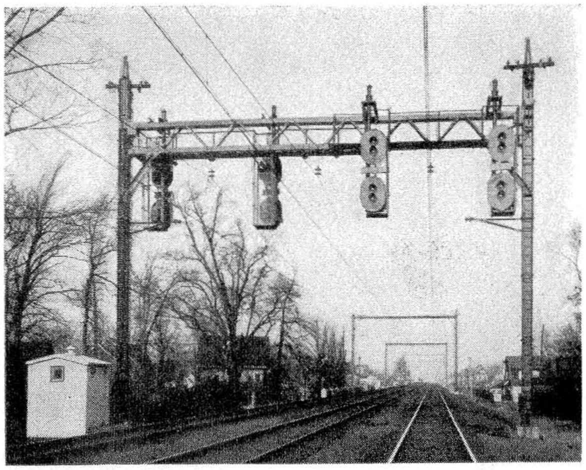


Automatic signals in three-track territory

The Signaling of Electrified

Automatic signals and interlockings revamped — Change-over accomplished without delay — Forces were well organized

WHEN they noted the first field operations, few of the 35,000 persons who regularly commute on the Lackawanna between their homes in the suburban residential district of northern New Jersey and New York City, thought that within 12 months they would be riding in the most modern type of multiple-unit electrically propelled cars and making the trip in from 15 to 30 per cent less time than when steam locomotives pulled the trains. Nor did they realize the magnitude of the project which involved 70 miles of road and 160 miles of track, and which made it necessary to raise overhead bridges, move retaining walls, change track levels for clearance, erect a catenary structure every 300 ft., string wires and cables, move the wood pole line previously used, erect substations, develop and put into operation mercury-arc rectifiers of a capacity and voltage never produced before, and finally to completely revamp an extensive signal and interlocking system under as heavy train operation as can be found on any steam railway in the United States. Yet all this was accomplished with but little interference with traffic, and without a single accident due to removal of the safeguards provided by automatic signaling and interlocking.

Traffic Conditions

The Lackawanna suburban lines, which are now electrified, extend from Hoboken to Montclair, Dover (via Morristown) and Gladstone, with a short section for freight movements only between the west end of Bergen tunnels and Secaucus. Both the Lackawanna ferries and the Hudson & Manhattan tube trains deliver passengers from New York at Hoboken terminal, where 17 station tracks are provided for passenger traffic.

Five reversible main tracks are used between the terminal and Grove street, at the east end of Bergen tunnels, a distance of 0.7 mile. These tracks converge to four, all reversible, through two tunnels to West End, which is the junction between the three-track Morristown line and the two-track Boonton line, which meet later at Denville. It is 1.4 miles from Grove street to West End, from where three main tracks extend to Millburn, a distance of 14.7 miles excepting at Passaic River drawbridge, Newark, which is double track. Three tracks are reversible through West End interlocking; two are reversible from the Hackensack river to Newark, and one is reversible from Newark to Millburn. A double track line runs from Roseville avenue to Montclair, a distance of 4 miles.

From Millburn to Denville there are two tracks for 19.4 miles. A 22.2-mile single track line connects Gladstone with the main line at Summit. From Denville to East Dover, 2.9 miles, two of the four tracks are electrified, and this continues as double track 1.2 miles farther to the Dover passenger station. The total length of main tracks electrified, including a 1.2 mile lead to Secaucus freight yard from West End, is 134 miles. Two hundred ninety-five passenger trains enter or leave Hoboken each week day.

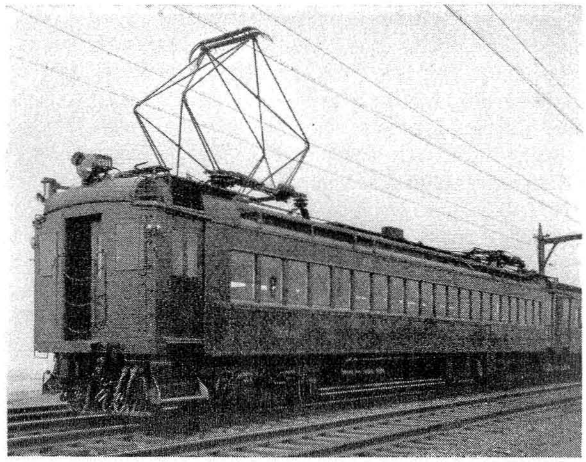
This district presents some interesting traffic problems, one of which is the restriction in space available for additional tracks, due to a narrow right-of-way and the high value of adjoining land. Thus the density of traffic on existing tracks is bound to be great and those available must be made to accommodate this traffic safely and without delay. Passenger traffic is heavy eastward in the morning and westward in the evening. This is taken care of by arranging for the reversal of traffic on certain tracks. Thus on the three-track section two tracks are operated eastward in the morning and two westward in the evening, the equivalent of a four-track railroad. The four-track section provides three in one direction, and the five-track section affords four tracks for parallel train movements into or out of Hoboken Terminal, during the rush hours.

Another traffic problem is the clearing of the Hoboken station tracks as soon as passengers are unloaded. Storage space is limited, indicating the advantage of electric shuttle service to and from Montclair, South Orange, etc. The Bergen tunnel will form a long block until steam trains can be eliminated; the two-track drawbridge at Passaic river, Newark, is between two three-track sections and may slow up traffic at times. River traffic through two drawbridges often proves troublesome. Other handicaps from both the traffic and revenue standpoints, are the short runs between terminals; Hoboken to Montclair is only 13.1 miles, and to South Orange 13.8 miles. It is difficult to secure satisfactory car and passenger miles on such runs.

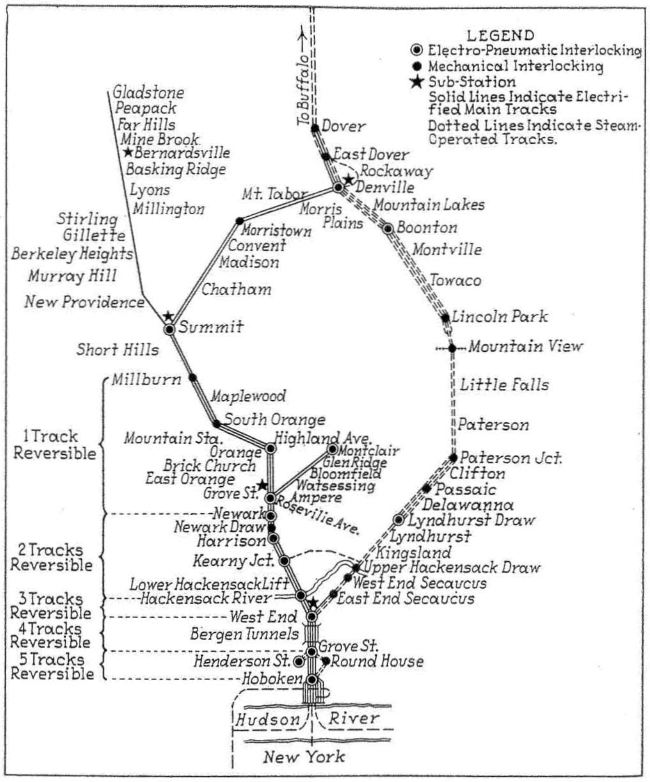
The safe operation of trains and maximum track capacity throughout the suburban zone are secured by directing train movements by signal indication with supervisory manual control through interlocked switches at junctions and other critical points. Where traffic is heavy, the signals are located less than braking distance apart and give three-block indications. Traffic-locking between towers allows the direction of traffic to be reversed and the tracks available to be used to full advantage at all times.

the Lackawanna Territory

By J. E. Saunders
Signal Engineer,
Delaware, Lackawanna & Western,
Hoboken, N. J.



Electrically operated train



Motor-driven air compressors and battery chargers receive power locally or from the electrical department 3-phase 60-cycle lines. All other signal department electrical energy requirements in the electric zone are supplied from the five substations, located at West End, Roseville, Summit, Bernardsville, and Denville, with emergency sources at Montclair, Summit, and Morristown. The substations receive energy from three public service corporations. Supply lines are in duplicate, with automatic change-over equipment in the substation signal feeders.

Power Supply and Distribution

The signal power transmission is at 60 cycles, 2,300 volts, single-phase. The allowable over-all variation in voltage at the point of supply is 5 per cent and the lines are laid out for a maximum drop of 5 per cent, thus the maximum variation should not exceed 10 per cent and really comes well within 5 per cent at most locations. The 2,300-volt wires are No. 0 to No. 4 A.W.G. medium hard-drawn stranded copper, strung at the tops of the catenary columns, 300 ft. apart, and on the top crossarm of the wood pole line on the Passaic & Delaware branch. These lines are sectionalized at both sides of each interlocking plant and where they are more than five miles apart, additional line switches are used. A ground wire is run on a bayonet support above the 2,300-volt signal transmission lines at both sides of the catenary supports.

Duplicate 2,300-volt lines are in service between Hoboken and Summit. A single line serves the purpose elsewhere, but provision is then made to reverse the direction of feed if the occasion should demand. At Newark and South Orange, voltage-ratio adjusters with auto-transformers provide a voltage boost in either direction when it is necessary for one substation to feed through and supply the signal load in the territory of the adjoining substation. This is done by manual switching.

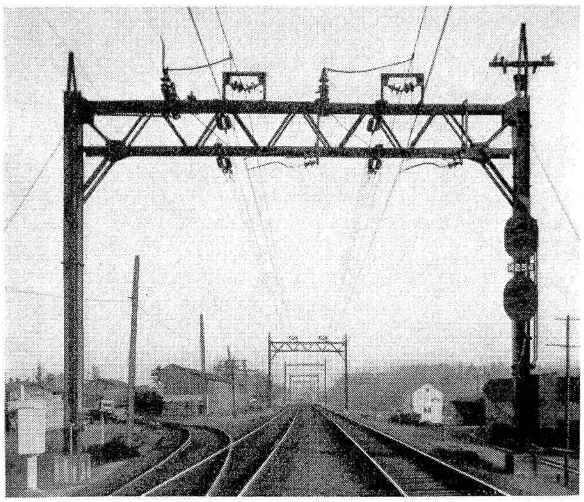
Signal line transformers are Type H, 2300/115-volt, air-cooled, with 5 and 10 per cent primary taps, and of standard capacities: 1.5, 3, 5, 7.5 and 10 kv-a. Enclosed porcelain fused-primary cutouts rated at 7,500 volts are used for isolating the line transformers and for sectionalizing, and poles for operating them are kept in nearby relay boxes. The lightning arresters are Pellet oxide film type.

At each transformer location where duplicate 2,300-volt lines are in service, there is a power transfer relay on the 115-volt side of the transformer, which controls the supply of energy to the signal system. The secondaries of no two line transformers are connected together, i. e., there is no common wire between transformers. No connections to earth are permitted in either the signal primary or the secondary distribution systems. Wherever possible to do so without additional expense, provision has been made for later changing the power supply from 60 to 100 cycles.

Track Circuits

Included in the territory are 327 single and 360 double-rail track circuits. Because of their lower first cost, single-rail track circuits up to 1,000 ft. in length are in use through interlockings where one rail could be released for exclusively signal track circuit currents. Each of these circuits requires a Model-15 2-element, 2-position relay, a 300-va. Style-W-10 track transformer rated at 115 to 17 volts with secondary taps for 0.375-volt adjustments, and two adjustable resistors, one between the transformer secondary and the rails and the other between the relay and the rails. Two 600-volt 20-amp. fuses are in series with the transformer secondary and two 600-volt 15-amp. fuses are in series with the track winding of the relay. A single 250-volt 10-amp. fuse protects the track transformer primary winding.

To avoid burnouts due to momentary high voltages imposed upon the signal rail of single-rail track circuits, shunt protectors (spark gaps) are connected between the signal and propulsion rails of all single-rail track circuits—one for circuits 200 ft. and less in length, two for all others. The shunt protector consists of parallel straps of brass, separated by slotted mica spacers, with an air gap which will break down at 600 to 800 volts. The two straps will then be welded. The purpose is to create a short circuit between the rails and thus prevent more serious damage elsewhere. The discharge unit is placed in an iron case, which is mounted on the tie. Terminal binding posts connect to cables which are in turn bonded to the rails.



Signal location east of Madison —Note telephone box at left

Of the 360 double-rail track circuits 289 are for electric road and 71 for steam road traffic. These track circuits are limited to 3,500 ft. in length, assuming a ballast leakage resistance of 2 ohms per thousand feet. The double-rail track circuit includes a Model-15 two-element two-position relay, a 300 v-a. track transformer, the same as is used in a single-rail circuit, a reactor between the transformer secondary and track, and two 500-amp. impedance bonds. A single 250-volt 15-amp. fuse is in series with the track winding of the relay. The primary side of the track transformer is protected by a 250-volt 10-amp. fuse.

The impedance bonds are generally mounted on creosoted tie grids, set in the ground at the end of each track section. These grids were made up of standard cross-tie stock, each grid for mounting two bonds requiring 1⅓ ties. These sections were cut, framed and bored by a jig, then they were loosely bolted together and given a full creosote treatment. The bolts were then tightened and the grids shipped. These layouts are located just beyond the ballast shoulder, adjacent to the insulated joints. The bonds are then set on the grids and held fast by lag screws.

This method has the following advantages over that of placing the bonds between the rails:

(1) The bond is free from damage due to dragging equipment.
(2) It is not subject to vibration from passing trains which tends to break the cables where attached to bond terminals.
(3) The space between the rails is free, so that the ties can be tamped and other track work done without interference.
(4) Spreading of ties to let the bond case drop between is avoided, thus maintaining the proper support for rails.

The distance between the halves of double bonds is constant, thus facilitating the use of a standard length of strap copper for the neutral connection instead of cables and lugs. Where there is no room adjacent to or between tracks, the bonds are placed between the rails. A few 1,000-ampere bonds are required at substations.

On multiple-track lines, bronze-taped cable is used for track wires, this being buried underground, with enough slack to allow for changes in steel, and brought up to the rail without special outlet boxes. The joint between the cable and bootleg wire is protected by tape and the application of a waterproof compound. Cross-bonding is permitted under certain regulations which insures a high degree of broken-rail protection. The catenary ground wires are generally connected to the rails at crossbonding locations.

Signals

Prior to the electrification two-arm two-position lower-quadrant semaphore signals were in use, from Hoboken to West End, from Orange west, and on the Montclair branch. In 1922 color-light signals were installed to replace the older semaphore signals between West End and Newark. At this time the three-block indication scheme was inaugurated on the Lackawanna. In 1923 color-light signals were installed between Newark and Brick Church, and in 1928 between Denville and East Dover. All the remaining high semaphore signals were replaced as a part of the electrification project. This included slotted mechanical, electric and electro-pneumatic mechanisms. Dwarf signals of the semaphore type were retained at interlockings, where their condition did not warrant replacement. Most of the other semaphore signals had been in service from 25 to 30 years and many of them were in urgent need of replacement. Their control and operating mechanisms were not immune to the effects of the high-voltage propulsion direct current and the cost of changing these mechanisms to a-c. operation was prohibitive. It was logical from both an economic and train operation viewpoint to replace the older signals by modern color-light signals, and to provide aspects and indications that had been made standard nine years before through a portion of the district being electrified.

The color-light signals are Style R-2, with individual transformers and 10-volt, 18-watt lamps, excepting through Hoboken terminal where a wide-spread, short-range indication was required, and the Style HC-32 with 10-volt 30-watt lamps and a 30-degree spreadlite lens was used instead. The new dwarf signals are Style N-2, also with the 18-watt lamp. The color-light signals installed included 416 two-light and 55 three-light long-range units; 128 Style HC-32 single-light short-range units; and 89 Style N-2 dwarf signals.

Spacing of Signals

The semaphore signals formerly in the electrification district were located for traffic of 20 to 30 years ago. In many places they were not separated sufficiently to allow a modern steam train to stop before reaching the next signal on a service application of the brakes. Therefore three factors entered into the location of the new color-light signals: (1) Braking distance for the heavy through trains, steam engine propelled; (2) braking distance for the new multiple-unit electric trains; and

(3) maximum length of track circuits. Naturally the effect of grades and curves had to be taken into account.

The braking distance for heavy steam trains had been determined through experience of many years. That assumed for electric trains was the result of a number of running tests made with Lackawanna multiple-unit cars on the General Electric Company's test track at Erie, Pa. The allowable length of track circuits was known. The result was that for two-block indications, signals are spaced approximately 6,000 ft. apart, and for three-block indications approximately 3,000 ft. apart. These are for a maximum speed of 60 m. p. h. and allow sighting time with a reasonable factor of safety. The multiple-unit cars are equipped with electro-pneumatic brakes.

Thus with the new location of signals, there is safe operation and increased track capacity, as signals are spaced more closely with three-block indications where the traffic is heavier, and are spread out, with two-block indications where such spacing and indications will keep the trains moving. To increase the track capacity in the outlying sections there need be only the addition of signals, line-control relays and wires. The track circuits are properly arranged, line transformers are in use for cut sections, and in most cases catenary bridge legs will serve as supports for the signals.

All signals are located to the right of or immediately above the track governed, the signals being kept as low as practical. For double-track lines most of the signals are mounted on the catenary support column, an "H" structure. For three or more tracks, the signals are on the beams of signal-catenary structures, placed as low as is considered safe, with the lowest part of the signal at least one foot above the contact wires. For the single track P. & D. branch, the old semaphore signal cases and masts were rebuilt in the signal shop at Dover and utilized for housing relays and supporting color-light signals. Lackawanna standard simplified color-light signal aspects and indications are provided.

Signal Control Wires and Circuits

The signal control circuits are kept away from the 3,000-volt catenary structures as much as possible. Where this is not possible, the insulated wires are suspended from a messenger that is insulated from the catenary structure. Where a wooden pole telegraph and telephone line was available, No. 9 A.W.G. bare hard-drawn copper signal control wires were placed thereon, or if space or clearance did not permit, cables were hung from a messenger. At other locations the cables are in underground conduits, or in bronze-taped cables run 20 in. below the ties and packed with clay. The local signal lamp wires are isolated from other 110-volt control wires by means of a special 10,000-volt 1:1 test transformer. No attempt is made to provide special insulation between these local wires and the catenary structures on which the signals are mounted.

Signal line-control relays are Model-15 two-element three-position vanes for polarized control, or direct-current relays, supplied with current from copper-oxide type rectifiers which receive alternating current over line circuits, for neutral control. Direct-current relays are generally used for repeaters, and wherever retarded release is desired.

For many years the Lackawanna standard relay box has been made of wood, and as it has given good service, this same standard was followed in the electrification work, except where the capacity of two 10-way relay boxes was exceeded where a 6 ft. by 6 ft. Massey concrete house was erected.

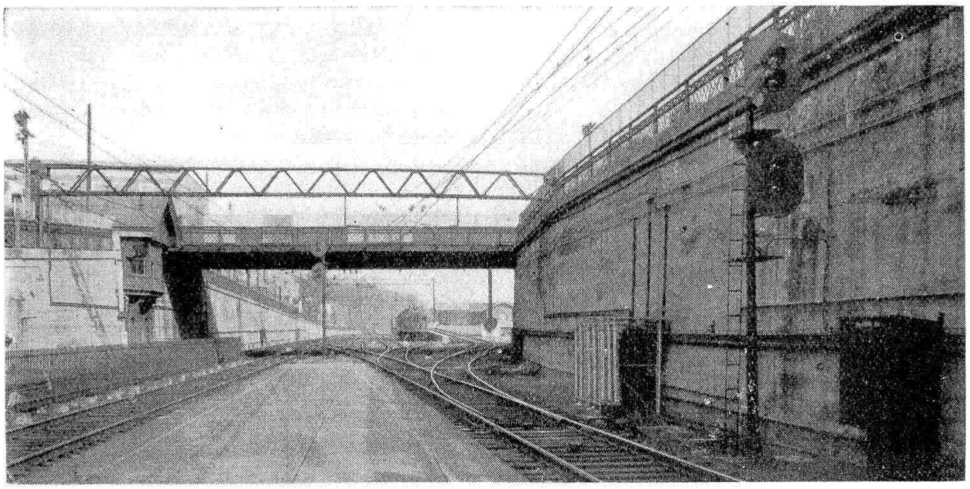
Interlocking Changes

The line of least resistance in converting interlockings to handle 3,000-volt direct-current electric trains would have been to replace all direct-current signal appliances, but this would have increased the cost materially. Only those changes were made that were essential for the safe handling of traffic. All semi-automatic signals were changed to color-light, thus substituting a signal without moving parts for direct-current magnets and motors. Electro-pneumatic switch valve magnets were left as before, but their control was changed to alternating current from the interlocking machine through copper-oxide rectifiers housed with the valve magnets. Circuits limited to the lower remained direct current and battery circuits, either positive or negative, were not allowed to be taken outside. The direct-current magnets of electro-pneumatic semaphore type dwarf signals were retained, but these are controlled by alternating current from the interlocking machine with rectifiers located at the valve magnets. The DR circuits are polarized, using alternating current, with Model-15, 3-position vane-type relays. The MR and approach locking circuits also utilize alternating current but with individual rectifiers at the relay, thus retaining the direct-current relays. Switch indication circuits are operated by polarized alternating current with Style-TV-40, three-position vane-type relays at electro-pneumatic plants. At mechanical plants, these continue to be operated by polarized direct current, as their function is merely the SS control of signals, and other safeguards minimize the possibility of failures. All mechanical switches have separate lock levers, electrically locked.

Entrance to Hoboken terminal with combined signal and catenary bridge in foreground—Short-range signals shown here

Systematic Change-Over

Without doubt the changes that had to be made at interlockings constituted the major portion of the signal work to be performed in connection with the electrification project. Here also was the greatest liability in doing the work under traffic. Much of this at the larger terminal plants had to be done at night and on Sundays to avoid interference. Practically all of the wires and cables in use were continued and in most cases for different functions. To change over from one system of power supply and utilization to another without resorting to new wire runs saved a considerable sum but necessitated very careful handling in order to avoid failures and possible train derailments. Supervision and inspection had to be tightened not only due to the character of the work but also to the number of new men employed. In so far as possible, men with experience on the Lackawanna were promoted to higher positions open on construction, and the others employed in advanced positions had had signal experience elsewhere.



East end of Summit interlocking—Note tower in wall at left

List of Interlockings Changed Over

Location	Type of Plant	Working Levers	No. Switches	No. Sig. Masts	Layout
Hoboken Term.	E.P.	143	180	123	Terminal
Grove Street	E.P.	62	55	75	Junction
Henderson St.	E.P.	22	22	17	End of Yard
Round House	Mech.	29	13	17	End of Yard
West End	E.P.	58	57	63	Junction
East Secaucus	E.M.	30	14	14	End of Yard
Hackensack Br.	E.P.	13	6	6	Drawbridge
Kearny Jct.	E.P.	15	10	10	End of Yard
Harrison	E.P.	22	15	19	End of Yard and 3-track Jct.
Passaic Bridge	E.M.	8	3	2	Drawbridge
Newark	E.P.	16	7	13	Through Track Junction
Roseville Ave.	E.P.	22	22	18	Junction
Montclair	E.P.	35	49	31	Terminal
Orange	E.P.	31	27	30	Crossovers and Yard
South Orange	E.M.	48	20	22	End of Yard
Millburn	E.M.	22	8	12	Three Track Junction
Summit	E.P.	18	21	17	Jct. and Yard
Morristown	E.M.	24	11	13	End of Yard
Denville	E.P.	35	33	35	Junction
East Dover	E.M.	23	12	10	Junction and End of Yard
Dover	E.M.	25	13	16	End of Yard
Totals		701	598	563	

It is impossible to describe in detail the changes that had to be made at the various interlocking plants, but the extent of these is indicated in the tabulation of machine set-ups.

Two major jobs came within the scope of the interlocking changes. At Grove street, the connecting switches from the Henderson street (Jersey City) yard were removed and these tracks were brought into the main tracks at a different point. New crossovers were required for parallel train movements across all four main tracks. It was necessary to substitute a new interlocking machine with 62 working levers for the old one having 51 working levers, originally installed at Hoboken in 1900 and moved to Grove street in 1908. Beside the extensive changes made in the location of switches, color-light signals replaced semaphores and a-c. track circuits supplanted d-c., all coincident with the electrification and under traffic. How the final changeover was accomplished is described in the May 1930 issue of *Railway Signaling*.

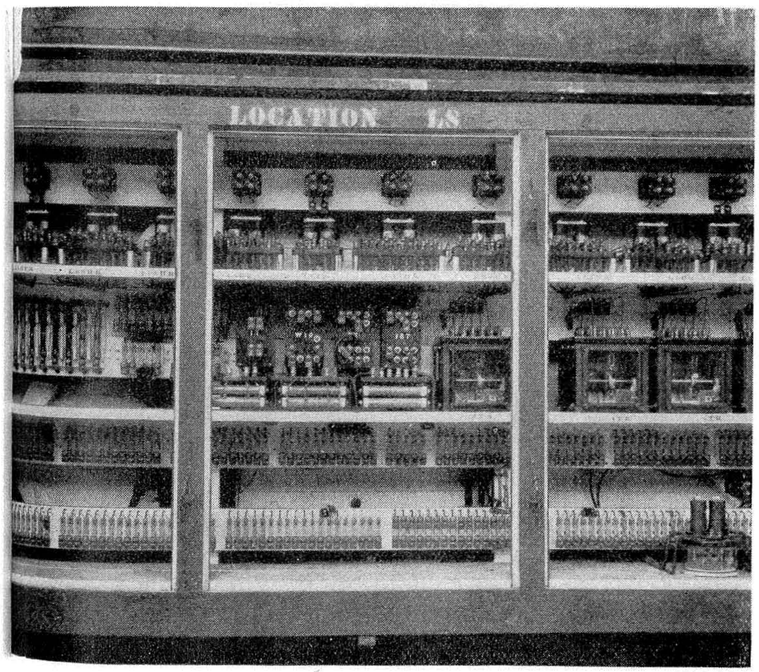
At Summit there were two mechanical interlocking machines in towers only 1,000 ft. apart. One was operated only one trick, all switches being set for parallel routes, and the signals made automatic during the remainder of the day. This deprived the operating department of the use of two three-track crossovers during a considerable portion of the day. The mechanical interlocking machines were 26 years old and worn out. The pipe lines and insulated wire runs all needed renewing. The obvious answer was to combine the two plants. An electro-pneumatic machine that had seen service elsewhere was rebuilt by railroad forces, and switch movements with the new Style-CP valves were installed. The net saving was $665 annually after deducting depreciation and interest on net capital investment required. The betterment in train operation became noticeable immediately. Twenty-four hour service allowed run-arounds not possible before. All switches and signals operated more quickly, thus saving time during rush hours. The interlocking was extended on the P. & D. single track branch to P. & D. Junction one mile away, thus allowing a train to be advanced one station to meet or be passed by another, without a written train order.

The P. & D. branch, 22.2 miles of single track, was formerly protected by 92 single-arm semaphore signals of the home or distant type, controlled by the preliminary-overlap system. These were replaced by 58 three-color light signals, controlled by the absolute-permissive scheme. These signals give more information to the enginemen and provide more satisfactory handling of trains than before. As some of the stations were separated but one block, it was necessary to deviate somewhat from the standard A.P.B. circuits.

Even though traversing a highly developed section there are but seven public highway grade crossings on the Lackawanna between Hoboken and Dover, via Morristown, and these are all protected by automatic flagmen, gates or watchmen. Coincident with the electrification work flashing-light signals were installed at seven crossings, mostly on the P. & D. branch.

Engineering

The preparation of plans and estimates for new signaling and interlocking, no matter what their magnitude, is relatively simple when compared with replacing the same amount of apparatus in use by that of a different character, particularly when the changeover must be made without interference with traffic. The signaling for the Lackawanna electrification had to be designed and the work accomplished not only without interference with train operation but also at a time and in a way not to retard other departments which were erecting overhead bridges and stringing catenary and power supply wires. While economically justified the coincident major changes in the track layout at Grove street and the combination of two mechanical plants in one power interlocking at Summit meant a heavy drain on available manpower when needed elsewhere. To put the signal department further on its mettle the time limit set and actually met by all departments was materially less than for any electrification project of equal magnitude before undertaken.



Instrument case at interlocking. On top shelf note d-c. relays with rectifiers fed by a-c. supply. Middle shelf right, a-c. track relays

The limitations meant that the work had to be laid out carefully. Before starting the preparation of plans and specifications a study was made of the signaling recently installed in electrified territory on other railroads. Apparatus and the method of its application were discussed with the engineering representatives of manufacturers. Standards were established, some of which, for the sake of economy, were radical departures from previous practice. Detail lists of material for each location were compiled, prices were secured and orders placed on the total requirement but with deferred delivery dates stipulated that would enable the signal department to maintain its schedule, and also avoid charges for storage and rehandling.

Organization of Forces

The engineering was carried through by men who had been trained in the Lackawanna signal department. The younger engineers were the output of a course in signal engineering apprenticeship started six years before. The plans were made under the supervision of A. Reilly, assistant signal engineer. The field construction was divided between two construction supervisors, W. A. Comstock and H. Rice, due to its magnitude and the short time in which it had to be completed. One engineer had charge of lists of material and its ordering. An inspector was responsible for receipt, check and delivery of materials to construction gangs where and when wanted. As each section was completed, inspectors under Chief Signal Inspector I. K. Johnson checked out and put the signal and interlocking appliances in service.

Electric train service was extended in five sections. In each case the signal and interlocking work was completed, tested, and in service sufficiently in advance to cause no delay in the running of trains. This required close cooperation between departments, as the power for the signals is carried in wires mounted in most cases on the catenary structures.

The signals, relays, track transformers, impedance bonds, etc. were supplied by the Union Switch & Signal Co. The insulated wire and cable is Kerite; the 2,300-volt line transformers, fused cutouts and lightning arresters are of General Electric manufacture.

Economics

The expenditure for signal and interlocking changes as a whole cannot be justified by any saving that is the direct result of such changes. This work was made necessary to provide for the safe operation of trains under electric propulsion. However, it is gratifying to know that certain savings were possible as the result of the changes in signals and interlockings. The saving at Summit has already been mentioned. Note has also been taken of the improvement in train operation on the P. & D. branch. Six men were released for work elsewhere because of the substitution of electric lamps for oil lamps, and of alternating current from the substations for energy from primary battery. Allowing for an increase in the cost of inspection and field tests, there is a net saving of $3,000 annually in labor. Most of the semaphore signals replaced were at or nearing the end of their lives. To have replaced these in kind would have cost double that of the color-light signal units which took their place. The expenditure thus avoided, figured on a ten year plan of substitution, is $12,000 annually.

The substitution of alternating current for direct current from primary battery previously used in the electric zone allows a saving in operating expense for materials amounting to $7,500 annually, notwithstanding the increase in facilities and electrical energy used.

Careful consideration of track circuits within interlocking limits and the effect of reducing their number on train operation, by both operating and engineering departments led to a net reduction of 71. One hundred thirty-three insulated joints (23 per cent of the total) were eliminated at Hoboken terminal interlocking alone.