these details, such as broken and loose wires, grounding of circuits, etc.

The train control apparatus now installed is, as regards basic operating principles, the same as that used in the test installation, but expanded to include a low-speed circuit to restrict the movement of a train through a "stop" block at a predetermined speed, with the accompanying permissive feature. The permissive feature permits the passing of a "stop" signal, after acknowledgment by the engine crew, if running below this predetermined speed, without application of the brakes. Of course, some desirable modifications were made in the details of some of the apparatus.

Interchangeability an Operating Problem

The development and application of a system which will permit the unrestricted operation of locomotives of any road over the tracks of any other road, which, of course, represents the goal toward which to work, appears to involve, not only the process of elimination and consolidation of various possible train control devices over a rather long period of time, but also more uniform basic signaling and operating practices. This latter phase probably represents as large an economic problem as train control itself. In view of the complexity of the entire matter, I have felt that it should not be given detailed consideration for some time yet. I desire to emphasize that the above refers to interchangeability for emergency detouring, and similar purposes. It is an immediate concern when a device is to be selected for application to an established joint track zone, and we do not know now of any reason why the device which we have adopted could not be used for such a zone.

Effect on Track Capacities

With our installation and its operation, as at present, we are safe in saying there is no decrease in track capacity. There may actually be an increase. Our ramps are located immediately in the rear of signals which necessitates overlapping. We, at first, anticipated some decrease, due to overlapping, but actual experience has developed that, except at a relatively few points where the overlap extends into a station, where there is frequent switching, we are not slowing up traffic. On the other hand, we have found it practicable to discontinue stopping trains at automatic signals indicating "red" and this has materially facilitated traffic. This increase much more than offsets any decreased facility due to overlaps. Of course, we have not yet concluded our developments as regards possible siding ramps and there is still some question as to the extent to which they, if finally installed, will affect track capacities. However, it is our desire to so handle this matter, that we will be able to avoid a decrease, and without very great additional expense.

Cost of Operation and Maintenance

The operation and maintenance costs of our train control are offset, to a certain extent, by the savings which we are effecting through the elimination of train stops at automatic block signals indicating "red." The extent of these savings has not been fully developed.

There is still some question as to the extent to which we have had to modify our signaling, on account of train control. We estimate that when through, it will have cost from $8,000 to $15,000 for the entire territory, a considerable part of which has already been accounted for.

Study of Train Control on the Michigan Central

By J. C. MOCK
Signal and Electrical Engineer, Michigan Central, Detroit

SOON after the introduction of air for train braking, about 1869, schemes for automatically setting the brakes were proposed and while they differed in detail they were the same in principle, which was to have a device on the locomotive hit a device on the roadside, and were what we now call the intermittent contact type. Going over the old files on train control is interesting, and also rather useless as the history of automatic stops and automatic train control has been written many times. In 1904, W. C. Brown, then vice-president of the New York Central Lines, directed the lines' signal committee to report on the feasibility of using automatic stops in the electric zone of the New York Central. The committee found nothing to recommend for the territory and traffic under consideration.

The five years, 1905 to 1910, was a period when the subject of automatically stopping trains was very much alive. The Railway Signal Association, signal engineers and other individuals were giving thought to the possibilities of making it practicable. The writer's part was to conceive and patent a speed control device. A note on a preliminary sketch, dated January 11, 1907, said: "In order that devices for automatically stopping railroad trains may be made more practicable for general use, I propose to make *speed* determine whether or not the devices on trains will operate when the complementary devices at the track are in position to cause an operation." This, I believe, was the first time speed was introduced into the problem.

The list of requirements first published by the R. S. A. in 1908 and thought by many members and inventors at that time to be too rigid and so severe as to discourage development, have since been made more rigid by the requirements of an A. R. A. committee and the Interstate Commerce Commission. The recent decision to insert paragraph 1-b has granted a much needed parole.

Two-Speed, Three-Position, Continuous Inductive Train Control

The Michigan Central have contracted with the General Railway Signal Company for an installation of train control on the division of double track road between Detroit, Mich., and Jackson. This is the selected and accepted territory in conformity with I. C. C. Order 13413, which requires five divisions of the New York Central Lines System to be equipped.

When it became apparent to the executive officers that the adequate schemes for such traffic as was handled over the assigned territories were really only in the experimental stage, it was thought the sensible thing to do was to begin on a typical short (Detroit to Toledo) division and that when completed and in satisfactory operation it would be regarded as a partial fulfillment of the order. Accordingly, specifications were prepared, bids received and analyzed and a report with recommendations made. The I. C. C. decided some months after, that no credit on the order would be allowed for any installation not in the territories designated by it.

Having been denied credit for a proposed installation regarded by the railroad officials as largely a contribu-

tion to the development of train control, it became necessary to get out other specifications to fit the assigned territories. On these specifications contracts were awarded.

The division of the Michigan Central to be equipped has now in service, a d. c. automatic signal system of the semaphore type. The signals are now being changed from two-position, lower quadrant, to three-position upper quadrant, and relocated so as to make the block length, as far as practicable, full braking distance.

Passenger engine No. 8336 is the first of Michigan Central locomotives to be equipped with the train control apparatus. Since its application the locomotive has been in regular service between Detroit and Chicago with a mileage up to September 15, of over 10,000 miles. Train 22, eastbound, occasionally gets above the high speed limit of 75 miles per hour so that the apparatus has had fairly good trial and has developed no weakness mechanically or structurally.

The running tests have been very useful also in the nature of exploring the roadway to locate and study the interfering and stray current conditions. We find that the engine relay picks up at Kensington interlocking plant (near Chicago) where there are 60-cycle a. c. track circuits in service and where there is, adjacent to and joining the steam tracks, an electric line using 25-cycle a. c. propulsion. The relay also picks up in the Detroit terminal electric zone which has d. c. propulsion and 60-cycle a. c. single rail track circuits.

Over all of the mechanical and electrical apparatus which is assembled on top of the tender we have built an auxiliary cab. There is a sliding window in the right side and two small windows looking toward the front of the locomotive. This provides a good place for the observers. In this cab there is a duplicate set of cab signals—buttons to repeat the acknowledging whistles and the (N S) indication. Lights are used to show when the acknowledging whistle and the speed limit whistle are blowing and to indicate whether or not the electro-pneumatic valve is energized. This enables the observers who have been riding the locomotive continuously, to tell exactly what is going on. There is no roadside equipment in service at present so that the reliability of complete operation is not known.

So far as we have gone with the survey of our electrified territory we anticipate no trouble from the propulsion currents due to the varying loads but it has shown, beyond doubt, that a change will have to be made in the 60-cycle a. c. single rail track circuits, probably the adoption of an odd frequency. While this is an objectionable remedy it is not so important in considering an isolated case, but in considering the entire field, the introduction of additional equipment to provide the proper frequency is a matter of considerable importance.

In selecting the two-speed, three-position type of inductive continuous train control, interchangeability was kept in mind. It is believed that the engines of the Michigan Central will be able to operate and have proper train control protection when running over the tracks equipped on the P. & L. E., Big Four and B. & A.

It is believed to be the system best suited for the maximum traffic conditions and the only system that will permit of omitting the way-side automatic block signals. It meets the various clearance conditions. It also provides the greatest protection on the one hand and the greatest facility on the other hand under conditions of block change ahead while train occupies a block, because it immediately indicates the change.

There is, of course, no data on the cost of maintenance and operation but it is expected that in the first five-year period this will be rather high due to obsolescence and changes. Still, it should not be much higher than the better intermittent types. The locomotive equipment is generally more elaborate with continuous control systems but the roadway equipment should be rather less expensive to maintain than for the intermittent.

On this division the a. c. line and track phases for the train control are superimposed on the present d. c. track circuits because it is less expensive and for the further reason that the block signal system is still intact when and if we have an interruption of train control power or difficulty with locomotive equipment.

Maintenance and Inspection

Neither the number of men nor the amount and kind of equipment for inspecting and maintaining have been defintely decided upon. I have a tentative scheme in mind which in outline is as follows:

Loops for the track and line phases should be installed in as many roundhouse stalls at the various engine terminals as may be needed.

Provide a portable testing outfit to include the necessary meters, transformers, resistances, reactance switches, etc., and plugs for connection to the 110 or 120-volt lighting circuits. This outfit should include a 32-volt storage battery or a small motor-generator set with a suitable rheostat for varying the voltage. This latter to be used on locomotives that have not sufficient steam pressure to operate the turbo-generator.

Since the apparatus should be tested on each locomotive as soon as practicable after getting into the roundhouse and just before it leaves the house for its run, such an outfit as outlined above, is, I believe, necessary so that the testing can be done in the shortest time.

To test locomotives equipped with speed control apparatus, it will probably be found desirable to have a convenient way of opening the cam actuated contacts that are normally operated by the speed governor, so as to check the circuits and apparatus dependent upon speed.

At present the stationary test panels are satisfactory as one stall in each roundhouse is reserved. For the single engine now equipped, steam is kept up to a pressure high enough to operate the turbo-generator set and the engine is fired up long enough ahead of starting time to make the test.

Testing outfits should be so arranged, if possible, that one man can make all the tests. That will mean that meters must be convenient and have large size scales and that proper lighting be provided so that they may be seen at some distance.

In 1918 I made the following statement in a report which I believe holds good now:

"As automatic train stop devices are required to act only on the rare occasions that enginemen fail properly to control their trains or disobey the *stop* (or restrictive) signal indications, the maintenance should be practically perfect. It will be necessary to attain very close co-operation of the operating, motive power and maintenance of way departments, as in many cases, a train is operated on parts of several railways, it will be necessary to have the co-operation of the several departments of the several railways and the devices should be standardized to permit the operation of a train on any railway.

"It will, in most cases, be impracticable to reproduce the actual conditions that exist at the time of a failure, because the two groups of apparatus, viz., that carried on the train and that located on the roadway, cannot be, without considerable expense, brought together under the same condition. It will, therefore, be quite difficult in some cases to find the cause and correct failures."