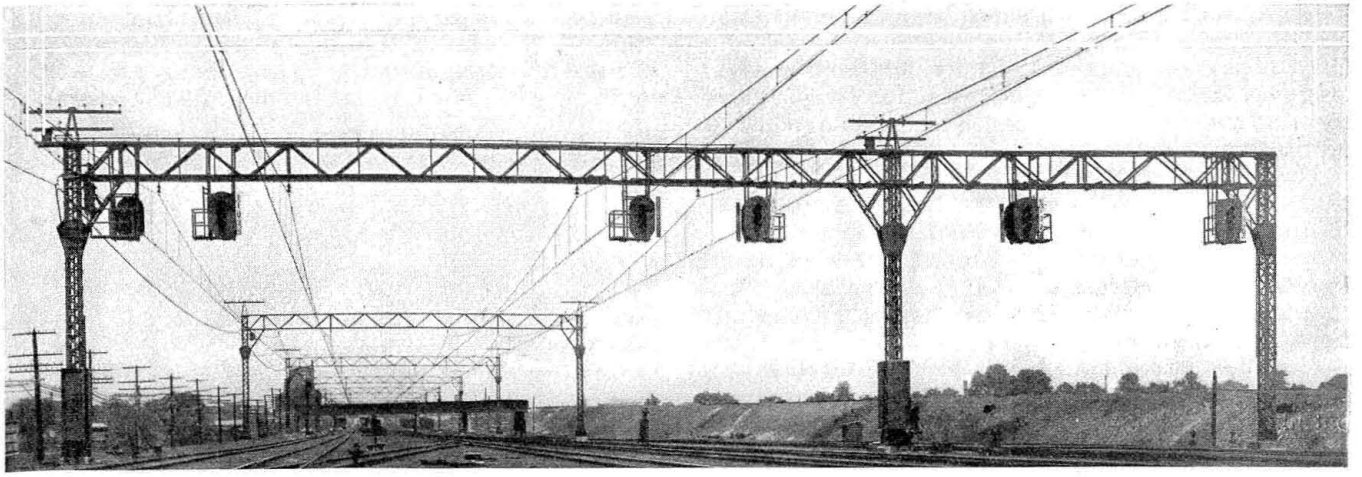


Typical automatic signal construction on Illinois Central terminal

Signaling of I. C. Chicago Terminal

Development of complete new system of signaling in connection with suburban electrification

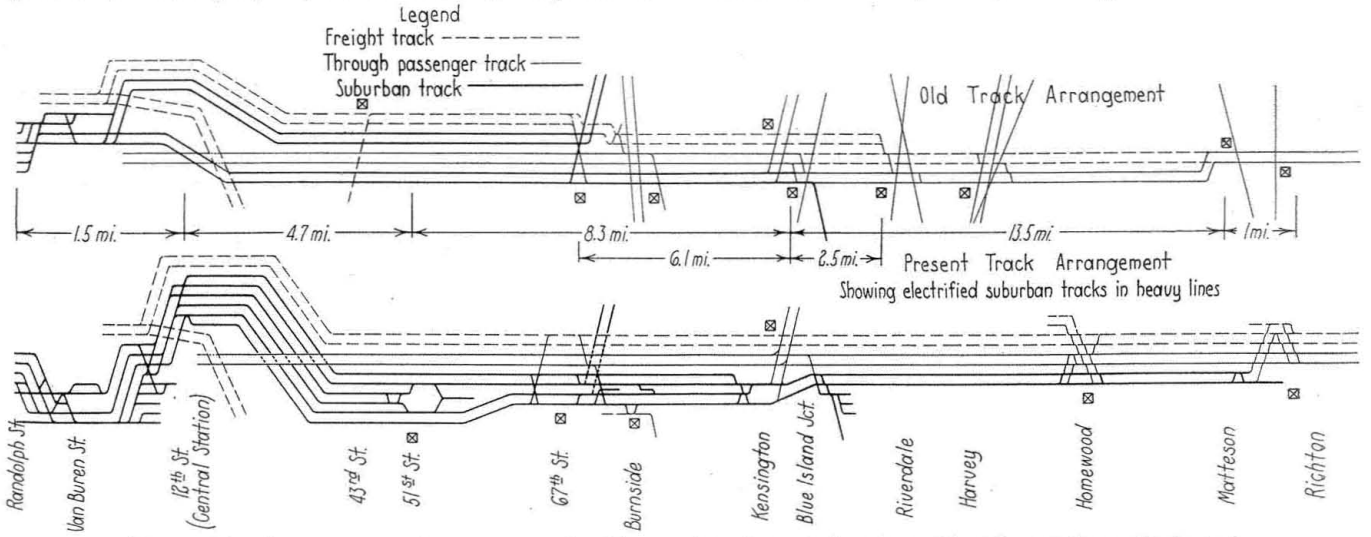
By H. G. Morgan

Signal Engineer, Illinois Central, Chicago

WHEN the Illinois Central was chartered in 1851, Chicago was a rapidly growing city with a population of 30,000. By 1870 its population had increased to around 300,000; by 1890, to more than 1,000,000; by 1910, to more than 2,000,000; today it is more than 3,000,000. The traffic of the Illinois Central in Chicago has increased along with the rapid growth of the city. Because of the rapid development of the communities along its lines and the quality of the service provided, the company's suburban traffic has experienced a remarkable growth in recent years. The average number of passengers carried daily increased from about 44,000 in 1910 and 60,000 in 1920 to nearly 80,000 in 1925. If this rate of increase is continued, it will be but a short time until suburban traffic on the Illinois Central at Chicago will exceed 100,000 passengers daily. The increases in through passenger and freight traffic in and out of Chicago have also been rapid.

Electrification of the terminal was not brought about entirely by economic necessity but as a part of the "Chicago Beautiful" development by the Chicago Plan Commission, which acts under the authority of the city and is entrusted with the development of an orderly city plan.

Under the terms of a city ordinance, dated July 21, 1919, the railroad is scheduled to electrify its suburban service by February, 1927; its freight service north of Roosevelt Road by 1930, its freight service south of Roosevelt Road by 1935; and its through passenger service within the city limits (under certain conditions) by 1940.



Present track arrangement as compared with previous layout showing railroad crossings eliminated

The Terminal Area

The main line of the terminal area extends from Randolph street to Richton, 29 miles, with three main branches on the south. The South Chicago branch is

a double track line 4.8 miles long, leaving the main line near Sixty-seventh street. It traverses a densely populated, high class suburban territory, and is primarily a suburban line. It is used, however, for freight movements to and from South Chicago and certain industries on the branch.

The Chicago, South Shore & South Bend is a double track electric line to South Bend, Ind., 75.6 miles from Kensington. That part between Kensington and the Illinois-Indiana state line, 6.5 miles, is owned by the Illinois Central and leased to the C. S. S. & S. B. It is both a suburban and freight line, having 66 scheduled suburban trains a day.

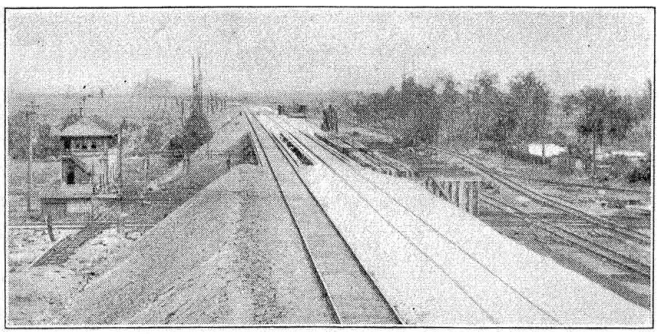
The Blue Island branch is a single track line four miles long. There are numerous industries on the line, but like the South Chicago branch it is a suburban road principally.

Rearrangement Account Electrification

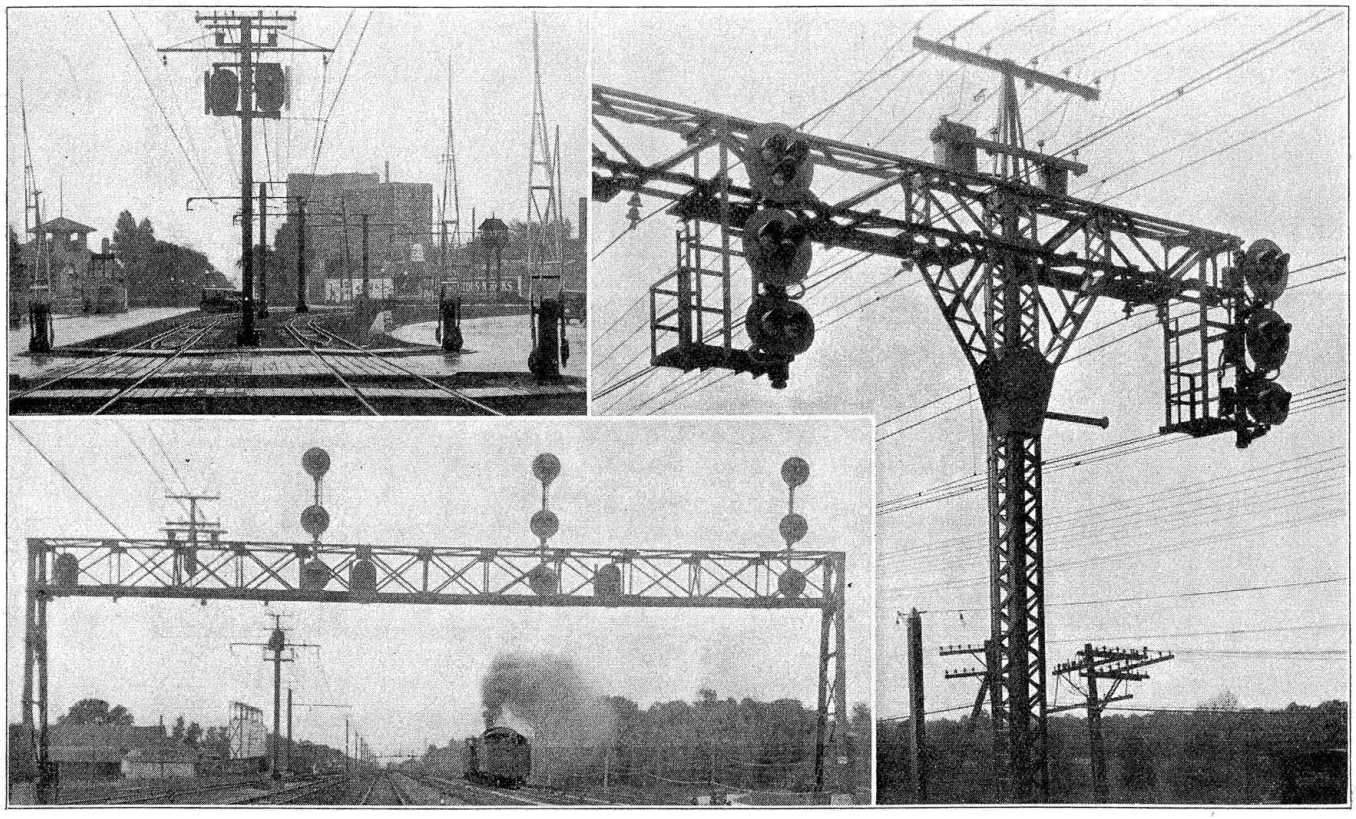
At the beginning of track rearrangement incident to the initial, or suburban, electrification of the Illinois Central, Chicago Terminal, there were about 168 miles of main track in the terminal area. The main line consisted of 46.8 miles of suburban tracks, 55 miles of through passenger tracks, and 66.2 miles of through freight tracks.

At the completion of the suburban electrification there are 106.9 miles of suburban tracks, 57.2 miles of through passenger tracks, and 57.5 miles of through freight tracks, a total of about 222 miles. The track diagrams show the trackage before and after suburban electrification. Suburban tracks are indicated by heavy lines, through passenger tracks by light lines and freight tracks by dotted lines.

In addition to the extensive track rearrangements shown by these diagrams, there were extensive changes in grade as well. Tracks were elevated from Blue Island Junction to Matteson 13.5 miles; from 53rd street to 47th street 0.6 miles; and depressed from 26th to 47th street, 2.9 miles. These changes have eliminated all grade crossings on the main line. Separation of grades has resulted in the elimination of interlocking plants at Matteson (2), Harvey, Riverdale, Blue Island Junction, Burnside and 43rd street.



The grades were separated by elevating the I. C. tracks through Matteson leaving the mechanical plant for protection of temporary railroad crossing at right



Upper—Signals on South Chicago line mounted on catenary supports
At right—Interlocking signals supported from catenary bridge
Lower left—Homewood interlocking, semaphore bridge used for signal and catenary support

To take care of crossover movements under the new track arrangement new electric interlocking plants have been built at 51st street, 67th street, Homewood and Richton. The existing electric interlocking plant at Kensington has been enlarged. A small electro-mechanical plant has been constructed at Burnside to control movements between track No. 1 and Burnside Yard.

Prior to track changes there were about 80 miles of main track protected with Hall disc signals and 57 miles of main track protected with semaphore signals. At the completion of suburban electrification there are 212.4 miles of main track protected with colorlight signals operated by alternating current. These changes have

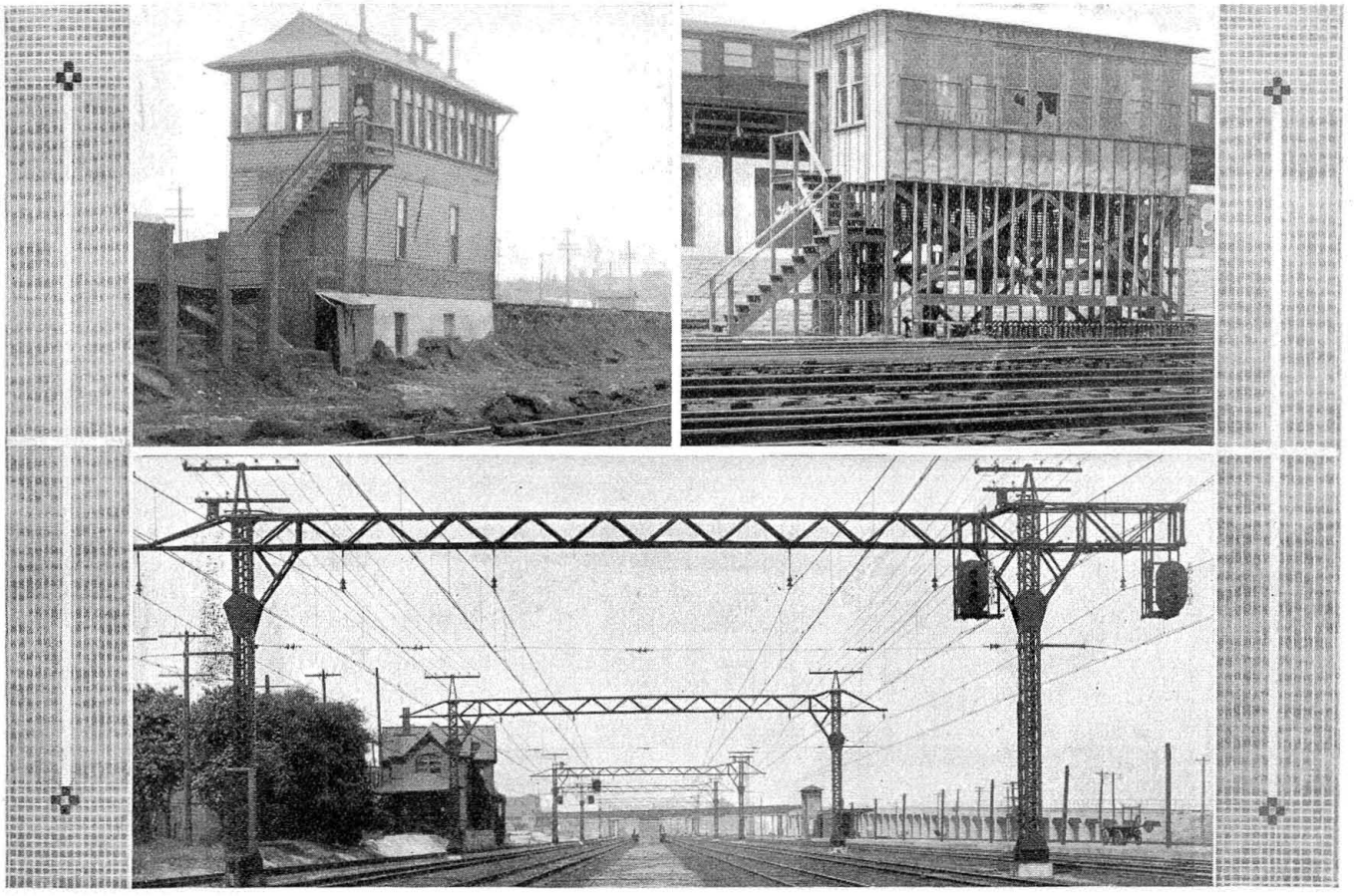
been brought about only by a long series of shifts and rearrangements during which signal protection has been maintained and trains handled without delay on a terminal on which about 525 trains per day were handled at the beginning of work and on which there are now about 600 trains per day.

Many Interlocking Changes

Prior to changes, the four track road ended just north of Matteson, which was the end of the suburban service, and the mechanical interlocking plant controlling the crossing with the Michigan Central also controlled the four-track two-track junction. Immediately south of the Michigan Central crossing another mechanical interlocking plant controlled the crossing with the Elgin, Joliet & Eastern. For a distance of 2¼ miles, two temporary main tracks were laid west of the regular mains while the latter were elevated. These temporary mains were signaled and interlocked until grade separation was complete. A temporary mechanical interlocking was installed at the temporary four-track two-track junction. At the Michigan Central crossing the elevation came between the temporary tracks and the tower and most of the interlocking connections had to be carried in two-inch pipes under the fill. At the E. J. & E. crossing the temporary tracks came back of the tower and the lead-out simply had to extend to the track.

At Harvey a mechanical interlocking plant with 75 working levers controlled the crossings with the Grand Trunk and the Baltimore & Ohio, as well as the crossing of these roads. The tracks immediately in front of the tower were elevated first so that temporary pipe lines had to be built back of the tower along the street. When pipe lines were in readiness, the tower was moved 25 ft. north and west, the rocker shaft leadout was turned around and connected to the new pipe line and the plant was reconnected in 53 hours. Cross connections were carried in two-inch pipe under the fill. A new tower was erected to control the remaining crossing of the Baltimore & Ohio with the Grand Trunk.

At Riverdale a 74 lever electric machine and a 52 lever mechanical machine operated the crossings with the street railway, the Baltimore & Ohio, and the Pennsylvania. The tower was moved back off the right-of-way to clear space for track elevation and was kept in service until grades were separated at which time the electric machine was removed while the mechanical machine still operates the crossing of the Pennsylvania and the Balimore & Ohio.



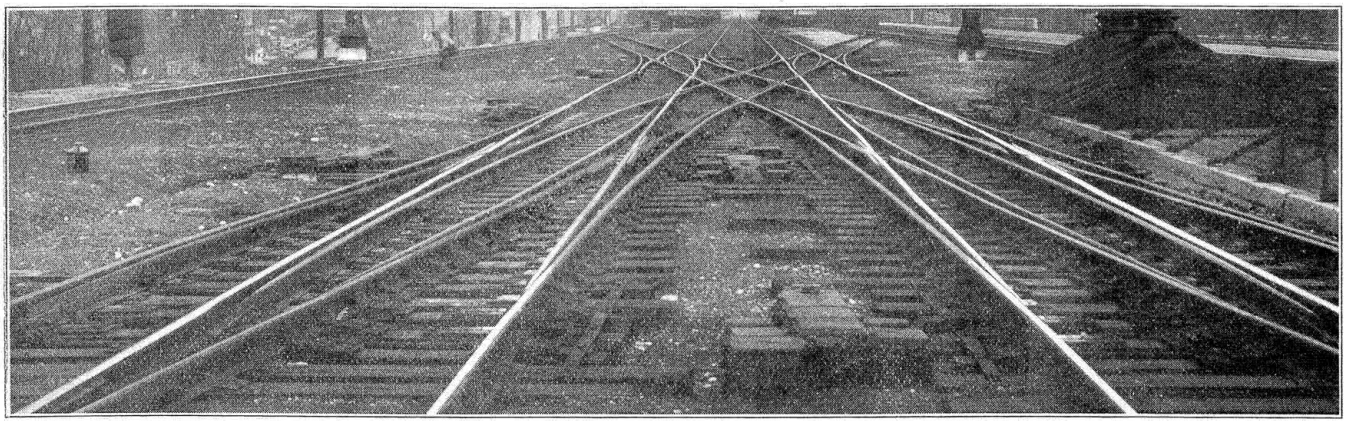
Three stages of construction at 43rd street
Upper left—Old tower after first grade cut, second cut eliminated tower
Upper right—Temporary tower for mechanical plant Lower—Final layout, overhead freight line in distance

At Kensington an existing electric interlocking plant was rearranged and extended. A mechanical plant governing the crossing with tracks of the Chicago & Western Indiana (used by the C. & E. I.) and the Blue Island connection of the Illinois Central is now in process of elimination due to the Chicago & Western Indiana crossing overhead and the Blue Island connection being taken into the electrical plant.

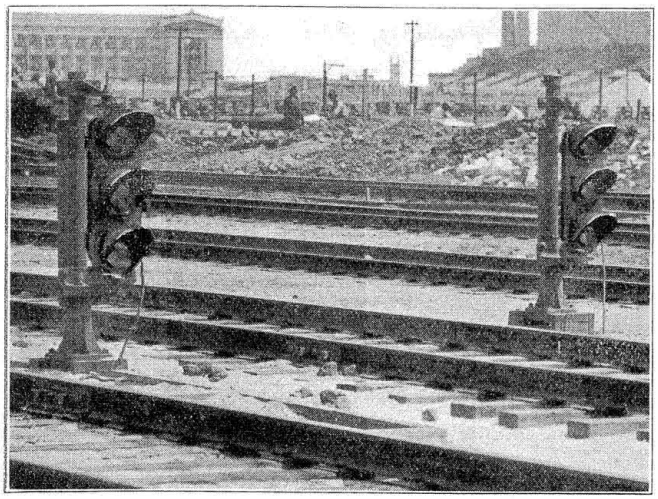
At Burnside a mechanical interlocking plant of 144 levers has been eliminated by the elevation of the Chicago & Western Indiana and Rock Island tracks. In order to make room for temporary tracks the tower had to be moved endwise 11 ft. New pipe lines were built and all connections made ready so that the plant was cut loose, the tower moved, and the plant reconnected in four days.

At 67th street a mechanical interlocking plant gov-

erned the junction with the South Chicago branch and a system of crossovers for suburban trains. A tunnel was built to pass trains to the South Chicago branch under the main line. While the north approach to the tunnel from the main line was being dug, a temporary track was built along the west side of the right-of-way behind the interlocking tower. Meanwhile a temporary tower was built on the east side of the right of way and an 80 lever all electric plant used to govern the track arrangement on the second stage. On the third stage, the plant was increased to 112 levers. In the final stage, a permanent tower was erected on the west side of the right-of-way. On the morning of May 30,



Double slip switch layout at 67th street interlocking



Temporary signals located between tracks during construction

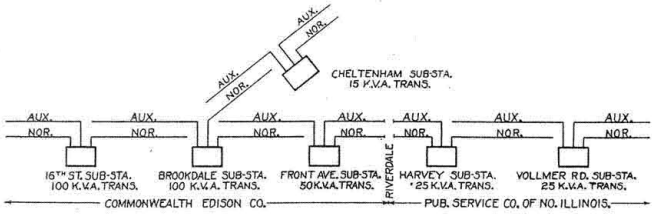
1926, between 1:00 a. m. and 5:00 p. m. the suburban platforms between 53rd street and 67th street were shifted to take care of the final system of operation and the cut-over was made from the old to the new tower in this period. At each switch machine which was to be cut over a temporary wood box was installed containing a triple pole double throw knife switch, and by reversing this, the cut-over was made. Two stages of the temporary electric interlocking and the permanent interlocking are shown in one set of the views.

The freight tracks formerly crossed all other tracks at grade at 43rd street to connect with the Chicago Junction Railway. An 80 lever mechanical plant was in service at this point with the tower and pipe lines on the east side of the tracks. In separating the grades, the main tracks were depressed 11 ft. (the depressing progressing from the east side). A temporary tower was built on the west side of the plant and operation transferred to the temporary tower until grade separation was complete. These changes are shown in one of the illustrations.

At 29th street a temporary grade crossing was provided for the movements of dirt trains during a portion of the construction period. A temporary electric interlocking plant was provided during this stage of construction.

Automatic Block Signal Changes

Prior to the beginning of the electrification, Hall disc signals had been in service from Van Buren street to Kensington and two arm lower quadrant semaphore signals from Kensington to Richton. The Hall signals were installed at the time of the World's Columbian Exposition in 1893 and were operated by storage batteries charged by motor generator sets. Only two indications were given and overlaps were provided. These disc signals were replaced with colorlight signals and rectifiers installed to trickle charge the storage batteries. When line wires were available, the colorlight signals were immediately made to provide three indications; in other cases the two indications and overlaps were retained. Later as progress of the work of grading eliminated all possibility of line control a satisfactory polarized track circuit control was developed which permitted three indication signals to be operated without flashing. Commercial power being available at stations all along the line, the floating charge system made possible the maintenance of uninterrupted signal service through a long series of shifts in signal locations and with no emergency power supply lines or equipment.



Diagrams of a-c. signal feeder circuits, power stations, etc.

Originally the semaphore signals were located on bridges and operated by storage batteries with a direct current charging line. This line was changed to an alternating current transmission line and rectifiers installed. Later when track shifts made necessary the removal of the bridges, colorlight signals were substituted. Between tracks, low signals were used as clearances were limited. This type of signal was em-

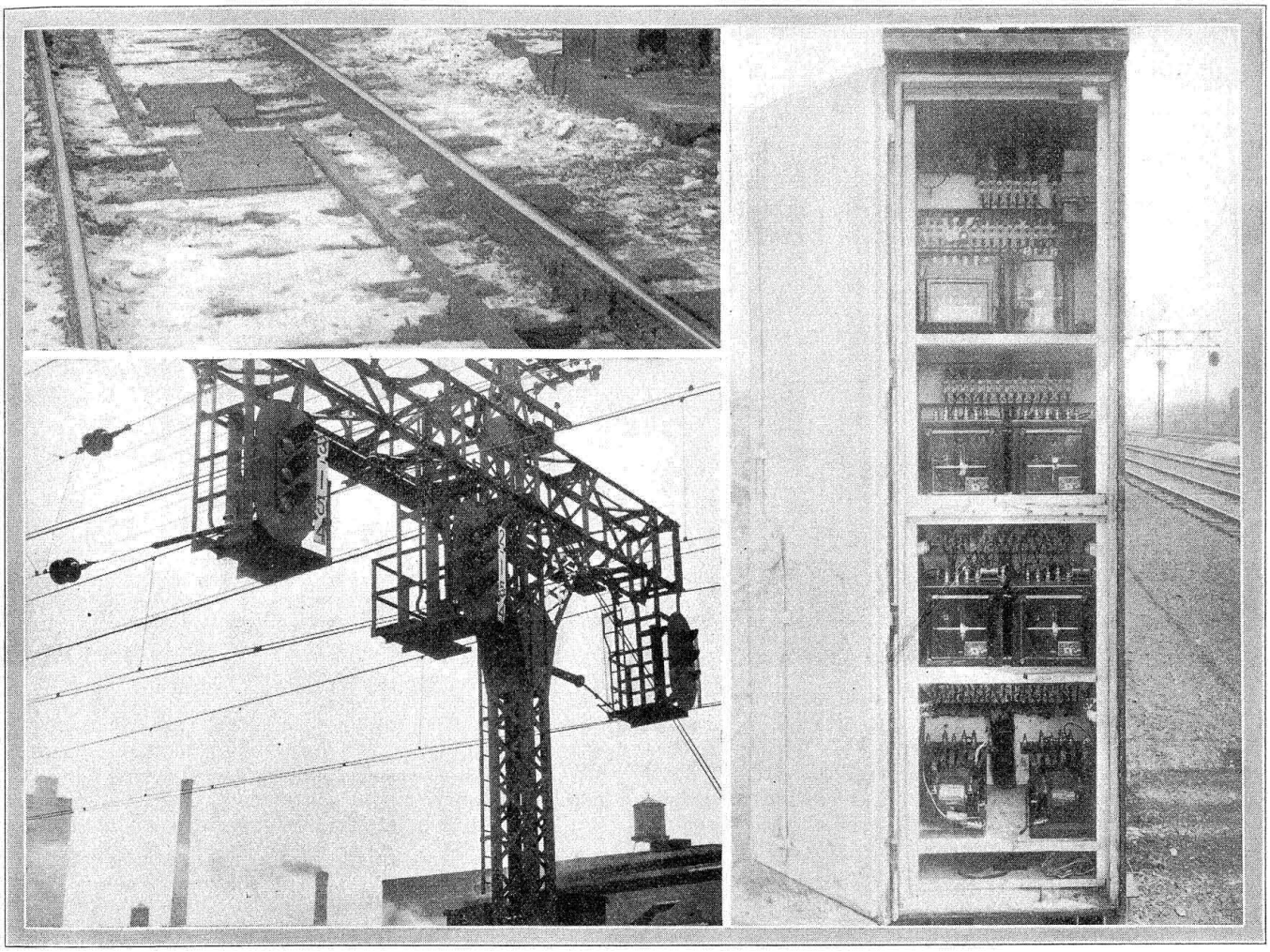
ployed over the whole terminal as track changes were made so frequently that temporary bridges were out of the question and permanent bridges were not yet in place. Examples of this type of construction are shown.

Alternating Current Power Supply

Power for the operation of the permanent signal system is obtained from the Commonwealth Edison Co., and Public Service Co. of Northern Illinois. Three generating stations guarantee the former and two generating stations the latter service. Substations are located about six miles apart and signal lines are served by one to one insulating transformers connected to one phase of the light and power buses. The capacities of transformers and the arrangement of normal and auxiliary signal transmission lines are shown in the accompanying diagram.

Duplicate single phase lines transmit power at 2,300-volts, 60-cycles. On the South Chicago branch, only one single phase transmission line is provided, but one phase of the three phase miscellaneous light and power line is used in emergency. These signal lines are sectionalized at each of the substations. Transmission wires are No. 1 AWG solid copper, and are carried on crossarms on the catenary structures.

Separate transformers are placed in each line at every signal location, and the 110-volt supply wires run from the transformer to the relay box. An automatic power switching relay is a part of the equipment. When this relay is energized from the normal supply line, it connects the normal supply to the relay box apparatus. When it is de-energized, the auxiliary supply is connected to the relay box apparatus. A lamp connected in each supply circuit indicates at all times whether the supply lines are alive. In event of a failure of the power supply through any substation, power is fed from adjacent substations. This switching is done manually under direction of a power supervisor. The signal power requirements during the present stage of electrification totals 115 KVA. To provide for emergency loading of substations, a total KVA capacity nearly triple the normal load has been provided.



Upper—Impedance bond layout with trunking over cable connections
Lower—Close-up of support cages for automatic signals
Right—Relay cases are narrow and attached to bridge supp orts

There are approximately 1,800 signal lamps, 35 switch lamps and 260 double rail track circuits on the terminal, and the total energy consumption varies from 52,000 to 59,000 KWH per month. The minimum consumption occurs in midwinter when lamps are dimmed the greater part of the 24 hours and ballast is frozen, while the maximum occurs in midsummer.

Colorlight Signals Used

In the final arrangement, all signals on the main line are located on bridges. Between Homewood and Richton four track bridges used for semaphore signals were extended to span six tracks and used for the colorlight signals. One of these bridges is shown. North of Homewood the signals are placed in cages suspended from combined signal and catenary structures. On the

South Chicago branch signals are placed on the columns of the catenary structures or on gate towers.

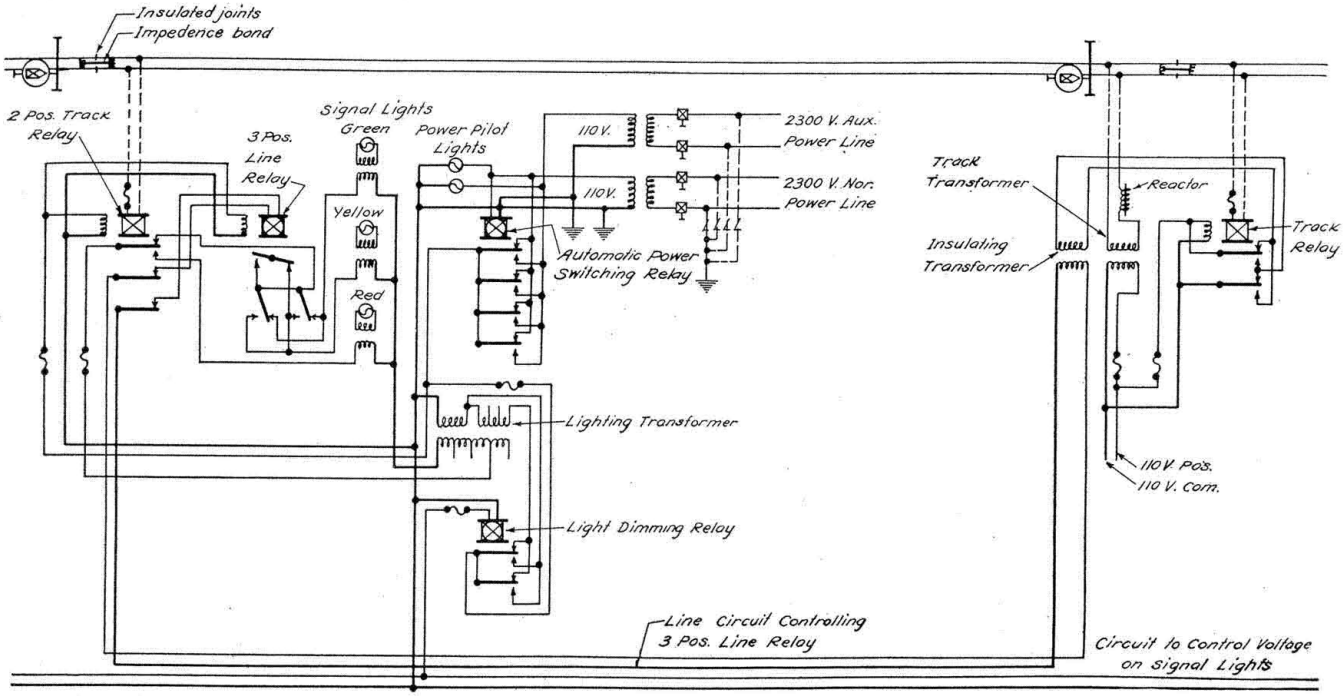
All the signals are three indication colorlight type. Indications displayed by the automatic block signals are green for "proceed," yellow for "caution" and red for "stop." Block spacing for high speed has been arranged so that the minimum length of block is, approximately, the maximum braking distance, plus a factor of safety of fifty percent. Block spacings at the south end of the terminal are as long as 5,000 ft.

North of Sixty-seventh street the block spacings for through passenger and freight tracks average 3,100 ft.; for express and special suburban tracks, 2,040 ft.; for local suburban tracks, 2,500 ft. This permits express and special suburban trains to run with clear signals with 1¼ min. headway; and local suburban trains with 3 min. headway. Where blocks shorter than braking distance are used, the caution indication is displayed by two signals in the rear of a stop signal.

At interlocking plants the home signals display three lights in a vertical row, and the indications are the same as those given at night by upper quadrant semaphore signals elsewhere on the system. For this reason enginemen have nothing new to learn to operate by signals on the terminal.

In the colorlight signals themselves, the green, yellow and red units are arranged in a vertical row in the automatic block signals; at interlocking plants a triangular combination is used for those which display three colors, and a horizontal arrangement for those which display two colors. This permits a closer spacing of the three lights in a vertical row and prevents the top light being obscured by the overhead structures. This arrangement of lights also allows a satisfactory close up indication from the top light. Deflecting prisms are employed where interlocking signals are located at platforms.

Lamps used in colorlight signals are 10-volt, 18-watt rating, and have two filaments in multiple. If one filament burns out, the fact may be detected and the lamp replaced without a failure resulting. Lamps are burned at 20 percent under their rated voltage to give long life.



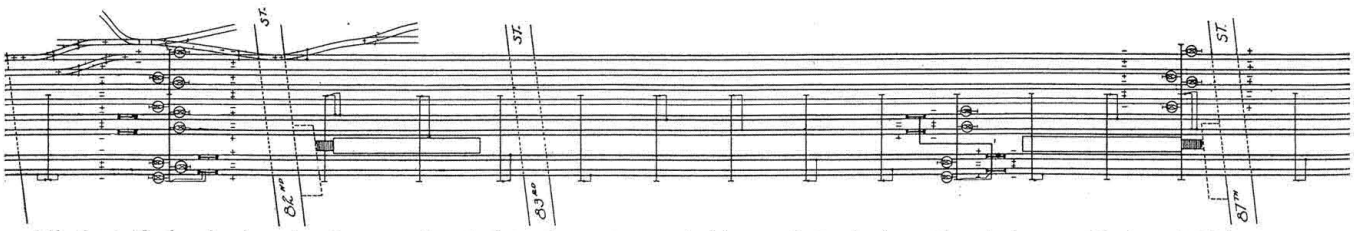
Typical automatic signal control circuits

Signal Control Circuits

From 22nd street to 80th street, all signal control wires are carried in clay duct underground. All control wires are No. 14 AWG copper with 5/64 in. wall, Kerite insulation, made up in cables and finished with single braid. Cast-iron terminal boxes are used in manholes and handholes. Joints are made by means of split sleeves.

From 12th street to 22nd street, south of 80th street and on the South Chicago Branch, aerial cables are used. Control wires are No. 14 AWG with 4/64 in. wall, Kerite insulation. Cast-iron terminal boxes are used mounted at the top of the columns supporting the catenary structures. The wires are terminated on standard A. R. A. terminal blocks.

Connections from relay boxes to manholes or handholes are made through five- and seven-conductor parkway cables. The wiring on all signal bridges is carried in galvanized iron conduits, 2½ in. being used for main runs and 1¼ in. for leads to signals. Crouse-Hinds condulets are used at all turns and outlets. Flexible



All electrified suburban tracks were bonded to the catenary bridges—A typical section between 82nd and 87th streets

conduit is installed between the rigid conduit and the signal case to permit alignment of the signal to suit the track conditions.

On account of possible auto-transformer action through the impedance bonds, it is not safe to use a three-position or polarized track relay on electrified roads, therefore, a three-position two-element vane-type line relay is used to govern the signal aspect as between the "caution" indication and the "proceed" indication to provide advance information to the approaching train. The line circuit passes through the contacts of the track relay and is subject to change in polarity.

The functioning of the contacts for the control of the signal is as follows: When a train enters the block, the track relay is de-energized and the moving member assumes a position by gravity so that a set of front contacts are open and a set of back contacts are closed. The red unit of the signal is then lighted through the back contacts. As soon as the train passes on into the next block, the above track relay becomes energized, closing the front contacts and opening the back contacts. This immediately puts out the red signal light and energizes the line relay in one polarity, closing one set of contacts which light the yellow unit of the signal. When train passes into the third block, the polarity of the line circuit is reversed and the moving member of the line relay reverses its position, opening the first set of front contacts which puts out the yellow light and closing a second set of front contacts which light the green unit of the signal.

Each line relay has the controlled element energized through an insulating transformer which limits the length of each circuit to one block and maintains a high dielectric strength in the circuit. The secondary winding of the insulating transformer has 1,800 ohms resistance to produce proper phase displacement in the relay and to provide protection against the effect of crosses or grounds. The system is also immune to induction since all adjacent wires in the signal control cable are parallel and connected together through transformers or relays and any inductive effect upon one line is compensated for by the inductive effect upon the adjacent line. The line relay has also a neutral, or bridging, contact to light the yellow signal unit and avoid a train stop in case of an open line circuit.

All hand-thrown switches, which must be lighted at night, are equipped with electric lanterns, lighted by a 110-volt, 10-watt lamp. Lighting wires are carried in duplex parkway cable to the nearest catenary structure where they are tapped to conductors in a miscellaneous aerial cable from the nearest signal bridge. The parkway cable terminates in a cast-iron junction box mounted on a concrete riser, and the wires are carried up the switch stand to the lantern in ½ in. double-strip flexible conduit.

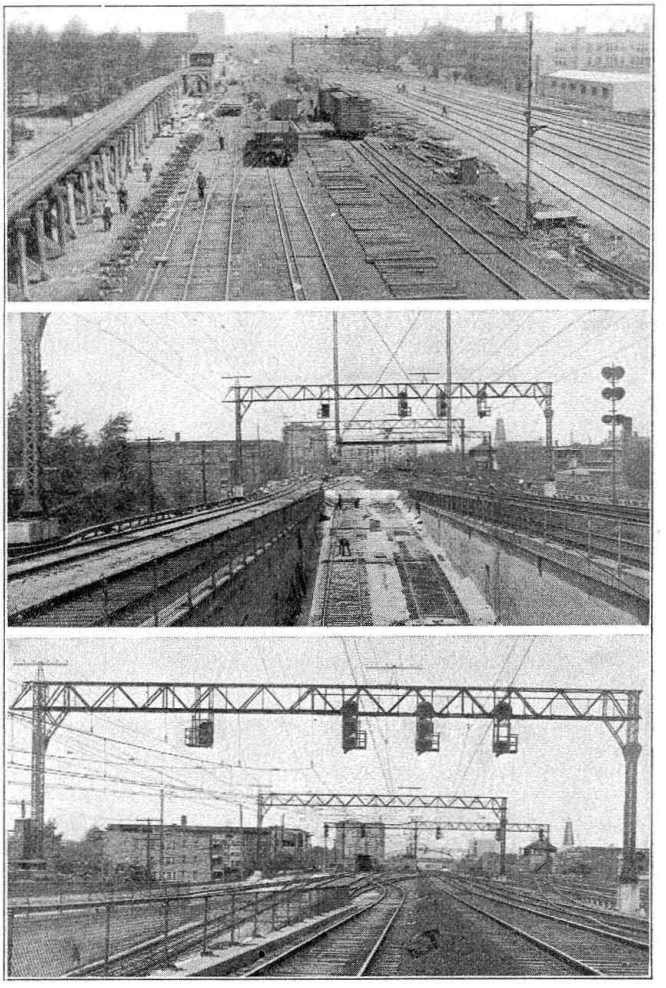
Two switch circuit controllers are connected to each facing point switch and one to each trailing switch to shunt the track circuit and set the signal to the "stop" indication, when the switch is thrown from its normal position.

Track Circuits

North of 69th street, the through passenger and freight tracks, as well as electrified tracks, are weld bonded to secure maximum return for propulsion current. All track circuits in this section and all track circuits in electrified tracks elsewhere, except in interlocking limits, are double rail, end fed and full block long. Two element, Model-15 vane relays of the U. S. & S. Co. manufacture are used.

Impedance bonds have an impedance of 0.70 ohm to 60-cycle alternating current and an ohmic resistance of .0014. They have a continuous carrying capacity of 500 amp., a 30-minute capacity of 900 amp. and a 5-minute capacity of 1,500 amp. and will withstand 150 amp. unbalancing. Bonds are mounted between ties. End terminals are connected to rails with 300,000 cir. mil copper cables by means of lugs welded to the rails. The middle terminal of the bond is connected with bolt connectors. All cables are covered by trunking as shown in the picture. Rail bonds for propulsion current are of the gas weld type applied to the ball of the rail.

South of 69th street, the electrified tracks only are bonded for propulsion current and on other tracks ordinary galvanized iron bond wires are used. For steam road track circuits, double element vane relays of the condenser type are used with limiting reactance at the transformer. At interlocking plants single rail track circuits are used. Polarities of adjacent track circuits are reversed so that in case of failure of an insulated rail joint, the current from the track transformer entering the relay of an adjacent track circuit will reverse the torque in the relay and cause the signal to indicate "stop."



Three stages of construction at 67th street
Top—Old tower at left, clearing tracks for tunnel
Center—Temporary tower at right, tunnel complete
Bottom—Layout complete, new tower at left

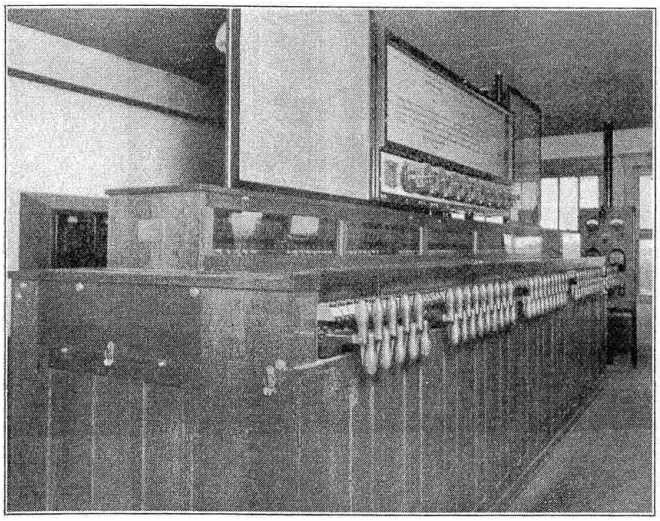
Parkway cables buried two feet below the base of the rail are used for track connection. These cables are single conductor No. 9 AWG solid copper with 5/64 in. wall, Kerite insulation, with one tape, one layer jute,

two layers steel tape and one layer saturated jute overall. Beneath the rail a vertical riser of cypress trunking brings the wire up to a cross piece of trunking forming the bootleg in which the parkway cable is spliced to No. 9 stranded wire which connects to each side of the rail.

Interlocking Layouts and Controls

The permanent plant at 67th street is the largest on the terminal. It is 3,645 ft. long and controls 15 switches, 2 single slip ends, 28 double slip ends and 15 movable point frogs and electric switch lock. The machine is all electric G. R. S. Model-2 unit lever type, having 176 spaces with 107 working levers, the 69 spare spaces being for further additions contemplated. Levers are equipped with rotary circuit controllers and forced drop locks.

The track circuits and signals are operated by alternating current as described in a preceding paragraph. The signals are controlled through direct current relays which are operated from interlocking machine. The GRS Model-5A switch machines are



Interior of one of the new interlockings at Richton

operated by direct current which is delivered from a 110-volt storage battery charged continuously by a motor-generator.

In addition to the mechanical locking in the machine, routes are controlled and switches are locked electrically by the presence of a train upon a given track circuit controlling a track relay which in turn interrupts the circuits of such locks, making them effective.

Another important safety feature is the means provided to check the correspondence of movement between a lever and the switch or signal controlled by it. In the case of switch levers this requirement is met by means of a momentary dynamic current generated by the momentum of the motor of the operated switch which gives the desired indication at the lever end of the circuit when the switch has completed its movement. Signal lever indicating magnets are energized by 110-volt alternating current received through a back contact of the control relay as soon as the signal displays the stop indication.

Each switch is arranged to reverse the polarity of a polarized relay according to whether the switch points are in the full normal or full reverse position, and every signal governing train movements over the switch is controlled through the polar contacts of this relay to assure that a route is set up before the signal can be cleared.

The position of trains is indicated to the towerman on a track diagram on which small spot-lights mark the occupied sections of track, both within the plant limits and approaching the plant. As soon as a train reaches the approach circuit, the route lined up is locked automatically and can be taken away only by the use of a clockwork time release which requires an elapse of one minute after the home signal has been set against the train. If the train should pass the home signal, the route is then locked the full distance ahead through the sectional route locking but the switches are released behind the train as each section is passed. A detector lock circuit for each switch breaks through the track relay of the section in which the switch is located to prevent the throwing of the switch under a train. Route and section locking may be released in case of emergency by breaking a seal on a special releasing device which must be restored to normal before the signals can be cleared again. Each signal control circuit is protected against crosses by an individual polarized relay, and the plant is equipped with a ground detector.

Main control wires are carried in underground cables in conduit. Cross runs from junction boxes to switch machines are carried in multiple conductor parkway cables. These cables terminate in a concrete riser with a cast-iron terminal box at the top. Individual return circuits are provided for all functions. All track wires are carried in single conductor parkway cables. The general construction is similar at other interlocking plants.

The plant at Richton is 4,050 ft. long and controls 36 switches and three derails, operated from a 104 lever G. R. S. machine consisting of 78 working levers. This is the southern end of the terminal and is the end of the six track and the beginning of the four track system. When this plant was installed emergency alternating current supply for the track circuits was provided by a gas engine generator set, which was relieved when the permanent transmission line was placed in service. Wires at this plant are carried in main runs of wood trunking on concrete foundations. Cross runs and track connections are parkway cable.

The interlocking plant at Homewood is 3,166 ft. long and controls 40 switches and 2 derails operated from a 64 lever G. R. S. machine consisting of 63 working levers. Construction is similar to Richton except that main wire runs are of braided underground cable in conduit.

At Kensington the plant governs the junction of the Michigan Central, the Chicago, South Shore, South Bend and the Blue Island branch with the main line. This plant is 5,350 ft. long and includes 27 switches, 17 derails, 8 single slip ends, 10 double slip ends and 14 movable point frogs operated from two U. S. & S. Type-F machines, one having 65 working levers and the other 12 working levers.

Plans, specifications, and material requisitions for the construction of all the interlocking plants, as well as the automatic block signals, were prepared by the Illinois Central signal department.

Work at all mechanical interlocking plants in connection with grade separation, as well as shifting of direct current automatic block signals, was done by signal department forces. All new electrical construction was handled by local electrical contractors under the supervision of the signal engineer.

Rapid construction made necessary the shop fabrication of as many items of material as possible including bending and drilling of switch plates. Uniform methods of construction were followed as much as possible.