.

figure at the convention in March 1926, it was shown that the costs varied from $5.40 to $25.00 on various roads and that the average was from $15 to $18, depending on local conditions.

"Realizing the importance of determining the value of the saving of a freight train delay hour for use in making estimates for future developments, the New York Central had made a study of actual costs, as ascertained by the division accountants, on each of the divisons of the railroad. Included in the data considered are such items as the class of power, wages, if they include overtime; fuel, water and oil; per diem on foreign cars; locomotive repairs; car repairs; interest, depreciation and taxes on system cars and locomotives. These studies showed that the value of a train hour reclaimed varied on different divisions from $13.68 to $24.94 for trains of one engine, and from $20.60 to $38.86 for trains double-headed. It is recognized that these figures do not include all of the incidental items or intangible benefits that result from reducing by one hour the time that a freight train consumes between terminals. However, it is a conservative basis on which to consider new projects. The New York Central has shown that these costs can be allocated and the matter is worthy of more study on other roads."

Whenever possible a specific amount for the train hour value should be agreed upon for the class of service under consideration for use in economic reports of signaling installations.

Train stop value.

The value of a train stop eliminated will vary according to the grades, curves, weather conditions, size of locomotive, number of cars in train, tonnage, cost of fuel, per diem, overtime wages, minutes delay time, and local conditions.

As early as 1905 a report* was presented to the Railway Signal Association in which it was stated that the cost of stopping and starting a 2000-ton freight train, from and to a speed of 35 m.p.h., was estimated at $1.00. So many intangible factors enter into the cost of stopping and starting a train that some railroads use the estimate of $1.00 as an average in spite of the fact that tonnage, speeds, wages and motive power have considerably increased since 1905.

The time loss incurred in stopping a train may vary from possibly one or two minutes for a light engine to as high as an hour for a heavy train that is stopped on a grade and is unable to accelerate readily, or even unable to start, making it necessary to double. Actual time tests, Table XIV, show that the minutes per stop vary from 5.5 to 8 minutes on one railway to 9 and 14.1 minutes on two other railways. Due to these variations, it is believed that the time element in stopping trains should be estimated in each case and the train hour value applied for the lost time. In order to avoid duplication it is necessary to place a value on a train stop which does not include the time resulting from improved dispatching of trains.

* R.S.A. Proceedings, Vol. I, p. 282.

Examples of a number of train stop values used in economic reports are shown in Table XXIX.

TABLE XXIX

Train Stop Values

Railway	Value	Remarks	Pub. ref.*
Signal Section, A.R.A. report	$6.25	15 minutes delay at $25.00 train hour	155
A.R.E.A. report	3.25	Average for 5,000 ton freight train	161
A. T. & S. F.	2.00	Average for branch line freight train	33
C. M. St. P. & P.	1.00	Average for passenger and freight trains	39
C. & N. W.	1.00	Average for 2,000 ton freight trains	164
I. C.	2.30	Average for 80 car freight train, overtime rate	79
I. C.	1.70	Average for 50 car freight train, overtime rate	79
I. C.	1.45	Average for 80 car freight train, non-overtime rate	79
I. C.	0.50	Average for passenger trains	79
M.-K.-T.	3.00	Average for freight trains	162
M.-K.-T.	1.50	Average for passenger trains	162
Railway Age	4.80	Maximum for 4,000 ton freight train at 30 m. p. h.	160
Railway Age	2.80	560 ton passenger train at 50 m. p. h. varied from 84 cents to $2.80	160
Railway Age	2.50	Minimum for 4,000 ton freight train	163

The I. C. and the A.R.E.A. report train stop values (Table XXIX) are based upon dynamometer car tests. The I. C. included $0.499 per diem on cars while the A.R.E.A. included $0.6854 for car repairs, depreciation and retirements, including interest on the investment.

The I. C. tests showed a time delay of 3 minutes for an 11-car passenger train, Pacific type locomotive on level tangent track, summer conditions, from and to a speed of 50 miles per hour and a 9 minute delay for freight trains. The A.R.E.A. tests were based on a Mikado locomotive, 70-car loaded freight train, 4.1 minutes for acceleration and deceleration, 10 minutes for the stop, of which 2 to 5 minutes are lost on account of time required to release the brakes, or a total of 14.1 minutes time lost.

Interest.

Interest should be computed at the current rate at which money can be obtained and will vary slightly for different carriers. Rates of 5 to 6 per cent have been used in economic studies while an average of 5.5 per cent is sometimes used where the current rate is unknown. Sometimes the carrier desires to leave out the deduction for interest and simply call attention to the fact that a certain return upon the investment will be shown above maintenance and operation.

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* For publication references, see p. 75.

Maintenance and operation.

The cost of maintenance and operation varies depending upon local conditions on each carrier. The cost may be low where additional signal maintenance labor is not involved, and may not run over 1.5 to 2 per cent of the total cost of the new signaling. Where possible, the actual labor and material costs should be estimated for the signal installation. In the absence of known figures, an average of 5 to 10 per cent of the investment cost is often used.

On account of signal installations being maintained for 100 per cent service it is not the usual practice to show a separate item for depreciation. Where desired, a charge of 2 to 5 per cent of the investment cost may be used for obsolescence.

Conclusion.

The conclusions of the economic study should be briefly stated in the front of the report.

Preparation of Economic Reports

The following parts of the Signal Section, A.R.A. Manual and reference to the Proceedings of the Signal Section, A.R.A., and American Railway Engineering Association will be of help in preparing economic reports:

Part 29—Method for comparing operating results before and after an improvement in signaling facilities.

Part 52—Estimating examples for use in determining the economic value of a remotely-controlled switch installation.

A.R.E.A. Vol. 31, p. 1014—Formula for determining comparative economics of flat and hump yard switching.

Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, pp. 21 and 22—Sample economic statement.

Summary of Economic Results

Type	Number of installations	Cost	Net saving per annum	Annual rate of saving, per cent
Automatic block signals	6	$2,452,186	$417,895	17.0
Interlockings:				
(a) Manually-operated	7	253,467	150,618	59.5
(b) Consolidation of plants	15	864,439	193,889	22.4
(c) Automatic	51	361,776	297,081	82.0
Train operation by signal indication	3	138,000	52,701	38.2
Remote control	14	223,953	111,165	49.6
Centralized traffic control	12	1,951,569	437,353	22.4
Car retarders	4	2,932,000	637,779	21.8
Highway grade crossing protection	144	236,854	135,300	57.1

References to Published Descriptions of Railway Signaling Installations

Number	References
1	Signal Section, A.R.A. 1928 Proceedings, Vol. XXVI, p. 635.
2	Signal Section, A.R.A. 1929 Proceedings, Vol. XXVII, p. 573.
3	A.R.E.A. Proceedings, Vol. 27, p. 739.
4	A.R.E.A. Proceedings, Vol. 27, p. 744.
5	A.R.E.A. Proceedings, Vol. 29, p. 441.
6	*Railway Age*, August 4, 1928, p. 213.
7	Signal Section, A.R.A. 1927 Proceedings, Vol. XXV, p. 797.
8	Signal Section, A.R.A. 1925 Proceedings, Vol. XXIII, p. 495.
9	Signal Section, A.R.A. 1922 Proceedings, Vol. XIX, p. A302.
10	*Railway Signaling*, August 1929, p. 295.
11	Signal Section, A.R.A. 1928 Proceedings, Vol. XXVI, p. 632.
12	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 598.
13	*Railway Signaling*, October 1931, p. 337.
14	*Railway Signaling*, March 1930, p. 95.
15	*Railway Signaling*, August 1931, p. 265.
16	*Railway Signaling*, January 1930, p. 26.
17	*Railway Signaling*, November 1930, p. 392.
18	*Railway Signaling*, May 1928, p. 180.
19	*Railway Signaling*, August 1928, p. 304.
20	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 7.
21	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 8.
22	Signal Section, A.R.A. 1930 Proceedings, Vol. XXVIII, pp. 303, 368
23	Signal Section, A.R.A. 1928 Proceedings, Vol. XXVI, p. 630. *Railway Signaling*, September 1928, p. 319.
24	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 596.
25	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 9.
26	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 21.
27	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 13.
28	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p.11.
29	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 15.
30	Signal Section, A.R.A. 1930 Proceedings, Vol. XXVIII, pp. 305, 368.
31	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 19.
32	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 17.
33	*Railway Signaling*, March 1930, p. 87.
34	*Railway Signaling*, February 1931, p. 42.
35	*Railway Signal Engineer*, June 1923, p. 253.
36	*Railway Signaling*, November 1929, p. 407.
37	*Railway Signaling*, June 1928, p. 209.
38	*Railway Signaling*, February 1928, p. 41.
39	*Railway Signaling*, March 1928, p. 79.
40	*Railway Signaling*, January 1927, p. 27.

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42	*Railway Signaling*, March 1929, p. 99.
43	*Railway Signaling*, November 1930, p. 397.
44	Signal Section, A.R.A. 1928 Proceedings, Vol. XXVI, p. 634.
45	*Railway Signaling*, September 1928, p. 324.
46	*Railway Signaling*, November 1929, p. 417.
47	*Railway Signal Engineer*, September 1923, p. 374.
48	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 58. *Railway Signaling*, February 1930, p. 51.
49	*Railway Signaling*, August 1927, p. 283.
50	*Railway Signaling*, January 1932, p. 13.
51	*Railway Signaling*, November 1927, p. 423.
52	Signal Section, A.R.A. 1930 Proceedings, Vol. XXVIII, pp. 292, 367.
53	*Railway Signaling*, October 1929, p. 375.
54	*Railway Signaling*, July 1929, p. 248.
55	*Railway Signaling*, November 1929, p. 410.
56	Signal Section, A.R.A. 1927 Proceedings, Vol. XXV, p. 819.
57	Signal Section, A.R.A. 1930 Proceedings, Vol. XXVIII, pp. 297, 367.
58	*Railway Signaling*, April 1930, p. 128.
59	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 734.
60	*Railway Signaling*, January 1931, p. 15.
61	*Railway Signaling*, November 1931, p. 365.
62	*Railway Signaling*, August 1929, p. 286.
63	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 799. *Railway Signaling*, May 1931, p. 168.
64	*Railway Signaling*, December 1929, p. 452.
65	*Railway Signaling*, August 1931, p. 273.
66	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 810.
67	*Railway Signaling*, February 1927, p. 70.
68	*Railway Signaling*, June 1931, p. 206.
69	*Railway Signaling*, February 1926, p. 55.
70	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 697.
71	*Railway Signaling*, May 1931, p. 164.
72	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 712.
73	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 718.
74	Signal Section, A.R.A. 1924 Proceedings, Vol. XXII, p. 727.
75	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 27.
76	*Railway Signaling*, February 1929, p. 58.
77	Signal Section, A.R.A. 1926 Proceedings, Vol. XXIV, p. 103.
78	A.R.E.A. Proceedings, Vol. 28, p. 473.
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80	Signal Section, A.R.A. 1923 Proceedings, Vol. XXI, p. 156.
81	Signal Section, A.R.A. 1928 Proceedings, Vol. XXVI, p. 188.
82	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 64.
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89	Signal Section, A.R.A. 1930 Proceedings, Vol. XXVIII, p. 387.
90	*Railway Signaling*, January 1929, p. 17.
91	*Railway Signaling*, March 1929, p. 89.
92	*Railway Signaling*, June 1931, p. 201.
93	*Railway Signaling*, December 1930, p. 429.
94	*Railway Signal Engineer*, October 1923, p. 401.
95	*Railway Signaling*, March 1929, p. 81.
96	*Railway Signaling*, April 1931, p. 118.
97	*Railway Signaling*, February 1932, p. 36.
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99	*Railway Signaling*, May 1930, p. 172.
100	*Railway Signaling*, June 1932, p. 173.
101	*Railway Signaling*, November 1931, p. 371.
102	*Railway Signaling*, May 1931, p. 153.
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104	Signal Section, A.R.A. 1930 Proceedings, Vol. XXVIII, p. 389.
105	*Railway Signaling*, March 1931, p. 73.
106	*Railway Signaling*, April 1930, p. 135.
107	*Railway Signaling*, September 1930, p. 318.
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109	*Railway Signaling*, February 1931, p. 37.
110	*Railway Signaling*, November 1929, p. 414.
111	*Railway Signaling*, February 1930, p. 48.
112	Signal Section, A.R.A. 1930 Proceedings, Vol. XXVIII, p. 390.
113	*Railway Signaling*, October 1930, p. 361.
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121	*Railway Signaling*, March 1930, p. 105.
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123	Signal Section, A.R.A. 1931 Proceedings, Vol. XXIX, p. 54. *Railway Signaling*, July 1931, p. 231.
124	*Railway Signaling*, March 1928, p. 85.

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126	Signal Section, A.R.A. 1928 Proceedings, Vol. XXVI, p. 865.
127	*Railway Signaling*, October 1930, p. 367.
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147	Signal Section, A.R.A. 1926 Proceedings, Vol. XXIV, p. 567.
148	*Railway Signaling*, September 1931, p. 316.
149	*Railway Signaling*, October 1928, p. 361.
150	*Railway Signaling*, May 1929, p. 173.
151	*Railway Signaling*, June 1930, p. 215.
152	*Railway Signaling*, January 1929, p. 25.
153	*Railway Age*, June 1, 1929, p. 1266.
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162	*Railway Signaling*, March 1928, p. 111.
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