1.0 PURPOSE

To establish standard test procedures for low- and medium-voltage ground wire devices.

2.0 SCOPE

These procedures apply to low- and medium-voltage ground wire devices used in conjunction with ground wire monitors and/or used as arc suppression devices.

3.0 REFERENCES

3.1. CFR, Title 30, Section 75 and 77, Code of Federal Regulations.

3.2. MESD-STD-281-19 Criteria for Low and Medium Voltage Ground Wire Device

3.3. ICEA P-46-426 Power Cable Ampacities

4.0 DEFINITIONS

4.1. Ground Wire Device - A device placed in series with ground wire to suppress intermachine arcing and/or to reduce the effect of interfering parallel paths to the ground wire monitor system.

4.2. Low Voltage – Voltages up to and including 660 volts, as defined in 30 CFR 75.2.

4.3. Medium Voltage – Voltages from 661volts to 1,000 volts, as defined in 30 CFR 75.2.

5.0 GENERAL REQUIREMENTS

5.1. Safety

Caution should always be used during these tests due to the hazardous voltage/current which will be used.

5.2. Documentation for MSHA evaluation:

5.3. A letter requesting evaluation and stating Maximum Cable Size Rating for which the ground wire device will be evaluated for. Note: Cable Size Rating is the trailing cables phase conductor size, reference table 1 on page 10

5.4. Assembly drawings or outline drawings of the device.

5.5. Bill of materials

5.6. Schematic drawings showing the location(s) where the ground wire device can be installed in power circuit(s).

5.7. Design specifications for all inductors

5.8. Arc suppressing ground wire devices must be submitted with a voltage current curve showing saturation characteristic of device.

5.9. One sample of the device prior to encapsulation, if encapsulated.

5.10. At the option of MSHA, all testing may be witnessed by an MSHA investigator. An advanced notice of at least four weeks shall be given for an MSHA engineer to be available to witness any of the tests.

6.0 TEST EQUIPMENT

6.1. Ohmmeter

6.2. Voltmeter (2)

6.3. 500 or 1000 ampere, 100 millivolt shunt

6.4. High speed voltage recorder

6.5. Thermocouple (2)

6.6. Thermocouple data logger

6.7. Power supply capable of delivering 50 - 27,200 amps single phase current at 60 hertz.

6.8. Resistors of various values capable of conducting 50 amperes.

7.0 TEST SAMPLES

A minimum of six samples will be required for these tests.

8.0 PROCEDURES

8.1. Three devices will be subjected to the saturation and transient test; five devices will be subjected to the high current test. The tests will be performed by MSHA with the exception of the high current test or by a laboratory chosen by the applicant. MSHA will have the option of witnessing the tests. The high current test requires a high current testing laboratory. The high current testing laboratory will submit a test procedure and instrument certification to MSHA. This information as well as the date and time reserved for the test will be submitted to MSHA at least four weeks in advance.

8.2. The ground wire device maximum impedance must not exceed the values listed in Table 2.

9.0 SATURATION TEST

9.1. Measure the DC resistance (both polarities) of the ground wire device. Record the resistance on Data Sheet 2a.

9.2. Connect the device between the phase and neutral connections of a continuously variable voltage power supply capable of supplying 50 Aac.

9.3. Size a resistor to limit current to 50 A at the maximum output of the power supply and connect it in series with the device.

9.4. Connect a voltmeter across the device terminals.

9.5. Connect another voltmeter across the terminals of the current measuring shunt.

9.6. Energize the power supply at its lowest output voltage.

9.7. Record the voltage across the device and the current (determined from the voltage across the current measuring shunt) through the device.

9.8. Increase the power supply voltage in increments until the circuit current equals 25 A. Record the voltage across the device and the current through

the device at every 0.1 A increment between 0 and 1 A. After the current has reached 1 A record voltage and current at 1 A increments. Data will be tabulated on Data Sheet 2a and plotted on a linearly scaled graph of amperes versus volts (Data Sheet 2b).

9.9. Adjust the power supply voltage to zero. When the current through the device reaches zero, de-energize the power supply.

10.0 TRANSIENT RESPONSE TEST

10.1. Connect the ground wire device between the phase and neutral connections of a continuously variable voltage power supply capable of supplying 25 A ac.

10.2. Size a resistor to limit current to 25 A continuous at the maximum output of the power supply and connect it in series with the device.

10.3. Place a high speed voltage recorder capable of measuring and storing transient response waveforms across the device. Proper range settings and test leads MUST BE USED.

Note: Transient Response Test is not usually required for diode type ground wire devices.

10.4. Set the high speed voltage recorder to record voltage greater than 110% of the steady state peak voltage across the device.

10.5. Energize the power supply.

10.6. Save the transient data as Data Sheet 2c.

10.7. De-energize the power supply.

10.8. Repeat steps 10.4 to 10.7 nine times for a total of ten tests.

11.0 HIGH CURRENT TEST

11.1. Data may be collected in the form of traces, magnetic storage media, or plotted graphs. Data will be tabulated on Data Sheet 2d.

11.2. Measure the DC resistance of the device (both polarities), to check for continuity. Record the resistance on Data Sheet 2d.

11.3. All five device tests A, B, C, D, E, F and G must be conducted in the order found in Flowchart 1.

11.4. Five devices will be tested in sequence at the following current levels. The time duration of the test is given in Table 1 based on the specified maximum ground wire device cable size rating requested by the applicant:

Test	Unit Number	Current (Amperes)
A	1	4,990
B	2	9,985
C	3	16,550
D	1*	20,450
E	2**	27,200

*If unit 1, does not pass test D, then perform Tests F and G:

Test	Units	Current (Amperes)
F	4	20,450
G	5	27,200

**If unit 2, does not pass test E, perform Test G:

Test	Units	Current (Amperes)
G	5	27,200

11.5. Test currents maybe symmetrical and must be within +/- 10% nominal values listed in Table 1.

11.6. The time of the test shall be adjusted to obtain an I^2t within +/- 10% of the values listed in Table 1.

11.7. De-energize the power supply. Record the physical condition of the device and note any defects on Data Sheet 2d. A photograph of the device may be used for this purpose. Allow the device to cool to ambient temperature by measuring the DC resistance (both polarities) until it is no more than 110% of the resistance measured in 9.1. Record the resistance on Data Sheet 2d.

11.8. Record the physical condition of the device after cooling and note any defects on Data Sheet 2d. A photograph of the device may be used for this purpose.

12.0 TEST DATA

12.1. Data from the saturation test will be tabulated on Data Sheet 2a.

12.2. Data from the saturation test will be plotted on a linearly scaled graph of amperes versus volts. This graph will be saved as Data Sheet 2b.

12.3. The transient data will be recorded and saved as Data Sheet 2c.

12.4. Data from the high current tabulated on Data Sheet 2d.

13.0 PASS/FAIL CRITERIA

13.1. A device will fail if it exhibits failure in any of the following modes during any test in this procedure:

13.1.1. Fails in an open circuit mode. (DC resistance at ambient temperature increases 10% above the value measured before the high current tests).

13.1.2. Emits flames, burns, melts or produces smoke for longer than 2 seconds.

13.1.3. Expels particles.

13.1.4. Exhibits structural damage.

13.1.5. Exhibits split or cracked external potting.

13.2. For a device to pass, its transient response voltage level and time measured in the transient response test must be in the pass region of Figure 1.

13.3. The voltage across ground wire device shall not exceed 29 V when 25 A or more is passed through the device during the saturation test in this standard test procedure.

Figure 1 - Transient Response

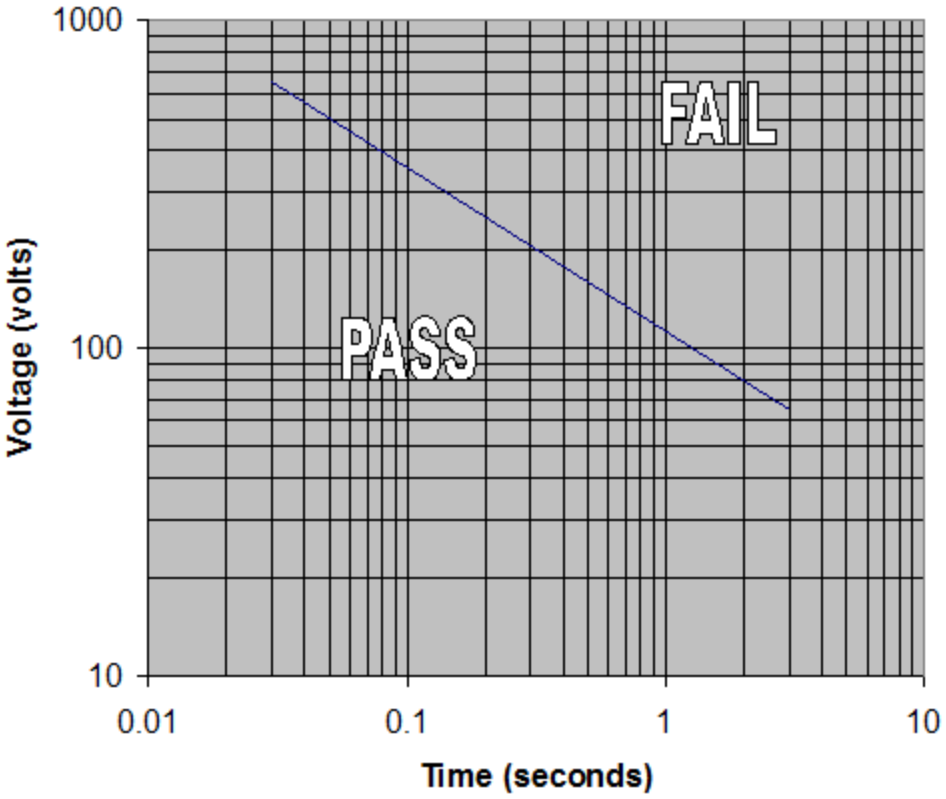


Table 1

CONDUCTORS				TIME - CYCLES				
PH	GROUND			T_1	T_2	T_3	T_4	T_5
	SIZE	MCM	$I^2T \times 10^6$	I_1 27,200 A	I_2 20,450 A	I_3 16,550 A	I_4 9,985 A	I_5 4,990 A
#4	#7	20.82	2.24	-----	-----	-----	1.3	5.4
#2	#5	33.09	5.67	-----	-----	1.2	3.4	13.7
#1	#4	41.74	8.90	-----	1.3	2.0	5.4	21.7
#1/0	#3	52.62	14.33	1.2	2.1	3.1	8.6	34.5
#2/0	#2	66.36	22.79	1.8	3.3	5.0	13.7	54.9
#3/0	#1	83.69	36.25	3.0	5.2	7.9	21.8	87.4
#4/0	#1/0	105.60	57.72	4.7	8.3	12.6	34.7	139.1
250	#2/0	133.10	91.70	7.4	13.2	20.1	55.2	221.0
300	#3/0	167.80	145.74	11.8	20.9	31.9	87.7	351.2
350	#4/0	211.60	231.75	18.8	33.2	50.8	139.5	558.4

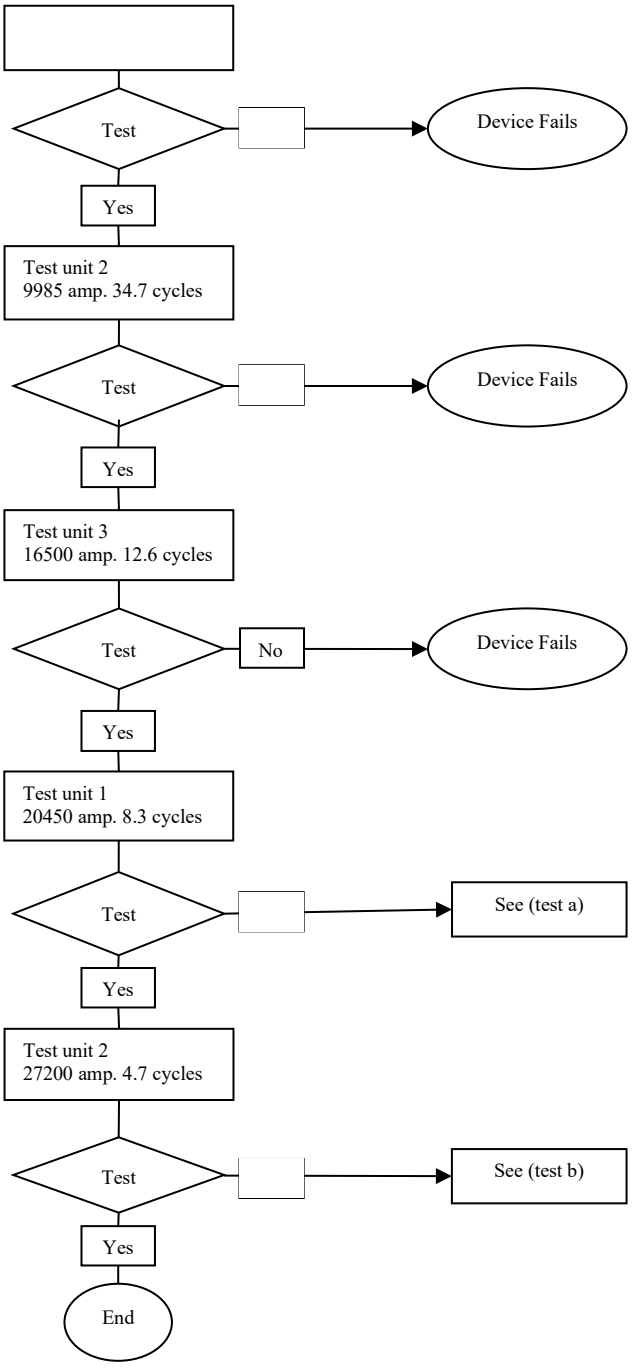
NOTE: 1 CYCLE = 0.01667 Sec.

Table 2 – Maximum Allowable Ground Wire Device Impedances

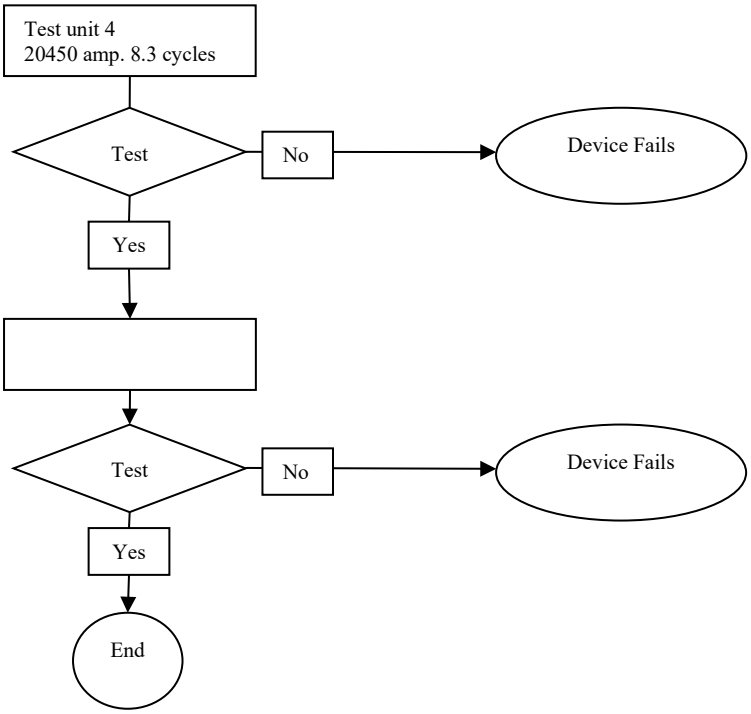
Conductors				Ground Wire Device Max. Impedance (Ω)
Phase	Ground Wire			
	Size	Max. Length (ft)	*Impedance (Ω)	
#4	#7	600	.418	.042
#2	#5	700	.307	.031
#1	#4	750	.261	.026
1/0	#3	800	.221	.022
2/0	#2	850	.187	.019
3/0	#1	900	.158	.016
4/0	1/0	1000	.137	.014
250	2/0	1000	.111	.011
300	3/0	1000	.089	.009
350	4/0	1000	.073	.007

Flowchart 1

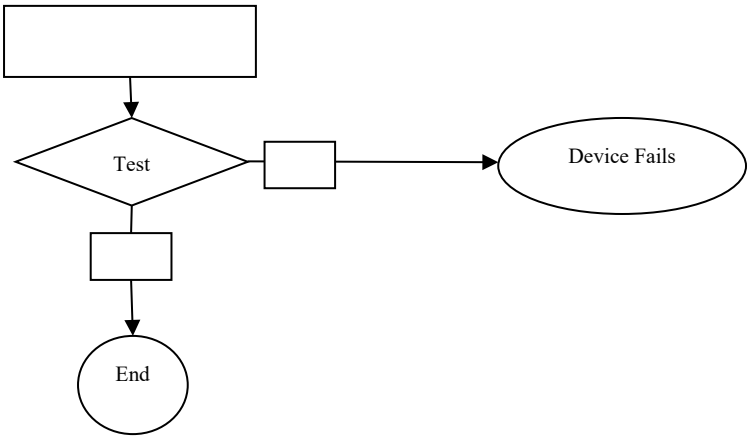
Example: The following are the current tests for devices to be inserted in trailing cables 4/0 or smaller.



Sub Test (a)



Sub test (b)



Data Sheet 2a
PAR Number: _____
Test Device: _____
Date of Test: _____

GROUND WIRE DEVICE
SATURATION TEST

Company Name: _____ MSHA Investigator: _____
Device Model Number: _____ Other Witness: _____

Initial DC Resistance
Positive Polarity _____ Negative Polarity _____

Test Number	Current (amperes)	Voltage (volts)	Test Number	Current (amperes)	Voltage (volts)
1			21		
2			22		
3			23		
4			24		
5			25		
6			26		
7			27		
8			28		
9			29		
10			30		
11			31		
12			32		
13			33		
14			34		
15			35		
16			36		
17			37		
18			38		
19			39		
20			40		

Data Sheet 2b
PAR Number: _____
Test Device: _____
Date of Test: _____

GROUND WIRE DEVICE - CURRENT TEST

Company Name: _____ MSHA Investigator: _____
Device Model Number: _____ Other Witness: _____

	High Current
DC Resistance before Test + polarity (ohms)	
DC Resistance before Test - polarity (ohms)	
DC Resistance after Test + polarity (ohms)	
DC Resistance after Test – polarity (ohms)	
Voltage Across Device (volts)	
Test Current (amperes)	
Actual Duration (seconds)	

Physical condition of device after High Current Test:

Other Observations during Test: