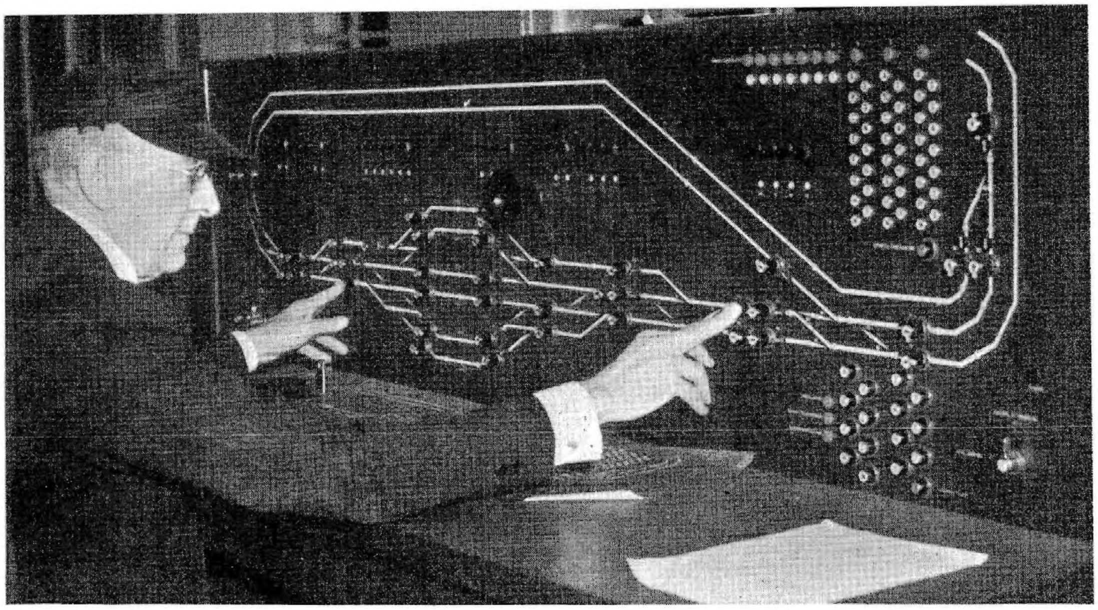


Operator at control panel at San Francisco showing method of operating the entrance and exit buttons to line up routes in the interlocking limits

San Francisco-Oakland Bay Bridge Interlocking Plants

Interesting details of the signaling arrangements, construction and operation of two large plants using the entrance-exit system of controlling routes—Interlocking signals used in an unusual manner

An article in the March issue of *Railway Signaling* described the track layout and traffic handled on the San Francisco-Oakland Bay Bridge Railway, and explained how two interlockings, together with cab signaling and train control, were applied to solve the operating problems. The following article is devoted to an explanation of the operation of the interlockings and a description of the construction details of the plants.

Entrance-Exit Interlocking System

The two interlockings, the one at San Francisco terminal and the other at the yards and junctions on the Oakland mole, are electrically operated, using Model 5C, 110-volt, d-c. electric switch machines and Type-SA searchlight signals; dwarfs or high signals being used as shown on the diagrams. The point of interest is that each plant is controlled by the entrance-exit system, by means of which a complete route, including the switches, crossovers, and signal or signals, is lined up by operating two buttons on a control panel, one located at the point representing the entrance to a route and the other at the exit. The towerman, knowing where a train is entering and leaving a plant, has all the information necessary to direct that train. The details were designed and the plants were installed by the General Railway Signal Company, this company having adopted the name "NX" as descriptive of its system, the name being derived from the two words "entrance" and "exit" as applied to a route through a plant.

Signaling Arrangements of the San Francisco Plant

All signals at San Francisco interlocking are Type-SA dwarfs. Although trains are normally operated in the counter-clockwise direction around the loop, the tracks are all signaled for movement in either direction. The signals governing in the normal direction of traffic operate to display three aspects, while those governing against the normal direction show red or yellow only. Since the cab signals are used for the spacing of trains, the yellow wayside aspect indicates only that a route is available. The green wayside signal aspect is used to inform a motorman that his cab signal will display better than a "red 11" indication when he passes the wayside signal. All signals, whether governing in the normal direction or against traffic, may be made stick or non-stick at the will of the towerman, as covered later in describing the operation of the NX control machines.

The switches and crossovers are divided into small groups, each group having its own set of protecting signals for each direction. This arrangement makes it possible to release the route locking behind a train quickly in case a reverse move is required for switching. One of the principal advantages is that a route can be cleared and released in short sections, which, of course, could be accomplished by sectional route release locking, but the important point is that, with a signal at each group of switches or crossovers, a second train can be kept moving at comparatively close spacing on a considerable proportion of the common section of the route, and as the leading train clears its turnout, the switch can be reversed and the signal cleared at once for the following train.

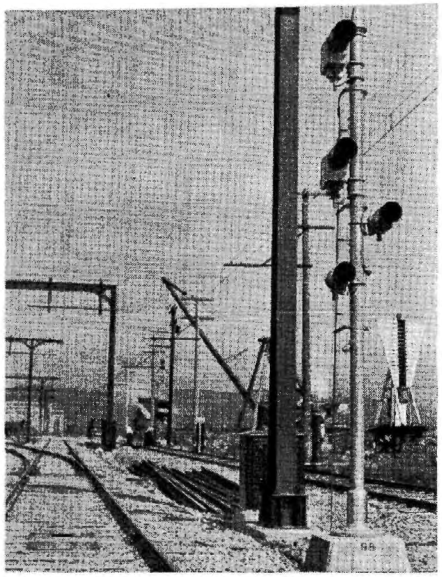
For example, a second train departing from a different track can be started and advanced to the signal and switch where the routes converge. As the leading train passes beyond the next signal in its route, the route can be lined and the signal cleared for the following train, thus saving considerable time, as compared with the use of one signal for each complete route from the westward entrance of the plant to a station track or from a station track to the leaving end of the plant.

Signaling Arrangement at Oakland

At the Oakland plant, the signals which control moves in the normal direction on the through routes are all high signals, including signals 98, 76, 72, 30 and 4 on the eastward routes, and 42, 46, 68, 100 and 122 on the westward routes. The remainder of the signals are dwarfs, and on the through routes they control movements against the normal direction of traffic, while on the yard tracks they control movements in either direction. Dwarf signals in the normal direction of traffic and all high signals display three aspects. As at San Francisco, the interlocking signals at Oakland can be made stick or non-stick.

In so far as the automatic train control is concerned, if the signal displays yellow or green, the cab signal indication is determined entirely by train spacing on the route set up. If the wayside signal displays red, then a succession of speed restrictions will be set up in the cab as a train approaches this wayside signal, culminating in a "red 11" on the track circuit or circuits immediately in the rear of the stop signal. These approach restrictions are determined by braking distances as though a train were standing on the track circuit immediately in advance of the red wayside signal.

The high signals, 42, 30, 98, 19 and 100, which are located in the approach



Eastward signal 98 at Oakland showing operative units and markers

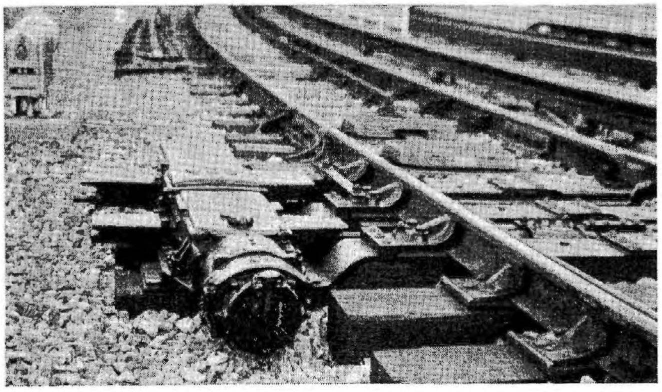
to a facing-point switch for a turnout from the main line to a yard, have two operating units, or in signal parlance "arms." The top arm governs moves on the through route, while the lower arm governs over the turnout.

Signal 72, with only one operating unit, governs through eastward moves to the Interurban Electric track at Oakland, as well as diverging moves to the left to the Key System track to Oakland. This is a No. 20 turnout, good for maximum speed of 35 m.p.h. When the operating signal is cleared for an I. E. move, a fixed lunar white marker unit, above the operative unit and on the right side of the mast, is lighted as an indication that the I. E. route is lined up. When the switch is reversed and the operating unit is cleared, a second lunar white marker, on the left of the mast, is lighted instead, as an indication that the Key System route is lined up. The two signals in approach to 72, i.e., 76 and 98, are also each equipped with markers which serve to give advance information concerning the route which is lined up at the junction switch 29. The markers on these three signals are an essential part of the arrangement, because the towerman cannot easily see the trains on the eastward track. If there has been a mistake in sending or interpreting the descriptions in the proper order, the towerman may line up the wrong route at the junction switch 29. In this case, the train is stopped short of the switch, and the towerman is notified by telephone to change the route. This circumstance occurs very rarely, but these provisions were essential because the 600-volt third rail used by Key trains does not extend onto the I. E., and vice-versa, the I. E. 1,200-volt overhead is not on the Key tracks.

Dwarf signals which control movements in the normal direction of traffic are operated to display three aspects, the display of the green aspect depending on the occupancy of the track circuits ahead. Dwarfs which control moves in the direction opposite to the normal direction of traffic operate to display only two aspects, red or yellow.

TC Markers

The yard storage tracks are not equipped with track circuits or cab signal controls. Therefore, signals on the leads from such tracks to the set-out tracks mark the points where trains enter signaled territory. Each such signal, as indicated on the diagram, has a special marker showing the letters TC mounted on the mast. When the block controlled by such a signal is occupied, and the towerman clears the signal, the aspect is a flashing yellow instead of a steady burning yellow. The flashing aspect requires that a train must stop before proceeding past the signal. The necessity for this special flashing yellow aspect is as follows: At signal locations in train control territory, the train is either proceeding in the normal direction of traffic under proper cab signal indication or running against traffic under a "red 11" cab signal. In the case of the TC signals leading from non-train control territory into train control territory, it is necessary, in order to set up train control operation, to provide a loop known as the "reset loop" in the approach to the wayside signal, which is energized to knock down the "NS" cab signal and cause a yellow 17 to be displayed in the cab. Inasmuch as the train is not permitted to enter train control territory unless the cab signal is operative, it is necessary to energize this loop even at times when it is desired to close the train up on another train standing less than "yellow 17" braking distance from the entering TC signal. The flashing yellow wayside indication is displayed under this condition, and, by requir-



The ties are dapped so the rods can be straight. The plates extend under machine ing a stop-and-proceed operation, insures that the train is proceeding under control when entering into the occupied section of the train control territory. As no track circuits are in service, no approach locking can be provided for these signals. By means of thermal time-element relays, an interval of 20 seconds is introduced from the time each of these signals is placed in the stop position until a switch or derail in the route can be operated. This method of locking a route also applies to all back-up dwarfs in both the Oakland and the San Francisco plants.

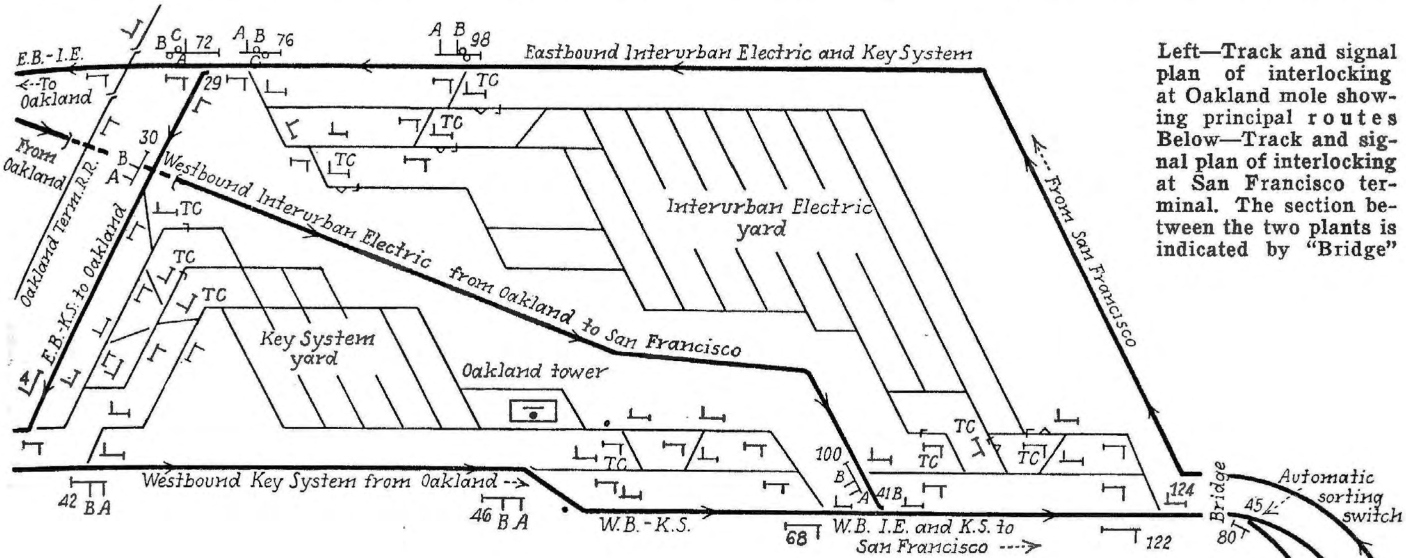
System Centers in Control Panel

From an operating and control standpoint, the important feature of each plant is the control machine which is made up in the form of a cabinet; the panel of each machine is 20 in. high and 76 in. long. In the face of the panel, the tracks and switches in the entire interlocking are represented by white lines 3/16 in. wide, which stand out in contrast with the dull-black finish of the panel. Small lamps mounted in the lines representing the track are normally extinguished, but are lighted to show white when each corresponding block is occupied by a train, thus outlining the route being used.

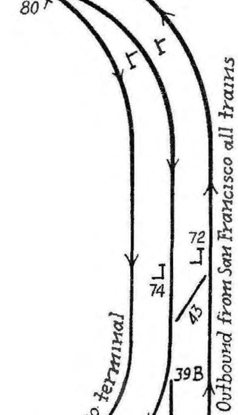
The switches and crossovers are represented by small, movable sections of the track which are called route indicators. The movable sections are operated by magnets mounted behind the control panel, and are actuated to positions which outline the route as soon as the towerman pushes the exit button. An indication as to whether each switch is locked is given by a small lamp with a red lens mounted behind the track lines adjacent to each route indicator. Each such lamp is lighted to show red when electric locking, including the equivalent of mechanical locking, has taken effect at the corresponding switch, and the switch is, therefore, not free to move. Thus these lamps are known as "lock lights."

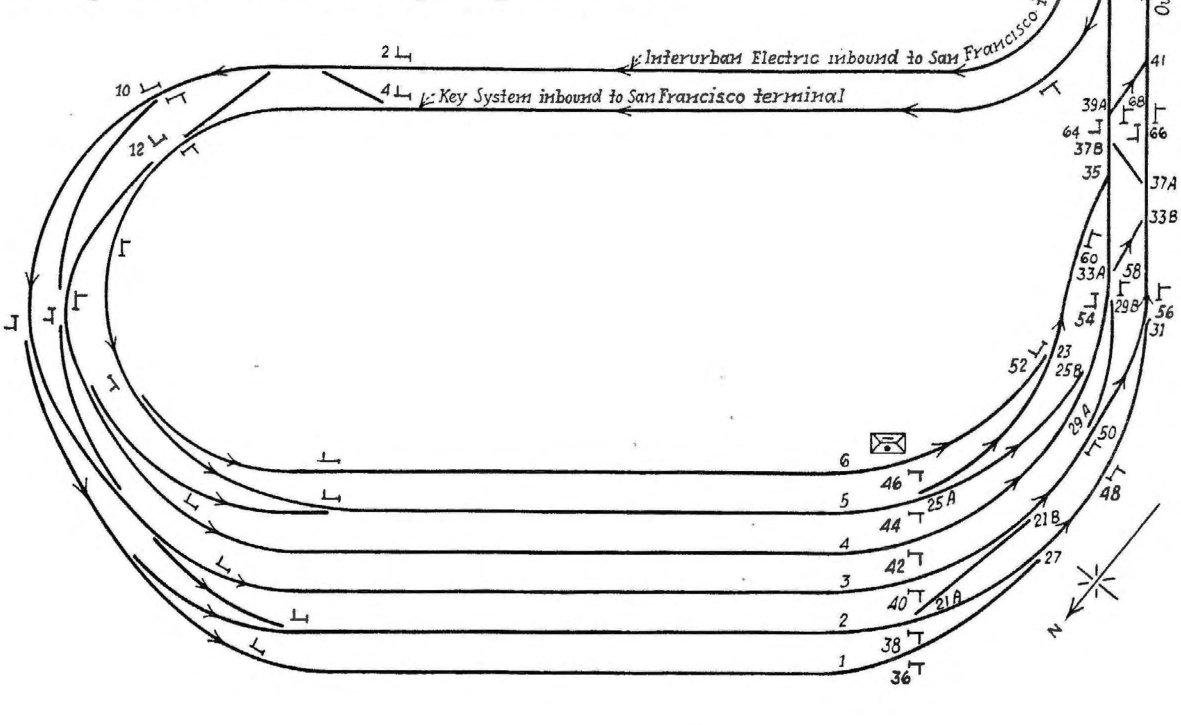
Entrance Knobs and Exit Buttons

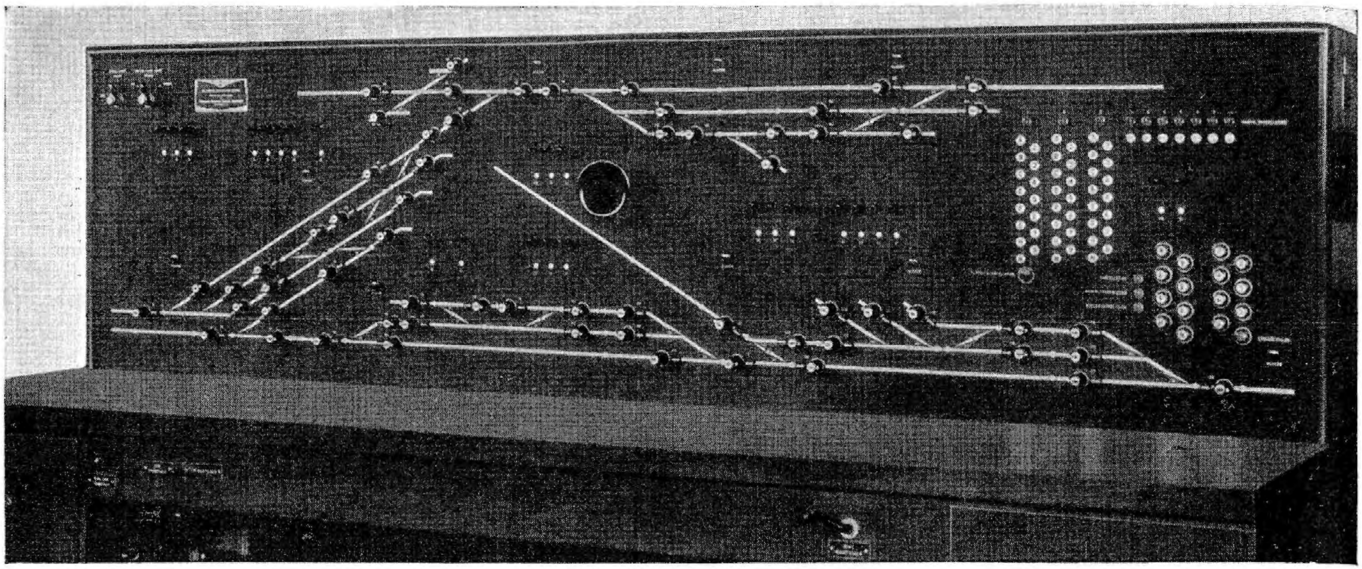
In the line representing the track, at the location corresponding to each interlocking signal, there is an entrance knob. As a means of effecting



Left—Track and signal plan of interlocking at Oakland mole showing principal routes Below—Track and signal plan of interlocking at San Francisco terminal. The section between the two plants is indicated by "Bridge"







The control panel of the interlocking on Oakland mole

different controls, each knob can be pushed, can be turned, or can be pulled, and in each instance a different set of contacts is operated. The knob is so constructed that it cannot be pressed while in a turned position; therefore, only one type of control can be initiated. When pushed, the knob returns to the normal position by spring action, as soon as the towerman removes his finger. When the knob is turned to initiate a control, it must be turned back to normal in order to cancel the initiation.

Each of these knobs is ¾ in. in diameter, and stands out 1 in. from the face of the panel. To facilitate identification, the number of the signal is etched in white, adjacent to each knob. The knob is hollow and surrounds a separately-supported round disk of translucent glass, which fits in the face of the knob. A black arrow in the face of the glass disk points in the direction in which the corresponding signal controls, and maintains this position. A small round white marker, on the outer rim of the knob, indicates the position of the knob, this marker normally being in line with the track and at the base of the arrow in the face of the knob.

Exit Buttons

An exit button is mounted in the line representing the track at each point where a train leaves the section of track over which a signal governs. Each exit button is 9/16 in. in diameter, and normally stands out from the panel 5/16 in. A white arrow on the face of each exit button points in the direction a train would be going when leaving the end of a route controlled by the respective button. These exit buttons are operated by pushing, and do not turn; they return to normal position by spring action as soon as the towerman removes his finger.

In normal operation, when a route is to be lined up, the towerman pushes the entrance knob corresponding with the signal for the track on which the train is to enter the plant. This action causes a white light to flash behind the lens in the face of the knob, as an indication that the lining up of a route has been initiated.

To Line Up a Route

The next action is to push the exit button corresponding to the end of the route, following which the route indicators immediately line up to correspond with the route desired. The red lock lights under the route indicators are lighted at the same time and indicate, in conjunction with the continuous white line, the route which has been set up. After the various switch machines have responded to the route called for and the signal clears, the flashing light in the entrance knob changes to a steady burning indication. If the towerman initiates by pushing or turning the entrance knob and the route desired is not available, the pushing of the exit button has no effect and the lamp in the entrance knob continues to flash. In this case the operator may cancel the initiated condition as described later, or may wait for the route desired to be available and again press the exit button. The non-availability of a route is indicated to the operator by following the desired route across the panel and noting whether the red lock light is lighted under any of the route indicators which must be operated in order to secure the desired route. As the train travels over the route, the signal goes to stop and remains at stop until the towerman again sets up the route (stick signal). This is known as "automatic route restoration."

Non-Stick Signal Control

When the towerman is lining up a route which is to be used by two or more following trains, the route can be held. In this case, instead of pushing the entrance knob, he rotates it 90 deg., and then pushes the exit button, following which the switches are positioned and the signal clears as explained previously. With this method of initiation, the signal will remain clear after the passage of the first train and does not go to the red position. In the case of end-to-end routes, only signals corresponding to initiating buttons which have been turned will fail to go to stop. Other signals go to stop when the train passes, and the portion of the route over which they govern is released for other routes as may be required.

Optional Route Selection

If there are several routes which a train might take from an entrance to an exit, the operation of the NX control would normally select and set up the preferred route. However, if this preferred route is blocked by a train or by the fact that another route is set up using part of the preferred route, the NX system automatically selects the next available route. For example, a train departing from track No. 2 at San Francisco can be routed from track No. 2 to track No. 1 over switches 21A and 27, then to signal 56 and on to the bridge; or the train could be routed over switches 21A, 21B, 29A and 31 to the track leading to the bridge; or it could be routed over 21A, 21B, 29A, 29B, 33A, 35, 37B, 39A and 41; or finally, over 21A, 21B, 29A, 29B, 33A, 33B, 37A and 41. The preference of the routes is in the order named. If the first route is not available, the next preferred route will be set up, and if that one is not available, the next one will be set up, etc., this control being effected automatically with no action on the part of the towerman, other than the original operation of the entrance and the exit buttons.

End-to-End Control

When lining up a route including several intermediate signals, the operation of the entrance knob and the exit button at the end of the complete route causes the switches to operate and all of the several intermediate signals, as well as the one at the entrance, to clear. This control feature is known as end-to-end control, and eliminates the necessity of operating entrance knobs and exit buttons for each of the intermediate sections.

At San Francisco, for example, the operator is thus free to line up an entire route from the station platform to the track leading on to the bridge or any portion of that route which he may desire. Thus where there is a succession of three or four signals governing in the same direction, the operator is able to clear all four by one initiation and one completion operation; or he can clear the first, second and third only; the second, third, and fourth only; or any combination of two signals; as well as clearing only a single signal. In each case, but one initiation and one completion is required, the initiating point being at the first signal which he desires to clear and the completion point at the end of the control of the last signal which he wishes to clear.

Under the operation explained, in which the initiation is accomplished by pushing the entrance knob, the signal changes to stop when the train passes it; and, as soon as the train clears the route, the control is automatically restored to the normal condition. The switches remain in the position corresponding to the route last used, and, therefore, do not have to be moved, providing that position corresponds with the next route being lined up. The establishing of a route does not depend upon the sequence of operation of the entrance knob first and then the exit button, but this is the logical and natural sequence, and is, therefore, taught to and followed regularly by the towermen.

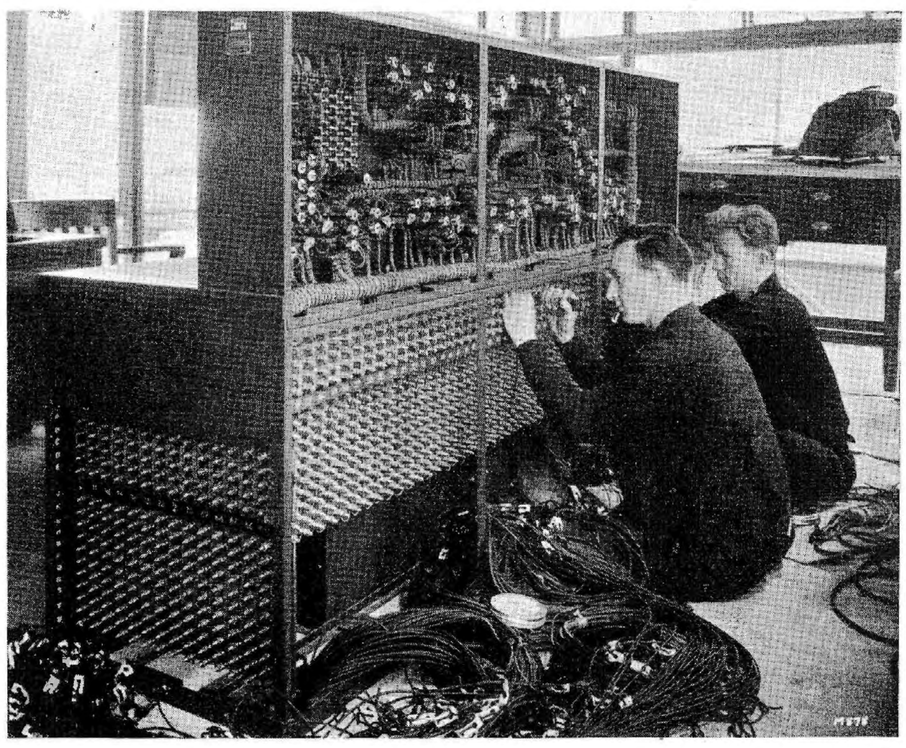
Signal Control With Track Occupied

A special and novel feature of both the San Francisco and the Oakland plants is that none of the wayside interlocking signals need be track circuit controlled, in so far as the yellow aspect is concerned. In other words, regardless of whether the track in the route proposed is occupied, the towerman can clear the signal by operation of the entrance-exit control. When initiated by pushing the entrance knob, the signal control is carried through the first track circuit in order to put the signal to stop and make the route self-restoring. However, if necessary to advance a train into the first track circuit, when occupied, the towerman is always free to do so by *turning* the initiation knob, since the non-stick control of wayside signals is not taken through any track circuits. This non-stick control is effective for only one signal, i.e., an end-to-end control cannot be set up by non-stick control unless the entrance knob for each intermediate signal is turned and the corresponding exit button operated.

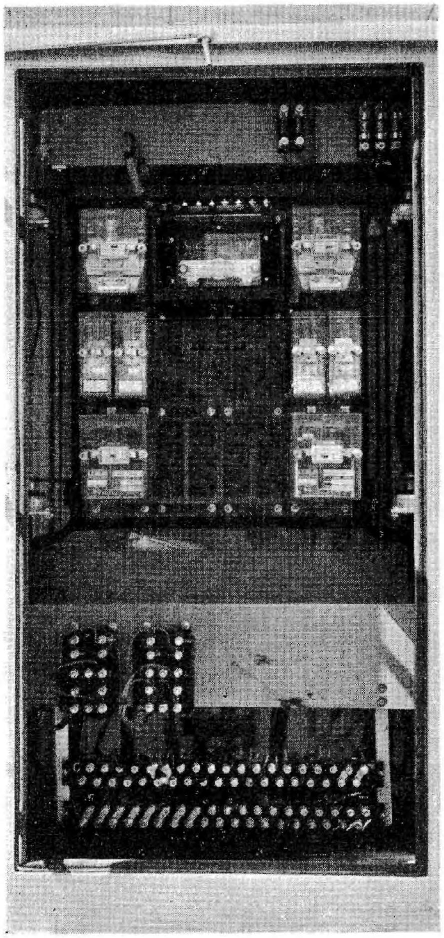
When non-stick controls with the immediate block occupied are established in this manner, the wayside interlocking signal or signals will display identical aspects as with the normal self-restoring or stick control. In the normal direction of traffic, when the train is more than 17 m.p.h. braking distance beyond the signal, the aspect will change to green. Under the non-stick signal operation, in which the initiation of a route is accomplished by rotating the entrance knob, the wayside signal will continue to display the yellow or green aspect until the towerman turns the entrance knob back to its normal position. Furthermore, in cancelling such a control, involving two or more signals, the entrance knob for each signal must be turned to normal.

Cancellation of Routes

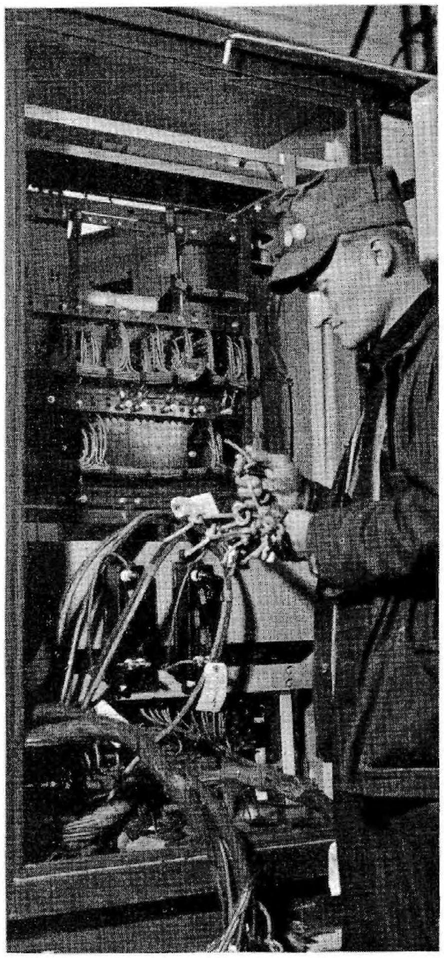
If a route has been established and the signal cleared, but a train has not yet entered the approach section, the route can be cancelled by *pulling* the entrance knob, providing the route was initiated by pushing the entrance button, or by rotating the button to normal if the route had been initiated by turning the knob. In the case of end-to-end routes, where a succession of signals have been cleared by one initiation and completion, each individual signal must be put to stop by pulling out its entrance knob. Thus, if the operator has set up an end-to-end route and finds it desirable to stop a train before it has reached the end of that route, he can always put the last signal, or any intermediate signal in the route, which the train has not passed, back to the stop posi-



Signalmen connecting wires to the rear of the control machine in the Oakland tower



Left—Interior of outdoor instrument case showing Type-B relays and code transmitter Below—Rear of case showing method used when connecting the incoming cable wires



tion without the necessity of holding the train at the first signal. If a train had already entered the approach section, approach locking is in effect and a proper time interval is introduced automatically by a thermal time-element relay, so that no switch in the route can be moved during this interval, which is of sufficient duration to have allowed the train to stop short of the signal or to lock up the route if the signal has been passed.

Test Keys for Control of Switches

Arranged in rows, near to but not directly associated with their respective switches, are small levers of the key switch type, which are used for test operation of the corresponding track switches. Associated with each test key is a correspondence light, which is lighted white whenever the respective switch is either in transit or is out of correspondence with the switch position called for by the route control set up by the entrance-exit system or by the test keys. During normal operation of the plant by the entrance-exit control system, the test keys are kept in the normal center position at right angles to the face of the panel. When the test key is moved to its downward position, the corresponding switch will operate to its normal position, and when the test key is moved to its upward position, the switch will operate to its reverse position. This method of individual control of switches was provided for use when a maintainer is testing or adjusting a switch.

The movement of a test key is ineffective to operate its corresponding switch when a route including that switch is established by the entrance-exit control system. Therefore, before using the test key, any existing route controls including the switch must be cancelled.

Locking with Reference to Test Keys

When a test key is placed in either its upward or downward position, its switch is locked in the position called for by the test key; therefore, if a route is to be lined up over the switch, that route can be only in accordance with the position of the switch as held by the test key. Where more than one route exists between an entrance and an exit, if a route other than the preferred route is desired, the towerman can line up such a route by using the test keys to operate the switches to the positions desired, and then operating the entrance and exit buttons.

Basic Principles of NX Control

The control for establishing routes in the NX system is accomplished by interconnection of circuits, no mechanical locking between the knobs or buttons, and no electric lever locks being used. Complete protection is provided to insure that a route is properly established and that no conflicting route can be established. Thus, the equivalent of mechanical locking is included in the control. The circuits provide approach, route, and detector locking, as well as sectional-release route locking, according to modern practice. The circuits are all of the direct-current, direct-wire type, no code equipment being used in the interlocking controls.

The arrangement of the NX circuits for establishing a route depend on the track layout and signaling arrangement for each individual group of possible routes starting from each signal. The number of single switches and crossovers in a plant determines the number of "route relays" or "selection relays." In every route that can be lined up there is a "conditioning" relay for each trailing switch. Each entrance button and exit button has associated with it a relay which sticks up when the button is pushed.

When an entrance button is pushed, a set of wiring connections are established which extend as "feelers" or "fingers" of available energy to every possible exit point for the routes initiated from that particular entrance button (except such exit points as are unavailable because of previously set up conflicting routes), and at the same time "conditioning" relays are picked up corresponding to each trailing switch encountered in all the available routes. When one of the exit buttons is pushed, thus completing the circuit at the end of one of the "fingers" of energy, the corresponding exit stick relay is picked up. This completes a circuit which energizes the "route-selecting" relays associated with each single switch or crossover, depending on the position of the aforementioned "conditioning" relays. The "route-selecting" relays cut off the unused "fingers" of energy, position the switches in the route, and provide the necessary interlocking against conflicting routes. The control circuit to clear the signal selects through the switch-repeater relays and contacts on both the entrance button and exit button stick relays, and also checks that the lock relays of all switches in the route are de-energized.

Wiring of Control Machine and Relay Room

On the back of the control panel, and enclosed within the cabinet, are the contact arrangements operated by the knobs and buttons, as well as the various indicating lamps, and the magnet devices for operating the route indicators. Wires are solder-connected to the prongs on these various devices, and extend to terminals mounted on insulated panels in the lower half of the rear and the two ends of the machine, as shown in one of the views. The connecting wires from the relay room to these terminals are brought up directly beneath the machine through a slot in the concrete floor.

Housing of Relays Concentrated

The relay room at the San Francisco terminal is 13½ ft. wide and 28 ft. long, with an 8½-ft. ceiling. In order to facilitate maintenance and inspection, as well as replacements in case of trouble, the relays for practically the whole plant are concentrated at this location. The operating coils of the SA searchlight signals are energized through signal control relays in this room. Likewise, the track circuits are extended to track relays in this room. For a few track circuits remote from the tower, in the vicinity of signal 80, track relays and repeaters are located in adjacent housings with secondary repeaters at the tower. Each of the Model-5C, 110-volt switch machines is equipped with its own controller housed in the switch machine case, this controller being operated by relays at the tower. The signal and switch repeating relays, locking relays, and relays used in the NX interlocking control are, of course, at this same location, making a total of 788 relays in the one room, exclusive of the 101 relays of the C.T.C. type used in conjunction with the train-describer system, described in the March issue.

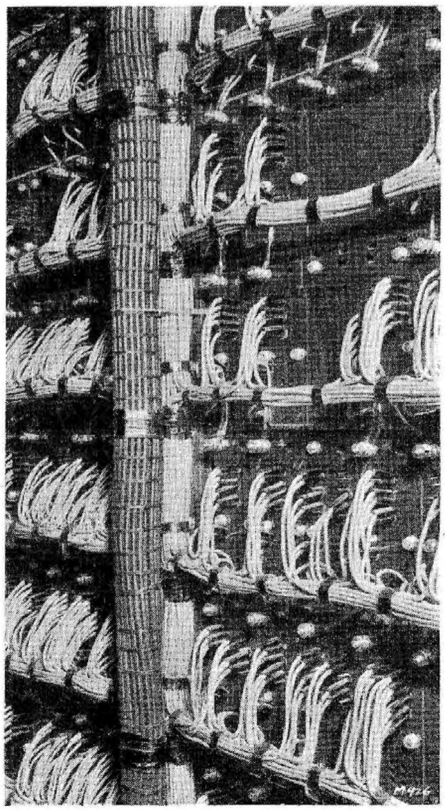
At Oakland, where the track layout is two miles long, it was not practicable to house the relays at one central point. The bulk of the relays are housed in six welded sheet-metal bungalows, each of which is centrally located in a zone or group of switch machines and signals. For two such zones adjacent to the tower, the relays are located in the tower relay room. In the case of the remote zones where the relays are housed in bungalows, the complete interlocking is accomplished at that point. The control relays are in general directly energized from the NX machine, and only such repeater relays as are required are brought into the Oakland tower. Controls and indications are combined effectively to reduce the number of wires to a minimum in a manner similar to that employed for direct-wire remote control and C.T.C. installations.

Quick-Detachable Relays

One of the outstanding features of this installation is the use throughout of compact relays of the quick-detachable type. The use of these relays has resulted in a space requirement about one-third as great as would have been the case had the older type of signal relay been employed. The relays are of five types, all 7⅜ in. high, as follows: The B1 neutral relay is 2½ in. wide and has a capacity for 6 front and back dependent contacts or 9 independent contacts; the B2 neutral relay is 5 in. wide and has a capacity twice as great as the B1; the B2 polar neutral relay is 5 in. wide and has a capacity of 4 normal and reverse dependent contacts and 8 front and back dependent or 12 independent neutral contacts; the B2 retained-neutral polar relay is also 5 in. wide and is designed to prevent the neutral armature dropping while the polar armature changes; the B2 vane a-c. track relay is 5 in. wide and has a capacity of one front and one back independent contacts. It is used in combination with a d-c. repeater relay to make a primary-secondary combination.

Any of these relays may be detached by the removal of two thumb nuts from the ends of the guide rods on which the relays are mounted. These guide rods insure proper alinement of the plugs when the relay is pushed into place. The quick-detachable feature permits the quick change of relays in case of necessity without any chance of making wrong connections. The working parts are enclosed in covers of transparent plastic moulded material. There being no exposed binding posts, auxiliary means are provided for opening and closing the circuit to the relay coils by means of a special tool and also for inserting an ammeter or an adjustable resistor or both for measuring the current being taken by the relay or testing its pick-up and drop-away characteristics while in place.

Below—Type B quick-detachable relays on board in tower
Right—Rear of the board showing the wires and cables



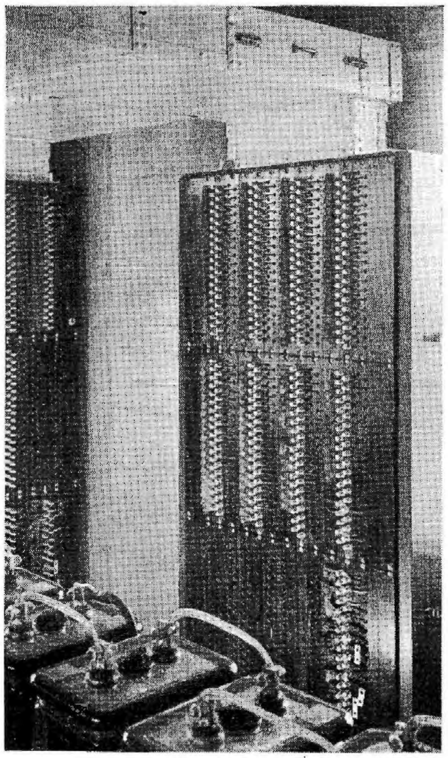
The stationary "plugboards," on which the relays are mounted, are supported in a vertical plane on a framework made of strap iron, using angle-iron posts at each end. Each such section is 24 in. wide and 8 ft. high. An ebony asbestos terminal board is provided at the top and at the bottom of each section, as shown in the illustration. The panel support at the floor includes a continuous resiliant rubber support under each section, while at the top the rack sections are supported by two rubber buttons fastened to longitudinal angles which are in turn fastened to the ceiling with strap iron braces. Sections are placed side by side in rows as required. There are two such rows, each 22 ft. long, in the room at San Francisco. At the rear of the panels, the tongue sections from the contacts in the receptacle extend out beyond the surface of the bakelite sheet, and wires soldered to these tongues run to terminals, at either the top or the bottom of the panel. Each panel was wired in the factory as a complete unit, and after installation in the field, wires were run from the terminal boards for panel-to-panel wiring and to other destinations.

The wiring on these panels is No. 16 flexible, with 2/64-in. Performite insulation and braid. The wiring extending up to the machine is No. 14 flexible, with 3/64-in. Performite insulation and braid. The panel wiring is covered with green braid and the external wiring with black braid so that the internal wiring may be easily distinguished from the external wiring on the binding posts.

Direct-Current Power Supply

The track circuits and track relays are operated by alternating current, in order to avoid interference with the direct-current propulsion energy. The coded pulsating energy superimposed on the track circuits for cab signaling control is 100-cycle alternating current.

The interlocking control circuits, the searchlight signal mechanisms, and the switch machines, are all operated on direct current supplied by storage batteries. At San Francisco a battery room is provided at each end of the terminal building. In each of these rooms there is a 55-cell battery for operation of the 110-volt switch machines in the particular vicinity. In the Oakland plant there are three separate 55-cell batteries for switch operation. At both the Oakland and San Francisco control stations, in addition to the 55-cell switch battery, there is a 12-cell split battery used for the operation of the train describer and also for the control and indication circuits; also a 6-cell battery is used for local circuits. In addition to the two 110-volt batteries located in bungalows at Oakland, each bungalow has a 6-cell local battery. The split battery in this case is omitted, the 24-volt split energy being obtained from rectifiers. The storage battery cells are all of one type, the Exide Type EMGS-7, a total of 353 such cells being used on the entire project. At all outside relay housings and junctions boxes where d-c. energy is required, a separate rectifier, or rectifiers, is furnished. Both the 24-volt and 12-volt batteries are supplied primarily for the purpose of maintaining stick relays in case of a momentary loss of a-c. energy. It is for this reason, and for uniformity in replacements, that all of the cells of storage battery used are of the one type, as the capacity provided would



Terminal board and storage battery in San Francisco terminal

furnish only a few hours reserve in the case of heavily-loaded local batteries at San Francisco and Oakland towers. However, since the entire operation of the track circuits and cab signaling system is dependent upon a continuous supply of 100-cycle alternating current, the question of reserve on these batteries appears to be of little importance.

Outside Cable Construction

The wiring distribution exterior to the towers and instrument housings is in cables. In order to minimize wire breakage that may be caused by vibration, the conductors in all cables are of the flexible type, using 19 strands to the conductor. Each No. 14 signal control wire has 5/64-in. wall insulation, with 3/64-in. insulation on single-conductor insulated wire in junction boxes or jumpers in cases. The 110-volt d-c. buses and the track connections are No. 6 conductors, with 5/64-in. wall. The track circuit connections are carried in two-conductor cables connected to terminals on the impedance bonds; therefore, no bootleg outlet connections at the rails are used. By making this connection to the impedance bond, damage to the signal equipment by the propulsion current is eliminated in case the connection from the impedance bond to the rail becomes broken. The outside protective covering of all cables is of the trenchlay type. All wires and cables were made to special specifications prepared by the engineers of the San Francisco-Oakland Bay Bridge.

On the main bridge structures the cables are carried directly on steel members with suitably placed steel strap "keepers." Off the structures, the cables were installed underground. On the elevated concrete viaduct in San Francisco, a cable trough was built into the structure. Within the San Francisco Terminal building, the cables were suspended from messengers carried in supporting brackets made of ½-in. by 2-in. strap iron, clamped to the roof beams of the train shed.

The 100-cycle a-c. supply is obtained from duplicate 2,300-volt sources located in the propulsion power substation at the Oakland end of the bridge. From this point, duplicate 2,300-volt mains are run in the direction of San Francisco and through the Oakland interlocking. These main power distribution circuits are in the form of loops, so arranged that, if a failure occurs in a section between any two transformers, the defective section can be disconnected and all transformers kept energized. Step-down transformers, 2,300-110-volt, are located at frequent intervals along the right-of-way, and from these transformers 110-volt energy is distributed to relay housings.

The interlockings at San Francisco and Oakland, as explained in this article, were installed under contract by the General Railway Signal Company. The installation was made under the jurisdiction of the State of California, Department of Public Works, San Francisco-Oakland Bay Bridge Division, of which C. H. Purcell is chief engineer; Charles E. Andrew, bridge engineer; Glenn B. Woodruff, engineer of design; and C. R. Davis, resident engineer in charge of signaling. An article in a future issue will explain the details of the construction and operation of the cab signaling and automatic train control which formed an important part of the Bridge Railway signaling project.