Lackawanna

Modernizes Signal System

for Automatic Train Control

Change from semaphore to color-light signals shows a net annual saving of over $2,000 for a 57-mile section of double track

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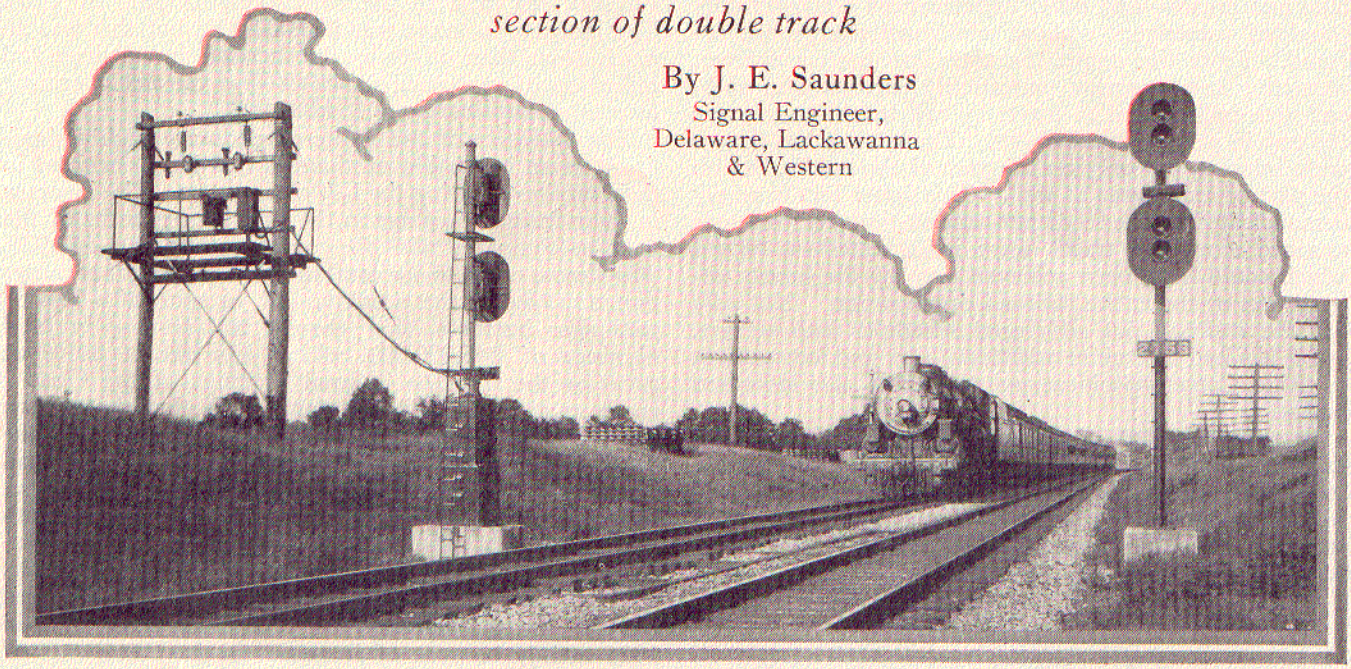


"Lackawanna Limited" Near Owego, N. Y.

THE introduction of automatic train control on many railroads has resulted in a careful consideration of its effect on track capacity, as well as the increase in safety of operation. Naturally, existing signal facilities were checked up in order that they might be made to conform to the braking distances required for automatic, rather than manual, control of the air brakes. In many cases this necessitated a reduction in the number of signals used and in the replacement or elimination of wornout roadside signal appliances. It has meant the substitution of central-station energy for batteries where the train control required alternating current. All these changes have added to the cost of train control, but it is interesting to note that there is some economic justification for the money thus spent. The first part of the main line of the Delaware, Lackawanna & Western from Buffalo to New York passes through rolling country with only a few grades over 0.5 per cent, but after leaving Binghamton, N. Y., two ranges of mountains are crossed before entering New Jersey. Because of heavy grades in portions of this territory, a number of changes were made in the existing signals when train control was introduced.

In compliance with the first order of the Interstate Commerce Commission, No. 13413, the Lackawanna installed automatic train control on the main line between East Buffalo, N. Y., and Elmira, which was placed in service on July 1, 1925. To meet the second order, a second installation, extending eastward from Elmira to Easton, Pa., was made, which was completed on July 1, 1928.

Extent	Miles of Line — Two Track	Three Track	Four Track	Locomotives
East Buffalo to Elmira....	141.0			69
Elmira to Scranton.....	91.44	14.84	9.27	128
Total	232.44	14.84	9.27	197

This territory included 256.5 miles of road and 564.5 miles of main track. It comprises one-third of the total passenger track-miles operated and two-thirds of the main line from Buffalo to Hoboken. Forty-two per cent of all the company's road engines are equipped.

Program to Promote Safety

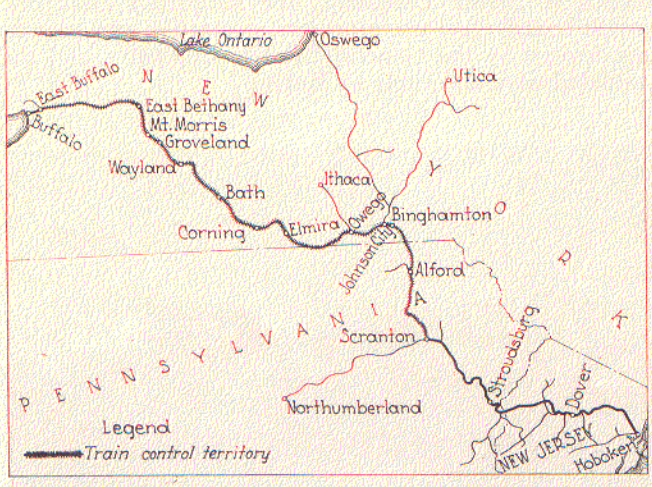
The Lackawanna has been particularly active in its endeavor to prevent accidents. Since 1910, about 248 grade crossings have been eliminated at a cost of approximately $19,000,000. By January 1, 1928, 36 per cent of all public highway grade crossings on the entire line had been eliminated at a cost of approximately $25,750,000. Of those remaining at grade, 25 per cent

have automatic and 24 per cent have manual protection. At the present time the elimination of 50 more crossings is under way or authorized at a cost of $3,000,000. This indicates clearly the policy of the road to invest in accident protective measure where the greater number of accidents occur; where more lives can be saved and personal injuries avoided. As a result, the Lackawanna has been able to minimize or actually reduce the number of fatalities at grade crossings throughout the years that highway traffic has so greatly increased, and this in the face of a steady increase in fatalities at grade crossings for the country as a whole.

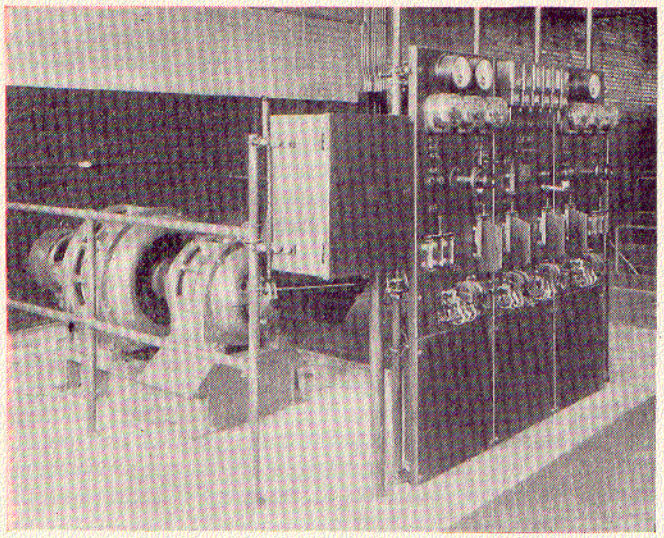
The Lackawanna conducted experiments with train stop systems on its lines as far back as 1913. However, it was found that these early systems did not fulfill adequately the requirements of the heavy traffic which is characteristic of this railroad, or else possessed inherent weaknesses that prevented their adoption. It was not until 1923 that a system was presented that could be accepted as providing adequate protection without too much complication and restriction of track capacity. It is true that train control devices had not even then been fully developed, and a number of changes in detail parts were made after the original installation from East Buffalo to Elmira, but no change has been made or is contemplated in the basic principle involved. Trains are receiving some degree of protection beyond that previously provided by a complete system of automatic block signals. However, there is no record of an accident having been avoided that the automatic signals would not have prevented without train control.

Two-Speed Continuous Train Control

The system adopted as best meeting the Lackawanna's operating conditions is the two-speed, continuous inductive train control of the Union Switch & Signal Company. The locomotives are equipped with both visual and audible cab signals. The visual signal provides a green light when the speed of the train is not automatically restricted and a yellow light to indicate that a speed of 20 m. p. h. must not be exceeded. A change from unrestricted (green) to restricted (yellow) is audibly indicated by means of a whistle in the cab. Both the engineman and fireman are thus given advance warning when entering a danger zone. This indication is given a sufficient distance from the obstruction to provide a six-second delay period to allow the engineman, if alert, to acknowledge it by moving a lever, and to initiate a service application of the air brakes.



Lackawanna Main Line Showing Extent of Train Control Territory



Frequency-Changer Sets and Switchboard at Elmira Power House

Unless either he or the firemen does act, a full service brake application (split reduction) will be made at the end of the six-second interval, and the train will be brought to a stop, the same as when the engineman applies brakes. The only difference is that if the engineman is alert, and does not acknowledge receipt of the restrictive light and whistle indications, and does initiate a brake application, he may, if track conditions permit, release the brakes after the train speed has been reduced to less than 20 m. p. h. As long as the slow-speed (yellow) cab signal indication persists, any increase in speed above 20 m. p. h. will cause an immediate service application of brakes to be made automatically, and the train brought to a stop.

While the cab signals repeat the restrictive indications of wayside signals they do more, for any change in conditions ahead is immediately reflected in the engine cab. Thus a switch thrown after a wayside signal has been passed, or a train backing into the block ahead, will cause a restrictive cab signal indication to be given, with coincident enforcement of speed limitation. Conversely, a train running at less than 20 m. p. h. under restrictive cab signal indication, can resume speed at once when conditions ahead improve; for instance, when the train ahead increases speed or pulls into a siding.

The cab signal is the only feature of the train control system which is of any help in getting trains over the road. It also increases safety, because it informs the fireman as well as the engineman of danger ahead; it also provides a means for taking immediate advantage of improved conditions and allows a train to proceed safely, independent of weather or other conditions that obscure the engineman's vision of fixed wayside signals. Experience has proved the value of this during storms.

The 6,600-volt generating, transforming and transmitting layout has sufficient capacity to supply an ultimate four-indication coder system of train control, a-c. track circuits, and switch and station lighting.

Automatic Signals

Originally, automatic signals on the double-track lines were spaced the practical length of a polarized track circuit, thus avoiding the use of line wires. This meant blocks ranging from 4,500 to 5,500 ft. in length, irrespective of grades. Train control and cab signals

introduced a new problem. The cab signal must give an indication consistent with that of a fixed wayside signal as it is passed. After receiving the cab signal, the engineman is allowed six seconds to acknowledge a restrictive indication and apply the brakes. At 70 m. p. h. for passenger trains this six-second delay means 616 ft., after which a split reduction must be made. Taking all delay factors into account, this meant a decided lengthening of the distance between caution and stop signal locations.

This condition was met on the Buffalo division by overlapping the caution signal controls, providing two caution signals approaching each stop signal, either interlocking or automatic. On steep ascending grades the regular signal spacing was sufficient. In all cases, full braking distance is provided after passing the first caution signal, at which point train control will be effective. While such an arrangement meant a minimum change in signal locations, it required a more complicated circuit scheme with extra signals, line wires, relays, etc. On the Scranton division between Binghamton and Scranton most of the semaphore signals were installed in 1915, and thus have about 15 years of service life left. Instead of overlapping the control of these, alternate signals were removed on down grades and level track, a few signals were moved, and most of them now provide a single caution indication approaching a stop indication.

Between Elmira and Binghamton the situation was different. These signals were installed in 1905, and were badly in need of replacement. After consideration of comparative maintenance and operating expense, it was decided to install color-light signals, and to erect a separate signal department pole line with power transmission at a sufficient voltage to take care of both the signals and the train control.

85 Daily Trains Over Division

Approximately 28 passenger and 57 freight trains are operated over this division each day. Most of these are high-speed trains, and to avoid train delays in the event of power interruption, storage batteries were installed, to provide current for the line relays and to serve as an emergency supply for the signal lamps. Neutral d-c. relays receiving energy from caustic soda batteries are used on track circuits. The train control track transformer secondary winding is connected in series with the track battery, so that the track circuit for signal control is also independent of the power supplied over the transmission line.

It was necessary to carry train control circuits through 19 interlocking plants, all but 5 of them being on the second division. Between Elmira and Scranton most of the top arms of interlocking home signals were changed from two-position lower-quadrant to three-position upper-quadrant in order to provide for equal spacing of trains. At these interlockings, complete approach, route and section locking are provided. All but four of the towers are of concrete.

Construction Details and Costs

Before starting work on the plans, a trip over the road with the superintendent and trainmaster afforded ample opportunity to discuss the respacing of signals. A number were eliminated, and the new color-light signals were spaced in accordance with braking-distance tables and graphs, taking into consideration the effect of grades and curves. Cab signals make the view approaching a roadside signal of less consequence and, therefore, permit of a more nearly ideal train spacing. In all, 128 semaphore signals were replaced by 93 color-light signals. The semaphores were two-arm, two-position, lower-quadrant, providing three indications, whereas the color-light signals provide up to six indications.

The cost comparison is based on replacement costs at current prices, as the old semaphore signals, line wires, insulated wire and cable, etc., were worn out and would have had to be replaced in any case. Relays and all track circuit materials were salvaged by being moved to new locations. While a smaller number of color-light signals displaced semaphore signals, the track capacity was actually increased. A closer spacing with three-block signal indications is provided adjoining terminals, and elsewhere signals are spaced according to the actual running time of trains, taking into account grades and curves.

The replacement cost for semaphore signals in 1928 was determined by using factors developed by the Signal Valuation Committee of the "Eastern Presidents' Conference Group." The cost of the high-voltage transmission line is not included as it would have been required for train control alone and would have been utilized for supplying energy to semaphore signals if these had been retained.

Cost of Automatic Train Control with Changes and Additions to Automatic Signaling and Interlocking*

1.	Cost of roadway equipment—train control parts only	$80,693.27
2.	(a) Cost of power lines chargeable to train control	157,006.05
	(b) Cost of power lines chargeable to signal system	42,792.01
3.	Cost of new color-light signal system	150,414.29
4.	Cost of changes in existing signaling	219,871.84
5.	Miscellaneous changes in tracks, crossing protection, etc.	13,475.64
6.	Total cost of roadway installation	$664,253.10
7.	Total cost of locomotive equipment	306,083.75
	Grand total	$970,336.85

* Figures are subject to slight adjustments resulting from agreements, not yet completed, covering line encroachments.

Cost Comparison of Color-Light and Semaphore Signals—Elmira to Binghamton

		Color-Light	Semaphore
1.	First cost	$150,414	$71,334
2.	Year installed	1928	1905
3.	First cost brought up to 1928 by applying valuation factors	$150,414	$123,943
4.	Increase in first cost	26,471	
5.	Annual charge for interest (5 per cent) and depreciation (5 per cent)	2,647	
6.	Cost of maintenance and operation per year	13,816	18,486
7.	Increase in maintenance and operation for semaphore signals compared with color-light		4,670
8.	Net saving in annual charges (7 minus 5)	2,026	

The plans and specifications were prepared in the signal engineer's office. W. A. Comstock, supervisor of construction, had charge of operations in the field, having at times as many as 100 men at work. The signal and train control materials were supplied by the Union Switch & Signal Company; the frequency changers, switch boards, line transformers, protective and switching devices by the General Electric Company, and the insulated wire and cable by Kerite.

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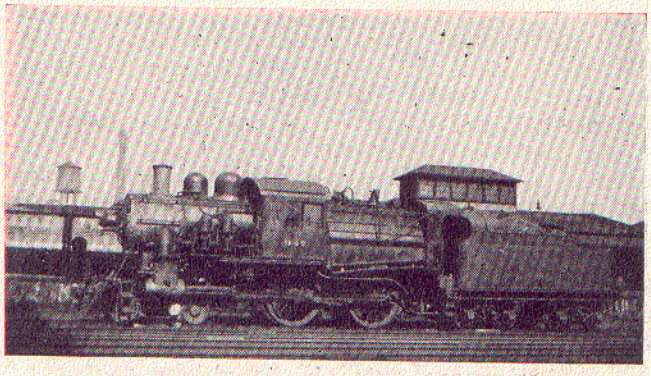

Passenger Locomotive on the Lackawanna