G. W. L.

American Railway Signaling Principles and Practices

CHAPTER I

History and Development of Railway Signaling

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CHAPTER I

History and Development of Railway Signaling

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INTRODUCTION

"*THEN*" (1828).

"You are welcome to the use of the school house to debate all questions in, but such things as railroads and telegraphs are impossibilities and rank infidelity," wrote a member of the Lancaster, Ohio school board in 1828.

"*LATER*" (1934).

The era of high speed train operation in the United States began on May 26, 1934 with the run of the Chicago, Burlington and Quincy R.R.'s streamlined "Zephyr" from Denver, Colo., to Chicago, Ill., 1,015 miles in 13 hours and 5 minutes, an average of 77.5 miles per hour for the entire distance.

"*NOW*" (January 1, 1953).

Automatic block signaling	78,958.5 miles of road.
Non-automatic block	29,758.1 miles of road.
Traffic control systems for train operation by signal indication without train orders	18,064.5 miles of road.
Automatic interlockings	543
Electric interlockings	1,044
Electro-mechanical interlockings	319
Electro-pneumatic interlockings	373
Mechanical interlockings	1,208
Remote control interlockings	845
Automatic train stop	8,944.6 miles of road.
Automatic train control	1,003.4 miles of road.
Automatic cab signaling	3,677.6 miles of road.
Spring switches	6,574
Facing point locks on spring switches	1,968
Electric locks on spring switches	50

ANCIENT RAILROAD RULES

(from Atlantic Coast Line News, June 1948)

"The following three rules were found in the Book of Rules of the old Tallahassee, Pensacola & Georgia R.R., dated April 3, 1858, and will be of interest to present-day train crews. We procured them from the files of our General Superintendent of Transportation:

"All engines unprovided with lamps, running at night out of time, will be required to keep their dampers open to show a light.

"*Rule 8.* As a general rule when two trains meet between stations, the train nearest the turn will run back. Any dispute as to which shall retire shall be settled by the Conductors without any interference on the part of the engineers. This rule is required to be varied in favor of the heaviest loaded train, if they meet near the center.

"*Rule 12.* Should a train run off or for any cause be stopped on the track at night, the red light must be instantly sent back to a safe distance to stop a train approaching in the rear. The green light will be in like manner sent forward to stop a train approaching in the front. A half mile each way from where the train is standing will be a safe distance. At that point a fire must be built in the middle of the track and a train hand stationed there who shall keep up the fire and the red or green lights burning.

"*Rule 16.* The spark catcher or chimney of an engine out of order so as to endanger the safety of the train, the Conductor must put his train on the first turnout and return his engine to Tallahassee for repairs."

CHAPTER I

HISTORY AND DEVELOPMENT OF RAILWAY SIGNALING

SECTION 1

DEVELOPMENT OF RAILWAY SIGNAL SYSTEMS

The American system of rail transportation, outrivaling all other forms of transportation in respect to speed of operation and the load per vehicle carried, is a direct result of Mr. George Stephenson of England having devised and put into practical use the first steam-driven locomotive, in 1814, for the hauling of tram cars. The steam era for railroads began in England in 1825 with the initial use of steam locomotives on the New Stockton & Darlington Ry., and in 1829 when the "Rocket" successfully outdistanced competitors.

During the early transportation development years, study was directed along the lines of providing adequate track construction and efficiency in locomotive and car design. Traffic was controlled by hand signaling at first; but as time passed and traffic grew in volume, the need for a more comprehensive method of directing traffic than by hand signaling became apparent. Being the first to build a steam-operated railroad, England was naturally the first to recognize the need of interlocking and block signaling as aids to rapid and safe train operation.

When America started building steam railroads, England had already established the essential elements of locomotive design, certain basic features of track construction, and the fundamental principles of interlocking and block signaling.

The first steam railroads in America were built along the Eastern seaboard where the population density was the greatest and where they entered into competition with the stage coach, the canal boat, and the river packet. Unlike England, a country of relatively small area, but with a comparatively dense population, America was a country of vast area, sparsely settled by people of many races and traditions with an urge to penetrate still farther into the unexplored regions lying to the west. It was because of these differences that modifications and refinements to English signal systems were deemed necessary before being suitable for conditions in America.

Various and sundry methods were devised for obtaining and transmitting information. At first, the lines were short and usually but one or two trips a day were made by one locomotive on a single-track line. The speed was about 15 miles an hour; and even this speed was considered by many as excessive and dangerous. In a few cases, a man on horseback was required to proceed ahead of the train with a flag to warn of its approach.

When more than one train operated on single track, sidings were built a few miles apart to enable them to pass. Half way between these sidings, tall posts were erected and the train first reaching this center post had the right-of-way to the next siding, the other train having to back up to that point. To avoid turning back, enginemen soon began racing for these posts; and many arguments arose between train crews and passengers as to which train would have to back up.

Time-tables were prepared to show the time of arrival and departure at junction or terminal points, but they were never taken seriously as delays were frequent and arose from many causes. In these early days of railroading, the trains did not always have exclusive rights to the track, as in some localities farmers were permitted to mount their wagons on the rails for taking their produce to town. After this practice was finally abolished, the railroads began to bring order out of chaos by the use of train schedules which told when and where trains should meet, the classification of trains, and the rights of each class. However, there still were frequent delays and many trains which were on schedule were compelled to wait hours at some scheduled meeting point.

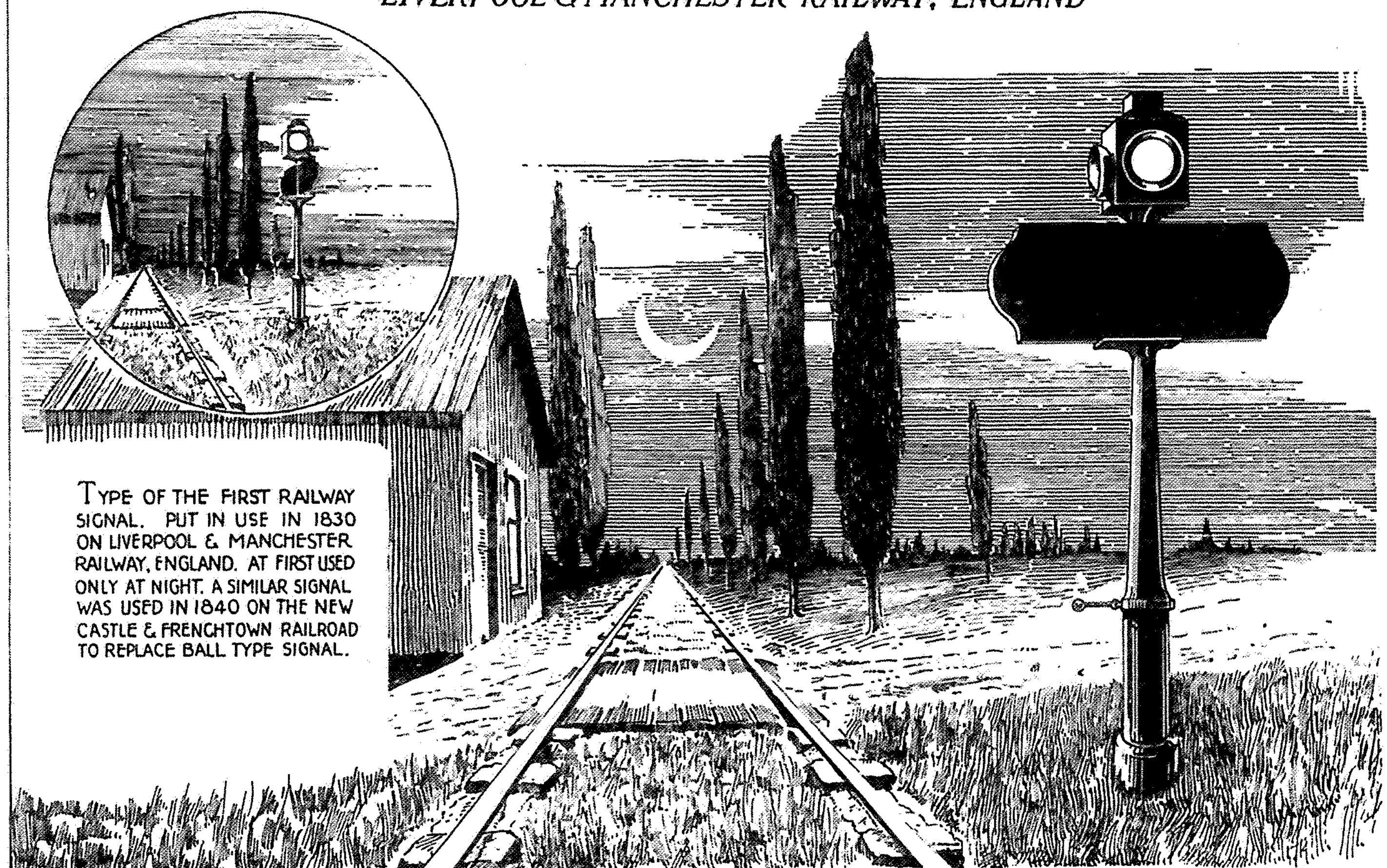
Many schemes were devised for obtaining and transmitting information as to train movements. Early records show that in 1806, signals were given by men manipulating their hands and arms so that the drivers of the animals pulling rail cars would know what action to take. These rail cars were used for transporting granite in the quarry of the Thomas Leiper Granite Quarry Co., located at Avondale, Pa. Hand signals, supplemented by flags in the daytime and by barn lanterns at night, were introduced on the Baltimore & Ohio R.R. in 1829. When hand signals, flags and lanterns were found inadequate, the railroads began to apply mechanical devices, located along the right-of-way, to supplement the earlier signaling methods. Progress in the development of railway signaling was very slow at first, but proceeded rapidly after the introduction of interlocking and the establishment of a block, or space interval method of operation.

The development of signaling on American railroads may be divided into two periods: that prior to 1920, and from 1920 up to the present. Prior to 1920, interlocking and manual and automatic block signaling constituted the major portion of all railroad signal activities. After 1920, several new systems found useful application on the railroads to meet the demand for increased speed with safety. Among these may be mentioned automatic train control, car retarders for classification yards, centralized traffic control, continuous cab signaling, and coded track circuit control.

Signaling in America may be said to have been started in 1832 on the New Castle & Frenchtown R.R. which ran from New Castle, Del., on the Delaware River, to Frenchtown, Md., near Chesapeake Bay, a distance of 17 miles. This pioneer American railroad was the connecting link for the steamboat lines from Philadelphia to New Castle, Pa., and from Frenchtown to Baltimore, Md., and in 1832 when the motive power was changed from horse to locomotive, there was put into use the first fixed signal system for sending information from terminal to terminal as to the movement of a train. The first signals employed made use of white and black flags. Later, as the flags would not unfurl properly at all times, bell shaped peach baskets were suspended from masts about 30 feet high, located about 3 miles apart. These signals were known as ball signals and they were covered with white or black cloth. The white ball was displayed at the top of the mast, when the train left the terminal; when displayed at other stations at half mast, the train was to "stop at station for passengers or freight." As the train passed each station the ball was raised to the top of the mast and then lowered after the train passed the next station; at the bottom of the mast, the indication was "stop and stay." A black ball displayed at the top of the mast indicated a delayed or disabled train.

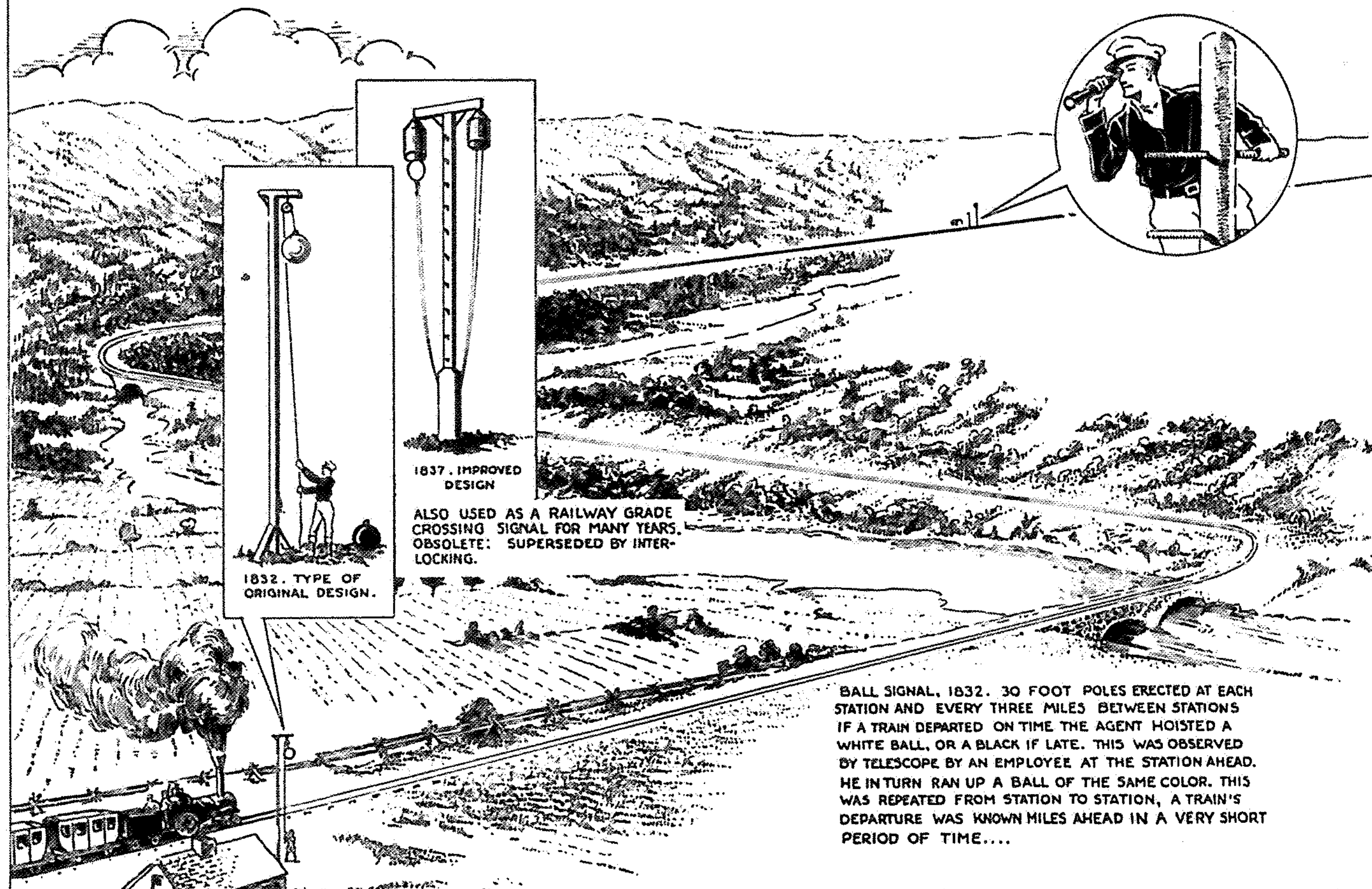
1830 · CROSS BAR & LAMP SIGNAL.

LIVERPOOL & MANCHESTER RAILWAY, ENGLAND

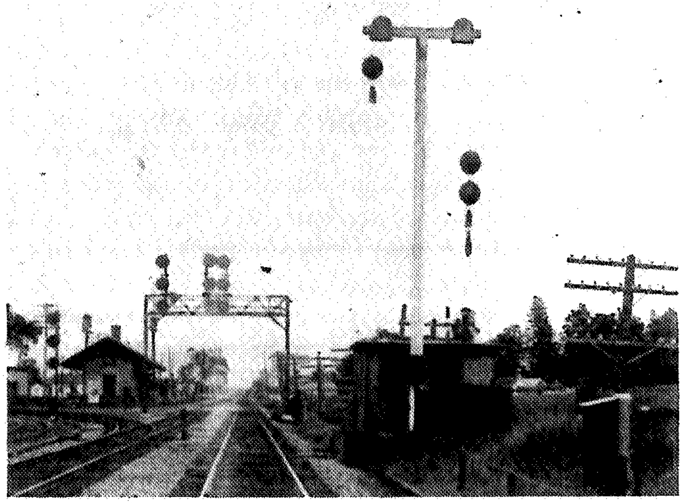


TYPE OF THE FIRST RAILWAY SIGNAL. PUT IN USE IN 1830 ON LIVERPOOL & MANCHESTER RAILWAY, ENGLAND. AT FIRST USED ONLY AT NIGHT. A SIMILAR SIGNAL WAS USED IN 1840 ON THE NEW CASTLE & FRENCHTOWN RAILROAD TO REPLACE BALL TYPE SIGNAL.

1832· BALL SIGNAL .. *NEW CASTLE & FRENCHTOWN RAILROAD.*



As no audible means of communication existed between stations, the signals were observed from adjacent stations by marine telescopes. When a train started from the terminal and the white ball was hoisted to the top of the mast, a flagman at the second station, observing its position, hoisted the white signal ball at his station to half mast, and the flagmen at the other stations repeated this signal, so that at New Castle it was known that the train had started from Frenchtown within a few minutes after it had left there.



Ball type signal still in use on Boston & Maine R.R. in early 1930's.

In 1840, this signal was superseded by a red metal disc 4 feet in diameter with the word DANGER painted on it. This disc was mounted on a revolving staff with a lamp attached to provide a night indication. The disc, when placed parallel to the track and displaying a white light at night, indicated "proceed" and when placed at right angles to the track and displaying a red light at night, indicated "stop and stay."

This primitive method of signaling the movement of the train by visual signals, used prior to the invention of the electric telegraph, was an early effort in train dispatching. It was limited to sending out the trains, as no means were then available for quickly reaching them with instructions for directing their movement.

It is interesting to note in connection with this era that when an engineman wanted to stop at either terminal he turned off the power and, at the station, slave roustabouts grabbed hold of the cars and stopped the train by main strength, sometimes assisted by a pole stuck through a wheel.

To evaluate properly the usefulness of railway signals and signal systems, a brief review will follow, of the methods employed to direct train operation, which will readily show why these systems now assume great importance in the direction of train movements with speed, safety, and economy. Two general methods are in use to direct train operation on the railroads of America: the time interval, and the space interval.

When train movements are controlled entirely by train schedules as in the early days, and by time-tables and train orders only as in later days, train operation is by the time interval method. The chief purpose of this method of train operation is to keep trains apart, when running, by a certain period of time. Under this system, all trains are expected to reach meeting points or passing points in ample time for inferior trains to clear for the superior trains. In this time interval method the crew of a given train, between stations has no way of knowing the location of a train ahead except by flagman protection.

The time interval system was the only method of controlling train movements for many years; but as traffic became heavier, requiring the running of more trains, it was found necessary to provide means to make train operation safer. As a result, the space interval method was introduced. Under this system, the railroad is divided into a number of sections or "blocks" with a fixed wayside signal placed at the entrance to each block (except in certain territories where the continuous cab signal system is used without wayside signals). This signal will indicate to the engineman of an approaching train whether the block is occupied by another train. Under this system, trains may be spaced with certainty. Trains operated under this method are directed by time-tables, train dispatching, train orders and train order signals and the block system. The introduction of the space interval resulted in the development and use of many kinds of fixed wayside signals. The new developments for fixed wayside signals which followed are described in Section 10.

The actual operation of the block system dates from December 1839, when the Great Western Ry. of England began to use a magnetic needle indicator for "telegraphing" the arrival and departure of its trains from station-to-station for a short distance near London. This was at the suggestion of Messrs. Cooke and Wheatstone, who later (in 1841) introduced separate instruments with magnetic needles for each direction of traffic, showing whether the sections were clear or blocked. Electric bells were also added. This installation was experimental and was used as the basis for publishing some formal suggestions relative to the use of block systems. They were in a pamphlet printed in London in 1842, entitled "Telegraphic Railways" by William Fothergill Cooke, Esq. The following principles for block systems were set forth:

> "Every point of a line is a dangerous point which ought to be covered by signals. The whole distance, consequently, ought to be divided into sections; and at the end, as well as the beginning of them, there ought to be a signal, by means of which the entrance to the section is opened to each train when we are sure that it is free. As these sections are too long to be worked by a traction rod, they ought to be worked by electricity. At the end of each section of from two to two-and-one-half miles, a line-keeper is stationed in a hut, with a turning disc or a semaphore. In each hut, there ought to be two telegraphs with magnetic needles, the one on the right hand being in communication with that on the left of the neighboring hut. The needle telegraph can only give two signals: 'Line clear' or 'Line blocked'."

The leading features of the block systems of today are embodied in the above quotation. The next improvement was a method of signaling by electric bells, devised by Mr. C. V. Walker in 1851 and installed on the South Eastern Ry. of England. The signals were by sound only, no needle instrument being used. Later (in 1854) the London & North Western Ry. introduced separate needle instruments for each track, in which the needle was operated in three positions, and a bell code used in connection therewith. In 1858, the positive-block system, based on the space interval system, was established in England.

The Sykes system of controlled manual block signaling was an English invention by Mr. W. R. Sykes in 1875 in which the signals at a block station were controlled by the signalman at the station in advance by means of electrically operated locks, the locking apparatus at the two stations being connected by an electric circuit. This provided a check against mistakes, or carelessness, for while each signalman operated his own signals, he could not operate them until unlocked by the signalman in advance, on request of the first signalman. By 1889 this system was being used successfully in America on the New York Central & Hudson River R.R., the New York, Lake Erie & Western, the New York, New Haven & Hartford and several other roads.

An electric train staff system for handling trains was in use shortly after this time and was the result of a gradual development of a simple principle recognized on English railroads as early as 1840. This principle was that for a train to pass safely over a given section of single track, it should have in its possession a tangible right to do so in the form of some specific article of which only one was obtainable. The first train staff was a metal bar about 2 feet long, which had cast or engraved on it the names of the two stations between which it alone gave authority for any train to proceed. Unless trains operated in both directions, a way had to be provided to return the staff to its original station.

In order to overcome this difficulty, the staff and ticket system was devised. The original staff was used as a key that would unlock a box at either end of the section to permit tickets to be taken as authority for train movements through the section. This system did not permit trains to enter a section from the end at which the staff did not happen to be. To correct this condition, Mr. Edward Tyer in 1878 introduced his electric tablet apparatus which consisted of two instruments, one at either end of a section, each instrument containing a certain number of tablets, any one of which conferred rights on a train to pass over that section. The two instruments were electrically connected and so arranged that the removal of a tablet from either instrument prevented the taking of another tablet.

The next refinement consisted of adding a permissive feature and the substitution of staffs for the tablets in the Tyer system. The permissive feature permitted several trains to follow each other into a block section, if desired, in a manner similar to that employed in the non-electric staff and ticket system. This system was known as the Webb & Thompson Electric Train Staff as it was invented by Mr. F. W. Webb, Chief Mechanical Engineer, and Mr. A. M. Thompson, Signal Superintendent, of the London & North Western Ry., in 1889. The first use of this system under American manufacturing rights was in May 1894, on the Chicago, Milwaukee & St. Paul Ry. between Savanna, Ill. and Sabula, Iowa.

The foregoing information on railway signaling in England has been presented in order to create an understanding as to how and why railway signaling practices were further developed in America. Since the English railroads were older than those in America, it naturally followed that when traffic conditions in America approximated those in England, adaptations of English practices were found beneficial. However, it is interesting to note that Mr. Ashbel Welch, who devised and put into operation the first manual block system with a space interval method for controlling train movements in America in 1863, had never had any prior knowledge of the English block system.

The block system, as previously stated, is a method of keeping trains a certain distance apart, but in its application various methods were developed which actually resulted, in 1897, in five different block systems being generally used: namely, "manual," "controlled manual," "auto-manual," "automatic," and "machine."

In manual blocking the block signals at the entrance to each block were wholly controlled and operated by the signalman at that station.

In controlled-manual blocking the block signals at the entrance to each block were controlled either electrically, as in the Sykes system, or mechanically, by the signalman at the station in advance, but were operated by the signalman at the entrance to the block. (Later required to have the additional feature of continuous track circuits.)

In the auto-manual (semi-automatic) system the signals were in general operated as in the manual, or as in the Sykes, but were restored to the "danger" position automatically by the train.

In automatic blocking the operation of the signals was entirely automatic, generally by electric power or compressed air, and with this system no signalman was required.

Machine blocking (electric train staff) was a method of controlled single-track blocking in which were used, in connection with the ordinary block signals, certain machines with detachable parts. These machines were worked mechanically, except they were unlocked electrically.

"Absolute blocking," in 1897, was known as a method of operation in which two trains were never allowed to be in a block at the same time, and "permissive blocking" was a form of blocking in which a train was allowed to enter a block before the preceding train had passed out of the block.

SECTION 2

THE ELECTRIC TELEGRAPH

As the use of the electric telegraph plays an important part in the development of signal systems in railroad service, it is in order to review briefly its development and its part in the operation of railway signal systems.

The first model of the Morse electric telegraph was designed to make V-shaped marks on tape to represent numbers. In October 1832, the dot and dash signs, now known as the Morse alphabet, were introduced; and in 1836 a model was placed on public exhibition in New York City. In 1837, Mr. Morse showed an improved model at the Franklin Institute in Philadelphia, Pa. and then applied to Congress for aid in constructing an experimental line from Washington, D. C. to Baltimore, Md., a distance of 40 miles.

The application for aid was referred to the Committee of Commerce, the Chairman of which was Mr. Francis Smith of Maine. The report of this Committee was favorable and a grant of $30,000 was recommended. However, Congress did not approve the plan until March 3, 1843. On May 27, 1844, the first message was sent from Washington by Miss Annie Ellsworth who transmitted the words "What Hath God Wrought?"

After the invention of the dot and dash alphabet, Mr. Morse cast a set of movable type with the dot and dash characters on their face. These were mounted on a frame, rotated by clockwork, to transmit the characters as the contact touched the type faces one by one. The receiver consisted of a ribbon paper tape actuated by clockwork. The characters were printed on the tape by an ink wheel actuated by a magnet.

After the introduction of the telegraph, the New York & Erie R.R. constructed a single line for telegraph between Piermont, N. Y., on the Hudson River, and Dunkirk, N. Y., on Lake Erie. This line was used for handling company business and it was over it that the first radical departure from the time interval and flagging method of train operation came in 1851. It is recorded that on September 22, 1851, Superintendent Charles Minot was on a westward train which was in charge of Conductor Stewart waiting at Turner's for a meet with the eastward express. Time passed and as the express did not arrive, Mr. Minot asked the operator to find out if it had arrived at Goshen, N. Y., 14 miles west. On being advised that it had not arrived, he issued the first telegraphic train order which read as follows:

"To operator at Goshen:

"Hold eastbound train till further orders.

"Charles Minot, Superintendent."

He then wrote an order which he handed to Conductor Stewart, reading:

"To Conductor Stewart:

"Run to Goshen regardless of opposing train.

"Charles Minot, Superintendent."

The engineman, Mr. Isaac Lewis, refused to run the train on such an order, saying he would "run this train according to time card rules, and no other way." Mr. Minot then took charge of the engine and ran the train to Goshen. As the eastward express had not arrived there, Mr. Minot repeated his orders and was able to reach Port Jervis, N. Y., saving 2 hours time for the westward train.

This move was so successful that it shortly led to the adoption, with some modifications, of this train dispatching method on the Susquehanna Division of the New York & Erie R.R. Its adoption over the entire line followed in spite of great opposition on the part of conductors and enginemen, many of whom resigned rather than run on telegraphic orders against the time of another train. This system spread rapidly to other railroads and in company with other features of railroad operation, was progressively developed and improved.

In 1854, when the Pennsylvania R.R. was completed from Philadelphia to Pittsburgh, Pa., Mr. Andrew Carnegie, who became famous in 1852 as an expert telegraph operator, obtained a job with it and became the first dispatcher on the Pittsburgh Division.

From 1859 to 1866, Mr. Carnegie was Superintendent of the Pittsburgh Division and to keep control over night traffic, he installed a telegraph instrument in his home in Homewood (Pittsburgh), Pa. Later, he secured the appointment of a night dispatcher, the first on any railroad. Apparently this was the start of centralized train dispatching in the United States as distinguished from the localized station master control used in Europe.

Telegraphic communication between block stations made feasible the operation of the first manual block system in 1863, based upon the space interval method of train operation.

Chronological

For chronological references see Section 18, years 1844 and 1851.

SECTION 3

MANUAL BLOCK SYSTEMS

Prior to 1863 the methods for directing train operation had not developed further than to use the time interval method described in Section 1. The railroads in England, however, had established a space interval block system in 1858 based on the principle that a "block" could always be assumed to be clear unless a red signal was displayed. If a train did not pass a station when it should, notice was telegraphed back to the next station to stop, or block the next train, till further notice. A fault of this system was that if the operator failed to transmit the notice, or if it was not observed or understood, or if the signal failed to work, no warning was given the train about to enter the block and the possibility of a collision existed.

The first manual block system for controlling train movements in America was devised and put in operation between Trenton, N. J. and Philadelphia, Pa. in 1863 by Mr. Ashbel Welch, General President and Chief Engineer of the United New Jersey Canal & Railroad Companies who, at the time the system was placed in operation, had never heard of the English block system.

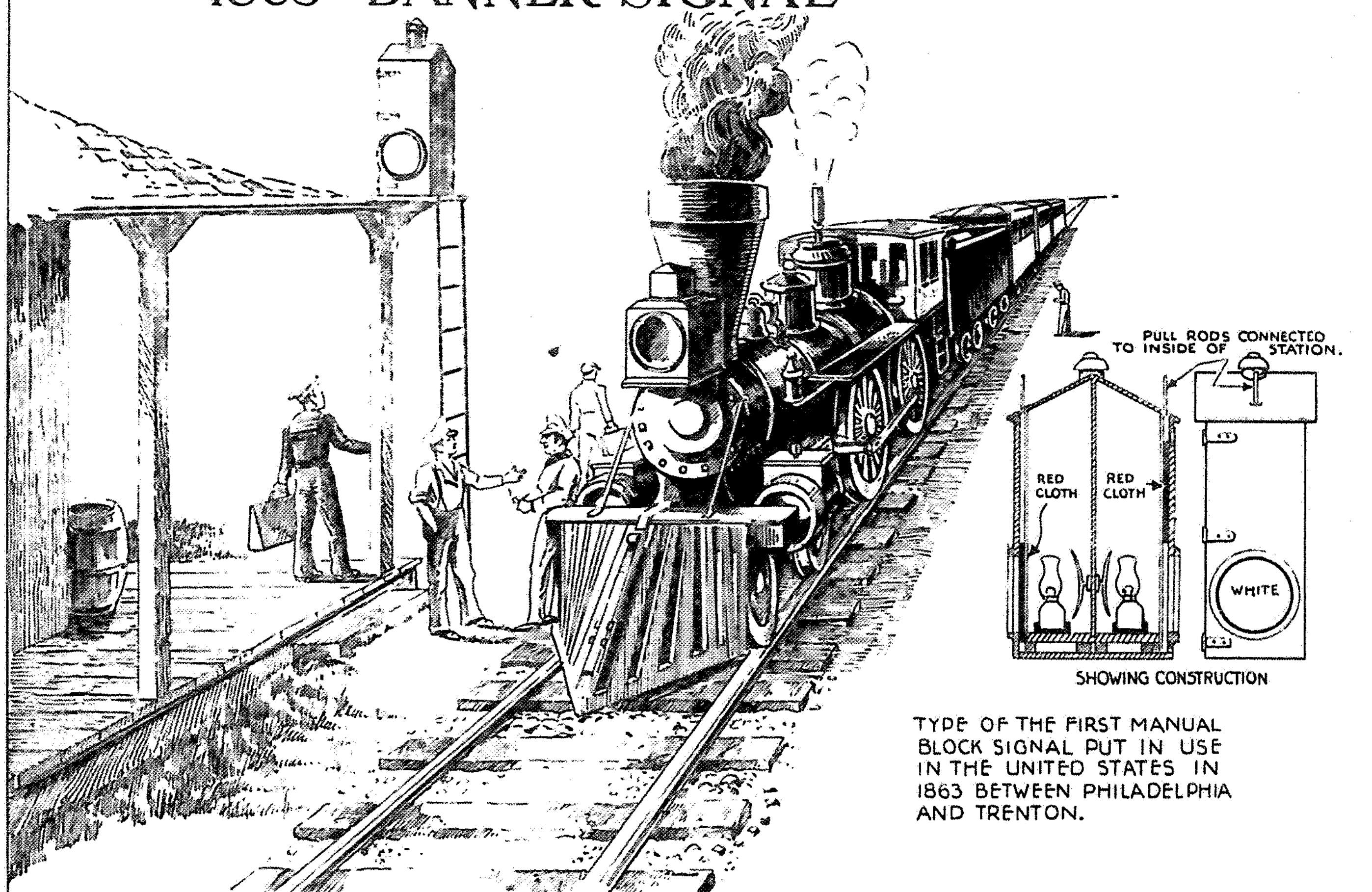
Mr. Welch's system used the space interval method of operation but was based upon a principle the reverse of that used in England in that he required that a train should not go "on a block" until notified by signal that the block was clear, instead of "proceeding unless a red signal was shown." Block station offices were located not over 6 miles apart, at points as far as practicable where there was a good view each way. Men were kept on duty at each office 24 hours a day. Each station was provided with simple telegraphic and all other necessary apparatus. An independent wire extended from each station to the next, with an independent instrument.

The original signal for this installation consisted of a white polished reflector 2 feet in diameter with a light in front at night, seen through an opening of the same diameter in a box, projecting over the platform from the upper part of the signal station building. The signal for northward trains was seen through an opening on the southerly side of the signal box; that for southward trains through an opening on the northerly side. These two signals were separated by a vertical partition, the inside of the box and the partition painted black, and the openings covered with glass. Each signal was operated by a rod and lever to lift it so it could be seen through the opening. When released, this signal would then drop down to the bottom of the box out of sight.

The installation was extended northward to New Brunswick, N. J. in 1865 and included some modifications to the signals by dropping red flannel banners in front of the white surface or white light "clear" indication, to give a red "stop" indication, the lamp remaining stationary. Prior to this, however, there had been trials with a lower opening showing red. The signals were known as the banner box type.

It will be observed that these signals indicated to a train, without its being stopped, that the track to the next office was clear. This fundamental principle was original with Mr. Welch as he explained in the report of the "Committee on Safety Signals" presented to the General Railroad Convention held in New York City on October 24, 1866. The same information was presented in a paper by Mr. Welch, dated December 23, 1865, to "The Committee of the Franklin Institute on Railroad Signals." This space interval method of train operation was adopted by Mr. Welch after the occurrence of a disastrous

1863 BANNER SIGNAL



TYPE OF THE FIRST MANUAL BLOCK SIGNAL PUT IN USE IN THE UNITED STATES IN 1863 BETWEEN PHILADELPHIA AND TRENTON.

rear-end collision of eastward trains at night carrying soldiers from the seat of war to New York and New England.

In 1867 the system was extended northward on the New Jersey R.R. to Jersey City, N. J., and in 1870, was extended westward to Mantua (West Philadelphia), Pa. When the Pennsylvania R.R. took over the control of these lines in 1871-1872 there were, therefore, 90 miles of road protected. In 1876, this block system was also extended over the main line of the Pennsylvania westward between Philadelphia and Pittsburgh, Pa.

The development of railway signaling practices in America as described in the foregoing pages resulted in systems of signaling best described by definitions in the A.A.R. Signal Section Manual as follows:

Block Signal System:

A method of governing the movement of trains into or within one or more blocks by block signals or cab signals. (I. C. C.)

Manual Block Signal System:

A block or a series of consecutive blocks, governed by block signals operated manually, upon information by telegraph, telephone or other means of communication. (Standard Code.)

Controlled Manual Block System:

A series of consecutive blocks governed by block signals, controlled by continuous track circuits, operated manually upon information by telegraph, telephone or other means of communication, and so constructed as to require the cooperation of the signalmen at both ends of the block to display a Clear or a Permissive block signal. (Prior to 1907 continuous track circuits were not used in controlled manual block.)

Lock and Block:

A term commonly used for the controlled manual block system.

The chronological record of the development of manual block systems which follows, includes references to the systems defined in the foregoing as well as to electric train staff systems (see Section 1). References for controlled manual block do not include systems using continuous track circuits, which started in 1907. These are covered in Section 9.

Chronological

For chronological references see Section 18, years:

1863	1892
1875	1894
1882	1900
1884	1902
1891	1910

SECTION 4

THE TRACK CIRCUIT

Dr. William Robinson's basic invention of the closed track circuit on August 20, 1872 constituted one of the most important contributions to railway transportation development. No clearer statement of this fact can be made than was published in the Third Annual Report of the Block Signal and Train Control Board to the Interstate Commerce Commission, dated November 22, 1910, quoted as follows:

> "Perhaps no single invention in the history of the development of railway transportation has contributed more toward safety and dispatch in that field than the track circuit. By this invention, simple in itself, the foundation was obtained for the development of practically every one of the intricate systems of railway block signaling in use today, wherein the train is, under all conditions, *continuously active* in maintaining its own protection.
>
> "In other words, the track circuit is today the only medium recognized as fundamentally safe by experts in railway signaling whereby *a train or any part thereof may retain continuous and direct control of a block signal while occupying any portion of the track guarded by the signal.*"

Railway signaling up to the 1870's was comparatively simple in design and operation and depended almost exclusively upon the human element to function properly. Increased safety had been provided to train operation, however, through the adoption of block systems and interlockings and the use of space interval methods rather than time interval methods. It was shortly after the introduction of the manual block system that certain people with inventive minds foresaw the need of a system operated automatically by the movement of a train over the track. Early efforts were directed more along the line of using treadles or track instruments actuated by the trains for the control of wayside signals. (Additional information on the use of these devices appears in Section 5.)

As far as can be ascertained, the idea of using the rails as electrical conductors for signal purposes was first suggested in an English patent of 1848. However, no specific method of use was described. In 1853, an English patent was granted to Messrs. George Dugmore and George Millward which described a method for using the rails to communicate between trains on the same line, and between trains and stations. An English patent was issued to Mr. William Bull on October 31, 1860, in which rail sections of "20 feet, more or less" were proposed for indicating at a station the progress of a train. Mr. Frank L. Pope conducted an experiment at Charlestown, Mass. in 1871, using a rail section 42 feet long. Otherwise, this circuit was said to be identically the same as described in Mr. Bull's patent. Both experiments used circuits of the "open circuit" type.

Dr. William Robinson, shortly after being graduated from college (1865), became interested in certain railroad accidents which had occurred for which there were no adequate means known for their prevention. Accordingly, about 1867, he became actively interested in the development of an automatic signal system for the prevention of various kinds of railroad accidents. In 1869, he constructed an elaborate model of his proposed signal system which he exhibited at the American Institute Fair in New York City in 1870. This system was what is now known in the art as a "wire" or "open circuit" system.

Mr. William A. Baldwin, then General Superintendent of the Philadelphia & Erie R.R., an old telegraph operator and a very able and progressive railroad man, became interested in Dr. Robinson's system and arranged for an installation to be made on his road. At that time, Mr. Theodore N. Ely was Assistant Superintendent and, under the direction of Mr. Baldwin, furnished Dr. Robinson with all the facilities and material necessary for installation purposes at Kinzua, Pa. This was in 1870. The installation was soon in perfect working order, performing all claimed for it, and considered satisfactory by the Railroad. This system was a normally open-circuit wire system controlled by "track instruments" or treadles operated by passing trains.

Dr. Robinson was the most severe critic of his own work, and he began to study his system from the standpoint of a railroad man with a view to finding its weak points. He soon discovered that any normal open-circuit system was extremely limited in its functions, as under certain conditions a Proceed signal could be displayed when danger actually existed. For example:

"*First:* A train enters regularly upon the section and sets the signal at danger; the train breaks in two, the forward part passes off the section, reverses the signal and shows ALL CLEAR behind that portion of the train remaining on the section; and a following train, lured on by the false signal ALL CLEAR, dashes into the stalled portion of the preceding train left standing on the section. This is extremely liable to happen on sharp curves and grades, where breaks are not of uncommon occurrence.

"*Second:* A train may enter the section from the opposite end or from a siding, thus blocking the track, while the signal, not having been affected, shows ALL CLEAR as before, a false signal again.

"*Third:* If a line wire breaks or a connection be interfered with accidentally or maliciously, or the battery fail from any cause, the signal will invariably show ALL CLEAR, under every train passing over the section, a false signal again."

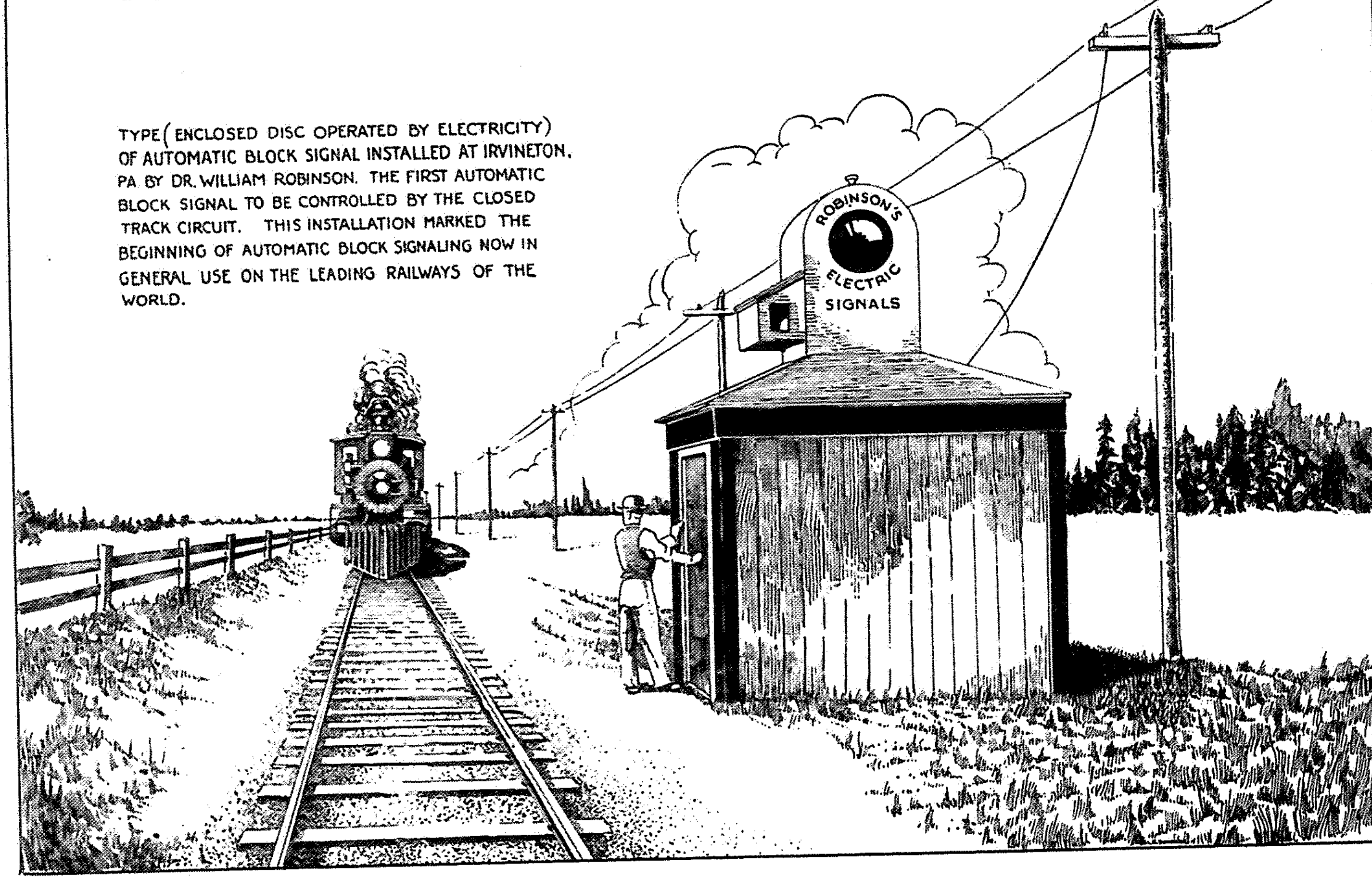
Dr. Robinson is credited with being the first to recognize the above-mentioned serious objections inherent in the systems then being developed and installed on some railroads. He at once began looking for a solution in order to provide a signal system which would meet all the requirements necessary for safe and efficient railroading, and reasoned that each car and each pair of wheels in a train must have control over the signal throughout every inch of the block section, and that the signal should go to danger by gravity, electricity being used to hold it at clear.

He concluded that a closed track circuit was the solution to the problem for the reason that if an attempt was made to use an open-circuit track circuit, sections of rails of even moderate length would form a good ground, especially in damp or wet weather, thus keeping the circuit closed continuously and preventing any operation of any kind. He then made drawings of the closed rail track circuit in 1869 or 1870 substantially as it is used today, and in 1871 applied for a patent on it, broadly covering the closed rail circuit system. A United States patent was issued on August 20, 1872, covering this system.

In 1872, Dr. Robinson exhibited this system at the State Fair held at Erie, Pa. It had previously been explained to Mr. Baldwin, who was greatly interested and expressed his confidence in it. He requested Dr. Robinson to install the system at Kinzua, Pa., to replace the open circuit wire system that had previously been installed. Another installation of a similar nature was also made on the same Railroad at Irvineton, Pa., in 1872. It was in connection

1872. DISC SIGNAL

TYPE (ENCLOSED DISC OPERATED BY ELECTRICITY) OF AUTOMATIC BLOCK SIGNAL INSTALLED AT IRVINETON, PA BY DR. WILLIAM ROBINSON. THE FIRST AUTOMATIC BLOCK SIGNAL TO BE CONTROLLED BY THE CLOSED TRACK CIRCUIT. THIS INSTALLATION MARKED THE BEGINNING OF AUTOMATIC BLOCK SIGNALING NOW IN GENERAL USE ON THE LEADING RAILWAYS OF THE WORLD.



with the installation of the closed track circuits at Kinzua and Irvineton that Dr. Robinson also conceived the invention of the bond wire method of electrically connecting the rails in order to provide a reliable electrical path around the rail joints, a method now in universal use.

At another installation on the Philadelphia & Erie R.R. in 1873, Dr. Robinson equipped three switches in one closed circuit block so that each switch had to be closed and locked for the main line or the danger signal would be displayed against approaching trains. The movement of a switch both opened the rail circuit and shunted the circuit to the relay. Dr. Robinson thus was the first to provide for switch protection in closed track circuit territory.

A similar installation was made in 1876 at Wilmington Jct., Mass., on the Boston, Lowell & Nashua R.R., equipping two parallel sections of a two-main track, including six switches. Other installations were rapidly made on various railroads in Pennsylvania and in New England as well as through the Tehuantepec Tunnel in California.

The use of the direct current track circuit extended rapidly to all steam operated railroads and had reached a high state of development by 1900. At this time it first became necessary to signal an electric propulsion road. Difficulties were immediately encountered, as the running rails were being used as the return for the propulsion current and one of these rails now had to be given up as a "block" rail for signaling purposes. One of the major problems was solved when the Boston Elevated in 1901, as a safety feature, provided for the polarization of the track relay against the effect of propulsion drop. However, there still remained the need for a solution of other problems before satisfactory track circuit operation could be accomplished for electric propulsion roads.

It remained for Mr. J. B. Struble, an engineer in the employ of the Union Switch & Signal Co. to solve the difficulty. He had been active on the Boston Elevated development but previously had conceived the simple idea of a selective relay designed to respond to alternating current only, and be absolutely free from the possibility of closing its contacts when direct current passed through its energizing coils. This involved a motor device working on the induction principle, which became known as the vane relay. The first extensive trial of Mr. Struble's invention was made in 1903 between Sausalito and San Anselmo on the North Shore R.R. in California.

Signaling for electrified roads had to be designed to operate safely when direct current propulsion was used or when alternating current propulsion was used. The alternating current track circuit was also to be found desirable on railroads without electric propulsion where direct current track circuits were being adversely affected by stray currents from outside sources.

Two schemes of alternating current track circuits were developed for use with electric propulsion: the single-rail return system and the double-rail return system. In the single-rail system insulated block sections for signaling purposes are provided in one rail, the other rail serving as a continuous return for the propulsion current and also as one side of the alternating current track circuit. In the double-rail system both rails are insulated into block sections and both are used for propulsion current return. This was accomplished by the use of balanced impedance bonds connected around the rail insulations at the ends of blocks. These bonds offer high impedance to the passage of the signaling track circuit current, but do not have any appreciable impedance for the passage of the return propulsion current.

The double-rail system was not available until the impedance bond was developed. The first installation was in 1904-5 when 14 track circuits were installed on the direct current propulsion Boston Elevated in the East Boston Tunnel under Boston Harbor.

Single-rail track circuit installations continued to be made for many years, but the fact that one of the propulsion rails had to be given up for signaling was a serious limitation on surface roads where the large conductivity of a structure which could be used for return, was absent.

The first large scale installation of double-rail track circuits, using impedance bonds and polyphase track relays, was made on the New York Central R.R. Electric Zone in 1906.

The first installation of the alternating current track circuit for steam-operated railroads was in 1906 on the Union Pacific R.R. near Council Bluffs, Iowa.

The Robinson direct current track circuit and the Struble alternating current track circuit both operated with continuous (or steady) application of energy to the rails and became the foundation for all automatic railway signal systems, without any major change in the basic design, until 1933, sixty-one years after Dr. Robinson's first trial. During this time the requirements of signal systems became increasingly severe, demanding solutions for many problems. To meet many of these problems the coded track circuit was developed and introduced in 1933. Simply described it is a track circuit in which the rail current is broken up into recurring pulses to form a code. Thus through the years, there has been developed and placed in service three general classes of track circuits: direct current (steady energy), alternating current (steady energy), and coded energy. The various types of relays used in track circuits, and their operation, are described in the following Chapters: VI—Direct Current Relays, VII—Non-Coded Direct Current Track Circuits, X—Alternating Current Relays, and XI—Non-Coded Alternating Current Track Circuits.

Coded Track Circuits

The "conventional" track circuits use steady uninterrupted energy for the operation of a track relay while the coded track circuits have steady energy periodically interrupted in accordance with a code pattern and frequency. Code patterns comprise one or more codes, each of which consists of a predetermined rate per minute of energy interruptions in practically even "on" and "off" periods.

It is important now to refer to the early development of continuous train control systems in which several non-coded schemes were employed (see Section 7). These non-coded arrangements had definite limitations, and, to correct for these, the development of coded systems was undertaken. Experience proved the coded system to be the simplest and most satisfactory scheme of control. By means of it, the further development of present-day multiple aspect cab signals and speed control was made possible and practical. At first, two forms of track circuit energy were used, alternating current coded track circuit energy for cab signal control being superimposed upon steady energy track circuits for controlling the wayside apparatus.

As development work progressed, it was recognized that coded track circuit energy alone could be applied successfully for energization of a track circuit, as practically the same apparatus (code-receiving and code-translating equipment) in use on locomotives equipped with either cab signals or continuous train control could also be used at the entrance to a block for the control of wayside signals. Accordingly, the first installations of coded track circuits were made for the control of both wayside and cab signals.

It was early realized that the use of coded track circuits need not be confined to any particular type of signal system and that smaller amounts of copper and other materials would be used in the system because signal control line wires were eliminated and cut-sections, with their insulated joints and associated apparatus, were seldom required.

The use of coded track circuits, therefore, has expanded very rapidly since 1933 and has resulted in appreciable economy, especially where signals have had to be spaced greater distances to allow for higher train speeds and where more signal aspects are used to improve train operation.

Chronological

For chronological references see Section 18 years:

For steady energy track circuits:

1871	1891	1904	1908
1872	1900	1906	1911
1873	1901	1907	1924
1876	1903	1907–08	1925

For coded track circuits:

1933	1939	1943	1947
1934	1940	1944	1948
1935	1941	1945	1953
1938	1942	1946	

SECTION 5

AUTOMATIC BLOCK SYSTEMS

In the Standard Code of the Association of American Railroads, the automatic block system is defined as: "A series of consecutive blocks governed by block signals, cab signals, or both, actuated by a train, or engine, or by certain conditions affecting the use of a block." The block signal then is defined as: "A fixed signal at the entrance of a block to govern trains entering and using that block." Further, the fixed signal is also defined as: "A signal of fixed location indicating a condition affecting the movement of a train or engine."

An automatic block system is generally designated as a single-track or a multiple-track system. For single track, the scheme of signaling is either the overlap type or the absolute permissive block (A.P.B.) type both of which are described in detail in Chapter XV—Automatic Block System. The signaling on single track is for train operation in both directions, while on multiple track it is usually for operation in one direction only.

The block is usually considered as a permissive block on multiple-track lines, based on the principle that a train is permitted to follow another train into the block. On single track, where A.P.B. is used, "stop" signals are set up for opposing train movements between fixed points, such as between sidings, and "permissive" or "stop and proceed" signals set up for following movements.

The actual operation of automatic block systems follows one or the other of two general classifications: the normal clear system or the normal danger system. The "normal clear system" is a term used to express the normal indication of the signals in an automatic block system in which an indication to proceed is always displayed except when the block is occupied. The "normal danger system" is a term used to express the normal indication of the signals in an automatic block system in which an indication to proceed is given only upon the approach of a train to an unoccupied block. In both systems the signals assume their most restrictive indication when a train enters the block.

Two distinctive features of automatic block systems are that a definite space interval is provided for between trains, and that the trains themselves, by occupying track circuits, control the signals automatically.

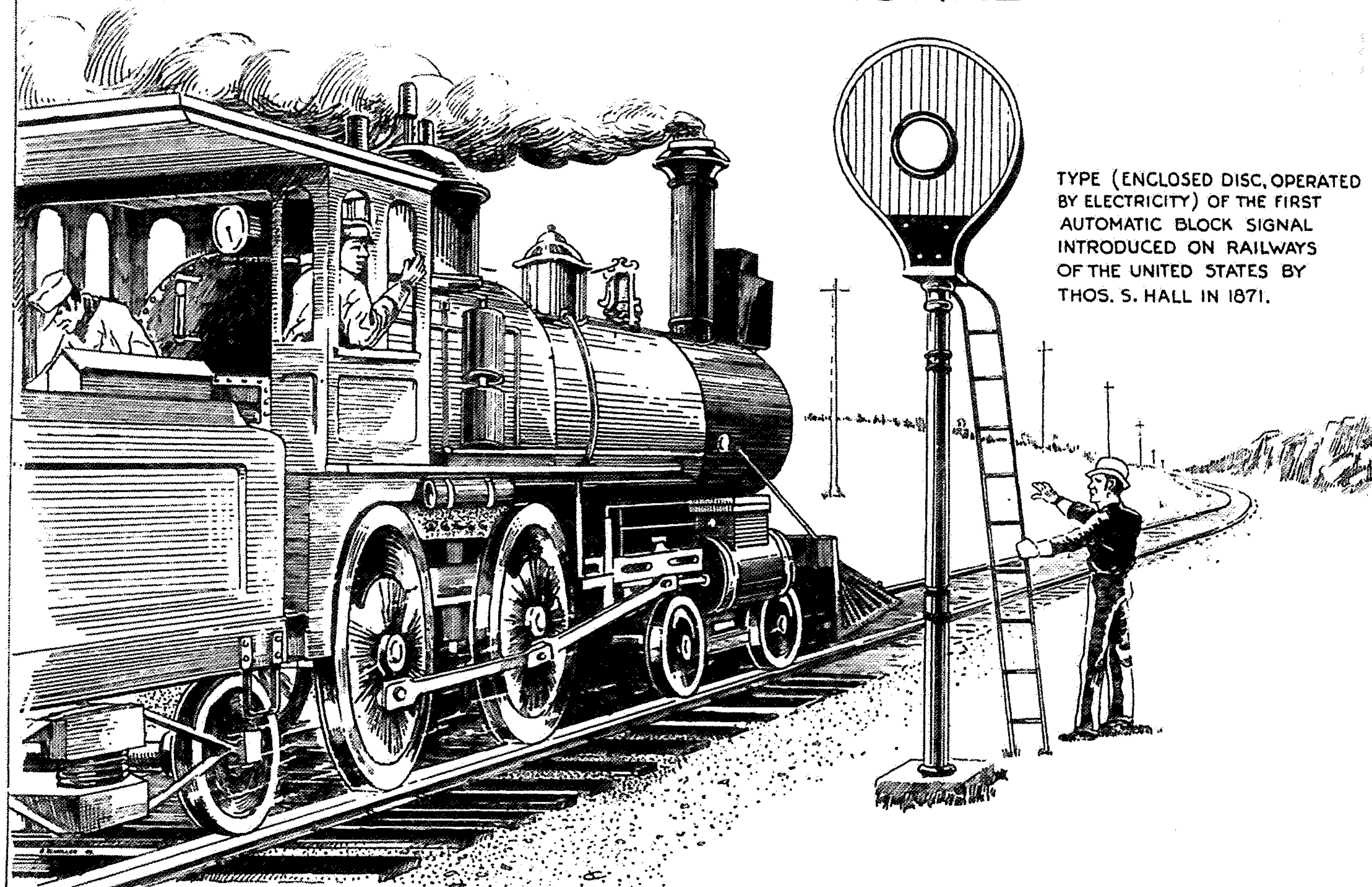
By means of track circuits this system also checks the position of all main line switches, detects broken rails, and provides for warning of cars which may be within the clearance points for fouling of main line switch turnouts. In addition, automatic block system circuits have been arranged to include detection of falling rocks or slides in cuts, fires on bridges or in tunnels, high water, dragging equipment, and other hazardous conditions.

Obviously a very necessary component of automatic block systems is the closed track circuit, described in Section 4. The invention of the track circuit by Dr. Robinson in 1872 initiated an extremely active development period for automatic block signaling and installations were rapidly made on many railroads.

The adoption of automatic block signaling in America was an outstanding example of the fact that railroads in America were confronted with entirely different operating conditions than existed in England and that English systems had to be modified or entirely new systems developed to meet America's needs.

Although automatic signaling apparently had not been tried in England prior to its adoption in America it is of interest to note that a patent was granted in England in 1862 to Mr. John Imray which covered the following

1871... BANJO SIGNAL



TYPE (ENCLOSED DISC, OPERATED BY ELECTRICITY) OF THE FIRST AUTOMATIC BLOCK SIGNAL INTRODUCED ON RAILWAYS OF THE UNITED STATES BY THOS. S. HALL IN 1871.

features: (1) a rotating banner signal operated by clockwork and controlled electrically; (2) control of the signal either by hand switches or by track treadle moved by passing trains, and (3) automatic signal repeaters, annunciators and track occupancy indicators.

In 1866 or 1867, six years before the track circuit was invented, Mr. Thomas S. Hall of Hartford, Conn., installed some clockwork enclosed disc type electric automatic signals on the New York, New Haven & Hartford R.R. at Meriden, Conn. The electric circuits for controlling the electromagnets in the signals were selected by track instruments or treadles actuated by the wheels of passing trains. This has been called the first automatic block system in America. Improvements were later made and installed by Mr. Hall in 1872 and 1873 on the New York & Harlem R. R. and on the Eastern R. R.

Numerous small installations on many roads were made in the period between 1866 and 1879 using enclosed disc type and clockwork type signals operated at first by the open circuit scheme with track instruments and later, after 1872, by the closed track circuit.

The semaphore signal was not yet ready for automatic controls. Manually operated, it had been in general use long before automatic control of signals by trains was in vogue but in manual operation it had become necessary to apply heavy counterweighting for the signal, to make certain of the return of the signal to "stop." The importance of this counterweighting was in no degree lessened when purely automatic action of a signal was introduced, as in automatic block signaling. Thus, a motor or other power device essential to this had to be adapted to operate against the counterweight's influence in clearing the signal. This was a formidable problem, primarily because adequate electric motors were then virtually undeveloped, and means for automatically controlling fluid pressure devices suited to the work were non-existent.

It was this situation that led to the development of the enclosed disc signals and the banner or clockwork signals for the first automatic signal installations. In spite of numerous faults inherent in both these types they served with commendable reliability in automatic service for many years even after means had been developed for permitting the semaphore to enter that field.

The development in 1882 of wholly practicable means for operation, and controlling operation, of the semaphore by electro-pneumatic devices, and the development some 10 years later of purely electrical means for doing the same were responsible for a gradual abandonment of the two previous types for automatic block signaling.

Inventive genius has continued throughout the succeeding years to introduce and make practical many other types of signals that have been extremely attractive for automatic block systems. It was necessary through these years to meet more and more exacting requirements resulting from changes in train speeds, length of trains, and weight of rolling stock, and from the need for economy in operation and maintenance. A description of the various types of fixed signals for all purposes will be covered later in Section 10, but it will be of interest here to mention the major development steps with regard to types of automatic block signals:

1866—Enclosed disc types.
1879—Exposed banner clockwork type.
1883—Electro-pneumatic semaphores.
1893—Low-voltage electric semaphore; mechanism and rods outside of mast.
1897—Low-voltage electric semaphore; mechanism enclosed at bottom of mast; rods inside mast.

1900—One-arm, three-position, lower quadrant electric semaphores.

1902—Electro-gas semaphores (liquid carbonic gas with electric valve control).

1904—Color light type signals for daylight use where short range (500 feet) was sufficient.

1904—Low-voltage electric semaphore mechanism mounted at top of mast.

1906—Operation of electric semaphores as three-position, upper right-hand quadrant.

1908—Electro-pneumatic mechanism moved to top of mast.

1908—American Railway Association adopted three-position, upper right-hand quadrant semaphore signals as recommended practice.

1912—Medium range (1,500 feet) color light signals for daylight use.

1914—Long range (3,500 feet) color light signals for daylight use, having concentrated lamp filaments, accurately located and factory adjusted.

1915—Position light signals with rows of three lights for each of the three corresponding semaphore upper quadrant positions. Range approximately 4,000 feet in daylight. Lights of amber color.

1920—Range of daylight color light signals improved to 4,500 feet by use of high transmission colors.

1920—Searchlight type of color light signal for long range in daylight, with a single lens opening and one lamp instead of three separate lenses and lamps for red, yellow, and green respectively.

1921—Color position light signals with two colored lights in each row: red for horizontal row, yellow for 45-degree diagonal row, green for 90-degree vertical row. Range of 4,500 feet in daylight.

Concurrently with the very active effort to improve the types of signals, there was considerable activity in connection with the basic track circuit necessary for the control of these signals. Prior to 1902, all automatic block systems on steam operated roads used direct current track circuits. The development of the direct current track circuit had reached a high state by 1900 and in view of its success on steam roads an attempt was made to apply the same track circuit to roads using electric propulsion. Difficulties were encountered which led to the development in 1901 of a modification of the track circuit to use alternating current power and alternating current relays. The first extensive trials were made in California in 1903, and in 1906 the first automatic block system using alternating current track circuits was installed on the steam-operated Union Pacific R.R. It was not long until electric signal mechanisms operated by alternating current were available and in extensive use for semaphore signals.

The development of color light signals for daytime use has been universally accepted as logical in that the wear and tear on moving parts of mechanisms is no longer present, thus reducing the cost of maintenance, and further, the signal indications are the same for daylight as for night whereas with semaphores the day indication is by semaphore position and the night indication by lights.

The use of semaphore signals for new work practically ceased in 1940 and many miles of semaphore signaling have been retired, since then, and continue to be retired by replacement with light signals. The semaphore signals that are still in service are principally of the upper quadrant type in which the arm moves in the right-hand upper quadrant between horizontal for "stop" and vertical for "clear." Some roads still retain many semaphores of the lower quadrant type in which the arm moves in the lower right-hand quadrant between horizontal for "stop" and 60 degrees for "clear." With a two-arm lower quadrant automatic block system the second arm, using a fishtail blade, indicates "approach" when in the horizontal position.

In recent years, several installations have been made where wayside automatic block signals have been supplemented by, and in some cases replaced by, cab signals located in the engine cab. Such signals cannot, of course, be obscured by weather conditions. These signals are discussed in Section 7. The signals give miniature aspects corresponding to color light or position light aspects, and in some cases merely an illuminated letter to indicate permissible speed. The first experimental installation operating with cab signals only and without wayside automatic block signals was made on the Pennsylvania R.R. on July 11, 1923 between Lewistown Jct. and Sunbury, Pa., on 43.5 miles of single track and 3.4 miles of two-track.

It is interesting to note that the Interstate Commerce Commission, in a report dated November 26, 1928 made the following statement: "Cab signals are without a doubt an important development in the art of signaling. They place the signal indication immediately in front of the engineman where it cannot be obscured by snow, fog, smoke or other obstructions; and where a combination of visible and audible indication is used, it is without a doubt a valuable addition to the signal system."

Chronological

For chronological references see Section 18, years:

1866	1891	1907	1930
1870	1892	1908	1931
1872	1893	1911	1933
1875	1894	1912	1934
1876	1897	1914	1935
1878	1898	1915	1938
1879	1900	1917	1939
1880	1901	1920	1940
1881	1902	1921	1941
1882	1903	1922	1942
1883	1904	1923	1943
1884	1905	1925	1945
1889	1906	1926–27	1948

SECTION 6

INTERLOCKING

Present-day practices under the designation "interlocking" represent gradual development which started early in the 19th century in England, when economic factors first forced consideration of means to eliminate train stops for crossing and switching moves and means to save the expense of individual switch operation labor.

Interlocking is now defined in the Standard Code of the Association of American Railroads as: "An arrangement of signals and signal appliances so interconnected that their movements must succeed each other in proper sequence and for which interlocking rules are in effect. It may be operated manually or automatically." The term is considered to include the interlocking station, the interlocking machine, the switches, the signals and all connections and auxiliary apparatus. Interlocking is so named because provision is made to insure proper sequence of operation of the machine levers in order to prevent conflicting routes being set up by the leverman which might result in a derailment or collision.

The Beginning of Interlocking

The initial start toward the modern interlocking systems in use today was the installation of the first mechanical interlocking at Bricklayer's Arms Junction in England in 1843, in which the signals were moved by stirrups and the switches by levers. The switches and signals were operated by a switchman who worked the switch levers with his hands and the signal stirrups with his feet. The switches and signals were operated by pipe or wire connections. The need for mechanical locking between levers was not thought of or deemed necessary at that time.

The Facing Point Lock

Since the first installation in England did not check mechanically the operation of the switches and signals, switches were sometimes thrown under trains, and signals occasionally cleared when switches were improperly set. To prevent switches being thrown under trains, the detector bar was designed, consisting of a long bar extending alongside the rail, which was raised and lowered each time the switch to which it was connected was operated. If a train occupied the track close to the switch the bar could not be raised, as it would strike against the car wheels. It was found, however, that when the bar was connected to the same lever used to operate the switch, the latter could be moved a dangerous amount before the bar would strike against the wheels. To remedy this condition, the detector bar was attached to a separate lever which was also used to lock the switch points. As these extra precautions were only considered necessary on facing point switches, the device became known as the "facing point lock," the name it still bears.

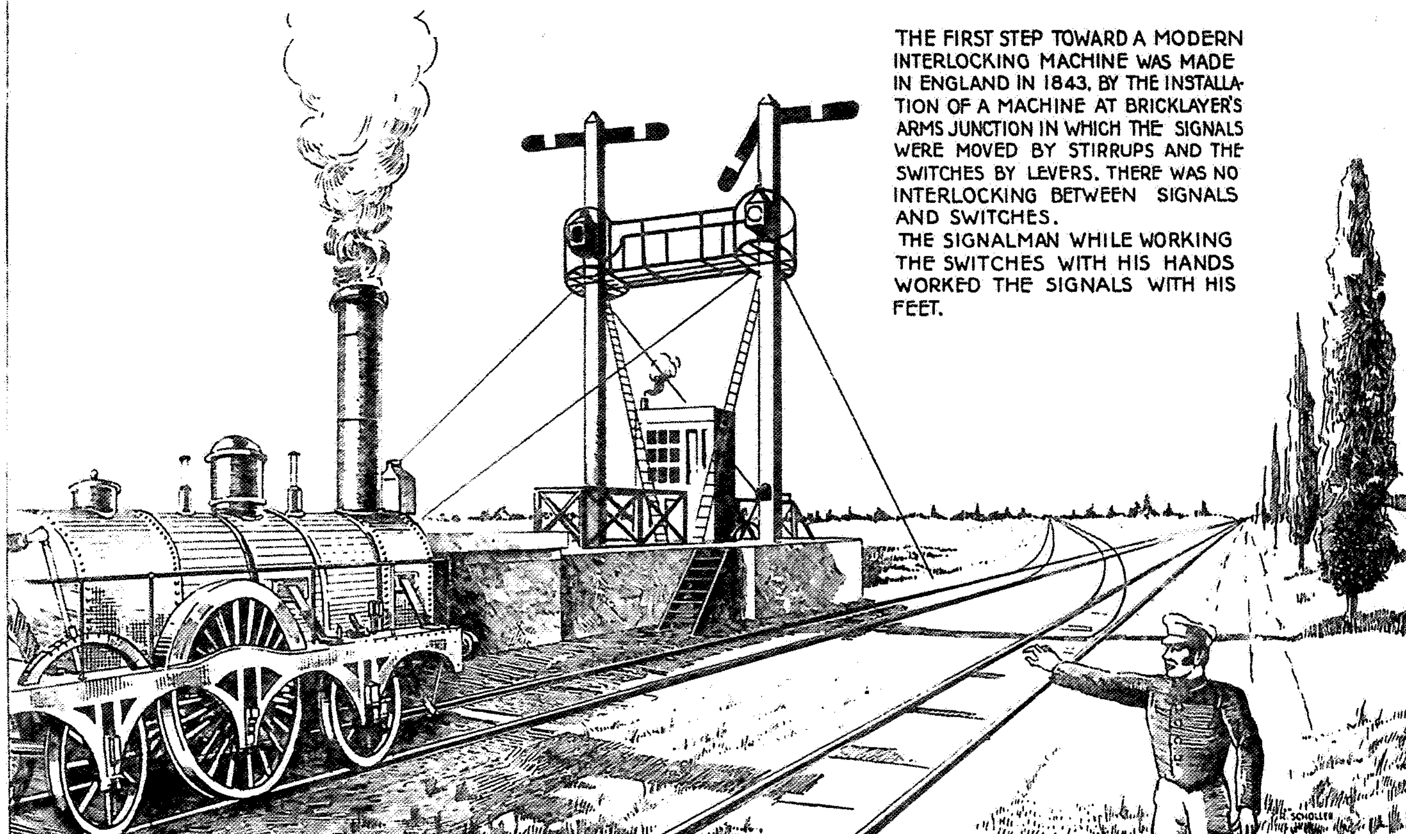
The first attempt to interlock the switch and the signal levers was made in England in the year 1847 when, due to several accidents having been caused by signalmen operating the wrong lever, Mr. Stevens devised a scheme of lever and stirrup arrangement in the machine which helped to remedy this condition. There was no mechanical obstacle, however, to the signalman moving a signal stirrup before he moved a switch, nor were there any mechanical connections between different levers or different stirrups.

MECHANICAL INTERLOCKING

FIRST INSTALLATION IN ENGLAND. BRICKLAYER'S ARMS JUNCTION 1843.

THE FIRST STEP TOWARD A MODERN INTERLOCKING MACHINE WAS MADE IN ENGLAND IN 1843, BY THE INSTALLATION OF A MACHINE AT BRICKLAYER'S ARMS JUNCTION IN WHICH THE SIGNALS WERE MOVED BY STIRRUPS AND THE SWITCHES BY LEVERS. THERE WAS NO INTERLOCKING BETWEEN SIGNALS AND SWITCHES.

THE SIGNALMAN WHILE WORKING THE SWITCHES WITH HIS HANDS WORKED THE SIGNALS WITH HIS FEET.



In a letter from the Railway Department of the Board of Trade addressed to the Railway Companies of Great Britain in 1858 there was covered in writing for the first time the more important requirements of the Board of Trade for new railway lines. This letter contained the first fundamentals on which railway signaling was to be based. The signer of this letter was Captain Douglas Galton. In the memorandum accompanying his letter, Captain Galton made no mention of interlocking. However, he did say, "In case of facing points at junctions it is most desirable that the signals should be connected with the points so as to be worked in conjunction with them and to indicate whether they are open or shut." In the very next year after the recommendations were issued another Board of Trade Inspector, Colonel Yolland asked for a simple form of interlocking at Kentish Town Junction.

The first real mechanical interlocking, in terms of present practice, appears to have been devised by Mr. John Saxby in 1856, and improved by Mr. Chambers and Mr. Saxby in 1860.

The First Interlocking in America

To Mr. Ashbel Welch, General President and Chief Engineer of the United New Jersey Canal and Railroad Companies, who established the first manual block system in 1863 for controlling train movements in America, also goes the credit of introducing to American railroads the first interlocking.

During a visit to England in 1869, Mr. Welch made a careful study of the interlocking system in use in that country; and upon his return, he made a report on his observations to the Executive Committee of the Joint Board, and he was authorized to make trial of the system at Trenton Station, New Jersey. The report was titled "Station and Switch Tending" and was dated December 27, 1869, the day it was presented to the Executive Committee. Because of its importance in the early development of railway signal systems in America, it is quoted below:

"Most American constructions and arrangements are better, at least for America, than the European. But this is not always the case.

"One of the arrangements which is much better in Europe than with us is the working of switches and signals. They have one man in a small glazed room or observatory, who works all the switches and signals anywhere near, in one of the directions from the station. No train can approach the station without signal from him that the track is clear.

"A signal and switch man should be under cover, protected from heat, sun, rain, snow, and cold, and danger, so that his whole time and attention may be given to his work instead of self protection, and so that discomfort, or fear shall not make him nervous, out of temper, or negligent.

"One man should work all the switches from one direction because:

"1st. His signals and points will not clash, as those of different men may, from want of understanding with each other.

"2nd. One man does the work of several, and so saves great expense.

"3rd. A good man put at a single switch has so little to do and think that he becomes stupid; the tender of many becomes bright.

"4th. A better class of men has our safety in charge.

"Experience is in favor of the European plan. At points where hundreds of trains per day pass, mistakes have not occurred in many years. At Paddington Station, one of the largest in the world, it is said only one run-off or mistake has occurred in nineteen years. At Crewe, one man works seventy-two levers of which probably one-third move different switches; two-thirds, signals.

"I recommend that the European system be tried at Trenton."

The above concise statement of the reason for an interlocking system is of interest as one of the earliest, if not the first, recognition of the need for interlocking in America. The action taken by the Executive Committee on Mr. Welch's report is indicated by the following extract from the minutes of the meeting on December 27, 1869:

"The General President made a report on the signal and switch system now in use in England, and it was

"Resolved, That the General President be authorized to make trial of the system at Trenton Station."

Mr. Welch then wrote (early in January 1870) to Mr. Herbert Ramsey, who had previously been connected with the London & North Western Ry., authorizing him to give Saxby & Farmer of London an order for the machine. Mr. Ramsey was employed to come to America to supervise the installation. He arrived at Trenton on October 7, 1870, and was met by Mr. Thomas B. Fidler, one of Mr. Welch's assistants. The interlocking material arrived later in the same month. In Mr. Fidler's diary appeared an entry, under date of December 7, 1870, reading, "Went to Trenton with Mr. Welch to see the workings of the points and locking apparatus just completed." This entry definitely fixed the time of completion.

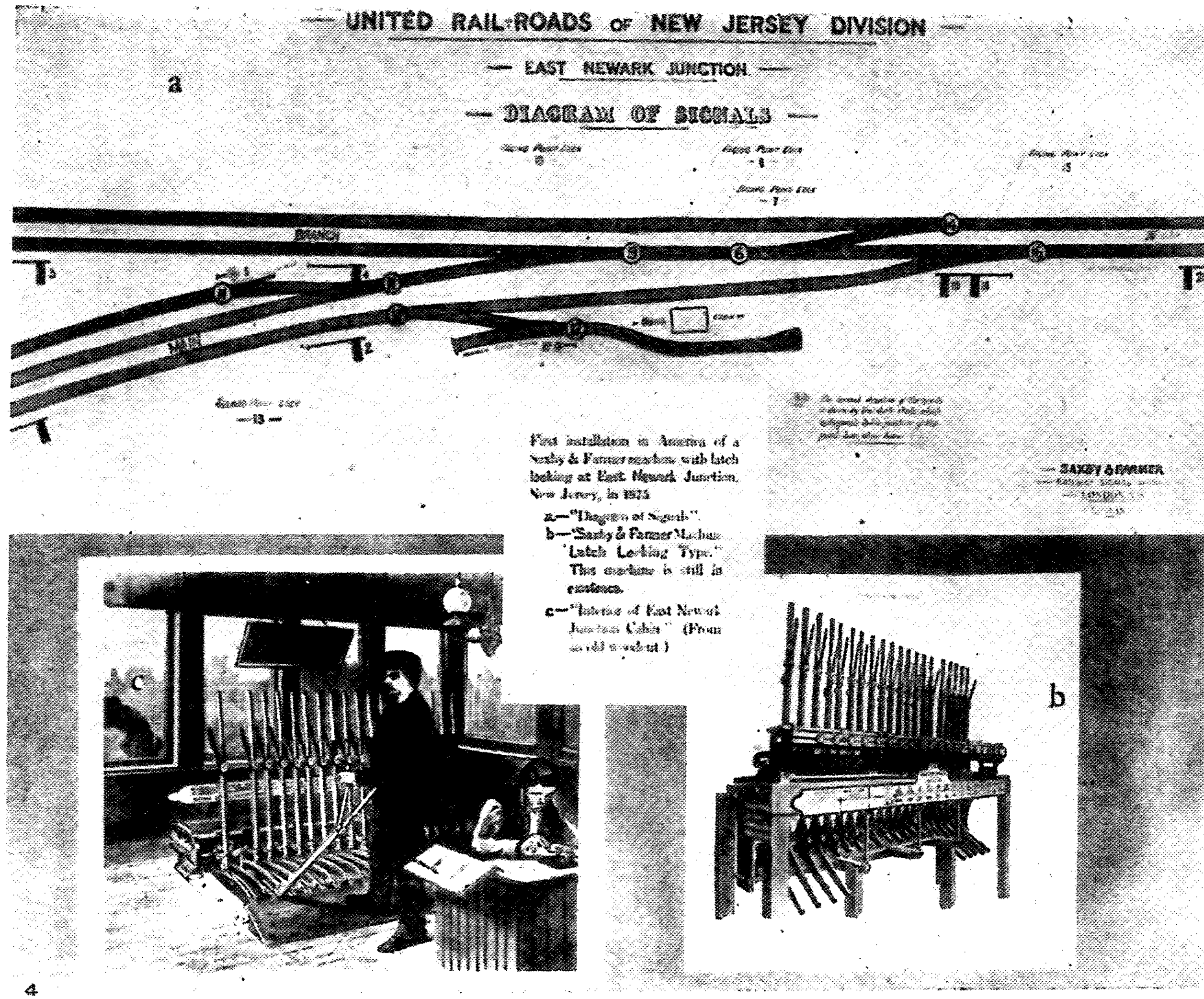
Original data indicate that this interlocking machine had been built for use at a junction proposed to be built near the Delaware Bridge in South Trenton, N. J., to connect the Belvidere Delaware R.R. by a short branch from a point north of Trenton, as the original connection for that road required modification because of changes made in the track layout north of Trenton. As the proposed track changes were abandoned, another place was found for the interlocking machine, and this was at "Top-of-the-Hill," a junction of the Bordentown Branch, with the siding on the canal bank at Hamilton Ave., Trenton, just south of the Clinton St. Station.

The machine used carried the maker's number 905. It was patented in 1867 and was of the spring catch type with signal locking above the floor. Apparently, the locking used on this machine represented an intermediate step between the early lever locking and the later complete latch locking which came into universal use in the United States. The raising of a latch on a lever did not lock the latches of conflicting levers, but locked the conflicting levers themselves.

This interlocking, having served its purpose as a trial installation and having demonstrated its usefulness in American railroad practice, was removed soon after the Pennsylvania R.R. leased the lines of the United New Jersey Canal & Railroad Companies.

The second English built mechanical interlocking machine in America was also on the Pennsylvania R.R. It was a Saxby & Farmer machine with serial number 2164, installed at East Newark Junction, N. J., and placed in service February 11, 1875. "Flop" type latch locking was used.

In the meantime, machines of American manufacture were being designed and built. The first ones were installed experimentally in 1874 at Spuyten Duyvil, N. Y. and at the 52nd St. crossing on the Hudson River R.R. They were Toucey & Buchanan machines. In 1876, several were installed on the



First S. & F. interlocking in America (1875).

Pennsylvania. These machines differed from the Saxby & Farmer machines in that they did not have preliminary locking. They were later replaced with Saxby & Farmer type machines with preliminary locking.

Mechanical Interlocking

In a field so new as signaling, many interlocking devices were developed, introduced and tested in the 1880's; but in the light of experience, they were considerably altered or abandoned for something better. Today's standard is the improved Saxby & Farmer. The characteristics of this type of machine were such as to warrant the favor of railroad men as it contained all the checks and elements of safety which were required. The original locking, however, was inconvenient in many ways. The construction of the old locking in two tiers was expensive from a maintenance standpoint, since a slight alteration in the lower tier required throwing the machine out of service and dismantling it. Simpler locking in one tier, so arranged that any required changes could be made by removing the caps which prevented the locking bars from lifting, was built into the improved machines. The ancient "flop" was replaced by a square shaft which revolved in turned bearings and drove the long locking bars. The arrangement of the bars provided for the greatest amount of locking in the smallest space.

In the various stages through the development period in the 1880's there appeared the following:

1. The application of an electric lock to the Saxby & Farmer machine to provide a control for lever movements that resulted in greater safety in operation.

2. The improved Stevens ground machine for use at isolated siding or crossover switches. It was furnished with two to eight levers without preliminary locking at first; later with preliminary locking.

3. The Hambay interlocking machine, similar to the Stevens machine but with locking between levers accomplished by locking discs. This locking was known as "butt" or "absolute" locking and was claimed to be much simpler and easier to maintain.

4. The Wheel, or Capstan, machine was devised for operation of switches and signals at railroad crossings and junctions where the tracks to be signaled were main line routes with little or no switching moves. The simplicity of the design enabled one wheel to be equivalent to three levers of the usual interlocking machine.

5. Horizontal lever machines for locations where movements required were few and simple. Each machine frame carried only two levers which operated through a full arc of 180 degrees.

6. The gear machine was operated by means of a crank or wheel for controlling switches and signals at approaches to drawbridges.

7. The block signaling machine for use with absolute block signaling systems consisted of two levers, each connected directly with its respective block signal and each provided with the Sykes electric locking apparatus.

8. The double ground lever device for use at outlying points was of value on curves or other places where switch lights could not be seen. Interlocking

required that the switch had to be normal before the signals could be cleared.

9. The triple ground lever device was really an interlocking machine with Stevens locking included. It was useful for operation of switches and signals at end of two-track and outlying crossovers where no signalman was employed. It could be moved at small expense when required.

In a mechanical interlocking machine the proper sequence of operation of the levers is accomplished by an arrangement called mechanical locking in which interconnected bars, dogs, and cross locking are actuated by latches on the levers. When conditions are such that a lever should not be operated, the latch handle cannot be moved and, consequently, the lever cannot be released for movement from its locked position.

The levers in a mechanical interlocking machine operate the switch and the signal functions through the medium of pipe lines. Formerly, wire lines were also used to operate some functions, but the use of wire lines has been obsolete in America for many years. The limits of a mechanical interlocking plant are determined by the greatest distance in which a pipe line can be operated effectively. The introduction and development of power interlocking has eliminated this distance limitation.

Another type interlocking used extensively is the electro-mechanical. This type provides for mechanical operation of the switches and facing point locks and electric operation of the signals.

Electro-Mechanical Interlocking

This form of interlocking can be traced to the activities of Mr. W. R. Sykes of the Sykes Interlocking Signal Co. of England. At Victoria Terminal, London, of the then London, Chatham & Dover Ry., he installed in 1883 no less than 50 electric switching signals. The problem at Victoria was how to provide a sufficient number of these signals to handle the heavy train movements while at the same time avoiding the necessity of providing additional levers in the interlocking machines from which the switches and signals were operated. The problem was solved by providing for the control of the electric signals with contact switches on the interlocking machine, these in turn being interlocked with the mechanical levers.

The first experiment with electro-mechanical interlocking in America was placed in service March 4, 1906 at Brandywine Draw, Wilmington, Del. on the P. B. & W. (Pennsylvania R. R. System), 23 years after the interlocking installation at Victoria Terminal, London. The machine for Brandywine Draw was of the mechanical type to the levers of which were attached small auxiliary special levers for the control of the signals.

In the meantime improvements were being made as the necessity for more suitable levers for the operation of the signals, a more direct electrical control of mechanical levers and more reliable circuit controllers, was apparent. The improvements resulted in the machine itself being designed to consist of a row of mechanical levers with another row of miniature levers, similar to those used in power interlocking machines, placed above them and so arranged that each switch-throwing mechanical lever had its electric controlling lever directly above it. The miniature signal operating levers were placed between the switch controlling levers. Each mechanical switch lever had mechanical locking between it and its electric signal lever.

This machine was called the electro-mechanical type. It had many attractive features as it offered essentially a combination of the advantages of power-operated and mechanical interlockings. The size of the machine was reduced so that a smaller tower was required. Less effort was needed for its operation and a reliable means for switch and signal indications was provided. It permitted the safe use of electric switch locking thus eliminating the use of facing point locks, bolt locks and detector bars.

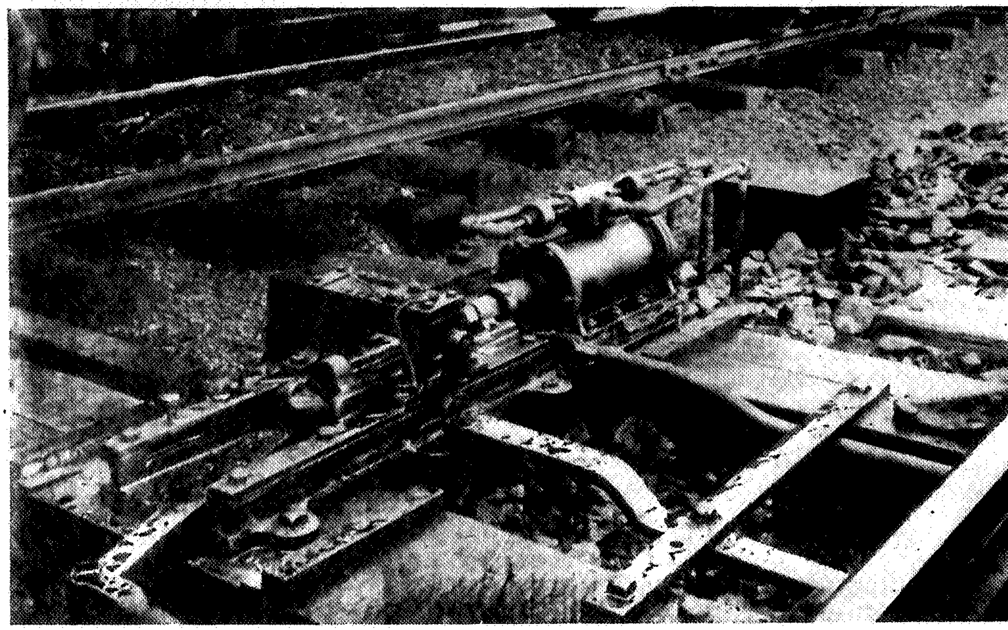
The first installation of this type was placed in service at Gap, Pa., December 30, 1909. The machine consisted of 24 miniature levers of which 3 were spare and 8 mechanical levers, 7 working and 1 spare. The machine was furnished by the General Railway Signal Co. and the signals were Model 2A, low-voltage type. Shortly after this another G.R.S. installation was placed in service at Elwyn, Pa. Early in 1910 the Union Switch & Signal Co. made two similar installations, one at Farmingdale, N. J. and the other at Whiting, N. J. at junctions of the Pennsylvania R.R. and the Central R.R. of New Jersey. In this way, electro-mechanical interlocking was introduced to American railroads.

Power Interlocking

As mechanical interlocking was being developed, inventors were already dreaming of interlockings operated by power. Power interlocking machines have levers that actuate electrical contacts which close or open the various electric circuits used for the operation of the outside functions, such as the power-operated switch machines and the signals. The miniature levers of certain power interlocking machines also have their proper sequence of operation checked by mechanical locking. The locking is of lighter construction than that used in mechanical machines, because, by the lever arrangement, space is considerably reduced and there is less strain put on the locking bars. Some types of power machines do not require mechanical locking between levers but have equivalent protection provided electrically through the interconnection of relays, circuits, and controllers. Power interlockings require, as part of the plant equipment, certain auxiliary apparatus, such as power switch boards, rectifiers, terminal boards, battery, and other power apparatus.

The first practical machine for this type of interlocking in America was placed in service on a trial basis for the Pennsylvania R.R. at the west leg of Mantua Y, Philadelphia, Pa., in 1876. The interlocking was of the pneumatic type, installed under the patents of Prall & Burr. While the apparatus was crude in many ways, as compared to present-day standards, still it gave reasonably good results; but the inventors, for some reason, lost interest and did nothing further with their invention. About this time, Mr. George Westinghouse had become interested in railway signaling as one of his many activities and in 1881 formed the Union Switch & Signal Co.

The first Union Switch & Signal Co. power interlockings were the hydraulic type and were installed at Wellington, Ohio, and at East St. Louis in 1882. These were followed by the installation of the first hydro-pneumatic plant, built and put in service in 1883 and 1884, at Bound Brook, N. J., on the Philadelphia & Reading Ry. After this installation, an electro-pneumatic system underwent rapid development through the work of Messrs. Westinghouse, Schreuder, Spicer, Coleman, Hanlon, and others.



Hydro-pneumatic switch-and-lock movement at Bound Brook, N. J. (1883)

While it was considered safe to operate signals electro-pneumatically as early as 1883, yet up to 1891 all switches were operated by valves in the interlocking machine admitting and releasing air to and from a normal and a reverse pipe filled with water in the summer and a non-freezing solution in winter, which operated an auxiliary valve near the switch. In 1891, however, the Union Switch & Signal Co. devised the electro-pneumatic switch valve, the first ones being installed on the drawbridge interlocking on the Chicago & Northern Pacific R.R. at Chicago, Ill. and in the Jersey City Terminal, N. J. on the Pennsylvania R.R. The results were so satisfactory that practically no further hydraulic installations were made. In the following years up to June 1, 1900 there were ordered 54 electro-pneumatic interlockings, having 1,864 levers, for use on 13 railroads.

In the meantime, the application of electricity to many phases of industry was making rapid progress; and its use for power interlocking purposes naturally received consideration. It was in 1888 that Mr. J. D. Taylor, then a telegraph operator in a small Ohio town, became interested in electrical devices to be used in train dispatching. Having obtained patents, he and some others attempted to interest the officials of the Baltimore & Ohio Southwestern R.R. Mr. I. G. Rawn, then General Manager, suggested to Mr. Taylor that some principles embodied in his device might be used in railway signaling. Although Mr. Taylor, at that time, had practically no experience in the signal field, he agreed to attempt to develop an electric interlocking system.

At the suggestion of Mr. Rawn, Mr. Taylor visited a mechanical interlocking plant in Indianapolis, Ind. and carefully studied the different parts of the apparatus. He then returned to Chillicothe, Ohio, and built the first Taylor electric interlocking in the Baltimore & Ohio Southwestern R.R. shops. This was installed at East Norwood, near Cincinnati, Ohio, at the crossing of the Baltimore & Ohio Southwestern and the Cincinnati Northern Railroads in in 1889.

In the first Taylor interlocking at East Norwood, the switch movements were mounted on platforms raised about three feet above the track level to keep the electrical parts from getting wet, and the insulated wires between the machine and the movements were buried in the ground. This installation was the first to employ "dynamic indication."

The first installation of a Ramsey & Weir electric interlocking was made at College Hill Jct. (Cincinnati), Ohio, on the Cincinnati, Hamilton & Dayton R.R. in 1888, and a second plant installed at the Grand Central Depot in Cincinnati in 1891.

In 1896 the Taylor Switch & Signal Co. of Chillicothe, Ohio, installed its second plant at Edgewood at the crossing of the Baltimore & Ohio Southwestern and the Illinois Central Railroads. This plant was also built in the Chillicothe shops.

In 1900 a low-pressure pneumatic interlocking system was introduced by the Pneumatic Signal Co. to overcome some difficulties encountered in high-pressure systems due to leaks and condensation of moisture. The first installation was made at Grand Central Terminal, New York City.

In 1901 the newly formed Taylor Signal Co. of Buffalo, N. Y., installed its first electric interlocking at Eau Clair, Wis., on the Chicago, St. Paul & Minneapolis R.R. The "dynamic indication" principle was used.

In 1904 the first electric interlocking of the Union Switch & Signal Co. was installed on the Lake Shore & Michigan Southern Ry. at Millbury Jct., Ohio.

Automatic Interlocking

Automatic interlocking, whereby the trains themselves establish their own routes, was considered in the early 1900's as desirable and economical for use at locations where train movements on one railroad crossing another were infrequent. As great strides had been made in the design of automatic signal and interlocking circuits, it was an easy step to design circuits for application to such crossings for the control of power-operated signals. We find the first automatic interlocking installed at Chester, Va., in 1907, protecting a crossing of the Tidewater & Western R.R. with the Virginia Ry. Power & Light Co. Numerous installations of this type were made in the next 14 years and the advantages were so obvious that in 1926 the Signal Section, A.A.R. authorized the preparation of requisites and circuits to cover recommended practice for the future.

All-Relay and Route Type Interlocking

In the late 1920's when the success of centralized traffic control systems had been fully determined, it was realized that safety of operation with power-operated switches and signals was being obtained using control machines without mechanical locking between levers, without lever electric locking, and with miniature levers that were free so that any or all could be moved at will by the operator. This resulted in the introduction of a new type of interlocking to be known as the "all-relay" system or simply "relay-type" interlocking.

Interlocking systems up to this time (except automatic interlocking) all employed control machines with mechanical locking between levers, as well as electric lever locking. In the new system the vital safety features inherent in the mechanical locking and the lever electric locking were transferred to relays and their controlling circuits. The free levers control the switches directly through relays or other control devices and the switch position is indicated to the tower by the usual switch repeater relay arrangements. The final network once established for a routing maintains its integrity irrespective of the interim positioning of any or all involved free levers, except the governing signal lever for the route.

In 1929, at Blue Island, Ill. on the Chicago, Rock Island & Pacific R.R., the first installation of an all-relay system as described above was made.

In the same year, on February 14, a unit-wire remote control system of all-relay interlocking was installed at Lincoln, Nebr. on the Chicago, Burlington & Quincy R.R. Also in 1929, on December 15, a coded remote control system of all-relay interlocking was installed at Eagle Bridge, N. Y., on the Boston & Maine R.R.

In 1930 the all-relay principle was first used as a substitute for lever indication devices of a large interlocking machine at the new Cleveland Union Terminal, Cleveland, Ohio. This installation utilized a dynamic selection of a polarized alternating current repeater relay, and lock rods were omitted from the switch machines. The interlocking machine had 576 levers, without indication magnets or detents.

Following the introduction of the free-lever type of control machine and all-relay interlocking, another type of control machine came into use in which the route principle of function control was provided. Complete routes may be established through a plant with this type of machine by the manipulation of a control button at the entering end of a route and another button at the leaving end. By this action the complete route is automatically established, including the throwing of the required switches and the clearing of the desired signal.

The first route-type interlocking was called "NX" type and was installed in 1937 at Girard Jct., Pa., on the New York Central System. In 1938 two more installations were made using a type called "UR." They were at Western Ave. and 14th St., Chicago, Ill. and at Elizabethport, N. J.

Chronological

For chronological references see Section 18, years:

1843	1883	1901	1929
1870	1884–91	1904	1930
1874	1885–90	1906	1937
1875	1888	1907	1938
1876	1891	1909	1939
1877–78	1891–00	1912	1948
1881	1900	1914	1951
1882	1900–02	1926	1952

SECTION 7

AUTOMATIC TRAIN CONTROL AND CAB SIGNALS

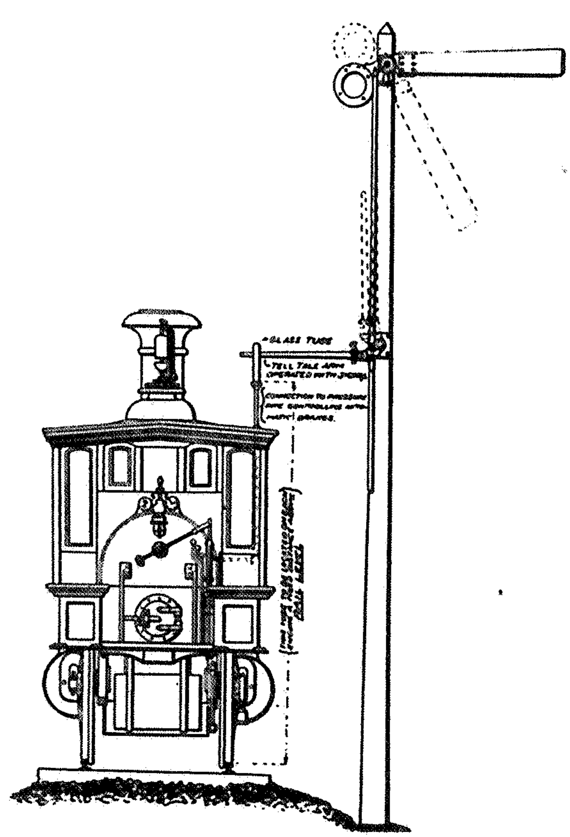
The expression "train control" is used somewhat loosely as a general term to include either the automatic stop, in which the brakes are applied and remain so until the train is brought to a stop, or a complete automatic speed control system where the speed of the train is maintained within fixed limits. Its use as a general term should be borne in mind as development is discussed.

A search in the patent office has revealed that in 1859 a patent was granted by which a train would automatically telegraph its position to the central office. This might be considered as the beginning of inventive thinking for automatic train control.

Even before the invention of the air brake, patent office records show patents were taken out to stop a train automatically as early as January 29, 1867, in which it was proposed to close the throttle and sound an alarm whistle on the locomotive.

However, shortly after the invention of the air brake by Mr. George Westinghouse, and its successful initial demonstration on the Pittsburgh, Cincinnati, Chicago & St. Louis R.R. at Pittsburgh, Pa. in April 1869, the very obvious idea was conceived of stopping trains through venting the train pipe by some device on the roadway.

The first manufacturing activity for an automatic train stop system is revealed in the 1889 "Pocket Reference Book" of the Union Switch & Signal Co. by a description and diagram of the device known as the Wood and Vogt automatic train stop, covered by patents issued in 1880 to Mr. Joseph Wood



Wood and Vogt train stop device (1880) on Pennsylvania R.R.

and to Mr. Axel S. Vogt, of the Pennsylvania R.R. at Altoona, Pa., and purchased by the Union Switch & Signal Co. This device in one form consisted of a glass tube projecting above the engine cab, designed to be broken by a horizontal roadside arm when signal was at stop, and connected to the brake pipe line so that such breakage would set the train brakes. In a modification, a mechanical lever connected to the brake control valve is used instead of the glass tube.

The first trials of the Wood and Vogt device were made in 1880 on the Middle Division of the Pennsylvania R.R. with the glass tube located near the rails and operated by a "track trip." Due to obstructions other than the "track trip" causing failures, the tube was moved above the cab in 1881 and trials continued until 1883 when there resulted many undesirable applications due to icicles in a tunnel breaking the glass tube. The principle, however, was later used on several interurban lines and was still in use in 1930 on a busy suburban electrified district.

In the early 1890's other practical tests were made. It was during this time the Kinsman device, a plain mechanical trip type, was tried out on what is now a section of the Boston & Maine R.R. in Massachusetts. The Rowell-Potter system, also a mechanical device, was tested at about the same time on the Boston, Revere Beach & Lynn R.R. and was later installed on the Intramural Ry. at the Chicago Exposition in 1893. Other devices were tried at different times, based upon the mechanical trip idea, but were generally considered as being impractical for steam-operated railroads.

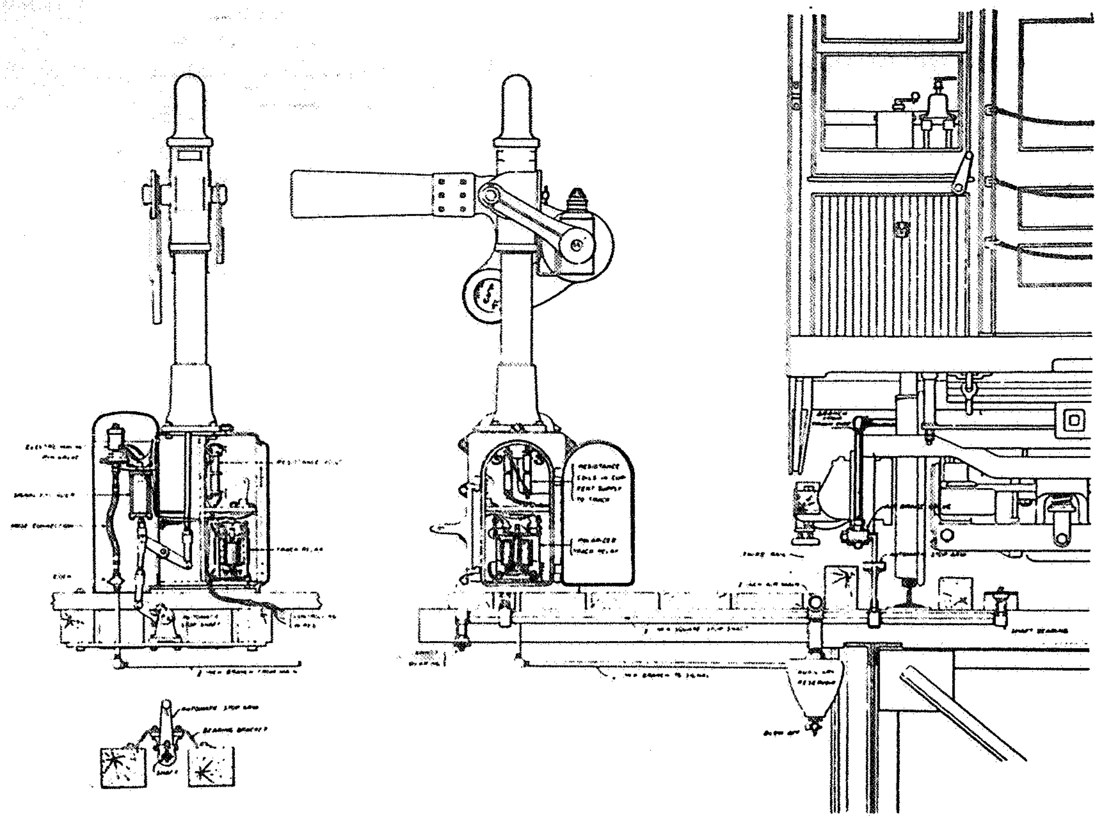
It was in 1901 that the Union Switch & Signal Co. installed the first permanent system of automatic stops. The installation was on the Boston Elevated and the stops were the mechanical roadside trip type. They were an adjunct to the electro-pneumatic interlocking and automatic signaling with which the road was equipped.

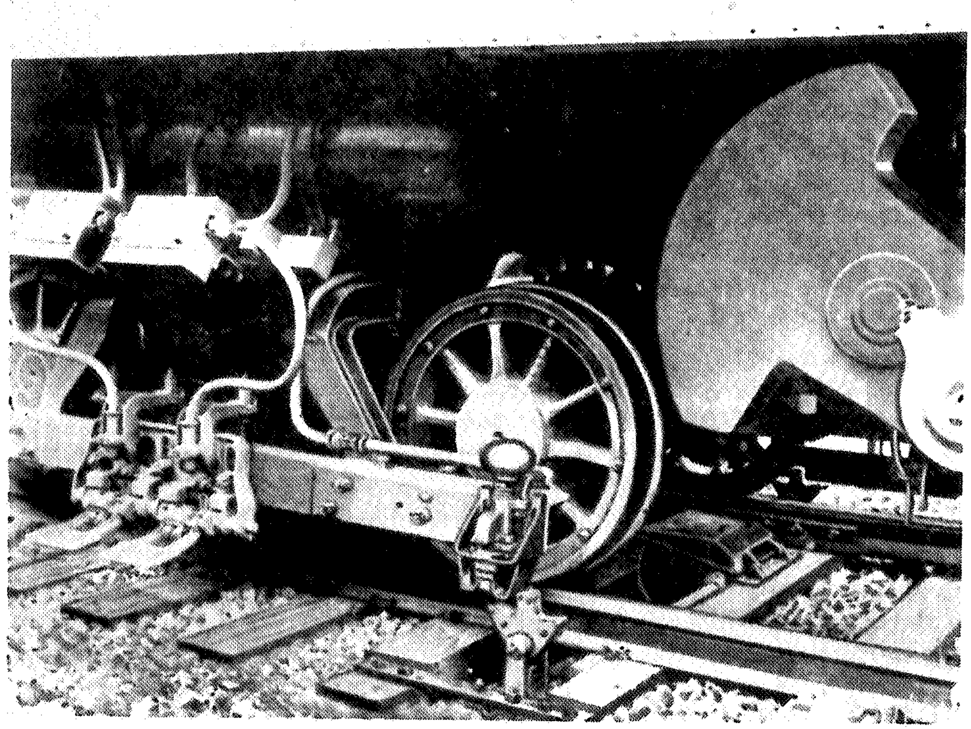
In 1904 this automatic stop was introduced by the Union Co. on the subway lines of the Interborough Rapid Transit Co. in New York City. The same system was also installed on the elevated and subway lines of the Philadelphia Rapid Transit Co. in 1907, and, subsequently, upon the Hudson & Manhattan R.R., the Pennsylvania Tunnel and Terminal Division of the Pennsylvania R.R., the Brooklyn Rapid Transit R.R., the New York Municipal Rys., and on the Frankford Elevated in Philadelphia.

Mechanically actuated stops were installed at a number of interlockings upon the lines of the Northwestern Elevated in Chicago which were not equipped with block signals. Later, the electro-pneumatic train stops were used on the Chicago Elevated lines in connection with electro-pneumatic interlockings. It will be noted that these mechanical roadside trip type stops were used almost exclusively on elevated or subway lines where the traffic is even, equipment uniform, and speed not excessive.

Another type was the Simmen system, first installed about 1909 on some electrically operated interurban lines. It was designed to give control from a central station by means of line wires, and used a ramp to transmit signals to a car. The same communication system permitted the car automatically to record its movement in the central office.

Shortly after 1909 there developed a demand for automatic stop protection on a number of electric interurban lines. The Wood and Vogt scheme, previously referred to, was the prototype of automatic stop installations for the San Francisco & Oakland Terminal and the Oakland, Antioch & Eastern Railways in California in 1913, and also for the Sparrow's Point line of the





Mechanical roadside trip, train stop device (1901) on Boston Elevated.

United Railways & Electric Co. of Baltimore, Md. in 1917. These installations were preceded by trial installations on the Illinois Traction Lines at Peoria, Ill., in 1911.

Before 1906, all train control activities were carried on voluntarily by the different railroad companies and by agreement between them and the owners of the various devices. Subsequently, however, there had been sufficient agitation to cause Congress to instruct the Interstate Commerce Commission to investigate the subject of automatic train control and that of automatic block signals.

There will be found in the Library of Congress under Card Number A29-110 a series of Bulletins published in 1929 and 1930 by the American Railway Association Committee on Automatic Train Control which was organized in 1920. These Bulletins cover quite completely the "Early Development, Tests, Types of Devices, Interstate Commerce Commission Orders, and Present Situation," concerning automatic train control as of that date, and are as follows:

Bulletin No. 1—Early Development and Report of the Committee since it was organized in 1920.

Bulletin No. 2—General Railway Signal Co. Intermittent Inductive Type.

Bulletin No. 3—Union Switch & Signal Co. Intermittent Inductive Type.

Bulletin No. 4—Miller Train Control Corp. Intermittent Electrical Contact Type.

Bulletin No. 5—Regan Safety Devices Co. Intermittent Contact Type.

Bulletin No. 6—National Safety Appliance Co. Intermittent Magnetic Induction Type.

Bulletin No. 7—Sprague Safety Control & Signal Corporation. Intermittent Magnetic Induction Type.

Bulletin No. 8—Union Switch & Signal Co. Continuous Inductive Types.

Bulletin No. 9—General Railway Signal Co. Continuous Inductive Types, and General-Miller Intermittent Inductive Type.

The material in these Bulletins is of value historically to those interested in the subject and is mentioned here for reference. No attempt will be made herein to repeat the descriptions of the various systems and devices that are discussed in the Bulletins, or to discuss the railroad and Government activities that are also fully covered up to 1930.

Government Activities

In the Bulletins previously referred to, published by the A.R.A. Committee on Automatic Train Control, there is a complete history relating to the issuance of Order 13413 by the Interstate Commerce Commission on June 13, 1922, which covered specifications and requirements for the installation of automatic train stop or train control devices on specified portions of railroads.

The next Order of the Interstate Commerce Commission of major importance as affecting railway signaling was dated April 13, 1939: "In the Matter of Rules, Standards, and Instructions for the Installation, Inspection, Maintenance, and Repair of Systems, Devices, and Appliances Intended to Promote the Safety of Railroad Operation in Accordance with Section 26 of the Interstate Commerce Act as Amended August 26, 1937." This Order included Rules, Standards and Instructions for Automatic Train Stop, Train Control, and Continuously Controlled Cab Signal Systems.

In 1946 the Commission instituted an investigation to determine whether it was necessary in the public interest to require any carrier to install signal systems or devices intended to promote the safety of railroad operation upon the whole or any part of the railroad on which any train is operated at a speed of 50 or more miles per hour. This was brought about by a continued great increase in the number of trains operated, and by a material increase in the speeds of both passenger and freight trains. The Commission commented: "Unquestionably, the higher speeds and the greater number of trains have increased the accident hazards and necessitate more and better protection for the traveling public and the train employees. While this need for better protection is more apparent in areas of high train density, it is generally required throughout the country."

The result of this investigation was Commission Order No. 29543 issued on June 17, 1947 requiring the railroads to install on that part or parts of their lines over which any passenger or freight train is operated at a speed of 80 or more miles per hour, an automatic train stop or train control system or automatic continuously controlled cab signal system, conforming to the Rules, Standards and Instructions as prescribed by the Order of the Commission of April 13, 1939.

On June 29, 1950 the Commission issued new Order Ex Parte 171, effective October 1, 1950, setting forth new Rules, Standards and Instructions which were prescribed to supersede the Commission's Order of April 13, 1939. This new Order made effective certain changes in requirements for train control devices resulting from the investigations of 1946 and Order No. 29543 of 1947.

Code Control

In the early development of continuous train control systems, non-coded energy was employed. Since these non-coded arrangements were found to have definite limitations, the development of coded systems was undertaken resulting in experience to prove that a coded system was the simplest and most satisfactory scheme of control. By means of it, the development of present-day multiple aspect cab signals and speed control was made possible and practical.

At first, two forms of energy were used: alternating current coded energy in the rails for cab signal control, superimposed upon non-coded energy track circuits for wayside apparatus control. Later it was recognized that coded energy applied only for the energization of the basic track circuit was all that was necessary as practically the same apparatus (code-receiving and decoding equipment), in use on locomotives equipped with cab signals or continuous train control, could also be used at the entrance to a block for the control of wayside signals. Accordingly, the first installations of coded track circuits were made for the joint control of both wayside and cab signals.

Cab Signals

The incentive for the development of cab signals grew out of two statements appearing in I.C.C. Order No. 13413. One passage read:

> "In prevailing practice the primary function of automatic train stop or train control devices is to enforce obedience to the indication of fixed signal; but the feasible operation of essentially similar devices used without working wayside signals may be regarded as a possibility."

In another part of the Order the following statement appeared:

> "We have decided not to limit by our order the installation of automatic train control devices to roads or portions of roads already equipped

with automatic block signals, because we have no desire to discourage efforts to automatically control trains without the aid of fixed wayside signals. The statement, therefore, of the primary function of automatic train stop or train control devices recognizes the possibility of installing such a device without the use of automatic block signals."

Order 13413 of the Interstate Commerce Commission in 1922 which resulted in the intensive development of automatic train control brought, as a by-product, continuously controlled cab signaling. The importance of this development is indicated in an I.C.C. report dated November 26, 1928, in which cab signals are mentioned as "without a doubt, an important development in the art of signaling."

As a result of an experimental installation on the Lewistown Branch of the Pennsylvania R.R., continuously controlled cab signals proved to be as reliable as wayside signals and instead of remaining an adjunct of train control rapidly developed into a new signal system. Having received the blessing of the I.C.C., 13 railroads later were permitted to eliminate the automatic brake application train control feature and use only cab signals. Today some roads are using cab signals *with* automatic wayside signals *and* automatic train control; other roads are using cab signals *with* automatic train control *but without* automatic wayside signals; still others use the cab signals *only with* automatic wayside signals and there are installations of cab signals *only without* the use of automatic wayside signals.

The cab signal consists of a comparatively small box with two or more lights, any one of which, on being lighted indicates to the engine crew the action required in line with track circuit condition ahead. Cab signals must be provided in positions to be easily visible for both engineman and fireman. A warning whistle always sounds whenever the cab signal changes to a more restrictive indication. An acknowledging switch is located within easy reach of the engineman; its operation causes the warning whistle to cease blowing.

The equipment used in the continuous cab signal system includes wayside as well as locomotive equipment. The indications received on the cab signal in the locomotive cab are controlled by current in the track rails. There are three general types of cab signals in service today: (1) the two-indication non-code system, (2) the three-indication non-code track and loop system, and (3) the code system.

In the two-indication system, alternating current is superimposed on the existing track circuit for the control of the locomotive-carried apparatus. A receiver on the locomotive is mounted approximately seven inches above the top of the running rails and an amplifier unit amplifies the current induced in the receiver coils by the track circuit current. Other locomotive-carried equipment consists of the control relays, the acknowledging switch, the whistle magnet, and the cab signal.

The three-indication track and loop system requires two alternating current circuits comprising the track rails. One circuit is the existing alternating current track circuit. The second, or loop circuit, is formed by connecting the two running rails of the track circuit in multiple through suitable resistors; the resistors, in turn, are connected to a return line wire to complete the circuit. This system makes use of two receivers on the locomotive, one mounted immediately ahead of the front wheels which is responsive to the a.c. track circuit current and one mounted to the rear of the locomotive, which is responsive only to the loop circuit current. The currents picked up by the two receivers are supplied to an amplifier unit where they are amplified and operate a two-element control relay for providing the proper cab signal indication. The acknowledging switch and relay, whistle magnet and cab signal unit are the same as used in the two-indication system.

The code system, which may embody two, three, or four indications, is a system in which the alternating current in the track circuit is "coded" or interrupted at fixed frequencies corresponding to the track conditions ahead. The number of interruptions per minute, or the "codes," determine which signal indication will be displayed in the cab of the locomotive. This system is the latest development in cab signaling and the one that is now being used most extensively. The locomotive-carried equipment consists of a receiver mounted ahead of the front wheels connected to an amplifier unit which amplifies the current picked up by the receiver and operates decoding equipment which selects the proper control relay in agreement with the code transmitted. These relays, in turn, actuate the whistle magnet and cab signal. The acknowledging switch and relay are also part of this equipment.

In each block a code transmitter interrupts the alternating current supplied to the rails at a certain rate called the code frequency. For a "clear" block this frequency is at the rate of 180 a minute; "approach medium" is 120 a minute and "approach" is 75 a minute. If the block is occupied, the coded current is shunted by the wheels of the train and does not reach the rails in the rear. Consequently, if a following train enters the block, the most restrictive indication is displayed by its cab signal. Any impairment in the continuity of the track circuit causes the most restrictive indication to be displayed by the cab signal. Since the decoding equipment is non-responsive to the presence of steady or uncoded current in the rails, this also results in the most restrictive cab signal indication.

Chronological

For chronological references see Section 18, years:

1880	1923	1930	1944
1901	1924	1933	1949
1914	1925	1939	1951
1919	1926–27	1940	1952
1920	1927		

SECTION 8

TRAIN OPERATION BY SIGNAL INDICATION WITHOUT TRAIN ORDERS

Operation of trains by signal indication only, without train orders, has been recognized as having many advantages ever since it was first demonstrated in 1843 by the Eastern Railroad Co. installation through the Salem, Mass. tunnel, and since the first application on 5.5 miles of single track and 2.5 miles of two main tracks by the Pennsylvania R.R. at the Louisville, Ky. bridge in 1882.

The invention of the track circuit in 1872 inspired rapid development through the means of controlled manual block signal systems, automatic block signal systems, remote control systems and centralized traffic control systems. The term "traffic control system" has, however, been used since October 1, 1950 by the Interstate Commerce Commission and by the railroads for all the various systems by which trains are operated by signal indication without train orders for both opposing and following movements on the same track.

The Interstate Commerce Commission's Bureau of Safety statistical report of January 1, 1953 reveals that 84 railroads are operating 18,064.5 miles of road by traffic control systems and 75 railroads are operating 17,128.8 miles of road in one direction by automatic block, all by signal indication without written train orders.

For a clearer understanding of the various systems which provide signaling for train operation without written train orders the following definitions which appear in the A.A.R. Signal Section Manual are important:

Automatic Block Signal System: A series of consecutive blocks governed by block signals, cab signals, or both, actuated by a train, or engine, or by certain conditions affecting the use of a block. (Standard Code.) (See Section 5 for development history.)

Controlled Manual Block System: A series of consecutive blocks governed by block signals, controlled by continuous track circuits, operated manually upon information by telegraph, telephone or other means of communication, and so constructed as to require the cooperation of the signalmen at both ends of the block to display a Clear or a Permissive block signal.

Lock and Block: A term commonly used for the controlled manual block system.

Remote Control: A term applied to a method of operating outlying signal appliances from a designated point.

Centralized Traffic Control: A term applied to a system of railroad operation by means of which the movement of trains over routes and through blocks on a designated section of track or tracks is directed by signals controlled from a designated point without requiring the use of train orders and without the superiority of trains.

Traffic Control System: A block signal system under which train movements are authorized by block signals whose indications supersede the superiority of trains for both opposing and following movements on the same track. (I.C.C.)

It is of interest that in 1932 Committee I—Economics of Railway Signaling, of the Signal Section, A.A.R. reported: "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."

Some of the early installations which were responsible, after study, for the quoted recommendation are described briefly below. They include what has been called traffic locking or lock and block (a form of controlled manual block), modified manual block, A.P.B. signaling with traffic locking, remote control systems, and the first centralized traffic control systems.

The Salem Tunnel (Boston & Maine R.R.)

Perhaps the first place where train operation by signal indication was the only feasible and safe method to employ was at the Salem Tunnel in Massachusetts. This tunnel was built by the Eastern Railroad Co., under direction of Colonel Fessenden, Chief Engineer, and was opened to traffic December 18, 1839. The whole length of the tunnel, 1,295 feet, including approaches, is covered by a public street. The track layout consists of two tracks merging to gantlet tracks through the tunnel with a junction switch at the west end leading to the Lawrence Branch.

The first protection by signals was not installed until approximately 1843, and consisted of the erection of a ball signal at the east end of the tunnel to govern train movements in each direction. As this signal could not be seen by eastward trains, a clock with about an 18-inch dial was located at each end of the tunnel, each clock being operated from the opposite end of tunnel. The clocks were really crude train describers and repeaters for the ball signal. When the right indication was received on a clock, an attendant on the ground instructed the engineman to proceed through the tunnel. Later, a banjo signal, manufactured by the Union Electric Signal Co., was located at the west end of the tunnel to stop eastward trains if the clock "did not tell the right time" and a westward train had entered the tunnel under the authority of the ball signal.

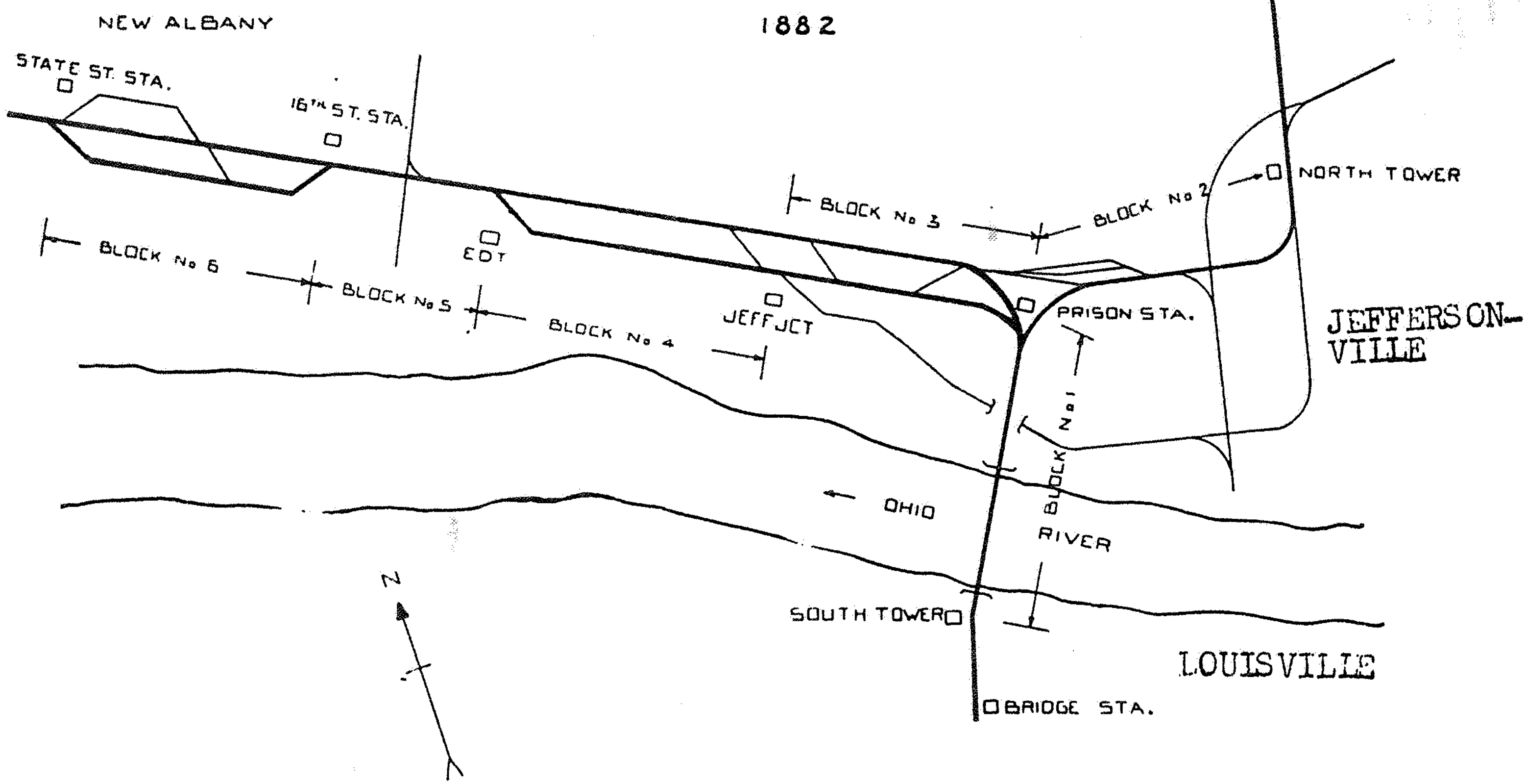
The next step was the establishment of a tower at each end of the tunnel with interlocking provided. These were placed in service on May 21, 1883. The machines used were Sykes and Stevens, imported from England. Tyler switches, thrown by a cam arrangement, were used at each end of the tunnel. In 1889, Saxby & Farmer machines were installed and the two machines were connected by a pipe line, controlled by a master lever in each tower, to provide interlocking protection between towers. The Tyler switches were removed at this time.

The number of train movements through the tunnel each 24 hours is well over 200, and trains are governed by signal indication only, protection now being afforded by modern apparatus.

The Louisville, Ky. Bridge (Pennsylvania R.R.)

"When we call to mind the number of bright men who have attained eminence in the profession from the vantage of the train dispatcher's chair, it is a matter of extreme surprise that so little development has been made in an element so vital to safe and economic train movement. The writer's experience justifies the broad statement that the present system of moving

TRACK LAYOUT & BLOCKS
LOUISVILLE KENTUCKY BRIDGE
1882



trains by telegraph is unworthy of the age of progress in which we live, and the time has come when it can and will be largely improved upon."

This quotation is from a paper read before a train dispatchers meeting at Louisville, Ky., in 1882, by Mr. E. W. McKenna, then Superintendent of the division which included the Louisville bridge. His statement is of interest as indicating recognition of the necessity of finding a better method of operating trains than by train orders and time-table schedule, 31 years after the first train order was sent.

Mr. McKenna, as Superintendent of the Louisville Division of the Pennsylvania R.R., formerly part of the Jeffersonville, Madison & Indianapolis R.R., was confronted with a very tough operating problem. Four different railroads were using the single-track bridge across the Ohio River and there were in excess of 120 train movements daily between 6:00 a.m. and 11:00 p.m. As standard time was not adopted until November 18, 1883, the different roads were using solar time at Chicago, Ill., Vincennes, Ind., Louisville, Ky., and Indianapolis, Ind., respectively. This added to the complications of the situation.

The only means of moving trains with any degree of safety was in the strict carrying out of a system of registering at each of the junction and terminal points. This resulted in a great loss of time. The impossibility of keeping trains on time, and the fact that one train off time in this intervolved movement threw the operation of the road into confusion, necessitated the issuing of train orders to all trains. The time consumed in handling each of these orders, not to mention the elements of danger they contained, was almost equal to the time required to make the authorized movement.

Mr. McKenna realized that the delays thus incurred, and the unsafe system of moving trains, called for a remedy. He, therefore, established in 1882, a manual block system on 5½ miles of single, and 2½ miles of two-track over the bridge and east and west of the bridge north of the Ohio River. Quoting further from his paper: "The portion of the road in question was divided into five blocks. Signal stations were erected at each of the dividing points, equipped with the Pennsylvania R.R. standard block signal, showing the three colors. The rules governing the train movements were made as few and as simple as possible, and were, in effect, the principles designated by the colors. Trains were governed entirely by the signal displayed from the station, and the character of the signal to be shown was directed by the dispatcher."

A mnemonic board similar to a cribbage board was designed at the time for use by the dispatcher to indicate occupied blocks by the placing of pegs as the trains advanced. This board provided a visual record of the location of all trains in the different blocks. All trains moved on block signal indication without regard to time-table superiority or the use of train orders. Throughout the years, this installation has been notably efficient.

The Burlington

In 1888, the Burlington first began operating trains by signal indication by means of a manual block system. In that year, there were four main tracks, extending from Canal Street, Chicago to Hawthorne, Ill., a distance of approximately 5½ miles. Three tracks extended from Hawthorne to Downers Grove, Ill., a distance of 14 miles. Two electro-pneumatic interlocking plants were built that year—one at Western Ave. and the other at California Ave., Chicago, Ill. In addition, there were three mechanical plants in service, a total of five interlockings in a distance of less than 5 miles between Canal Street and Hawthorne.

The five interlockings were within Chicago Yard limits and were used as block stations to operate trains by block signals in this territory. No orders were issued and trains were moved by signal indication only.

As this first installation proved to be very successful, it was decided, in 1889, to extend the system to Aurora, Ill., 37 miles west of Chicago and 16 miles beyond Downers Grove. Regular stations were used as block stations where practicable, but it was necessary to build several special block cabins. Between Hawthorne and Downers Grove, seven blocks were established in the three-track territory, averaging 1.75 miles long. On the two-track stretch between Downers Grove and Aurora, Ill., there were eight blocks, averaging 2 miles in length. These block signals remained in service until they were replaced by an automatic block signal system 25 years later, in 1914.

The block signals used were wooden semaphores, made in the Burlington Shops and known as the "Smith" signal, so named for the Chief Engineer, George C. Smith, who designed them. They were two-armed, lower quadrant, 60-degree signals. The top arm was a square-ended red blade with white stripe, and the lower arm was a fishtailed green blade with a white stripe. The aspects and indications were:

Both blades horizontal—Stop.

Red blade inclined downward, green blade horizontal—
Proceed with caution, expecting to find block occupied.

Both blades inclined downward—Proceed.

It will be noted that the second aspect was used instead of a caution card and *not* as a distant signal for the next block signal. On three-track lines, the middle track was signaled for both directions.

Miscellaneous

Another early installation of train operation by signal indication was made in 1889 on the Nashville, Chattanooga & St. Louis Ry. between Chattanooga and Wauhatchie, Tenn. This system covered 4.4 miles of single track and 1.6 miles of two-track and this distance was divided into three manual block sections, all under the control of the dispatcher at Chattanooga. The Southern Ry. and the Alabama Great Southern Ry. also operated over this stretch of track. The installation was continued in operation until June 1912, when a second track was installed. During this time, not a single written train order was issued.

The American Railway Association adopted rules in 1903-1904 which permitted train operation by signal indication, superseding time-table and train orders, on two or more main tracks, with or against the current of traffic.

The Central New England Ry. put into service a signal system on November 10, 1909, between Highland and Maybrook, N. Y. The installation covered 13.2 miles of single track and 7 miles of two-track, divided into nine controlled manual block sections. Trains were moved by signal indication without train orders, thus relieving traffic congestion which, at times, taxed the train dispatchers to the utmost.

In 1911 the Baltimore & Ohio R.R. signaled 36 miles on the Cumberland Division for operation in either direction by signal indication, and in 1913 the Pennsylvania R.R. did likewise for the middle track between Spruce Creek and Tyrone, Pa.

The American Railway Association adopted rules in 1915 which permitted ain operation on single track by controlled manual block signal indications, perseding time-table and train orders.

The Chesapeake & Ohio Ry. placed in service on November 1, 1919, a traffic locking scheme in conjunction with A.P.B. signaling embodying new ideas for the operation of trains by signal indication over a 4-mile section of single track between Cotton Hill and Gauley, W. Va. This single-track section was a bottleneck connecting the ends of two-track at Cotton Hill and Gauley and ran through a very narrow gorge or canyon with the river on one side and high cliffs of solid rock on the other. As all main line eastward and westward traffic was handled through this "bottleneck," a serious operating problem was solved after the installation was in service. The apparatus used for traffic locking consisted primarily of a generator, hand-driven where power was not available, a selective switch, a selective frequency lock, a push button and a buzzer. With the exception of the generator and selective switch, the apparatus was duplicated for each traffic lever. This scheme involved the use of 125 cycles alternating current, which made the system immune to the effects of direct current and of alternating currents having commercial frequencies of 60 cycles or less. Traffic was previously controlled by means of an absolute train staff system.

In March 1923, the Chesapeake & Ohio Ry. installed the same type of traffic locking on 28 miles of two main tracks between Scott and "DK" cabin near Huntington, W. Va., for operation of trains in either direction by signal indication.

Another installation of record was that on the Pennsylvania R.R. in connection with a trial installation of a 3-speed continuous automatic train control system on its Lewistown Branch. (See Section 7.) The only wayside signals used were those located where it was necessary to stop and hold trains. On the western section of the Branch, what was known as a modified A.P.B. system was installed, by which the train itself, if conditions were right, set up the combination by which it would receive "clear" signals, and an opposing train would receive "stop" signals. On the eastern half of the territory, what was known as the dispatcher's remote control system was used. This system permitted the operator at Sunbury, Pa., to set up the proper combination in the wayside apparatus. This was placed in service on July 11, 1923 and was the forerunner of centralized traffic control which is now in service on many railroads.

However, it appears that the Missouri Pacific R.R. was the first road to install a complete system of signaling facilities for the direction of train movements by signal indication without written train orders over an entire operating subdivision of a steam road. This installation was placed in service on July 3, 1925, between Leeds (Kansas City, Mo.) and Osawatomie, Kans. on 50 miles of single track and 3 miles of two-track. This installation included four mechanical interlocking plants for the operation of adjacent switches with remote control power machines for outlying switches. Controlled manual block was used for the control of signals governing train movements. The National Safety Appliance Co. type of intermittent inductive train control was superimposed on the controlled manual block system.

At this same time, the General Railway Signal Co., in cooperation with the New York Central R.R., was developing a system in which the dispatcher at a central point operates the siding switches and signals so as to have complete direction of train movements. This is termed "the dispatching system" in which only one wire together with the common wire is required to control the switch and signals at the end of a siding and to provide the necessary indications. The first installation of this type was placed in service on July 25, 1927, between Stanley and Berwick, Ohio, on the New York Central System, a distance of 40 miles.

This was followed by the first installation on June 30, 1928 of a Union Switch & Signal Co. code control system using selectors, on the Pere Marquette Ry. on 19.8 miles of single track between Mt. Morris (Flint, Mich.) and Bridgeport, Mich.

The foregoing mentioned installations were the forerunners of what is known as centralized traffic control. Obviously, it is impossible to make mention of all installations, but those discussed herein are important in that they denote a trend through the years toward more efficient, safe, and economical train operation.

Prior to the introduction of centralized traffic control, one or more men, located at one or more places, functioned in the operation of moving trains by signal indication. Centralized traffic control provided this facility over short or long distances by centralizing the control of the entire territory under one operator located at a convenient place. This greatly increased the efficiency of operation over that obtained with operators located at many points of control. With the later development of engineering technique, it was feasible to locate this control point at division headquarters.

Train Dispatching and Selector Controls

Centralized control of train operation can be assumed to have been first established through the appointment of a train dispatcher by Mr. Andrew Carnegie when he was Superintendent of the Pittsburgh Division of the Pennsylvania R.R. from 1859 to 1866.

The telephone was first used for transmitting train orders in 1897 on the South Fork Branch of the Pennsylvania R.R. but the extension of main line telephone train dispatching had to await the development of suitable selector calling devices, as party line ringing was found to be wholly inadequate.

The Gill selector was developed by the Hall Switch & Signal Co. around 1905 for use on telegraph way station circuits, but additional circuit developments and improvements made on this selector enabled it to be used in connection with the first main line telephone dispatching circuit installed by the New York Central R.R. from Albany to Fonda, N. Y. This circuit was placed in service on October 2, 1907. The Groce selector was installed on the Illinois Central R.R. the next year.

Rapid progress was made in the extension of telephone train dispatching circuits. These circuits, like the first centralized traffic control line circuits installed some 20 years later, relied on new copper and better line construction to minimize line failures. These circuits cost about eight times as much as the grounded iron line wire circuits of the telegraph. However, the copper line wires later proved economical, as joint use was made of them by superimposing other circuits on the same wires. As an example, the St. Louis-San Francisco Ry. built the first four-wire dispatching and message circuit in 1908 on which were superimposed long distance telephone and telegraph circuits.

The introduction of the telephone selector in 1907 led to the application of selectors to various railway signaling problems during the next two decades. All the efforts, however, were not limited to applications of telephone selectors but also included suggestions for the continuous code control of manual block signals and combinations of continuous code control and selector control. In this field, the Hall Switch & Signal Co., the Western Electric Co. and the

Automatic Electric Co., were active and the period from 1907 to 1927 is represented by about 70 patents relating principally to manual block signal systems.

In 1906 there was first shown an electro-mechanical train order signal put to stop by selector operation and latched clear mechanically by the train crew after receiving orders. The Hall electro-mechanical slot, introduced in 1910, embodied this development. A similar joint development made by the Union Switch & Signal Co. and the Western Electric Co. was made available for use in 1912 and an extensive single-track signaling system of this type was installed that year by the two companies on the Piedmont & Northern Traction Lines.

Centralized Traffic Control

Centralized traffic control is a term for one of the methods of operation under the October 1950 definition of traffic control system and, as it is known today, was made possible through prior development and application of major component parts for other signal systems. The development and use of power-operated signals for block signaling and interlocking purposes was one contribution usable in C.T.C. systems. Another important contribution was the development of power-operated switch machines for use at interlockings. Next, it was established that power-operated switch machines and signals for a siding could be remotely controlled safely from an interlocking tower or a way-station through the use of safety (vital) circuits. The final step may be considered as an assembly of parts, already proved reliable in signal systems, into a complete system controlled from a designated point.

The following groups of apparatus are commonly used in a centralized traffic control system:

1. A control machine with miniature levers for the operation of switches and signals; indication lights showing the position of switches and signals and also the occupied or unoccupied condition of sections of track; and an automatic train graph which records the passage of all trains.

2. Equipment at the controlled location consisting of power switches, signals, relays, etc. Track circuits approaching and within the limits of the controlled signals for actuating indications on the control panel of the machine of the passage of all trains.

3. A set of control wires extending from the control machine to all controlled locations, over which the circuits actuating the switches and signals are carried and indications of conditions at the outside locations are returned to the control panel of the machine.

On the control machine before the operator is a miniature track layout of the district. Indication lights on the control panel make it possible to follow the progress of a train over the entire territory and also show the operator if the switches and signals have responded properly to the movement of the levers. The power-operated switch machines mostly are of the dual-control type which permit hand operation for local switching after authority is first obtained from the operator of the control machine. These switch machines may be electric or electro-pneumatic.

The centralized traffic control system combines the safety features of modern automatic signaling and power interlocking. Each end of each siding is, in fact, a small interlocking plant remotely controlled. The signals are "stop and stay" signals while those between the sidings operate automatically with some form of traffic locking. Railway signal relays of the vital circuit type are used in circuits where safety of train operation is involved while smaller, quick-acting, non-vital circuit types are used in the communication circuits and for all purposes where safety of train operation is not affected. The relays in the field are not only controlled by track circuits, but are interlocked by their circuits so as to adequately protect traffic movements without lever locking of any form at the point of control. The safety circuits make it impossible for an operator to set up an unsafe condition for train movements.

The control of wayside equipment in centralized traffic control installations, from one central point is obtained by a coded relay scheme which is very rapid in operation. After switch and signal levers have been positioned, codes are sent out by pushing a starting button. Two wires are used for sending from the machine and receiving on it the code indications to and from the field. In addition, the same two wires are frequently used for telephone and other circuits throughout the territory.

The later introduction of coded carrier control removed the limitations as to the extent of territory and number of stations that can be controlled over a single pair of line wires. The carrier line circuit, extending the length of the centralized traffic control territory, is divided into sections controlling 128 stations or less. Each line section provides a physical circuit for that section. The codes sent out from the control machine are repeated by two-way carrier current transmission between the office and the near end of each remote line section, where the physical circuit for that section then functions.

The fact that a clear line of demarcation has been maintained in centralized traffic control between vital and non-vital circuits has also made possible the introduction of other closely related systems such as relay and route interlocking, and the modern method of remote control.

The development of centralized traffic control began very soon after a letter written by Mr. A. R. Fugina (Signal Engineer, Louisville & Nashville R.R.), dated October 17, 1921, and addressed to Mr. K. E. Kellenberger (Editor, *Railway Signal Engineer*), outlined a plan of train operation for single-track roads in which he proposed to use the absolute permissive block system for protection; together with a telephone train dispatching system for control, with local operators for each of three sidings provided with table circuit controllers for operating low-voltage switch machines and take siding signals. The system was to include also a comprehensive announcing system at the dispatcher's office with lamps for indicating the position and movement of all trains.

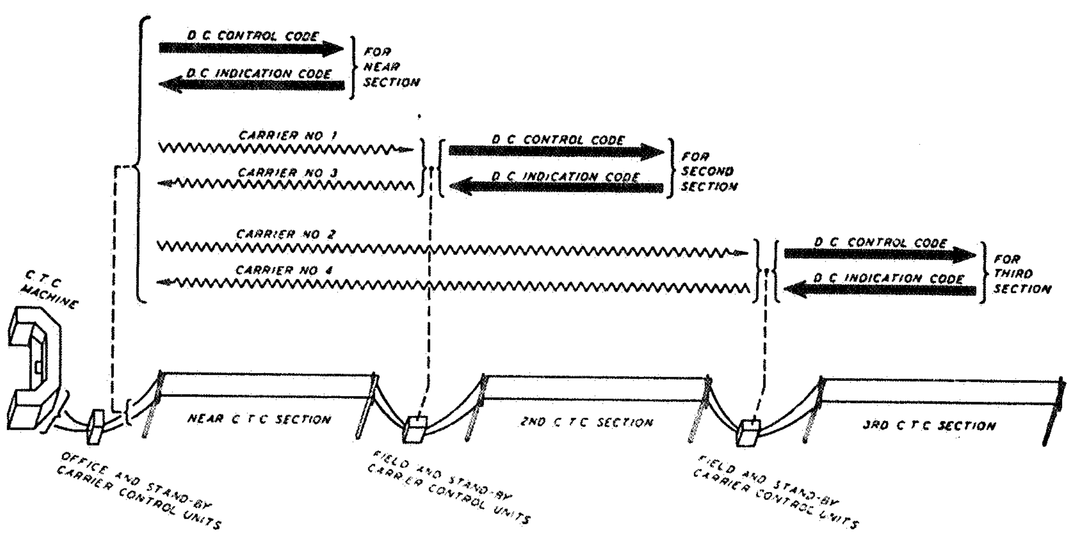
In July 1927 the first installation of centralized traffic control was made on the Ohio Division of the New York Central R.R. from Stanley to Berwick, Ohio. This installation covered 37 miles of single track and 3 miles of two-track, and used a system known at the time as "General Railway Signal Co.'s dispatching system." It provided all the essential means for operating trains by signal indication without written orders.

The development of centralized traffic control is attributed to Mr. S. N. Wight of the General Railway Signal Co. The "Modern Pioneer" Award was presented to Mr. Wight in 1940 by the National Association of Manufacturers, commemorating the 150th anniversary of the American patent system. The citation to Mr. Wight read: "Has been honored for his invention of centralized traffic control, first installed on 40 miles of the New York Central Lines in 1927, the fundamental patents for which were applied for in 1925 and 1926 and granted in 1937." The Henderson Award was presented to Mr. Wight in 1947 by the Franklin Institute. The citation read: "In consideration of his accomplishments in the invention and development of major railroad signaling systems, thus contributing to the safety, speed and reliability of railroad operation."

Mr. H. A. Wallace of the Union Switch & Signal Co. received the "Modern Pioneer" Award from the National Association of Manufacturers in 1940. His citation read: "Has contributed to the field of railway signaling, including block signaling, interlocking, cab signaling, train control, etc. His inventive achievements in connection with a system for supervising train operations have made possible what is now known as centralized traffic control. His basic and fundamental patents, filed March 20, 1922, proposed a complete integrated system by means of which information is transmitted directly to a train crew by placing wayside apparatus, and particularly signals, under the control of a remotely located dispatcher. Mr. Wallace holds nearly one hundred United States patents."

Coded Centralized Traffic Control Systems

It was early recognized that coded systems, capable of transmitting controls and indications between the control office and the field locations over a minimum number of line wires were necessary if long distances of territory were to be operated economically by centralized traffic control systems. As a result, the coded principle of control is firmly entrenched as a requisite of all modern systems. The acceptance of this principle as a practically indispensible requisite resulting in installation and operating economies, has caused new installations of non-coded centralized traffic control to practically cease, except for short installations and where additions to existing installations are made.



Schematic diagram illustrating application of coded carrier control to C.T.C. traffic control system.

Three types of code systems for centralized traffic control have been developed and installed. These types are the "time code system," the "circuit code system" and the "polarity code system."

The first time code scheme was on the basis of 12 controlled stations. It used long or short pulses to register station selection and function control. In this scheme, the pulses only were used to provide the distinguishing characteristics. This system (12-station type) required approximately 7.5 seconds for the transmission of a code. A later development was a time code scheme based on greater station capacity which used both the pulses and the off times of the code to register distinguishing characteristics. This scheme required approximately 4 seconds for transmission of a code.

Carrier systems were later adapted to the time code line circuits making it possible to handle as many stations as required on a single line circuit for any desired distance. Thus was made possible the installation of the many long distance stretches in service today. This same single line circuit is also used to provide additional facilities economically, such as telephone, simplex and multiplex telegraph circuits, phantom circuits, etc., superimposed on it.

The circuit code system was developed simultaneously with the 12-station time code system and consisted of an all-relay system using two series line circuits with a common return. This three-wire line circuit, however, was an economical disadvantage when compared with the two-wire circuit for time code, and limited its use considerably. The system was developed to accommodate those installations requiring a larger number of stations or where traffic was so heavy that the longer time of coding action (7.5 seconds) of this 12-station time code system would be objectionable. The first development had a capacity of 27 stations and a code time of approximately 1.5 seconds. Later the system was developed so that it had a capacity of 81 stations with the same time per code. Character selection in the circuit code system depends upon the de-energization of either or both code line circuits during the coding action.

In the polarity code system, codes for transmitting control information were composed of polarized pulses of equal duration. The individual character of each code was determined by the sequence in which the positive and negative pulses were arranged. In transmitting indication information, codes composed of open and closed conditions of indication line circuit were impressed upon the line. The individual character of each code was determined by the sequence in which the open and closed conditions were arranged. With the polarity code system, simultaneous transmission of control and indication codes was possible. The 10-step system had a normal rating of 4 controls at 64 control stations and 13 indications from 64 indication stations. One to 7 steps could be used for station selection; 9 to 3 steps, for control or indication purposes.

C.T.C. Operation Via Railroad and Commercial Telegraph and Radio Facilities (Pennsylvania R.R. Demonstration)

The Pennsylvania R.R., on September 19, 1946, successfully demonstrated for the first time that commercial communication circuits off railroad property may be utilized in emergencies to transmit electrical impulses to control railroad switches and signals in centralized traffic control territory. The test was arranged by the Pennsylvania R.R. in cooperation with the Radio Corporation of America, the Western Union Telegraph Co. and the Union Switch & Signal Co., at Brady Tower, 65 miles north of Pittsburgh, Pa., the location of the C.T.C. machine for the control of switches and signals between Redbank and Oil City, Pa., a distance of 52.8 miles. For the purposes of the demonstration, instead of transmitting the codes directly over the pair of line wires extending the length of the controlled territory, they were first sent over a roundabout circuit of approximately 1,130 miles before their transmission to the field stations.

The control codes were sent by carrier current pulses from Brady Tower to Pittsburgh, Pa., over Pennsylvania R.R. wires by means of the Union Switch & Signal Co.'s coded carrier control. These pulses then traveled over Western

Union aerial and cable circuits via Washington, D. C. to Philadelphia, Pa., approximately 550 miles, using telegraph carrier. At Philadelphia there were coordinating circuits where the control pulses were converted to a super high frequency and beamed by radio to New York City, a distance of about 90 miles. From New York the pulses were transmitted over Western Union telegraph carrier circuits to Pittsburgh, approximately 370 miles, thence via railroad wires by C.T.C. carrier to Brady Tower where the pulses were converted from carrier current to direct current and sent over the regular code line to the field locations. Indication codes were transmitted in the opposite direction to the control machine over the roundabout path just described.

In this demonstration the centralized traffic control carrier system used two frequencies of 12.3 and 25.4 kilocycles for the control and indication codes which could be transmitted in opposite directions on one line pair at the same time between Brady Tower and Pittsburgh. One multiplex telegraph channel was utilized on the Western Union carrier telegraph circuits which operated with all carrier frequencies below 30 kilocycles. The radio beam between Philadelphia and New York uses two separate frequencies of 3,970 and 4,120 megacycles and can handle 256 multiplex telegraph circuits, of which one was used for the experiment.

This demonstration was of great significance as it showed that railroad signal and communication engineers can coordinate existing outside communication facilities to a very large extent in their control systems.

Chronological

For chronological references see Section 18, years:

1842	1910	1928	1943
1843	1911	1929	1944
1882	1912	1930	1945
1887	1913	1931	1946
1888	1914	1932	1947
1889	1915	1937	1948
1902	1923	1938	1949
1903-04	1924	1940	1951
1907	1925	1941	1953
1909	1927	1942	

SECTION 9

CAR RETARDERS

Less time from consignor to consignee is a service all transportation companies wish to provide to their customers. On the railroads, shipping time includes both road time and yard time. Centralized traffic control for train movements on the road reduces road time, and car retarder installations in classification yards have proved their ability to reduce yard time. In addition, the economies resulting from a car retarder installation are such as to make a profitable return and further justify the investment.

Added to the tangible savings are other advantages and economies, difficult to evaluate, but important in speeding up yard operations; for example: it is possible to keep a yard open and functioning under all weather conditions; there are no interruptions and the hourly capacity of the hump is increased; extra switching is reduced; cars with defective hand brakes may be classified directly to the bad order tracks; cars may be moved from the receiving yard over the hump more promptly.

In addition to car retarders being used at classification yards, they are also used at car dumper facilities to control movements of cars to and from the dumpers.

The car retarder is an arrangement of brake shoes located along and parallel to the track rails. These brake shoes are forced against the inside and outside faces of the car wheels. Force is applied to the brake shoes by either of two methods. In one method, compressed air acting on a piston applies force to the shoes. In the other method, springs are used to apply force to the shoes. The effect on the car is the same as if either the hand brake or the air brake had been applied; that is, the retarder, as its name indicates, reduces the speed of the car.

The essential parts of a modern car retarder system are: (1) car retarders for controlling the speed of cars from the crest of a hump to the classification tracks; (2) power-operated switch machines; (3) detector track circuits to prevent power-operated switches from being thrown between the trucks of a car; (4) control machines which carry the levers controlling the units; (5) signal system for controlling the movements of trains to and over the hump; (6) loud speaker system or yard telephone communication system for verbal communication between yardmaster, hump master, retarder operators and yard engine crews, car inspectors, etc.; (7) means, usually teletype, for delivering duplicate copies of switching list to the hump and to the retarder operators; (8) power plant equipment; (9) flood lights for night operation; (10) skate machines, when required, on entering ends of classification tracks for placing skates on rails to stop cars not having been properly retarded, or to hold cars for subsequent rehumping.

Hump classification yards are located at strategic places on a railroad system. A freight pulling into a receiving yard at such a place is made up of cars going to various destinations. Accordingly, these cars have to be classified and made up into other trains for the new destinations.

The car retarder for hump yard operation stands out as a remarkable achievement in effecting large economies and marked changes in yard operating practices. Rarely has any invention been conceived, developed, and applied successfully in such a short period of time as has the car retarder, a performance which has been truly phenomenal.

In the early days of railroading, freight was handled from place to place by being picked up and set out by road trains. As traffic increased, flat switching yards were built for classifying freight cars, a method still being used where the traffic density is light. Next, hump and gravity yards were built so that gravity would do a large part of the work formerly done by the switch engine. It is believed that the first hump yard to be built in the United States was constructed by the Pennsylvania R.R. in March 1883, near Greensburg, Pa. Then, in 1891, a move for effecting additional economies in yard layouts was the installation of power-operated switches, controlled centrally, whereby one operator replaced a number of switchmen. Again in 1924, the car retarder was made practicable, whereby a few operators can do the work formerly requiring a large number of car riders.

Since 1924, major developments and improvements have been made in the car retarders themselves, in the other apparatus associated with a car retarder installation, in yard design, and in the application and use of proper gradients.

In 1941, the Norfolk & Western Ry. made a first installation of retarder speed control applied only to the retarders ahead of the scales. The purpose of this speed control was to deliver cars to the scales at a speed that would result in proper weighing. The installation used Union Switch & Signal equipment and Model 31 electro-pneumatic retarders. The same feature was included later in the installations of automatic switching made in 1950 on the Canadian Pacific Ry. and in 1951 on the Southern Ry. using General Railway Signal Co. equipment and Type E electric retarders.

In 1950, the General Railway Signal Co. developed a system of automatic switching controlled at the hump office by a push button control machine. A car being classified to its classification track is routed by simply pushing a button bearing the classification track number. The switches are automatically positioned just ahead of the car as it moves along, so that several cars can be routed to different classification tracks at the same time. Cars are spaced properly by remote control of the retarders. The first installation placed in service was on the Illinois Central R.R. on March 28, 1950 using General Railway Signal Co. equipment and Type E electric retarders. A similar installation was placed in service shortly afterward on the Canadian Pacific Ry.

In 1952, first installations of automatic switching using Union Switch & Signal equipment and Model 31 electro-pneumatic retarders were made on the Illinois Central R.R. and on the Chicago, Milwaukee, St. Paul & Pacific Ry.

The Milwaukee installation also included a new "retarder speed control" system which automatically controlled the braking effect of all the retarders, to produce a leaving speed selected by the operator.

In the "retarder speed control" system as applied to the Milwaukee installation, the speed at which a car, or cut of cars, is to leave the retarder is selected by push button. The speed selected by the operator depends upon car weight and other factors and produces proper braking action automatically, with provisions available for a selection of six speeds.

Early in 1953 a General Railway Signal Co. system of retarder operation was installed which automatically controls cars to suitable speeds subject only to the supervisory control of a retarder operator. Weight and speed factors are integrated by the system to establish the proper control for each car or cut of cars. The weight factor is established directly and automatically by the cars. The speed factor is determined instantaneously and continuously while the wheels are within reach of the retarder brake shoes. The first installation of this system was made at the Kirk Yard, Gary, Ind. on the Elgin, Joliet & Eastern Ry.

As of December 31, 1952 car retarder systems were in service, or being installed, in 72 yards on 33 railroads. These yards contained 2,593 classification tracks with control of the various functions centralized in 159 towers, housing 183 control machines. The equipment consists of 1,479 retarders (totaling 101,166½ rail feet), 2,666 power switches, of which 2,278 are protected with detector track circuits, and 709 power skate machines. Some of these yards are, or will be, equipped with retarder speed control and automatic switching.

In addition there are 23 other installations, mostly in connection with car dumpers for railroad, coal, steel and power companies. These total 75 tracks, 68 retarders—both power-operated and inert—(totaling 4,859⅚ rail feet) and 46 power-operated switches of which 42 are protected by detector track circuits.

Chronological

For chronological references see Section 18, years:

1924	1929	1941	1952
1926	1931	1949	1953
1927	1932	1950	
1928	1937	1951	

SECTION 10

FIXED SIGNALS

In recording the history and development of railway signaling there is much to be said with regard to signals, which are by definition, a means of conveying information. Throughout the ages, communication has been carried on by the use of many and varied types and forms of signals, but signals for railroad operation have a special name, being called "fixed signals." The Standard Code definition is: "A signal of fixed location indicating a condition affecting the movement of a train or engine."

The Semaphore Signal

Fixed signals have been of many different types depending considerably upon the particular ideas of those responsible for their design. In the early days each railroad assigned certain meanings to their signals irrespective of what they might mean on another road, but in the year 1841 at New Cross, England, Mr. C. H. Gregory designed and erected, for the first time, the semaphore type signal for railroad use, which proved to be a very important step to reduce confusion and accidents.

The early days of signaling in America were also with many and varied types of signals, starting with the "center post" arrangement described in Section 1, but in the early 1860's the semaphore type came into use and gradually displaced other types. The name "semaphore" has been synonymous with "signaling" in this country ever since, in spite of the gradual evolution of the light signal which now is rapidly replacing the semaphores. But this name is by no means original with the railroads, for it dates back to 1884 B.C., almost 4,000 years ago, as recorded in ancient Grecian history by Polybius, a talented Greek historian, who stated that the name, "semaphore," was derived from two Greek words meaning "a sign" and "to bear." The semaphore was employed by the Romans and later by the French, Germans, Russians and English for conveying both civil and military information, before the invention of the telegraph.

Long before automatic control of signals by trains was in vogue, the semaphore type signal was in general use. While a considerable variation in form and method of mounting characterized the early types, they all embodied the same idea of utilizing the several positions that the blade could assume with relation to its supporting post, as a medium for expressing their messages to enginemen by day, and changes in the color of a light, corresponding with the changes in blade position, by night.

The earlier types of semaphore signal were of the lower-quadrant type, the arms being displayed to the left of the mast in England and on the Continent where left-hand running is the practice, and to the right of the mast in America where right-hand running is used.

In 1908 the upper-quadrant type semaphore was standardized by the Railway Signal Association and has been used extensively by American railroads since that time.

Manual operation of semaphores originally employed a single wire between the signal and its lever, and hence, a heavy counterweighting of the signal to insure the latter's return to stop both under normal conditions and in the event of the wire breaking while the signal was at proceed. Even the eventual use of a second wire or of a rod or pipe connection for "pulling" the signal to


1841..SEMAPHORE SIGNAL
INTRODUCED ON RAILWAYS OF ENGLAND BY C. H. GREGORY IN 1841 AND SOON BECAME THE STANDARD SIGNAL ON ENGLISH AND AMERICAN RAILROADS.

A New York Central & Hudson River R.R. signal of 1890, near Poughkeepsie, N. Y.
(Imported from England)

stop did not permit of the safe abandonment of this counterweight, which in later forms of semaphore signals was made an integral part of the semaphore proper.

When manually operated signals were adapted to assume stop by train influence, the importance of ample counterweighting was in no degree lessened, and, so, when purely automatic action of the signal (to both proceed and stop) was introduced, as in automatic block signaling, the motor, or other power device essential to this, had to be adapted to operate against the counterweight's influence in clearing the signal.

Simple as may appear that problem today, 80 years ago when automatic signaling was first receiving encouraging recognition, it was a formidable one, and primarily because adequate electric motors and generators were then virtually undeveloped and means for automatically controlling fluid pressure devices suited to the work were non-existent.

The Enclosed Disc Type Signal

This situation led to the development, for automatic service, of two forms of signals, that differed radically from the semaphore type: the rotating and the swinging disc types, both enclosed in a housing of circular form fitted with a glass "window" through which the disc was made visible to enginemen. These discs comprised a wire ring over which a red (or green) bunting was stretched and through which a lantern projected its beam (colored by the bunting) when the disc assumed the stop position. When the electromagnets, by which the discs were moved, became energized (when no train was in the block), the disc was turned "edgewise" to the light or swung to an even more invisible position, thus permitting the white light of the lamp to display Proceed—the then accepted practice.

Such signals, however, were subject to misinterpretation by reason of the occasional reflection of light from the sun, or other foreign source, upon the glass, and were also rendered equally obscure at times by snow clinging to the glass. Notwithstanding these faults, the swinging disc type especially received extensive application and served with commendable reliability in automatic service for many years after means had been developed for permitting the semaphore to enter that field.

The Banner or Clockwork Signal

Prior to this latter event, an electro-mechanical signal employing a rotary target (similar to that visible today on switch stands) which was exposed to the elements and carried a lamp (as in switch stands) upon its shaft above the target, made its appearance. A heavy weight, periodically wound up by hand, comprised its motive power, and this, through suitable gearing, rotated the target (and lamp) through 90 degrees each time the electromagnet became energized or de-energized by train action upon track devices through which the state of the magnet was controlled.

This signal, too, served well in automatic service for a period approximating that of the enclosed disc type signal's service. Both, however, fell gradually from grace as wholly practicable means were developed for operating and controlling operation of the semaphore by electro-pneumatic devices in 1882, and by purely electrical means some 10 years later.

Efforts Towards Greater Visibility

Notwithstanding the greater visibility of the semaphore than that of the several types referred to, the background of signals in general were not always favorable to clear distinction of signals, as maximum safety demands. This fact inspired several attempts to render them more discernible, which, while not found practicable, will be mentioned to show a trend of thought in that direction.

One of these was the illumination of the semaphore arm at night by reflecting the light of a lamp against it, in its several positions. Another proposed the revolution of the blade on its bearing (to be located near its center) as a means of displaying the Proceed indication, and on the theory that a moving object is always more discernible than a stationary one. There were many reasons why this latter method was not acceptable; one alone is sufficient for the purpose for which it is here mentioned: namely, to emphasize a faulty principle in the conception. The proposal contrived to make more conspicuous the Proceed indication, whereas maximum safety would call for means for making the Stop indication the more conspicuous of the two.

Automatic Signals in the 1870's

In the early 1870's, and especially after 1872 when the track circuit development inspired an intense interest in automatic signaling, there were many inventions and trial installations made to provide for automatic operation. The importance of having an approved standard practice for the design and operation principles of wayside signals, as the final step in conveying information to a train, prompted an important move by the Massachusetts Railroad Commissioners in 1879. They passed a resolution to investigate the subject of railroad signals and to report the result of their investigation to the several railroads in the Commonwealth and to the next General Court. The Board examined many models and a greater number of working signals on railroads in that and other states. The 11th annual report of the Commissioners covered the state of the art at that time in a complete and thorough manner. They concluded as follows:

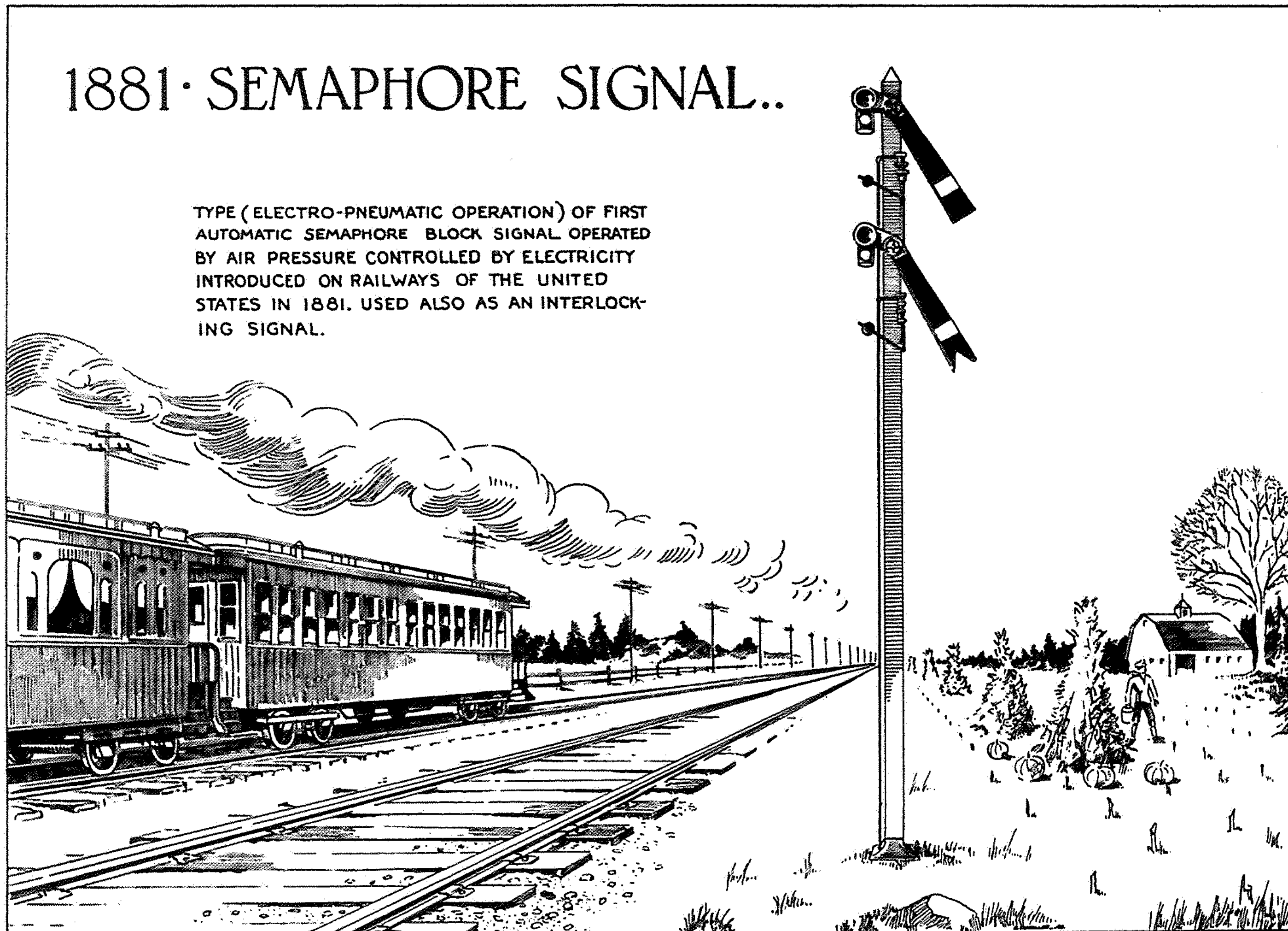
> "It is evident that the time has not come when the adoption of any one of the devices exhibited for giving automatic signals should be required by law. * * * Nor, pending further experience on the part of railroad men, and further experiments by electricians and other inventors, can it be thought strange that railroad companies hesitate to equip their roads fully with imperfect devices, which may soon be set aside for better. Many ingenious men are giving their thoughts to railroad signals. * * * The desire is natural that some tribunal should decide at once which is the best, and that the Legislature should order its adoption. But the time for such a decision has not yet come, even if any automatic device can ever be formed which will alone answer all the purposes of a safety railroad signal. Yet it should be remembered that these imperfect devices do render great service in announcing danger and preventing accidents. * * * The public have a right to expect that their safety will be guarded by every reasonable precaution, and that devices designed for this end should not be rejected, simply because they have not attained perfection."

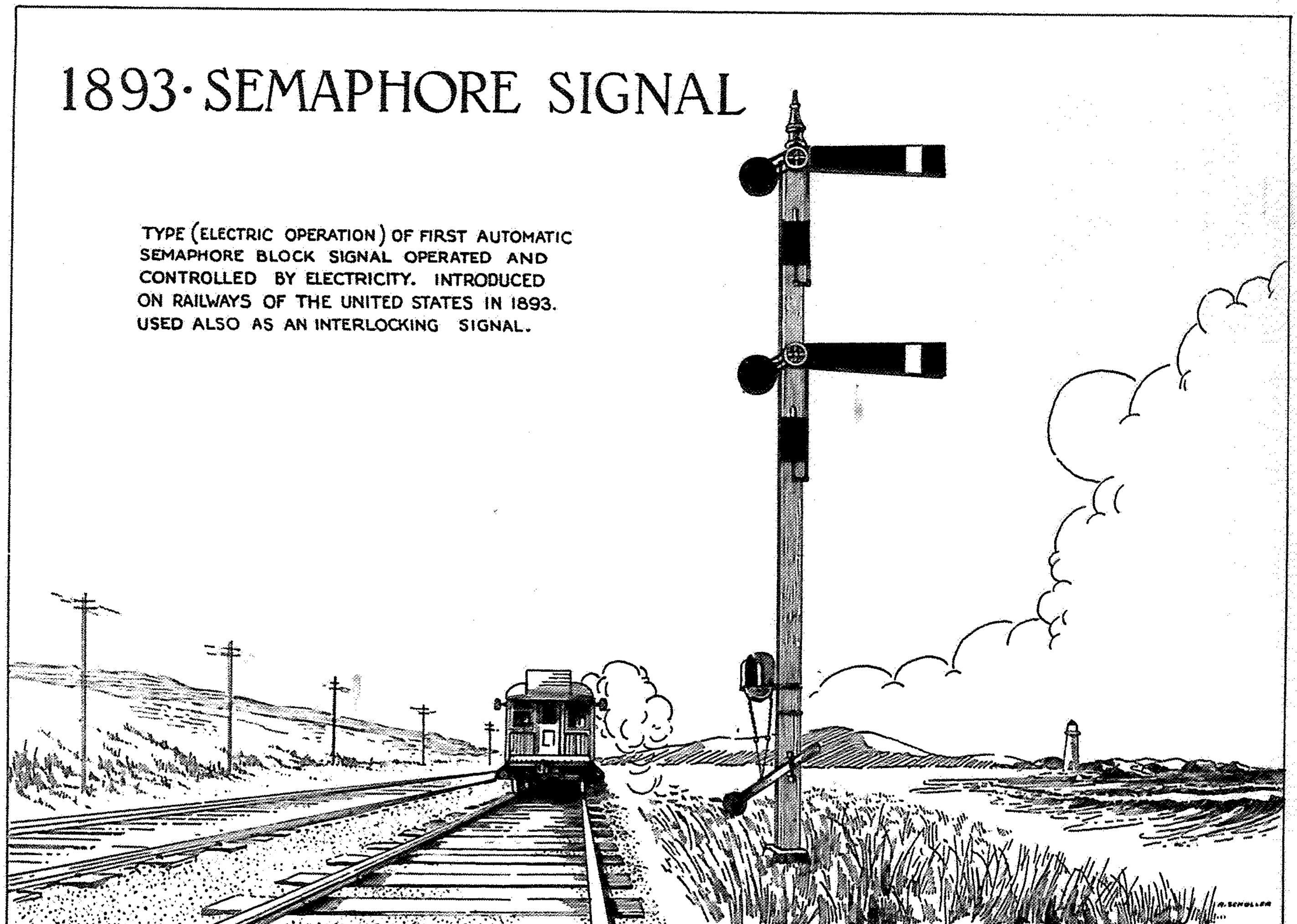
Power-Operated Semaphore Signals

The operation of semaphore signals by mechanical means such as wire or pipe connections to levers, manually operated, from a control machine, was universal in England and the Continent as well as in America until power-operated interlocking systems were proposed.

1881 · SEMAPHORE SIGNAL..

TYPE (ELECTRO-PNEUMATIC OPERATION) OF FIRST AUTOMATIC SEMAPHORE BLOCK SIGNAL OPERATED BY AIR PRESSURE CONTROLLED BY ELECTRICITY INTRODUCED ON RAILWAYS OF THE UNITED STATES IN 1881. USED ALSO AS AN INTERLOCKING SIGNAL.




1893 · SEMAPHORE SIGNAL
TYPE (ELECTRIC OPERATION) OF FIRST AUTOMATIC SEMAPHORE BLOCK SIGNAL OPERATED AND CONTROLLED BY ELECTRICITY. INTRODUCED ON RAILWAYS OF THE UNITED STATES IN 1893. USED ALSO AS AN INTERLOCKING SIGNAL.

The U. S. Patent Office records reveal means disclosed by Messrs. Schnable and Henning, of Germany, for operating signals by hydraulic pressure as early as 1871, but it was not until 1880-1881 that Messrs. Harvey Tilden and F. S. Guerber developed and brought about means for the first practical application of such a system for operating switches and signals. Installations were made in 1882 at Wellington, Ohio, and at East St. Louis, Ill. The first of these was a small installation and was abandoned shortly after for economy reasons, but the second continued for 7 years before being converted to pneumatic operation by the railroad. This conversion was not entirely satisfactory. Improvements for pneumatic operation then followed very rapidly through the efforts of the Union Switch & Signal Co., the Pneumatic Signal Co., and others.

Electromagnetic control of compressed air for signal operation was first used in 1882 and made possible the practical application of such operation extensively for automatic signals as well as interlocking signals, the first large installation being at Bound Brook, N. J., in 1883 at a crossing of the Philadelphia & Reading R.R. with the Lehigh Valley R.R.

In the early 1890's electric motors for direct current operation of semaphore signals were first applied to service. The initial developments were by Messrs. Ramsey and Weir, Taylor, Lattig and others, and used a mechanism attached to the outside and at the base of the signal mast.

In 1897 the first motor-operated semaphore with the mechanism housed in the base of the mast and the rods enclosed within the mast was demonstrated and placed in service. It was the Union Style C. It was followed in 1898 by the improved Style B, and in 1899 by a Sargent type top-of-mast mechanism.

In 1902 electro-gas semaphores were being supplied by the Hall Signal Co. in which operation was by means of liquid carbonic gas controlled by an electric valve.

In 1906 a top-of-mast mechanism for direct current motor-operated semaphores was made available by the General Railway Signal Co. This was their Model 5 and was followed in 1908 by an improved design known as Model 2A.

In 1908 the first motor mechanism for operating a semaphore in three positions upper quadrant from the base of the mast was used. It was the Union Style S.

In 1911 and 1912 the Union Switch & Signal Co. furnished their Style T and T-2, and in 1917 the Hall Signal Co. furnished their Style L, all of these having the top-of-mast type of mechanism and representing the last stage of development for semaphore signal operation. The time was near for the general acceptance of light signals for all new work.

The semaphore signal had served its purpose very well but had its limitations, due to height, to length of arms, and to moving parts which involved expensive maintenance. Its practical use was further complicated in that two entirely different aspects were used, one by day and the other by night.

Light Signals

When the necessity for signaling tunnels and subways first presented itself in 1904 a light signal was developed for the East Boston Tunnel of the Boston Elevated. Indications were displayed equivalent to those given by the semaphore signal at night, by the use of individual lamps behind the proper colored lenses.

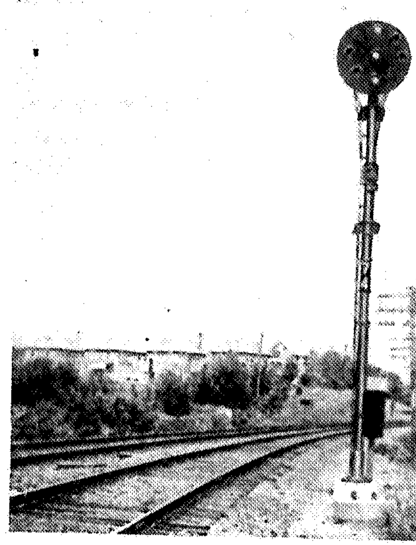
It was soon found that by using lamps of sufficient wattage, proper lenses, reflectors and backgrounds, light signals could also be used in daylight to display the same aspects for day and night.

The first installations for daylight were in locations where comparatively short range was required, such as in 1905 on the New York Central R.R., in 1906 on the Long Island R.R. and in 1910 at the Pennsylvania Station in New York City.

In 1912 and 1913 medium range (1,500 feet) color light signals were first used. It was being demonstrated that the range and spread of light signals varied considerably with the type of lamp used. The more distributed the filament the greater the spread and the shorter the range. The more concentrated the filament the greater the range.

In 1914, therefore, development was refined to such an extent that long range (3,500 feet) daylight indication signals were practical with concentrated lamp filaments, accurately located, and factory adjusted. Installations were made on the New York, New Haven & Hartford R.R. and the Chicago, Milwaukee & St. Paul R.R.

The improvement in lamp design and manufacture enabled development of a new type of light signal to give 4,000-foot range in daylight by displaying rows of amber colored lights in the three positions previously used for semaphores, for day and night indication. This was the position light signal first installed in 1915 between Paoli and West Philadelphia, Pa., on the Pennsylvania R.R.



The first position light signal, Pennsylvania R.R. (1915)

In 1920 the daylight range of the color light signals was further improved to 4,500 feet by the use of newly developed higher transmission colors for the lenses.

Also in 1920, the searchlight type of color light signal (for long range) appeared, in which a single lens opening was used to display each of the three colors, red, yellow, or green, as required, by operating one lamp.

In 1921 the color position light signal was introduced. Two colored lights were used in each row: red for horizontal, yellow for diagonal and green for vertical, as required, and with qualifying marker lights of clear white for special aspects.

In 1930 additional refinements to the searchlight type color light signal brought out the compound lens doublet in place of the single stepped or

Fresnel lens. This improvement made possible the procurement of long range daylight indication with as little as three watts in the light source.

The result of this light signal development has been that since 1940 very few semaphore signals have been manufactured and most roads now install light signals for both new work and for replacement of semaphores.

Chronological

The conveying of information by fixed signals has been accomplished in many different ways depending upon the conditions surrounding various phases of train operation, and depending upon inventive genius finding ways to improve reliability and to provide better and longer range indications. It appears desirable to classify the development chronologically under several headings which are representative of distinctive types of signals.

For chronological references see Section 18, years:

Special signals:

1832	1876	1899	1908
1840	1885–87	1900	1915
1853	1885	1901–03	1922
1863–67	1895	1902	1926
1871	1896	1903	1929

Train order signals:

1851	1871	1887	1896
1860	1874	1889	1908
1864	1880	1890	1910
1868	1883	1891	1911
1869	1885	1892	1924

Railroad-railroad grade crossing signals:

1852	1866	1876	1885
1855	1870	1880	1890
1860	1871	1882	1896

Drawbridge signals:

1854	1868	1876	1884
1866	1871	1877	

Semaphore signals:

1863	1888	1897	1906
1866	1889	1898	1907
1870	1890	1899	1908
1874	1891	1900	1910
1882	1892	1901	1911
1884	1893	1902	1912
1885	1894	1903	1917
1886	1895	1904	
1887	1896	1905	

Disc signals:

1862	1873	1883	1893
1864	1874	1885	1894
1870	1878	1889	1905
1871	1881	1890	1906
1872	1882	1892	

Banner signals:

1879	1880	1885	1891

Flag signals:

1868	1869

Time interval signals:

1871	1875	1894	1902
1874	1890	1895	

Pneumatic signals:

1872	1874	1877
1873	1875	1902

Electro-mechanical signals:

1876	1882	1889

Electro-pneumatic signals:

1882	1891	1906
1884	1904	1908

Light signals:

1858	1906	1915	1924
1866	1907	1917	1926
1873	1910	1920	1930
1874	1912	1921	1931
1891	1913	1922	1938
1904	1914	1923	1941
1905			

Color position light signals:

1882	1886	1921

SECTION 11

DEVELOPMENT OF SIGNAL GLASS FOR LIGHT INDICATIONS

At the Boston, Mass. meeting of The Railway Signaling Club on November 14, 1899 a paper was presented by Mr. H. M. Sperry discussing "Progress in Signaling." This discussion included some important information relative to the use of colors for night signals as contained in the 1899 report of the Massachusetts Railroad Commission.

In this report we are reminded of a situation as follows:

1. The usual colors for railroad signals almost universally adopted in all civilized countries are: white for safety, red for danger, and green for caution.
2. These colors were agreed upon at a Congress of railway men held in Birmingham, England in 1841.
3. The Chappe brothers, in France, were responsible for the choice of these colors which they established through experiments in connection with a signal system devised by them. They stated that the visibility of a red light was but one-third that of a white light of the same intensity; that of a green light, one-fifth and that of a blue light one-seventh. White was chosen as the safety indication as it was the usual light as well as the most easily visible. Red, as the most easily visible of the colored signals, was chosen for the most important indication, that of danger, and green was used to signify caution, where needed.
4. Serious objections to the use of white as a safety signal soon became evident. The breakage of a red glass resulted in a white or safety indication being given, or if the light was out on a danger signal some other white light could be mistaken by the engineman for a safety signal. These conditions resulted in accidents. As a consequence, in England, green was substituted for white as the safety indication on fixed signals and cautionary signals were abandoned. The permissive block system so widely used in America was not in use in England so that a caution signal there was not considered necessary, the distant signal simply being a duplication of the home signal.
5. On September 6, 1898 there was a train collision at Whittenton Jct., Mass., resulting from the fact that an engineman mistook the white lantern on a highway crossing gate for a safety home signal wherein the signal was in reality at danger, though its lantern was extinguished.
6. Following the Whittenton accident, and as a consequence of it, the New York, New Haven & Hartford R.R. adopted the green light as a safety signal at night in place of the white light. All signals on the system were changed early in 1899 by substituting double light semaphore castings for the single light, the new standards being red for stop, green for clear and yellow for caution. This appears to be the first use made of yellow as a caution signal, and it was on November 14, 1899, that Mr. A. M. Keppel, Jr., President of the Railway Signaling Club, announced at its Boston, Mass. meeting that a number of members would like to see the yellow semaphore light in service on the New Haven. That evening at 7:30 p. m. a visit was made to the new South Station in Boston for the inspection.
7. In America the general practice continued with night colors of red for danger, green for caution, and white for safety or clear. When general objections to the use of white began to be raised the principal arguments used against giving it up were: (a) the enginemen were accustomed to its use, and any change would be dangerous since a white light alongside the rail-

road might be taken as a safety signal from force of habit; (b) because of the extensive use of the permissive block system it was necessary to have a signal indication for caution and it appeared difficult to find a suitable color for that purpose. A compromise, however, was established on the Chicago & North Western Ry. in 1896 by the use of a red light horizontally spaced 9 inches from a green light, both illuminated from one light source. This provided the caution indication. Green alone was used for the clear indication. A few roads used combinations of position and lights.

8. Color for night indications received serious consideration by the American Railway Association and by other official railroad organizations before the Railway Signaling Club was organized on March 11, 1895, but general agreement was very difficult to establish. In 1894 the A.R.A. Committee on Interlocking and Block Signals recommended red for danger, violet for caution and green for safety but within a month they changed their opinion and recommended continuing the use of green for caution and white for safety. The A.R.A. then voted to continue the use of white for safety. Later in the year this Committee reported that the use of blue or orange lights did not appear practicable but that a combination of red and green could be used for caution. In March 1895, the following resolution was passed: "That the Committee does not at this time deem it wise to recommend abandoning white for a night signal; as, first, three indications are necessary in many cases, and, second, no entirely satisfactory single color has been found for a third indication. The Committee approves, however, the use of red for danger–stop, and green for clear–proceed; as good signal practice."

It was obvious in this period (the late 1890's) that with each railroad selecting its own combination or different shades of colors for its signal system night indications, no uniformity of hue or saturation existed. Reds varied from orange to a very dark red; greens ranged all the way from a yellow chrome to blue and there were various nondescript yellows, blues and purples. As for the yellow for a third night indication, difficulty was experienced in that the tints ranged from a reddish-yellow, which was easily confused with red, to a greenish-yellow which was easily mistaken for green. By 1899 it was generally conceded that the green light was the proper one for a clear indication, but opinion differed as to the color to use for a distant or caution signal. With these conditions existing, the question naturally arose as to whether it was possible to determine the best colors for signal glass by scientific investigation so that standards could be established which would provide for uniformity.

After the Railway Signaling Club was organized, the subject of night indications was so important that a Committee was appointed at its second meeting on April 9, 1895, to investigate the question of colors for night signaling. This Committee, appointed by President W. J. Gillingham (Signal Engineer, Illinois Central R.R.), consisted of Messrs. W. B. Turner, (Signal Engineer, Chicago & Western Indiana R.R.), W. H. Elliott, (Signal Engineer, Chicago, Milwaukee & St. Paul R.R.), H. C. Wilson, (Wilson Railway Gate Co.), J. W. Peck and G. M. Basford, (editorial staff, *Railway Review*). At the March 10, 1896 meeting the report of this Committee was presented and when the Club met on May 12 a motion was passed to submit to letter ballot the question "Shall the Club recommend any system colors for night signals?"

This subject continued to receive the attention of the Railway Signaling Club and its successors, the Railway Signal Association and the Signal Section, Association of American Railroads, as well as interested organizations and companies. Impetus to standardization was given by Professor E. W. Scripture, of Yale University, through a lecture he gave in 1899 on color blindness, at a meeting of the New York Railroad Club. It was stated that correct signal colors could be determined by a careful study of the physical and color conditions involved. This statement so impressed Mr. Alanson B. Houghton, Sales Manager of the Corning Glass Works, who was in the audience, that he asked Professor Scripture to make a laboratory investigation to establish correct values for each of the possible signal colors. Preliminary research was conducted at Yale by Professor Scripture and Dr. William Churchill.

In 1904, Dr. Churchill was employed by the Corning Glass Works to establish an optical laboratory for special research on colors and the optics of signal glassware. Considerable progress was made and at the Ninth Annual Meeting of the Railway Signal Association held at Niagara Falls, N. Y., on October 11, 1905, Dr. Churchill presented his paper, "The Roundel Problem," at which time he stated: "That all semaphore signals are largely dependent for their efficiency, twelve hours out of every twenty-four, upon the lens in the lamp and the roundels in the spectacle, may perhaps be regarded as an axiom of railroad signaling. The most perfect mechanism cannot atone in the slightest for lack of light or weakness of color indication. With the increasing realization of this simple fact, the need for standards of color, insuring uniformity of hue and intensity, has become more and more obvious."

Preceding this meeting, however, Dr. Nelson Miles Black presented a paper, "Preliminary Report of Comparative Tests of Roundels, from an Ophthalmologist's Standpoint," at a Chicago, Ill. meeting of the R.S.A. on September 13, 1904. The complete report was given at the St. Louis, Mo. meeting held on October 11-12, 1904. At the 1905 meeting at Niagara Falls there was presented, in addition to Dr. Churchill's paper, a second report by Dr. Black on "Comparative Tests of Roundels," and Dr. Charles H. Williams presented a paper on "Some Observations on Signal Lenses."

In view of these activities it is not surprising that Mr. J. C. Mock, in discussing the Standardization of Color Glasses at the 39th Annual Meeting of the Signal Section in New York, May 9-10, 1933, said: "We might think of the years 1904 to 1906 as the period when the greatest improvement was made in railway signal glasses in this country and I think it may appropriately be called the Renaissance of Railway Signaling."

During this period of 1904-1906 there developed an insistent demand for better lights and glasses, as was evidenced by the numerous tests conducted on railroads and at glass factories by such committees as the Pennsylvania Lines Special Signal Committee and the New York Central Lines Signal Committee. However, Dr. Churchill, in his paper, proposed the fundamental principles and methods of testing for the colorimetric specification of colored glassware that were necessary for the standardization of signal colors. He told of the development of new glasses with a satisfactory manufacturing range between light and dark limits to provide a three-color signal system and he also proposed lunar white, a new blue and a new purple for certain kinds of signals. At the October 1906 meeting of the Railway Signal Association he presented another paper on "The Optics of the Signal Lens," and at this same meeting the Association adopted Mr. A. H. Rudd's motion "that the Association endorse the use of green for clear and yellow for caution for night indication signals."

A period of great activity was witnessed in the new Corning optical laboratory from 1905 to 1908. A Railway Signal Association Committee was working closely with the laboratory and participated in laboratory and field tests.

Sample colored roundels were selected as representative of the Committee's opinion as to the ideal colors. These included red, yellow, green, blue, purple, and lunar white and were arbitrarily called 100 per cent standards. A specification was written around these arbitrary standards which was presented at and adopted by the Association at its October 1908 meeting. This specification defined the photometric limits for the various colors and required that each piece of colored signal glass be photometrically measured and marked with a sticker indicating that it was within the R.S.A. limits. As a result, the railroads gradually abandoned their individual color requirements to use glasses meeting the R.S.A. specifications, and by 1910 the use of white for "clear" was quite generally abandoned when red for "danger," yellow for "caution" and green for "clear" were adopted.

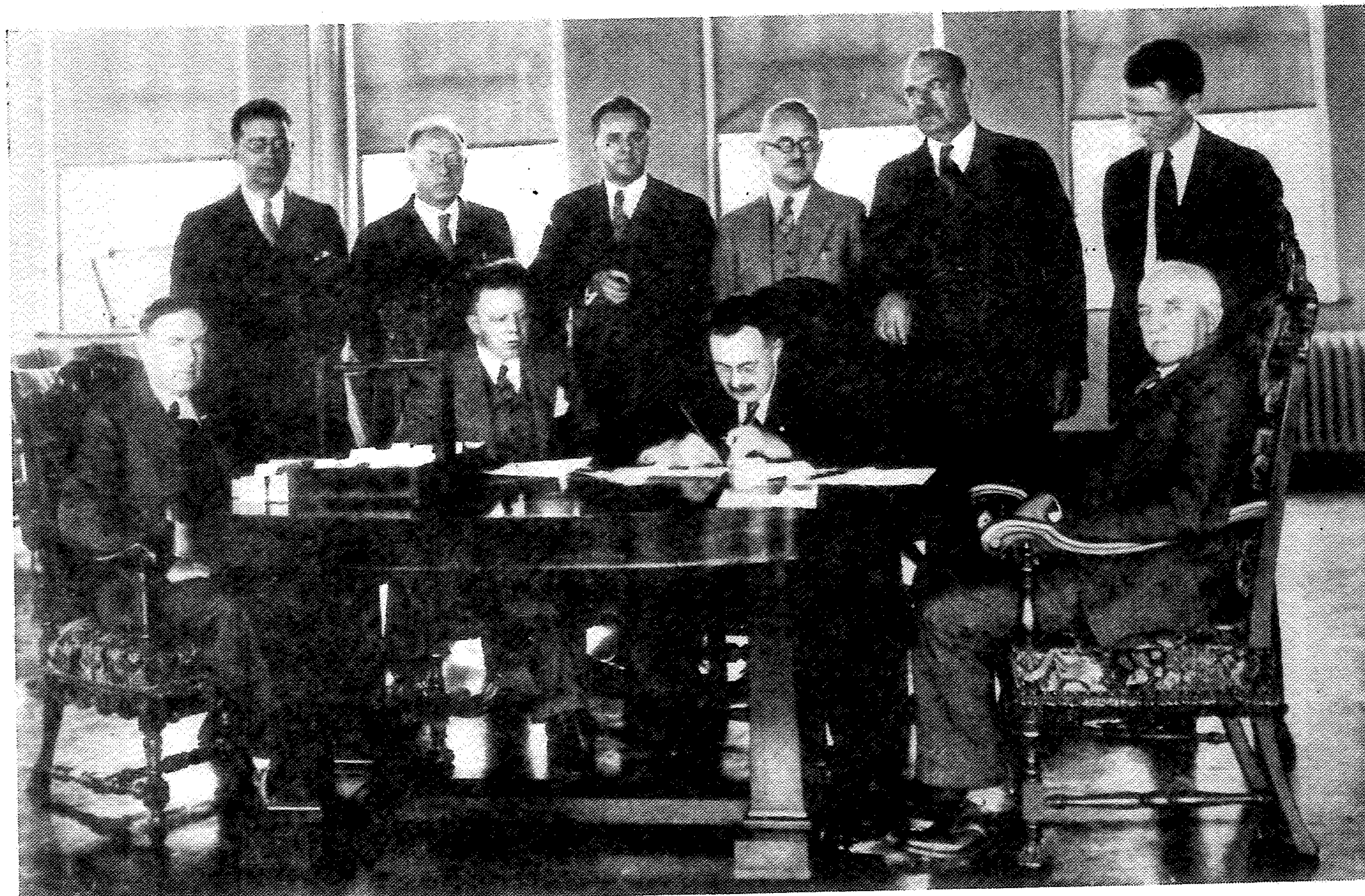
It was in 1908 also that a new low expansion borosilicate glass was introduced for railway signal lantern globes which would withstand sudden temperature changes.

In 1911, Dr. H. P. Gage, a Cornell physicist, joined the laboratory staff at Corning to become actively engaged in signal color standardization work and later succeed Dr. Churchill as head of the optical laboratory. This laboratory produced the doublet lens combination in 1913 which was adopted immediately for use in long range daylight color light signals for railway signaling.

In the meantime, research work was being actively carried on with regard to the need for further improvement in the color specification and in 1917 and 1918 an R.S.A. Committee again visited the Corning Glass Works to examine the improved signal glass then available. As a result of the continuous study devoted to this subject, a revised specification was adopted by the R.S.A. based on some improvement in color and in transmission. The standards established by this 1918 specification were in the form of 8⅜ inch diameter, ¼ inch thick flat roundels. In October 1930, Mr. J. C. Mock, Signal Engineer of the Michigan Central R.R. and Chairman of the A.A.R. Signal Section subcommittee visited Corning to engrave a set of these standards "J. C. Mock, 10-3-30."

As it was the desire of the Signal Section to progress this matter still further and have a more complete specification suitable for National standardization, it was necessary to have a spectro-photometric analysis of each color and means to procure accurate certified duplicates of the standards. The work was actively started in 1930 and standardization finally resulted from the cooperative efforts of the A.A.R. Signal Section, Corning Glass Works, and the National Bureau of Standards. Limit glasses in the form of two-inch polished squares were prepared for each color and in June 1931, Committee VI—Designs, of the Signal Section met in Corning, N. Y. with Dr. H. P. Gage to review the spectrophotometric data and make field observations. The two-inch polished square limit glasses suitable for standards were approved and endorsed by Mr. Mock as such on November 6, 1931. One set was given to the Bureau of Standards for file in Washington, D. C.; a second set was held by the Signal Section and a third set was kept on file at the Corning Glass Works. Arrangements were made whereby certified duplicates of these standards could be obtained only through the National Bureau of Standards.

Experience gained in the field and in manufacture and test at Corning, combined with further research work at the Bureau of Standards, resulted in getting enough information to complete the revision of the specification in 1935. This specification permitted use of higher transmission glasses and defined color values in a way that inspection could be made in any laboratory suitably equipped. The selection of limit glasses for highway crossing signal red was made later and included in the specification in 1939.



Dr. H. P. Gage signing, with diamond pointed pen, sample glasses of light and dark color limits selected by Signal Section, A.A.R. Committee VI for railroad use. Samples were spectrophotometrically analyzed by Bureau of Standards and placed on file in the Bureau as permanent records, November 6, 1931. (Standing left to right: G. K. Thomas, A. J. Patterson, O. S. Field, A. W. Fisher, C. J. Kelloway and A. S. Haigh. Seated left to right: H. G. Morgan, I. G. Priest, Dr. H. P Gage and J. C. Mock.)

As a result of the years of intensive color research and tests on the part of the railroads, glass manufacturers, signal manufacturers and Bureau of Standards, the American railroads have in their facilities today the best designed lenses and colors that can be produced.

The development of the color specification can stand as one of the most important events in railway signaling, for by establishing a suitable yellow it quickly settled all doubts about the use of green instead of white for clear, and with additional colors established means for making signal systems flexible enough to meet practically all demands and to operate by colored light for both daylight and night conditions.

SECTION 12

ELECTRIC LOCKING

Electric locking, as used in railway signal systems, is a means adopted for securing increased safety by decreasing the human element as a vital factor and substituting the more dependable automatic control. Originally, electric locking was mostly used at mechanical interlockings to prevent a leverman inadvertently taking a line-up away from a train once the line-up had been accepted.

As electric locking developed through the years, it was classified as: indication locking, detector locking, route locking, stick locking, approach locking and sectional route locking. These classifications met the basic locking requirements, but additional special locking features were frequently needed to meet local conditions or arrangements. The most important of these auxiliary electric locking features were check or traffic locking, bridge locking and outlying switch locking, each providing the type of protection implied by its name.

With the introduction of power-operated signals and power interlockings it became necessary to provide indication locking which insured the correspondence of the position of the function and the lever. Detector locking prevented a switch being thrown under a train, as the train provided its own protection by shunting the track circuit and locking the switch lever to prevent its movement. The track circuits were usually extended to the fouling points of the switches controlled or protected. This locking has been called "detector locking" as it was used in place of detector bars or in conjunction with them. Route locking locked all switches and derails in a complete route from the moment a train entered the first detector circuit until such time as the route was cleared. This was a logical development beyond detector locking which had its protection for train movements limited to one track section only.

Stick locking was so designed that the clearing of a signal would cause the locking of the route to be effected and then was released automatically by the passing of a train. Approach locking, like stick locking, was generally used on high-speed routes to provide protection for an approaching train. This locking took effect only when a train was approaching and a signal was clear. It was sometimes termed "advance locking" and applied to locking other than high-speed routes by effecting the locking of the route before the train had actually entered the route. Sectional route locking was a later development of detector locking and route locking. This locking, so arranged that a train in clearing each section of the route, released the locking affecting that section while the sections in advance were still locked. This provided for the maximum number of train movements in busy terminal areas with maximum safety.

Check or traffic locking was designed to prevent the entrance of trains from opposite directions on to the same piece of track (usually located between two adjacent interlockings a short distance apart). This locking required both operators to cooperate to permit a train to use the track between the towers. Bridge locking is used to lock movable types of bridges in a position to permit safe passage of a train. It is so interlocked with the signals governing the approach to the bridge that they cannot be cleared unless the bridge is locked in its properly closed position. Outlying switch locking places the control of an outlying switch in the hands of a leverman or operator by locking electrically so that it cannot be moved without his knowledge or consent.

Why Electric Locking Was Developed

When the use of mechanical interlocking machines was being established the need for something more than mechanical locking and detector bars became apparent. The mechanical locking which prevented the setting up of conflicting routes, and detector bars which kept levermen from throwing locks and switches under moving trains were safeguards that seemed sufficient where slow moving trains were the rule and where well disciplined levermen manned the interlockings. However, at busy interlockings and at those where high-speed train movements were the rule, the possibility existed that a leverman, having cleared a route for the passage of a train, could take this route away and set up a conflicting route before the train, having accepted the clear distant signal, had passed through the interlocking. The distant signal clear under these conditions was a hazard as it invited high speeds and increased the possibility of a derailment or collision. It was early recognized that means for preventing such a condition were necessary.

Attention was being given to the use of electric locking of components at interlockings but little was being done about its use for other purposes. However, soon after Dr. William Robinson invented the direct current track circuit in 1872 he, in company with Messrs. Oscar Gassett, Israel Fisher and others, developed a system of block signaling employing the track circuit as a means for controlling signal operation, locks on switch stands, highway crossing gates, alarm bells, and annunciators.

Early Installations

The practical application of the track circuit to the electric locking of switch stands and movable bridge mechanisms was first made on the Fitchburg R.R. in Boston, Mass. and on the Boston & Maine R.R. in 1878-79. On the Fitchburg R.R., Mr. Gassett equipped a number of switch stands with electric locks in the block signaled territory at Waltham, Mass. The electric locking was so arranged as to prevent a switch being thrown while a train was approaching in the block. Similar devices were applied on the Old Colony, Boston & Maine and Eastern Railroads. Movable bridges on these railroads were also provided with electric locking.

Returning now to the use of electric locks at interlockings, we find that the Jackson Switch & Signal Co. of Harrisburg, Pa., had erected several Saxby & Farmer and Toucey & Buchanan interlockings in 1879-80 and shortly thereafter Mr. Jackson devised a scheme for attaching an electromagnet to the machines to operate a latch which locked the signal levers when a train was in the section.

In 1878 the Union Electrical Signal Co. was organized in Boston by Dr. William Robinson with Mr. Oscar Gassett as Superintendent and Electrician and the devices he and others had invented were the stock in trade. As a result of the search for a means for electrically locking levers, Mr. Jackson became acquainted with Mr. Gassett. This acquaintance soon resulted in the two men working together on the common problem. Mr. Gassett had devised a scheme for locking the levers of an interlocking machine by means of electric latches operated both by track instruments and track circuits and Mr. Jackson's device for the same purpose anticipated the use of the track circuit. One of Mr. Gassett's schemes provided for the locking of signals as soon as a train had passed a clear distant signal. The locking was established by means of a track instrument located near the distant signal. The release of the locking was accomplished through the use of a second track instrument located just beyond the interlocking limits. The ideas of the two men were identical in that their purpose was to lock up the route by electrically locking the signal levers for the passage of a train and releasing the route after the train had passed through the interlocking. Later on Mr. Jackson devised a more extended use of his electric latch which provided for the locking of levers of opposing routes in their normal danger positions instead of those of the desired route in their safety positions.

Electric Locking as a Safety Feature

The Union Switch & Signal Co., after its organization in 1881, actively advocated the use of electric locking for mechanical interlocking machines, as stated in its 1885 catalog of Saxby & Farmer Interlocking under the heading "The Automatic Electric Locking of Interlocking Levers." The following statement is made:

> "With the interlocking above described, it is impossible to set conflicting switches and signals for approaching trains.
>
> "The following contingency, however, might arise: It is proper for the operator to put the distant signal to the caution position as soon as the train has passed it, in order to protect the train from a rear collision. He might then, confused by several train movements happening at once, by rapid manipulation or careless haste, reverse the home signal and move a lock and a switch in front of the train, which would have attained such speed (assured of right of way by the distant signal) that it could not be stopped in time.
>
> "No interlocking system is absolutely safe which leaves a chance for so grave a possibility.
>
> "The locking of the levers (out of the control of the operator) by the simple presence of a train upon the track is the most important improvement in modern signaling, and provides complete protection against a source for errors which has led to very serious accidents. It is effected by the electric lock and an electric current established through the rails, and applied in such a manner that, signals having been given for a route, all other switches and signals, the use of which might interfere with the safety of the train, are locked and cannot be used until the train has passed beyond the fouling point, or has come to a full stop in advance of it. This electric locking, however, does not prevent the simultaneous operation of signals and switches for non-conflicting train movements."

The electric locking of levers of mechanical, hydraulic and pneumatic interlocking machines was put into practical operation at various locations during the years 1882–1885, in which use was made of the track circuit to effect the locking and its release. The first application was to a Saxby & Farmer machine on the Pennsylvania R.R. in 1882. Signal levers were locked at safety by the train passing a clear distant signal, and the levers remained locked until the train had passed through the interlocking. It soon became evident that this was not the proper principle as it prevented the signals being restored to their most restrictive position until the train was clear of the interlocking.

To rectify this condition, the locking arrangement was changed so that the lever locks of the switches were electrically locked, thus permitting the signal levers to be restored to their normal positions as soon as the train passed the signals. However, the lock levers remained electrically locked until the train had cleared the limits of the interlocking on single track or had passed beyond the crossing frogs on grade crossings. The expense of bonding and insulating the rails, and the maintenance problems, led to another change in methods. The locking was effected, when the distant signals were cleared, through a circuit breaker operated by the blade. This circuit breaker opened the circuit of the electric latches on the lock levers by means of a relay in the tower. The signals could be restored to danger but the train had to complete its movement over the plant before the latches could be released. The tracks inside the home signal limits were included in one common section. Another arrangement used was to have the circuit breakers located in the tower and operated by the levers.

Early Difficulties

Many difficulties were experienced in the early days of electric locking. During bad weather levers had to be operated from time to time to see that they were in working order. This resulted in locking up a machine electrically; trains had fouled at crossings, which should have been prevented by electric locking, and inspectors found that levermen had installed secret circuits to by-pass electric locks entirely. These conditions led to the introduction of release buttons which allowed the operators to test their signals and then release the electric latches. The convenience of the release buttons could be used also to nullify the electric locking, so they were later placed downstairs or at a remote distance from the operating floor. Still there were some ingenious levermen who rigged up "jump wires" to beat the system. As a result, expensive and complicated "time movements" and different kinds of apparatus were devised and installed to check the levermen. These only resulted in complicating matters.

In those early days, when electric locking was struggling to gain a foothold as a desirable and necessary feature of railway signal systems, the road was rough. Many railroad managements were not particularly favorable toward the use of signaling. Consequently it was almost impossible to have track circuits, used for electric locking at interlockings, maintained properly to keep them in working order. Much trouble was experienced, as the failure of the track circuits caused the levers to be locked up indefinitely or until the locks were released by "plugging." The maintenance of the operating batteries was in the hands of telegraph repairmen who gave them attention only when completely run down or when the repairmen had the time or the inclination to attend to them.

Up to November 1885, there were 3,165 working levers in use in 227 interlocking plants in service on 35 railroads in America. Seventy of these plants had electrically locked levers. During the next 10 years there were not over a dozen instances where electric locking of levers was applied, aside from its use with power interlocking machines. From the first, however, the electric locking of levers has always been a feature of electro-pneumatic and electric interlocking apparatus. Even though electric locking was actually applied in practical form before the introduction of interlocking machines in America and became a feature of the earliest installations and continued so for a number of years under more or less adverse conditions, it fell into disfavor and was generally abandoned until it was found desirable and necessary again to resume its use in the early 1890's.

The first detector locking by depression of trips by car wheels (the wheels depressed a bar to close a series of contacts which grounded the indication circuit and kept the switch closed) was installed on the Pennsylvania R.R. at Pittsburgh Terminal, Pa., between 1885 and 1890.

The first detector track circuit locking as invented by the Pennsylvania R.R. was installed at Altoona, Pa., between 1900 and 1902.

The first approach locking with automatic release, was on the Pennsylvania R.R. at Zoo Garden, Philadelphia, Pa., December 31, 1905.

Through route locking designed by the Pennsylvania R.R. was installed at Hoboken Terminal, N. J. (D. L. & W. R. R.) December 1, 1907 and at Broad Street Station (P. R.R.), Philadelphia, Pa., January 19, 1908.

Today (1953) the trend in railway signaling is more and more toward all-relay and route type interlockings, remote control, and the consolidation of interlockings. This is accomplished electrically rather than by mechanical means. Formerly electric locking was but an adjunct of an interlocking, and machines, whether of the mechanical or power type, were always provided with mechanical locking.

The present trend establishes an elaborate use of "electric locking" under the modern definition which reads: "The combination of one or more electric locks and controlling circuits by means of which levers of an interlocking machine, or switches or other units operated in connection with signaling and interlocking, are secured against operation under certain conditions, such as: (1) approach locking, (2) indication locking, (3) switch lever locking, (4) time locking, (5) traffic locking."

SECTION 13

THE ORIGIN AND HISTORY OF THE SIGNAL SECTION

A small group of railway signal enthusiasts met on the evening of March 11, 1895 in Chicago, Ill. This gathering was destined to have a far-reaching effect on rail transportation. The group was comprised of the younger signalmen from the roads terminating in Chicago who saw the need of recognition of the standing and possibilities of signals and signalmen. To Mr. G. M. Basford goes the honor of having called the group together in his office. Mr. Basford, formerly Signal Engineer on the Chicago, Milwaukee & St. Paul R.R., had left that railroad in January 1895 to join the editorial staff of the *Railway Review*.

Those who attended this meeting on that historic evening were Messrs. W. H. Elliott (Signal Engineer, C. M. & St. P. R.R.), H. D. Miles (Signal Engineer, Michigan Central R.R.), W. B. Turner (Signal Engineer, Chicago & Western Indiana R.R.), W. J. Gillingham, Jr. (Signal Engineer, Illinois Central R.R.), and V. K. Spicer (Western Agent, Union Switch & Signal Co.). The object of the meeting was to consider forming what that night became the "Railway Signaling Club" with Mr. Gillingham as the President and Mr. Basford as the Secretary-Treasurer. A Constitution was ready at this first meeting which went into effect immediately. By the end of the year there were 18 members, which number increased during the first 8 years to about 350 members.

Before the election of officers, Mr. Basford said: "This meeting has been called with the purpose of inaugurating a systematic movement in the improvement of the signaling of railroads in the hope that the development now begun may lead to such a growth of signaling, and of signalmen, as to place this country at the head, rather than at the foot, of the list as to the destruction of life and property, through accidents, which correct and complete signaling would prevent." At this time, signals and interlocking were appreciated only by those making and selling the apparatus and as far as the railroads were concerned, signals and signalmen were both considered as necessary evils. Signaling was not thought of as a means for increasing track capacity or introducing economies not otherwise obtainable.

In 1890 signalmen had little authority, except on a single railroad system. There were but few men in the signal departments and the salaries received for their services were hardly worth mentioning. Quoting one who had been a signal engineer of that period, he said: "I was at one time responsible for all the signaling of a 6,000-mile railroad. My salary was $90.00 per month and I had the assistance of two men in the care of some 15 interlocking plants, and in a lot of new construction. The few wrecks which did occur were always at one of these plants. The nights were full of trouble, and the winter storms kept the so-called 'Signal Engineer' himself at the large plants trying to keep the machines working; there was no one else to do it."

Under the best of conditions, those hardy men at that time working in the signal field, found the going rough and rugged. There had been little or no opportunity for the men to get together to discuss mutual problems except as they met occasionally in the offices of the signal companies in Chicago. Some had up-to-date apparatus; others had the old "wheel machines." As an example of the conflicting conditions, at one interlocking there were three different kinds of signaling employed with three different and contradicting sets of rules as to the significance of the signals. The time was indeed right for the formation of the Railway Signaling Club. The object was to make the title of "Signal Engineer" mean all that it implied. Discouragements soon developed within as well as outside the little organization and that the Club held together at all was largely due "to two men whose energy and fidelity were more severely tested than they will care to tell."

Signaling as a Science

In its issue of April 13, 1895, the *Railway Review* printed an article titled "Signaling as a Science" which covered the organization of the Club and its objectives so thoroughly that it merits a place in any history of "railway signaling." Quoting:

> "The Railway Signaling Club announces its organization, and that it has begun a career which, it is hoped, will be one of practical usefulness and of benefit to all who are concerned with the questions pertaining to safe movement of trains. The movement was started by the younger signalmen upon the roads terminating in Chicago, and it was deemed advisable to make the beginning as unpretentious as was consistent with a good foundation upon which to build for the future. While this was commendable it is desirable, at least, that all of the forces engaged in this important branch of engineering be rallied to the end that the recommendations of the organization may carry weight and be representative of the best thought, study and experience which has been given to the matter of railway signaling. This branch of railway working is a specialty in which the best work must come from specialists, and the 'Signal Engineer' must be reckoned with in its best development. There is no doubt of the ability of the signalmen in an organization to improve the present state of the art, and in turn the signalmen have much to learn and much to do before the term or title 'Signal Engineer' will mean all that it implies.* * * * * *
>
> "The organization of the Club is simple and the idea of plan outlined is by discussion and committee work, to bring the various systems or plans used by different roads in signaling into uniform and more nearly standard form. In this line work has already been started by two committees upon the subjects of colors for night signaling and the compilation of a set of rules to govern the use of interlocking signals. Both of these are practical subjects, and it is hoped that they will receive intelligent and careful consideration to the end that something may be recommended to the roads which will provide the means of simplifying these matters. The membership is as yet hardly large enough to bring out a representative discussion of such questions in the sense of bringing in the experience of men from a large number of roads. However, before a satisfactory code of rules can be arranged, enough time will elapse to admit of sufficiently increasing the membership to secure as general a representation as such an important discussion demands. In the meantime these matters can be brought up for preliminary discussion, and it is a good idea to get something started at once in a line of practical value.* * * * * *
>
> "All who are interested in signaling will undoubtedly be glad to know that this Club has been started. It surely merits the assistance and good wishes of all in its efforts to fill a vacancy in the sphere of technical investigation and discussion."

In those early days of the Club's existence it was indebted to the generosity of Mr. Willard A. Smith of the *Railway Review* for many courtesies extended in connection with the publication of papers as there were no funds available for printed proceedings. The fact that Mr. Smith allowed Mr. Basford to use the facilities of the publication for the assistance and promotion of the organization in its infancy was largely responsible for its ability to carry on at a time when it was badly in need of influential backing.

Constitution and By-Laws

At the organization meeting on March 11, 1895, the Constitution, as adopted, stated that the object of the Club was the discussion of the subject of railway signaling. The intention was to endeavor to systematize and to put into as definite a form as possible the conclusions reached through the discussions. The management of the Club was retained in the hands of the railway members and the membership consisted of three classes, viz., Members, Associate Members and Honorary Members. As outlined in the Constitution: "Members shall be persons who are or have been connected with the designing, construction, maintenance or operation of signals, and in responsible charge thereof upon a railway and who have occupied such a position not less than one year, and excepting persons who are engaged with companies other than railways in the manufacture and sale of signaling material." Candidates for Associate membership were required to have satisfactory experience in signal work but not necessarily as employees of railways, and they, as well as Honorary Members, had all the privileges of membership except the right to vote and to hold office.

A new Constitution and By-Laws was discussed and adopted at the meeting of the Club held on January 28, 1896, at the Great Northern Hotel in Chicago, Ill. This Constitution provided for the holding of the annual meeting in January. The monthly meetings were then changed to longer intervals of five times a year. Mr. Gillingham was again elected President, Mr. H. D. Miles, Vice-President and Mr. Basford, Secretary-Treasurer. Membership dues were provided for, but even these did not help out materially at the time. This Constitution remained in effect, with slight alterations, until 1906.

One of the more important provisions of the new Constitution was that the Club would recommend to the American Railway Association such matters as it might deem necessary to perfect a uniform practice in the construction, maintenance and operation of signaling devices. It was recognized that by this means only could the ultimate intention and desire of the Club be accomplished, as the adoption of a standard and uniform practice needed the endorsement of the A.R.A. to become effective. Prior to this change in the Constitution, a Committee on Rules had been appointed to prepare a set of rules governing the operation and maintenance of interlockings. Having made its final report at the March 9, 1897 meeting in Chicago, the rules were approved by the Club and the Secretary was instructed to submit them to the A.R.A. with a recommendation that they be generally adopted throughout the United States. These rules were the first subject discussed by the Club which took the form of a recommendation to the A.R.A. and were the first ever completed for interlockings.

It was at the March 10, 1903 meeting in the Manhattan Hotel, New York City, that Mr. C. C. Rosenberg (Signal Engineer, Lehigh Valley R.R.), presented a motion to change the name of the organization from the "Railway Signaling Club" to the "Railway Signal Association." This motion was not acted on until the Annual Meeting was held in the Wayne Hotel at Detroit, Mich., November 10 and 11. Thus it was that the Railway Signaling Club became the Railway Signal Association on November 10, 1903, through the formal adoption of Mr. Rosenberg's original motion. The first officers elected for the new Association were: President, J. C. Mock (Electrical Engineer, Detroit River Tunnel Co.); Vice-President, Lawrence Griffith (Vice-President, Federal Ry. Signal Co.); Secretary-Treasurer, B. B. Adams (Editor, *Railroad Gazette*); Member of Executive Committee, L. R. Clausen (Signal Engineer, C. M. & St. P. R. R.).

In the Great Northern Hotel, Chicago, Ill., on March 8, 1904, the date of holding the Annual Meeting was changed from November to October and amendments to the By-Laws, as proposed at the January 12 meeting, were adopted. Again, at the Annual Meeting held at Niagara Falls, N. Y. October 10-12, 1905, it was proposed by Messrs. Rosenberg and Peabody on October 11 that the Constitution be amended so as to provide for two vice-presidents, one to be located in the East and the other to be from the West. This amendment was adopted at the January 9, 1906 meeting held in New York City and Mr. A. H. Rudd was elected as the new Vice-President. It was at the Niagara Falls meeting where the members felt that the Constitution and By-Laws then in effect should be completely revised to conform to changed conditions. Accordingly, on duly adopted motion, a committee was appointed for this purpose. This committee presented a revised Constitution at the Chicago meeting on March 19, 1906. After corrections in certain paragraphs had been made, it was adopted at the New York meeting on May 8, 1906. This was amended at the following meetings: October 16, 1906, October 8, 1907, October 13, 1908, and October 12, 1909.

Changing conditions indicated the need of further revisions and at the Richmond, Va., Annual Meeting on October 11, 1910, a number of amendments were proposed and later adopted by letter ballot. These changes were effective as of January 1, 1911. One of the changes adopted was to eliminate the necessity of dividing the country into two sections which required one vice-president and one executive officer to be from each section. Another amendment changed the name of the "Executive Committee" to the "Board of Direction," while still another required the election of a Nominating Committee.

World War I

The next major change in the "laws" of the Association was made after the railroads were taken over and operated by the government during World War I. The Railway Signal Association Constitution was replaced by government approved Regulations for the Signal Division of the American Railroad Association as of March 16, 1919. These Regulations were formally approved by those present at the first meeting of the Signal Division held in the Auditorium Hotel, Chicago, Ill., on March 17, 1919. And again the name of the original Railway Signaling Club was due for a change.

On May 2, 1918, a conference of presidents of voluntary railroad organizations was held at 75 Church Street, New York, N. Y., at the call of Acting President Thompson of the American Railway Association to comply with the request of the Director General that the several associations be amalgamated to form one congress of associations. After this meeting, the Board of Direction of the Railway Signal Association with eleven other representative members, held a conference at Chicago, Ill. on May 9 and 10, 1918, at which a plan was outlined and submitted to the joint conference of the several railroad organizations. On January 10, 1919, the Director General of Railroads issued

Order No. 70 to provide, during the period of Federal Control, a responsible channel through which he could obtain recommendations for bettering railroad practices.

This order changed the name of the "American Railway Association" to the "American Railroad Association" and its scope was enlarged so as to include the Railway Signal Association along with other organizations. It was on February 24, 1919, that the Board of Direction, in compliance with Order No. 70, passed a resolution terminating the affairs of the Railway Signal Association, effective at midnight, February 28, 1919, and transferring the activities of the Association to the American Railroad Association and all memberships were transferred to the Signal Division of the A.R.A. As a result of a letter ballot by railroad members, returned October 1, 1920, the title of the American Railroad Association was changed to American Railway Association and the Signal Division was changed to Signal Section. This was not a change in organization but was merely a method of identification in the A.R.A.

On October 12, 1934, the Signal Section, A.R.A. became the Signal Section of the Association of American Railroads, Operations and Maintenance Department, Engineering Division.

Early Activities and Dark Days

It may be said that the formation of this organization was directly the result of Chicago being the railroad capital of the nation. It was here where the complications introduced by crossings, junctions, etc. were perhaps unlike the conditions in any other city in the United States. Signaling devices were necessary and the applications of these usually resulted in a variance of specifications and practices both confusing and, in some instances, perhaps misleading. At that time, signal work was, in most cases, in charge of persons having other duties to perform. When a question of signaling came up it was handled as best it could be with the knowledge possessed by the person in charge or on information he could obtain from manufacturers of signal appliances. As a natural sequence, the idea of an organization developed among those whose duties brought them into direct contact with each other; its purpose being to unify practice and to provide for an exchange of views on signal problems.

During the first 5 years of the organization, its existence, at the best, was precarious. The year 1898 was the blackest, it being a question as to whether the Club would continue to function. At a meeting held at the Hotel Lafayette, Philadelphia, Pa., on February 21, 1899, Acting President W. H. Elliott, in his opening address announced that the Secretary was missing, as well as the funds of the Club and that there were some unpaid bills for which he evidently had no funds. Mr. Elliott then put the question: "Shall the Club disband or shall it continue?" The 35 members present decided that each member would advance a pro rata amount to cover unpaid bills and that the Club would continue as an organization. This was the turning point as from that time on greater interest was manifested by the membership with the result that today (1953) the Signal Section, Association of American Railroads, is the authoritative body in this field of engineering, with a membership of about 2,300.

It was at the 19th Annual Convention, held at Hotel Champlain, Bluff Point, N. Y., September 22-24, 1914, that Mr. A. H. Rudd, referring to the dark days of 1898, said: "It has been brought to my attention within the last two or three days, as a historical fact, that at that Philadelphia meeting, while the members pledged to take care of the expense pro rata, the expense was largely borne by one man, Mr. A. M. Keppel, Jr., who is now Superintendent of the Washington Terminal. I would suggest the Secretary look into that, and if that is true, that Mr. Keppel be given due credit for it. I have understood he saved the Association at that time when he could ill afford to do so, by going into his own pocket for the funds." The Secretary acknowledged Mr. Rudd's statement to be a fact and Mr. Keppel was given due credit for the personal interest he took in the Association at that time which made it possible for its continued existence and the work it has accomplished since then. It was at the Philadelphia meeting in 1899, that Mr. Keppel, then Supervisor of Signals, Pennsylvania R.R., was elected President of the Railway Signaling Club and Mr. W. H. Elliott a member of the Executive Committee.

The Establishment of Work by Committees

The original idea of the members of the Club was to have papers on signaling prepared for presentation at the meetings. These papers were of an instructive nature and were open for discussion, but early records show that no definite action was taken. However, at the second meeting of the Club at Dearborn Street Station, Chicago, Ill., on April 9, 1895, two committees were appointed whose activities were of historical importance. Messrs. H. D. Miles, H. R. Nixon and H. M. Sperry were appointed a committee to formulate a Standard Code of Rules for the Operation and Maintenance of Interlocking Plants. Messrs. W. B. Turner, W. H. Elliott, H. C. Wilson, J. W. Peck and G. M. Basford were appointed a committee to investigate the question of colors for night signaling. The results of the work of these two committees have been discussed previously.

While the preparation of papers was considered to be of some value, it was thought that they mostly expressed the opinion of the individual. And so we find that, in 1903, it was decided that other procedures should be adopted for reaching definite conclusions which would give to members a uniform method of installing and maintaining signals. It was agreed that committees should be appointed on different subjects to prepare specifications, general and detail, for the different classes of signaling, as well as standard designs. The committee reports were to be discussed at the Stated Meetings and after definite conclusions were reached, the reports were to be presented at the Annual Convention for adoption as recommended practice. Later, so as not to limit the approval to only those attending the convention, the letter ballot was introduced, which gave all Active Members an opportunity to vote on all subjects presented for such action.

The work accomplished and approved has been published as a Manual of Recommended Practice. This Manual is of the loose-leaf type and so arranged that the subject-matter can be kept up-to-date at all times by the addition of new material approved, or by substituting all or in part any subject which had been approved by annual letter ballot. The Association also prepared a volume, "Index to Signal Literature," in addition to its yearly proceedings. The "Index" was a ready reference book for locating any subject on signaling published in the technical journals.

Mrs. W. J. Eck originally prepared the Index to Signal Literature, which was published as a part of Volume I of the R.S.A. Digest of Proceedings, doing most of the work at the Library of Congress in Washington, D. C. This index was complete to April 30, 1910 and nothing further was done until 1935. Starting with 1935 a bibliography of "Applications of Electricity to Railways" has been prepared for each calendar year by the Assistant Librarian, Bureau of Railway

Economics, A.A.R., Washington, D. C. An appendix in this yearly publication is devoted to a Signaling Bibliography.

Signal Section and World War II

This nation's entrance in World War II resulted in very important changes in the activities of the Signal Section as its work had to be adapted to meet the emergencies brought about by the sudden transition from peacetime activities to the prosecution of an all-out war program. Immediately after December 7, 1941, the first thought of the officers was to determine ways and means by which the Signal Section could be of help to the railroads and the nation. Two major problems confronting the nation were: (1) the conservation of critical materials and (2) better maintenance and operation of signal systems in service to increase safety and reduce to a minimum signal failures which could cause train delays, and provide new signaling facilities on certain sections where movement of troops and war materials could be expedited by increasing track capacity.

An Emergency Specification Committee was appointed shortly after December 7, to cooperate with the officers of the Association of American Railroads in revising specifications to conserve vital war materials. These specifications were to be effective only for the duration of the war emergency. The men appointed to this Committee were: Messrs. H. L. Stanton (P. R.R.), Chairman; J. A. Beoddy (N. & W. Ry.); E. W. Reich (Reading Co.), and J. J. Corcoran (N. Y. C. R. R.). The committee members were located short distances from Washington, D. C. and near each other, better to facilitate the committee work and conferences with the War Production Board. Work was started on December 20, 1941. The Committee's suggestions in each instance were submitted to the chairmen of the standing committees who would ordinarily handle the respective subjects. After receiving standing committee approval, with revision, if any, the emergency specifications were then approved by the Signal Section Committee of Direction before being issued to the railroads.

Primarily it is the duty of the Signal Section to develop recommended practices for equipment and materials for signal systems. The war modified the Section's activities through coordination with the government's war policies and plans. The activities of the Signal Section, in cooperation with the manufacturers of railway signal apparatus, resulted in substantial savings of critical materials used in signal system apparatus, accessories, signal wire and cable, track circuit and electric propulsion bonds, primary batteries, and other items. Because of the cooperation of the railroads, acting both individually and collectively through the A.A.R., and also the cooperation of the railway supply industry, the Transportation Equipment Division of the War Production Board found it unnecessary to issue a special conservation order affecting this industry.

Conservation of Materials

Fully realizing that unsafe or unreliable signal apparatus was more dangerous than none at all, the railroads and the manufacturers of signal apparatus directed their conservation efforts along lines not affecting reliability and safety. For example, when it was practical to use a smaller gage wire, the savings in copper were substantial, as by using a 16-gage wire in place of No. 14, 4.61 pounds of copper were saved for each 1,000 feet. Using No. 14 for No. 12, the saving was 7.33 pounds; No. 14 for No. 10 resulted in a 19-pound saving while by using No. 9 wire instead of No. 6, 39.83 pounds of copper were saved per

1,000 feet. The substitution of copper-covered iron line wire for solid copper produced savings varying from 66 pounds per mile for No. 12 gage wire to 191 pounds for No. 8 gage wire and in many installations where electrical resistance was not the controlling factor, iron line wire was used, thus effecting a further saving in copper.

Based upon a survey conducted by the Signal Section, 170 tons of copper and 1,800 tons of steel were saved annually by the railroads through the use of rail head bonds in lieu of the web type or long bonds for rail bonding. Another recommendation resulted in an estimated annual saving of 300 tons of copper through salvaging exhausted primary battery elements and by making slight changes in manufacturing details. Substantial quantities of copper, brass and bronze are involved in the production of railway signal apparatus, there being between 1,500 and 2,000 items made of this material regularly carried in inventory. By the substitution of less critical materials it was estimated by two signal companies that their annual savings amounted to approximately 145 tons of copper and copper alloys based on 1941 production. Because of the substantial increase in business during the war years, this saving was probably greatly exceeded. These figures also covered only part of the industry.

Nickel, aluminum, tin and cadmium also were metals in short supply. Through the cooperation of the Signal Section and the manufacturers of railway signal equipment the substitution of less critical materials resulted in a saving annually of approximately 7,500 pounds of nickel, 30,000 pounds of aluminum, 15,000 pounds of tin, and 20,000 pounds of cadmium. In addition to the savings made of such critical materials as mentioned in the foregoing, substantial savings were made by industry in the use of other scarce materials such as rubber and chromium.

Further material savings were brought about through developments and changes in design of signal systems. Among the developments which resulted in substantial savings of material were the use of coded track circuits and the multiple use of centralized traffic control line wires.

Increased Track Capacity

Of major importance to the railroads were methods designed to increase track capacity and to provide for more expeditious movement of war traffic with safety and with a minimum use of critical materials. It was early recognized by the War Production Board that signal systems could make valuable contributions to railroad transportation and it seemed obvious that the savings in transportation time and the increased track capacity produced by signal systems were comparable in value to savings in materials which were effected by substitutions.

The War Production Board, in passing on projects, said: "The criteria therefore followed in determining essentiality for transportation projects was the usefulness of such facilities in the elimination of excessive delays in the movement of trains and in the servicing of locomotives and conditioning of rolling stock, thereby increasing the availability of equipment and making greater use of man power. While there was general recognition of the over-all importance of adequate and efficient railroad transportation to the war effort, the material situation was so acute that it was necessary to restrict expansion to the barest minimum essential to safety and efficiency in operation."

One of the principal means employed for increasing track capacity was the installation of centralized traffic control. This system increased track capacity from 50 to 75 per cent and was the most economical method as it required the least critical materials and labor. Interlocking, automatic block signaling and car retarders also produced savings in addition to the increased safety of operation. For example: the installation of an interlocking eliminated 29,400 train stops a year; a study of 12 installations of automatic block signaling showed an average saving of 5,805 freight train hours per installation per year, and represented a saving of approximately 70 minutes per trip for each train; on 10 installations of centralized traffic control, the freight train time saved averaged 1.43 minutes per train mile. One installation eliminated 46,355 train stops per year. One car retarder installation resulted in an average saving of 54 minutes on each car classified. The processing of applications for signal projects was done by the Signal Unit of the War Production Board. This processing involved a technical analysis in screening the use of critical materials.

Signal installations approved and authorized on all railroads from June 1940 through May 1945, totaled in cash approximately eight million dollars. The amount of traffic handled during the war was the greatest in the history of the American railroads. The War Production Board stated that "the traffic, measured in revenue ton-miles on the railroads of the United States, reached an over-all maximum of 121.2 per cent in 1944 over 1939; passenger revenue miles increased 322 per cent. These figures are significant to show the transportation load during the war and the need for increasing line capacity, and for obtaining greater productive use of available locomotives and rolling stock."

World War II placed the greatest burden in history on the American railroads. They were, however, in a much better position to meet the challenge than they were back in 1917 in spite of the fact that they had fewer locomotives, cars and miles of track. During the lean depression years the railroads were quietly spending millions for new equipment, additions and improvements which included centralized traffic control and other signal systems. This was one reason why, when the emergency arose, the railroads were able to meet it. This emergency called for the greatest movement of men and supplies ever known in world history. As an example, there were times when a special troop movement was started every six minutes, and a freight train loaded with vital war goods and food left some yard in the United States every four seconds.

After the war the railroads received the acclaim of the nation for a magnificent job, well done. The painstaking, careful work performed through the years by the Signal Section and its predecessors and the research and developments of those companies engaged in the manufacture of signal apparatus paid huge dividends when the emergency arose.

SECTION 14

ECONOMICS OF RAILWAY SIGNALING

The consolidation of a number of switches and signals under control of a man located at a central point was first developed in England for reasons of economy, to save the labor of switchmen. On the contrary, in America early interlockings were installed largely as a measure of safety. Gradually it began to be realized that interlocking also was an economic factor in train operation in that each stop saved for a crossing or to throw a switch produced an actual saving in dollars and cents.

In 1881, power interlocking was commercially unknown in America and automatic block signaling was in a crude state of development. Prior to 1890 progress in this field was slow because of the many obstacles to be overcome. Railway men were antagonistic, not only to power-operated switches and signals, but also toward the automatic operation of block signals.

From 1890 to 1900 a change of attitude developed. The antagonistic feeling gradually gave way to an awakening as to the possibilities of power-operated switches and signals and there began to be a realization of the great economy and safety to be derived from the use of automatically operated block signals as compared with those manually operated. This period also saw the development of the electric motor to a point where its possibilities as a means for operating switches and signals was so realized as to bring about the advent of both block and interlocking systems using electric motors as prime movers.

The organization of the Railway Signaling Club on March 11, 1895 was destined to be a very important vehicle to complete the removal of the antagonistic attitudes which formerly existed against signaling. At first, papers on signal subjects were presented by the members for discussion. The subjects mostly dealt with maintenance and operating problems. However, members were beginning to think along the lines of economics. Mr. H. M. Sperry, then agent for the National Switch & Signal Co. presented a paper at the May 11, 1897 meeting on "Some Signal Problems." Mr. W. M. Camp, Editor of the *Railway Review*, presented for discussion the question "Does the Block System Increase the Capacity of the Line?" at the May 12, 1903 meeting. Prior to this time, two other papers which contained germs of signal economics were read before the Club. One paper by Mr. V. K. Spicer, Western Agent, Union Switch & Signal Co. was titled "Success of, and Successful Automatic Signals." This was presented on November 16, 1897. The other paper "Possibilities of Three-Position Signaling" was presented by Mr. Frank Rhea, Signal Inspector, Pennsylvania Lines, West, at the November 14, 1899 Club meeting.

Further evidence of the trend of thought toward economics appeared in a paper on "Some Questions about Progress and Uniformity" presented by Mr. B. B. Adams, Editor of the *Railroad Gazette* at the November 13, 1900 meeting of the Railway Signaling Club at St. Louis, Mo. Perhaps one of the first papers to discuss the actual economics of railway signaling was that presented by Mr. J. A. Peabody, Signal Engineer of the Chicago & Northwestern Ry. at the Annual Meeting of the Railway Signal Association on October 11, 1905 at Niagara Falls, N. Y. The title of this paper was "Cost of Stopping Trains, Compared with the Cost of Maintenance, Operation and Inspection of Interlocking Plants."

Publications devoted to the railroad field were destined to play an important part in advancing railway signaling to the position it occupies today as a railroad department of major importance. Articles on economics began to appear in print from time to time with editorial comment directed to all interested railroad officers in the executive, operating and signal departments.

The signal manufacturers, recognizing the value of economics, were interested in developing statistics as to resultant savings made through the installation of railway signal systems. Accordingly, the Union Switch & Signal Co., the General Railway Signal Co., the Federal Signal Co. and the Hall Switch & Signal Co. formulated a plan under which the results of studies were to be made available to the makers of railway signals and to the railroads, and on January 1, 1917, Mr. Henry M. Sperry was appointed Publicity Representative of the new Bureau of Railway Signaling Economics for the four signal companies, with headquarters at 120 Broadway, New York City. Mr. Sperry carried out invaluable pioneer work in his investigations of the economic value of railway signaling during his service as Director of the Bureau, which continued to his death in 1933.

Following Mr. Sperry's death, Mr. W. H. Elliott who retired as Signal Engineer, New York Central Lines, Buffalo and East, on September 1, 1933, was appointed Director of the Bureau effective October 16, 1933 and remained until about September 1, 1934 when he resigned because of ill health. The work of the Bureau was then continued under the direction of Mr. B. T. Anderson until January 1, 1937 when he was appointed General Sales Manager of the Union Switch & Signal Co. Mr. Stanley E. Gillespie was the next Director, assuming his duties on May 1, 1937. The Bureau of Railway Signaling Economics was discontinued December 31, 1938, most of its material being turned over to the Secretary of the Signal Section.

Returning to the activities of the Signal Section:

On June 6, 1921 a recommendation was made which later proved to be of historic importance to those engaged in railway signaling. The third Annual Meeting of the Signal Section, American Railway Association and the twenty-sixth of the former Railway Signal Association was under way at the Drake Hotel in Chicago, Ill., when Chairman F. W. Pfleging (Union Pacific R.R.), in his opening address said, in part:

> "We have not changed, to any great extent, the method of directing train movements. Some advancement has been made, but not the advancement that efficient and economical operation demands. It is the tonnage train, kept moving, which returns interest in capital invested. This movement can be facilitated by the elimination of train orders, and by communicating the movement to be made by signal indication. This would permit the men who are responsible for the operation and direction of the train to devote more of their attention to its better movement.
>
> "Committee X—Signaling Practice has done excellent work along these lines. The support of the operating members is necessary, if satisfactory progress is to be made, and your Chairman recommends that a Joint Committee on the Economics of Railway Signaling be appointed, this committee to be similar to the present Committee on Automatic Train Control, and to consist of operating members and signal members.
>
> "The scope of its work should be, to make recommendations for the handling of traffic by signal indications; the operating of outlying switches at sidings by remote control from some distant point, and to increase efficiency and economy in the movement of trains."

As recommended by Mr. Pfleging, the Committee of Direction at a meeting on November 17, 1921 established a Special Committee on Economics of Railway Signaling. The men selected on this committee were highly qualified and greatly interested in the subject of economics; it was composed of Messrs. B. T. Anderson, D. L. & W. R.R., Chairman; F. L. Dodgson, G. R. S. Co.; J. A. Peabody, C. & N. W. Ry.; F. W. Pfleging, U. P. R.R.; W. M. Post, P. R. R.; and H. M. Sperry of the Bureau of Railway Signaling Economics. Mention should be made of this Committee because of the excellent ground work laid by it for future activities. Because of the scope of the work other members were added later, until in recent years there have been approximately 20 who represent various railroads and 9 who represent the signal industry.

The Special Committee funtioned until March 1922 when it became Committee XIX. In March 1923 it became Committee I, and still continues as such.

SECTION 15

MAGAZINE HELPS BUILD SIGNALING PRESTIGE

Elsewhere mention is made of the valuable help accorded the railway signal field in the early days of signaling and of the Railway Signaling Club, by the technical press. With a rapidly increased interest in signaling being manifested in the railroad field, the idea was conceived of starting a journal devoted to this branch of railroading. Accordingly, in 1908, such a magazine was started and through the years it has done much to help establish signaling as a major railroad department and to demonstrate conclusively its ability to provide economical train operation with speed and safety. Therefore, this history would not be complete unless brief mention be included covering the start of the magazine, its objectives and personnel.

The idea of starting a journal devoted to signaling was conceived originally on the Illinois Central R.R. while Mr. Mark H. Hovey was Signal Engineer and Mr. L. B. Mackenzie was Office Engineer. These two men organized the Signal Engineer Co., Mr. Hovey being elected President and Mr. Mackenzie, Vice-President. Mr. A. F. Klink, then President of the Bryant Zinc Co., was elected Secretary and Treasurer. The new magazine was called *The Signal Engineer,* the first issue being published in June 1908. Mr. Mackenzie acted as Managing Editor and Mr. Fred W. Bender of the Central R.R. of New Jersey was Eastern Representative.

The leading editorial of the first issue set forth the policy of the magazine as follows: "In announcing the advent of the new journal, the Signal Engineer Co. feels that it is quite unnecessary to emphasize the value of a monthly journal in the growing field of signaling. The profession has reached the stage of technical and industrial development that demands a representative publication."

The second issue of the magazine contained an editorial predicting the increased importance of signaling from an operating standpoint and offered certain suggestions as pertinent today as they were in July 1908. In part, the editorial said: "The signal engineer of the future must necessarily take rank with the more important operating officers. It is freely admitted that signaling is growing in importance yearly, and today the signal engineer occupies a very important position, not only with respect to maintenance and construction, but to operating matters as well. However, he is going to become more closely affiliated with the operating department as the mileage of signaling and the number of interlocking installations increases, and when railroads reach a point where practically their entire mileage is signaled, the question will have assumed such a serious aspect that the signal engineer will become of necessity an important operating officer."

In August 1908, Mr. Hovey sold his interest in the company and Mr. Mackenzie became President. It was in June 1909 that the name of the company was changed to the Mackenzie-Klink Publishing Co. "The Signal Engineer" publication was then purchased by "The Railway Gazette, Inc." in June of 1910 where it remained until January 1912 when the Simmons-Boardman Publishing Co. (now the Simmons-Boardman Publishing Corp.) was organized to combine "The Railway Gazette, Inc." with other railroad magazines, including the "Railway Age." "The Signal Engineer" formed a unit in the new organization and has continued as such, under changes of name, since that time.

Changes of Name

Changing conditions in the field during the years resulted in a change of names in order that its title would express more completely the functions of the paper in serving its readers. When "The Signal Engineer" was first established the railroads were extensively engaged in the installation of single track automatic signals, and power interlocking was being installed more generally at many locations where mechanical interlocking only would have been considered before. This period may be referred to as the engineering period, as signal work was largely in connection with improving existing apparatus as well as making extensions of the systems. The publication's name thus described adequately the field covered. The first change in name appeared with the publication of the January 1916 issue which carried on its masthead "Railway Signal Engineer." This title more clearly defined the particular field it served.

Between 1916 and 1923 the railways were called on to handle an ever increasing amount of traffic and it was imperative that every logical means be used to speed up train movements with safety, and signal systems had demonstrated their ability to be of major assistance. The changing conditions broadened signal department work to such an extent that this department was called on to assist in the solution of many operating problems. So that the title again would express more completely the functions of the paper in serving its readers, it appeared desirable to change to "Railway Signaling" with the September 1923 issue and this name was retained for over a quarter of a century. During this time train communication and other modern communication systems came into use and were largely under the jurisdiction of the signal departments. And, with the January 1949 issue the name was expanded to "Railway Signaling and Communications" with the editorial content broadened to include more information on railroad telegraph and telephone practices and equipment.

Personnel

As previously mentioned, Mr. Mackenzie acted as the first Managing Editor with Mr. Fred W. Bender as Eastern Representative. In January 1909 the editorial staff was increased with the appointment of Mr. A. D. Cloud as Associate Editor in which position he remained until he was appointed Editor in February 1910 with Mr. Mackenzie still retaining the title of Managing Editor. With the May 1910 issue, the masthead carried the name of Messrs. A. F. Klink as President and A. D. Cloud as Editor. After the purchase of "The Signal Engineer" by "The Railway Gazette" in 1910, the staff was made up of Messrs. Samuel O. Dunn, Editor; B. B. Adams, Consulting Editor; A. D. Cloud, Managing Editor; H. H. Simmons, Associate Editor; L. B. Mackenzie, District Manager until February 1911 and Fred W. Bender, Eastern Representative.

From June 1908 to 1950 a total of 28 persons have served on the editorial staff in various capacities including representatives in Great Britain, Europe and Washington, D. C. All these people to a greater or lesser extent have contributed to the progress made in railway signaling during the years. The publicity accorded this branch of railroad work has been instrumental in obtaining that respect for the profession which was lacking in the early days. In passing, mention should be made of Mr. B. B. Adams who acted as Consulting Editor from June 1910 to November 1911, inclusive, and as Associate Editor from December 1911 to December 1936. Through the years he worked constantly to place railway signaling in the position he felt it so well deserved. As an Editor and as a member of the first Block Signal and Train Control Board he was in an enviable position to keep abreast and ahead of the field.

The policy of any publication is largely dictated by the editor and upon his judgment and foresight largely depends the success of a magazine. An editor must be enthusiastic in his work and believe in his field of endeavor to promote beneficial conditions. This appears to have been true of the eight men who for the past 45 years have served as editors or managing editors of "The Signal Engineer," known today (1953) as "Railway Signaling and Communications." Those men were Messrs. L. B. Mackenzie; A. D. Cloud; S. O. Dunn; R. H. White; K. L. VanAuken; H. H. Simmons; K. E. Kellenberger, and the present Editor, J. H. Dunn. The results of their endeavors are a matter of record. This journal, dedicated to the railway signal field, should continue through the years to influence the continued development of the art, working in cooperation with the railroads, the Signal Section, the manufacturers and all of those interested in the subject of railway signaling and safety of operation on our railroads.

SECTION 16

OFFICERS OF FORMER YEARS

RAILWAY SIGNALING CLUB—March 11, 1895, to November 10, 1903

Year	President	Vice-President	Secy.-Treasurer
1895	W. J. Gillingham, Jr.†	H. D. Miles	G. M. Basford†
1896	W. J. Gillingham, Jr.†	H. D. Miles	G. M. Basford†
1897	W. J. Gillingham, Jr.†	H. D. Miles	E. M. Seitz
1898	G. D. Fowle†	W. H. Elliott†	E. M. Seitz
1899	A. M. Keppel, Jr.	J. Cargill	C. O. Tilton
1900	A. M. Keppel, Jr.	C. C. Rosenberg†	C. O. Tilton
1901	C. C. Rosenberg†	S. E. Denny	C. O. Tilton
1902	C. C. Rosenberg†	C. A. Dunham†	C. O. Tilton
1903	H. C. Hope†	J. C. Mock	B. B. Adams†

RAILWAY SIGNAL ASSOCIATION—November 10, 1903, to March 1, 1919

1904	J. C. Mock	L. Griffith	B. B. Adams†
1905	J. C. Mock	L. Griffith C. H. Morrison†	H. S. Balliet†
1906	C. H. Morrison†	J. A. Peabody† A. H. Rudd†	H. S. Balliet†
1907	J. A. Peabody†	A. H. Rudd† L. R. Clausen	C. C. Rosenberg†
1908	A. H. Rudd†	L. R. Clausen H. S. Balliet†	C. C. Rosenberg†
1909	L. R. Clausen	H. S. Balliet† C. E. Denney	C. C. Rosenberg†
1910	H. S. Balliet†	C. E. Denney C. C. Anthony†	C. C. Rosenberg†
1911	C. E. Denney	C. C. Anthony† B. H. Mann†	C. C. Rosenberg†
1912	C. C. Anthony†	B. H. Mann† F. P. Patenall†	C. C. Rosenberg†
1913	B. H. Mann†	F. P. Patenall† T. S. Stevens†	C. C. Rosenberg†
1914	F. P. Patenall†	T. S. Stevens† W. J. Eck	C. C. Rosenberg†
1915	T. S. Stevens†	W. J. Eck C. A. Dunham†	C. C. Rosenberg†
1916	W. J. Eck	C. A. Dunham† W. H. Elliott†	C. C. Rosenberg†
1917	C. A. Dunham†	W. H. Elliott† R. E. Trout	C. C. Rosenberg†
1918	W. H. Elliott†	R. E. Trout C. J. Kelloway†	H. S. Balliet†

AMERICAN RAILROAD ASSOCIATION, SIGNAL DIVISION, SEC. II—ENGINEERING—March 1, 1919 to October 1, 1920

Year	Chairman	First Vice-Chairman	Second Vice-Chairman	Secretary
1919	R. E. Trout	C. J. Kelloway†	F. W. Pfleging†	H. S. Balliet†
1920	C. J. Kelloway†	F. W. Pfleging†	F. B. Wiegand†	H. S. Balliet†

† Deceased.

AMERICAN RAILWAY ASSOCIATION, SIGNAL SECTION, DIV. IV—ENGINEERING—October 1, 1920 to October 12, 1934

Year	Chairman	First Vice-Chairman	Second Vice-Chairman	Secretary
1921	F. W. Pfleging†	F. B. Wiegand†	C. A. Christofferson†	H. S. Balliet†
1922	F. B. Wiegand†	C. A. Christofferson†	B. T. Anderson†	H. S. Balliet†
June 1922-March 1923	C. A. Christofferson†	B. T. Anderson†	W. M. Vandersluis	H. S. Balliet†
1923	B. T. Anderson†	W. M. Vandersluis	W. M. Post	H. S. Balliet†
1924	W. M. Vandersluis	W. M. Post	A. H. McKeen†	H. S. Balliet†
1925	W. M. Post	A. H. McKeen†	C. H. Tillett	H. S. Balliet†
1926	A. H. McKeen†	C. H. Tillett	C. F. Stoltz†	H. S. Balliet†
1927	C. H. Tillett	C. F. Stoltz†	H. W. Lewis†	H. S. Balliet†
1928	C. F. Stoltz†	H. W. Lewis†	P. M. Gault†	H. S. Balliet†
1929	H. W. Lewis†	P. M. Gault†	A. H. Rice†	H. S. Balliet†
1930	P. M. Gault†	A. H. Rice†	H. H. Orr	H. S. Balliet† R. H. C. Balliet
1931	A. H. Rice†	H. H. Orr	J. E. Saunders†	R. H. C. Balliet
1932	H. H. Orr	J. E. Saunders†	H. G. Morgan	R. H. C. Balliet
1933	J. E. Saunders†	H. G. Morgan	G. H. Dryden	R. H. C. Balliet
1934	H. G. Morgan	G. H. Dryden	E. G. Stradling	R. H. C. Balliet

ASSOCIATION OF AMERICAN RAILROADS, OPERATIONS AND MAINTENANCE DEPARTMENT, ENGINEERING DIVISION, SIGNAL SECTION—October 12, 1934 to date

Year	Chairman	First Vice-Chairman	Second Vice-Chairman	Secretary
1935	G. H. Dryden	E. G. Stradling	B. J. Schwendt†	R. H. C. Balliet
1936	E. G. Stradling	B. J. Schwendt†	E. P. Weatherby	R. H. C. Balliet
1937	B. J. Schwendt†	E. P. Weatherby	J. S. Gensheimer†	R. H. C. Balliet
April 6, 1938-Dec. 31, 1938	E. P. Weatherby	J. S. Gensheimer†	H. G. Morgan	R. H. C. Balliet
1939	E. P. Weatherby	J. S. Gensheimer†	G. K. Thomas	R. H. C. Balliet
1940	J. S. Gensheimer†	G. K. Thomas	C. A. Taylor* J. J. Corcoran**	R. H. C. Balliet
1941	G. K. Thomas	J. J. Corcoran	S. W. Law	R. H. C. Balliet
1942	J. J. Corcoran	S. W. Law	J. P. Muller†	R. H. C. Balliet
1943	S. W. Law	J. P. Muller†	S. E. Noble	R. H. C. Balliet
1944	J. P. Muller†	S. E. Noble	E. W. Reich†	R. H. C. Balliet
1945	S. E. Noble	E. W. Reich†	L. B. Porter	R. H. C. Balliet
1946	E. W. Reich†	L. B. Porter	J. A. Beoddy	R. H. C. Balliet
1947	L. B. Porter	J. A. Beoddy	L. S. Werthmuller	R. H. C. Balliet
1948	J. A. Beoddy	L. S. Werthmuller	W. S. Storms	R. H. C. Balliet
1949	L. S. Werthmuller	W. S. Storms	D. W. Fuller	R. H. C. Balliet
1950	W. S. Storms	D. W. Fuller	E. S. Taylor†	R. H. C. Balliet
1951	D. W. Fuller	E. S. Taylor†	R. W. Troth	R. H. C. Balliet
1952	E. S. Taylor†	R. W. Troth	W. N. Hartman	R. H. C. Balliet
1953	R. W. Troth	W. N. Hartman	T. W. Hays	R. H. C. Balliet

* January 1-May 22, 1940.
** May 22-December 31, 1940.
† Deceased.

SECTION 17

ACKNOWLEDGMENT

The preparation of this Chapter was started in 1926 under the supervision of Committee V—Instructions, Mr. J. S. Gensheimer, Chairman. The completion of the work in 1953 is presented by the Special Committee on Education and Training of Signal Department Employees, Mr. B. F. Dickinson, Chairman.

Acknowledgment is given herewith for the very valuable assistance that has made this Chapter possible, as follows:

1. To Mr. H. S. Balliet (deceased), Secretary of the Signal Section for 16 years, who gathered information for many years and placed it in chronological order.

2. To Messrs. J. P. Coleman (U. S. & S. Co.), deceased; J. S. Hobson (U. S. & S. Co.), deceased; H. M. Sperry (G. R. S. Co.), deceased; B. T. Anderson (U. S. & S. Co.), deceased; K. E. Kellenberger (U. S. & S. Co.); A. G. Moore (G. R. S. Co.); and many others who have contributed valuable data from time to time.

3. To the Union Switch & Signal Co. for the technical assistance of Messrs. K. E. Kellenberger and A. W. Fisher in preparing the text, supplying many of the illustrations and developing and editing the arrangement in its final form. Also, for the line drawings by Mr. R. G. Scholler illustrating the very early developments of railway signaling.

4. To the General Railway Signal Co. for the technical assistance of Mr. A. G. Moore in the preparation of historical data and for providing many of the illustrations.

SECTION 18

CHRONOLOGICAL

1832 The New Castle & Frenchtown R.R. installed the first fixed signal system in America. A ball or spherical shaped object was suspended from a mast about 30 feet high, and was known as a "ball" signal. The masts were located about 3 miles apart.

1840 The "ball" signal of the New Castle & Frenchtown R.R. was superseded by a red metal disc, four feet in diameter, with "Danger" painted on it.

1842 As early as 1842, the safety, efficiency and economy of operating trains by signals was set forth by Sir William Fothergill Cooke, of England, an accomplished electrical engineer, in his book, "Telegraphic Railways."

1843 Interlocking had its inception in a crude mechanical machine put into use at Bricklayer's Arms Junction, England, to operate switches and signals from a central point by levers with pipe or wire connections.

The Eastern Railroad Co. installed a ball signal to provide for train operation by signal indication over gantlet tracks through the 1295-foot tunnel, Salem, Mass.

1844 The Morse code electric telegraph was successfully introduced on May 27 when a message was transmitted over a 40-mile line from Washington, D. C., to Baltimore, Md.

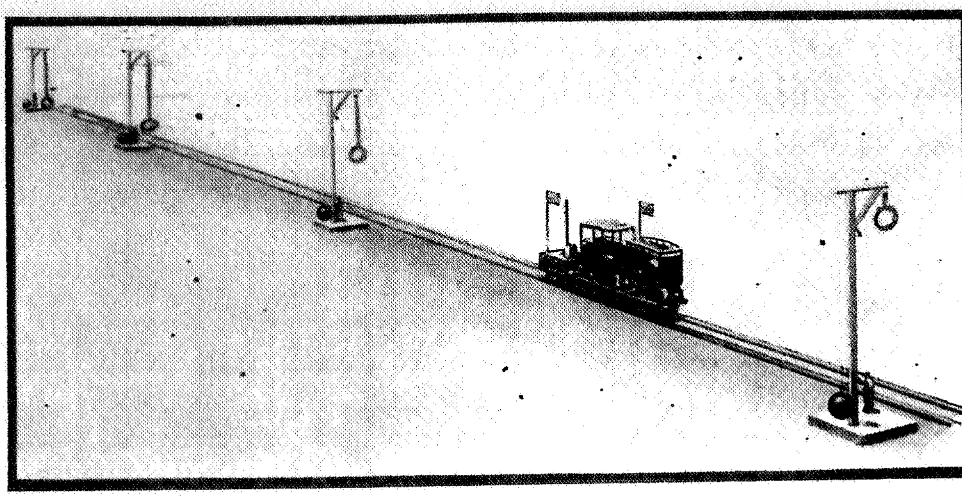
1851 Morse code electric telegraph first used in train operation for the sending of train orders. First telegraphic train order was given by Mr. Charles Minot, Superintendent, New York & Erie R.R., on September 22, and shortly afterward became the adopted practice over the entire railroad. In combination with the Morse code for dispatching trains, metal banner signals were used, attached to short sticks and hung at the window of train order offices. A monument, dedicated to Mr. Charles Minot, commemorates this event and is located at Harriman, N. Y.

The Western & Atlantic R.R. used metal banner signals similar to the New York & Erie R.R. train order signals, for manual block signals.

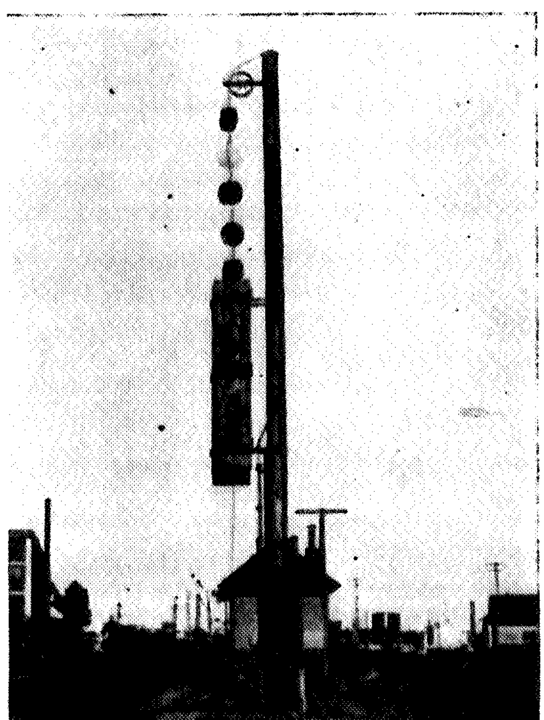
1852 At a grade crossing of the New England and New Haven Railroads, there was in use a red "ball" signal. It was used under a code agreed upon by both roads to stop or permit trains to proceed.

1853 The Philadelphia & Reading R.R. installed signal towers for the purpose of giving information to approaching trains of the occupancy of the track in advance. A large metallic banner was used having four square discs or wings fastened to a shaft, hand-operated by a lever located within the tower, and was called the "strip" signal.

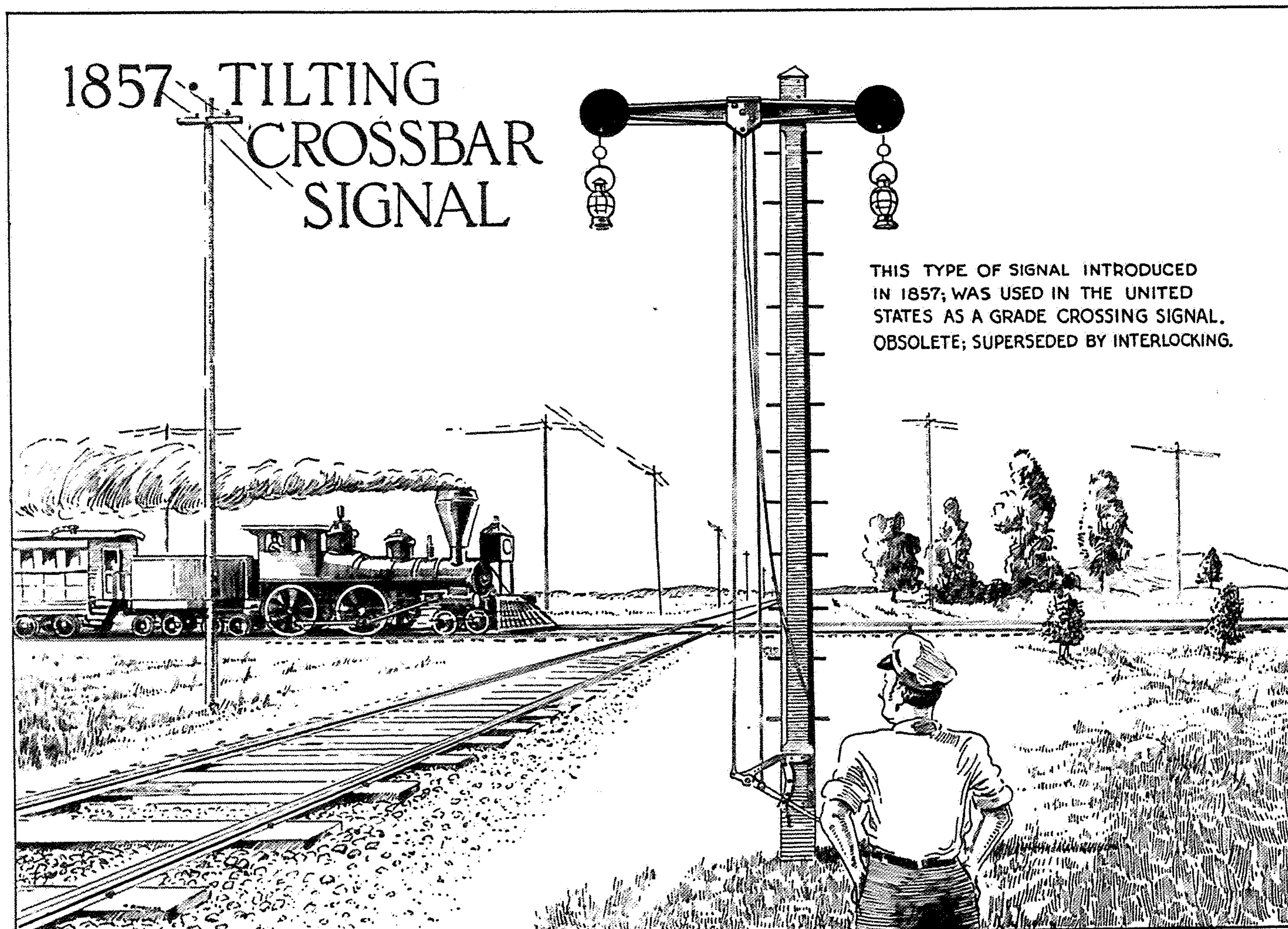
1854 The Belvidere & Delaware R.R. used signals at movable bridges which could only be displayed by the insertion of the bolt which fastened down the latch of the bridge.

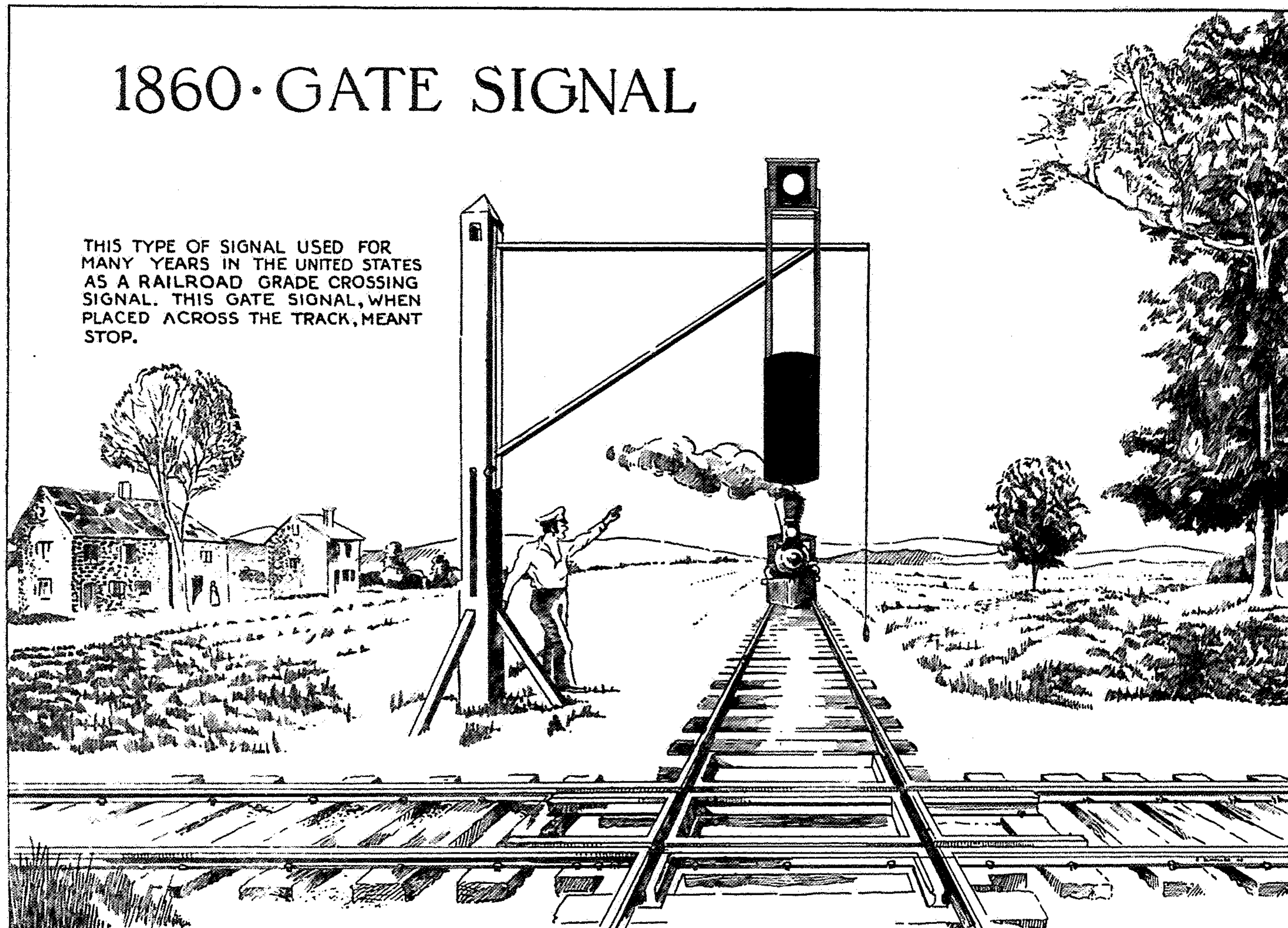


Ball signal system on New Castle & Frenchtown R.R. in 1832.



Ball signals, such as this one, on the Boston & Maine R.R., were observed from adjacent block stations by Marine telescopes.

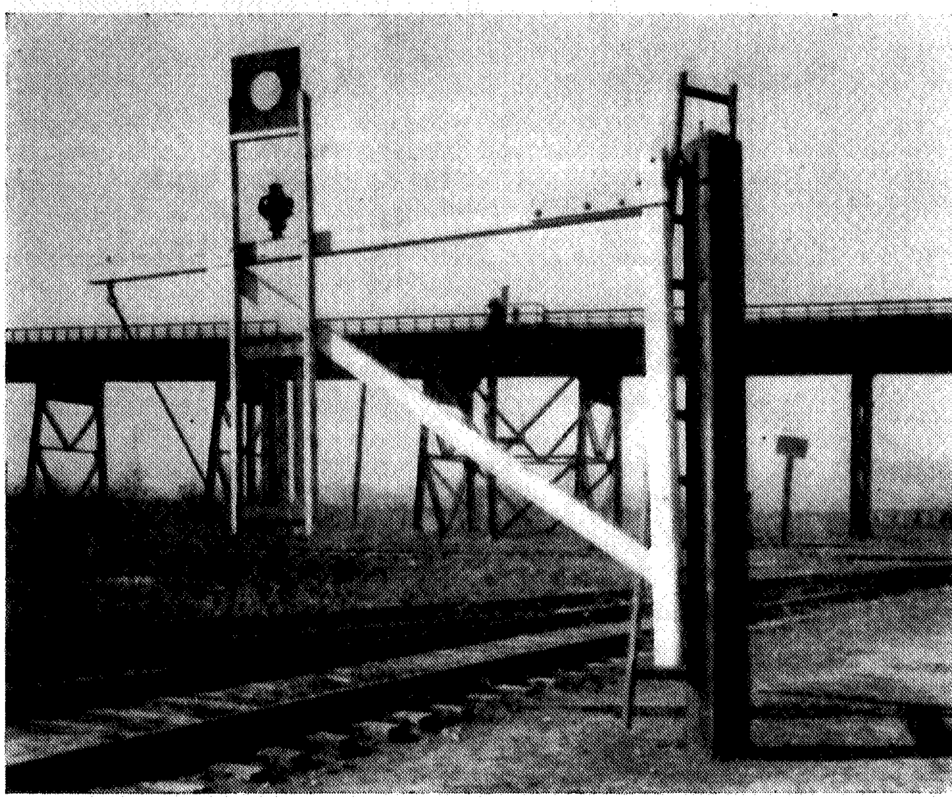

1857 · TILTING CROSSBAR SIGNAL
THIS TYPE OF SIGNAL INTRODUCED IN 1857; WAS USED IN THE UNITED STATES AS A GRADE CROSSING SIGNAL. OBSOLETE; SUPERSEDED BY INTERLOCKING.


1860 · GATE SIGNAL
THIS TYPE OF SIGNAL USED FOR MANY YEARS IN THE UNITED STATES AS A RAILROAD GRADE CROSSING SIGNAL. THIS GATE SIGNAL, WHEN PLACED ACROSS THE TRACK, MEANT STOP.

1855 The Michigan Southern & Northern Indiana R.R. and the Erie & Kalamazoo R.R. used, at railroad grade crossings and at yard entrances, the crossbar, sometimes called the pole target, and at other times the tipple board signal.

1857 Tilting crossbar signal used in the United States as a grade crossing signal.

1860 Beginning in 1860, at locations where a railroad crossed another railroad at grade, barriers (called gate signals) were used. The stop indication only, was displayed, by placing on top of the gate, for day indications, a red banner, red disc or red flag; and at night a red light.



A gate signal protecting a crossing. (1860)

At a crossing of the New England R.R. with the New Haven R.R., a train order signal was in use having a pivoted blade attached to a post suspended from the side of a building. The blade was painted red and had a white vertical stripe near one end; at the other end there was inserted a red glass. This was a two-position upper right-hand quadrant signal, working from horizontal to 45 degrees.

1862 The Rousseau enclosed disc type of clockwork signal, with the mechanism enclosed within a case at the top of the mast, was introduced.

1863 The Utica & Black River R.R., a single-track line, had in use a system of signals where two semaphore arms were mounted on the same mast, one for each direction. There were three glasses in each spectacle. The indications displayed were: arm inclined downward, and at night a white light, "Proceed;" arm horizontal, and at night two red lights, "Stop."

The first manual block signal system in America, using the space interval method of operation, was placed in service in 1863 on the United New Jersey Canal & Railroad Co. between Kensington, Pa. (Philadelphia) and Trenton, N. J. Banner box type signals were used.

1864 The Belvidere & Delaware R.R. had in use the balloon train order signal. This was a balloon-shaped container, suspended from a gallows, which was used to hide a lantern when it was not intended to stop the train; the lantern, when lowered so that it could be seen, indicated the train was to stop for orders.

The New Haven R.R. and the Hudson River R.R. installed Hall enclosed disc signals, top-of-mast type, operating under certain principles of the Morse electric telegraph instrument.

1866 The first automatic electric block system in America was installed on the New Haven System at Meriden, Conn. Hall enclosed disc signals, open circuit, were operated by track instruments.

The Philadelphia & Trenton R.R. crossed at grade, the tracks of the Philadelphia & Reading R.R., and used a signal consisting of a fixed cylinder with openings through which light indications would be displayed in four directions.

The Stead design of disappearing semaphore arm was invented. It was a mechanical device consisting of signals on stands, not interlocked, with a red light displayed for the "stop" indication and a white light for the "go" or "safe" indication.

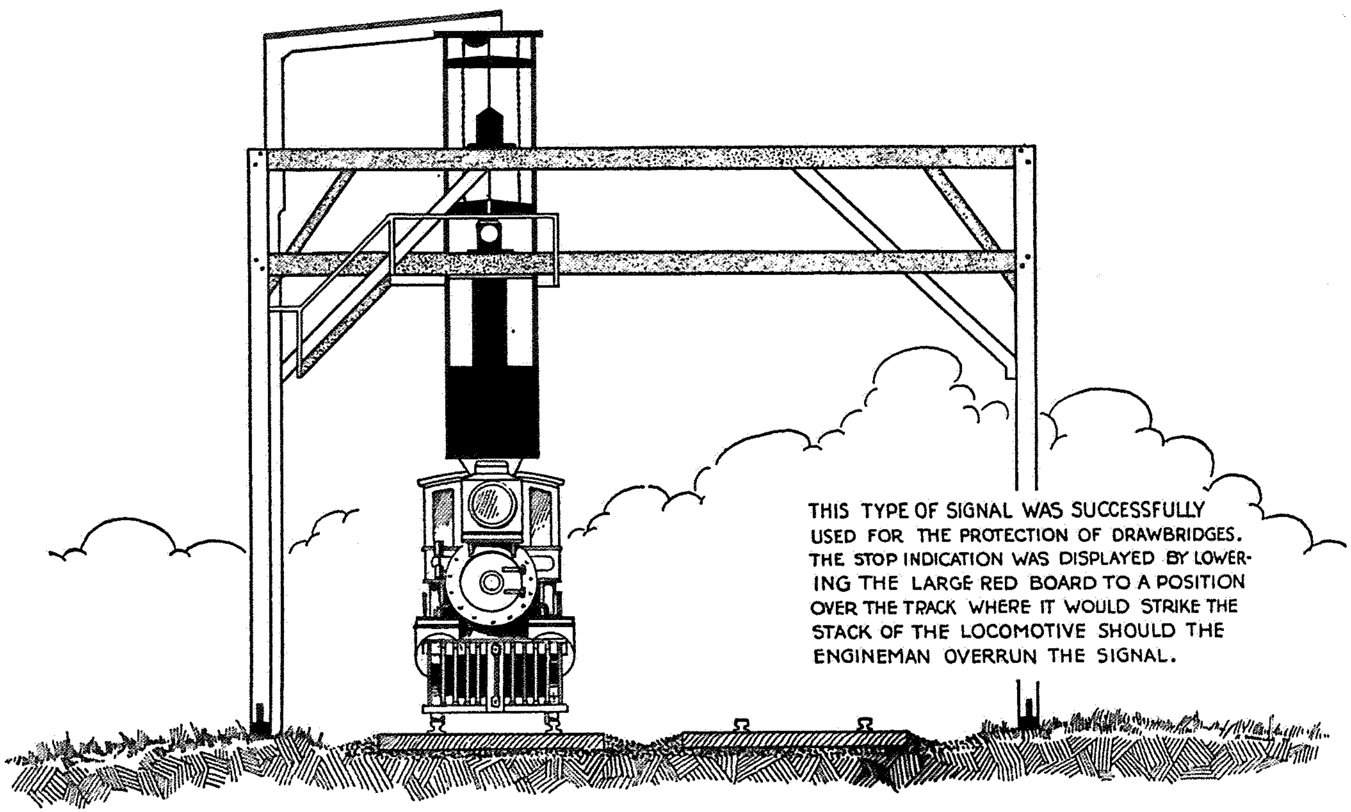
1868 A form of block signal was used on the Hudson River R.R. having a high mast with a pulley attached on or near the top. A rope was run through the pulley so that a man could raise or lower a red flag.

A smashboard signal was in use at a movable bridge (drawbridge) on the Belvidere & Delaware R.R. and also on the New Haven R.R. It was a device which was lowered and so placed across the track as to form an obstruction to the passage of trains or cars. It was lowered or raised by the bridge operator by means of a rope.

There was in use on the Pennsylvania R.R. a type of train order signal which was under the control of the train dispatcher who could set it in the stop-danger position at any station however distant from the dispatcher's office. The control of the signal was provided through a selective device which was operated over the regular Morse telegraph circuit.

1869 The Stewart train order signal was invented by Phelps and Stewart. It was an electric motor device and displayed a flag when a train was to be stopped for train orders.

1868 •• SMASHBOARD DRAWBRIDGE SIGNAL



1870 The Robinson clockwork enclosed disc signal was in use on the Western New York & Pennsylvania R.R. This installation operated on what is known as the open circuit principle, *i.e.*, there were circuit closing instruments at each signal in proximity to the track, actuated by the wheels of a train. The action of the wheels on this instrument at a point in advance of a signal closed a circuit to operate a relay to clear the signal. This relay was so arranged that once it was energized, it remained energized until the holding circuit was opened by the train passing the next instrument.

At a point where the New England R.R. crossed the New Haven R.R. at the same grade, a signal was used consisting of a revolving disc located on top of a tower.

A disappearing semaphore arm signal also known as the jack-knife signal was in use on the Auburn R.R. It provided protection on curves and for facing point switches where it was difficult to observe the presence of trains. The arm was pulled to the "Clear" position by the use of a wire, and was so constructed that normally the arm was withdrawn from view for the "Proceed" indication.

The first interlocking machine in America was installed at Top-of-the-Hill, a junction in Trenton, N. J. on the old Camden and Amboy Division of the Pennsylvania R.R. This machine was a Saxby & Farmer type employing "flop" locking of the spring-catch type and was imported from England.

1871 The earliest installation of a system of automatic block signals, comparable with present practice, were of the Hall enclosed disc type used on the New York & Harlem R.R. and the Eastern R.R.

At a grade crossing on the New York & Harlem R.R. a single enclosed disc signal of the Hall type remotely controlled by the dispatcher was used to protect traffic.

The New York & Harlem R.R. installed at a movable bridge the Hall enclosed disc signal, smashboard and bells. When the disc signals were in the stop position the bell rang continuously. The smashboard was a heavy plank and was controlled by the bridge tender by means of levers and cables. The controlling devices were interlocked with the bridge rails in such a manner as to guarantee the continuity of the rails whenever the smashboard was not displayed.

The Fogerty semaphore type of train order signal was invented. Colored glasses placed in a separate receptacle, and moved by a connection with the semaphore arm, were used to display the indication. It was a gas-lighted device.

A hydraulic pressure device, otherwise known as a pneumatic signal, was invented by Messrs. Schnabel and Henning of Germany.

Tisdale invented a time interval signal which consisted of a horizontal, liquid-charged tube equipped with vertical piston cylinders upon the rods of which were placed signals. The rods were operated by a track instrument or treadle.

Dr. Wm. Robinson used levers actuated by car wheels to open or close a direct current relay circuit in a model exhibiting his wire or open-circuit signal system in New York City (1870), and installed such a circuit at Kinzua, Pa. on the Philadelphia & Erie R.R. in 1871.

1872 The 1871 lccation of Dr. Robinson's circuit (Kinzua, Pa.) was selected for the first installation of the closed direct current track circuit, invented in 1872, because it was a simple process to replace the wire control by the track circuit control. A similar installation was also made at the same time (1872) at Irvineton, Pa.

The track circuits installed at Kinzua and at Irvineton, Pa., revealed the need for some means to conduct current around rail joints, which resulted in the development of the bonding wire, invented by Dr. Robinson.

Spang patented a method for shunting the main track circuit when a car on a siding was foul of the main track; also, the first track circuit embracing a simple overlap.

A pneumatic signal operated by the pressure and suction of air was invented by Mr. Sweet.

Mr. Townsend produced a pneumatic signal which consisted of two red and two white discs provided with a lamp or lantern chamber.

The Spang type enclosed disc signal, normally at danger with an open signal control circuit, was put in use on the Philadelphia & Reading R.R.

On the New York & Harlem R.R. and the Eastern R.R., installations were made of Hall enclosed disc signals for automatic block systems similar to the 1866 installation on the New Haven R.R. Track instrument control was the same as for the Robinson disc signal installed in 1870 on the Western New York & Philadelphia R.R. In this system, after a train entered a siding and had cleared the fouling point and the switch had been restored to normal it was necessary to operate a "clearing-key" to restore the signal to the Proceed indication. Protection for a train moving out of the siding was provided by a circuit breaker attached to the main track switch which opened the signal circuit with the switch reversed. The wire circuit did not indicate the presence of a detached car or part of a train if it remained in the block, because the forward or leaving section of the train when passing the next track instrument restored the signal block behind the separated portion of the train to the Proceed indication. These signals were revised, shortly after installation, to a closed-circuit type, by the use of a "Z" armature electromagnet.

1873 Spang invented a light signal in which he used a Geisler tube to give the indication. This tube contained platinum electrodes and was filled with rarified gas which glowed when high voltage was applied.

On the Philadelphia & Erie R.R., Dr. Robinson installed a closed track circuit block which included three switches and for the first time used circuit controllers whereby a switch movement both opened the circuit to the rails and shunted the circuit to the relay. This was the first installation to provide for switch protection in closed track circuit territory.

Mr. Spang, through the use of the Robinson track circuit, designed a distant signal, controlled by a polarized wireless track circuit.

1874 The first Saxby & Farmer interlocking machines made in the U.S.A., and without preliminary latch locking, were installed experimentally at Spuyten Duyvil Jct. and at the 52nd St. crossing of the Hudson River R. R., N. Y. The installation was made by Messrs. Toucey and Buchanan.

1875 The Sykes system of controlled manual block signaling was invented by Mr. W. R. Sykes (England).

A second English built Saxby & Farmer machine was installed by the Pennsylvania R.R. at East Newark Jct., N. J. "Flop" type latch locking was used.

1876 The banner box type signal was in use on the Pennsylvania R.R. at Mantua "Y," West Philadelphia, Pa., the first power interlocking in America (Burr pneumatic type).

Rousseau enclosed disc type clockwork signals were installed at Philadelphia, Pa., by the Pennsylvania R.R.

A special Rousseau signal was installed on the New York & Harlem R.R. for use in foggy weather. It consisted of a track device which operated a whistle on the engine.

The Boston & Lowell and the Boston & Providence Railroads introduced the Robinson electro-mechanical signal for automatic blocking, controlled by direct current track circuits. This Robinson type was also in use at a grade crossing on the Boston & Providence R.R., and at a movable bridge on the Old Colony R.R. One feature consisted of a pole-changing attachment so arranged that by the movement of a cam, the polarity through a magnet was changed. When desired, the batteries were connected in the circuit so that reverse currents would be passed through the magnets every time the batteries were renewed. The polarity of the track circuit could also be changed by an electromagnetic commutator.

The Robinson type of electro-mechanical signal was used at a movable bridge at the Old Colony R.R.

Several of the Toucey and Buchanan mechanical machines were installed on the Pennsylvania R.R. during the Centennial Exposition at Philadelphia, Pa. These were replaced later with Saxby & Farmer machines having preliminary locking.

The first power interlocking in America was installed on a trial basis on the Pennsylvania R.R. It was used in connection with the handling of traffic for the Centennial Exposition at Philadelphia, Pa. and located at Mantua "Y" in West Philadelphia from 36th to 40th Streets. This interlocking was a pneumatic type designed under the patents of Mr. D. A. Burr using compressed air for control and for operation of switches, in which the air for the control was cut off after the switch had operated. This was an improvement over contemporary inventions for pneumatic systems by Mr. W. E. Prall.

The Pennsylvania R.R. block signal system was extended westward over the entire main line from Philadelphia to Pittsburgh, Pa.

Dr. Robinson used the polarity of the track circuit in his signal system in combination with an electromagnetic commutator. Dr. Robinson used one cell of battery on his track circuit.

The Pope type of direct current track circuit was exhibited at the Centennial Exposition, Philadelphia, Pa. and the rails were submerged in water to prove the efficiency and reliability of such an arrangement.

1877 The Bean atmospheric (pneumatic) type signal was used on the Old Colony R.R. as a station signal, and also for the protection of movable bridges.

1877–1878 The first important permanent installations for American-made Saxby & Farmer machines were on the Manhattan Elevated Lines of New York City with machines built by the Jackson Manufacturing Co. of Harrisburg, Pa. These machines embodied the feature of preliminary latch locking.

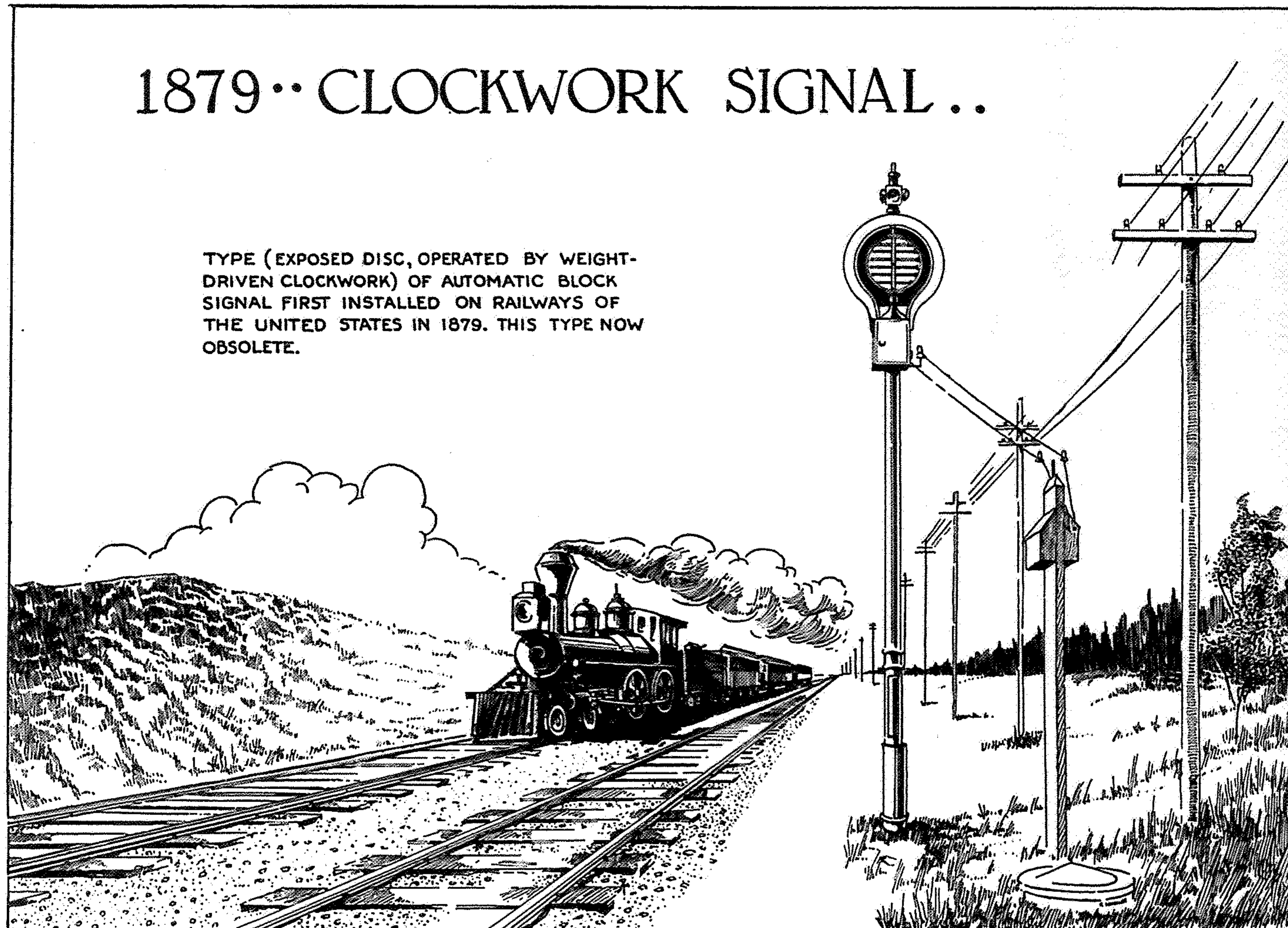
1878 The Union Electric Signal Co.'s clockwork automatic block signal was introduced on the Fitchburg R.R.

The overlapped automatic block system was introduced on the Boston & Maine R.R.

1879 The Gassett and Fisher clockwork exposed banner type of automatic block signal was put in use on the Fitchburg R.R. The direct current track circuit was used on part of the system and track treadles on the remainder to control the signals. When a train entered a track circuit, a pawl on the clockwork was released to place the signal to stop position by gravity. When the train passed off the track circuit another pawl released and a weight acted to turn the banner to the clear or proceed position. It was wound up every few days. When nearly run down a circuit was opened to place signal at stop and hold it so until it was rewound.

1879 ·· CLOCKWORK SIGNAL ..

TYPE (EXPOSED DISC, OPERATED BY WEIGHT-DRIVEN CLOCKWORK) OF AUTOMATIC BLOCK SIGNAL FIRST INSTALLED ON RAILWAYS OF THE UNITED STATES IN 1879. THIS TYPE NOW OBSOLETE.



1880 The first automatic train stop placed in trial service was on the Middle Division of the Pennsylvania R.R., using the devices invented by Messrs. Joseph Wood and A. S. Vogt. A glass tube in the train air line located on the locomotive near the rails was designed to be broken by a "track trip" set in operating position when the signals were in the stop position.

The Philadelphia & Reading R.R. used a revolving banner signal in which a three-way banner or disc was used to display the following indications: red for Stop, blue for Caution, and white for Clear. Lights of the corresponding colors were used at night.

The Old Colony R.R. installed the Pennsylvania Steel Co.'s type of top-of-mast exposed banner signal electrically controlled. The signal in automatic block territory was set about 100 feet from the blocking point so that the engineman could see it turn to the stop position. It was known as the "barber-pole" signal because the color striping of the mast resembled a barber pole.

The Lehigh Valley R.R. used the Ireland banner box type signal for switch and curve protection. The banner was drawn to the proceed position by the use of a wire rope.

The Lake Shore & Michigan Southern Ry. used the boot-jack type train order signal invented by Mr. Gravit. The blade or arm was operated with a rack and pinion movement. Night indications were displayed by moving a lamp on an elevator cage in front of the proper roundel or lens. This signal was also used for railroad crossings at grade.

1881 The first interlocking machine installed in New England was at the crossing of the New York & New England and the Old Colony Railroads at Walpole, Mass. This was the first crossing where trains were not obliged to make a full stop before crossing the tracks of another railroad. A 32-lever machine of the tappet (Stevens) pattern, manufactured by W. R. Sykes Interlocking Signal Company, Ltd. of England, was used.

The first interlocking of the hydraulic type was installed by the Union Switch & Signal Co. at Wellington, Ohio, for a crossing of the Wheeling & Lake Erie Ry. with the Cleveland, Cincinnati, Chicago & St. Louis Ry.

The Pennsylvania R.R. installed the Gassett and Fisher clockwork type of exposed disc automatic block signal between Altoona and Gallitzin, Pa.

1882 The first and only application of major importance for hydraulic interlocking, similar to Wellington, was at Relay Station, East St. Louis, Ill., for the St. Louis Bridge & Tunnel R.R. Co., just east of the portals of the Eades Bridge spanning the Mississippi River. The system operated by means of a steam-driven pump and an accumulator for maintaining a constant hydraulic pressure within a given volume of non-freezing liquid which was 75 per cent water and 25 per cent pure grain alcohol. Operation was successful for several years but in 1888 the railroad forces converted the operation to pneumatic by substituting compressed air for the liquid. This conversion was not very satisfactory due to the fact that compressed air was used for both the control and the operation of the switches and signals. The later successful operation of interlocking by compressed air was to be accomplished by its use only for operation, after the control had been perfected by the electromagnetic valve.

The Sykes type of lock and block for controlled manual block signaling, based on the original English principle, invented in 1875, was placed in use on the New York & Harlem R.R. Manufacture of this equipment as modified for use in the United States continued from this date for various railroads; for example: 440 miles on the New York Central & Hudson River R.R., 220 miles on the New York, New Haven & Hartford R.R., and 46 miles on the New York & Erie R.R. were in service by 1901.

The first installation of the Union Switch & Signal Co. electro-pneumatic semaphore type of automatic block signal was made on the Pennsylvania R.R. between East Liberty and Wilkinsburg, Pa.

The Means electro-mechanical type signal was invented and placed in use on the New York & New England R.R.

A color and position signal was used by the Boston & Albany R.R. It was made up of a semaphore arm and lights. Two white lights arranged horizontally indicated "stop;" two green lights arranged vertically indicated "proceed" or "clear."

The Louisville Bridge, Louisville, Ky., and several miles of track, approaching from the east and the west on the north side of the Ohio River, were equipped by the Pennsylvania R.R. with signals for governing traffic in either direction on each track. This was the first extensive installation for successful operation of trains by signal indication without train orders or time-table superiority.

The Rousseau and Smith clockwork enclosed disc type signal was invented and placed in use on the New York, New Haven & Hartford R.R. as a block signal.

When the Pennsylvania R.R. was completed between Philadelphia, Pa. and Baltimore, Md. the New Castle & Frenchtown R.R. and its associated steamship lines were discontinued and all the "ball" signals were abandoned except one. This one was relocated at Hurlock, Md. in 1882 for use at the crossing of the Baltimore & Eastern R.R. and the Cambridge Branch of the Pennsylvania R.R. and remained in service as a crossing signal until September 1948 when it was retired and set up for historical display purposes at Cape Charles, Va.

Last survivor of 1832 "ball" signal preserved at Cape Charles, Va., by Pennsylvania R.R., Del-Marva Division Headquarters.

Exposed disc clockwork type signal on the New York & New England R.R. (1882).

The New York & New England R.R. placed in use the Union Switch & Signal Co.'s type of clockwork exposed disc signal, a modification of the Gassett and Fisher signal. The following railroads also used it: Boston & Albany; New York, Providence & Boston; Providence & Worcester; Fitchburg; Eastern; Boston & Providence; Boston & Maine; Boston & Lowell; New York, Lake Erie & Western; West Jersey & Seashore; Baltimore & Potomac; North Central; Philadelphia, Wilmington & Baltimore; Pennsylvania; Pittsburg, Cincinnati & St. Louis; Allegheny Valley; Pittsburgh, Ft. Wayne & Chicago; and the Lehigh Valley.

Mr. John W. Thomas installed at Nashville, Tenn., a pneumatic interlocking system with mechanical valves to conserve the use of air by reusing it after each movement.

1882–1901 The J. P. Coleman lock and block instrument was in service on 44 miles of the Providence Division of the New York, New Haven & Hartford R.R.

1883 The first hydro-pneumatic interlocking was installed at Bound Brook, N. J., by the Union Switch & Signal Co., on the Philadelphia & Reading R.R. at crossing of the Pennsylvania, Lehigh Valley and Reading Railroads. Electro-pneumatic signal controls and hydraulic switch controls were used for the pneumatic operation.

The Boston & Albany R.R. installed an automatic block system in which was employed the enclosed clockwork disc signal invented by Rousseau and Smith. It was controlled by direct current track circuits.

The West Shore R.R. had in use probably the most unique train order signal. A point was selected where the train was to receive telegraphic orders and a wooden post, painted white, was placed there.

An installation of Union Switch & Signal Co. electro-pneumatic automatic semaphore block signals was made on the Fitchburg R.R.

1884 There were in use on the Central R.R. of New Jersey a number of movable bridge signals worked by a gear.

The Chicago, Burlington & Quincy R.R. placed in service 67.7 miles of three and four-track, either-direction manual block signaling.

1884–1891 In this period, 18 hydro-pneumatic interlockings using 482 levers were installed on six railroads.

1885 The Chicago, Milwaukee & St. Paul Ry. used a two-arm, two-position, lower-quadrant semaphore pipe-connected train order signal.

The banner box type (Ireland signal) was used on the Lehigh Valley R.R. as a train order signal.

The Pennsylvania and the Delaware, Lackawanna & Western Railroads used a banner box type of signal in which a red banner was displayed outside the box.

The Rousseau enclosed clockwork disc signal operated by a commutator or circuit controller under the rail, was in use at a grade crossing on the New York & Harlem R.R.

In certain terminal territories where a single semaphore signal governed to several routes, numbers were used in conjunction with the signal. The routes were designated by numbers displayed under the semaphore.

The Koyl parabolic semaphore signal was invented. This differed from other semaphore signals in that the arm was illuminated by a beam of colored light from an oil lamp to display the night indication, the color corresponding to the position of the arm.

1885–1887 The "Dutch Clock" device for establishing time intervals between trains was in use on the New York, New Haven & Hartford R.R. and the New York Central & Hudson River R.R. For manual operation it consisted of a panel mounted as close to the track as possible on which was displayed by an attendant, the number of the train passing it and the time of its passage. When operated automatically by a treadle device on the rail, the passing train released a pointer which started to move around a segmental dial in which three segments each represented 5 minutes. The pointer movement was controlled by an escapement so that it moved across the dial in a period of 15 minutes. Headway for the train ahead was thus indicated up to 15 minutes.

1885–1890 The first electric detector locking for interlocked track switches was installed by the Pennsylvania R.R. at the Pittsburgh, Pa. terminal by using depression trips to ground the indication circuit.

1886 Ramsey and Weir invented a high-voltage motor-operated semaphore signal.

The Boston & Albany R.R. had in use left-hand, lower-quadrant semaphore signals.

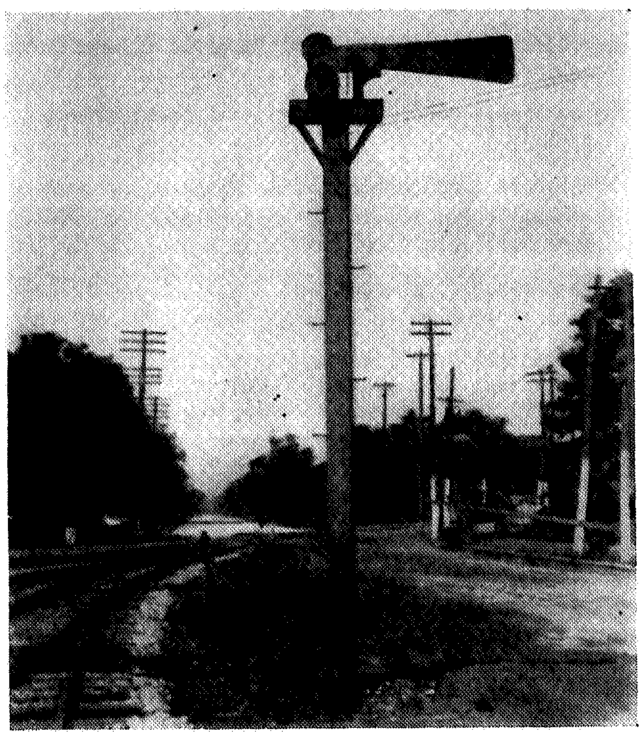
The Black type of semaphore, automatically operated and mechanically controlled by a track device resembling a detector bar, was in use on the Manhattan Elevated System, New York City.

The Cummings illuminated semaphore was a modification of other semaphores of this type in that the arm was equipped with prism reflectors.

Color position light signals were used on the Boston & Albany and the Old Colony Railroads. The indications displayed on the Boston & Albany were: home signal, two white lights horizontal, "stop;" distant signal, two green lights horizontal, "caution;" home and distant signals, two green lights vertical, "clear." Those displayed on the Old Colony were: home signal, two red lights horizontal, "stop;" distant signal, two green lights horizontal, "caution;" home and distant signals, two white lights vertical, "clear."

1887 The Cox and Black three-position, lower-quadrant semaphore signal was designed and installed on the Jeffersonville, Madison & Indianapolis Ry.

The Kentucky & Indiana R.R. had in use the Cox and Black three-position, upper-quadrant type of semaphore signal.



This Cox type of station signal, a three-position, upper-quadrant semaphore, was installed on the Kentucky & Indiana R.R. in 1887.

A semaphore signal, termed the "spiral" type, was in use on the Lake Shore & Michigan Southern Ry. It was operated by a wheel-type interlocking machine.

The Ohio & Mississippi Ry. used a center-pivoted, two-position train order signal.

On the Boston & Maine R.R. opposing train movements over Bridge 32 crossing the Deerfield River at Greenfield, Mass., were governed by signal indication, controlled by a single track circuit with a preliminary track circuit at one end. This was a single-track bridge on which a gantlet with two-track approaches had been installed in 1885. The signaling was changed in 1912 when a new two-track bridge was built.

1888 The Union Switch & Signal Co. introduced the J. G. Schreuder illuminated semaphore signal, similar to the Koyl type. In this type the lamp was stationary on the post, and so placed that the center of the flame and lens was directly in line with the center of the blade's pivot. The light from the lamp was reflected directly against a 45-degree concave reflector forming part of the blade. The reflector was so arranged as to receive and reflect the light at right angles against a long, corrugated reflector in the back of the blade in any position. Many different forms of this blade were available. Briefly, they covered, in the main, a two or three-position signal: (1) in any given position there was a beam of white light along the blade; (2) a color changing type, *i.e.*, in a two-position signal while the blade is in the stop position (horizontal), the strip presents a red or green bar of light; on arriving at the inclined safety position, a white strip of light shows. The three-position signal in the horizontal position presented a red bar of light; the inclined position of the blade (caution) showed a green strip of light; and when the blade was in the vertical, or proceed position, a white beam of light appeared.

The Rousseau and Smith enclosed disc signal, of the clockwork type, was in use on the New York, New Haven & Hartford R.R. It was controlled by direct current track circuits.

The Chicago, Burlington & Quincy R.R. operated trains by signal indication by means of a manual block system over approximately 5½ road miles of four-track line between Canal Street, Chicago and Hawthorne, Ill. This was extended in the next 7 years to cover all the 174 miles of two-track road from Aurora, Ill., to West Burlington, Iowa.

The first Ramsey and Weir electric interlocking was installed on the Cincinnati, Hamilton & Dayton R.R. at College Hill Jct. (Cincinnati), Ohio. The mechanical thrust developed in motor-driven centrifugal devices was used to impart motion to the switch or signal.

Mr. Ramsey invented an interlocking signal which was used in the Ramsey and Weir interlocking signal system at College Hill Jct. (Cincinnati), Ohio, on the Cincinnati, Hamilton & Dayton R.R. The motor was in a casing attached to the lower part of the mast.

1889 The Nashville, Chattanooga & St. Louis Ry. installed manual block sections between Chattanooga and Wauhatchie, Tenn. for train operation by signal indication only, on 4.4 miles of single track and 1.6 miles of two-track road. This operation continued until 1912 when the road became all two-track.

The fishtail semaphore signal blade which originated in England was in quite general use in America as a distant signal because of its distinctive form from all other types.

The Pennsylvania R.R. used home and distant electro-pneumatic semaphore signals. Both arms were mounted on the same mast. The distant arm was distinguished by its fishtail design.

The Union Switch & Signal Co. designed a mechanical slot to disconnect the up-and-down rod on a mechanically operated semaphore distant signal to prevent the clearing of the distant signal when mounted on the home signal mast of an adjacent interlocking.

There was in use on the Staten Island Rapid Transit Co., N. Y., an exposed semaphore signal, which was operated by a clockwork mechanism, the weight of which had to be wound every twentieth movement of the arm.

The Manhattan Elevated, New York City, had in use the gallows type of signal. This was a type of disc signal, consisting of a large sheet iron disc painted red, provided with a red lens in its center, which was made to hang vertically, in the danger position, opposite an ordinary signal lamp secured to the mast for night use; the Clear or Proceed indication was displayed by an operating rod being moved up, by crank motion, which caused the disc to disappear behind a shield.

On the Kanawha & Michigan R.R. a low switch stand type signal with two metal banners, one painted red, the other white, and a lamp similar to a switch lamp, operated by a rope, was used as a train order signal.

The first electric interlocking, employing dynamic indication, was installed at East Norwood, Ohio, at the crossing of the Baltimore & Ohio Southwestern and the Cincinnati Northern Railroads. The inventor of this system was Mr. John D. Taylor of Chillicothe, Ohio.

1890 The box type train order signal, consisting of a wooden housing in which was placed a red cloth banner which was pulled up when the "proceed" indication was given, was used on the Pittsburgh, Ft. Wayne & Chicago Ry. It was a modification of the banner box type used for a block signal on the Philadelphia & Trenton R.R. in 1863.

The New York Central & Hudson River R.R. used, for switching purposes, wooden signal masts with an opening for the arm to be pulled in to display a "proceed" indication.

The Newport News & Mississippi Valley R.R. had in use the Yarrington type of train order signal consisting essentially of four discs, three red and one white, facing the four points of the compass and attached to the ends of horizontal arms fastened to the upper end of a vertical iron rod made of 1-inch gas pipe.

The Chesapeake & Ohio Ry. used the Hudson type of semaphore signal which consisted of a semaphore arm that disappeared behind a shield rotated at right angles to the track to display the "clear" indication.

The Boston & Maine R.R. had in use the Johnson automatic time interval signal. The indication was displayed by the use of purple alcohol, visible by day or night.

A so-called semaphore signal was installed at a railroad crossing with other railroads, on the Louisville & Nashville R.R. It consisted of a square mast, at the top of which was an arm, about 2 inches wide and 4 feet long, with a 6-inch disc at the end of the arm. About 18 inches below was another arm, and a third arm was located 18 inches below the second arm. All three arms were movable by a pulley and wires similar to the way the Harrington train order signal was operated. The arms were painted white and the discs green. Green lanterns were hung on the ends of the arms. Indications: one arm horizontal, crossing clear for Road A; two arms horizontal, crossing clear for Road B; all three arms horizontal, crossing clear for Road C.

The Pennsylvania R.R. had in use the Rousseau indicator for a time interval signal. It was a device having an electromagnet which shifted a heavy pointer, suspended between two gongs, one marked "block" and the other "clear."

1891 The Buchanan polarized direct current track circuit was patented. It followed closely the patents of Spang and Pope.

The Pennsylvania R.R. put in use semi-automatic electro-pneumatic distant semaphore arm signals in terminal territory. Home and distant signals were used to control the entrance to the shed tracks at the Jersey City Terminal, N. J.

A banner type train order signal, which was operated by a rope and supported on a hollow square mast, was in use on the Baltimore & Ohio R.R. This Railroad also used the Selden-Ott signal having two arms on each side of the mast, one red and one green, normally hidden behind a shield.

The Johnson type of lock and block was installed on the New York & Harlem R.R.

The first use of an electro-pneumatic valve for control of compressed air to switch movements was made at Drawbridge, an electro-pneumatic interlocking on the Chicago & Northern Pacific Ry. in Chicago, Ill. The installation required the interlocking machine to be located on the movable draw span, which created obvious difficulties in applying hydraulic controls.

Also, the electro-pneumatic switch valve was used for the first time on the Pennsylvania R.R. for its Jersey City Terminal, N. J. interlocking installation.

After the installation of electro-pneumatic switch control in Chicago, Ill., the use of hydraulic control for pneumatic switch operation was quite generally abandoned and superseded by electromagnet control which had been used successfully for pneumatic signals since 1882.

A single-track installation of semaphore automatic block signals was in use on the Cincinnati, New Orleans & Texas Pacific Ry., using overlap control without distant signals.

A mechanically operated revolving light signal was installed in connection with the lock and block on the New York Central & Hudson River R.R.; the lamp was of French design and kerosene oil was used.

1891–1900 In this period, 54 electro-pneumatic interlockings were installed, using 1,864 levers, on 13 roads, while 18 hydro-pneumatic interlockings were installed using 482 levers on 7 roads. These interlockings used nearly 2,000 electro-pneumatic semaphore signals.

1892 Mr. Henry Johnson, President of the Johnson Railroad Signal Co., brought from England the Webb and Thompson staff machine. The staffs used were 22 inches long and weighed 7 pounds each.

Anticipating the World's Fair at Chicago, Ill., the Illinois Central R.R. installed in terminal territory, Hall enclosed disc signals. This was on an 8-track section of track, each track being thus signaled. Part of the section was controlled by track instruments and wire circuits, and the remainder by direct current track circuits.

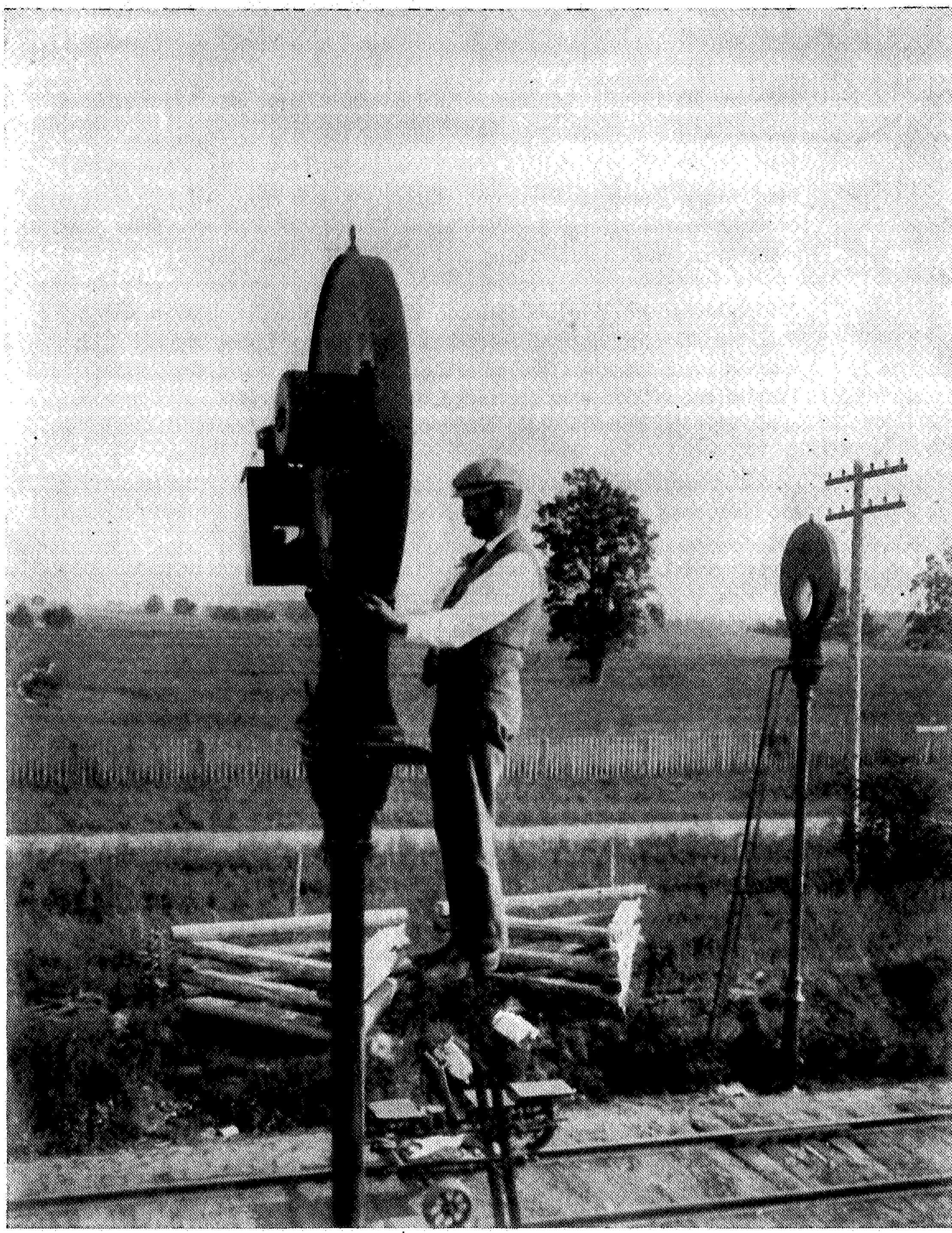
A center-suspended, mechanically operated semaphore was in use on the New York Central & Hudson River R.R.

The English type of disappearing fishtail switch signal was introduced on the New York Central & Hudson River R.R. These signals were wire-connected with a switch stand in such a manner as to pull the arm to the caution position when the switch was set for other than the main track.

The Stewart-Hall electric enclosed disc train order signal, resembling a Hall or Union banjo signal, was in use on the Central R.R. of New Jersey.

1893 The first low-voltage direct current motor-operated automatic semaphore block signals (National Switch & Signal Co., Lattig design) were installed on the Central R.R. of New Jersey in Black Dan's Cut, east of Phillipsburg, N. J. They were two-position lower-quadrant signals with the motor and driving chain outside the mast.

The Lehigh Valley R.R. installed the home and distant Hall banjo type of enclosed disc signal, both mounted on the same mast, and normally in the stop and caution position. This system was controlled by direct current track circuits and line wires extending the length of the block. The signals were set to the proceed position when a train entered the track circuit immediately adjoining the distant signal. The clearing of the distant signal was an indication that the two block sections immediately ahead were unoccupied. The home signal was set to the proceed position in the same manner, but it was in multiple with the distant signal line circuit. This system of track circuits was modified (1896) in order that irregularities produced by foreign current would be ineffective by placing at the entering track section a 16-ohm relay in multiple with the track battery (Lattig and Balliet design).



Enclosed disc signals on the Michigan
Central R.R., Niles-Kensington (1896).

The Johnson type of fishtail or notched wire-operated distant signal was introduced.

The National Switch & Signal Co. type of time space interval signal was placed in use; it was similar in design to the Johnson type (1890).

1894 A parabolic illuminated semaphore signal was introduced by the National Switch & Signal Co.

The Union Switch & Signal Co. type of enclosed disc signal was introduced.

The Philadelphia & Reading Ry. installed Hall enclosed disc automatic block signals, controlled by direct current track circuits. At interlockings these disc signals were mounted below the interlocked semaphore signals and performed the function of block signals. They were controlled through suitable circuit controllers attached to the semaphore arms to provide block information when the semaphore arm was at "proceed." The block signals were operated as a normal-danger system, and to set them to the proceed position automatically, a low resistance relay was used in series with the track battery. Switch indicators were installed.

The first installation of the Webb & Thompson staff system was made in May on the Chicago, Milwaukee and St. Paul Ry. between Savanna, Ill., and Sabula, Iowa with very satisfactory results.

1895 The National Switch & Signal Co. introduced a semaphore signal illuminated by rows of incandescent electric lights placed thereon, producing, by the operation of a commutator, a band of white light outlining the arm. An arrangement of colors to correspond with the position of the arm was also available (Lattig patents).

The Bezer signal, sometimes called the motion type, or "when I go or revolve you (the engineman) may proceed," was used on the Delaware, Lackawanna & Western R.R.

The Fontaine electric time space signal was introduced in America; it was controlled by a track treadle device.

1896 The Erie R.R. used the Mosier three-indication upper and lower-quadrant type of train order signal.

The Atchison, Topeka & Santa Fe Ry. used the Coleman three-position type of train order signal.

A permissive semaphore signal was used for signaling trains in a tunnel on the New York Central & Hudson River R.R.

The Carter distant signal was in use on the Chicago & Northwestern Ry. giving a caution indication by means of a red light horizontally beside a green light. The clear indication was green only.

There was in use at a grade crossing an arm with an outline of a hand and extended index finger, worked on a spindle and used to indicate when trains could use the crossing.

1897 The first semaphore automatic block signals, motor-operated, having the up-and-down rods which operate the semaphore arms, placed inside the signal mast, known as the Style C (Union Switch & Signal Co.) were installed on the Pennsylvania, Michigan Central, and Cincinnati, New Orleans & Texas Pacific Railroads. They were operated by direct current; the motor and mechanism were placed in a housing located at the bottom of the mast.

The Pittsburgh, Ft. Wayne & Chicago Ry. put in use the Gray type one-arm, three-position, lower-quadrant direct current electric motor semaphore. Motor and mechanism were in a case at base of mast.

1898 The Union Switch & Signal Co. Style B, Spicer patent, one-arm two-position lower-quadrant semaphore automatic block signal was first used on the Atchison, Topeka & Santa Fe Ry. This had an electric motor, operated by direct current, housed in a case forming the base of the mast. The up-and-down rod was inside the mast.

The Hall Signal Co.'s Style C motor-operated semaphore signal (Lattig patents) was installed on the Illinois Central R.R.

1899 The New York, New Haven & Hartford R.R. adopted the Baird yellow roundel for the distant signal night indication for "caution," green for "clear," and red for "stop."

The General Electric Co. (Herman patent) direct current motor-operated semaphore automatic block signal was installed on the Pittsburg, Cincinnati, Chicago & St. Louis Ry. It was a one-arm, three-position, lower-quadrant type with mechanism located at ground level, the housing being part of the mast.

The Buffalo, Rochester & Pittsburgh Ry. and the Staten Island Rapid Transit Co. had in use the Sargent semaphore signal, operated by an electric motor, the arm extending to the left of the mast. It was a top-of-post mechanism.

1900 Mr. William McC. Grafton, Signal Engineer of the Pittsburgh, Ft. Wayne & Chicago Ry., installed a one-arm, three-position, lower-quadrant, low-voltage direct current, motor-operated semaphore system for 34 miles between Allegheny (Pittsburgh) and Homewood, Pa. The signal was made under a patent by Mr. G. B. Gray, Inspector on the P. F. W. & C. Ry., and was a modification of the Union Style C signal introduced in 1897 for two-position lower quadrant. This installation proved that positive and characteristic home and distant indications could be given with a single arm operating in three positions.

Three-block indication was installed for the first time on the Pennsylvania R.R. between Altoona and Cresson, Pa. The signals were two-position, lower-quadrant, home and distant automatic semaphores.

The Hall Co.'s Style D signal, direct current, motor-operated home and distant semaphore, on the same mast, automatic block signals were installed on the Lehigh Valley R.R.

The low pressure pneumatic interlocking system was developed by the Pneumatic Signal Co. and an installation was made at Grand Central Terminal in New York City.

In Acton Town, England (known as Mill Hall Park) an illuminated track diagram was first used. It was in connection with resignaling on the District Ry. due to electrification. It dispensed with a considerable number of separate track indicators and brought all track occupancy information on to the plan of tracks and signals, enabling the signalman better to concentrate on the work of handling the traffic.

Mr. Frank P. Patenall, Signal Engineer of the Baltimore & Ohio R.R., developed a high-speed staff machine, using staffs about 6 inches long and weighing ¾ pound each. These could be delivered and collected at 70 miles per hour.

The Buchanan polarized direct current track circuit was installed on the Delaware, Lackawanna & Western and the Michigan Central Railroads for operating automatic semaphore block signal systems.

An automatic electrically approach-lighted semaphore signal was put into operation on the Atchison, Topeka & Santa Fe Ry. It consisted of two incandescent electric light bulbs, one for regular operation and the other for reserve in case of a burned out filament or other difficulty. The reserve bulb was lighted from a separate circuit and a separate battery.

1900–1902 The first track circuits for detector switch locking, invented by the Pennsylvania R.R., were put in service at Altoona, Pa.

1901 The single-rail direct current track circuits controlling the automatic block signals on the electrified Boston Elevated (this was a direct current electric propulsion line) were changed over to use a special polarized direct current track relay in order to protect against adverse effects of propulsion current. This was the first attempt to operate track circuits upon a railroad where electricity was the propelling energy and the rails a medium for return of that energy to the power house.

The Taylor Signal Co. put in service its first electric interlocking embodying the now well-known "dynamic indication" principle, at Eau Claire, Wis., on the Chicago, St. Paul, Minneapolis & Omaha Ry.

The Style W, Hall type automatic semaphore block signal, home and distant on the same mast, was installed on the Lehigh Valley R.R. This was a direct current motor-operated device consisting of a clutch traveling on an endless chain; direct current track circuits were used to control the signal, which was normally at danger.

A top-post semaphore signal, electrically operated, was invented by Mr. R. Herman (General Electric Co.).

The first permanent installation of an automatic train stop system was made on the Boston Elevated. It was a system of mechanical roadside trips engaging with apparatus on the moving car (Wood and Vogt devices).

1901–1903 A low-voltage electric fan was introduced by Mr. H. S. Balliet on the Lehigh Valley R.R. for blowing air on the commutators of motor-operated semaphore signals to prevent an accumulation of frost.

Mr. H. D. Miles, of the Michigan Central R.R., provided a glass cover to protect the armature of the Style B normal-clear signal from frost.

The American Railway Signal Co. also used a fan on its signals to prevent the formation of frost on the commutators.

1902 Trains moving over the single-track bridge No. 296 at Rotterdam, N. Y. across the Mohawk River on the Boston & Maine R.R. were governed wholly by signal indication.

A self-acting time or space interval signal of the dial type, like a clock face, which indicated minutes elapsed since the last train passed, was in use.

The Lehigh Valley R.R. and the Lake Shore & Michigan Southern R.R. installed the Hall type (Coleman patent) electro-gas lower-quadrant two-position semaphore automatic block signal. Both railroads placed the home and distant arms on the same mast. In the same year, the Union Switch & Signal Co. type was installed on the Delaware, Lackawanna & Western R.R.

The Gary type of automatic block signal was used which consisted of a magneto-electric machine in which the oscillatory motion of a rocking lever, operated by a passing train, was made to give rotary motion to a train of wheels which revolved an armature between the poles of a powerful horseshoe magnet, thus producing an alternating current which was used without rectification, or was changed into continuous current by a commutator.

The Bellows pneumatic type of signal was in use. By alternate expansion and contraction, or by rise and fall of the top, it drew in air through a valve orifice and expelled it more or less forcibly through a small pipe to the signal, which was a red disc.

1903 The Delaware, Lackawanna & Western R.R. used a Millar type of motor-operated semaphore signal which provided a power drive to the danger position in the event of failure of the holding latch to release automatically.

The Loree and Patenall type of three-position upper-quadrant semaphore spectacle was invented.

The North Shore R.R. of California made the first installation of alternating current track circuits. These were single-rail type with direct current propulsion. This road was originally for narrow gage steam locomotive operation; later there was added thereto a standard gage direct current electric propulsion service, making a composite steam and electric operated line, but each service had its own system of track rails. Three rails were used, one common to both services. The common rail was used as a single-rail track circuit.

The first installation of alternating current track circuit control for automatic block signals was made on the North Shore R.R. of California.

The Cade automatic block signal was installed on the Northern Pacific Ry. It was an electric motor type with the mechanism located at the bottom of the mast, the semaphore operating two positions in the lower quadrant.

1903–1904 The American Railway Association adopted rules which permitted train operation by signal indication, superseding time-table and train orders, on *two or more main tracks,* with or against the current of traffic.

1904 The first installation of double-rail alternating current track circuits with impedance bonds was made in the East Boston Tunnel, Mass., of the Boston Elevated.

The first installation of a new type electric interlocking, designed by the Union Switch & Signal Co., was made at Millbury Jct., Ohio, near Toledo, on the Lake Shore & Michigan Southern R.R. One of its special features was the generating of an alternating current for signal and switch indication by use of a special commutator effective only when the motor idled after the movement of the switch or signal was completed.

The Baltimore & Ohio R.R. installed three-position lower-quadrant home and distant signals on the same mast. The automatic block signals were operated by low-voltage electric motors and controlled by direct current track circuits.

The Interborough Rapid Transit Co., New York, N. Y., on its subway lines, installed electro-pneumatic type signals for automatic and interlocking purposes.

The Boston Elevated, in the East Boston Tunnel, Mass., installed short range color light type of automatic block signals controlled by double rail alternating current track circuits with impedance bonds.

1905 A take siding signal of the enclosed disc type was put in use on the Southern Pacific and Union Pacific Railroads.

The Style F motor-operated semaphore, Hall Signal Co., was put in use on the West Shore R.R., and the New York Central & Hudson River

R.R. This mechanism was similar to the electro-gas type, except that an electric motor was substituted for the gas valve.

A type of manual block system using station block instruments, developed by the General Railway Signal Co., was placed in service over a 100-mile district of the Illinois Central R.R.

The New York Central & Hudson River R.R. installed home and distant short range color light signals, both at the same location.

The first approach locking with automatic release was installed on the Pennsylvania R.R. at Zoo Garden, Philadelphia, Pa.

1906 An upper left-hand quadrant, two-position home and distant semaphore automatic block signal operated by alternating current motors, was installed on the New York, New Haven & Hartford R.R.

The first large scale installation of double-rail track circuits, using impedance bonds and polyphase track relays, was made on the New York Central R.R. Electric Zone. This was the first system in which power for all purposes including signals, track circuits, relays, etc., was taken from a single alternating current power transmission line.

In October, the Railway Signal Association recommended changing the semaphore signal arm so as to give the caution and proceed indications of a three-position signal in the upper right-hand quadrant. Final adoption was made in 1908.

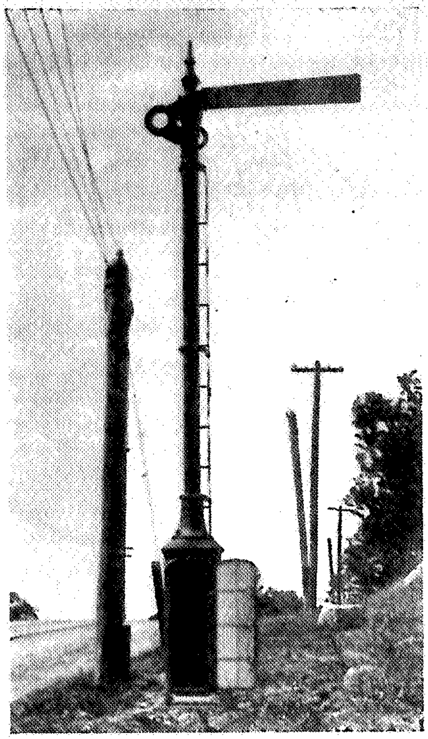
The first three-position upper right-hand quadrant semaphore signals in America were installed on the Pennsylvania R.R., from West Philadelphia to Elwyn (P. B. & W.), Pa. on September 25. They were electro-pneumatic type.

The first installation of alternating current track circuits on a steam-operated railroad was on the Union Pacific R.R. covering a territory of 2 miles with 16 track circuits between Council Bluffs, Iowa, and Missouri River Bridge. The alternating current was 60-cycle and was used also for signal lighting. The signals were operated by direct current.

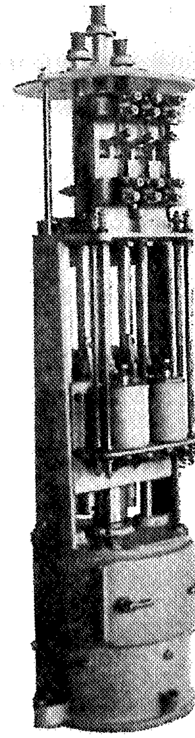
The first signal system with alternating current track circuits on a road using alternating current propulsion power was made on the New York, New Haven & Hartford R.R. in the States of New York and Connecticut. Track circuits were the two-rail type, 60-cycle, with impedance bonds. Propulsion current was 25 cycles.

On the electrified lines of the New York, New Haven & Hartford R.R. suspended type automatic semaphore signals operated by alternating current, were in use.

The Model 3, General Railway Signal Co., two-position, lower-quadrant motor semaphore was placed in use at Salt Lake City, Utah, on the Oregon Short Line of the Union Pacific R.R.

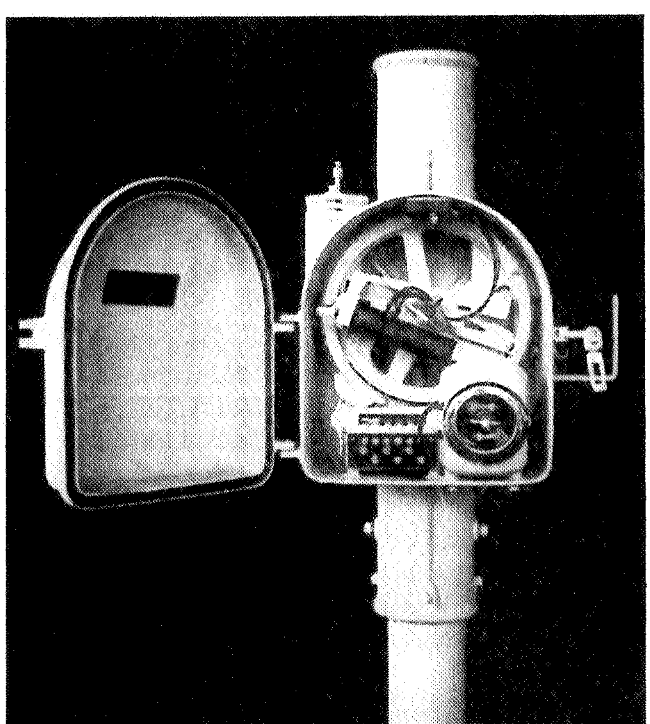


Model 3 electric semaphore signal. (1906)



Model 3 electric semaphore signal mechanism housed in signal base. (1906)

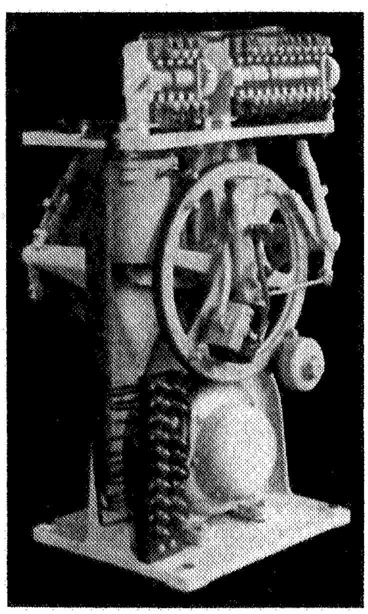
The Model 5, General Railway Signal Co., top-of-mast, direct current motor semaphore was installed on the Illinois Central R.R.



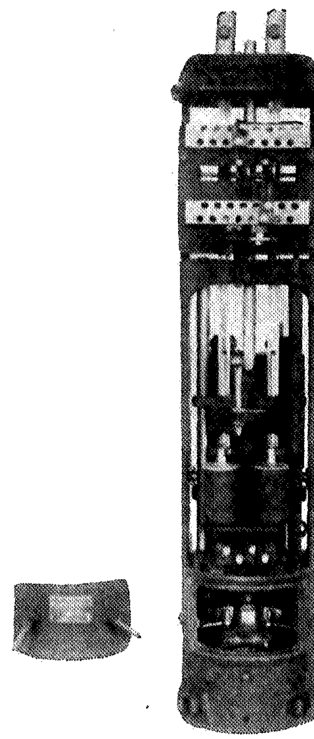
Model 5 semaphore signal mechanism. (1906)

The Model 6, General Railway Signal Co. type of automatic block signal was installed on the New York Central & Hudson River R.R. This was an alternating current motor-driven mechanism, home and distant semaphore signal operating in two-position, lower quadrant. This installation was in operation in the first heavy electric traction electric line of a four-track system using 660 volts direct current. The signals were controlled by 25-cycle alternating current track circuits.

The General Railway Signal Co. Model 7, 110-volt direct current electric motor-operated semaphore type signal, a modification of its Model 3, was installed on the New York Central R.R. Electric Zone.



Model 6 a. c. semaphore signal mechanism. (1906)



Model 7 enclosed semaphore signal mechanism. (1906)

The Harrington automatic type of electro-hydraulic semaphore block signal was in use on the New York, New Haven & Hartford R.R.

The West Jersey & Seashore R.R. installed electro-pneumatic home and distant semaphore automatic block signals. In this system the frequency type alternating current track relay (Howard & Taylor) was used.

The first modification of a mechanical machine for electro-mechanical interlocking operation was placed in service March 4, at Brandywine Draw, Wilmington, Del. on the P. B. & W. (Pennsylvania System). Small auxiliary levers for the electric control of the signals were mounted on the standard levers of a Saxby & Farmer mechanical machine.

1907 Installation was started on the Chicago, Burlington & Quincy R.R. for a lock and block system for (controlled manual block) operation of trains by signal indication without train orders on 1,300 miles of single track.

Train operation by signal indication was installed on the single-track line on the Renova Division of the Pennsylvania R.R. between Huntley and Cameron, Pa. Operation was controlled by means of a system of continuous track circuits and traffic locking developed by Mr. C. C. Anthony. This was the first controlled manual block system with continuous direct current track circuit control.

The New York, New Haven & Hartford R.R. was the first to install two-arm home and distant semaphores of the Style B type using alternating current, similar to the direct current type installed on the Santa Fe in 1898.

The first automatic interlocking for the protection of a railroad crossing was installed at Chester, Va., at a crossing of the Tidewater & Western Ry. with the Virginia Railway, Power & Light Co.

The City of New York installed short range color light signals on the Brooklyn Bridge, with overlaps, controlled by alternating current track circuits.

1907–1908 The Baltimore & Ohio R.R. installed direct current track circuits to control top-of-post, motor-driven direct current type semaphores.

1908 The first color specification for railway signal lights was approved by the Railway Signal Association. A complete system of colors was established, viz.: red, yellow, green, blue, purple, and lunar white.

Alternating current for operating the track circuits and the signals and lighting were used for the first time on a steam-operated railroad (the Cumberland Valley R.R.), between Lemoyne and Mechanicsburg, Pa. Track circuits were "polarized," using galvanometer type alternating current relays, and signals were Style B semaphores with induction type motors for three-position upper right-hand quadrant.

The first use of alternating current track circuits with centrifugal frequency type relays and designed for either direct current or alternating current propulsion was made on the New York, New Haven & Hartford R.R. for 8 miles between East Hartford and Vernon, Conn. The relays were operable only by the 60-cycle track circuit current and were immune to 25-cycle or to direct current. Impedance bonds at each end of the track circuits were designed to carry the heavy direct current propulsion return and were perfectly balanced to offer the least possible impedance to alternating current propulsion return.

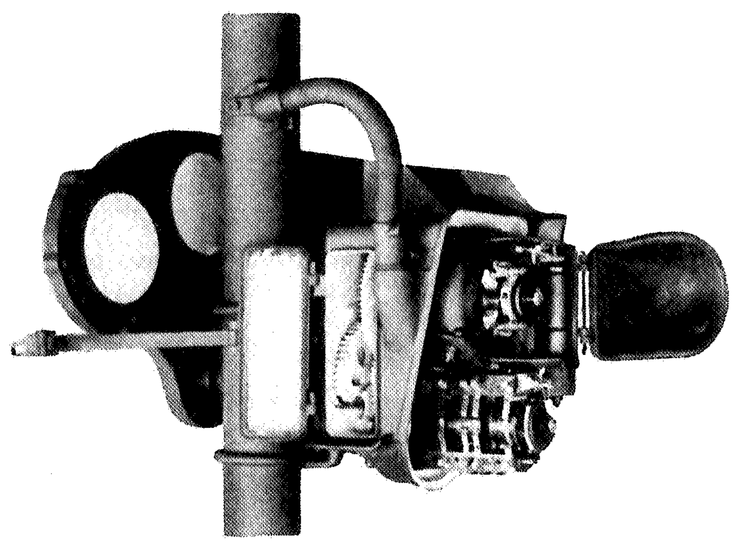
A semaphore signal for marking the "end of block" was in use on the New York Central & Hudson River R.R.

The American Railway Signal Co. type of electric motor semaphore, including an electric fan to intercept the accumulation of frost on the commutator and also act as a dash-pot when the arm returned to the stop position, was put in use.

A top-of-mast electro-pneumatic semaphore signal was in use on the Pennsylvania R.R.

The Baltimore & Ohio R.R. installed the top-of-mast electric motor-driven semaphore (three-position) automatic block signal of the General Electric Co. Type M-110, commonly known as the Clark and Moak.

The General Railway Signal Co. Model 2-A top-of-mast semaphore signals were first furnished to the Baltimcre & Ohio R.R. In the signal mechanism, the motor was direct-connected and rotated backward when the semaphore blade went to stop by gravity thus effecting dynamic braking.



Model 2-A top-of-mast semaphore signal mechanism. (1908)

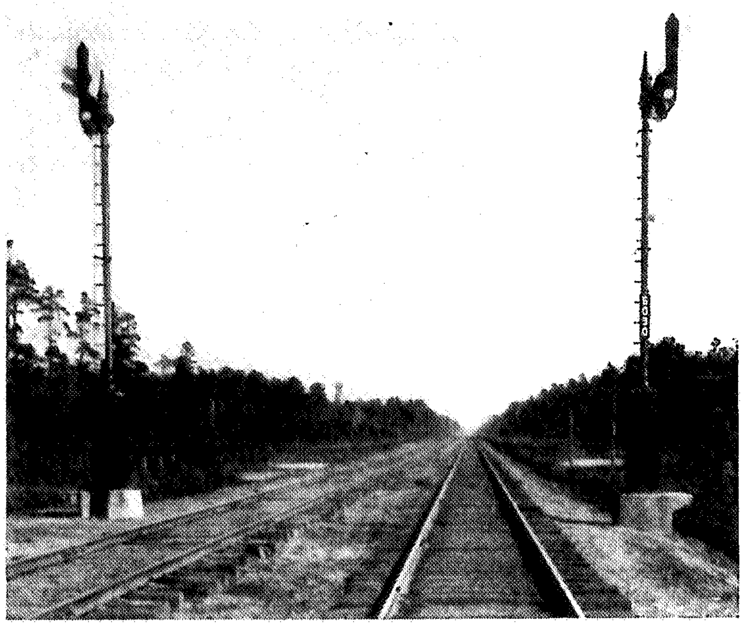
The Model 2-A three-position, upper right-hand quadrant, alternating current automatic semaphore block signal was installed on the New York Central R.R. on a heavy traction suburban line.

The direct current motor-operated three-position upper-quadrant Hall Signal Co. Type H semaphore automatic block signal was installed on the Northern Pacific Ry. It was a top-of-mast type signal using an oil dash-pot for retarding and holding the signal at "proceed."

The Baltimore & Ohio R.R. introduced the Loree-Patenall upper-quadrant, three-position type of signals.

Center suspended semaphore arm signals, operated by the Model 7 motor-driven type of mechanism of the General Railway Signal Co. were installed on the New York, New Haven & Hartford R.R. They were of the home and distant type, both located on the same mast and controlled by alternating current track circuits.

The first Union Switch & Signal Co. Style S electric motor-operated semaphore automatic block signals were installed on the Erie, the Chicago, Rock Island & Pacific and the Lake Shore & Michigan Southern Railroads. These were for three-position, upper right-hand quadrant, with mechanism at bottom of mast.



The first Style S three-position upper-quadrant signals. (1908)

The electric motor type upper-quadrant dispatcher's control signal (Blake patents) was in use as a train order signal.

The Patenall-Dryden system of approach lighting was installed on the Baltimore & Ohio R.R. in connection with a normal danger system of automatic block signals.

Through route electric switch locking, designed by the Pennsylvania R.R., was installed at Broad St. Station, Philadelphia, Pa.

1909 The Erie R. R. installed automatic signaling for train operation by signal indication on a two-track division, 139.7 miles in length, which directed trains to: (1) stop and hold main track; (2) take siding; (3) proceed on main track regardless of superior trains.

The Central New England Ry. operated trains by signal indication without the use of written train orders over 13.2 miles of single track and 7 miles of two-track which was divided into 9 controlled manual block sections.

The first electro-mechanical interlocking machine, with small levers for electric control mounted separately above the large mechanical levers, was installed at Gap, Pa. on the Pennsylvania R.R.

1910 The Erie R.R. put in use remotely controlled, three-aspect telephone type train order signals, located in automatic block signal territory at outlying passing tracks. They were under the control of the dispatcher.

The Erie R.R. equipped four main tracks for operation in either direction by signal indication.

The Union Switch & Signal Co. Style T top-of-mast semaphore signal was first used on the Baltimore & Ohio R.R. for upper right-hand quadrant.

The Union Switch & Signal Co. Style E top-of-mast semaphore signal was first used on the New York, New Haven & Hartford R.R. for 60-degree lower quadrant.

Color light signals, short-range type, developed by the Union Switch & Signal Co., were installed by the Pennsylvania Tunnel & Terminal Co. at the Pennsylvania Terminal, New York City.

The Simmen and the Perry-Prentice types of controlled manual block were put in use.

The first Federal Signal Co. type of electric interlocking with high-voltage impulse indication was put in service on the Boston & Albany R.R. at Allston, Mass.

1911 The Boston & Maine R.R. protected gantlet track through the Greenfield, Mass. tunnel by an automatic signal installation which provided for train operation by signal indication.

The Chicago, Burlington & Quincy R.R. installed "split b'ock" on two sections of single track, between Indianola and McCook, Nebr. and between Wray and Eckley, Colo., for train operation by signal indication.

The American Railway Signal Co. designed the first so-called A.P.B. circuits to select train direction and to provide limits of protection accordingly. These circuits were applied to an automatic block signal system installed between Dunfee and South Whitney, Ind., on the New York, Chicago & St. Louis R.R.

The absolute permissive block system (APB), developed by the General Railway Signal Co., was first installed on The Toronto, Hamilton & Buffalo R.R. between Kinnear and Vinemount, Ontario, Canada, using Model 2-A direct current semaphore signals.

The Chicago, Milwaukee & St. Paul Ry. (1911-1914) signaled more than 454 miles of its two-track steam-operated main lines. Union Style B automatic block signals, equipped with induction motors (110-volt, 60-cycle), were used; they were three-position upper right-hand quadrant signals. The second arms at interlockings were two-position, as were the train order semaphore signals. The semi-automatic interlocking signals were T-2 top-of-mast Union Switch & Signal Co. type except at electric interlockings, where the General Railway Signal Co. Model 2-A were used.

Alternating current track circuits were installed for a new three-block indication upper-quadrant automatic block signal system introduced on the Pennsylvania R.R. from "OS" to Summit Ave., Jersey City, N. J. Steam-operated trains and electrically operated trains used the same tracks jointly. The signals were three-position, right-hand upper-quadrant, Union Switch & Signal Co. Style T, top-of-mast, direct current, motor-operated.

The Baltimore & Ohio R.R. signaled 36 miles on the Cumberland Division for operation in either direction by signal indication.

1912 A three-position upper left-hand quadrant alternating current motor-operated semaphore automatic block signal was installed on a New York, New Haven & Hartford R.R. electrified line.

The Hall Signal Co. Style K top-of-mast direct current motor-operated semaphore automatic block signal was installed on the New York Central and on the Chicago, Rock Island & Pacific Railroads.

The Indiana Union Traction Co. installed on its electric lines a General Railway Signal Co. system of A.P.B. signals using overlap and medium range light signals with double-rail, alternating current track circuits with impedance bonds.

The Union Switch & Signal Co. Style T-2 top-of-mast direct current motor-operated automatic semaphore signal was first installed on the Pennsylvania R.R.

The first Union Style T-2 signals with alternating current motors and with an induction holding device were installed between Bowie and Landover, Md., on the Pennsylvania R.R.

Train movements on the Chesapeake & Ohio Ry. were directed for the first time by signal indication without written train orders.

At this time there were 440 electric interlockings in service on 83 roads with 21,370 levers.

Medium range color light automatic block signals, controlled by alternating current track circuits, were installed on the high-speed electric line of the Washington, Baltimore & Annapolis R.R.; they were Union Switch & Signal Co. Model 12.

1913 The Reading Co. equipped 25 miles of single track between Carlisle Jct. and Gettysburg, Pa. for train operation by signal indication in both directions for the handling of heavy passenger traffic incidental to the 50th anniversary celebration of the Battle of Gettysburg.

The Ohio Central Lines installed signals on a two-track section in Columbus, Ohio, for the operation of trains by signal indication for movements in both directions. The system included automatic block, manual block and interlocking.

The Union Switch & Signal Co. Model 13, medium range color light signal was installed on the Northwestern Pacific R.R.

The Pennsylvania R.R. signaled the middle track on their main line between Spruce Creek and Tyrone, Pa. for operation in either direction by signal indication.

The Federal Signal Co. Type 4 top post, universal semaphore signal was introduced on the Boston & Albany R.R.

1914 An automatic interlocking was installed on the Great Northern Ry. at Hanover, Mont., to protect two single tracks on a gantlet over a bridge.

The Atchison, Topeka and Santa Fe Ry. installed an automatic interlocking at Canyon Diablo, Ariz., to govern movements over gantlet tracks. Its operation was special, giving preference at all times to westward movements.

The St. Louis-San Francisco Ry. operated trains in both directions by signal indication only over a 1.1 mile single-track section handling 300 trains in 24 hours.

The first permanent train control installation in steam road territory was of the Miller Train Control intermittent electrical contact type installed on approximately 100 miles of two-track between Chicago and Danville, Ill., on the Chicago & Eastern Illinois R.R.

The first Union Switch & Signal Co. Model 14 color light automatic block signals were installed on the New York, New Haven & Hartford R.R. This was the first installation of long range color light signals for daylight indication, and the first use of concentrated filament lamps accurately based and accurately located at the focal point of the optical system, which consisted of a doublet lens combination.

1915 The Illinois Central R.R. had in use the Kendall single-track block signal circuit in connection with Hall Switch & Signal Co. signals.

The first installation of position light signals (for long range) was on the electrified line of the Pennsylvania R.R. near Paoli, Pa. These signals (Rudd and Churchill patent) had rows of amber colored lights to give indications corresponding to a three-position upper-quadrant semaphore signal and were furnished by the Union Switch & Signal Co.

The American Railway Association adopted rules which permitted train operation on single track by controlled manual block signal indications, superseding time-table and train orders.

1917 The Hall Signal Co. Style L direct current, motor-operated semaphore automatic block signal, top-of-mast type was installed on the New York Central R.R.

The Union Switch & Signal Co. Style L, long range daylight type color light signal was first installed on 450 miles of the Chicago, Milwaukee, St. Paul & Pacific R.R.

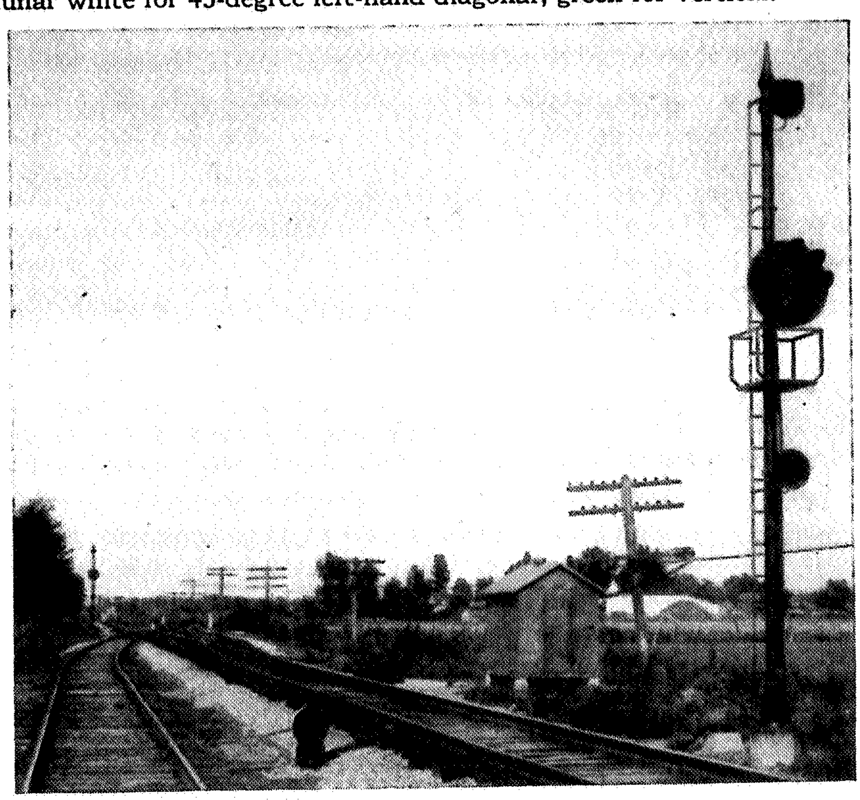
1919 The Chesapeake & Ohio Ry. installed the American type train control system, which was of the intermittent ramp type, on 21 miles of single track between Charlottesville and Gordonsville, Va.

The Buffalo, Rochester & Pittsburgh Ry. made the first trial installation of the General Railway Signal Co. intermittent inductive train stop system. In this system magnetic induction is used to transfer controls from the wayside signal controls to the locomotive equipment.

1920 The first installation of automatic speed control in the United States was that of the Regan Safety Device Co. intermittent electrical contact ramp type train control system on the Chicago, Rock Island & Pacific R.R. between Blue Island and Joliet, Ill.

The searchlight type of color light automatic block signal, invented by Mr. Blake, was introduced by the Hall Signal Co. The first installation was on the Grand Trunk Western Ry.

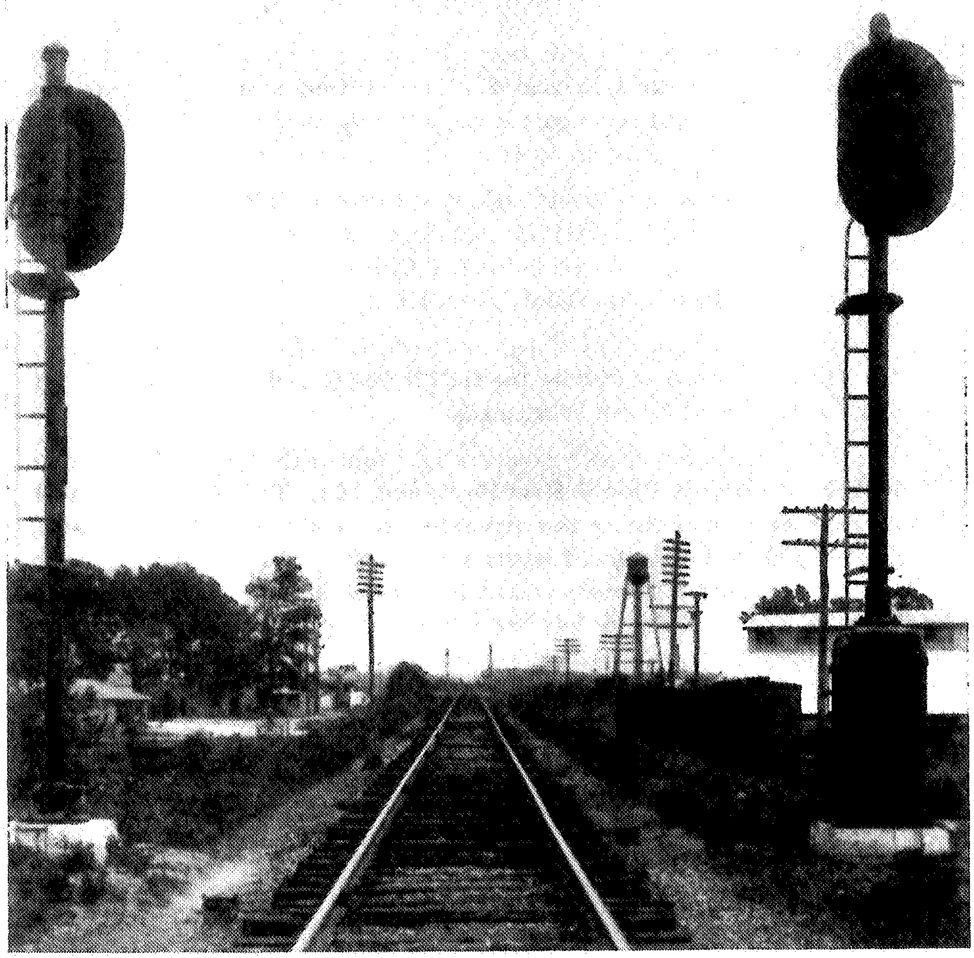
1921 The first installation of color position light signals (long range) was made by the Baltimore & Ohio R.R. at Baltimore, Md. This signal displayed its aspects by combining the aspects of the color and of the position light signals. Two colored lights spaced 30 inches are used for each aspect: red for horizontal; yellow for 45-degree right-hand diagonal; lunar white for 45-degree left-hand diagonal; green for vertical.



Color position light signals, Baltimore & Ohio R.R. (1921)

1922 The Northern Pacific Ry. installed a slide detector fence which functioned to open the signal control circuits upon the impact of a slide against the fence.

The first installation of Style R long range color light automatic block signals (Union Switch & Signal Co.) was made on the Illinois Central R.R. Lenses were arranged vertically.

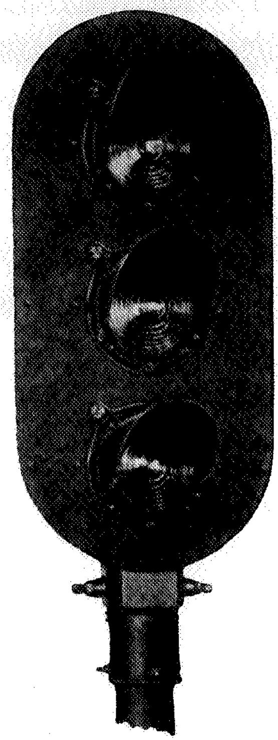


The first Style R color light signals. (1922)

1923 The Pennsylvania R.R. placed in service, experimentally, on July 11 the first installation anywhere of the continuous inductive cab signal and train control system, between Lewistown and Sunbury, Pa., covering 43.5 miles of single track and 3.4 miles of two-track. It was the first instance where vacuum tubes were used for purposes other than in communication circuits. This installation also was the first time that cab signals were used in lieu of wayside signals for operating trains by signal indication.

The first commercial installation of intermittent inductive train stop was made on the Chicago & North Western Ry. between West Chicago and Elgin, Ill., using General Railway Signal Co. equipment.

The General Railway Signal Co. Type D long range color light block signals, vertically arranged, were installed on the Philadelphia & Western Ry.



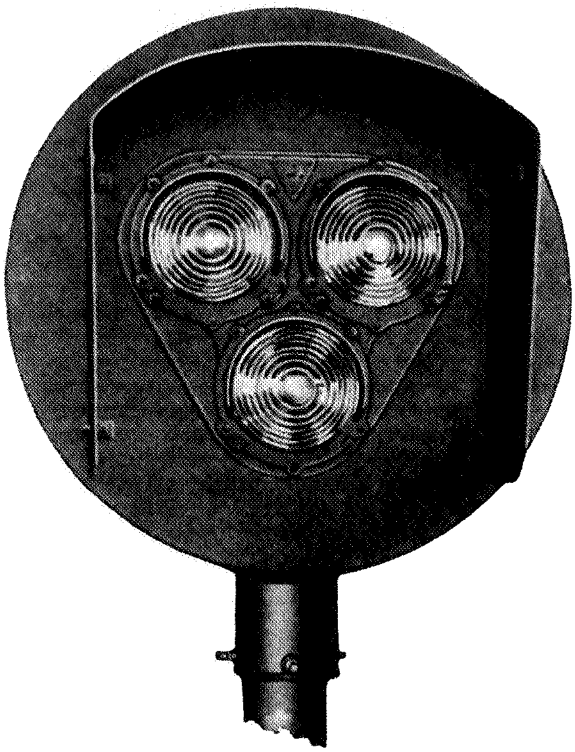
Type D long range color light signals, vertically arranged. (1923)

1924 The Southern Pacific R.R. operated their snow shed territory with color light signals.

The Chicago & North Western Ry. installed horizontally arranged Type E long range color light block signals developed by the General Railway Signal Co.

Type E long range color light signals, horizontally arranged. (1924)

The General Railway Signal Co. triangular arrangement Type G color light automatic block signals were put in service on the New York Central R.R. Electric Zone.



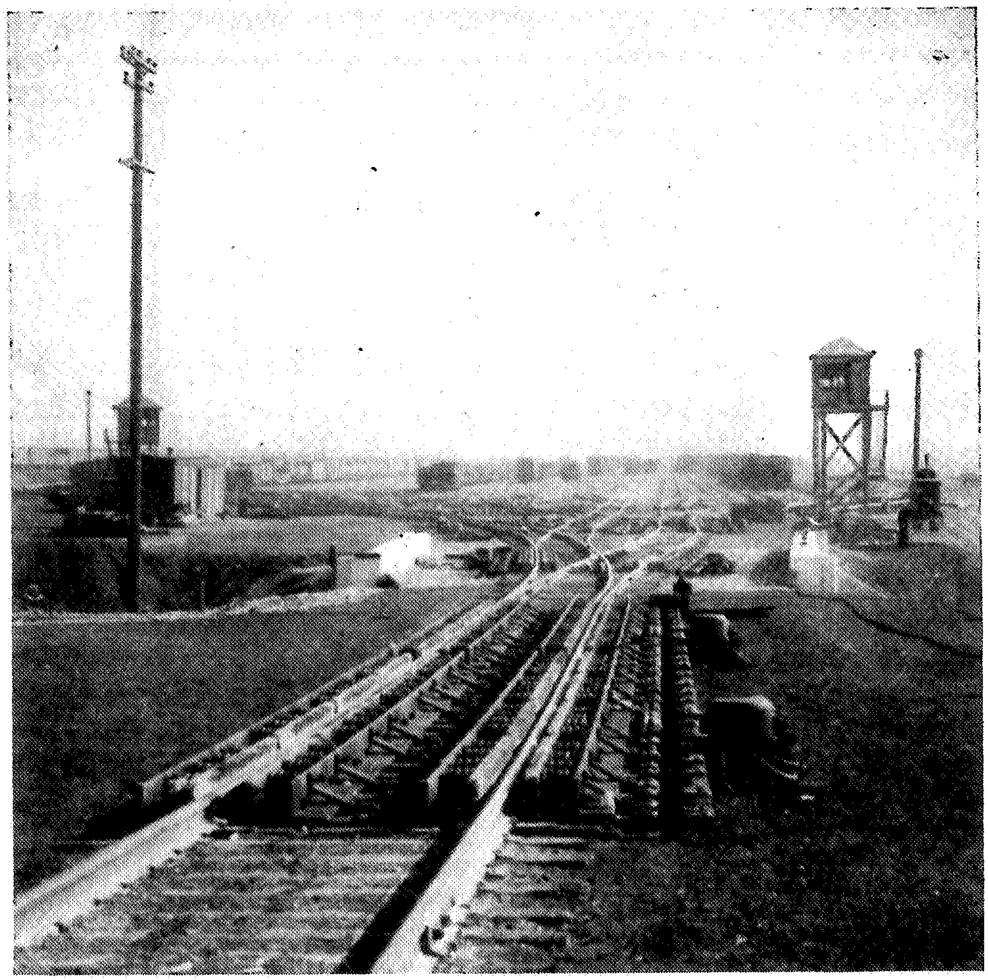
Type G color light signals arranged in a triangle. (1924)

Train order signals of the color light type were in use on the Southern Pacific R.R.; they differed from the customary installation because they were normally dark, *i.e.*, displayed no indication. When a train entered the approach-lighting circuit, a red light was displayed; when the train order signal was in the proceed position, the green light was displayed.

The Central of Georgia Ry. operated 4½ miles of single-track main line near Macon, Ga. for train operation by signal indication.

A reversal of traffic system of automatic block signals was installed on the New York Central R.R., using color light signals providing for three indications and controlled by alternating current track circuits; this was on a four-track electrified railroad and only one track was thus equipped. In 1931 this system was applied to all four main tracks using the General Railway Signal Co. SA searchlight signal.

The first installation of car retarders in the United States was made at Northbound Yard, Gibson, Ind., on the Indiana Harbor Belt R.R. The retarders were the Hannauer type, operated electro-pneumatically.

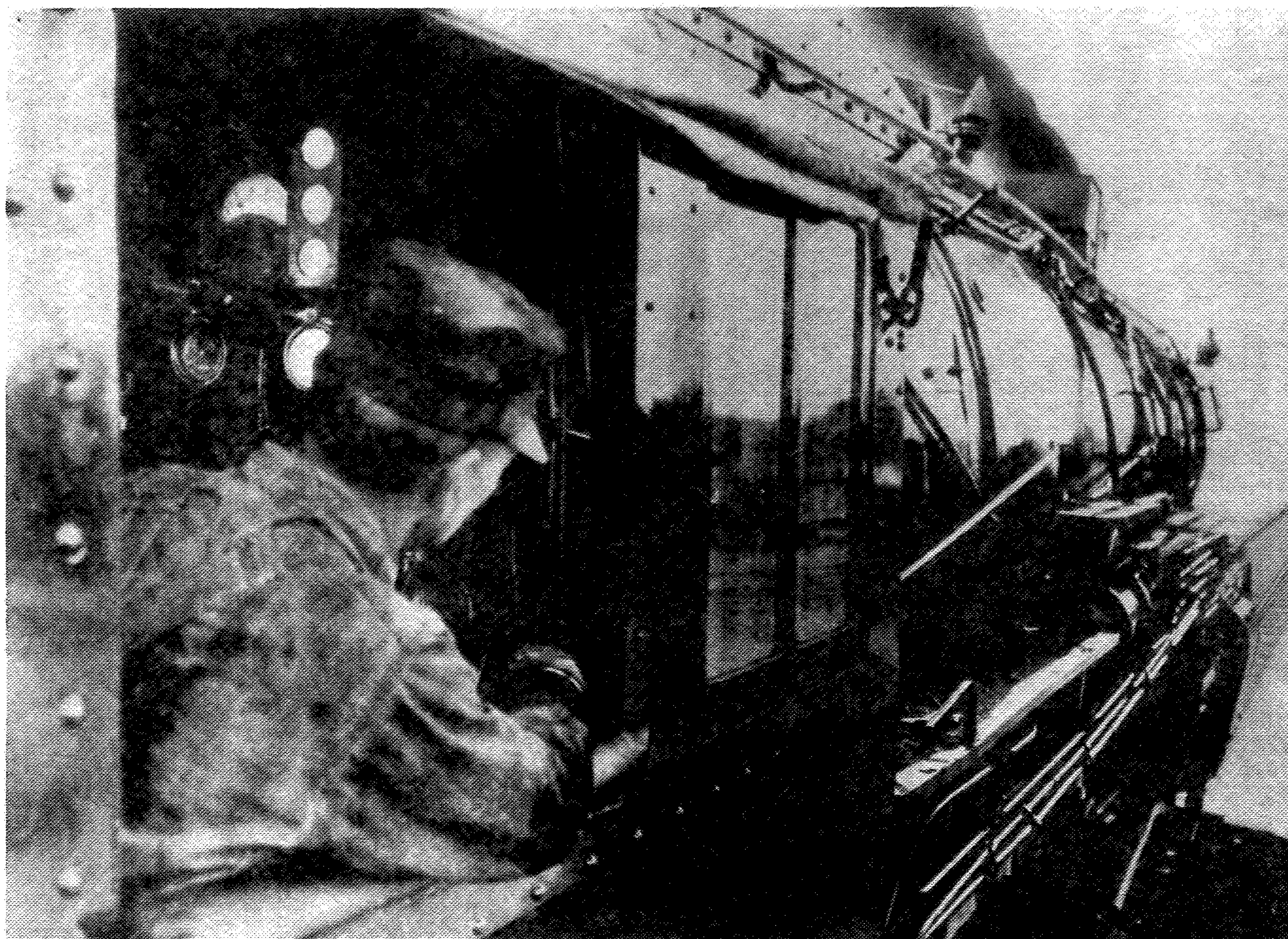


The first installation of car retarders
in the United States. (Dec. 1924)

1925 The first permanent installation of cab signals without wayside automatic block signals was made on the Atchison, Topeka & Santa Fe. Ry. in connection with a Union Switch & Signal Co. three-speed continuous inductive type train control installation between Chillicothe, Ill. and Ft. Madison, Iowa (102.7 road miles). This was in two-track territory and all tracks were operated in both directions by signal indications. Alternating, 60-cycle current was used for track and loop circuits.

A preliminary installation of the Union Switch & Signal Co.'s intermittent inductive train stop system was made on 20 miles of the New York, Chicago & St. Louis R.R.

The New York, New Haven & Hartford R.R. installed a two-indication continuous inductive train stop system between Cedar Hill, Conn. and Springfield, Mass.



A. T. & S. F. Ry. three-speed train control cab signals. (1925)

The Missouri Pacific R.R. placed in service a complete system of signaling facilities for train operation by signal indication without written train orders over the operating subdivision between Leeds (Kansas City, Mo.) and Osawatomie, Kans. Controlled manual block was used, and General Railway Signal Co. intermittent inductive train control was superimposed on the system.

The Burlington extended operation of two-tracks by signal indication beyond West Burlington, Iowa, to make a total of 1,064 miles.

The Illinois Central R.R. installed a system of signaling and interlocking on a very busy 20-mile section of two-track between Gilman and Otto, Ill., by which train operation was handled by signal indication only without the use of written train orders.

1926 The Michigan Central R.R. installed at Bay City Junction near Detroit, Mich., a scheme for selectively controlling switches and signals by means of currents of different frequencies.

The first commercial installation of a retarder system was with the Type A electric retarders in the East St. Louis Yard, Ill., of the Illinois Central R.R.

The first installation of the Markham type of electro-pneumatic car retarder was made at northbound Markham Yard, Chicago, Ill. on the Illinois Central R.R.

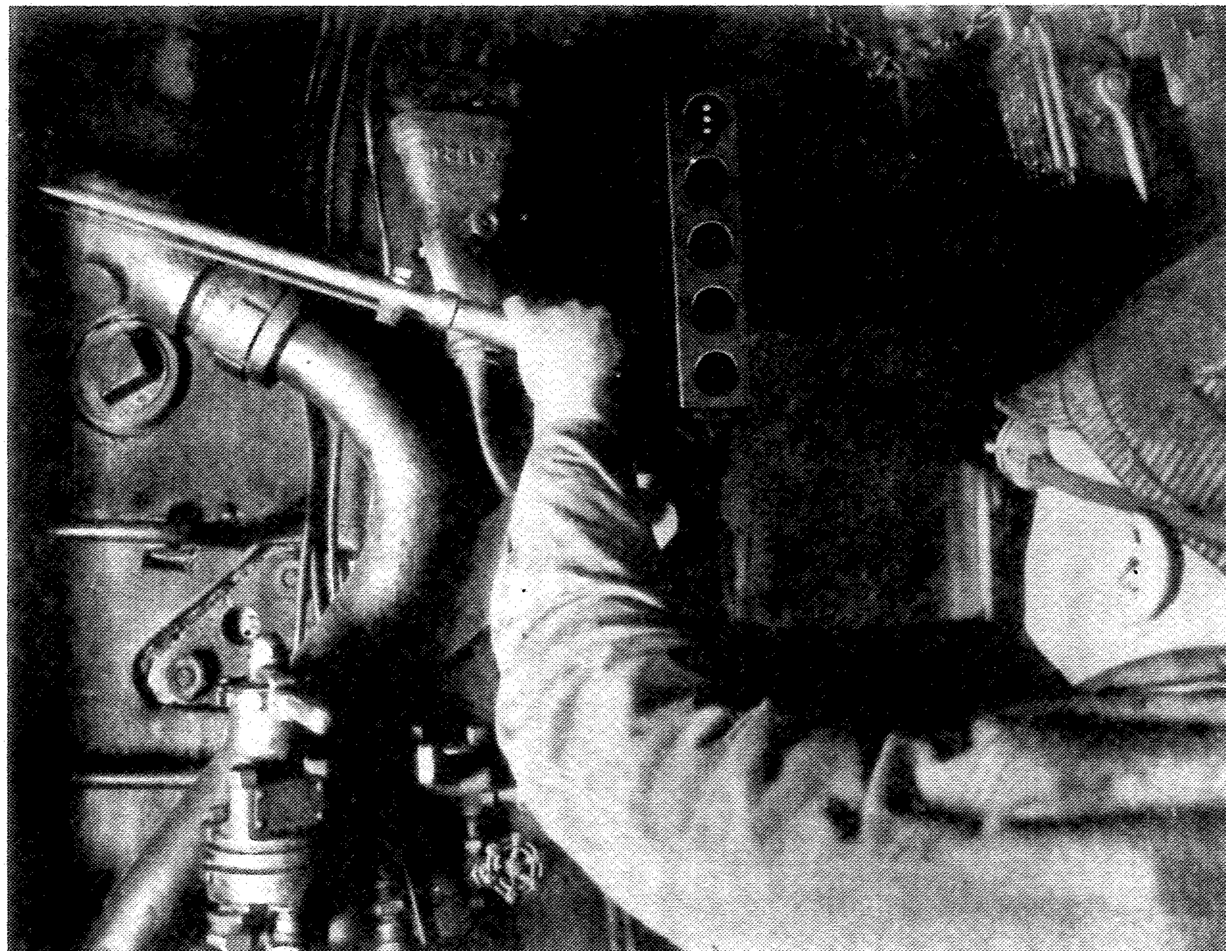
The Pennsylvania R.R. placed in service on July 17, a continuous automatic stop system using three-indication cab signals with whistle and acknowledger between Baltimore, Md. and Harrisburg, Pa. The system was controlled by track and loop circuits and was the first to operate on 100-cycle alternating current.

A two-indication color light type of trimmer signal was in use on the Illinois Central R.R. in connection with car retarder layouts.

The first installation of the General Railway Signal Co. Type S searchlight signal was made on the New York Central R.R. Electric Zone.

The Illinois Central R.R. was the first to equip an operating division with automatic train stop and two-indication continuous cab signals without wayside automatic block signals. The installation included one division of 97.6 miles of single-track from Waterloo to Fort Dodge, Iowa and another division of 121.8 miles of two-track road from Champaign to Branch Jct., Ill.

1926–1927 The Chicago & North Western Ry. installed a two-indication cab signal system in three installation stages; Boone to Council Bluffs, Iowa; Clinton to Boone, Iowa; and Chicago, Ill., to Clinton. This system operated over two-track and three-track territory without wayside signals, except at interlockings and in a part of the Chicago suburban territory. It extended over 511 miles of road.



Pennsylvania R.R. four-indication cab signal. (1927)

1927 The Pennsylvania R.R. installed for the first time, a four-indication coded continuous cab signal system with automatic stop and forestaller. The installation was between Camden and Atlantic City, N. J. The cab signal indications were determined by various "codes" or rates of interruption of an alternating current track circuit. This system provided for two, three, or four cab signal indications and was suitable for automatic train stop or for speed control.

An installation of the General Railway Signal Co. Miller Type intermittent inductive train stop system was installed on 161 miles of the Chicago, Indianapolis & Louisville R.R. between Hammond and Indianapolis, Ind.

The first car retarder installation using the Type B electric retarder was made on the Boston & Maine R.R. at Mechanicville Yard, N. Y.

The first installation of the Boston type of electro-pneumatic car retarder was made at Inbound and Outbound Boston Yards on the Boston & Maine R.R.

On the Cleveland, Cincinnati, Chicago & St. Louis Ry. unattended remotely controlled manual block stations were installed at Horace, Ind., and at four similar locations with automatic equipment which permitted trains to meet at sidings under block protection without written train orders. The Union Switch & Signal Co.'s selector system of centralized dispatcher control was used.

The first General Railway Signal Co. centralized traffic control system was installed on the New York Central R.R. between Stanley and Berwick, Ohio. The first dual-control electric switch machines, which provided for either hand or electric operation, were introduced on this installation.

1928 More than 100 automatic interlockings at grade crossings were in service on various roads and their use was quite generally acceptable.

A selector code control system, using Gill selectors, was first placed in service on the Chicago, Burlington and Quincy R.R. between Concord and Arenzville, Ill.

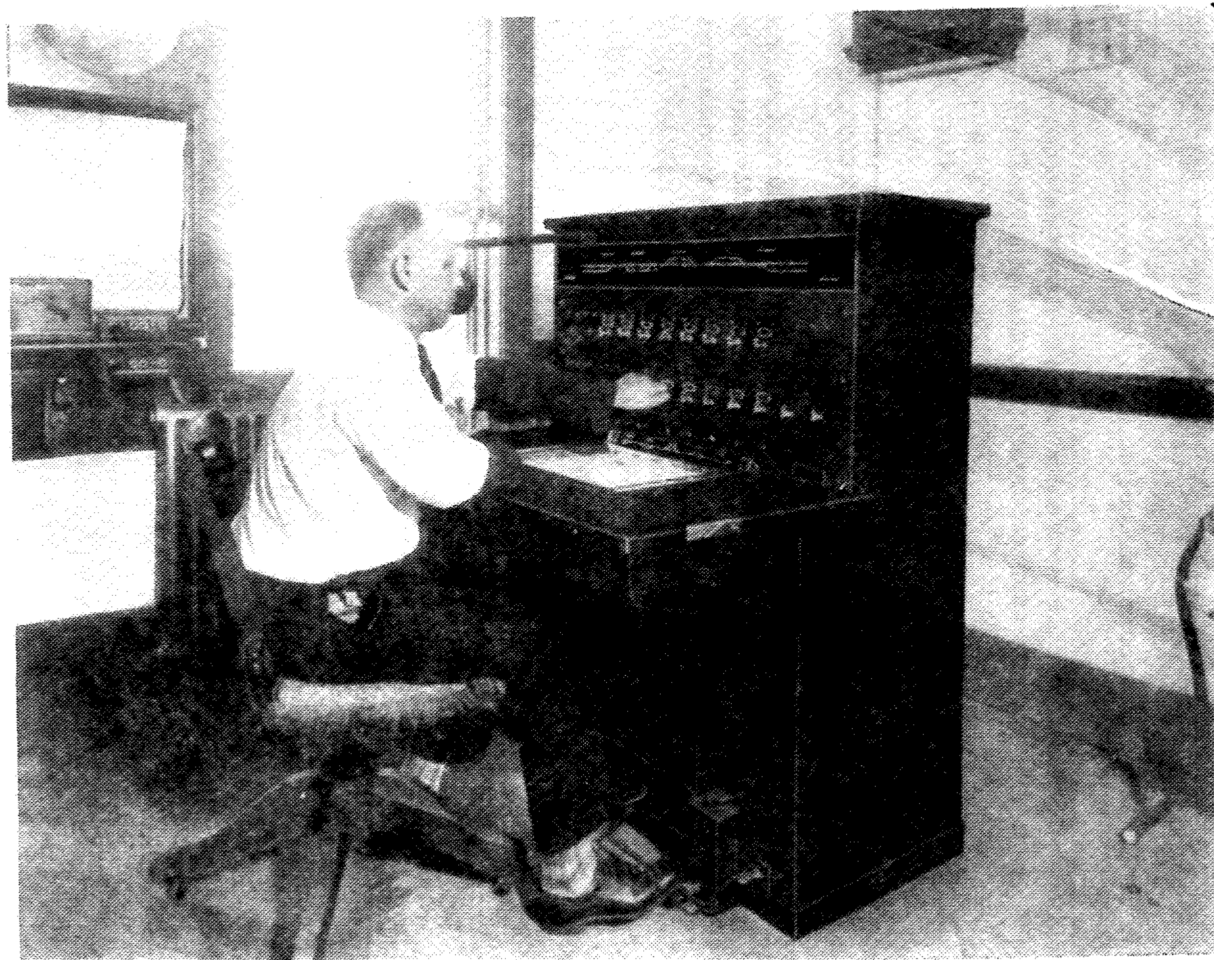
A Gill selector system, with audible answer-back, for central office selective code control, was installed at Roanoke, Va., on the Norfolk & Western Ry.

Centralized traffic control was installed on the Boston & Maine R.R. using color light signals.

Centralized traffic control was installed in Canada on the Canadian Pacific Ry., using semaphore signals.

The first extensive installation of centralized traffic control employing coded transmission of controls and indications, as developed by the Union Switch & Signal Co., was placed in service on the Pere Marquette Ry. extending from Mt. Morris to Bridgeport, Mich., a distance of 19.8 miles of single track. Automatic indication of the passage of trains was provided at 10 points. The code line consisted of two line wires of open construction, and the functions were controlled by means of selectors.

The control machine for the first installation of the G.R.S. dispatching system (C.T.C.) between Stanley and Berwick, Ohio, on the New York Central R.R. (1927)



Pere Marquette Ry. machine for first coded control system, June 30, 1928.

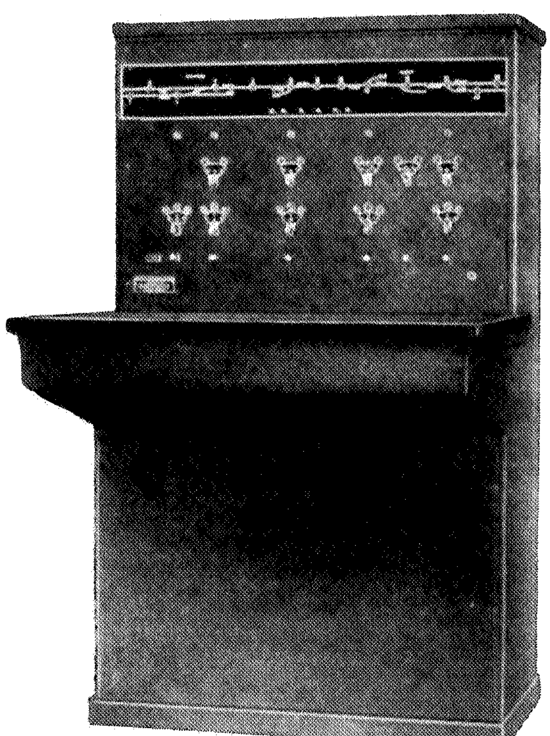
Color light signals were installed on the Boston & Maine R.R. Some of these were in centralized traffic control territory.

Cab signals were installed in the pusher locomotives at three gravity classification yards on the New York Central R.R. The first installation was at Westbound Selkirk Yard, N. Y.

1929 The development of all-relay interlocking was started with the first installation at Blue Island, Ill., by the Chicago, Rock Island & Pacific Ry. It was designed by the railroad in cooperation with the Chicago Railway Signal & Supply Co. and Automatic Electric, Inc.

On December 15, the Boston & Maine R.R. placed in service at Eagle Bridge, N. Y., an all-relay interlocking remotely controlled by a Union Switch & Signal Co. centralized traffic control system which operated three miles of two-track road from Eagle Bridge to Hoosick Jct., N. Y. This was the first installation of a three-wire, 27-station circuit code system and was the first one to control an interlocking in addition to main track (3 miles of two-track) in a centralized traffic control system.

The all-relay centralized traffic control code system was introduced as a two-wire, 12-station time code system on the Chicago, Burlington & Quincy R.R. between Waverly and Greenwood, Nebr. Series-connected line circuits were used.



C.B.&Q.R.R. machine for first all-relay code system, September 17, 1929.

On February 14, the Chicago, Burlington & Quincy R.R. placed in service the first all-relay interlocking remotely controlled by a General Railway Signal Co. unit-wire system at Lincoln, Nebr.

The first yard to be equipped with the Union Switch & Signal Co. Model 28 electro-pneumatic car retarder was Westbound Sharonville Yard, Ohio, on the Cleveland, Cincinnati, Chicago & St. Louis Ry.

First Model 28 electro-pneumatic car retarder, C.C.C.&St.L. Ry., August 1929.

1930 An all-relay interlocking, General Railway Signal Co. type, was installed on the Cleveland, Cincinnati, Chicago & St. Louis Ry. at Linndale, Ohio.

The first General Railway Signal Co. unit-wire, near group control all-relay interlocking was installed at Linndale, Ohio, on the Cleveland, Cincinnati, Chicago & St. Louis Ry. In this installation, 42 signals and 33 switch machines were controlled.

The General Railway Signal Co. Type U color position light signal was put in service on the Baltimore & Ohio R.R.

The first use of the all-relay interlocking principle, as a substitute for indication parts and magnets at the levers of a large interlocking machine equipped with mechanical locking, was at the Cleveland Union Terminal, Ohio.

The Pennsylvania R.R. placed in service the first installation of cab signals with whistle and acknowledger, that is, cab signals only without brake applying equipment. This was a Union Switch & Signal Co. four-indication coded continuous system in which a cab signal was mounted on each side of the cab, one for the engineman and one for the fireman. On any change in cab signal to a more restrictive indication, the whistle would blow continuously until acknowledged by the engineman.

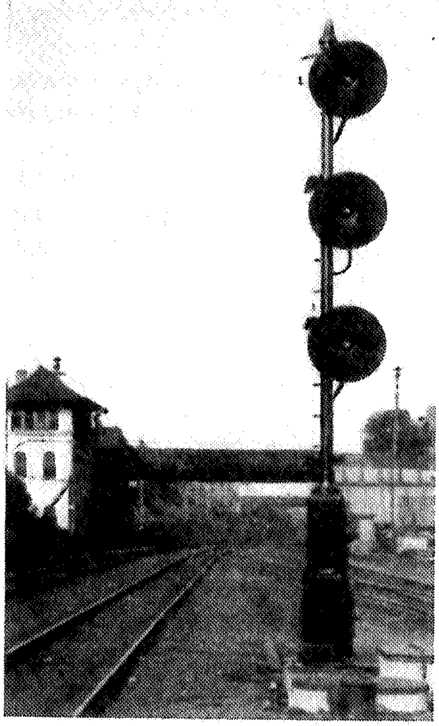
The Central R.R. of New Jersey installed 11 miles of cab signaling on single track without wayside signals, between Matawan and Atlantic Highlands, N. J.

The Atchison, Topeka & Santa Fe Ry. made the first installation of the Union Switch & Signal Co. three-wire, 81-station circuit code system at Sibley, Mo., on July 7.

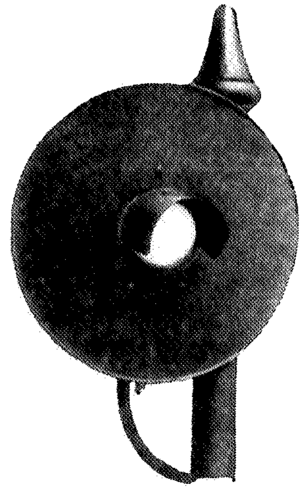
The Delaware & Hudson R.R. placed in service a General Railway Signal Co. Type B synchronous-carrier coded centralized traffic control system between Lanesboro and Center Village, N. Y., a distance of 12.7 miles. The system used two line circuits (three wires), one for maintaining synchronism between offices and field stations, the other, a message circuit, for controls and indications, all scanned on every cycle. The first "central battery" was used on this installation. Consolidation of four interlockings was made possible.

The Michigan Central R.R. installed General Railway Signal Co. SA searchlight type color light automatic block signals.

Searchlight type color light signals were installed on the Boston & Maine R.R.—General Railway Signal Co. Type SA and Union Switch & Signal Co. Style H.

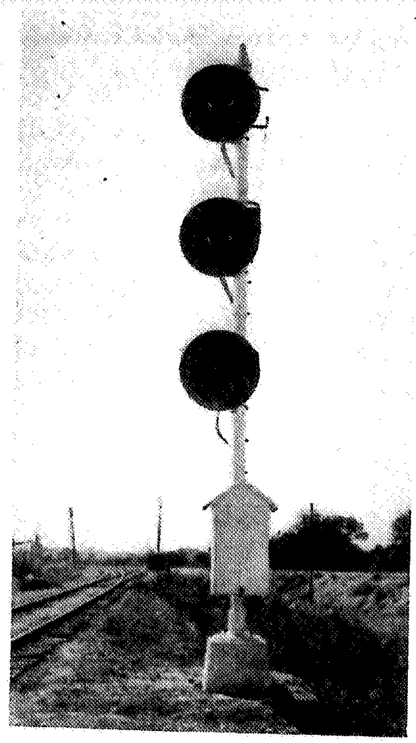


Style H searchlight type color light signals on the Boston & Maine R.R. (1930)



Type SA searchlight signals introduced on the Boston & Maine R.R. (1930)

The Atlantic Coast Line R.R. placed in service its first installation of searchlight type color light signal, Union Style H-2. These signals were lighted by 8-volt, 5-watt lamps operating from primary battery.



Searchlight signals on the Atlantic Coast Line R.R. (1930)

1931 The Peoria & Pekin Union Ry. placed in service the first General Railway Signal Co. Type C duplex system of centralized traffic control between Peoria and North Pekin, Ill. It was a two-circuit (three wires—four wires if installed in cable) system and employed polar code control and closed-open conditions for indications. The system transmitted controls and indications simultaneously, with a code time of 4 seconds. The normal rated capacity, using the 16-step code, was 128 stations.

The two-wire time code system was improved to increase its speed of operation and to increase its capacity from 12 stations to 35 stations. The first installation was for a replacement of the selector system on the Pere Marquette Ry.

The Chicago Railway Signal & Supply Co. type of color light signal, a triangular design, was installed on a joint line of the Chicago, Milwaukee, St. Paul & Pacific and the Chicago, Rock Island & Pacific Railroads, and the same signal with chromatic lenses was installed at Blue Island, Ill., on the Chicago, Rock Island & Pacific Ry.

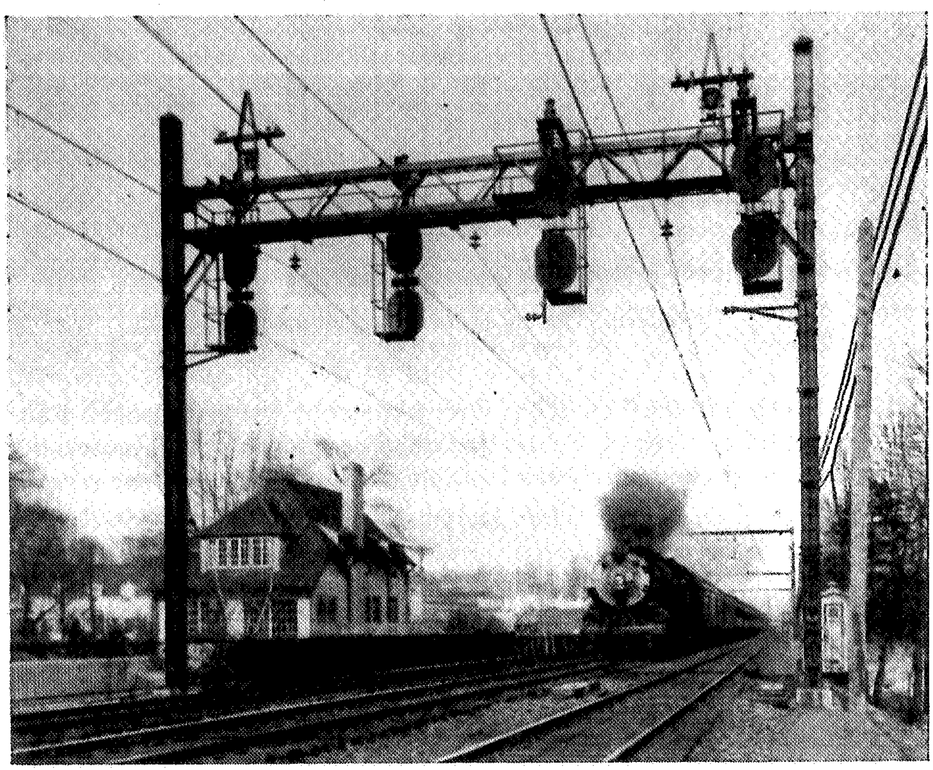
The Chicago, Milwaukee, St. Paul & Pacific and the Chicago, Rock Island & Pacific Railroads, in territory involving both single and two-track operation installed automatic color light type signals using APB control circuits for the single-track line and polarized line control for the two-track line.

The New York Central R.R. installed a system of four-block indication signals on a line equipped with automatic block signals in heavy suburban traffic territory. General Railway Signal Co. SA searchlight type signals were used. The scheme of aspects and indications followed the standard adopted by the New York Central Lines Signal and Train Control Committee in 1931.

The Pere Marquette Ry. installed a system of dwarf signals for main line operation. They were SA searchlight color light type.

Color light type, two and three-position, signals were in use on the New York Central R.R. for hump signals in classification yards.

The Delaware, Lackawanna & Western R.R. installed Style R-2, Union Switch & Signal Co. color light automatic block signals in a system applied to numerous combinations of tracks and for reversible traffic on the main tracks.



Style R-2 signals on Delaware, Lackawanna & Western R.R. (1931)

1932 The Philadelphia Subways installed a modified type of the three-wire circuit code scheme of centralized traffic control.

The first General Railway Signal Co. Type F duplex centralized traffic control system was installed on the Boston & Maine R.R. between South Acton and Hill Crossing, Mass. It was a two-circuit (three or four wires) system and employed polar code control and closed-opened conditions for indications. The normal rated capacity, using the 10-step code, was 128 stations. Type A plug-in relays for non-vital circuits were introduced.

The first Union Switch & Signal Co. Model 31 car retarder installed in regular hump yard service was at the Portsmouth, Ohio, yard of the Norfolk & Western Ry.

The first General Railway Signal Co. Type G centralized traffic control system was installed on the Lehigh Valley R.R. at Van Etten Junction, N. Y. It was a one-circuit (two wires) duplex system and employed polar code control and time code indications. The normal rated capacity, using the 8 or 10-step code, was 64 or 128 stations, respectively.

1933 The first installation of Union Switch & Signal Co. coded track circuits for three and four-indication wayside and cab signaling in electrified territory, was made between Zoo and Arsenal, Philadelphia, Pa., on the Pennsylvania R.R., in March. This installation operated on 100-cycle alternating current.

The Pennsylvania R.R. was granted permission by the I.C.C. to convert all its locomotives equipped with the coded continuous train stop system to the coded continuous cab signal system with whistle and acknowledger. This was done with the understanding that the Pennsylvania R.R. would voluntarily extend cab signal territory to include most of its main line trackage.

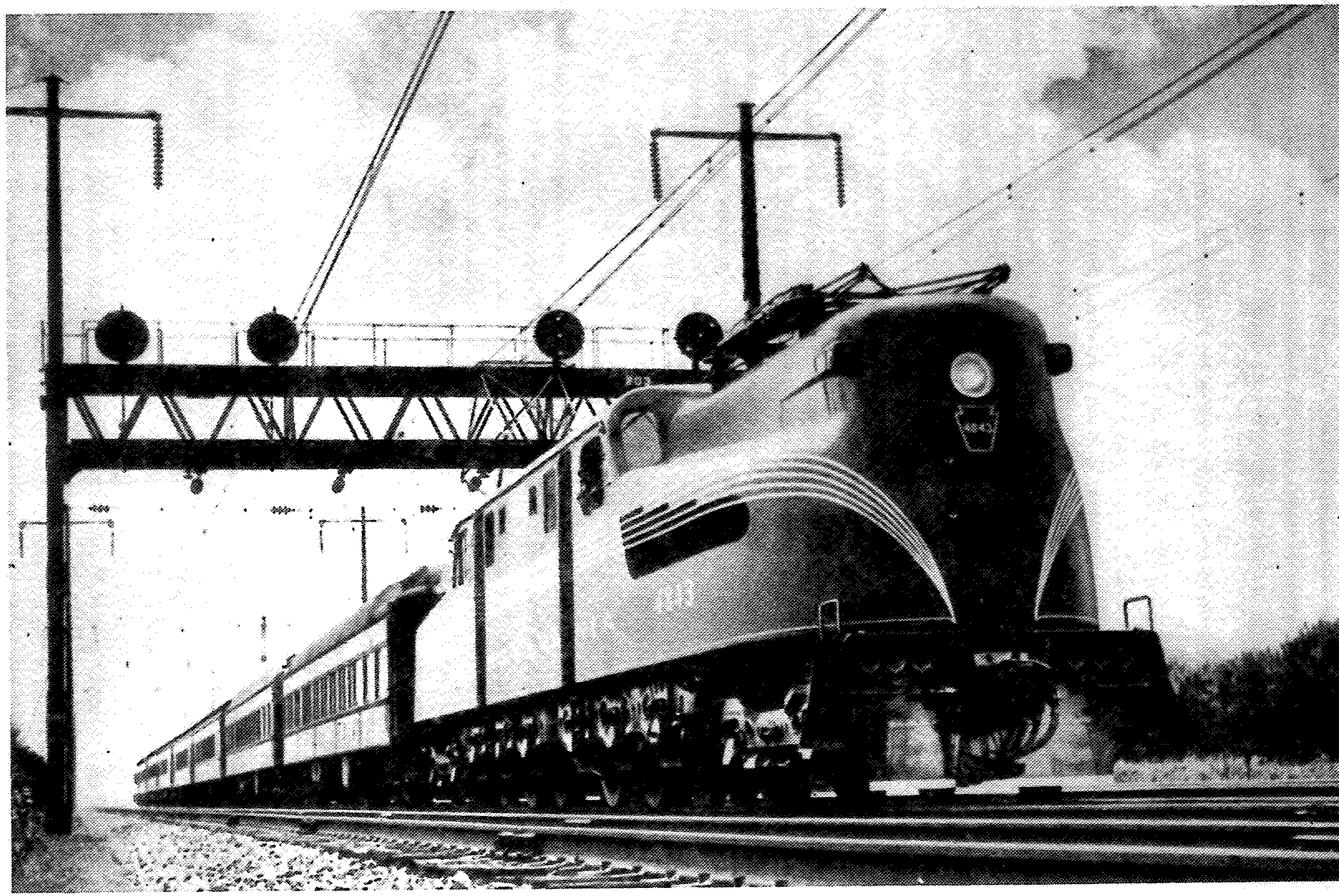
The Boston & Maine R.R. was granted permission by the I.C.C. to discontinue maintenance and operation of the pneumatic stop feature of its automatic train control system and to continue operation as a cab indicator system. This is a two-indication system in which the green cab signal aspect is used for clear while a lunar white indication is used for restrictive. This restrictive indication requires that the train speed be controlled in accordance with indications displayed by wayside signals, rules and special instructions applicable thereto.

1934 The first installation of coded track circuits on steam-operated territory was made between Lewistown and Mt. Union, Pa., on 20 miles of four-track main line on the Pennsylvania R.R. The average length of track circuit was 5,201 feet. Energy was coded storage battery for three and four-indication wayside signals, with coded 100-cycle alternating current superimposed for continuous cab signals.

First installation of coded track circuits in multiple track territory with reverse running on one track was placed in service on Pennsylvania R.R. between Davis and Regan, Del.

1934–1935 A second installation of coded track circuits for three and four-indication wayside and cab signaling in electrified territory was made on 400 miles of track between Wilmington, Del., and Washington, D. C., on the Pennsylvania R.R. Operation of track circuits was with 100-cycle alternating current.

1935 The Pennsylvania R.R., in connection with the electrification of a portion of main-line tracks where it used the three-indication position light signal for the automatic blocking of trains, spaced them for speeds of 90 miles per hour and installed the new Union Switch & Signal Co. coded track circuit system, by means of which the wayside signals as well as the continuously controlled cab signals, are controlled without the use of line wires.

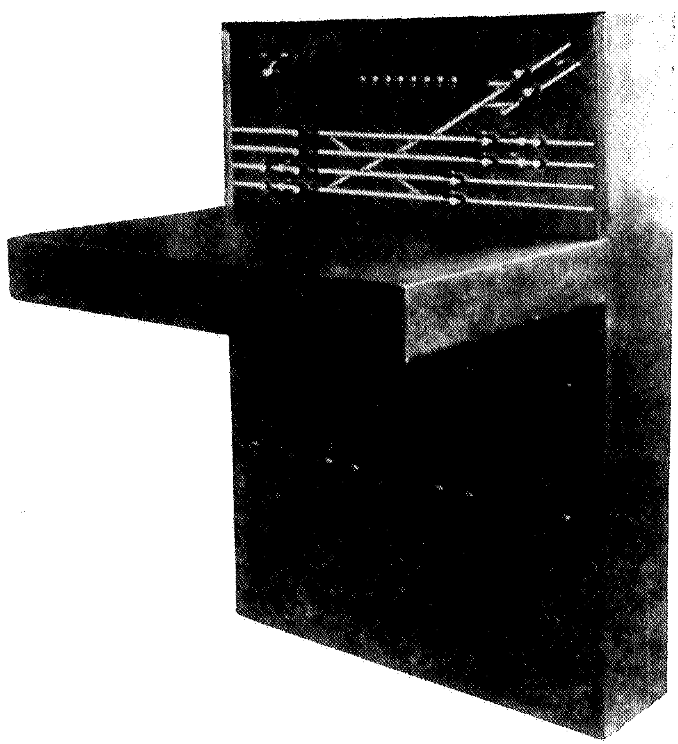


Electrified main line, with position light signals, Pennsylvania R.R. (1935)

1937 The Delaware, Lackawanna & Western R.R. equipped its Hampton (Scranton) Yard, Pa., with Model 31 electro-pneumatic car retarders. It was the first complete yard installation of this type.

The line circuit portion of the 35-station time code system was improved by the Union Switch & Signal Co. to adapt the system for use over long cable lines, and the first installation embracing an entire engine division was that on the Chicago, Burlington & Quincy R.R., Akron to Denver, Colo. A trend toward longer installations started with this Akron-Denver installation.

The first installation of a relay-type interlocking with push-button automatic selection of routes and positioning of switches and signals, General Railway Signal Co. Type "NX", was made at Girard Jct., Ohio, on the New York Central R.R. This installation included the first use of the Type B plug-in relay.



Control machine at Girard Junction, Ohio, on the New York Central R.R. (1937)

1938 The first 11,000-foot coded track circuits using primary batteries were installed at Hulton, Pa., on the Pennsylvania R.R.

The first General Railway Signal Co. Type H centralized traffic control system was installed on the Chicago, Burlington & Quincy R.R. between Gaines and Brickyard, Nebr. It was a one-circuit (two wires) simplex system and employed polar code control and time code indication. Indication cycles were clipped to suit conditions. This system had cycle distribution (which prevented one indication station from "hogging" the line). The system was designed for superimposed telephones.

The first installation of a coded reverse circuit for approach lighting of wayside signals and approach energization of cab signal energy was made at Longfellow, Pa., on the Pennsylvania R.R.

On May 11 the first installation of the Union Style "UR" relay-type interlocking, with push-button route control, was made. It was on the Baltimore & Ohio Chicago Terminal R.R. at Western Ave. and 14th St., Chicago, Ill.

At Elizabethport, N. J. on the Central R.R. of New Jersey the Union Switch & Signal Co.'s Style H-5 searchlight type color light signal was first installed. This signal was similar to the previous Style H-2 except that the operating mechanism was entirely separate and independent of the optical system. Both the reflector and the operating mechanism were plug-connected for quick detachment. This installation was also the first to use the PN-50 plug-in relay for vital circuits.

1939 The first application of coded detector track circuits in interlocking was made by the Norfolk & Western Ry.

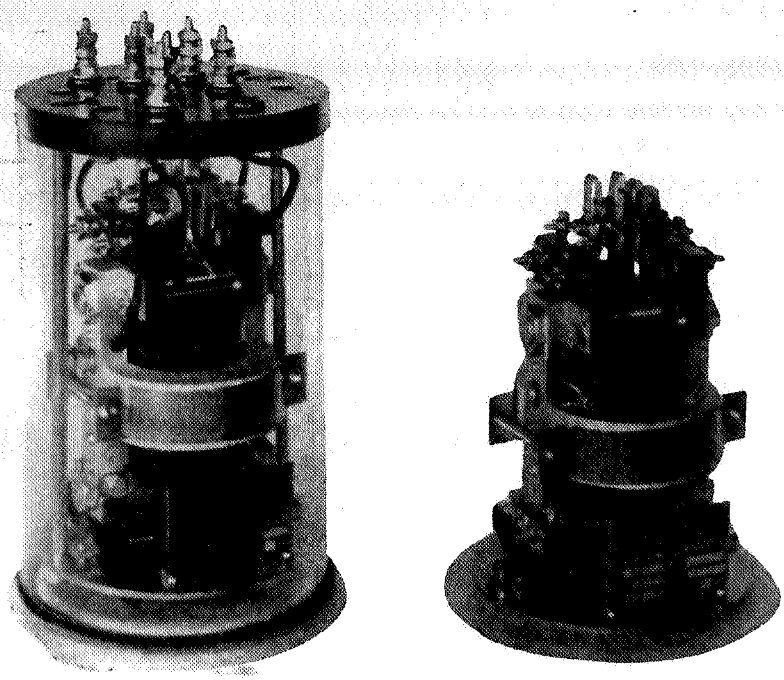
The first installation of three-indication wayside signaling only in steam territory, employing 11,000-foot coded track circuits, was placed in service between Rochester and Wampum, Pa., on the Pennsylvania R.R.

A four-indication four-speed coded continuous train control system was installed on suburban cars of the Key System, Southern Pacific and Sacramento Northern Railroads operating over the San Francisco-Oakland Bay Bridge, Calif. The system was designed to handle 10-car multiple unit trains operating on a 1-minute headway. The wayside equipment and the Key System and Sacramento Northern car equipments were of General Railway Signal Co. manufacture. The Southern Pacific car equipments were furnished by the Union Switch & Signal Co. The installation included an NX interlocking system with a train describer and automatic operation of a single switch.

The first application of the tuned alternator, developed by the Union Switch & Signal Co., as a "stand-by" for the supply of cab signal energy, was placed in service between Tyrone and Huntingdon, Pa., on the Pennsylvania R.R.

1940 The first installation of coded track circuits for continuous cab signaling without wayside automatic signals in steam territory, developed by the Union Switch & Signal Co., was made between Conpit and Kiskiminetas Junctions, Pa., on the Pennsylvania R.R.

The first application of approach-energized tuned alternators as the sole source of cab signal energy was made on the coded track circuit installation between Conpit and Kiskiminetas Junctions, Pa., on the Pennsylvania R.R.



Tuned alternator for stand-by for coded
cab signal energy. (1939)

The Pennsylvania R.R. installed a centralized traffic control system between Harmony and Effingham, Ill., using the Union Switch & Signal Co. two-wire, 35-station time code type for the first time on a multiple-connected line circuit in which the line wires were continuous throughout the territory, and which provided for the coordination of the code circuit and communication circuits over the same line wires. This was the first installation of a centralized traffic control system to employ a two-wire code line circuit in which all the field locations were connected in multiple across the line wires.

The first installation of reversible coded track circuits in single-track territory with centralized traffic control was made between Machias and Hubbard, N. Y., on the Pennsylvania R.R.

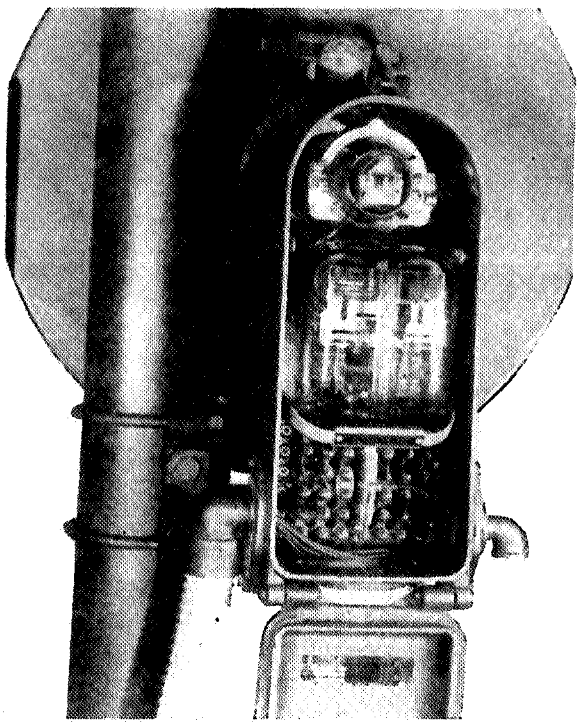
An installation of storage battery fed coded track circuits on two-track road was made on the Baltimore & Ohio R.R. at Versailles, Pa. to overcome improper signal operation due to foreign direct current originating from electrolytic protection provided on adjacent oil pipe lines.

The first installation of absolute permissive block signaling with three and four indications with coded track circuits was made on the Norfolk & Western Ry. between Petersburg and Evergreen, Va.

The first installation of absolute permissive block signaling using coded track circuits for detection only was made on the Chicago, Rock Island & Pacific R.R. between Des Moines and Iowa Falls, Iowa.

1941 The Canadian National Ry. installed centralized traffic control between Catamount and West End (Moncton), New Brunswick, using a two-wire polar control simplex system (series-line), with provision for superimposing telephone on the code line wires.

Between Tower A and Silver Lake, Mass., on the Boston & Maine R.R., the General Railway Signal Co.'s Type SC searchlight type color light signal was first installed. This signal employs two tractive armature relays so mechanically interconnected that the vane carrying the colored roundels is moved progressively from the red to the yellow to the green positions, and vice versa.



Type SC searchlight signal first installed on Boston & Maine R.R. (1941)

The first installation of speed control for car retarder operation was made on the Norfolk & Western Ry. at Roanoke, Va. Model 31 electro-pneumatic retarders were used.

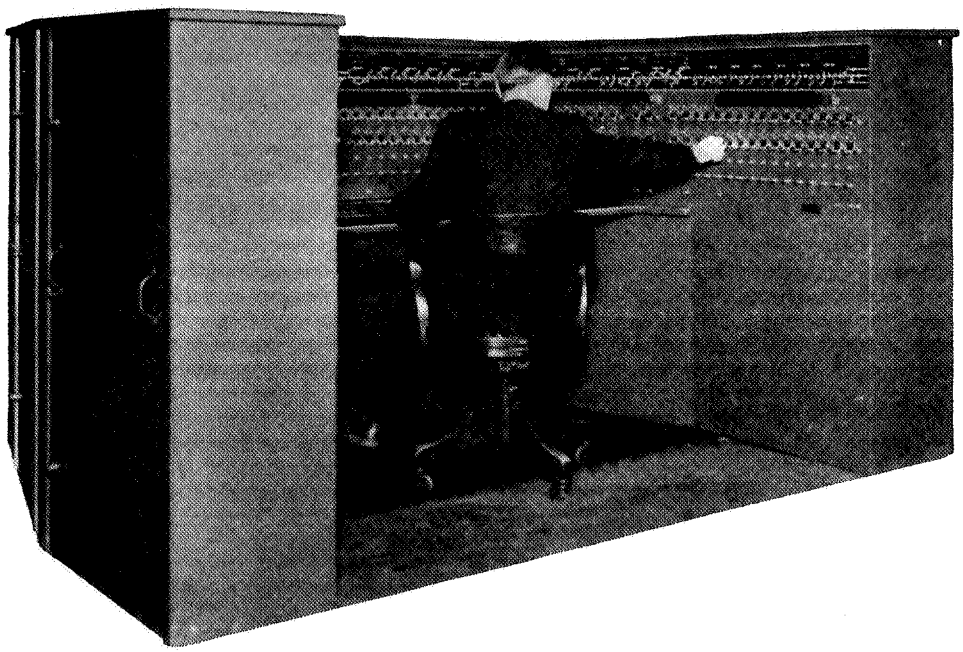
The first installation of normally de-energized coded track circuits was placed in service through the Moffat Tunnel on the Denver & Salt Lake Ry.

The New York Central R.R. installed coded track circuits on multiple-track steam road between Batavia and Corfu, N. Y., providing regular four indications in automatic block territory and, for interlocking approach signals, the fifth and sixth indications. Approach lighting and approach locking were also provided, making on some circuits as many as eight controls, all without the use of line wires. Only three code speeds were employed; forward codes being polarized where controls for more than three proceed aspects were provided. Inverse codes supplied the required approach controls and follow-up codes were used to cut out rail-highway grade crossing signal operation after the passage of a train. No batteries were used on this particular installation, the energy being rectified alternating current.

Coded track territory on the main line of the New York Central R.R. equipped with intermittent inductive train control. (1941)

1942 The first installation of coded four and five-indication signaling in electrified territory was made on the New York, New Haven & Hartford R.R.

The Union Switch & Signal Co. coded carrier control system for use on multiple-line centralized traffic control installations was first tested successfully on the Seaboard Air Line R.R. between February 9 and 14 and later was installed between Raleigh, N. C. and Alberta, Va. to control the territory between Alberta and Richmond, Va. from the dispatcher's office at Raleigh.



Seaboard Air Line R.R. machine for carrier controlled C.T.C. (1942)

The first Union Switch & Signal Co. coded carrier control section to be placed in regular operation was on June 4 between Dunsmuir and Delta, Calif., on the Southern Pacific Co.'s Redding to Black Butte, Calif. centralized traffic control installation.

The first General Railway Signal Co. Type K centralized traffic control system was installed on the Chicago, Burlington & Quincy R.R. between Aurora and Steward Junction, Ill. It was a one-circuit (two wires) simplex system and employed time code control and indication.

1943 The Union Pacific R.R. placed the Las Vegas, Nev.—Yermo, Calif. 171-mile centralized traffic control installation in service in June. Two carrier control sections with carrier repeater, and one direct current section were used. It was the longest centralized traffic control installed by any railroad up to this date.

The first installation of coded track circuits using polar reverse codes with three-indication signaling for either-direction operation was made on the St. Louis & Southwestern Ry.

The New York Central R.R. installed polar impulse coded track circuits in a tunnel where exceptionally low ballast resistance and unfavorable shunting conditions existed. Because of these combined adverse conditions, it was recognized that a high amount of energy would have to be fed into the track to secure proper operation. To overcome the restrictions as to the amount of current which could be handled dependably by relay contacts, a single half-wave 60-cycle energy pulse was fed to the track through relays controlled by electronic tubes in such manner that the contacts would close and open during the "off" periods of the half-wave energy. With contacts never closing or opening the circuit while current was flowing, the amount of current that could be fed to the track was not critical.

1944 The Chicago, Rock Island & Pacific R.R. replaced its Regan intermittent electrical contact ramp type automatic speed control system with Union four-indication coded continuous inductive cab signaling on 165 miles of two-track main line between Blue Island and Rock Island, Ill. and abandoned the Regan installation between Rock Island and Des Moines, Iowa.

The first installation of normally de-energized coded track circuits for centralized traffic control on single track was placed in service December 28, between Laredo and Polo, Mo., on the Chicago, Milwaukee, St. Paul & Pacific R.R.

Remote control manual block with reversible normally coded track circuits was installed on the Wabash R.R.

The first application of coded unit carrier apparatus for handling of vital circuits was made on the Pennsylvania R.R.

1945 A centralized traffic control system with provisions made to receive indications on track motor cars direct from the track, employing steady energy normally in the track circuits and coded energy for the clearing of signals, and transmitting indications to the motor cars, was first installed on the Western Pacific R.R.

The Chicago, Rock Island & Pacific R.R. installed single-track station-to-station automatic block signaling between Omaha, Nebr. and Limon, Colo., using coded track circuits at low code speeds without line wire. This permitted the use of a large number of cut-sections and the system was capable of automatically being set up for operation in either direction. Polarized coded track circuits were used between head blocks.

The Pennsylvania R.R. installed at Bulger, Pa., on the Panhandle Division, normally steady reversible coded track without line wire to provide for cab signaling in either direction.

The Atchison, Topeka & Santa Fe Ry. successfully demonstrated the feasibility of centralized traffic control operation over long distances on existing railroad communication lines. Test was made over 2,200 miles of telegraph circuit.

1946 The Pennsylvania R.R. demonstrated the feasibility of centralized traffic control operation over commercial communication circuits, including beamed radio. The test was made over approximately 1,130 miles of Western Union carrier telegraph circuit including about 90 miles of beamed radio. This was the first time beamed radio was used for this purpose.

The first General Railway Signal Co. carrier link control was applied to centralized traffic control line circuits between McCook and Hastings, Nebr., on the Chicago, Burlington & Quincy R.R.

Reverse code with lockout protection against foreign direct current was installed on the Pennsylvania R.R.

Reverse code with approach type lockout was installed in connection with normally de-energized track circuits on the Chicago, Rock Island & Pacific R.R.

The Central R.R. of New Jersey installed a half-wave rectified track circuit with special features for the operation of the code following direct current track relays and coded cab signals in connection with a polarized code system for reversal of traffic between Towers C and BV.

The Pennsylvania R.R. installed the first automatic regulating track transformer for cab signal track circuits.

1947 Normally de-energized track circuits without line wires, using coded track capable of being set up from entering end of single-track section with centralized traffic control, and provision for automatically or manually setting up the direction of traffic in case of centralized traffic control failure, were installed on the Seaboard Air Line R.R.

1948 The Chicago & North Western Ry. installed a centralized traffic control system between West Chicago and Nelson, Ill., a distance of 70.5 miles, superimposed on the existing cab signal system.

1949 The first installation of coded NX interlocking, developed by the General Railway Signal Co., was installed at Kansas City, Mo., on the Missouri Pacific R.R.

The first installation of coded track automatic block signaling with multiple aspects, approach lighted, was put in service on the Buffalo, Rochester & Pittsburgh Ry. between Rochester and Scottsville, N. Y., by the General Railway Signal Co. The installation included both forward and inverse track coding which was started automatically by approaching traffic. At all other times the system was non-coding, the signals dark.

The Union Pacific R.R. converted its two-indication non-code continuous cab signal system between North Platte, Nebr. and Cheyenne, Wyo. and its two-indication non-code continuous speed control system between The Dalles and Portland, Ore., to three-indication coded continuous cab signaling.

The Union Pacific R.R. installed a 325-mile centralized traffic control system between Salt Lake City, Utah and Caliente, Nev. The entire territory is controlled by two machines located at Salt Lake City. Only two code line wires are used to handle the controls and indications for the entire installation, which consists of one direct current section and five coded carrier sections.

The first diagrammatic type control machine for car retarders was installed on the Monongahela Connecting R.R. at the East Yard, Pittsburgh, Pa.

The first installation of Type E electric car retarders for regular hump service was made at DeWitt Yard, Syracuse, N. Y. on the New Ycrk Central R.R.

1950 The Richmond, Fredericksburg & Potomac R.R. placed in service a consolidation of controls covering four of its main line interlockings on multiple track between Richmond and Alexandria, Va.. The interlocking function control and indication was effected by conventional coded control features including carrier circuits remotely controlled from Richmond, Va.

The Illinois Central R.R. installed at its southbound Markham Yard, Chicago, Ill., on 27 of its 45 tracks, a system of automatic switching developed by the General Railway Signal Co.

The Canadian Pacific Ry. installed at St. Luc Yard, Montreal, Quebec, Canada, the first car retarder system to be completely operated by automatic switching. The system, developed by the General Railway Signal Co., included speed control for movements through the retarders located ahead of the scales.

1951 The Long Island R.R. installed a two-speed continuous inductive train control system in which a limit of 12 miles per hour was imposed in uncoded track circuit territory, 30 miles per hour with 75 code, and no limit with 180 code. These speed limits were later changed to 15 miles per hour and 33 miles per hour respectively.

The Pennsylvania R.R. installed a three-speed continuous inductive train control system in which the limits were 20 miles per hour with no code, 30 miles per hour with 75 code, 45 miles per hour with 120 code and no speed limit with 180 code.

The first coded remote control system using the General Railway Signal Co. syncrostep system, was installed at Fort Plain, N. Y., on the New York Central R.R., Lines East.

The Seaboard Air Line R.R. installations of coded carrier control for centralized traffic control reached a total of 1,045 miles, between Richmond, Va. and Miami, Fla.

The first use of a portable radio, called "Dick Tracy," by yard switchmen was on the Southern Ry. in connection with coupling cars in the classification yard and transferring them to the departure yard.

The Southern Ry. was the first to use a special "Shove Signal" to facilitate car movements into the departure yard after classification, and to devise a special wedge to keep couplers open for firm couplings in the classification tracks.

Push buttons for control of automatic switching for classification yards were included in the main control machine in the tower, for the first time, at the Rutherford, Pa. Yard of the Reading Co.

1952 The Erie R.R., on October 26, placed in service at Waterboro, N. Y., in connection with the establishment of a remotely controlled interlocking, a system of automatic train identification. This sytem automatically identifies the direction and the number of a train as it clears a manual block on a branch line. The OS is automatically transmitted from the unattended location by carrier circuits to the dispatcher's office, 22 miles away.

Statistics for automatic interlockings reveal that for the 10 years prior to 1952 the number of installations averaged 15 per year, and during 1952 there were 27 mechanical interlockings at outlying railroad grade crossings replaced by automatic interlocking.

The Richmond, Fredericksburg & Potomac R.R. converted its three-indication non-code continuous inductive two-speed train control system to a four-indication coded continuous inductive two-speed train control system.

In order to overcome interference from commercial 60-cycle power lines, the Louisville & Nashville R.R. converted its two-indication continuous non-code 60-cycle one-speed train control system so as to operate on 100 cycles for the territory between Corbin, Ky. and Etowah, Tenn.

The first installation of a complete automatic switching system, combined with a retarder speed control system, developed by the Union Switch & Signal Co., was made at Air Line Yard, Milwaukee, Wis. on the Milwaukee Road. Model 31, Union Switch & Signal Co. electro-pneumatic retarders were used.

The Illinois Central R.R. equipped northbound Markham Yard, Chicago, Ill. with Model 31 electro-pneumatic car retarders and an automatic switching system, developed by the Union Switch & Signal Co.

1953 A new General Railway Signal Co. automatic retarder operation system for electric car retarders was installed at the Kirk Yard, Gary, Ind. on the Elgin, Joliet & Eastern Ry.

The first installation of cab signaling using transistors in place of vacuum tubes was placed in service on the New York, New Haven & Hartford R.R.

The first installation of inductive carrier transmission for cab signal indication in classification yards was put in service at Grand Junction Yard, Colo., on the Denver & Rio Grande Western R.R.

The first installation of a centralized traffic control system in which control and indication of intermediate signals is accomplished without the use of line wires, was installed on the Cincinnati, New Orleans & Texas Pacific Ry. between Tateville and Ludlow, Ky. The system, which was developed by the General Railway Signal Co., is called "Trakode."

The first installation of a new multiplex code control system was completed by the Delaware, Lackawanna & Western R.R. at Newark, N. J., for the consolidation of three important electro-pneumatic interlockings, handling 233 through trains and 30 drilling movements daily. The interlocking at Newark is controlled by direct wire while all switch, signal and associated functions at Harrison, N. J., where 38 controls and 72 indications are involved, and at Kearny Jct., N. J., where 21 controls and 54 indications are involved, are controlled remotely over a single pair of wires by high speed code. Codes for both sections can be transmitted simultaneously and each code contains complete control and indication information for all functions in its associated remote section. The system is known as the Union 516 multiplex code control system in which 25 controls and 50 indications are transmitted concurrently per second. An interesting feature of the system is that its capacity can be expanded in multiples of 25 controls and 50 indications per second, such as 50-75 controls and 100-150 indications, respectively, simultaneously over one pair of line wires. In this first installation, all track circuits are alternating current type and are repeated by Type PN 50B plug-in direct current relays in the instrument housings. Trains in this territory are operated by 3,000-volt electric propulsion, direct current.

The Union Pacific R.R. made the first installation of the 506C code control system, a new development by the Union Switch & Signal Division of Westinghouse Air Brake Co. extending from Cheyenne to Laramie, Wyo., and the Texas & New Orleans R.R. made the first installation of the 514 code control system, another new development by Union Switch & Signal, extending from Rosenberg to Harrisburg, Tex. Both of these are time code systems which provide facilities for increasing the number of control and indication steps as required at any particular location without requiring any additional station assignment.

The first installation using transistors instead of vacuum tubes in safety type (vital circuits) carrier equipment was made on the Pennsylvania R.R. The equipment was developed by the Union Switch & Signal Division of Westinghouse Air Brake Co.