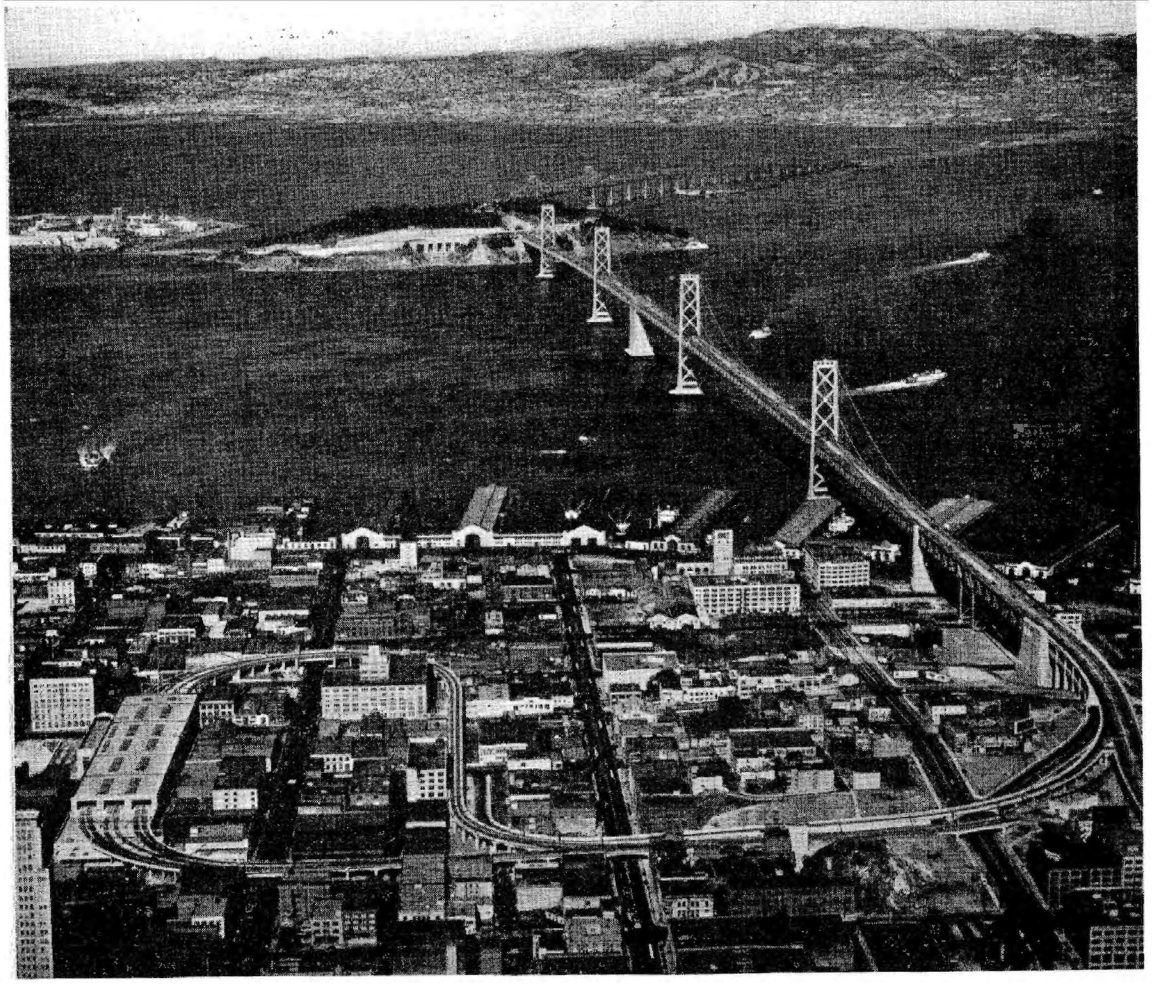


View of the bridge from the San Francisco end—The two tracks for the interurban cars are on the lower of the two decks.

Cab Signaling and Train Control

On the San Francisco-Oakland Bay Bridge

Details of circuits and equipment used on wayside and cars on the San Francisco-Oakland Bay Bridge Railway to permit trains to be run on 63.5-sec. headway at 35 m.p.h.

AN ARTICLE in the March issue of *Railway Signaling* explained in general how the interlockings and the cab signaling with train control are utilized to solve the operating problems on the two tracks on the San Francisco-Oakland Bay Bridge Railway. A second article, in the April number, explained the details of construction and operation of the two interlockings, while the following article has to do with the details of the cab signal and train control equipment. In recent years, the term automatic train control has been rather loosely applied, while as a matter of fact this term applies only to a system in which the speed of the trains is governed automatically in conformance with the signal aspects, regardless of whether wayside signals, cab signals or both are used.

Aspects and Indications

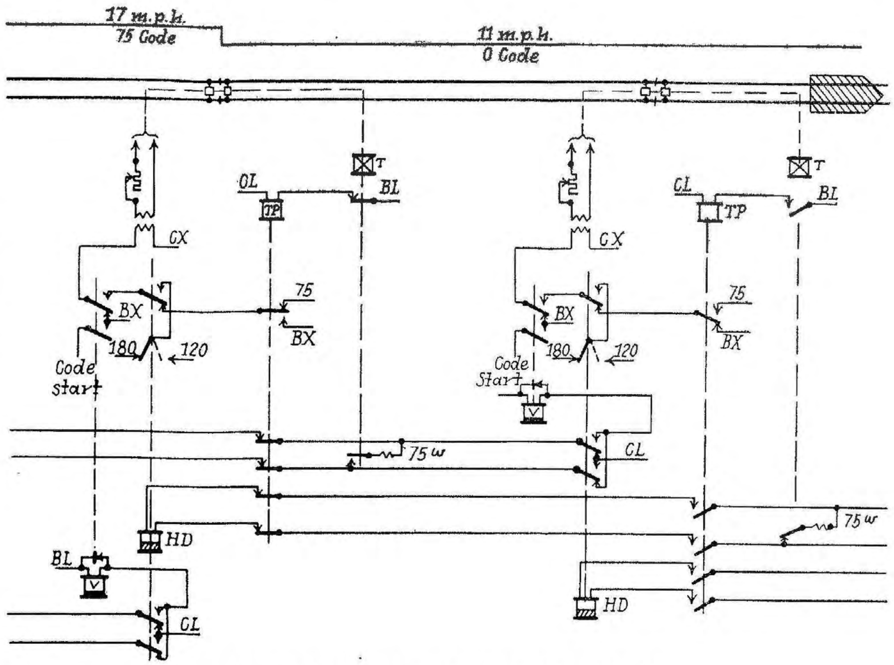
No wayside automatic block signals are used on this installation, and the cab signaling and continuous automatic train control is used in a manner somewhat different from any previous installation, the main objective being to secure maximum track capacity and flexibility of train operation.

The lengths of the track circuits in the automatic territory on the bridge range from 370 ft. on the 3 per cent ascending grades to 500 ft. on the 3 per cent descending grades, except approaching San Francisco, where 250-ft. track circuits are used in order to obtain headway. On the bridge between interlocking limits, the eastward track is 28,580 ft. long, including 67 track circuits, and the westward track is 23,750 ft., with 64 track circuits. The track circuits are of the customary type, using a-c. equipment; they are normally energized and are used to detect track occupancy by the ordinary method of shunting.

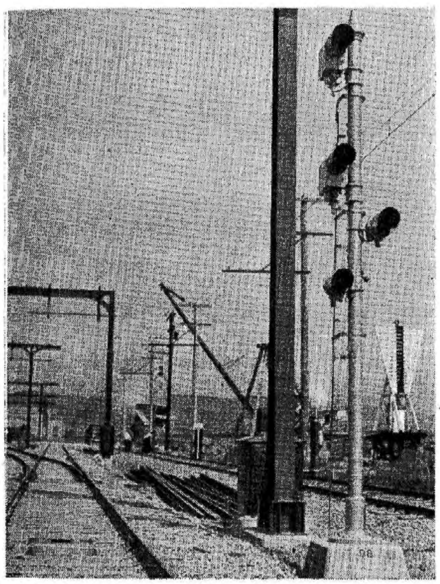
A distinctive feature of the installation is that a train occupying any one track circuit automatically establishes three control areas or speed zones to the rear. The entering end of each of the respective restricting speed zones is far enough in the rear of the occupied track circuit to permit a motorman of a following train, by use of the service application of brakes, to reduce the train speed in each successive zone to conform with the gradually reduced limits established, and thereby to maintain safe braking distance between two following trains or to stop short of a standing train. Thus, instead of blocks extending from one wayside signal to the next, as in ordinary practice, the protection in the rear of a train, in effect, moves along with the train in short jumps of 250 to 500 ft. This feature is one of the important factors which made it possible to operate trains on 63.5-sec. headway at 35 m.p.h., thereby solving the problem of track capacity.

Equipment on Wayside

The cab signaling and automatic train control apparatus on the multiple-unit cars is controlled by coded



Typical arrangement of wayside circuits

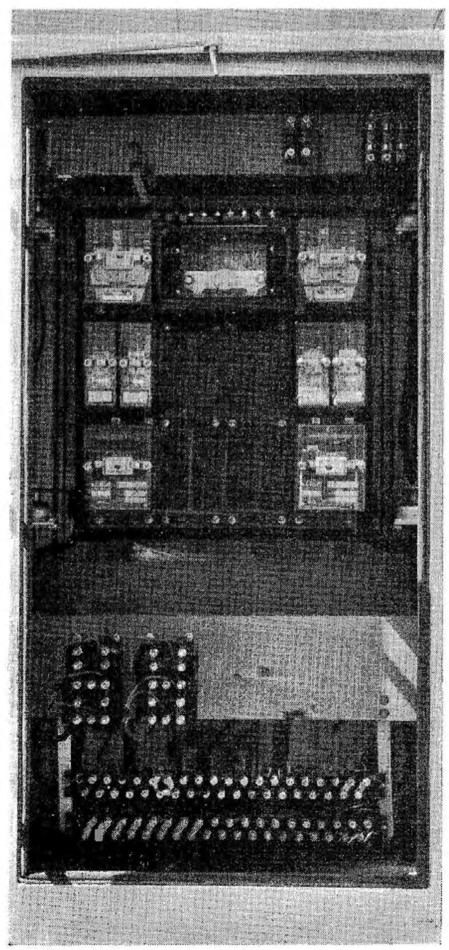


Interlocking signal 98 at Oakland showing operative units and markers

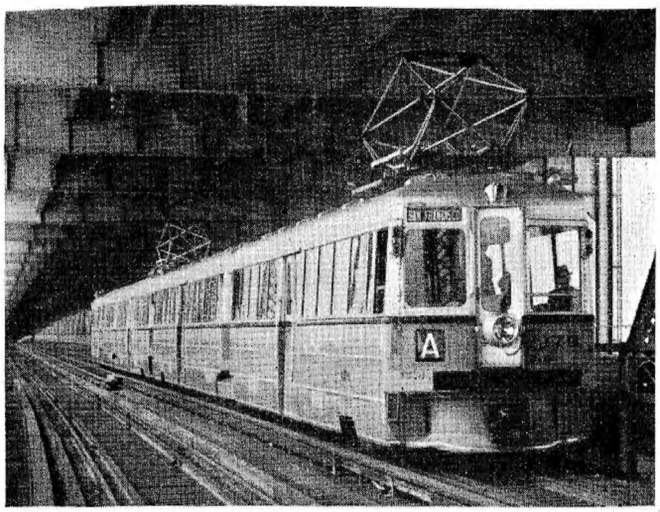
impulses superimposed on the rails in the speed zones to the rear of a train, the code which is effective throughout each individual speed zone being the same number of pulsations per minute. The code impulses are provided by code transmitters, each of which consists of a condenser-start-and-run synchronous motor which drives, at a constant speed, gears connected to a shaft on which are mounted three sets of cam wheels, each with different numbers of undulations, and each wheel operates a separate set of contacts. These contacts are fed 100-cycle a-c., and, when connected, one set puts out 75 pulsations per minute, and the others 120 and 180 per minute.

As shown in the circuit diagram, these transmitters are normally not in operation, but when a train enters the track circuit and shunts the track relay at the entering end, a V relay is picked up which starts the code transmitter at the leaving end of the track circuit, thus putting coded energy in place of steady 100-cycle energy on the primary of the track transformer. The normal a-c. track circuit steady current and coded impulses cannot both be fed to a track section simultaneously, because the normal feed is controlled through back contacts of the V relay, and the code is fed through front contacts of the same relay. In case the V relay fails to pick up, the flow of constant alternating current does not operate the cab signal and train control apparatus on the train, and, therefore, the most restrictive "Red 11" aspect and speed control is effective.

Referring to the diagram showing the arrangement of speed zones: In the track circuit occupied by the rear of a train, and in the zone which may consist of one or more track circuits immediately in the rear of that occupied, a "no code" condition is effective. A train entering such a zone would receive a "Red 11" cab signal indication, and the maximum speed at which the train may be operated is 11 m.p.h. In the next zone to the rear, which may include one or more track circuits, a 75 code is effective and a train entering such a zone would receive a "Yellow 17" cab indication, and the speed restriction would be 17 m.p.h. In the third zone to the rear, which may include one or more track circuits, the 120 code is effective, and a train entering such a zone would receive a "Yellow-Green 25" cab signal indication, and the restriction is 25 m.p.h. In the track circuits to the rear of the third zone, the 180 code is effective, and a train entering such "clear" areas receives a "Green 35" indication and the speed limit is the maximum, i.e., 35 m.p.h. More details as to the arrangement of zones



A code transmitter is shown in the center of top row



Typical train on the bridge where cab signals and train control is in service without wayside automatic signals

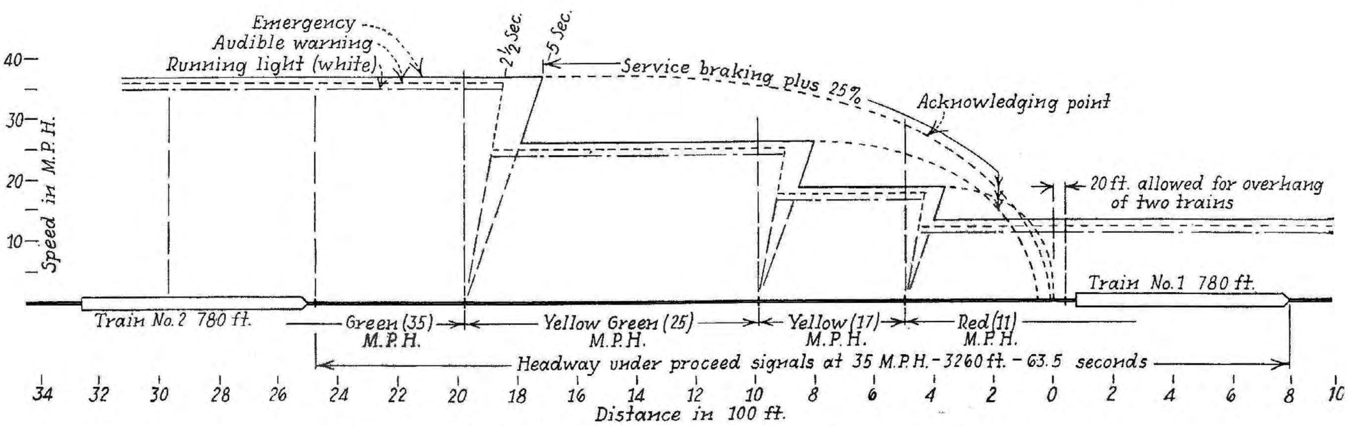
with reference to braking distances are given on page 150 of the March issue.

Wayside Signals at Interlockings

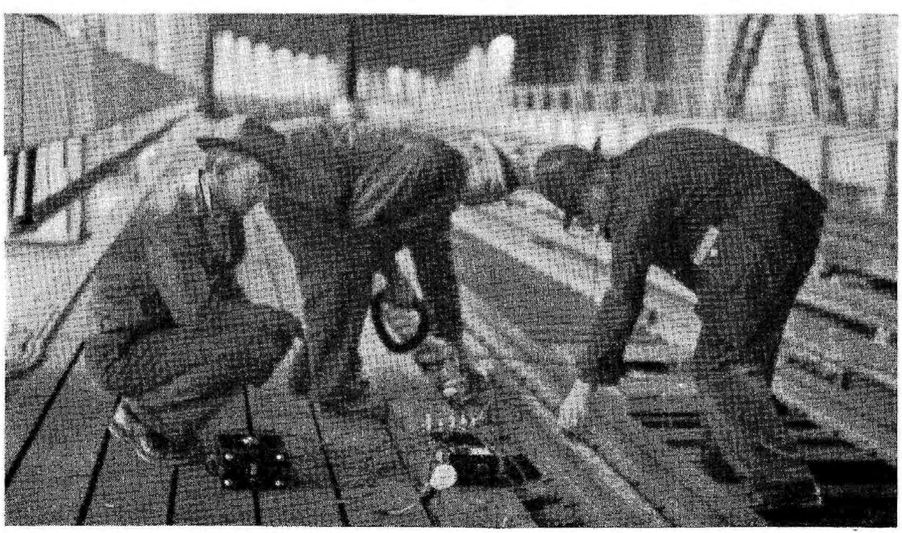
Although no wayside automatic block signals are used on the bridge, operative wayside signals are, of course, used as interlocking signals to mark the locations at which trains may be required to stop, and also to indicate to motormen that routes are lined up. In so far as the automatic train control is concerned, with reference to the wayside interlocking signals, if a wayside 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 the 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.

Throughout the Oakland plant, the action of the speed control depends on the permissible speed over the route set up and the occupancy of the track ahead. For a train entering the San Francisco plant, the 25 m.p.h. limit is in effect on the curve leading off the bridge, and when the train enters the loop near signal 74 the 17 m.p.h. limit governs over the sharp curves leading into and out of the station, where the 25 m.p.h. limit again goes into effect until the straight track of the bridge is reached, after which the maximum speed is 35 m.p.h. A yellow aspect on an interlocking signal indicates a "no code" condition in the block; that is, on passing a yellow signal the train receives a "Red 11" speed limit. Dwarf signals at entrances to cab signal territory, such as those leading from storage tracks to set out tracks at Oakland, have a small sign reading TC, mounted on top of the signal. When such a signal is cleared with the immediate block occupied, the aspect is a flashing yellow instead of a steady yellow. The flashing yellow aspect requires that the train must stop before proceeding past the signal.

All of the wayside control equipment on the bridge and in the interlockings at San Francisco and Oakland was furnished and installed by the General Railway Signal Company. The wayside equipment on the 26th



Arrangement of blocks and speed curves for *descending* grade

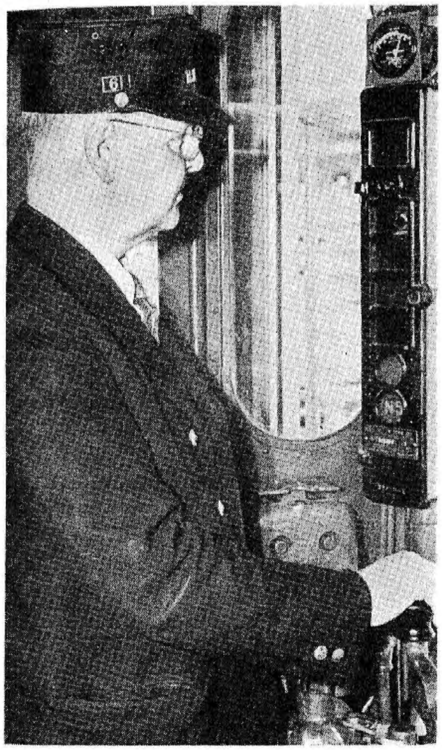


Testing equipment was used for locating grounds on the rails on the bridge tracks

Street overhead wye at Oakland, where the Bridge Railway connects to the tracks of the Southern Pacific, is controlled by the Southern Pacific Sixteenth Street tower. To conform with the balance of that plant, this equipment was furnished by the Union Switch & Signal Company and installed by Southern Pacific forces.

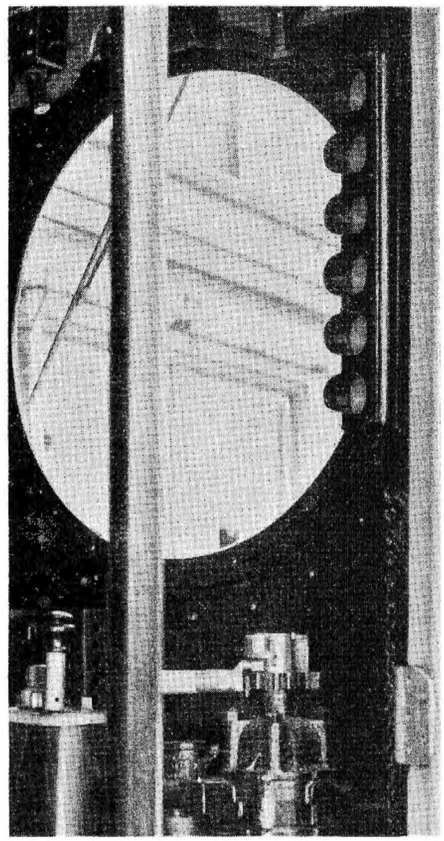
Equipment on Cars

The code pulsations are fed out on the two rails from the leaving end of each track circuit toward an approaching train. The circuit across the rails is completed by the wheels and axles. The coded pulsations in the rails are picked up inductively by two receiver coils, one above each rail



Cab signal in Key System car

and located ahead of the leading wheels of the car. From the receivers, the impulses pass through an amplifilter which filters out any stray frequencies and amplifies the energy sufficiently to operate the master code relay CR. (See diagram.) This CR relay is energized by each impulse received, and then releases so that its operation is identical with the code frequency in the track. A front contact in the CR relay controls relay CRFP, which repeats the front contact of CR. The CRFP relay is picked up with the first closing of the master relay front contacts, and stays up as long as the master relay is operating, being sufficiently slow-releasing to tide over the code interruptions. The 75 rate relay, 75R, will pick up through a back contact of CR and a front contact of CRFP. This control is dependent upon regularly-spaced operation of the master relay with uniform code to hold up the CRFP and 75R. The 75R relay controls the "Yellow 17" cab signal aspect and corresponding train control features. An important point is that this 75R relay also is energized when 120 or 180 code is being received. The negative feed for the master transformer is controlled through the front contact of the 75R, thereby insuring that a more favorable cab aspect or speed control cannot be obtained unless 75R is up.



Right — Cab signal in an Interurban Electric car

Use of Decoders

In order to isolate the controls effected by the 120 and 180 rates of impulses, decoding apparatus is used. When either 120 or 180 codes are being received, the CRFP and the 75R relays are picked up; therefore, the front and back contacts of the master relay feed direct current at 32 volts, in pulsations of either 120 or 180 per minute, to the primary of the master transformer, and the secondary feeds the resultant alternating current of code frequency to the two wires that extend to the two decoders. The separation between the 120 and 180 code is accomplished by using condensers of suitable capacity in series with the feed to the decoder transformers. The transformer in each decoder feeds a full-wave rectifier which, when the code corresponds with the tuned circuit of the decoder primary, picks up a d-c. relay, i.e., 120R or 180R. One or the other of these relays, depending on the rate of code received, is picked up, and remains up, being made slightly slow-releasing to bridge the periodicity of the code. Each of these relays is repeated by a slow-acting relay. If the code is 75, neither the 120 nor the 180 relays is affected. The 120R relay controls the "Yellow-Green 25" aspect of the cab signal and affects the 25 m.p.h. speed restriction. The 180R relay controls the "Green 35" aspect of the cab signal and corresponding speed controls. When a no-code condition exists in the rails, all of the relays, including CR, CRFP, 75R, 75RP, 120R, 120RP, 180R and 180RP, are de-energized, and energy

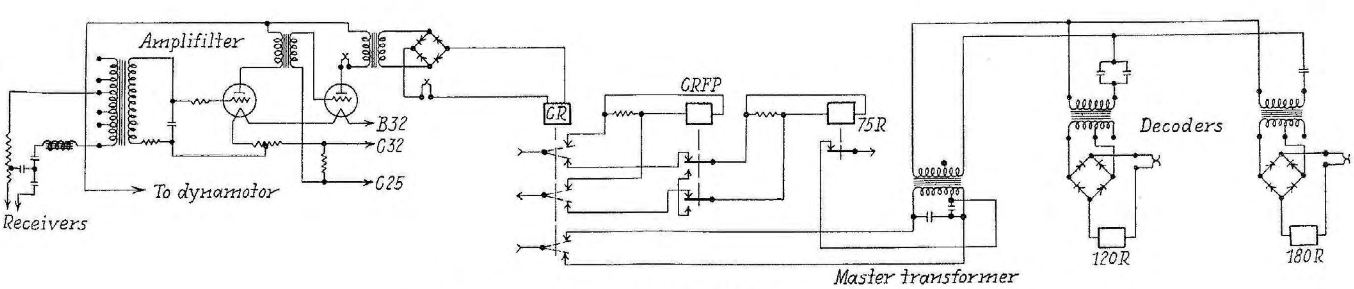
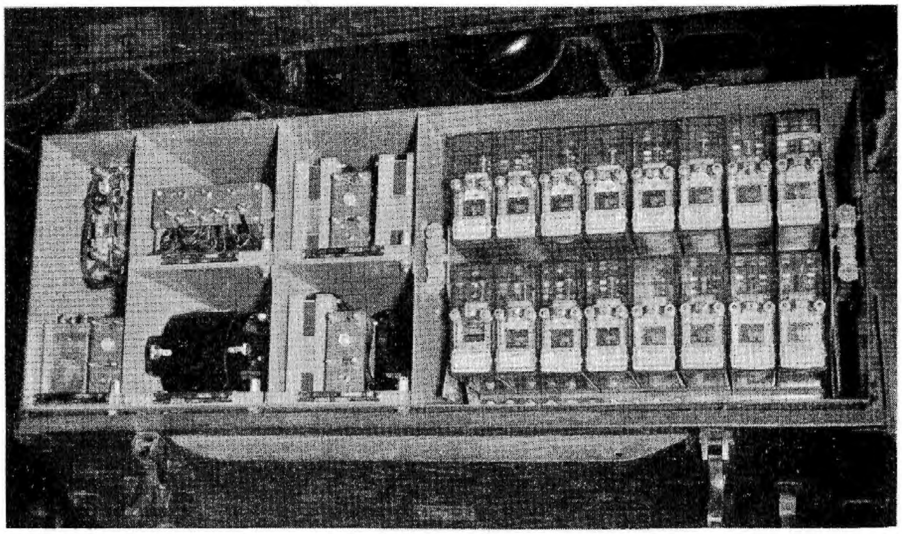
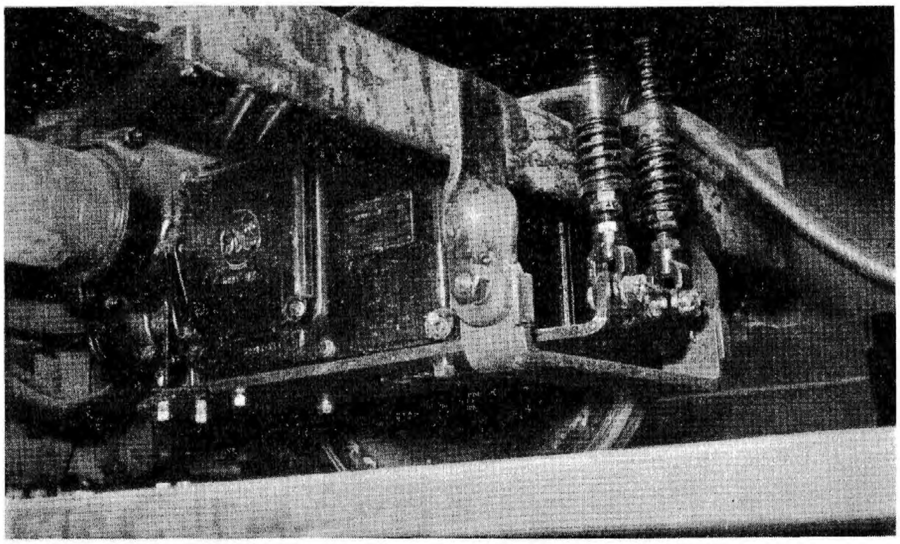


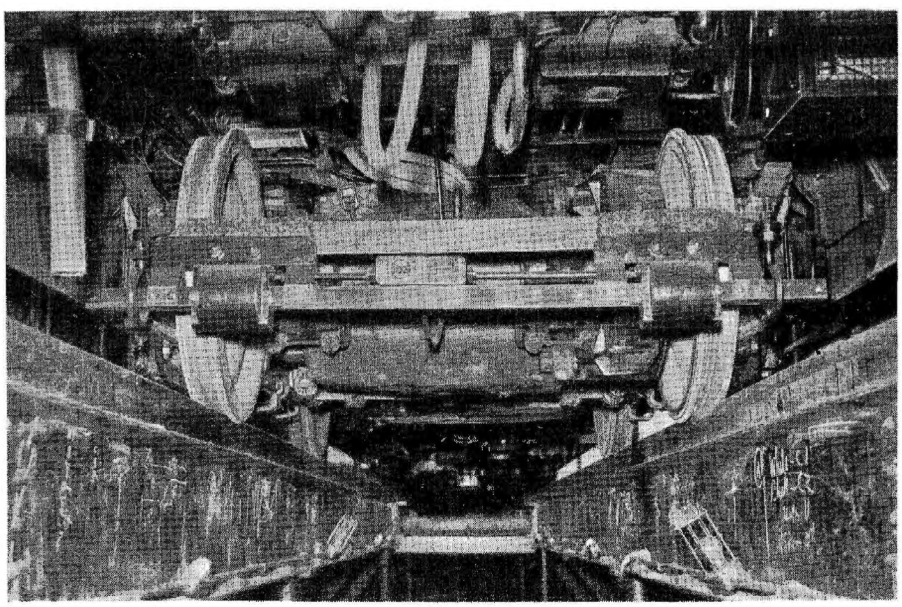
Diagram of circuits included in car equipment



The views on this page show the cab signal and train control equipment on a Key System car. Above—Equipment case showing amplifiers, dynamotor, decoders and relays used for various circuits



The speed governor is mounted on a car truck, being geared to one axle and arranged to drive a governor which actuates contacts



The receiver coils are mounted in front of the leading wheels of a car and about six inches above the level of the top of the rail

to feed the "Red 11" cab signal aspect and associated brake control apparatus is controlled through contacts of the proper relays.

In addition to the fundamental control on the cars, as explained above and as shown in the diagrams, the circuits are extended to include the cab signal lamps, audible signal, speed governor, acknowledging arrangements, and electrically-operated valves to control the air-brake system. The operation of a car in conformance with the aspects of the cab signal, and the automatically-enforced speed restrictions with reference to the brake applications, are all explained on page 151 of the March issue.

The System in Operation

The cab signal lamp (second from the bottom) which has a white lens and no figures, is lighted when a train is running at or above the maximum speed permitted by one of the colored aspects. Should the speed rise a mile above the authorized speed, an audible signal is sounded. On the Key System and the Sacramento Northern cars, when he receives this warning, the motorman must take action to prevent further increase in train speed. If he does not take such action, and the speed continues to increase, an automatic emergency application of the brakes is made and the power is cut off when the train speed reaches one mile above the speed at which the audible signal sounds. On the Interurban Electric cars, when the audible signal is sounded, indicating that the train is running above the speed limit, the power is automatically shut off, and, if the motorman does not place his brake valve handle in the full service position within 2½ sec., an emergency brake application is made automatically.

Audible Signal Operates

Each time the aspect of the cab signal is changed to one more restrictive, the audible indication is given, and the motorman has 2½ sec. to suppress, i.e., shut off power and initiate a service brake application. Of course, if he is running below the new speed limit, no audible indication is given and he takes no action whatever. When a "Red 11" is received, an additional distinctive signal is sounded, and the motorman is required to press an acknowledgment lever within 2½ sec. thereafter, or before applying power or moving the brake handle from the full service position.

A special feature of the system is that operation of the brake handle to the service position is checked by a contact which is closed only when the handle is in the full service position. This contact is included in circuits which, in effect, forestall an emergency application. This feature, known as suppressed braking control, is one of the important items which made it possible to eliminate the use of overlaps, thereby reducing the spacing between following trains. In case of any automatic application of the brakes, it is impossible to release the brakes until after the train comes to a stop.

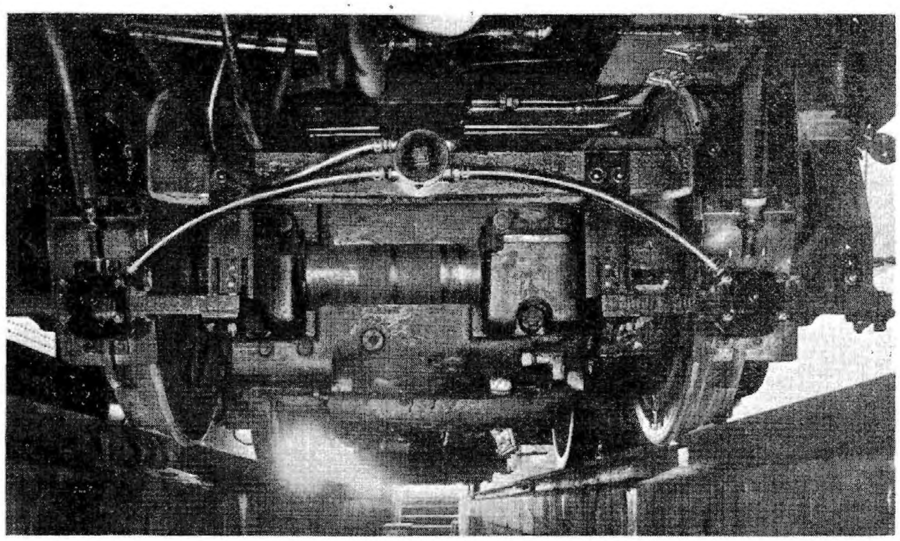
Location of Equipment on Cars

The equipment on the 88 Key System articulated units and the 17 Sacramento Northern cars was furnished by the General Railway Signal Company, while that on the 110 Interurban Electric cars was furnished by the Union Switch & Signal Company. The electrical equipment, including the dynamotor, amplifiers, relays, decoding apparatus, etc., with shock-absorbing mountings, is housed in a sheet-metal case mounted on the car. All relays are the quick-detachable, plug-in type, and similar connections are provided for the other units of equipment mentioned above. The illustrations show the two types and mountings of the speed governors. The wiring connections between the various devices are in metal conduit, except that rubber-covered, swing-loop cable is extended to the speed governors and the receivers on the trucks. The equipment on the cars was installed by forces of the individual railroads.

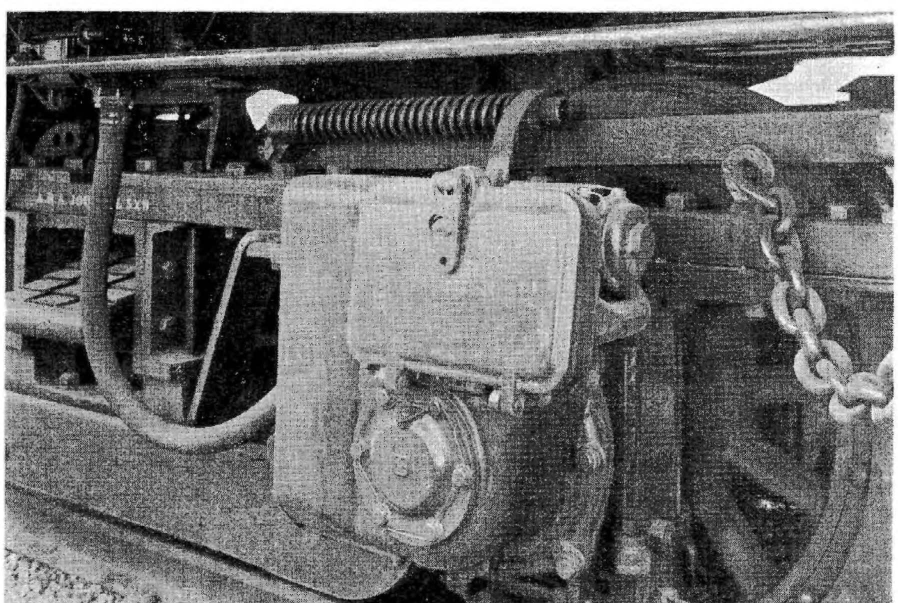
Engineering and Plans

The installation of the interlockings, and the cab signal and train control system were 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. The specifications for the cab signaling, train control and interlocking prepared by the bay bridge authorities, was the ultimate outcome of a series of informal conferences held daily by a committee for several weeks in September and October, 1934. The members of this committee included C. R. Davis, R. D. Moore, signal engineer of the Southern Pacific, W. H. Evans, signal and electrical supervisor of the Sacramento Northern, D. L. Babcock, electrical engineer of the Key System, and representatives of each of the signal manufacturers.

The views on this page illustrate the cab signal and train control equipment on an Interurban Electric car. Above—The amplifier, relays and decoders are mounted in a case mounted under the car



The receiver coils are mounted ahead of the leading wheels of a car and about six inches above the level of the top of the rail



The speed governor is mounted on the end of the car truck being geared to the end of the axle to drive a governor which actuates contacts