The wayside inductors and connections are tested semi-monthly on or near the 14th and 28th of the month. The schedule for these tests and equipment needed was prepared with the idea of requiring a minimum of labor and time on the part of the signal maintainer and yet secure readings to assure that the circuits and inductor are in condition to function properly. The following tests are made at each inductor location:

(1) Test for short circuit or open circuit, by inserting signal battery and ammeter in the inductor circuit as shown for Test *A* in the diagram herewith.

The amount of current shown will indicate the condition of the circuit. With a potential of approximately 11.5 volts, the meter should show a reading of approximately 2.6 amp. for the territory east of Clarksville, and .75 amp. for the territory west of Clarksville. Special report must be made when a variation of over 10 per cent is found in these readings. With this same hook-up a test should be made of the inductor circuit with control relay shunted: Meter should read zero.

(2) Test for grounds by inserting ammeter between positive battery and test terminal, and ground negative side of battery as shown for Test *B* in this drawing.

With the other lead from the test terminal free, the circuit should test clear of grounds.

(3) Test for grounds on signal line circuits, first by inserting the voltmeter between the negative side of the battery and ground, then second by inserting the voltmeter between positive battery and ground, all as shown for Test *C* in the diagram. Testing terminals are installed in instrument cases at all inductor locations so that it will not be necessary to open up signal circuits.

Directing Trains by Signals

Comparison of Time and Space Interval Methods, Early Developments of Block Signals and Present Day Uses Explained

By H. M. Sperry

Consulting Signal Engineer, New York.

THE efficiency of train operation depends upon several factors, the most important of these being: Adequate and properly maintained trackage and terminals; properly maintained locomotive and cars; and a system of directing train movements that will insure the maximum utilization of track and equipment capacity and the maximum output of train miles in a unit of time. The prime purpose of a system of train direction is to keep trains in motion. This paper is to deal primarily with the relation between modern signaling and train service efficiency under present-day conditions. Inasmuch, however, as present practice is the result of nearly a century of evolution, some attention will be given to the outstanding historical facts connected with the development of train movement direction.

These methods from the beginning of steam transportation have been based upon one or the other or both of two definite principles—(1) the time interval, and (2) the space interval. In the earlier days general practice favored the time interval, but under modern conditions the space interval, under signal indication, is universally recognized as the method which insures the maximum of train production with the minimum of train delay, risk, and expense. With the time interval method train movements are directed by time tables, train orders and train dispatching. Prior to the electric telegraph the time-table was the sole authority for train movements and serious delays were often unavoidable. The Morse electric telegraph came into use in 1844 and seven years later it was first used in train operation for the sending of train orders.

Growth and Present Day Volume of Train Orders

With the first train order came telegraphic train dispatching which offered an effective means for reducing the delays incident to operation under time-tables. Time-tables make no provision for the prompt movement of delayed trains or for the running of extra trains. A description of the first train order, in Mott's History of the Erie Railroad, explains how train dispatching came into use.

"To Charles Minot belongs the honor of having made the first practical application of the Morse telegraph to railroading, either in this or any other country, when in the early autumn of 1851 he successfully ran a train by a telegraph order for a distance of 14 miles on the Erie."

Superintendent Minot was our first train dispatcher. Today there is a force of 5,400 train dispatchers and, in addition, 59,600 other employees wholly or partially employed in supervising and directing the movement of trains. Their total wages in 1925 was $122,000,000.

Two forms of train orders are in use, form "31" and form "19." The rules require that form "31" shall be receipted for in writing by the conductor of the train addressed. Form "19" is receipted for by the station operator, who is held responsible for the delivery of the order to the conductor and engineman of the train addressed. Because of this difference in delivery, a moving train is required to stop for a "31" order, but need only slacken speed for a "19" order. If the order should authorize the train to continue its journey, then the delivery of the "31" order, requiring the train to stop, causes a useless delay that might have been avoided by the use of the "19" order.

When Superintendent Minot, in his effort to keep trains moving, issued his first train order he probably did not dream of the magnitude of the effort that must be made today. It is estimated that no less than 130,000 train orders are issued daily, a total of over 47,000,000 orders a year. As practically all train orders are issued in duplicate, the total number delivered to trains is nearly 95,000,000 orders. This is a conservative figure as sometimes even three or more copies of an order are made.

Space Interval Gives More Adequate Protection Than a Time Interval

With the space interval method, train movements are directed, as in the time interval method, by time-tables, train orders and train dispatching, and in addition by

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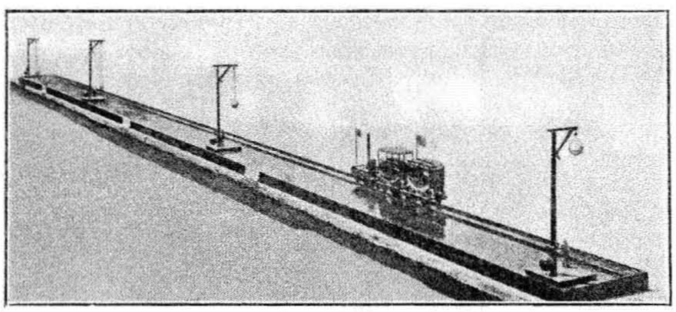
block signals. Block signals are for the purpose of reducing the hazards of train operation by maintaining a space interval between trains. Space between trains spells safety from collision.

In the time interval method the effort to maintain a space interval by requiring trains to run at least 5 or 10 min. apart too often fails of its purpose. It is practically impossible always to maintain under any *time* interval method a *space* interval between trains running at different speeds. For example, trains may be scheduled to move on 10-min. intervals, but unless these trains are kept moving at the same speed the 10-min. margin may be reduced to zero. Should the margin be reduced by one of the trains stopping, entire dependence for protection against accident is placed upon the vigilance of the engineman for an approaching train and upon the alertness of the flagman of the stopping train. In the space interval, or block signal system, space is maintained between trains by dividing the road into sections with fixed signals to govern the movement from section to section.

Block Signals Used in America 90 Years Ago

The following abstract from a paper on "Signals" by J. Elfreth Watkins of the Pennsylvania, presented in 1899, shows that the value of maintaining space interval between trains was recognized over 90 years ago:

"Although the block system of signals is generally believed to be of English origin, it is a matter of record that it was in use on an American railroad, now forming a part of the Pennsylvania in 1832. Soon after the New Castle & Frenchtown Railroad was opened for steam traffic the necessity for establishing a system of signals became apparent. Poles 35 ft. high were located about three miles apart, and when the train started from either end the flagman at the terminal station hoisted a white flag to the top of the pole. The flagman at the second station, whose duty it was to look through a nautical telescope every few minutes during the day, hoisted his flag to a point a few feet from the top of the pole. The remaining flagmen followed his example so that at New Castle it was known that the train had started from Frenchtown within a few minutes after it had left that station and each flagman was able to note its passage through each "block." When for any reason the locomotive became disabled, or the train was delayed by other circumstances, a black flag instead of a white flag was hoisted. This method of block signaling proved so satisfactory that flags after a time were dispensed with and bell-shaped signals, consisting of peach baskets covered with colored cloth, were used."



Model of Block Signal System in Use in 1832 on the New Castle & Frenchtown

This crude block system, put in use 12 years before the advent of the electric telegraph in America, had many of the features of present day signaling. The division of the road into block sections with fixed signals governing the entrance to each section corresponds with present day practice.

The first complete block signal system in the United States was established in the year 1863 on the railway between Philadelphia, Pa., and Trenton, N. J., now a part of the Pennsylvania, to provide for a heavy movement of trains carrying troops during the Civil War.

Why the Time Interval Fails to Give Full Protection

The following brief accounts of three collisions due to a misunderstanding of written instructions serve to emphasize the importance of providing a check against the possibilities for error.

The first case illustrates the fact that the ever-present danger of misunderstanding the meaning of the train order is an inherent defect in the method of directing train movements by written instructions. It is a startling example of a misunderstood order resulting in a collision between a northbound passenger and a southbound freight train on a single-track road about six years ago. Ten persons were killed and 32 injured. The order was misunderstood because the name of the station where the trains were to meet was written so carelessly as to be misleading.

But no matter how plainly a train order may be written, the chance for a misunderstanding may still exist. This is illustrated by a serious head-end collision that occurred last year between two passenger trains. The collision occurred on a single-track line operated by timetable and train orders, no block signal system being in use. The order that was misunderstood read as follows:

"Order No. 137
First No. 82 meet No. 89 on double track at U——".

The engineman of Train No. 89 stated that he read the orders to the conductor while the wind was blowing considerably and that in holding train order No. 137 his thumb covered the word "first" in the order and he read it as:

"No. 82 meet No. 89 on double track at U——".

Because of this misunderstanding, after first No. 82 passed, train No. 89 departed from S—— and about three miles beyond collided with second No. 82. One person was killed and 31 were injured.

These two cases illustrate but do not exhaust the possibilities for grave errors in the use of written instructions for directing train movements. The possibilities include not only the misunderstood order, but also the order that is forgotten and the order that is overlooked. Thus, my third illustration describes how an overlooked order caused a head-end collision between two passenger trains. The collision occurred on a single track line operated by time tables and train orders. No block signal system was in use. In this case three orders were issued, together with a clearance card stating that there were three, and were delivered in duplicate to the conductor of the south bound passenger train, who in turn delivered one set to the engineman.

After the collision the engineman stated that he read the clearance card and *two* of the orders. About this time the engineman received a proceed signal, put the orders in his pocket and started. The engineman also stated that when he read the clearance card, he did not have on his glasses, and while the figure on the clearance card showing the number of orders was a plain "3," he said he must have read it for a "2," and that he did not check the orders against the clearance card as the rules require.

These three collisions under the time interval method illustrate the danger in directing train movements by papers bearing written or printed instructions which may be forgotten and overlooked, and, in which a word misread may completely change the meaning.

The space interval method, on the other hand, through the use of block signals, provides an effective check against this class of errors. In the three cases cited the engineman would have had his error brought to his attention, not by a collision with an opposing train, but by the indication of a signal giving him ample warning of danger ahead. In the time interval method, as previously stated, the movement of trains not provided for in the time-able is directed by train orders. In the space interval method, although train orders are also used extensively, the standard code rules provide that block signals may be used in place of train orders.

Space Interval Permits Movement in Either Direction on All Tracks

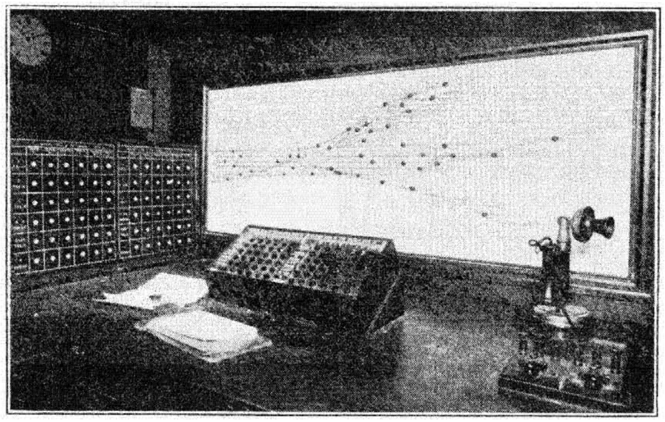
The movement of trains by block signals on two or more tracks *with* the current of traffic is in general use. Train movement *against* the current of traffic, that is, in either direction on one or more tracks of a multiple-track road, is in use on a number of heavy traffic roads. This method of directing the movement of trains by signal indication without train orders eliminates the unavoidable delays of the written train orders, and makes the operation of trains at maximum track capacity possible.

The economic advantages of the space interval method, particularly for operation *with* the current of traffic, are fully appreciated, and increasing consideration is now being given to a more intensive use of track facilities by train operation by signal indication in either direction on one or more tracks of multiple-track roads. Either-direction operation first came into use as a means to increase the track capacity of double-track roads, by adding a third track and operating the middle of the three in either direction. The following is a brief summary of what has been done:

The Chicago, Burlington & Quincy was one of the first railroads to operate three tracks in this way, this practice being applied to a 14-mile section of the main line near Chicago in 1888. At present the main line from Chicago west to Galesburg, Ill., consists of 119 miles of double track and 44 miles of three tracks, or a total of 163 road miles. Both tracks of the double track and the middle track of the three tracks are signaled for operation in *either* direction.

The Baltimore & Ohio put a 36-mile section of three tracks in service in 1911 with the middle track operated in either direction by signal indicaton. Operation during the past 15 years has proved so satsfactory that the construction of a fourth track has not yet been found necessary.

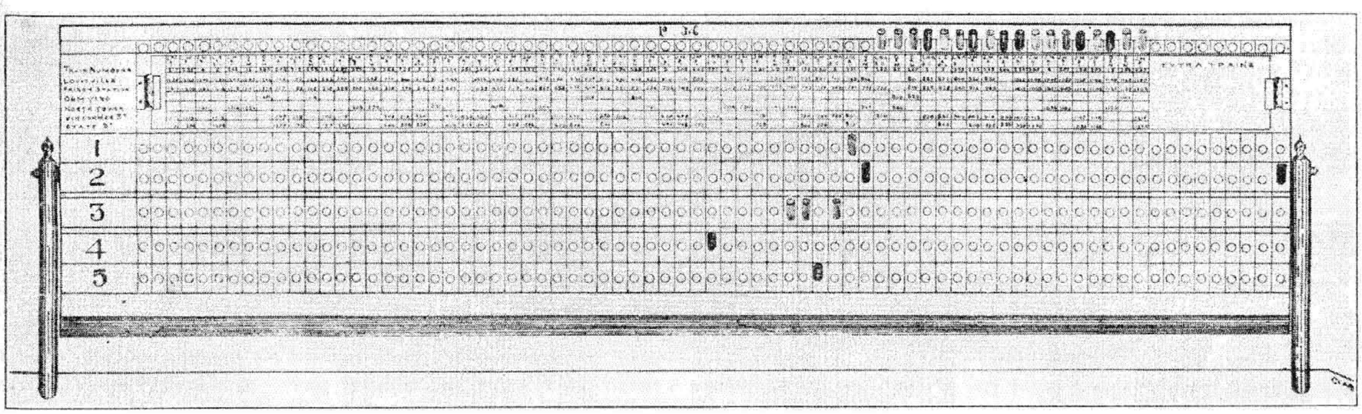
The Pennsylvania Railroad had to meet a difficult situation on a section between Spruce Creek, Pa., and Tyrone Forge, where the road follows the Juniata river which it crosses 17 times in a distance of 7 miles. On account of the heavy cost of construction, this portion of the line has only three tracks, whereas the rest of the division has four tracks. To provide for an increasing traffic in 1913 the middle track in this three-track section was signaled for operation in either direction, and in consequence the construction of a fourth track has not yet been found necessary. Through this method of increasing track capacity the construction of a fourth track has not yet been found necessary. The saving in interest charges alone on the cost of an additional main



New York Central Inter-Communicating Apparatus and Illuminated Train Diagram in Train Director's Office, Grand Central Station

track has been at the rate of $45,000 a year, or for the 13 years, $585,000. This amount is enough to pay for half the construction of a fourth track.

The Illinois Central, in 1925, put a 25-mile section of three tracks in service near Chicago with the middle track operated in either direction by signal indication. The Delaware, Lackawanna & Western moves a heavy suburban traffic over its line between Hoboken, N. J., and Millburn, and has three tracks for 15 miles between West End Junction (two miles from Hoboken) and Millburn. In 1922 either-direction operation was put into use on the middle track for this 15 miles and on the north track for 4 miles. This arrangement provides a track capacity nearly equal to that of four tracks, for



Pennsylvania Railroad Mnemonic Board in Train Dispatcher's Office, Louisville Bridge

in the morning rush hours trains to New York use two tracks for 11 miles and three tracks for 4 miles. In the evening rush hours trains from New York use two tracks for the entire distance.

The Chesapeake & Ohio, at West Ashland, Ky., put a three-track section, 3.3 miles in length, into operation in 1925. This is the last word in three-track operation,