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.

1. Scope

1.1 These specifications cover 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 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 Units of measurement used in this specification are in the Metric system (SI) with English units given in parentheses.

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 and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B193 Test Method for Resistivity of Electrical Conductor Materials

F855 Specifications for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment

2.2 *IEEE Standards:*[3]

IEEE Standard 80–1986 IEEE Guide for Safety in AC Substation Grounding

IEEE Standard 1048–1990 IEEE Guide for the Protective Grounding of Power Lines

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 80–1986 and IEEE Standard 1048–1990.

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

[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.

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

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 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.

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 centimetres.

7.5 *In-Service Electrical Resistance Pass/Fail 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 the expected normal deterioration of the 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 Copper Cable Resistance, mΩ[A]

Grounding Cable Size	Resistance, mΩ/ft at 5°C (41°F)	Resistance, mΩ/ft at 20°C (68°F)	Resistance, mΩ/ft at 35°C (95°F)
#2	0.1471	0.1563	0.1655
1/0	0.0924	0.0983	0.1040
2/0	0.0733	0.0779	0.0825
4/0	0.0461	0.0490	0.0519

[A]Values are calculated from data in Test Method B193.

7.5.1 *Cable Resistance*—Table 1 provides resistance values for various sizes of cables used in grounding jumper assemblies. The cable resistance can change with ambient temperatures. A ±9°F change in ambient temperatures will cause a ±2 % change in the measurement of resistance values. Table 1 gives cable resistance values for a practical range of temperatures (41, 68, and 95°F). Results from the ASTM Round Robin Tests have shown that an increase in cable resistance at a given temperature due to aging effects should not exceed 5 %. Therefore, the maximum acceptable resistance in cables used in temporary protective grounding jumpers should be equal or less than 1.05 RL, when R = cable resistance from Table 1, and L = cable length in feet.

7.5.2 *Resistance and Impedance of Copper Grounding Jumper Assemblies*—See Table 1.

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

$$Rm = 1.05\ RL + 2Y \quad (1)$$

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

$$Zm = \sqrt{(1.05RL + 2Y)^2 + (XL)^2} \quad (2)$$

where:

X = reactance of the cable in mΩ.

NOTE 1—Values of X can be found in data books such as the Standard

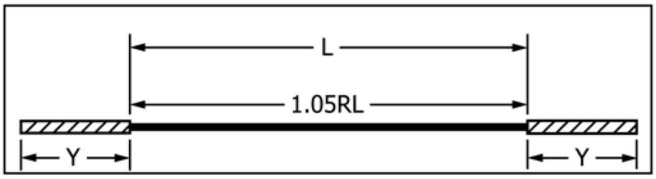


FIG. 1 Resistance and Impedance of Copper Grounding Jumper Assemblies

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.

Handbook of Electrical Engineers.[4]

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 1 or it can be compared to the resistance values in Table 2. The calculated criterion for pass/fail is based on 2/0 cable fault tests conducted in Round Robin III (See Appendix X1). The resistance of Y in the Rm (Eq 1) 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 2 Y = 0.32 mΩ for all cable sizes. Therefore, the pass/fail resistance value is:

$$Rm = 1.05\ RL + 0.32\ \text{m}\Omega \tag{3}$$

NOTE 2—Table 2 was derived from Eq 3.

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 2 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:

$$Zm = \sqrt{(1.05RL + 0.32)^2 + (XL)^2} \tag{4}$$

If multiple spacings of the cable are utilized in the test setup, the above equation becomes:

$$Zm = \sqrt{(1.05RL + 0.32)^2 + (X_1L_1 + X_2L_2 \ldots + X_NL_N)^2} \tag{5}$$

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).

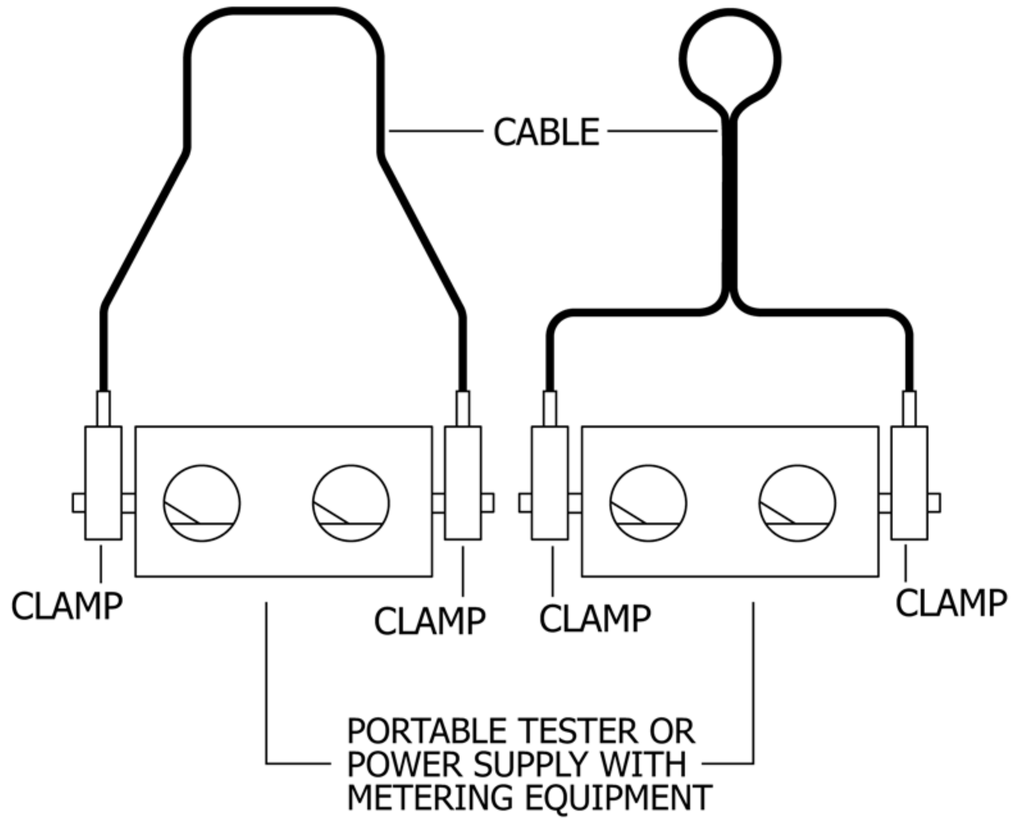
NOTE 4—AC testing measurements of grounding jumper assemblies are

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

TABLE 2 Pass/Fail Resistance Values for Copper Grounding Jumper Assemblies

Cable Length, ft	Rmax Limits—DC Resistance, mΩ											
	#2 Cable			1/0 Cable			2/0 Cable			4/0 Cable		
	5°C (41°F)	20°C (68°F)	35°C (95°F)	5°C (41°F)	20°C (68°F)	35°C (95°F)	5°C (41°F)	20°C (68°F)	35°C (95°F)	5°C (41°F)	20°C (68°F)	35°C (95°F)
0.25[A]	0.039	0.041	0.043	0.024	0.026	0.027	0.019	0.020	0.022	0.012	0.013	0.014
0.5[A]	0.077	0.082	0.087	0.049	0.052	0.055	0.038	0.041	0.043	0.024	0.026	0.027
0.75[A]	0.116	0.123	0.130	0.073	0.077	0.082	0.058	0.061	0.065	0.036	0.039	0.041
1	0.474	0.484	0.494	0.417	0.423	0.429	0.397	0.402	0.407	0.368	0.371	0.374
2	0.629	0.648	0.668	0.514	0.526	0.538	0.474	0.484	0.493	0.417	0.423	0.429
3	0.783	0.812	0.841	0.611	0.630	0.648	0.551	0.565	0.580	0.465	0.474	0.483
4	0.938	0.976	1.015	0.708	0.733	0.757	0.628	0.647	0.667	0.514	0.526	0.538
5	1.092	1.141	1.189	0.805	0.836	0.866	0.705	0.729	0.753	0.562	0.577	0.592
6	1.247	1.305	1.363	0.902	0.939	0.975	0.782	0.811	0.840	0.610	0.629	0.647
7	1.401	1.469	1.536	0.999	1.043	1.084	0.859	0.893	0.926	0.659	0.680	0.701
8	1.556	1.633	1.710	1.096	1.146	1.194	0.936	0.974	1.013	0.707	0.732	0.756
9	1.710	1.797	1.884	1.193	1.249	1.303	1.013	1.056	1.100	0.756	0.783	0.810
10	1.865	1.961	2.058	1.290	1.352	1.412	1.090	1.138	1.186	0.804	0.835	0.865
11	2.019	2.125	2.232	1.387	1.455	1.521	1.167	1.220	1.273	0.852	0.886	0.919
12	2.173	2.289	2.405	1.484	1.559	1.630	1.244	1.302	1.360	0.901	0.937	0.974
13	2.328	2.453	2.579	1.581	1.662	1.740	1.321	1.383	1.446	0.949	0.989	1.028
14	2.482	2.618	2.753	1.678	1.765	1.849	1.398	1.465	1.533	0.998	1.040	1.083
15	2.637	2.782	2.927	1.775	1.868	1.958	1.474	1.547	1.619	1.046	1.092	1.137
16	2.791	2.946	3.100	1.872	1.971	2.067	1.551	1.629	1.706	1.094	1.143	1.192
17	2.946	3.110	3.274	1.969	2.075	2.176	1.628	1.711	1.793	1.143	1.195	1.246
18	3.100	3.274	3.448	2.066	2.178	2.286	1.705	1.792	1.879	1.191	1.246	1.301
19	3.255	3.438	3.622	2.163	2.281	2.395	1.782	1.874	1.966	1.240	1.298	1.355
20	3.409	3.602	3.796	2.260	2.384	2.504	1.859	1.956	2.053	1.288	1.349	1.410
25	4.181	4.423	4.664	2.746	2.900	3.050	2.244	2.365	2.486	1.530	1.606	1.682
30	4.954	5.243	5.533	3.231	3.416	3.596	2.629	2.774	2.919	1.772	1.864	1.955
35	5.726	6.064	6.402	3.716	3.933	4.142	3.014	3.183	3.352	2.014	2.121	2.227
40	6.498	6.885	7.271	4.201	4.449	4.688	3.399	3.592	3.785	2.256	2.378	2.500
45	7.270	7.705	8.140	4.686	4.965	5.234	3.783	4.001	4.218	2.498	2.635	2.772
50	8.043	8.526	9.009	5.171	5.481	5.780	4.168	4.410	4.651	2.740	2.893	3.045

[A] This value may only be added to the full foot length measurements.



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

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.

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.

APPENDIXES

(Nonmandatory Information)

X1. DATA ANALYSIS OF ASTM—BPA GROUNDING JUMPER ASSEMBLY TESTS

X1.1 This data was used in the development of this specification and is included for informational purposes only. This data will not be included in future revisions of this specification.

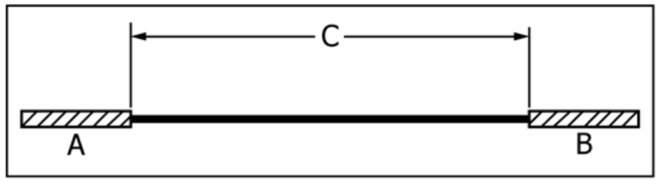
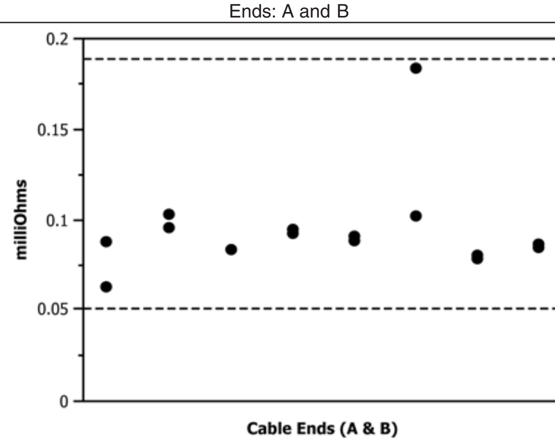


FIG. X1.1 Resistance Areas

TABLE X1.1 2/0 Copper Cables that Passed the High Current Fault Tests

Total Length: A, C, B			
Length, ft	Calculated mΩ	Actual mΩ Reading	Percent Difference
15	1.2	1.24	3.4
18.5	1.48	1.52	2.7
20	1.6	1.64	2.6
30	2.4	2.5	4.2
35	2.8	2.9	3.6
35	2.8	3.11	11.1
40	3.2	3.31	3.4
40	3.2	3.29	2.8
Middle Section: C			
Length–2, ft	Calculated mΩ	Actual mΩ Reading	Percent Difference
13	1.04	1.09	4.5
16.5	1.32	1.31	-0.4
18	1.44	1.48	2.6
28	2.24	2.31	3.1
33	2.64	2.73	3.4
33	2.64	2.79	5.7
38	3.04	3.14	3.3
38	3.04	3.11	2.3
Ends: A and B			

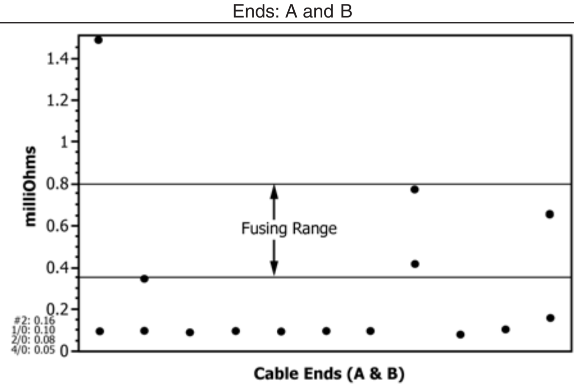


(*a*) Total Range: 0.08 to 0.183
(*b*) Passing Range: 0.08 to 0.183
Avg = 0.094 mΩ
Ontario Hydro = 0.160

X2. TEMPERATURE DIFFERENTIAL TEST METHOD FOR IN SERVICE TESTING OF COPPER GROUNDING JUMPER ASSEMBLIES

TABLE X1.2 2/0 Copper Grounding Jumper Assemblies that Passed the High Current Fault Tests with Some Fusing

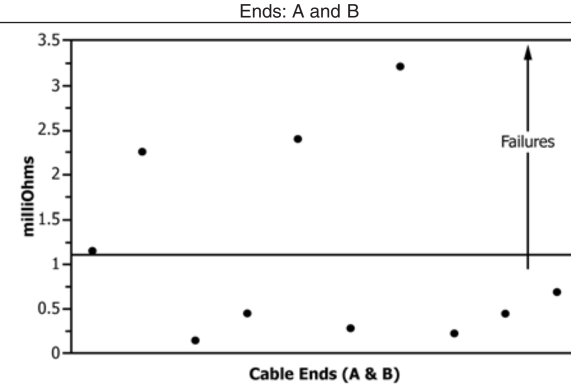
Total Length: A, C, B			
Length, ft	Calculated mΩ	Actual mΩ Reading	Percent Difference
6	0.48	2.04	325
8	0.64	0.94	47
10	0.8	0.83	3.3
10	0.8	0.83	3.8
10	0.8	0.83	4.3
10	0.8	0.83	4.4
10	0.8	0.83	4.3
12	0.96	2.04	112.5
15	1.2	1.23	2.3
30	2.4	2.5	4.2
35	2.8	8.35	198
Middle Section: C			
Length–2, ft	Calculated mΩ	Actual mΩ Reading	Percent Difference
4	0.32	0.42	31.3
6	0.48	0.486	1.3
8	0.64	0.645	0.8
8	0.64	0.646	0.9
8	0.64	0.657	1.9
8	0.64	0.647	1.1
8	0.64	0.652	1.9
10	0.8	0.837	4.6
13	1.04	1.084	4.2
28	2.24	2.31	3.1
33	2.64	7.53	185.2
Ends: A and B			



(*a*) Total Range: 0.07 to 1.486
(*b*) Fusing Range: 0.353 to 1.486
The high end No. (1.486) could be in the fusing-failure range, so new fusing range is 0.353 to 0.77
Avg = 0.56 mΩ (0.407 mΩ for Ontario Hydro)

TABLE X1.3 2/0 Copper Grounding Jumper Assemblies that Failed the High Current Fault Tests

Total Length: A, C, B			
Length, ft	Calculated mΩ	Actual mΩ Reading	Percent Difference
6	0.48	1.72	258
6	0.48	3.04	533
7	0.56	1.47	162
8	0.64	1.26	97
10	0.8	3.55	344
10	0.8	1.17	46
13	1.04	7.92	662
19	1.52	1.59	4.3
19	1.52	2.2	45
35	2.8	8.35	198
Middle Section: C			
Length–2, ft	Calculated mΩ	Actual mΩ Reading	Percent Difference
4	0.32	0.39	21.9
4	0.32	0.391	22.2
5	0.4	1.198	199
6	0.48	0.598	24.6
8	0.64	0.69	7.8
8	0.64	0.754	17.8
11	0.88	0.965	9.7
17	1.36	1.234	-9.3
17	1.36	1.663	22.3
33	2.64	7.53	185
Ends: A and B			



(*a*) Total Range: 0.14 to 3.19
(*b*) Failure Range of the Test Samples: 1.153 to 3.19
Avg = 2.25 mΩ

X2.1 Temperature Differential Measurements

X2.1.1 All precautions and inspections required in the dc and ac test method shall be adhered to. This test method can be used as a supplement to the test methods outlined in Section 7 of this specification.

X2.2 Temperature Differential Method

X2.2.1 Equipment requirements include:

X2.2.1.1 *AC High Current Source,* 200 amps minimum and controllable to 5 % of the output current, short circuit protected. The current source should have a continuous duty cycle rating of the current values needed to apply the continuous rating A RMS 60 Hz per Specifications F855 Table 2, Protective Ground Cable Ferrule, and Assembly Ratings.

X2.2.1.2 *Digital Multimeter,* optional—Used to screen grounding jumper assembly for full 3 min test interval; commonly available with a minimum 3½ or 4½ digit meter.

X2.2.1.3 *Measuring Tape,* optional—Used if voltage screening method is utilized; for measurements of cable length to the nearest inch or centimetre.

X2.2.1.4 *Non-contact Thermometer,* infrared with digital readout (laser sighting recommended-observe normal eye protection requirements when handling lasers). Check specific manufacturer's instruction book for emissivity setting for test area background. **Warning**—Background temperature can influence the temperature readings.

X2.2.1.5 *Adequate Hand Protection,* defective cables may develop hot spots during testing.

X2.3 Test Set-up

X2.3.1 Test should be performed indoors if possible or out of direct sunlight.

X2.3.2 For best accuracy, grounding jumper assembly temperature should be allowed to reach equilibrium with the test environment. (This is essential for large mass connectors and dead front grounding assemblies.)

X2.3.3 To minimize the impedance effect of AC testing, it is recommended that the grounding jumper assembly under test be laid out in a tight parallel configuration.

X2.4 Test Procedure

X2.4.1 Connect the grounding jumper assembly to the high current source. Torque the clamps to the manufacturers' specifications (typically 25 ft/lb).

X2.4.2 Apply the rated current, per Specifications F855 Table 5, for 3 min (see Note X2.3). Immediately after the 3 min, reduce the current to zero and turn off the current source. Scan the entire ground assembly, including the cable, with the infrared thermometer held 12 in. from the ground assembly. (In the case of deadfront underground assemblies, the elbow should be removed from the feedthru and the temperature of both the elbow and feedthru bushing's current path measured.)

X2.4.3 The pass/fail criteria of a ground jumper assembly is based on the temperature variance (differential) of any components of the ground jumper assembly after the 3 min test. All components should read within 15°F (or 8.3°C) of each other. Large-mass ground components will have less temperature variance and acceptance values should be based on user experience. Small-mass grounding clamps composed of bronze (ball and socket style) will have a higher temperature variance and acceptance values should be based on user experience.

X2.4.4 Should any part of the grounding jumper assembly exceed the temperature of another part of the assembly by 15°F or more, it shall be disassembled, inspected, repaired and reassembled. The repaired assembly shall be retested.

NOTE X2.1—AC testing measurements of grounding jumper assembly are susceptible to errors and inconsistent results due to induction if the cable is not properly laid out.

NOTE X2.2—AC testing measurements of grounding jumper assembly 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 reinforcing bar embedded in a concrete floor.

NOTE X2.3—If the voltage drop measured across the grounding jumper assembly exceeds the allowable in the AC Test Tables, the test need not run the full three minutes. The location(s) of the high resistance can be quickly determined by scanning the grounding jumper assembly with the infrared thermometer, halting the test and repairing the grounding assembly.