Relation of Insulated Joint to Track Circuit*

Why a Poor Joint May Be the Cause of a Clear or Other Signal Failure—
A Method of Measuring the Joint Resistance

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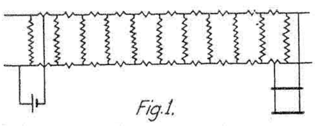
The insulated track joint is perhaps one of the most important elements of the automatic block signal system, and while there has been a great deal done in the way of providing joints with sufficient strength for carrying their load, and of such a design that the necessary insulating material would not be injured quickly by wear, nothing at all has been done in the way of determining what is necessary in the way of insulation characteristics, or what the actual resistance of a joint is when it is in place in the circuit. The object of this paper will be to show what would happen if the joint should have insufficient insulation and also to show how to obtain more information as to what actually exists in the track circuit. Imagine, now, a track circuit as it actually exists in the track. The first things conceivable would be two parallel conductors, each with innumerable resistances; also innumerable resistance paths connecting the conductors. At one end there would be a battery connected between them, with a relay similarly connected at the other end. Putting this picture in a more concrete form, the circuit diagram would look somewhat like that shown in Fig. 1.



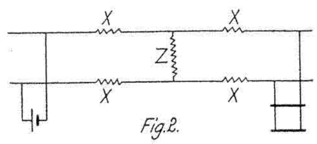


Diagram Representing Innumerable Resistance Paths and Their "Equivalent Resistances"

All of the resistances which appear in this circuit diagram can be replaced by five resistances which are called "equivalent resistances." If the amount of current flowing into the track circuit, and the amount of current flowing through the relay, and the voltages between rails at the battery and relay ends are known, then the exact values of these resistances can be determined. A circuit diagram with these resistances is illustrated by Fig. 2.

The resistances X, which are all equal, may be said to represent the resistances in the rails, and the resistance Z is the equivalent of all of the resistances between them. This is perhaps the simplest circuit diagram that can be drawn of a track circuit, and if only one track circuit were considered, it would be all that is necessary, because from this circuit any values desired can be calculated correctly when the proper data are known. If, however, two adjacent track joints are to be considered, this circuit diagram is not sufficient. The author has found by actual test that the resistance Z is really divided into three parts: The resistance of one of the rails to ground; the resistance of the other rail to ground; these two resistances joined together, forming that part of the resistance path between rails which passes through ground. There is another resistance path between the two rails which does not pass through ground. From the few experiments made, while this resistance is very noticeable, it is evidently large when compared with the other two resistances; nevertheless, it exists, and for certain calculations it must be taken into account. Consequently, when a circuit diagram is drawn to represent two adjacent track circuit sections, it must be as shown in Fig. 3.

Call the two parts of the resistance path between rails which pass through ground z^1 and z^2, and the resistance path between rails which does not pass through ground, t. The resistances z can be considered as being joined together by a conductor in the manner shown, which can be considered without serious error to be one without any resistance. This, again, is the simplest circuit diagram which can be drawn of two track circuit sections. It is quite a simple matter in this diagram to trace the flow of current from the two batteries. For example, assuming the two insulated joints to have some conductivity, there would be a circuit for the battery of the right-hand section which would pass through one of the joints, then through the relay of the left-hand section and back to the battery. Now consider that the rail polarity of the battery of the left-hand section was the same as that of the right-hand section, then the current from the battery of the left-hand section would flow through its relay in the same direction as current would flow through that same relay from the battery of the right-hand section. This at once shows that as far as the operation of the relay is concerned, joints of low resistance or joints of no resistance at all will not affect it. On the other hand, assume that there is a shunt on the left-hand section at some point near the battery, and that this shunt is of such resistance that some current from the left-hand battery flows through its relay, then any current from the battery of the right-hand section which flows through that same relay would tend to prevent its shunting. It is quite evident also that all of the current which flows from the right-hand section through the joints into the left-hand section does not flow through the relay. Part of this current would flow through the shunt, if there were one, but the resistance of this shunt would never be low because it would include all, or practically all, the resistance of the rails of the right-hand section. Now assume that the rails on the same side were of opposite polarity, then it can be seen at once that the current from the two batteries would flow in opposite directions through the relay of the right-hand section. In this case low resistance joints would interfere with the operation, but at the same time they would help in the shunting because no current flowing from the left-hand section would tend to decrease the current flowing from the battery of the right-hand section. As far as safety is concerned, therefore, it seems quite evident that the better way is to arrange the track circuits so as to have what has been termed "stag-

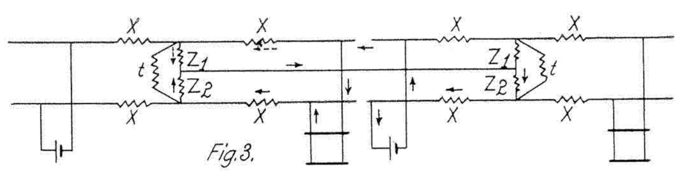


Diagram to Represent Two Adjacent Track Circuit Sections

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gered polarities." There is another interesting feature in the flow of current from one track circuit section to another. Assume that one joint has perfect insulation and that the other joint is low, or has no insulation qualities at all. This would give a circuit for the left-hand battery which would flow as indicated by the full-line arrows. It will be noticed that this circuit does not include the good joint at all. Again, all of the current which flows through the joint would not flow through the relay, because part of it would be shunted out by the circuit which it indicated by dotted arrows. If, however, the upper rail of the right-hand section should be broken near the relay end, then this shunt circuit would not exist and all of the current which flows through the joint would flow through the relay. In order that a person may determine for himself the resistance of such a circuit, some actual values of the resistances z and x will be given. For a track circuit

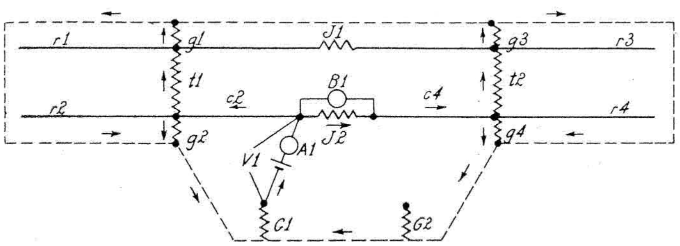

Fig. 1.

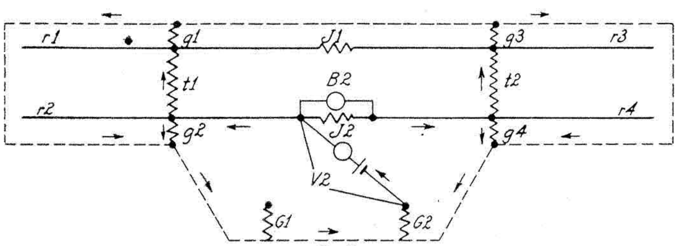

Fig. 2.

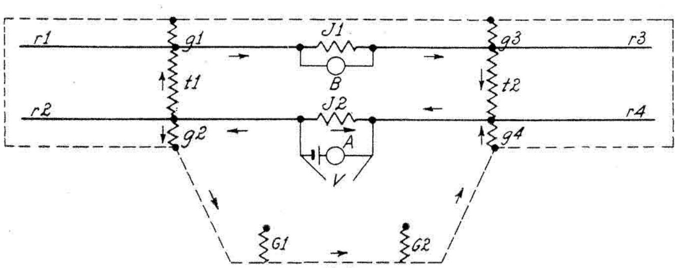

Fig. 3.

Diagrams Illustrating Method of Testing Joints

3,000 ft. long, with a ballast resistance of 2 ohms per 1,000 ft., and a rail resistance of .15 ohm per 1,000 ft., the resistances x would be approximately 0.1 ohm, and the resistances z would be approximately 0.3 ohm. If the track circuit resistance was 8 ohms per 1,000 ft., the value of the resistances x would be approximately .11 ohm, and the resistance z would be approximately 1.3 ohms. It may be seen from this that even if the joint has some ohms resistance, the amount of current which might flow through the relay from this source would be considerable, particularly when there is a broken rail. It is thus seen that insulated joints will either interfere with the operation or with the shunting of the relay. Further, if there is a broken rail, a low insulated joint may take away broken rail protection entirely. The question may be asked as to what can be done to overcome these difficulties. The natural answer is, that in order to overcome the operation difficulties the amount of current which can flow from the battery must be increased. To do this, particularly when using caustic soda batteries, the amount of the limiting resistance which is used between the battery and the rail must be decreased. On the other hand, in order to overcome the shunting difficulties, this limiting resistance must be increased, but increasing it means shortening the length of the track circuits which can be operated properly. This raises the question as to what limiting resistance should be used so that the track circuits may be safe as to their shunting qualities when low resistance insulating joints are considered. Unfortunately, we are unable to answer this question because of the limited knowledge of the actual resistance of an insulated joint when it is in the track, or the resistance which can be practically maintained in such a joint. Until this question can be answered, there is no way of determining what would be a proper limiting resistance. When we try to measure the resistance of an insulated joint in place we are confronted with some very serious difficulties. The voltage drop can be determined across the joint when current is made to flow through it; but what is needed in order to determine its resistance is a knowledge of the quantity of current that is flowing. This is hard to determine, because of the fact that there is a path around the joint through the earth and it is impossible to separate these two paths without breaking the rail and placing an ammeter in the break. After a good deal of study the author has produced a method for measuring the resistance of a track joint, and while it is not simple nor easy to do, it is not impossible nor beyond the attainments of a maintainer or supervisor.

Measuring the Resistance of an Insulated Joint

Figure 1 represents two track circuit sections (from which both the battery and relay have been removed) which are joined together by the insulating joints J^1 and J^2. In the left-hand section t^1 represents the equivalent of all the resistances between the rails r^1 and r^2 which are not connected to ground. We will also let g^1 represent the equivalent of all the resistances between the rail r^1 and ground, and g^2 the equivalent of all the resistances between the rail r^2 and ground. In the right-hand section t^2, g^3 and g^4 are similar resistances. The resistances of the rails we will assume to be combined with the resistances t and g. In Fig. 1, G^1 is the resistance of a connection to ground, which may be a lightning arrester ground, and G^2 is the resistance of another connection to ground, which may be a rod driven for this particular purpose. Now connect an ammeter of very low resistance in parallel with the joint J^2; also, connect a battery and an ammeter between the ground connection G^1 and the rail r^2. If we represent by A^1 the current flowing through the ammeter A, and by B^1 the current flowing through the ammeter B, and neglecting the current which would flow through the joint J^2, which under these conditions would be very small, the current c^2 which flows to the ground G^1 from the left-hand section would be equal to the differences between the currents flowing through the ammeters A and B, or

$$(1)\quad c^2 = A^1 - B^1$$

The current c^4 which flows to the ground G^1 through the right-hand section would be equal to the current flowing through the ammeter B, or

$$(2)\quad c^4 = B^1$$

If we let R^1 represent the resistance of the total circuit for the battery and V^1 the voltage between the ground connection G^1 and the rail r^2, we would have

$$(3)\quad R^1 = \frac{V^1}{A^1}$$

Representing by G the equivalent of all the resistances through which the current A^1 passes before reaching ground, we have

$$(4)\ R^1 = G + G^1$$

Now connecting the battery and ammeter A between the ground G^2 and the rail r^2, as shown in Fig. 2, and letting R^2 represent the total resistance of this circuit, and A^2 and V^2 the current and voltage, respectively, we obtain

$$(5)\ R^2 = \frac{V^2}{A^2}$$

$$(6)\ R^2 = G + G^2$$

Again connecting the battery and ammeter A between the grounds G^1 and G^2 and representing by R^3 the total resistance of this circuit, and by A^3 and V^3 the current and voltage, respectively, we would have

$$(7)\ R^3 = \frac{V^3}{A^3}$$

$$(8)\ R^3 = G^1 + G^2$$

From equations 4, 6 and 8 we obtain

$$(9)\ G = \frac{R^1 + R^2 - R^3}{2}$$

$$(10)\ G^1 = \frac{R^1 + R^3 - R^2}{2}$$

$$(11)\ G^2 = \frac{R^2 + R^3 - R^1}{2}$$

In Figs. 1 and 2 let X represent the equivalent of the resistances through which the current c^2 passes before reaching ground, and Y represent the equivalent of all the resistances through which the current c^4 passes befor reaching ground. With these assumptions we would have, from Fig. 1,

$$(12)\ X = \frac{V^1 - G^1 A^1}{A^1 - B^1}$$

$$(13)\ Y = \frac{V^1 - G^1 A^1}{B^1}$$

Or from Fig. 2 we would have,

$$(14)\ X = \frac{V^2 - G^2 A^2}{A^2 - B^2}$$

$$(15)\ Y = \frac{V^2 - G^2 A^2}{B^2}$$

The values of G^1 and G^2 have been obtained in equations (10) and (11). Consequently, the values of X and Y can be obtained from equations (12) and (13) or (14) and (15). Now place the ammeter A and the battery in parallel with the joint J^2, as shown in Fig. 3, and the ammeter B in parallel with the joint J^1. The current flowing through the ammeter A in this figure can be divided into three paths, i. e., (1) that flowing through the joint J^2; (2) that flowing through the rail r^2 through the ground to the rail r^4; (3) the current flowing through the resistances between the rails r^1 and r^2, the ammeter B and the resistance between the rails r^3 and r^4. The resistance from the rail r^1 to ground we have assumed to be X, and the value of this is obtained from equations (12) or (14). The resistance from the rail r^4 to ground we have assumed to be Y, and the value of this can be obtained from equations (13) or (15). If we represent the voltage across the joint J^2 by V, and the current flowing through the ammeter A by A, and the current flowing through the ammeter in parallel with the joint J^1 by B, we would have for the value of the current flowing from the rail r^2 to the rail r^4 through ground,

$$\frac{V}{X + Y}$$

The current flowing through the second path, which we describe, is the current flowing through the ammeter B. Hence, the current c through the joint J^1 is,

$$c = A - \left[\frac{V}{X + Y + B}\right]$$

and the resistance of the joint J^2 is,

$$J^2 = \frac{V}{A - \left[\frac{V}{X + Y} + B\right]}$$

In using this method it will be well to use the readings in all cases with the polarity of the battery reversed and use the mean of the two readings in the formulas. The reason for this is that nearly always *some* current will be flowing in the rails when the battery is removed, and also invariably there will be a voltage drop between the rails and ground. Using the mean of the two readings suggested will eliminate any error which might be caused by these stray currents.

REPORT ON WALTON COLLISION

The Interstate Commerce Commission has issued a report, dated January 6, and signed by W. P. Borland, chief of the Bureau of Safety, on the rear collision which occurred on the Norfolk & Western at Walton, Va., on December 18. In this collision, in which five passengers were killed, the leading train, which was at a standstill, consisted of eight steel cars and three wooden cars, the wooden cars being at the rear end; and the report calls attention to the probability that if all the cars had been steel the results would have been far less disastrous.

The trains were eastbound passenger No. 4, second section, and eastbound passenger No. 26. The leading train was standing at a water tank some 2,000 ft. east of the tower located at the junction where the trains had come on to this line, No. 4 coming from the Bluefield line and No. 26 from the Bristol line. The time was about 6:44 p. m. (dark), and the weather was clear. No. 26 had passed signal 8L, about 1,287 ft. back of the point of collision, and was moving under a calling-on signal. The engineman claims to have passed through a cloud of steam or smoke, blowing from a standing locomotive, which impeded his view; but regardless of this feature of the case, which is not corroborated by other witnesses, he was bound to proceed under control. He had made, before this, only two trips with this train.

The fireman excused himself for not seeing signal 8L because he was looking out on the left side of the engine to see the position of the train-order signal. Between signal 8L and the point of collision the engineman worked steam for some little distance, and this also appears to have led the fireman to think that the engineman was in proper control of the movement of the train. Testimony concerning the speed of No. 26 a few hundred feet back from the point of collision varied from 15 miles an hour to 25 miles an hour, except that the operator at the tower and a road foreman of engines, who was nearby, put it much faster, the road foreman estimating the rate at 35 miles an hour.

The engineman had been in the service 41 years and a runner for 37 years. The flagman of the standing train, who is censured for not going back fast enough, has been in the service about four years. Both had good records.