Designation: G165 – 99 (Reapproved 2017)

Standard Practice for Determining Rail-to-Earth Resistance[1]

This standard is issued under the fixed designation G165; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the procedures necessary to follow for measuring resistance-to-earth of the running rails which are used as the conductors for returning the train operating current to the substation in electric mass transit systems.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *cross bond*—insulated copper cables that connected between adjacent sections of track to ensure electrical continuity between them.

3.1.2 *direct fixation fastener*—a device for fastening running rails to their support structures.

3.1.3 *impedance bond*—a device connected to running rails for automatic train operations.

3.1.4 The terminology used herein, if not specifically defined otherwise, shall be in accordance with Terminology G15. Definitions provided herein, and not given in Terminology G15, are limited to this practice.

4. Significance and Use

4.1 Low resistance between the rails and earth could result in large magnitudes of stray earth currents with the attendant corrosion damage to underground metallic structures.

4.2 These measurements are of a low voltage type and are not designed to evaluate the high voltage dielectric characteristics of the rail insulating elements.

4.3 Sections of track with rail-to-earth resistances less than acceptable minimums must be tested in greater detail to determine the reason(s) for this condition. Determination of the reason(s) for any low rail-to-earth resistance may require the use of special testing techniques or special instruments, or both, beyond the scope of this practice.

4.4 The electrical tests call for the use of electric meters that have varying characteristics depending on cost, manufacture, and generic type. It is assumed that any person employing the test procedures contained herein will know how to determine and apply proper correction factors and that they will have sufficient knowledge to ensure reasonable accuracy in the data obtained.

4.5 This practice does not encompass all possible field conditions to obtain rail-to-earth resistance characteristics. No general set of test procedures will be applicable to all situations.

5. Equipment

5.1 Indicating dc; high impedance (minimum ten megohm) voltmeter (two required); multi-scale, capable of reading positive and negative values without removing test leads; and covering at least the following full scale ranges:

5.1.1 0 to 10 mV,
5.1.2 0 to 100 mV,
5.1.3 0 to 1 V,
5.1.4 0 to 10 V, and
5.1.5 0 to 100 V.

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[1] This practice is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.10 on Corrosion in Soils.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

5.1.6 Meters shall be accurate within 1 % of full scale.

5.2 Direct current ammeter, multi-scale, covering the following full scale ranges:

5.2.1 0 to 1 A,

5.2.2 0 to 10 A, and

5.2.3 0 to 100 A.

5.3 Direct current milliammeter, multi-scale, covering the following full scale ranges:

5.3.1 0 to 15 mA,

5.3.2 0 to 150 mA, and

5.3.3 0 to 1500 mA,

5.4 An alternative to the ammeter and milliammeter is a millivolt meter and external shunts covering the listed current ranges. Meters (and shunt combinations if used) shall be accurate to within 1 % of full scale.

5.5 Direct current power source with control circuits. Generally, 6 or 12 V automotive type wet cell batteries will suffice.

5.6 Test wires, assorted lengths and sizes, to suit field conditions. Wires should have minimum 600 V insulation in perfect condition (no visible cuts or abrasions) and be multistrand copper conductors for flexibility.

5.7 Miscellaneous tools as required for making wire connections, splicing, and so forth.

5.8 Vehicle to transport equipment and personnel along track to facilitate testing.

6. Visual Inspection

6.1 The track section to be tested should be visually examined to ensure the insulating components have been installed and there is no debris, water, or other conductive material in electrical contact with the metallic track components that could result in the lowering of the effective track-to-earth resistance thus producing incorrect data.

7. Electrical Tests

7.1 Electrically isolate sections of track (see typical arrangements in Figs. 1 and 2). Length of track section to be tested is dependent upon the locations of rail insulators. Rail insulators are found at the ends of turnouts and single and double crossovers. The lengths of the track sections will vary within the general range of 60 to 2750 m (200 to 9000 ft).

7.1.1 Remove cable connections from across rail insulators.

7.1.2 Disconnect cross bonds within section of track being tested and other track.

7.1.3 Disconnect power traction substation negative feeder cables from track section being tested.

NOTE 1—Switches within substation can be opened.

7.2 Ensure electrical continuity between the rails within the insulated track section being tested by the use of the existing cables at impedance bonds or by installing temporary wire connections between the rails.

7.3 Track-to-earth resistance measurements will be obtained as shown on Fig. 3 for main track sections and as shown on Fig. 4 for main track sections containing double crossovers. Measurements on track sections containing turnouts and single crossovers will be similar to that shown on Fig. 4 with the number of test points being determined by the electrical configuration of insulating joints and bonding cables.

7.4 The track-to-earth resistance measurements for the track in the train storage yards will require special consideration for each section to be tested because of the number and location of insulating joints resulting from the type of signal system being used within the yard area and because of the number of cross bonds and other bonding cables used within the yard.

7.5 All data shall be recorded.

7.6 A sketch showing location of the test and the electrical test set-up used shall be included.

7.7 The number of readings taken to determine an electrical constant or property must be sufficient to ensure that random

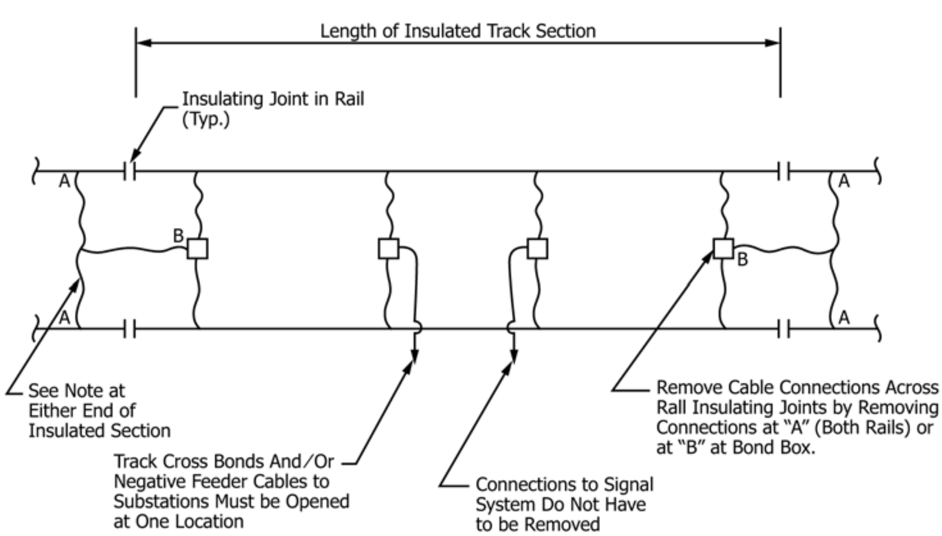


FIG. 1 Schematic Diagram — Typical Mainline Track Section

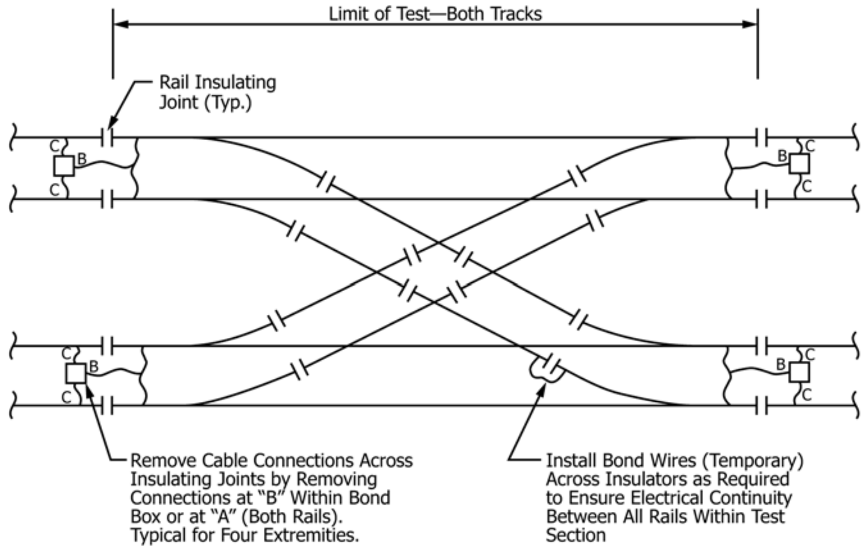
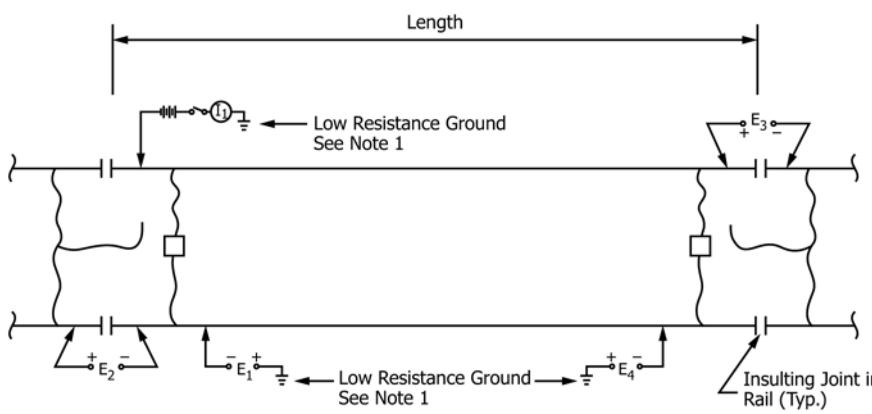


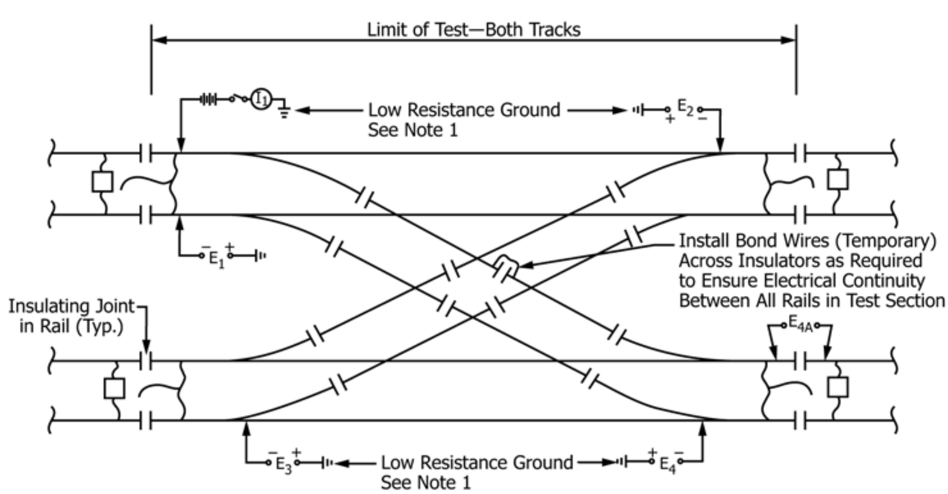
FIG. 2 Schematic Diagram — Typical Double Crossover Track Section



NOTE 1—All cable connections removed for measurements as shown on Fig. 1.

NOTE 2—Ground resistance to be on the order of 1/100 (or less) of the track-to-earth resistance for the section being tested.

FIG. 3 Schematic Diagram — Mainline Test Arrangement



NOTE 1—All cable connections removed for measurements as shown on Fig. 2.

NOTE 2—Ground resistance to be on the order of 1/100 (or less) of the track-to-earth resistance for the section being tested.

FIG. 4 Schematic Diagram — Double Crossover Test Arrangement

factors due to human error in reading the instruments and transient disturbances in the electrical network have negligible influence on final results. A minimum of three readings should be obtained but additional readings may be required depending upon the exact circumstances of the test. The adequacy of data generally can be established by the tester. Once the specified minimum number of readings have been obtained, data should be examined to see that removal of neither the highest nor the lowest value will alter the arithmetic average of group by more than 3 %. If the average is altered by more than 3 %, one more complete set of data should be taken and the results combined with the first set. If the test of the data still produces a change in the average value greater than 3 %, it may indicate an unstable condition in the system.

7.8 *Measurements Procedure*—(Fig. 3 for main track section, Fig. 4 for crossovers and turnouts).

7.8.1 Establish current circuit (I_1).

7.8.2 Establish rail-to-earth voltage (E_1) measuring circuit.

7.8.3 Obtain change in (E_1) per ampere of test current (I_I) (number of readings obtained to be in accordance with 7.7).

7.8.4 Calculate the effective track-to-earth resistance, $R_{1.1}$, (ohms) as change in (E_1 (volts) per ampere of (I_1):

$$R_{1.1} = \frac{\text{delta E}_1}{\text{delta I}_1} \tag{1}$$

7.8.4.1 With $R_{1.1}$ expressed in ohms, E_1 expressed in volts, and I_1 expressed in amperes.

7.8.5 Obtain similar data for:

$$R_{2.1} = \frac{\text{delta } E_2}{\text{delta } I_1} \tag{2}$$

$$R_{3.1} = \frac{\text{delta } E_3}{\text{delta } I_1} \tag{3}$$

$$R_{4.1} = \frac{\text{delta } E_4}{\text{delta } I_1} \tag{4}$$

$$R_{4A.1} = \frac{\text{delta } E_{4A}}{\text{delta } I_1} \left(\text{crossovers and turnouts only}\right) \tag{5}$$

7.8.6 *Main Track Sections Only:*

7.8.6.1 Compare $R_{2.1}$ with $R_{1.1}$. $R_{2.1}$ should be equal to or no more than 3 % less than $R_{1.1}$. Greater variation could indicate the test rail section is not effectively insulated from the adjacent section.

7.8.6.2 Compare $R_{4.1}$ with $R_{1.1}$. These values should be equal within about 3 %, with $R_{4.1}$ being less than $R_{1.1}$. More variation than about 3 % could be indicative of attenuation resulting from the relationship of the resistance of the rail and the track-to-earth resistance. A significant variation between $R_{1.1}$ and $R_{4.1}$ would be expected only in the event the track-to-earth resistance was much less than anticipated values.

7.8.6.3 Compare $R_{3.1}$ and $R_{4.1}$. A variation of more than about 3 % could indicate that the track section under test is not effectively insulated from the adjacent section.

7.8.7 *Crossovers and Turnouts Only*—Compare values obtained. All values should be within 3 % of each other because of the relatively short lengths of track involved. Any variation in the values obtained of greater than 3 % should be evaluated, to determine the reason(s) and what, if any, further action is required.

NOTE 2—Measurement of change in potentials across the insulating joints at all extremities are not required because these measurements will be obtained during tests on the adjacent track section.

7.8.8 Compute the average resistance-to-earth of the test section for 305 m (1000 ft) of track. The length (L) track must include both main tracks plus crossover. (Thus a double crossover on 36 ft to 10 in. track centers would contain in the order of 366 m (1200 ft) of track.)

$$R_T = R_{4.1} \frac{\text{x } L}{305} \tag{6}$$

where:

R_T = average resistance for 305 m (1000 ft)
$R_{4.1}$ = track-to-earth resistance, Ω, and
L = length of track within section, m.

7.8.9 Record data.

8. Acceptance Criteria

8.1 *Direct Fixation Track Construction:*

8.1.1 The track-to-earth resistance for direct fixation track is governed by the electrical resistance associated with the direct fixation rail fasteners and the number of fasteners.

8.1.2 Under ideal conditions where there are no conductive materials in electrical contact with the metallic rail or fastener components, or both, that contact the minimum electrical resistance through a direct fixation rail fastener is typically specified as 100 megohms ($10^8 \Omega$).

8.1.3 Spacing of the direct fixation rail fasteners on main track is typically 762 mm (30 in.). At this spacing there will be 800 direct fixation rail fasteners in 305 m (1000 ft) of main track.

8.1.4 The minimum track-to-earth resistance for 305 m can, therefore, be calculated by assuming each direct fixation rail fastener has the minimum specified resistance (R_p) and using the number (N) of these fasteners in parallel between the rails and earth.

$$R_T = \frac{R_p}{N} \frac{100 \times 10^6}{800} = 1.25 \times 10^5 = 125\,000\ \Omega \tag{7}$$

where:

R_T = track to earth resistance for 305 m,
R_p = resistance of one fastener, and
N = number of fasteners in 305 m of track.

8.1.4.1 It is anticipated the actual resistances will be less than their specified minimum under actual installed conditions. Acceptance criteria will, therefore, have to be based on an engineering evaluation of what can reasonably be anticipated.

8.1.5 Any type of track that is constructed with dielectric isolators may be evaluated in a similar manner as described above with adjustment for the expected electrical resistance of the fastener.

8.2 *Wooden Tie Track Constructions:*

8.2.1 The track-to-earth resistances for wooden tie construction depends on several factors, the major ones being the resistivity of the wooden ties, the drainage characteristics of the road bed, and the spacing of the ties.

8.2.2 The resistivity of the wooden ties depends on the moisture content of the wood. At low moisture content (less than 10 %) the wood is a moderately good insulator, but decreases rapidly in effectiveness as the moisture content rises.

8.2.3 The condition of the ballast and the road bed in general to provide good water drainage and prevent the accumulation of dirt, debris, and other materials that can provide an electrically conductive path between the rails and ground.

8.2.4 The spacing between ties is typically 686 mm (27 in.) on the main track and 762 mm (30 in.) on yard and secondary track.

8.2.5 The acceptable criteria for track-to-earth resistances must be based on an engineering evaluation of what is reasonable for the specified construction and an evaluation of what can be expected in magnitudes of stray earth currents under these conditions.

8.3 *Wooden Tie and Direct Fixation Construction in One Test Section:*

8.3.1 The track-to-earth resistance for each type of construction within the test section can be calculated from the length of track of each type. These resistances can then be combined by laws of parallel resistances to determine the theoretical value or comparison with the measured value.

$$\frac{1}{R} = \frac{1}{R_A} + \frac{1}{R_B} + \frac{1}{R_C} + \ldots \tag{8}$$

where:

R = combined resistance of all parallel components, Ω, and

R_A, R_B, R_C... = resistances of the individual resistance to be put in parallel, Ω.

8.3.2 The anticipated resistances for direct fixation and wooden tie construction must be based on an engineering evaluation of what is reasonable for the specified construction and an evaluation of what can be expected in magnitudes of stray earth currents under these conditions.

8.4 *Embedded Track Construction*—The track-to-earth resistance for embedded track is governed by the electrical resistance associated with the track fastening system and the specific material that is in contact with the running rails. The acceptable track-to-earth resistance values are determined by an engineering evaluation of what can reasonably be anticipated given the specifics of the track isolation system.

9. Keywords

9.1 direct fixation; mass transit systems; running rails; track ballast; track-to-earth resistance; traction power substations; wooden tie