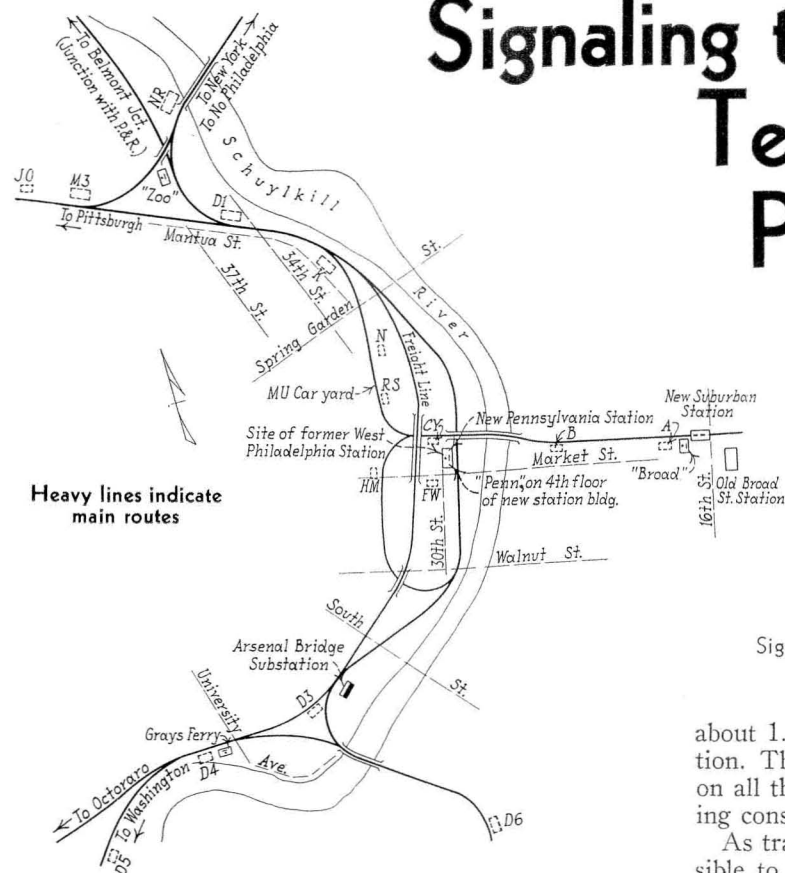


Signaling the Philadelphia Terminal of the Pennsylvania



Heavy lines indicate main routes

Four large interlockings handle new facilities including many of the functions formerly included in 16 old plants

By E. K. Post

Signal Engineer, Pennsylvania Railroad, Philadelphia, Pa.

In 1926 the Pennsylvania started an extensive program to improve the passenger terminal facilities and track layouts in Philadelphia. The improvements center about a large new passenger station to be located on the site of the old West Philadelphia station at 30th street and Market on the west bank of the Schuylkill river.

Operating Difficulties

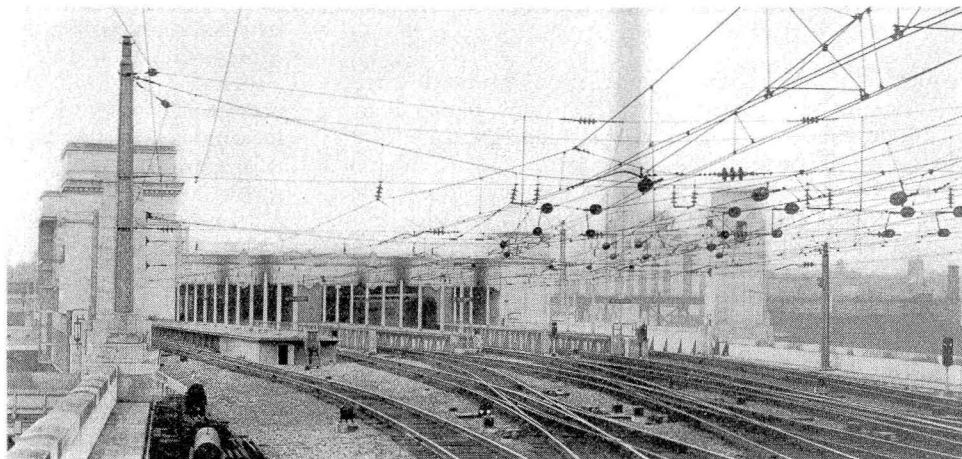
In order to understand the difficulties of operation prior to the inauguration of the Philadelphia terminal project, it will be well to review briefly the operating conditions in this area. The old Broad Street station was opened in 1881, with 8 tracks which number was later increased to 16. This was a stub-end terminal with tracks in a general east and west direction, the station being about a mile east of the West Philadelphia station, which is on the north and south line between New York and Washington, while the main line from Pittsburgh and the west joined the north and south line at a junction

about 1.5 miles northwest of the West Philadelphia station. This arrangement necessitated the reversal of power on all through trains into and out of the city, thus causing considerable inconvenience and loss of time.

As traffic increased during the years, it became impossible to handle all the trains into and out of the Broad Street station. As a result, certain of the through New York to Washington trains passed through the West Philadelphia station without going to Broad street. Likewise, some of the through trains between New York and Pittsburgh and the west, stopped at North Philadelphia without coming down town. Frequent service of suburban trains between the Broad Street station, and West Philadelphia and North Philadelphia made connections with through trains.

Some idea of the difficulty of operation can be gathered from the fact that about 510 scheduled revenue trains were operated in and out of the Broad Street station on each week day. Approximately 220 of these were classified as through or long distance trains. At North Philadelphia, in addition, about 75 trains stopped daily and of this number approximately 47 stopped also at West Philadelphia. This brought the total number of trains using the three stations up to about 587 each day. All but 30 of these stopped at West Philadelphia, which fact led to the selection of this location as the

"Broad" interlocking—Looking west to 30th st. station



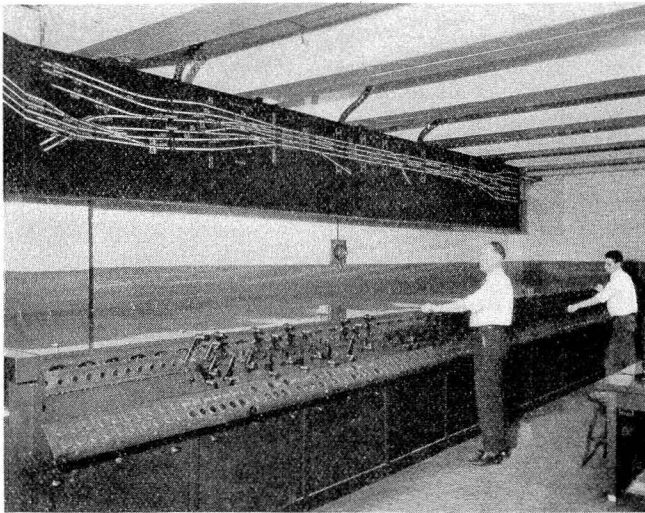
site for the new station. This new improvement, now known as the Pennsylvania station, is to have a through track layout. Trains between New York and Washington will pass directly through the station, while through trains, between New York and points west, enter and leave the station by means of loop tracks on the lower level, no reversing being necessary. The station at North Philadelphia, located north of the junction where the line from the west joins the line from Philadelphia to New York, will, of course, be continued in service.

The suburban business had formerly been handled along with the other trains, in the old Broad Street station, which is to be abandoned. Therefore, it was necessary to construct a new suburban station at a down-town location, these facilities being constructed at an underground location at Sixteenth street just north and west of the old Broad Street station.

The new Pennsylvania station for through trains is only about one mile west of the old Broad Street station and passengers going to the City Hall district can pass from the lower to the upper concourse, where they can take suburban trains directly to the new Broad Street suburban station.

Four Plants Replace Sixteen

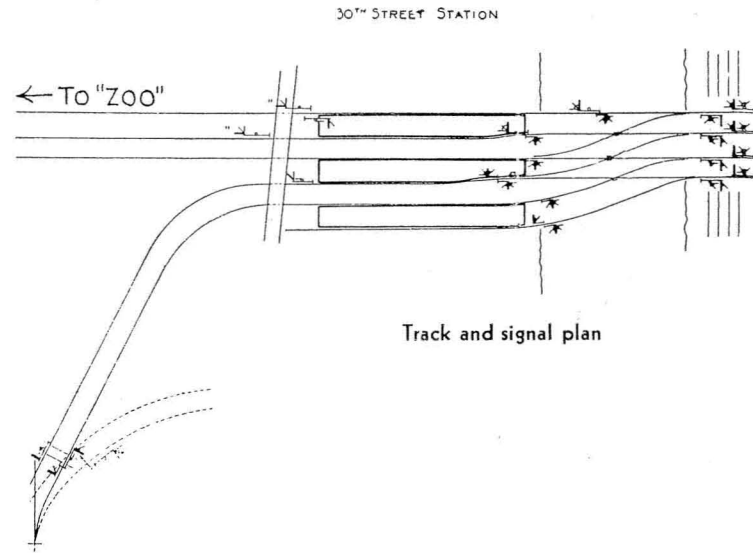
Prior to the time work was started on these terminal improvements, a committee was appointed to study the operating conditions and to recommend the best arrangement of interlocking and signaling. After a careful study, it was decided that the terminal area would be served by 4 interlockings where formerly a total of 16 plants were



In "Broad" interlocking tower

required in this district. The electro-pneumatic type of interlocking was selected for these new plants because of the flexibility and speed of operation.

One of the new plants, to be known as "Penn," will be located on the fourth floor of the new Pennsylvania station at 30th street, and will control the switches and signals in the Pennsylvania Terminal area. A second plant is located at the junction of the line to the west, close to the Zoological Gardens, and has been named the "Zoo" interlocking. A third plant, which will be known as Gray's Ferry interlocking, will handle the switches and signals on the tracks approaching the main station from the south, the tower being near the present D-4 tower. The fourth interlocking, which handles the



switches and signals in the new Broad Street underground suburban station at 16th street, is known as the Broad interlocking.

The four interlockings are to be, in effect, combined as a unit system, so that the operation of trains in the whole area will be simplified very much as compared with the former track arrangement, which was handled by 16 interlockings. One man will have a larger territory under his control and, therefore, can handle more traffic with increased efficiency.

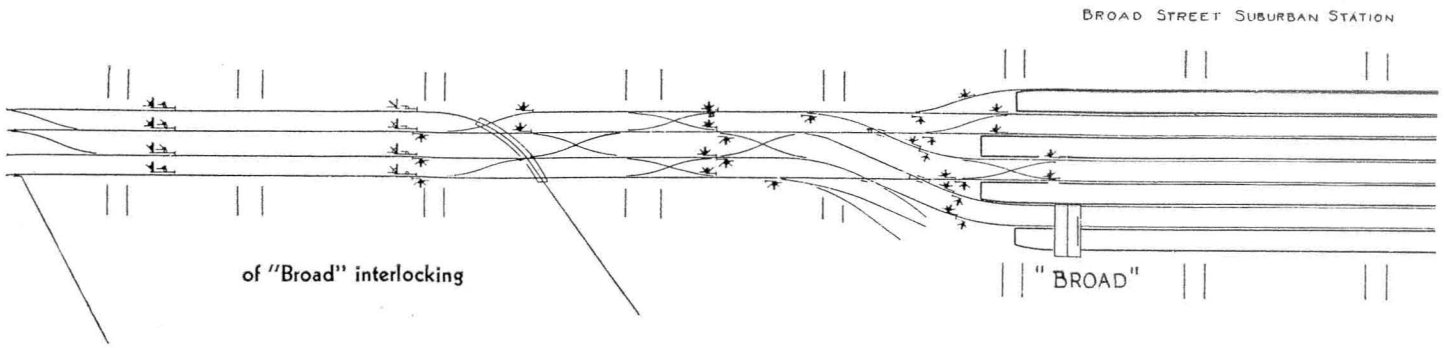
The tracks will be signaled so that movements are protected by the lock and block system, which will make it possible to use any track in either direction without train orders. The direction in which the lock and block system will govern will be indicated on the model boards in the respective interlocking rooms by means of a green spot light in an arrow.

The Broad plant, and a portion of the Zoo interlocking, are in service; the Penn and the Gray's Ferry plants will be constructed as the new track arrangements and buildings progress in construction.

Work Completed by Stages

The whole project is of unusual interest because of the extent of the work involved, the engineering problems presented, and the necessity of handling a very dense traffic while track and interlocking changes are made. The new facilities are being placed in service in a series of stages. Cut-overs are being made from the old to the new tracks and corresponding changes made in the interlockings as the work progresses. A part of the first stage to be placed in service was the new Broad Street suburban station and the suburban facilities of the new 30th Street station, which were thrown open to the public on September 28, 1930. All suburban, local and other "MU" service is segregated in an area wherein the entire interlocking and terminal facilities are particularly adapted to this class of traffic, without its interfering with the through passenger service.

In order to eliminate the interference of freight trains in the terminal area, an elevated line was built in 1904, extending for 3 miles from Gray's Ferry on the south to 37th street on the north, where it comes to grade and enters the Zoo interlocking. Freight trains between New York and Washington are operated over this "high line," while freights on the New York-Pittsburgh line pass through a portion of the Zoo interlocking and out through the Pittsburgh tunnel. Thus the freight traffic does not



interfere with passenger trains in the terminal.

The cars for both the suburban and through service were previously handled in one yard at West Philadelphia. Now a separate yard for the MU service is located at right angles, and to the north of the new 30th Street station, being an island yard lying between incoming and outgoing MU tracks. Connection to the south end of this yard is handled by the Broad interlocking, while the connection to the north end of the yard is included in the Zoo interlocking, these two interlockings control only the exit and entrance ends of the yard; they do not handle the switches within the yard.

Broad Interlocking

The Broad interlocking machine is located in the Broad Street suburban station and controls all switches and signals on the suburban tracks from 16th street to a point about 700 ft. west of the suburban platform of the new 30th Street station, a distance of 6,050 ft. from Broad. The western end of this plant is the diverging point for all multiple-unit electric train movements to Trenton, Paoli, Wilmington, Norristown, West Chester and Chestnut Hill. At the western end also are located the connections to the passenger car yards.

Included within this interlocking are two temporary connections, one at the present "B" tower at 23rd street, and the other at the tunnel portal for movements to and from "A" tower. These connections permit steam service in and out of the old Broad Street station until the new Pennsylvania station at West Philadelphia is completed.

The Broad interlocking consists of a 135-lever Model-14, Union Switch & Signal Company electro-pneumatic machine operating 48 single switches, 8 double-slip switches and movable-point frogs, 22 high signals, 51 one-arm dwarf signals and 18 two-arm dwarf signals of the position-light type. The maximum speed limits from 34th street to Broad interlocking terminal has been established at 30 m.p.h., this limit, of course, being modified by signal aspects.

Zoo Interlocking

Prior to the opening of the new Broad Street suburban station and the suburban section of the 30th Street station at West Philadelphia, it was necessary to place in service a portion of the new Zoo plant. Of a total of 227 levers 86 were placed in service on September 14, 1930. About 540 scheduled trains are handled daily.

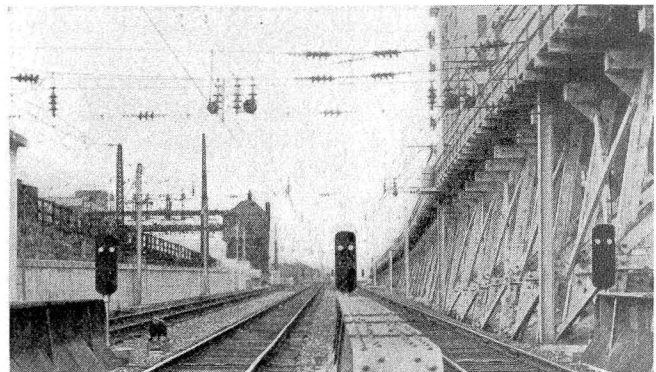
Zoo interlocking is located in the northeast corner of the triangle formed by the inward and outward New York division tracks, the inward and outward main-line tracks, and the New York-Pittsburgh tunnel. This plant extends to 33rd street beyond the Schuylkill river, a distance of 4,300 ft. from the tower, and west to 49th street and Girard avenue, which is 4,650 ft. from the tower. To the south, it extends 4,750 ft., as far as Spring Garden street. When the interlocking is completely in service,

it will replace the two electro-pneumatic interlockings at "JO", and "K", one all-electric interlocking at Mantua and one mechanical interlocking at "D1". The "JO" and "Mantua" plants are still in service but will be transferred to the Zoo machine within a few months.

This 227-lever Model-14 electro-pneumatic machine will operate 88 single switches, 14 double slips and movable point frogs, 2 movable point frogs, and 75 high and 52 one-arm dwarf signals of the position-light type. The switch movements are the Type-A1 with rotary circuit controllers and Style-CP valves.

Penn Interlocking

After the Broad and Zoo interlockings are placed in complete service, work will proceed on the installation of a machine consisting of approximately 259 levers to be located on the fourth floor of the new Pennsylvania station at West Philadelphia to be known as Penn interlocking. This plant will operate all switches and signals for through trains at the north and south ends of the



New type of double-arm dwarf signal

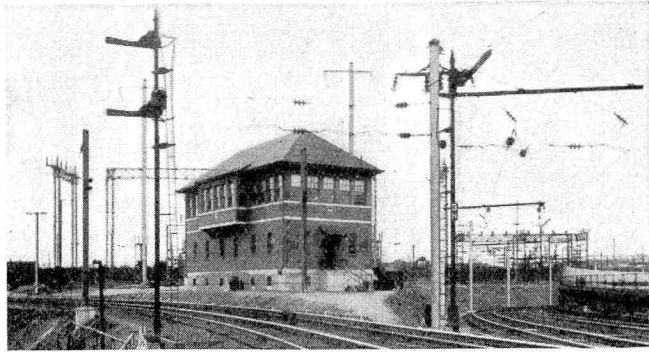
main station tracks. The operating limits of the interlocking will be from a point 500 ft. north of Spring Garden street; south to South street; also around the Walnut street loop; and north through Market street tunnel to and including the present "HM" interlocking. When complete, this interlocking, with Broad interlocking, will replace the seven electro-pneumatic interlockings known as "A", "B", "CY", "FW", "HM", "RS" and "N". The work on this plant has not progressed far enough definitely to determine the lever distribution.

Gray's Ferry Interlocking

Gray's Ferry interlocking will be located on the east side of the railroad along the west bank of the Schuylkill river just south of University avenue. This machine, which will be of the electro-pneumatic type, will probably have a 135-lever frame operating 70 switches and 71 signals, the controlled territory extending from a point opposite the present "D3" interlocking to a point about

700 ft. south of 49th street. This machine will operate also the new switches and signals on the Octoraro branch north of 49th street, and the switches and signals at Arsenal drawbridge.

As the preliminary work progressed, it became neces-



"Zoo" interlocking tower

sary to change the former electro-mechanical plant at "D4" to electro-pneumatic so that each successive change in track layout could be handled more efficiently, with greater ease and with far less expense. The electro-pneumatic machine used for this purpose was formerly at "N" tower and consisted of a 29-lever frame. It is placed in the tower so that extensions to the ends of the buildings may be added with provision for placing the new machine in its proper location later. Space will be provided

apparatus, the extent of such information being limited by the expense that would be justified for that purpose.

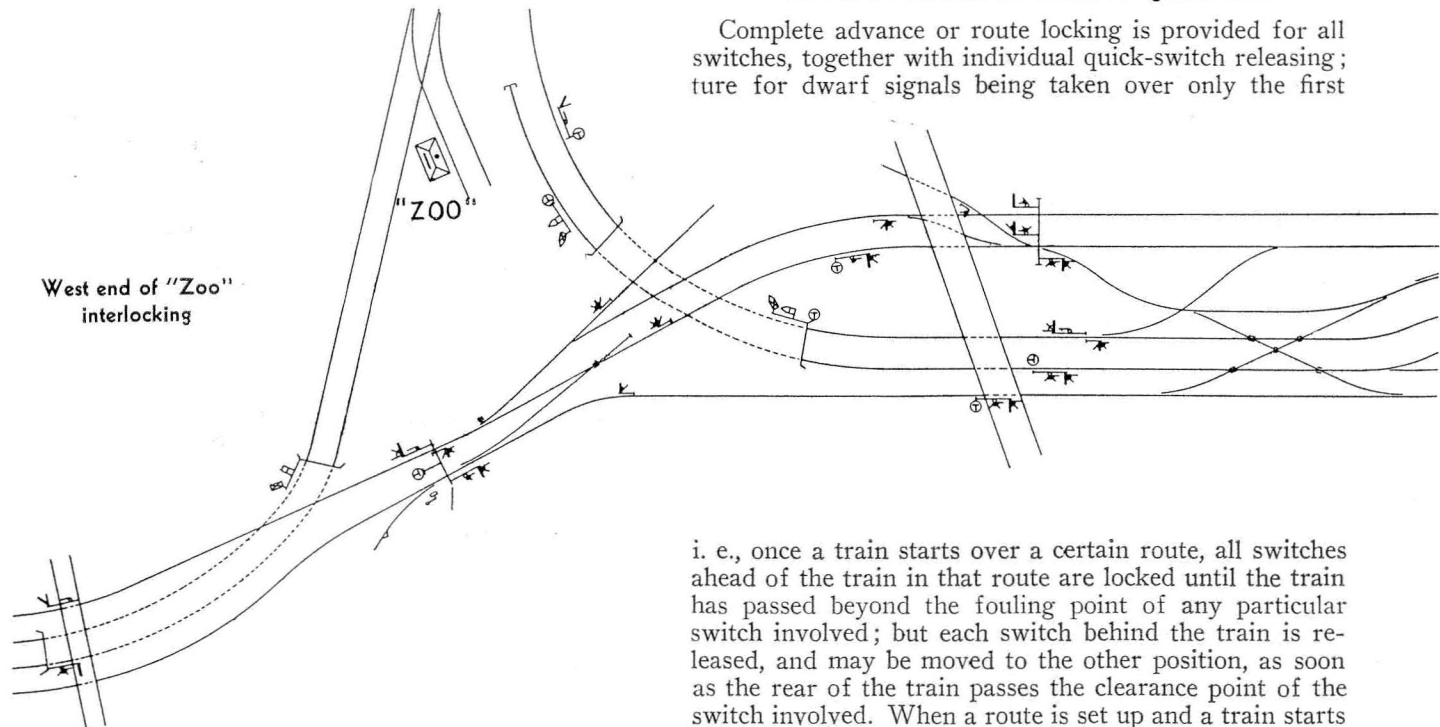
The model boards are made of 1/4-in. sheet aluminum with an angle-iron frame. At Broad the board is supported from the ceiling. At the Zoo plant, the model board is 4 ft. wide by 38 ft. in length and is supported on 5-in. channels extending between floor and ceiling, the channels in this case being used as wire chases for the model board circuits.

The entire track arrangement on the board is painted white on a flat black background, the tracks being cut into track sections corresponding to the arrangement on the ground, each track section having at least two red lights, which are lighted only while a train is occupying the section involved. At each point corresponding to a signal location, an amber light is used, which is illuminated when the lever is pulled and the signal on the ground indicates that the train may proceed; the lamp is extinguished when the train enters the track section immediately ahead of the signal.

The numbers on the signal, switch, traffic and check levers are painted yellow. The lights on traffic and check levers are green on painted arrows, the lights being illuminated to indicate the direction for which traffic is set. The lamps are 18-24-volt, 2-c-p., miniature base with jewel lenses, the jewels being the only part of the lamp and receptacle which is exposed on the front of the board. All the wiring, receptacles and terminals on the back of the board are exposed, the wires being laced in neat order.

Indication Received on Interlocking Machine

Complete advance or route locking is provided for all switches, together with individual quick-switch releasing; ture for dwarf signals being taken over only the first



in the machine also for operating the track layout known as "D6" interlocking at Washington avenue. When Gray's Ferry is placed in service, it will replace interlockings D3, D4, and D5, with provision for replacing D6 later.

The train director directs all operations, and calls the desired route to the levermen for any particular movement. The model boards are designed primarily to convey to the train director, levermen and others interested in train operation, information as to the location and movements of trains and the working of outside signal

i. e., once a train starts over a certain route, all switches ahead of the train in that route are locked until the train has passed beyond the fouling point of any particular switch involved; but each switch behind the train is released, and may be moved to the other position, as soon as the rear of the train passes the clearance point of the switch involved. When a route is set up and a train starts over that route, the lights go out on all switch levers which are electrically locked due to that particular movement, indicating to the leverman that those levers can not be operated.

In the case of the signal levers, when the light is burning, the leverman knows that conditions on the track ahead of that signal are such that if he pulls that lever, a train will get a better indication than "stop and proceed"; if the light is out, the push-button would have to be operated to obtain a "stop and proceed" aspect.

All interlocking signals, except a few lever-controlled advance signals, are semi-automatic stick, the stick fea-

track circuit ahead. This is done so that in case a dwarf signal displays the "caution slow speed" aspect, with a train between it and the next signal in advance, it will automatically show a more favorable indication to a following train, providing the first train has passed the signal in advance before the following train reaches the first signal.

The dwarf signals at Broad show any one of four positions, depending on conditions ahead, and are time-locked. The high signals are approach-locked. Three time releases are used for the entire interlocking, and they are arranged to provide two time settings, namely, 20 sec. and 45 sec.

About 90 track circuits are included in the Broad interlocking, approximately 200 at Zoo and there will be approximately 260 at Penn. These track circuits are arranged to give the maximum flexibility of movements consistent with safe operation.

Ground Detector System

A ground detector system is provided at each interlocking plant. A voltmeter, reading positive and negative, is connected through radial switches to the 12-volt d-c. buses of all locations where a-c. is transformed and rectified through copper-oxide rectifiers. This system enables the maintainer to take regular readings at the tower to determine if positive or negative grounds exist at any of the many instrument locations, as well as on the frame of the interlocking machine.

In addition to the ground-detector system, a set of 110-volt lamps is conveniently located in each tower and connected directly with the 110-volt a-c. bus at each location where the 440-volt lines are sectionalized. Through

the use of these lamps, tests are made with push-buttons arranged in a cabinet to determine between which locations trouble exists if the 440-volt line should fail. These tests can be made rapidly by the maintainer. Copper-oxide rectifiers are used throughout for obtaining 12 volts

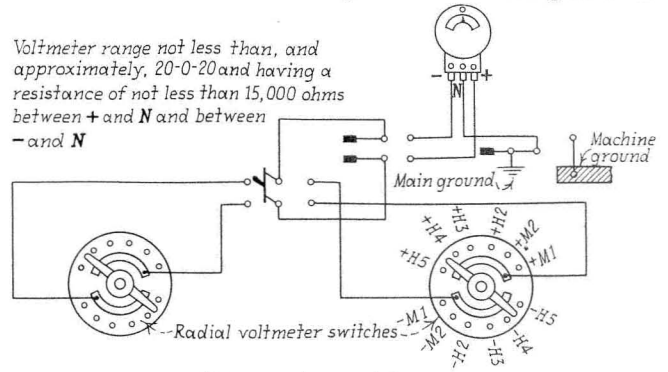


Diagram of ground detector

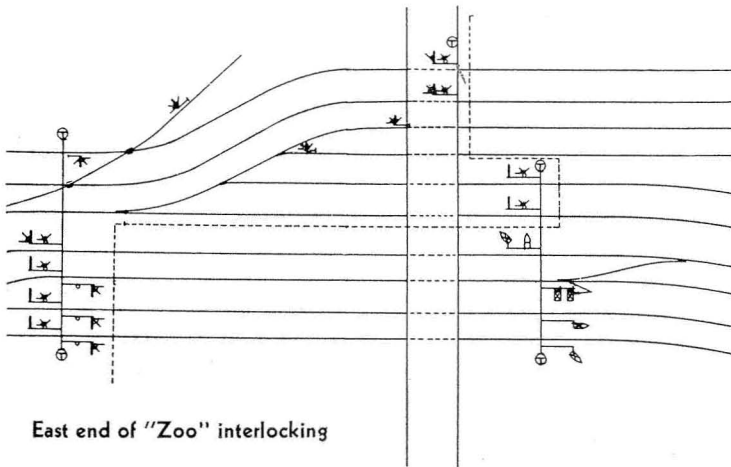
d-c., except at Zoo, where storage batteries with suitable motor-generators and charging panels are employed.

Interlocking Machine Rooms

At Broad the 135-lever machine and the instrument room are located on the same floor and adjacent to each other. Six rectangular ducts terminating at convenient places along the length of machine are built into the concrete floor and arranged for carrying wires from each of the four instrument cabinets to the machine. Other outlets are located conveniently for the communication circuits to the train director's and operator's tables. Also ducts are built in the ceiling for carrying control wires from the instrument room to the model board.

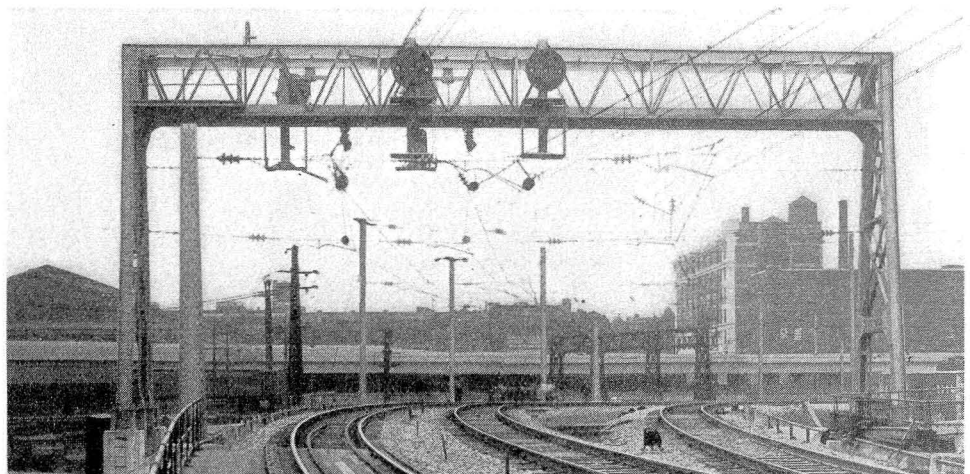
The cables from the outside duct lines that terminate in the tower are arranged on a separate terminal board from which the control wires are carried to the various instruments through insulated rings supported by a frame work of angle-iron, above, and communicating with, all parts of each cabinet. The wiring is in the open, except where it is necessary to run through the floor or ceiling. All wiring is thoroughly laced in proper order. This system minimizes the fire hazard, prevents trouble due to rats gnawing through any of the wires and also provides easy access for making changes.

At Zoo the same system was followed except that here the instrument and cable racks are located in the room below and directly under the machine, so that fibre bushings, spaced on 12-in. centers, were placed in the floor during construction. The basement is used entirely for housing the switching equipment of the 6,600-volt feed-



East end of "Zoo" interlocking

Standard signal mounting in electrified territory

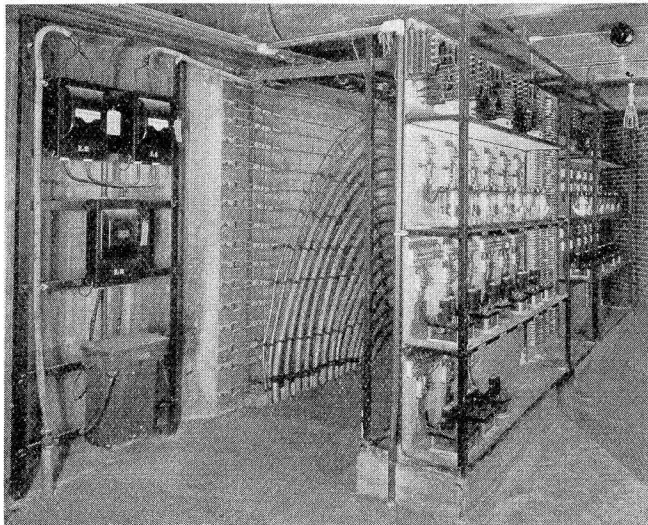


ers and the storage batteries and their charging equipment.

The new relay locations are of two types: metal relay cases, closely resembling in dimensions the old wooden cases, and for the larger locations, concrete houses 5 ft. by 8 ft. or 8 ft. by 12 ft. are used. The main cables between the cabin and the outside locations, are lead-sheathed and are run in concrete ducts. All switch and signal leads from instrument locations are parkway cable, terminating in parkway junction boxes, mounted on concrete piers, or attached to conduit or signal poles.

Relay and instrument locations are provided with shelves 14 in. deep placed 21 in. apart, this spacing being necessary to provide room for double rows of terminals because of the large number of contacts required on the majority of the relays. The relays are spaced on 12 in. centers. The A. R. A. terminals are bolted to the asbestos terminal board.

The transformers, reactance coils and other heat-producing apparatus are placed near the top of the cases so that the proper circulation of air may be secured. This prevents the relays from becoming unduly overheated and reduces to a minimum the chances for rapid changes



View of relay racks and sectionalizing switches, showing cable installation

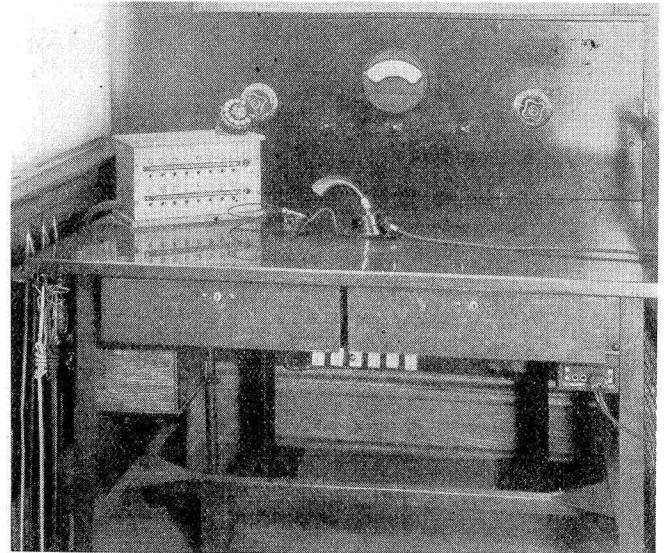
in temperature, with its accompanying condensation. For the convenience of the construction forces, working drawings were prepared for each instrument location, being drawn so that the wireman virtually would have a picture of the location of each relay and the terminals with the wire numbers that were to be used in connection with that relay.

Flexible Communication System Facilitates Operation

A flexible telephone system was provided throughout the entire terminal area, which permits of rapid communication with the train directors in the different towers. Telephones, located at each interlocking home-signal location, are connected directly with the tower controlling the signals at which the phone is located.

Also, a complete telephone communicating system is provided for the use of the signal maintainer's forces. At each instrument location outside, there is a telephone which connects directly with a jack box in the respective tower. This system is arranged so that the leading maintainer can communicate with any of his assistants at any instrument location. Also through the jack box, connections can be made from any location to the other towers or with any of the locations normally connected up with

the other towers. Provision is also made so that a maintainer at any of the 6,600-volt sectionalizing locations can communicate directly with the power director for the purpose of sectionalizing the power lines. Also, each of the instrument locations may be connected through the tower jacks, directly with the local telephone exchange. And in addition, plugs are placed back of each interlock-



Ground detector board, voltmeter and test set at "Zoo" tower

ing machine so that a man working under or back of the machine may talk directly with any instrument location. Such a flexible communication system insures that train delays will be reduced to a minimum if a signal failure should occur any place within the terminal area.

In addition to other means of communication, an electro-pneumatic whistle system is provided, these whistles being employed primarily for stopping all trains in the vicinity of the whistle in case of absolute necessity or for calling the signal maintainer in case of trouble which must be corrected immediately.

Compressors and Air Lines

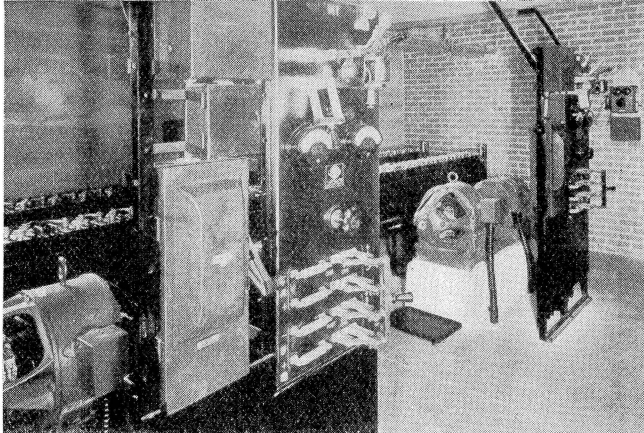
The entire terminal area is provided with duplicate 2-in. main air lines, one on either side of the interlocking system. These, in turn, are connected by 2-in. cross runs spaced not over 400 ft., and frequently closer, to meet certain conditions of switch layouts. Each cross run is provided with a full set of rising-stem valves at its junction with the mains. The individual distribution of air from cross runs to switches is arranged so that not more than two switches are fed from a $\frac{3}{4}$ -in. line.

The main air lines, generally placed above ground on concrete pedestals, are of copper bearing steel, but where it was necessary to place the main line underground, extra heavy galvanized wrought iron was used and the cross runs were of the same material. Expansion joints at proper intervals, with air line anchors between, are in service at points selected after a careful study of each condition, due consideration being given to expansion and contraction. Drip tanks are installed at all low points in the lines, and reservoirs and alcohol feed tanks are placed at suitable locations.

Air is furnished at present from the main compressors at the West Philadelphia power plant and are connected to the signal air lines through reducing valves and suitable cooling apparatus. When the machinery room at Penn is constructed, duplicate signal line compressors may be installed at that point for furnishing low-pressure cooled air.

Duct and Cable System

All signal, telephone, power, light and catenary sectionalizing control wires are carried in lead-covered cables through a concrete fibre duct system, extending from the



Battery, motor-generator and switchboard room in "Zoo" interlocking tower

Broad interlocking, west to the 30th Street station, thence north and south. The duct system extends north to Zoo, where it branches east again over the Schuylkill river to 33rd street, and west through the Mantua car yard to 46th street. It extends south from 30th Street station to Gray's Ferry avenue. A loop duct line is provided from Spring Garden street around the MU car yard joining an extension of the duct line from 30th Street station, thence through the Market Street tunnel, around the Walnut street loop where it joins with the line from the 30th Street station to Gray's Ferry avenue at a point just north of South street. Throughout this territory, manholes and laterals of the same construction are provided for carrying the various cables to each instrument location. High and low-voltage ducts are run in the same system, but with the required separation between lines, and with separate manholes for high and low-voltage cables. The sheaths of all cables are grounded to a common wire.

Power Transmission and Distribution

Two 75 kv-a. generators, located in the central steam heat plant at West Philadelphia, furnish 100-cycle current at 440 volts, which is transformed to 6,600 volts and fed through suitable sectionalizing switches to any or all of five transmission lines. Number 1 line carries 6,600 volts directly to BH location at 18th street, where it is transformed to 440 volts through duplicate 25-kv-a. transformers with the necessary switching arrangement.

Number 2 line carries 6,600 volts directly to B6A location at Schuylkill river; it is transformed at that point to 440 volts through duplicate 25 kv-a. transformers. This location is used as an emergency feed. From BH location at 18th street, through the B6A location, and to P3 location at 32nd street, a 440-volt line is sectionalized at each intervening instrument location.

Number 3 line will carry 6,600 volts directly from the steam heat plant to a suitable sectionalizing location in the machinery room of Penn interlocking, thence south to a sectionalizing location at P13, just north of South street.

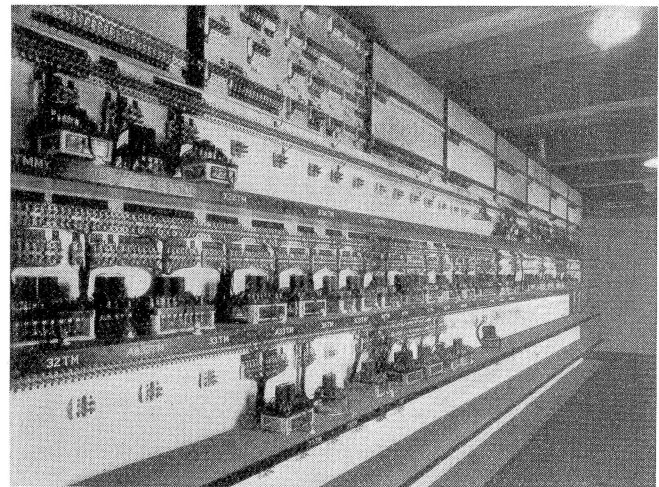
A 440-volt line will run through Penn interlocking from Spring Garden street to P13 location, connecting in on the sectionalizing location in the machinery room at Penn. This 440-volt line will be sectionalized in each intervening instrument location. Another 440-volt line is carried from Spring Garden street around the MU car yard joining the 440-volt line from B6A at P3 location,

thence going south through Market street tunnel around the Walnut street loop and joining the 440-volt line south from Penn at P13 location.

In connection with line No. 3, there will be installed two emergency lines connected to the 6,600-volt bus at Arsenal substation. One of these lines will sectionalize at location P13, just north of South street, where it will be transformed to 440 volts through duplicate 25 kv-a. transformers. The 6,600-volt line will continue on to the sectionalizing location in the machinery room at Penn. The other line from Arsenal substation will run directly to the machinery room at Penn. Number 4 line carries 6,600 volts directly to Spring Garden street, location PZ, where it is sectionalized and continues north to Zoo.

Number 5 line carries 6,600 volts directly to Zoo interlocking where it is sectionalized with line No. 4 and transformed to 440 volts through duplicate 25 kv-a. transformers. From the 440-volt bus at Zoo, power is carried south to location PZ at Spring Garden street, east to location Z15 at 33rd street and west to location Z21 at 46th street, each of these lines being sectionalized in each main instrument location between Spring Garden street, 33rd street and 46th street.

At D1 substation, adjacent to Zoo tower, an emergency connection is taken off the New York division 6,600-volt aerial line, carried into Zoo tower and suitably section-



Relay and terminal racks

alized with the other power lines at that point. At 33rd street, location Z15, a connection is taken off the New York division 6,600-volt aerial line and transformed through a 25 kv-a. transformer to 440 volts. This line furnishes power from 33rd street to Zoo tower, and it is sectionalized through the intervening instrument locations.

Two 440-volt lines are taken off the bus at Zoo tower and run west to 46th street. One of the lines is sectionalized through the various locations in the territory, while the other runs directly to 46th street and is used as an emergency line in case sectionalizing is necessary. The direct current requirements at Zoo are supplied by storage batteries, charged by a motor-generator set, operated from a separate 60-cycle feeder, which also provides energy for the tower lighting. All outside locations are provided with individual copper-oxide rectifiers.

All signal material was furnished by the Union Switch & Signal Company and all signal construction work is being handled by the signal construction forces of the railroad.

[A continuation of this article, explaining the methods of cutting these new plants in service, will be published in an early issue.—Editor.]