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Standard Specification for In-Service Test Methods for Temporary Grounding Jumper Assemblies Used on De-Energized Electric Power Lines and Equipment[1]

This standard is issued under the fixed designation F2249; 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.

~~ε1 NOTE—In 7.5.3, reference to Tables X3.2 and X4.2 was removed editorially as these tables were removed in the last edition. In X3.2.1.1, the reference to Specifications F855 Table 2, and in X3.4.2, the reference to Specifications F855 Table 5 were corrected to Specifications F855 Table 1, and in X1.1 and X2.1, the first sentences were corrected from "four acceptable cables" to "two acceptable cables" editorially in January 2021.~~

1. Scope

1.1 ~~These specifications cover~~This specification covers the in-service inspection and electrical testing of temporary protective grounding jumper assemblies which have been used by electrical workers in the field.

1.2 ~~These specifications discuss~~This specification discusses methods for testing grounding jumper assemblies, which consist of the flexible cables, ferrules, clamps and connectors used in the temporary protective grounding of de-energized circuits.

1.3 Manufacturing specifications for these grounding jumper assemblies are in Specifications F855.

1.4 The application, care, use, and maintenance of this equipment are beyond the scope of this specification.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.6 The following safety hazards caveat pertains only to the test portions of this specification. *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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]

B172 Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors

[1] This specification is under the jurisdiction of ASTM Committee F18 on Electrical Protective Equipment for Workers and is the direct responsibility of Subcommittee F18.45 on Mechanical Apparatus.

Current edition approved ~~Aug. 1, 2020~~Feb. 1, 2023. Published ~~September 2020~~February 2023. Originally approved in 2003. Last previous edition approved in ~~2018~~2020 as ~~F2249~~F2249 – 20ε1~~-18. DOI: 10.1520/F2249-20E01.~~. DOI: 10.1520/F2249-23.

[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.

B173 Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors
F855 Specifications for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment
2.2 *IEEE Standards:*[3]
IEEE Standard 80–2013 IEEE Guide for Safety in AC Substation Grounding
IEEE Standard 1048–2016 IEEE Guide for the Protective Grounding of Power Lines
IEEE Standard 1246–2011 IEEE Guide for Temporary Protective Grounding Systems Used in Substations

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *grounding jumper assembly*—grounding cable with connectors and ground clamps attached, also called a *grounding jumper* or a *protective ground assembly* installed temporarily on de-energized electric power circuits for the purpose of potential equalization and to conduct a short circuit current for a specified duration (time).

4. Significance and Use

4.1 Grounding jumper assemblies can be damaged by rough handling, long term usage, weathering, corrosion, or a combination thereof. This deterioration may be both physical and electrical.

4.2 The test procedures in this specification provide an objective means of determining if a grounding jumper assembly meets minimum electrical specifications. These methods permit testing of grounding jumper assemblies under controlled conditions.

4.3 Each responsible entity must determine the required safety margin for their workers during electrical fault conditions. Guidelines for use in the determination of these conditions are beyond the scope of this specification and can be found in such standards as IEEE Standard 80–2013 and IEEE Standard 1048–2016, and IEEE Standard 1246–2011.

4.4 Mechanical damage, other than broken strands, may not significantly affect the cable resistance. Close manual and visual inspection is required to detect some types of mechanical damage.

4.5 The test procedures in this specification should be performed at a time interval established by the user to ensure that defective grounding jumper assemblies are detected and removed from service in a timely manner.

4.6 Retest the grounding jumper assembly after performing any maintenance, in order to ensure its integrity.

5. Inspection of Grounding Jumper Assemblies

5.1 Visual inspection shall be made of all grounding jumper assemblies prior to testing.

5.1.1 If the following defects are evident, the grounding jumpers may be rejected without electrical testing:

5.1.1.1 Cracked or broken ferrules and clamps,

5.1.1.2 Exposed broken strands,

5.1.1.3 Cut or badly mashed or flattened cable,

5.1.1.4 Extensively damaged ~~cable- covering~~ cable-covering material,

5.1.1.5 Swollen cable jacket or soft spots, indicating internal corrosion, and

5.1.1.6 Cable strands with a black deposit on them.

5.1.2 Grounding jumper assemblies which are visually defective shall be removed from service and permanently marked, tagged or destroyed (if beyond repair) to prevent re-use.

[3] Available from the Institute of Electrical and Electronics Engineers, Inc. (IEEE) 1828 L St., NW, Suite 1202, Washington, DC 20036–5104.

5.1.3 Before the grounding jumper assembly can be placed back in service, it must pass the inspection requirements in 5.1.1, and the electrical requirements in Section 7.

5.1.4 All physical connections should be checked for tightness with specified torque values.

6. Cleaning and Measuring of Grounding Jumper Assembly Prior to Electrical Testing

6.1 Identify the cable gage (AWG) and a make a precise measurement of the cable length. See Fig. 1.

6.2 Thoroughly clean the jaws of the clamps with a stiff wire brush.

6.3 Attach the grounding jumper assembly clamps firmly to the test set.

7. Electrical Requirements

7.1 The user must select the test method with the desired precision and repeatability. The test instrument should be sufficiently accurate to detect at least a one foot or less change in cable length to ensure that the cable meets requirements.

7.2 Each method must take into account a precise cable resistance per foot and the length of the cable being tested.

7.3 Electrical tests relative to this standard are:

7.3.1 DC resistance measurements,

7.3.2 AC impedance measurements, and

7.3.3 Temperature rise measurements (supplementary method).

7.4 *DC Resistance or AC Impedance Method*—Equipment required includes:

7.4.1 A minimum 10 A dc source controllable to 5 % of output current, short circuit protected, or

7.4.2 A minimum 10 A ac source controllable to 5 % of output current, short circuit protected.

7.4.3 Measuring method for measurements of cable length calibrated in inches or centimeters.

7.5 *In-Service Electrical Resistance Pass/Fail* ~~*Criteria —*~~*Criteria—*The pass/fail criterion of a grounding jumper assembly is based on the resistance value of the assembly (cable, ferrules and clamps) which is higher than the established resistance value for new assemblies. This increase in resistance accounts for manufacturing tolerance and the expected normal deterioration of the

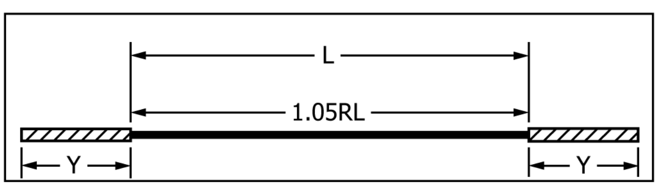


FIG. 1 Resistance and Impedance of Copper Grounding Jumper Assemblies

Y = resistance of clamps, ferrule and portions of the cable inside the ferrule, mΩ,
L = cable length expressed in feet (ferrule to ferrule measurement to the nearest inch, not including shrouded portion of some ferrules which cover the cable insulation), and
R = cable resistance from Table 1, mΩ/ft.

assembly due to aging, contamination and corrosion, particularly in the contact areas of the cable ferrules and clamps. The allowable increase in resistance is such as to permit the grounding jumper assembly to perform safely during electrical faults. The grounding jumper assembly, when subjected to its rated maximum fault current and duration, must withstand the fault without its components separating, but some heat damage and discoloration is acceptable. The electrical resistance value for the pass/fail criterion is made up of two parts (Fig. 1), the cable resistance and the resistance of the two ends containing short cable sections, ferrules and clamps. When the grounding jumper assemblies are tested with a dc source, the dc resistance of the assembly is used for the pass or fail purposes. With an ac source, the impedance of the cable and the impedance of the ends (ferrules and clamps) are used to determine if the grounding jumper fails or passes the test.

TABLE 1 Class K Copper Cable Nominal Resistance, mΩ/ft[A]

Grounding Cable Size	Resistance, mΩ/ft at ~~5°C (41°F)~~5 °C (41 °F)	Resistance, mΩ/ft at ~~20°C (68°F)~~20 °C (68 °F)	Resistance, mΩ/ft at ~~35°C (95°F)~~35 °C (95 °F)
#2	0.15433	0.16400	0.17367
1/0	0.09693	0.10300	0.10907
2/0	0.07773	0.08260	0.08747
4/0	0.04893	0.05200	0.05507

[A] ~~20°C~~ 20 °C Resistance values are taken from Table 2, B172~~–10.~~ – 10.

7.5.1 *Cable Resistance*—Copper cables used as part of a grounding jumper assembly must be constructed in accordance with Specifications B172 or B173 as specified in Specification F855. Two cable classes are identified in Specification F855 as being acceptable cables for use in ground cable assemblies. They are Class K and Class M. Class K cable has proven to be a very popular cable class for use in ground cable assemblies. Table 1 provides the nominal resistance values for typical sizes of Class K cables used in grounding jumper assemblies. If the user is unable to determine the specific class of cable used in a ground cable assembly, the resistance values in Table 1 are a reasonable approximation for both cable classes. Cable resistance values for both cable classes are located in Appendix X1 through Appendix X2.

7.5.1.1 The cable resistance can change with ambient temperatures. A ~~±5.09°C (±9.16°F)~~±5.09 °C (±9.16 °F) change in ambient temperatures will cause a ±2 % change in the measurement of resistance values. Table 1 and Tables X1.1 and X2.1 give cable resistance values for a practical range of temperatures ~~5°C, 20°C, and 35°C (41°F, 68°F, and 95°F).~~5 °C, 20 °C, and 35 °C (41 °F, 68 °F, and 95 °F). Resistance values for different temperature values can be computed using Eq 1, where R_{20} is the cable resistance per foot in mΩ/ft at ~~20°C,~~20 °C, R_{T2} is the cable resistance at the desired temperature T_2, and T_2 is the desired temperature in °C.

$$R_{T2} = R_{20} * [1 + 0.00393 * (T_2 - 20)] \text{m}\Omega/\text{ft} \quad (1)$$

7.5.1.2 Results from the ASTM Round Robin Tests have shown that an increase in cable resistance at a given temperature due to a combination of manufacturing tolerance and aging effects should not exceed 5 %. Therefore, the maximum acceptable resistance in cables used in temporary protective grounding jumpers should be equal to or less than 1.05 *RL*, when *R* = cable resistance in mΩ/ft from Table 1, and *L* = cable length in feet.

7.5.2 *Resistance and Impedance of Copper Grounding Jumper Assemblies*—See Table 1, X1.1, or X2.1.

7.5.2.1 *Maximum Resistance of the Grounding Jumper Assembly (Rm):*

$$Rm = 1.05\,RL + 2Y \text{m}\Omega \quad (2)$$

7.5.2.2 *Maximum Impedance of the Grounding Jumper Assembly (Zm):*

$$Zm = \sqrt{(1.05RL + 2Y)^2 + (XL)^2}\,\text{m}\Omega \quad (3)$$

where:

X = reactance of the cable in mΩ/ft.

NOTE 1—Values of *X* can be found in data books such as the Standard Handbook of Electrical Engineers.[4]

[4] Standard Handbook for Electrical Engineers—Thirteenth Edition by Fink & Beaty, McGraw-Hill Book Co., New York, NY.

7.5.3 *Testing with a DC Source*—A dc source can be used to determine the pass/fail value for a given grounding jumper assembly. The resistance value (R) obtained from such a measurement should be compared with the calculated limiting maximum resistance (Rm) using Eq 2 or it can be compared to the resistance values in Tables X1.2, or X2.2. The calculated criterion for pass/fail is based on 2/0 cable fault tests. The resistance of Y in the Rm (Eq 2) has been determined by conservative analysis of the data to be 0.16 mΩ. This value is below the "fusing range" of cables that passed the fault tests. The value of Y = 0.16 mΩ or 2Y = 0.32 mΩ for all cable sizes. Therefore, the pass/fail resistance value is:

$$Rm = 1.05\,RL + 0.32\ \text{m}\Omega \tag{4}$$

NOTE 2—Tables X1.2 and X2.2 were derived from Eq 4.

7.5.4 *Testing with an AC Source*—When an ac source is used, it will determine the grounding jumper assembly impedance (Z). This impedance is a function of the cable and the test electrode spacing. For cable spacing of 12 in. or less, the cable reactance can be very low and the impedance value can approach that of the cable resistance. The impedance (Z) obtained from such a measurement should be compared with the calculated limiting maximum impedance (Zm) using Eq 3 to determine if the grounding jumper assembly has passed or failed the test. The pass/fail impedance value based on 2/0 cable fault tests is:

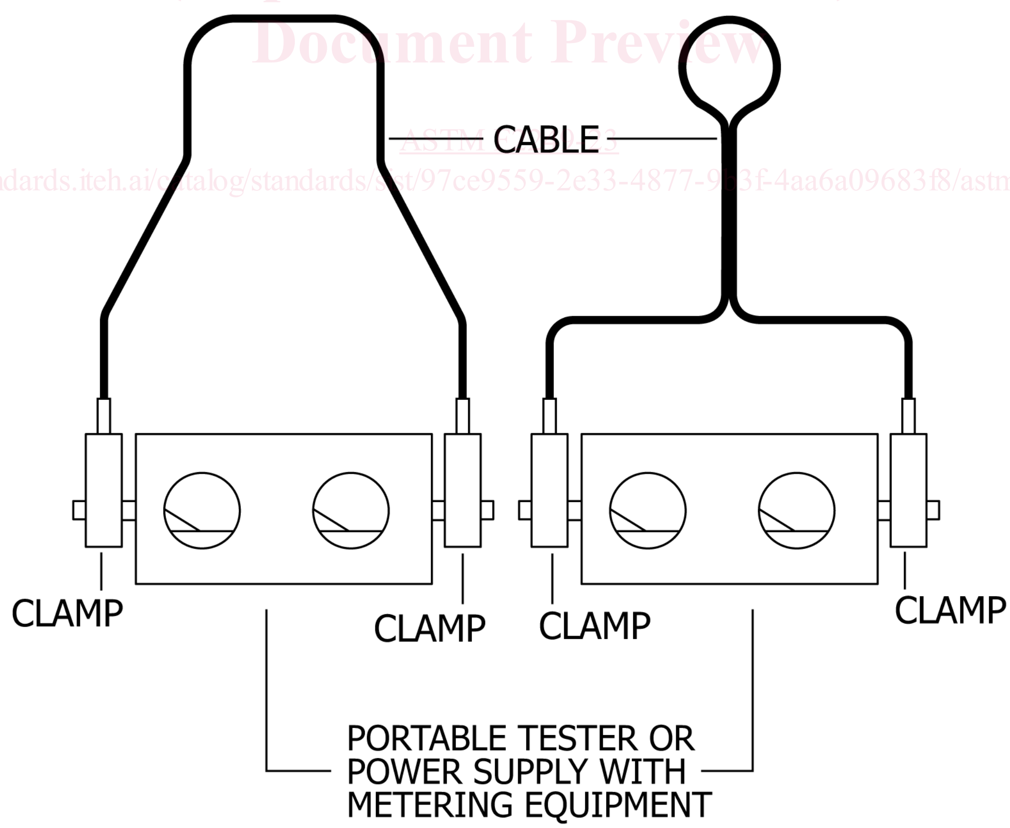
$$Zm = \sqrt{(1.05RL + 0.32)^2 + (XL)^2}\ \text{m}\Omega \tag{5}$$

If multiple spacing of the cable is utilized in the test setup, the above equation becomes:

$$Zm = \sqrt{(1.05RL + 0.32)^2 + (X_1L_1 + X_2L_2 \ldots + X_NL_N)^2}\ \text{m}\Omega \tag{6}$$

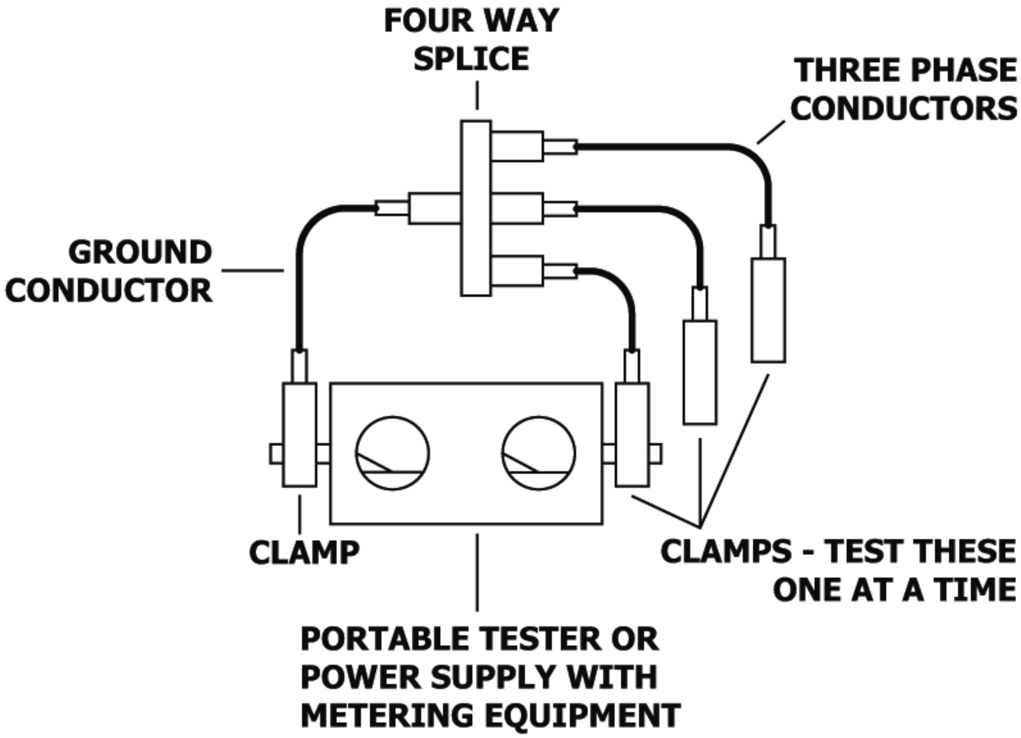
NOTE 3—AC testing measurements of grounding jumper assemblies are susceptible to errors and inconsistent results due to induction in the cable if the cable is not laid out per the test method instructions. Different instruments require different configurations (see Fig. 2).

NOTE 4—AC testing measurements of grounding jumper assemblies are susceptible to errors if metal is laid across the cable or the cable is laid across a metal object, even if the metal object is buried, such as a reinforcing bar embedded in a concrete floor.



NOTE 1—The cable configuration may have a dramatic effect on the readings. Shown above are two different methods currently in use by different manufacturers. The manufacturer of the equipment will specify the exact method to be used with their equipment.

FIG. 2 Typical Configurations



NOTE 1—When testing a three-phase cluster assembly, the ground (or single side) conductor should stay attached to one electrode of the tester, while alternately connecting and testing each of the three phase conductors one at a time to the other side of the tester.

FIG. 3 How to Test Three-Phase Grounding Sets

8. Cleaning/Reconditioning of Grounding Jumper Assembly after Electrical Testing

8.1 For the readings which are high, additional cleaning and tightening of the assembly may restore its electrical integrity.

8.2 Disassemble the grounding jumper assembly and thoroughly clean the ferrule and clamp interface with isopropyl alcohol and a stiff wire brush.

8.3 Inspect all components during the disassembly and reassembly process.

8.4 Reassemble the grounding jumper. All physical connections should be checked for tightness with specified torque values.

8.5 Grounding jumper assemblies that fail the electrical test after additional maintenance or repairs are performed, shall be removed from service and permanently marked or destroyed to prevent reuse.

9. Keywords

9.1 cable; clamp; ferrule; portable tester; temporary grounding jumper assemblies

APPENDIXES

(Nonmandatory Information)

X1. CLASS K COPPER CABLE NOMINAL RESISTANCE VALUES

X1.1 Specification F855, Section 35.1 lists Class K cable as one of two acceptable cables for ground cable assemblies. The resistance characteristics at ~~20°C~~20 °C for typical cable sizes of Class K cable are documented in Table 2 of Specification B172. These values are repeated in Table X1.1 along with resistance values for ~~5°C and 35°C.~~5 °C and 35 °C. These values are used in Eq 4 along with the resistance values for the cable assembly terminations to compute the total cable assembly resistance. Eq 4 was used to compute the resistance values shown in Tables X1.2 and X1.3. The resistance values in Table X1.2 are cable resistance only, no terminations. The values in Table X1.2 are intended to be added to the values in Table X1.3 to derive the calculated resistance of the complete ground cable assembly.

X1.2 *Example*:

X1.2.1 Calculate the predicted resistance at ~~20°C~~20 °C for a Class K 2/0 Copper Ground Cable Assembly that is 26 ft - 4 in. long.

X1.2.2 The resistance at ~~20°C~~20 °C of the 4 in. cable section = 0.02891 mΩ.

X1.2.3 The resistance at ~~20°C~~20 °C of the 26 ft cable section = 2.57498 mΩ.

X1.2.4 The total cable assembly resistance equals 0.02891 + 2.57498 = 2.60389 mΩ.

TABLE X1.1 Class K Nominal DC Resistance (mΩ/ft)

Cable Size (AWG)	~~5°C~~5 °C ~~(41°F)~~(41 °F)	~~20°C~~20 °C ~~(68°F)~~(68 °F)	~~35°C~~35 °C ~~(95°F)~~(95 °F)
#2	0.15433	0.16400	0.17367
1/0	0.09693	0.10300	0.10907
2/0	0.07773	0.08260	0.08747
4/0	0.04893	0.05200	0.05507