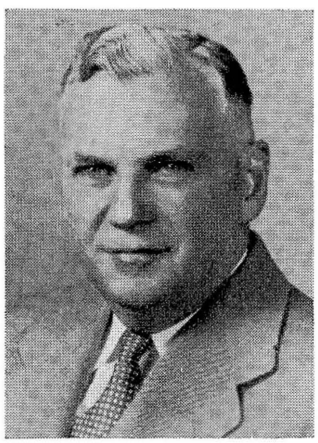
How to Control Signals Safely

Where Lightweight Trains are Operated

This article, dealing with lightweight trains, is being presented with special reference to operation of the signal system, because a number of railroad people have asked for a clear presentation of the problems, and an indication of the solutions. The presentations are made on a scientific basis, as simply as facts permit, and with the minimum of bias from any commercial standpoint. The material presented is based on many years of experience and study in this field, and includes the work and observations of many people on the railroads and in the signal companies. No claim is made to originality of the material presented. It represents what is considered to be the composite of the best and most practical information available on the subject.



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- **Keep wheel treads clean**
- **Reliable electric path between wheels**
- **Adopt and enforce reasonable sanding rules**
- **Improve and modernize track circuits**
- **Last resort—Check-in Check-out**

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Chapter I—Mounting of Wheels and Types of Brakes

MANY SIGNAL ENGINEERS of this country have been placed at a disadvantage because, in too many instances, they were not told that lightweight trains were being purchased, and were not aware of the characteristics of the new vehicles or trains which affect the operation of signal systems. Competition is keen between the various builders of these lightweight trains and, therefore, they are reluctant to release design information at an early date. Only recently have some of these characteristics been made available. In the meantime, lacking the necessary information, the signal engineers were not able to state positively whether the new trains would operate the signal systems satisfactorily.

A basic element of modern signal systems is the track circuit, which continuously detects the presence of a train. The track circuit, in its simplest form, is an electrical circuit which includes the rails as the main electrical conductors. The detection is dependent upon the train producing a low resistance electrical connection from one rail through the wheels and axles of the train to the other rail, which is commonly referred to as "shunting" the rails. The value of this electrical resistance has been considered so important that a standard minimum value has been assigned by the Signal Section, A.A.R. A track circuit is considered satisfactory if it detects (i.e. is shunted by) a resistance of 0.06 ohm connected from one rail to the other. This value was established as result of long experience with conventional types of railway vehicles.

Mounting of Wheels

In conventional construction the two wheels of each pair are pressed on one axle so that there is a direct low-resistance electrical path from one rail through the wheel, the axle and the other wheel, to the other rail.

If a type of construction is used in which two wheels of a pair are not pressed on the same axle it is necessary to resort to slip rings, brushes and jumpers to form a low resistance path from one wheel to the other. In such construction, a strict inspection program is necessary because the brushes and the jumpers are not self checking.

No such brushes and jumpers are required in conventional construction with both wheels pressed on one axle. It should be understood, also, that ball or roller bearings have no adverse affect on shunting when both wheels are pressed on one axle.

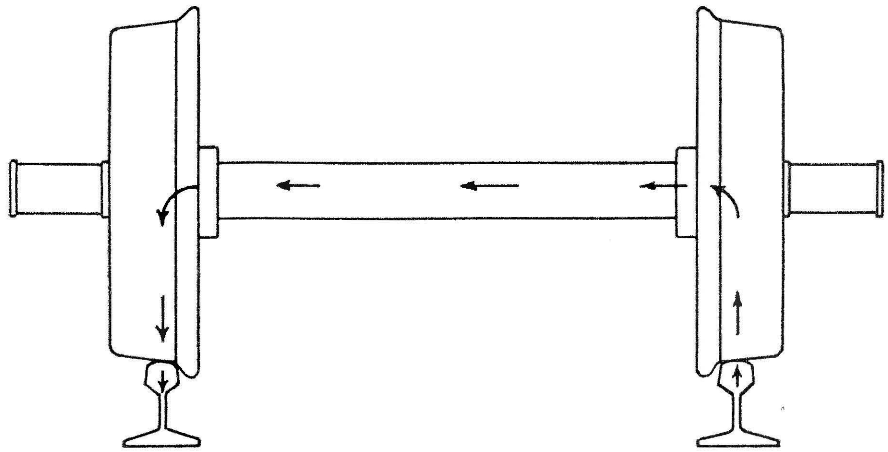
Clean Tread Is Important

The electrical resistance from one rail to the other, through the wheels and axle, includes the contact resistance between each wheel and the rail. Therefore, a clean wheel tread contributes to the low resistance path required. The outstanding performance of modern railway signal systems leads definitely to the belief that the conventional brake shoe, operating on the tread of the wheel, performs this function in an adequate manner.

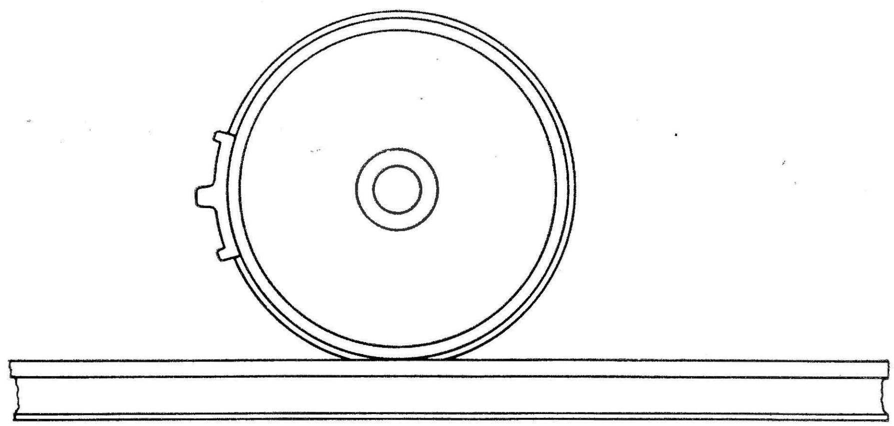
The need for keeping the wheel treads clean has been demonstrated in actual service with the single-unit, self-propelled cars, using "off tread" brakes. Because of the irregularities experienced in the shunting of track circuits, one manufacturer is furnishing cleaning shoes for the express purpose of keeping the wheel treads clean. Each shoe presses against the wheel tread continuously, with a force that is adjusted to approximately 30 lb. However, an important fact is that these shoes are not self checking, and therefore a strict inspection program is necessary.

Experience with single-unit, self-propelled cars should make signal engineers alert to the possibility of some decrease in the reliability of shunting of trains which include one or more cars having "off-tread" brakes, but with no special devices such as cleaning shoes on the wheel treads.

Of no direct concern here, but of educational value, is the fact that the conventional brake shoe on the tread of a wheel has a coefficient of friction which is less at high train speeds than at low. Advocates of the "off-tread" brake point to one of its features, the relatively uniform coefficient of friction with respect to train speed. Research and development have been directed to a brake shoe material, suitable for use against the wheel tread in the usual manner, which has uniform characteristics as to coefficient of friction at various speeds. Brake shoes with these characteristics, made by two manufacturers, are now in service on new trains and, according to reports, are giving satisfactory service.



With the two wheels pressed on one axle, there is a direct low resistance electrical path from one rail to the other through the wheels and axle



The brake shoe cleans the wheel tread, which contributes to the low resistance of the shunt path between rails

Sand, an Enemy of Signaling

Sand is an insulator, and, therefore, interferes with the good electrical contact that is required between the wheel and the rail in order to shunt track circuits. Thus sanding is a potential enemy of signaling, and, therefore, should be decreased to the greatest extent possible. Methods should be employed which place the minimum required amount of sand on the rail, and thus protect against all wheels being insulated from the rails. Some roads have adopted a rule that a train must advance a predetermined distance and make a second stop, following any stop that employs sand. This is done with the thought that the train will "run off" the sand which otherwise might insulate it from the rails.

Particularly with the new self-propelled cars, using off-tread brakes, there has been a tendency in recent years to use sand quite generously for both accelerating and braking. An important fact is that clean wheel treads (cleaned by brake shoes) contribute to a minimum requirement for sand, whether the required adhesion is for acceleration or braking.

A review of the discussion is that, for main-line service, it will be found practicable to operate lightweight trains of the type now in service with little or no change in modern signal systems, if:

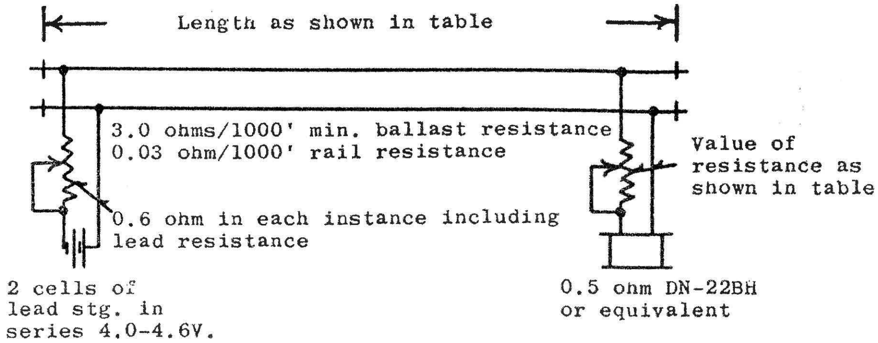
(a) The two wheels of each pair are pressed on the same axle.
(b) The wheel treads are kept clean.
(c) Provision is made to minimize the amount of sand used, and to avoid stopping on sand.
(d) Use practices as explained in Chapter II to improve operation of track circuits.

If the basic principles of good shunting (a), (b), (c) and (d) above, have not been observed, it will quite likely be necessary to resort to other methods dealt with in Chapter III.

Chapter II—How Track Circuits Can Be Improved

Improvement or modernization of track circuits may be all that is required for safe operation of lightweight trains if the track is regularly used; if both wheels of each pair are pressed on the same axle; and if the wheel treads are kept clean.

Track circuit shunting may be intermittent, particularly with single-unit trains operated at high speeds. However, the fact that the shunt may be lost for a short interval does not necessarily mean that the track circuit is near the point where it will fail to shunt entirely. For use on such track circuits, an improvement, that is being used successfully, consists of a repeater of the track relay having the characteristics of quick release and slow pick up. A relay, such as the DN-18, with a pick up of approximately one second is effective for taking care of momentary



Track Circuit Length	Total Resistance Relay to Track (Ohms)	Min. D.C. Rail Volts	Calc. Absolute Shunt Res. (Ohms)	Min. Shunt Current Relay End (Amp.)	Battery Amps. at 4.6V. Min. Ballast	Infinite Ballast
0	11.40	3.82	0.82	6.67	0.37	0.37
500	10.20	3.43	0.64	6.50	1.07	0.41
1000	9.34	3.15	0.55	6.35	1.58	0.44
1500	8.50	2.88	0.46	6.20	2.05	0.48
2000	7.82	2.66	0.41	6.05	2.43	0.51
2500	7.25	2.48	0.36	5.92	2.75	0.55
3000	6.62	2.28	0.32	5.80	3.05	0.59
3500	6.18	2.14	0.29	5.67	3.30	0.62
4000	5.70	1.99	0.26	5.56	3.52	0.67
4500	5.30	1.86	0.24	5.44	3.67	0.70
5000	4.88	1.72	0.22	5.34	3.82	0.75
5500	4.52	1.61	0.20	5.23	3.93	0.80
6000	4.22	1.51	0.19	5.12	4.07	0.84

0.5 Ohm DN-22BH Relay—Working 0.320A. Specification Release 0.256A. Calculated shunt resistance based on relay releasing with 85 per cent of specification release

Note that the ohmic shunt resistance varies between three and thirteen times that of the standard 0.06 ohm value which has been a recognized standard for shunting for many years.

loss of shunt. Other methods are also available. Attention is called to an important result obtained from using a rather high resistance in series with the track relay. This contributes to a favorable time constant, and thus permits the track relay to release faster than if no resistance were used.

The same principles which have been presented for track circuits in automatic signaling territory can be used for the track circuits in interlockings. There should be even greater effort to provide safe track circuits operation in interlockings.

A favorable factor for interlocking track circuits is that they are relatively short, and the various shunting factors improve as the length decreases. For example, a track circuit in the order of 100 ft. in length can be arranged so it will shunt much more readily than a conventional circuit a few thousand feet long. For obstinate cases of shunting, there are the high-voltage coded track circuits with decoding circuits incorporating delay times to take care of momentary loss of shunt.

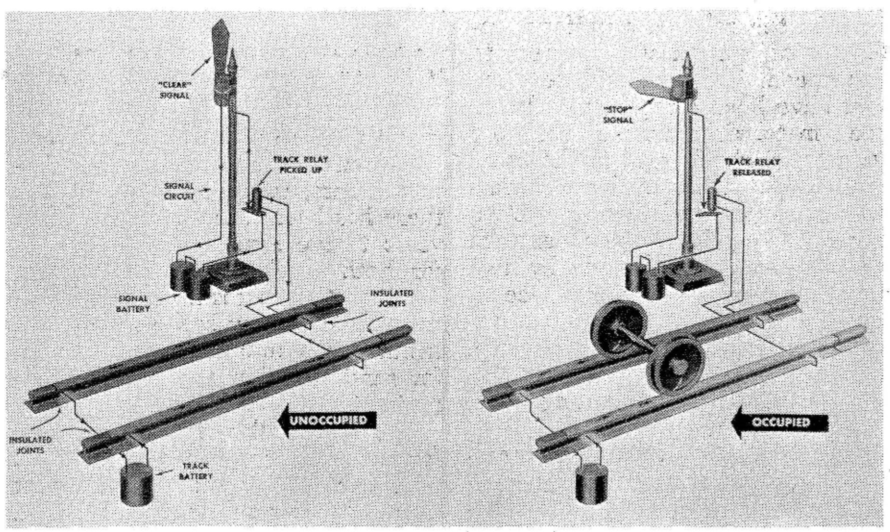
To Break Through Rail Film

For many years the ohmic shunting sensitivity was considered as the best method for comparing the shunting characteristics of track circuits. Then it became known that a film developed on the rail even though there might be a considerable amount of traffic over the rail. This rail film is believed to be somewhat more of a problem now than it was when steam locomotives were in general use. There is an appreciable percentage of oil in the samples of film which have been removed from rails and analyzed. This may be due, at least in part, to the use of various types of flange oilers. Shunting troubles have been experienced with single-unit, self-propelled cars and diesel shifter locomotives to a greater extent than have been reported with other vehicles or trains.

A voltage somewhat higher than regularly used on track circuits may be required to puncture the rail film, in order that the track relay will release properly when these single-unit trains are involved. It is desirable to have a reasonably large amount of current to flow, following the puncturing of the film. This may be visualized as a burning action to maintain electrical contact, or it may be considered that the film has the characteristics of a semiconductor, and exhibits a continuously decreasing resistance as the current flow increases. Both these factors point to the desirability of a high voltage for the source of the track circuit energy, and a low limiting resistance between the source of energy and the track.

Rail Film

Another characteristic of this rail film is the time lag required to puncture the film—particularly in the voltage region of breakdown. This characteristic makes itself evident when comparing the moving and standing shunting characteristics of a track circuit. All other conditions being the same, the standing train is more certain to shunt a track circuit than is the moving train. One explanation is the time lag in the



In an unoccupied track cricuit, current flows through the rail of the entire section between the battery and the relay

In an occupied track circuit, current flows in the rails as far as the wheels but not to the relay

puncturing of the film. The moving train is continuously moving on new portions of film which must be punctured if the shunt is to be maintained. When tests are made to demonstrate this fact, great care must be exercised because the mere stopping of a car or train on a track circuit may cut through the film mechanically, and thus interfere with the accuracy of the technical observations. In a similar manner the acceleration of a train may cut through the film; this is evident in regular service where the shunting on down grades is frequently poorer than it is on up-grade. This is explained by the use of power on the up-grade which tends to cut through the film; but the coasting on the down-grade, because of the smooth rolling action, does not cut through the film.

Let us now consider these basic facts and determine the apparatus or track arrangement which will yield the most favorable results.

The track relay should receive very careful attention. It should have a release value which is high in percentage with respect to its pick-up value. Friction in the relay is adverse to good shunting, and special attention should be directed to the armature hinge. The pressure on the contact springs is an important factor in the release value of the relay. The wearing away of the front contacts decreases the releasing force and thus decreases the releasing sensitivity of the relay. This indicates the desirability of arranging the local circuits so that no heavy currents will flow through the front contacts of the track relay. This is frequently accomplished by using a repeater of the track relay, and carrying the heavy current circuits through the contacts of the repeater.

In the interest of brevity and simplicity, steady energy d.c. track circuits are being referred to rather than the other types of track circuits. It is understood that the same basic principles being presented apply to a.c. track circuits as well as to coded track circuits with either d.c. or a.c. as the source of energy. It is further understood that the coded track circuits will yield better results than the steady energy circuits.

The diagram and table show a track circuit arrangement with adjustments for various lengths of track circuit. A large improvement is shown over conventional steady-energy track circuits in Ohmic shunting sensitivity, film breakdown voltage, and shunting current to maintain the film breakdown. Broken-rail protection is provided in each of the adjustments shown in the following table. The DN-22-BH relay has characteristics that have been referred to previously and is used as the track relay in this presentation.

According to recently published reports of tests, the wheel-to-rail normal contact (without sand) is improved by cleaning the rail by the use of a liquid, such as a detergent. Such tests should include the electrical conductivity of any film that might be left on the rail. If a liquid can be found that cleans the wheel and rail, and provides both good adhesion and good electrical contact from wheel to rail, it would be a real contribution to the safe operation of trains.

Chapter III—Supplements to Track Circuits

If the construction of the rolling stock, as discussed in Chapter I, is such that all the improvements in track circuits discussed in Chapter II are not successful in securing proper shunting, the next resort is to supplement the track circuits with additional equipment or systems of protection. If only a few "problem" vehicles are involved in operations with numerous other trains on extended signaled mileages, the solution should be sought on the vehicles. However, if the "problem" vehicles are relatively numerous, and their operations are confined to short mileages, perhaps the solution should be sought in connection with wayside apparatus.

On the Vehicle

Let us explore what is available for installation on the vehicles to improve the shunting. It has been established that a wheel-to-rail voltage is effective in the electrical puncturing of the film between the two surfaces. The more adverse the film, the higher is the voltage required. These basic principles were developed and applied with some measure of success in the early 1930's, and are now being revived for application to the vehicles. The scheme consists of a vehicle-carried source of electrical power, applying a voltage across the wheel to rail contact. The breaking down of film by this auxiliary circuit provides a low resistance path for the flow of track circuit current and thus is an aid in shunting. If such a scheme is used it should be with the realization that:

1. Since the current from the auxiliary source will flow through the track circuit, the magnitude and frequency of the current should be selected so there will be no adverse effect on any of the regular functions of the track circuit (or cab signaling if used). With more and more functions being handled by circuits using the track rails, great care should be exercised in the decisions regarding this type of solution.

2. The scheme is basically on the open circuit principle. If an open develops in the circuit, the protection is lost. In such an instance provision must be made to protect the train in some other way.

There is a variation of this same basic principle consisting of a wayside application of the auxiliary voltage. One example would be in the case of a d.c. track circuit where fundamental improvements had been applied but something more was required to puncture the wheel and rail films. This could be on a branch line where, because of light traffic, an adverse film condition exists. Since the track circuit under consideration is d.c., we may apply a "film puncturing" voltage of a.c. at either or both ends of the track circuit. Detailed consideration would be required in any instance to arrange the circuit to approach as nearly as practicable to a fail-safe and self-checking arrangement, and so the auxiliary voltage would not affect the safety of the track circuit apparatus adversely.

Further Help for Track Circuit

Let us now assume that everything which has been discussed previously has received due consideration but something further is required to obtain reliable operation.

Because of the eminent service that has been rendered by the track circuit throughout the years, and because of its performance of other functions in addition to the detection of trains, great efforts should be exerted in the direction of supplementing rather than replacing the track circuit.

There are examples where a shunt may be obtained promptly but may not be retained reliably. Where the shunt is merely intermittent in nature the solution may be, as given previously, by the insertion of a time delay in the picking up of the track relay. But assume a more difficult case, such as a train with a locomotive that shunts well but the shunting by the cars cannot be relied upon. In this instance, the track relay can be arranged so that once it releases, it can not be picked up again until the rear of the train passes out of the circuit at the exit end. This scheme may be considered as the first approach to the check-in check-out type of system. The shunting of the circuit is the check-in. The check-out is obtained by the cooperation of a device on the rear of the train and a wayside device at the exit end of the circuit. This scheme may appear quite simple but it must be realized that although it may be made reliable as far as safety is concerned, under the condition specified, there will be some sacrifice in the flexibility of operation.

At this point it appears desirable to call attention to one form of train similar to the one just discussed. This is the train with a diesel locomotive at each end. This indicates that each end of the train will provide a satisfactory shunt.

Although the cars may not provide a reliable shunt, there would not appear to be the need for any special consideration in straight automatic signal territory. But special consideration should be given to interlockings or other locations where, because of relatively short track circuits, one or more track circuits might be occupied by cars only and no locomotive. In this instance a solution may be found in the modification of the short track circuits because as pointed out previously the short track circuits respond more readily to the modifications than do the longer ones.

The Last Resort

Next let us assume the most adverse case, where the vehicle can not be depended upon to shunt the track circuit, and it is necessary to provide another method for detection. The method for detection may be:

1. A special short track circuit with high voltage and shunt current. A track circuit in the order of 100 ft. in length can be arranged so it will shunt much more readily than conventional circuits a few thousand feet in length.
2. A magnetic or inductive device that would be responsive to the wheels or some other portion of the train.
3. A mechanical treadle which is depressed by some portion of the wheel of a passing vehicle. A contact operated by the treadle would be opened by the passing train, and this would release the track relay.
4. A light or radio beam responsive device.

After the train has "checked-in," the track relay remains in its released position until the train has checked out of the particular circuit. The "check-out" may be, just as described previously, by the cooperation of a device carried on the rear of the train with a wayside device located at the exit end of the circuit.

Count-In and Count-Out

Another basic principle that has been applied to the solution of this problem is known as "count-in—count-out." For the purpose of explanation, it may be visualized as replacing a track circuit. As the train passes a pre-selected point the signal displays stop, and a counting scheme proceeds to count wheels or axles. The signal continues to display stop until a count is made of wheels or axles passing out of the exit end of the circuit, and an automatic check is made that the number counted out is the same as the number counted in.

It is not within the scope of this presentation to go into further detail in describing the design of signal systems using either the "check-in check-out" or "count-in count-out" principles. We do, however, consider it essential to point out the main requisites of systems designed on these principles so a reasonable perspective may be established for signal engineers designing such circuits.

(A) Requisites for a signal system using the check-in check-out principle:

1. A check-in, check-out signal system must be based on a fail-safe principle. All the rules and principles of a signal system using continuous track circuits must apply in so far as possible.
2. All entrance points into a block must be governed by signals.
3. A train entering a block from any entrance point, must, by a positive method, set all the protecting signals governing moves into the block to STOP or to their most restrictive aspects.
4. A train entering an interlocking must, by a positive method, set all protecting signals to STOP or to their most restrictive aspects and effect route switch locking for the route required.
5. With a train occupying a block, all signals protecting the block must display STOP aspects or their most restrictive aspects until the train has cleared the block.
6. With a train occupying a route within an interlocking, that route and the switches in the route must remain locked until the train completes its movement through the route.
7. If all signals employed are absolute—entrance, leaving and intermediate signals —this means that only one train or engine at one time may occupy a block governed by entrance, leaving or intermediate signal. If a train should enter a block while the signal governing the entrance is displaying Stop aspect, the check-in, check-out signaling system must continue to hold all signals governing movements into the block at Stop until the signaling system is reset by manual operation.
8. A check-in, check-out signal system that allows two or more following trains into the same block must be provided with some means for counting trains, cars or axles in and out of a block.
9. The positive method for check-in may be any method designed on a fail-safe (closed circuit) principle. If the check-in device should fail, all the protecting signals governing movement into the block must display Stop or their most restrictive aspects.

Motor cars or any other rail vehicles not governed by signals should not accomplish a check-in.

(In the use of a magnetic type of cut-in device, selection between motor cars and other railway vehicles may be made by using non-magnetic wheels on the motor cars.)

10. Any method of check-out may be used that is designed on a fail-safe (open circuit) principle. The method must be arranged and designed so that a block will be protected by signals displaying Stop or their most restrictive aspects until the block is clear of all trains.
11. The check-in and check-out devices must be designed and arranged so they are protected against accidental or malicious operation and respond only to the passage of a train.
12. A method based on vital principles should be provided to reset the system when a lock-out condition occurs. This means of resetting the check-in, check-out system must not be accomplished until a positive check determines the block is clear of trains. Also, this means of resetting must be accessible only to authorized personnel.

(B) Requisites for an Axle Counting Scheme if used in signaling systems as a substitute for conventional track circuits:

1. The device in the track used to count axles into the block must be based on a fail-safe, closed circuit principle. If during a count-in operation the device fails to register all axles, the device must so indicate the condition to the signaling system. For example, if the counting device counts in 100 axles, then because of some fault in the device, such as a loose wire, etc., fails to count the remaining axles accurately, the counting device must inform the signaling system that the number of axles counted is in error.
2. The unit that stores the axle count must be based on a fail-safe principle. When the unit has reached the limit of its storage capacity, the condition must be indicated to the signal system. If the unit in itself creates an error in the count, this condition must be indicated to the signal system.
3. The device in the track used to count axles out of a block must be based on a fail-safe, open circuit principle. If during the operation the device cancels more axles out of the block, because of some fault in the device, such as a loose wire, etc., than have been stored, this condition must be indicated to the signal system.

Signal engineers will recognize immediately that the systems based upon supplements to or substitutes for the track circuit have important differences with respect to the present conventional systems which are based fully upon track circuits.

It is the sincere hope of the author that the material which has been presented has shown the relationships which exist between railway mobile units and railway signaling, and thus emphasizes the desirability of cooperation of the various interested parties, as progress is made in either field.

Note: The use of word "trains" in these requisites refers to a locomotive either alone or with cars or may refer to a single car.