1.0 PURPOSE

This test procedure is used by the Electrical Safety Division (ESD) for testing of intrinsically safe apparatus to determine if wires, connections, and traces meet the requirements of ACRI2001 "Criteria for the Evaluation and Test of Intrinsically Safe Apparatus and Associated Apparatus," Section 8.11.

2.0 SCOPE

This Standard Test Procedure (STP) is used to conduct adequacy testing of conductors of intrinsically safe apparatus and associated apparatus approved, evaluated or certified under 30 CFR Parts 18, 19, 20, 22, 23, and 27.

3.0 REFERENCES

3.1. ACRI2001 "Criteria for the Evaluation and Test of Intrinsically Safe Apparatus and Associated Apparatus"

3.2. 30 CFR Part 18 "Electric Motor-Driven Mine Equipment and Accessories"

3.3. 30 CFR Part 19 "Electric Cap Lamps"

3.4. 30 CFR Part 20 "Electric Mine Lamps other than Standard Cap Lamps"

3.5. 30 CFR Part 22 "Portable Methane Detectors"

3.6. 30 CFR Part 23 "Telephones and Signaling Devices"

3.7. 30 CFR Part 27 "Methane-Monitoring Systems"

4.0 DEFINITIONS

4.1. **Maximum Fault Current** – The highest current that can be applied through the wire, connection, or trace under the worst-case, two-fault condition. Transient current conditions are not to be used for the test because the test is to be for conducted for 1.5 hours. I.e., Tests will be conducted at the appropriate multiple of the fuse rating per ACRI2001 Section 8.9, without the fuse in the circuit.

4.2. **Maximum Fault Voltage** - The highest voltage that can be applied across the wire, connection, or trace under the worst-case, two-fault condition.

4.3. **Protective Connection** – Either a single connection or two connections that comply with ACRI2001 section 8.11. The connection(s) is/are so unlikely to fail that the connection(s) is/are to be considered not subject to fault. Where two connections are utilized in the design, no fault is permitted to be applied to either connection. The complete two connection assembly is to be subjected to the test described by this procedure.

4.4. **Protective Trace(s)** – Either a single trace or two traces that comply with ACRI2001 section 8.11. The trace(s) is/are so unlikely to fail that the trace(s) is/are to be considered not subject to fault. Where two traces are utilized in the design, no faults are permitted to be applied to either trace. The complete two trace assembly is to be subjected to the test described by this procedure.

4.5. **Protective Vertical Interconnect Access(es) (VIAs)** – For the purposes of this STP, a protective VIA is to be treated the same as a protective trace.

4.6. **Protective Wire(s)** – Either a single wire or two wires that comply with ACRI2001 section 8.11. The wire(s) is/are so unlikely to fail that the wire(s) is/are to be considered not subject to fault. Where two wires are utilized in the design, no fault is permitted to be applied to either wire. The complete two wire assembly is to be subjected to the test described by this procedure.

5.0 TEST EQUIPMENT

5.1. Data recorder with at least 3 channels, sufficient voltage range for the parameters of the test circuit, a resolution of at least 3 significant figures, an accuracy of at least ± 1.5% of the reading, a minimum of 1000 data points per test, and able to plot voltage of 3 or more channels versus time with a resolution of 1 minute, and an accuracy of ± 1 minute. [Example: Agilent 34970A].

5.2. Electrical power source having sufficient voltage and current capacity to sustain the required electrical energy throughout the test.

5.3. Switch rated for the maximum voltage and current of the test circuit, as necessary.

5.4. Digital thermometer with analog/digital output, range of at least the maximum permissible surface temperature of the component under test, resolution of at least 0.2 °C, and an accuracy of at least ± 1 °C. The sensing element of this thermometer must not significantly cool the component under test. Thermocouple wires must not be larger than No. 24 AWG. [Example: Omega Model 650].

5.5. Series-connected resistor with a known resistance value to measure the current flow through the test circuit. The power dissipated by this device shall not exceed 10% of its rating during this test. [Example, Dale RH-250, 0.1 Ω, 1%, 250 watt resistor]. The value of the series-connected resistor may exceed the resistance of the assembly being tested. The test voltage may need to be raised to achieve desired test current.

5.6. Various connecting wires, test chamber, etc. as necessary.

5.7. A four-wire ohmmeter to measure the value of the series-connected resistor, and the conductor under test with a resolution of at least 3 significant figures, and an accuracy of at least ± 1% of reading. [Example: Agilent Model 3458A Multimeter].

5.8. Calibrated test equipment to verify, by measurement, the required electrical test parameters.

6.0 TEST SAMPLES

One sample of the protective wire(s), connection(s), and/or trace(s)/via(s) either on a marketable form printed circuit board. Note: the printed circuit board may have some or all components unpopulated to facilitate proper testing.

7.0 PROCEDURES

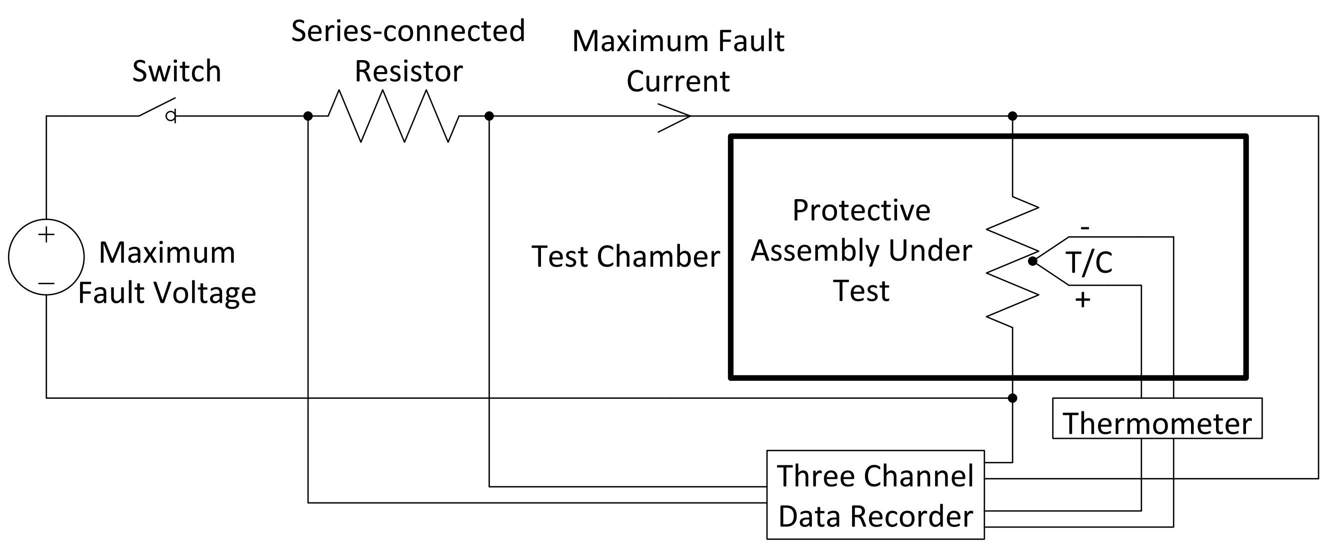
7.1. The test shall be conducted at ambient room conditions of 25 ± 5 °C. Record the ambient room temperature.

7.2. Attach test leads to the sample to be tested for connection to the power supply and series-connected resistor. The test leads must be adequate for the maximum fault current to be applied during the test yet small enough to minimize heatsinking effects. The installation of the test leads must not damage or interfere with the test. The test leads must be connected at a location that allows the test current to flow through the entirety of the protective assembly being tested.

7.3. Disable any components or paths on the printed circuit board sample that are not intended to have test current flow through them. This may require desoldering components, cutting circuit board traces, cutting wires, drilling out vias, etc.

7.4. Measure and record the resistance of the series-connected resistor and the protective assembly under test. The value of the series-connected resistor and circuit connection resistance must be taken into account during the test. Increasing the test voltage may be necessary to obtain the desired maximum fault current.

7.5. Connect the test circuit (see the following diagram) using wiring methods that will minimize the resistance and heat-sinking effects of the test circuit. The test circuit is not to include any current-interrupting devices. Any current-interrupting device that remains after a worst case two-fault analysis is to be accounted for in the calculation of the maximum fault current. Place the test circuit in a location that reduces the likelihood that air currents will affect the surface temperature of the component under test.



7.6. Place the thermocouple junction in secure contact with the surface of the protective assembly under test at a point most likely to be the hottest. If no specific location on the protective assembly can be considered the hottest, place the thermocouple near the center/middle of the conductor. If the conductor is not accessible (e.g. internal to a connector or an internal circuit board trace), place the thermocouple as close as possible to the point considered most likely to be the hottest (e.g. exterior of circuit board above the internal trace). Note: It is recommended that a thermal imaging camera is used to determine the hottest location on the protective assembly.

7.7. Set the open circuit voltage of the power supply to the maximum fault voltage. Record the test voltage.

7.8. Set the short-circuit current of the power supply to the maximum fault current.

7.9. Apply the maximum fault voltage/current to the conductor under test by closing the switch. If the test current does not equal or exceed the maximum fault current, adjust if necessary. Once the maximum fault current is confirmed to be met, continue the test for 1.5 hours. During the test, record the voltage across the protective assembly under test, the voltage across the series-connected resistor (current through the protective assembly under test), and the temperature of the protective assembly versus time.

7.10. At the conclusion of the test, inspect the protective assembly under test for any signs of damage incurred during the test.

7.11. Measure the resistance of the protective assembly under test after it cools to ambient temperature.

8.0 TEST DATA

General

8.1. Ambient temperature.

8.2. Size of thermocouple wire.

8.3. Resistance of the series-connected resistor, and its specified power rating.

8.4. Pre-test resistance of the protective assembly under test.

8.5. Post-test resistance of the protective assembly under test.

8.6. Continuous recording of the voltage versus time across the protective assembly for each test conducted.

8.7. Continuous recording of the current versus time through the protective assembly for each test conducted.

8.8. Continuous recording of the surface temperature versus time of the protective assembly for each test conducted.

8.9. Manufacturer, model, serial number or other identification number and calibration due date (if applicable) for each piece of test equipment.

8.10. Circuit diagram of test being conducted including power supply connection points and thermocouple location(s).

8.11. Simplified schematic diagram and description to describe the critical function of the protective assembly.

8.12. Test schematic diagram to show the interconnection between the test sample and external laboratory equipment (e.g. power supply, switch, etc.).

8.13. Observation of flaming, deformation or any other potentially hazardous behavior.

Protective Wires

8.14. Quantity of wires.

8.15. Overall wire gauge(s).

8.16. Whether the wire(s) is insulated, and the temperature rating of the insulation.

8.17. Conductor material (e.g. copper, tinned copper, etc.).

8.18. Insulation material.

8.19. Whether the wire(s) is solid or stranded.

8.20. If the wire(s) is stranded, the quantity and gauge of the individual strands.

8.21. Unsupported length of wire(s).

Protective Connections

Connectors

8.22. Manufacturer and part number of the connector.

8.23. If manufacturer and part number of the connector is not available, then a reference to a drawing number providing detailed dimensions and materials of the connector.

Wire Connections

8.24. Quantity of connections in parallel.

8.25. Method of attachment of the wire connection to the printed circuit board (e.g. bent over after passing through circuit board and soldered, machine soldered, crimped connection, brazed, or welded).

Soldered Joint

8.26. Length, width, and depth of overlap of the surface mount connection to the solder pad (ref. ACRI2001 section 8.11 for a diagram).

Single Screwed or Bolted Connection

8.27. Material of the connection (aluminum is not permitted).

8.28. Description of the connection construction/assembly.

8.29. Drawing reference to the connection construction/assembly.

<u>Protective Traces/Vias</u>

8.30. Excerpt of electronic file (e.g. Gerber file, PDF file, CAD file, etc.), photograph, or sketch showing exactly what trace(s)/via(s) had current passing through them for the test.

8.31. Specified copper thickness (e.g. ounces, or thickness in microns) of the traces(s)/via(s) being tested.

8.32. Specified/measured length and width of trace(s)/via(s) being tested.

8.33. Specified/measured circuit board material.

8.34. Specified/measured circuit board thickness.

8.35. Specified/measured inner diameter of vias.

8.36. Indication of whether the trace(s) are internal or external (e.g. unexposed to air currents) to the circuit board. Note: Internal trace(s) typically have lower current carrying capacity.

8.37. Indication of whether the vias(s) are blind (e.g. sandwiched between layers of a circuit board and inaccessible from exterior) or open (e.g. accessible from the exterior). Note: Internal via(s) typically have lower current carrying capacity.

8.38. Location of trace(s) on the board (e.g. layer 1, top, or component side, etc.).

8.39. Size of wires used to connect circuit board to test circuit.

8.40. Orientation of the trace during the test (e.g. up or down).

9.0 PASS/FAIL CRITERIA

9.1. Deform in any way (e.g. melting of insulation, delamination of a trace, etc.),

9.2. Flame, or

9.3. Have the protective assembly post-test resistance increase by more than 1000% of the pre-test resistance.

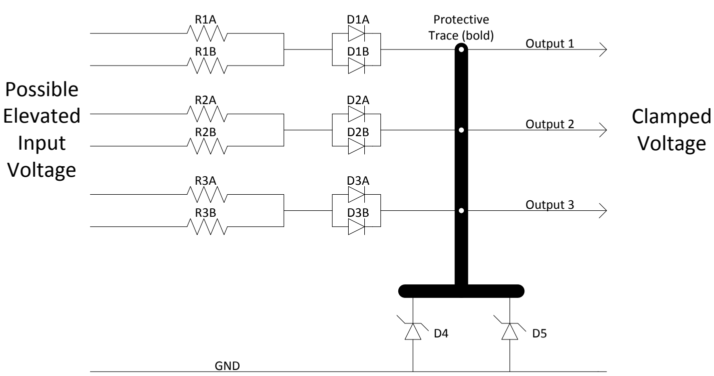
	DATA SHEET NO.	2
	INVESTIGATION	IA-XXXXX
	TEST SHEET NO.	1
	PAR NO.	99999
	COMPANY	John Doe Inc.
	TESTER	ABC
	ASTP NO.	2249
Protective Wire, Connection, and Trace Test	RESULTS	PASS
	DATE	5/2/2015

Subject:

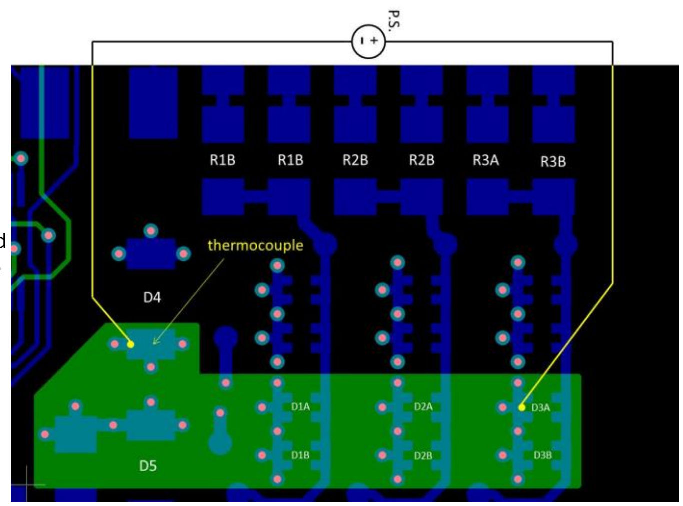
Protective trace test for the trace shown/described below. The trace is critical by preventing one open circuit trace fault from bypassing two clamping diodes (D4 and D5). The trace is located on the XYZ circuit board. A full schematic of the PCB can be found on drawing No. 123. The current to this trace is limited by fuse F1 (0.5 A).

Ambient Temperature	21 degrees C	Pre-test Protective Assy. Resistance	0.0115 ohms
Series-connected Resistor Resistance	0.1043 ohms	Post-test Protective Assy. Resistance	0.0117 ohms

Simplified Schematic



Excerpt of Gerber File of Trace/Via Under Test



In the above Gerber file, the green trace is the protective trace being tested. It is located on the bottom of the PCB. The blue traces are located on the top of the PCB. The vias are shown in pink. Thermocouple placed as shown on bottom of the PCB. The bottom of the PCB was facing up during the test. Two of the three D4 vias and two of the three D3A vias were drilled out to ensure adequacy. The yellow dots were the location where two 24 AWG copper wires were soldered for connection to the power supply. The test sample was completely unpopulated.

Protective Trace/Via Test Data

Circuit Board Material	FR4	Circuit Board Thickness	1.5 mm
Length of Trace	19 mm	Width of Trace	4 mm
Internal or External Trace	External	Trace Copper Thickness	17.5 µm
Via Inner Diameter & Blind/Open Via	0.3 mm (open via)	Via Copper Thickness	15 µm

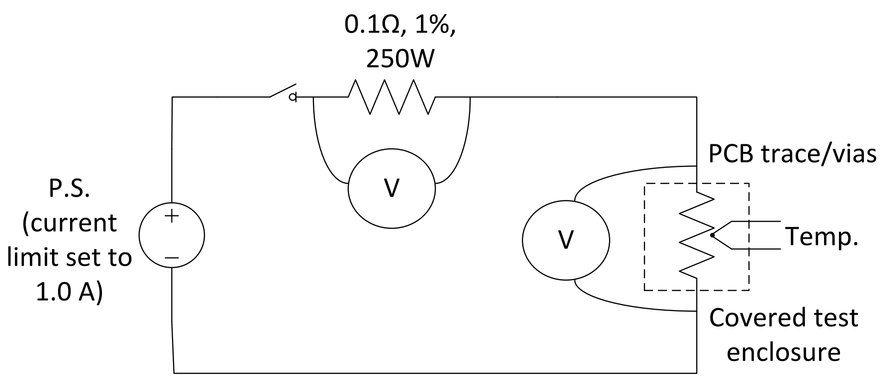
Equipment: Fluke Ti400 IR Camera (Cal. Due 10/31/16) used to determine hottest spot of trace; HP7090A (S/N 1, Cal. Due 10/31/16), Agilent 6038 P.S., Omega Model 650 (S/N 2, Cal. Due 10/31/16). Thermocouple size was 0.010 inches.

Observations/Conclusions: Trace showed no signs of damage, no flaming, and did not increase in resistance by more than 10%.

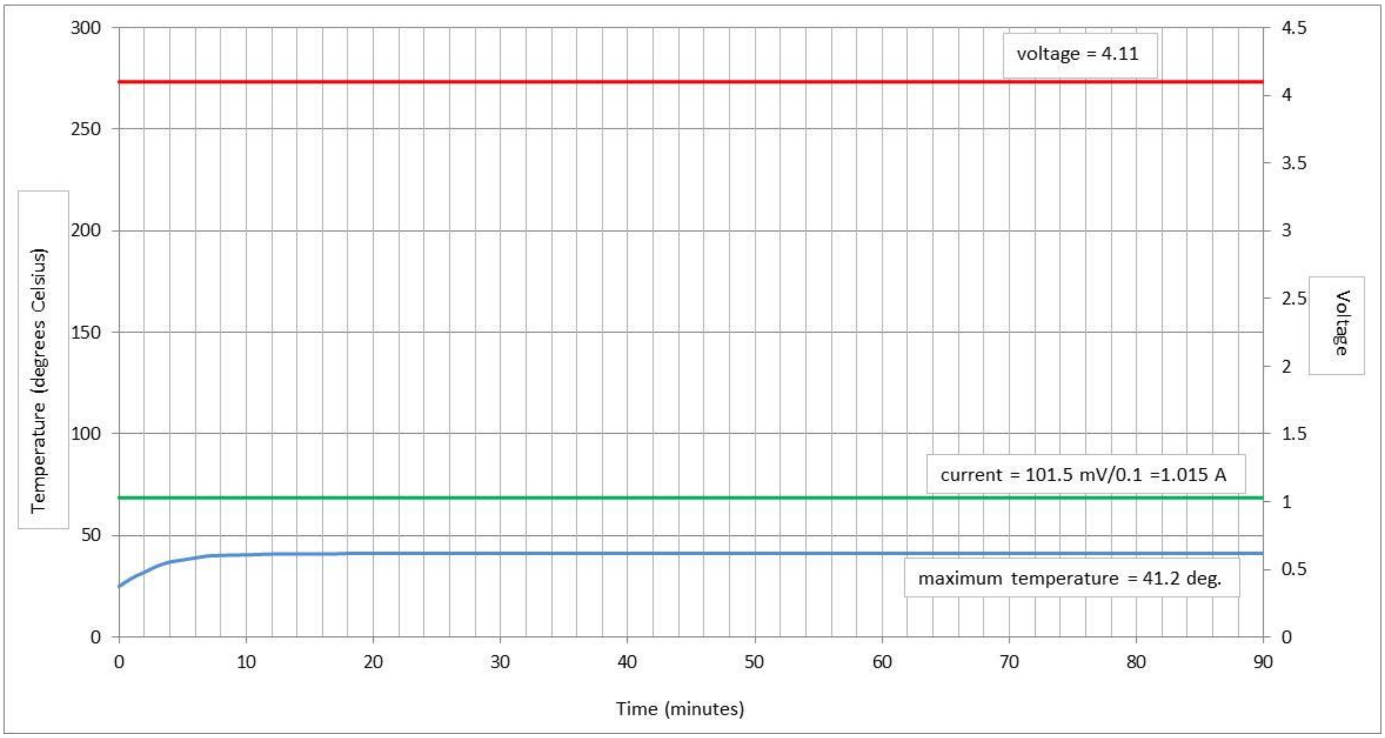
DATA SHEET NO.	2
INVESTIGATION	IA-XXXXX
TEST SHEET NO.	1b
PAR NO.	99999
COMPANY	John Doe Inc.
TESTER	ABC
ASTP NO.	2249
RESULTS	PASS
DATE	5/2/2015

Protective Wire, Connection, and Trace Test (cont'd)

Test Schematic



Voltage/Current/Temperature Measurements Versus Time



United States Department of Labor
MSHA
Mine Safety and Health Administration

DATA SHEET NO.	2
INVESTIGATION	
TEST SHEET NO.	
PAR NO.	
COMPANY	
TESTER	
ASTP NO.	2249
RESULTS	
DATE	

Protective Wire, Connection, and Trace Test

Subject:

Ambient Temperature		Pre-test Protective Assy. Resistance	
Series-connected Resistor Resistance		Post-test Protective Assy. Resistance	

Simplified Schematic

Excerpt of Gerber File of Trace/Via Under Test

Protective Assembly Test Data

Equipment:

Observations/Conclusions:

United States Department of Labor
MSHA
Mine Safety and Health Administration

DATA SHEET NO.	2
INVESTIGATION	
TEST SHEET NO.	
PAR NO.	
COMPANY	
TESTER	
ASTP NO.	2249
RESULTS	
DATE	

Protective Wire, Connection, and Trace Test (cont'd)

Test Schematic

Voltage/Current/Temperature Measurements Versus Time