1.0 PURPOSE

This test procedure is used by the Electrical Safety Division (ESD) for testing of intrinsically safe apparatus to determine if the electrical energy within a circuit is a potential spark ignition source.

2.0 SCOPE

This Standard Test Procedure (STP) is used to conduct spark ignition tests 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. ACRI2011 “Intrinsically Safe Active Voltage/Current Power Source Criteria”

3.3. ASOP2026 “Investigative Procedures for Evaluating Equipment from Mine Explosions”

3.4. 30 CFR Part 18 "Electric Motor-Driven Mine Equipment and Accessories"

3.5. 30 CFR Part 19 "Electric Cap Lamps"

3.6. 30 CFR Part 20 "Electric Mine Lamps other than Standard Cap Lamps"

3.7. 30 CFR Part 22 "Portable Methane Detectors"

3.8. 30 CFR Part 23 "Telephones and Signaling Devices"

3.9. 30 CFR Part 27 "Methane-Monitoring Systems"

4.0 DEFINITIONS

4.1. **Critical component** – A protective component or significant energy-storing component that affects the energy at the point of test.

4.2. **High frequency / high voltage circuit** - A test circuit operating at more than 60 Hertz or 24 volts peak.

4.3. **Inductive circuit** – For calibration purposes, it is a circuit having an inductance value greater than 5 μH. Note: The 5 μH threshold is only a dividing line used to determine the type of calibration for the test. It does not mean that inductances of 5 μH or less may be neglected.

4.4. **Point of test** - The place in the test circuit where the spark test apparatus is inserted to simulate an interruption, short-circuit or fault to ground occurring in the hazardous location to determine if the electrical energy is intrinsically safe.

4.5. **Programmable Logic Controlled (PLC) spark test apparatus** – This is a spark test apparatus meeting the construction requirements of Section 5.1 of this test procedure with the addition of a PLC used to control the drive motor that operates the electrode and disc shafts. The PLC has inputs that allows the user the ability to stop and start the spark test apparatus drive motor to aid in testing unusual circuits, such as: active current-limited circuits that would shut down upon short circuiting and require a stoppage in order to reset; or, circuits with large values of inductance and/or capacitance that require stoppage to reach steady-state current or charge voltage.

4.6. **Representative sample** – A component provided by the applicant that will be used in the test circuit (e.g., solenoid, motor, speaker, etc.).

4.7. **Safety factor** – A factor used to ensure that the circuit that is being evaluated and tested in the laboratory environment is demonstrably more likely to cause ignition than the equipment that will be used in the field. For the purposes of this document, and as required by ACRI2001 and ACRI2011, a safety factor on energy is required at the point of test for 0 and 1 fault scenarios. It is not acceptable for the input voltage and current to be raised if this effect is not observed at the point of test (ref. Appendix point 4). The use of a more easily ignitable test gas, such as propane, hydrogen, or oxygen-enriched methane-in-air mixtures, shall not be used to obtain the safety factor.

4.8. **Suitable component** - An electrical component of the test circuit that will sustain the required electrical energy at the point of test throughout the spark ignition test.

4.9. **Test circuit** - An electrical circuit constructed of suitably rated components used to simulate the electrical characteristics of the circuit being evaluated for intrinsic safety.

5.0 TEST EQUIPMENT

5.1. Spark Test Apparatus complying with IEC Publication 60079-11 (2011), Annex B: "Spark test apparatus for intrinsically safe circuits".

5.2. Gas mixing equipment with the capability to provide the desired test gas concentration. [Matheson Multiple Dyna-Blender 8284]

5.3. A source of methane gas having a purity of at least 95 %.

5.4. A clean, dry source of air having an oxygen content of 21 (± 0.5) % by volume. [Aadco Model 737 Pure Air Generator]

5.5. Electrical power source having sufficient voltage and current capacity to sustain the minimum required electrical energy at the point of test throughout the spark ignition tests.

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

5.7. Adequately rated non-inductive resistors for limiting the current during calibration and, if necessary, during testing.

5.8. Air core inductance of 100 mH (± 10 %) for performing inductive calibrations.

5.9. Gas analyzer with a range of at least 0 to 10 % volume methane-in-air; a resolution of at least 0.01 % volume methane-in-air, and accuracy of at least ± 0.05 % volume methane-in-air [Horiba Model VIA-510].

5.10. Gas to calibrate the gas analyzer with a traceable accuracy of at least 0.01 % volume methane-in-air.

5.11. Digital thermometer with a minimum resolution of 0.2 degree Celsius and minimum range from 0 to 40 degrees Celsius [Omega Model 650].

5.12. A flow meter for measuring the test gas with a range of at least 2 liters per minute and a resolution of at least 0.01 lpm. [Sensidyne/Gilian Gilibrator 2]

5.13. Stopwatch for measuring the wire electrode holder revolutions per minute, and for calculating number of cycles; if not calculated and displayed by the spark test apparatus.

6.0 TEST SAMPLES

Test circuit constructed of suitable components and representative samples.

7.0 PROCEDURES

7.1. The calibration(s) and test(s) shall be conducted in an ambient temperature of 25 ± 5 degrees Celsius. Record the ambient temperature.

7.2. Pre-test Preparation. The following steps describe the proper procedure for selecting the disc material, wire electrode size and quantity, inspecting the spark test apparatus, and setting the test gas.

Note: After successful completion of a pre-test calibration, the spark test apparatus is not to be adjusted in any way prior to testing the test circuit. Adjustment of the spark test apparatus would include: replacing or adjusting the electrodes, adjusting the carrier or component flow rates, adjusting or replacing the disc, or opening the spark ignition test apparatus ignition chamber. If changes must be made, they may only be done after the completion of a test or part of a test (e.g. post-test calibration obtained). If adjustments are made, a successful pre-test calibration must again be obtained before retesting.

7.2.1. Disc Material Selection and Conditioning

7.2.1.1. Select the type of disc material to be used in the spark test apparatus. A copper disc will be used for one of the two tests performed on high voltage/high frequency circuits (see Appendix). All other circuits are required to use a cadmium disc. Record the type of disc used throughout testing.

For accident investigations, a brass disc is to be used (ref. ASOP2026).

WARNING: CADMIUM IS A TOXIC METAL.
You must use caution when sanding the cadmium disc to avoid inhaling cadmium dust particles. Wash hands after handling cadmium.

7.2.1.2. Verify the disc is clean and is not damaged. If necessary, clean the disc with sandpaper.

7.2.1.3. If the disc is new, it may be conditioned by connecting it to the circuit specified in 7.3.1.1 for tests requiring inductive calibration or the circuit specified in 7.3.1.2 for tests requiring resistive calibration, while being run in air for a minimum of 20,000 revolutions.

7.2.1.4. Secure the disc to the proper rotating shaft of the spark test apparatus using a set screw so that the top of the disc is 10 (± 1.0) millimeters from the lower edge of the wire electrode holder as shown in 7.2.2.4.

7.2.2. Electrode Selection

7.2.2.1. Calculate the current at the point of test to determine the proper electrode size and material to be used according to the following table. Record the size and type of material of electrodes used throughout testing.

Expected Test Current	Wire Electrode Size and Material
Less than 5 amperes	8 mil (0.008 inch diameter) Tungsten
5 to 10 amperes	10 mil (0.010 inch diameter) Tungsten
Greater than 10 amperes	No. 24 AWG Copper

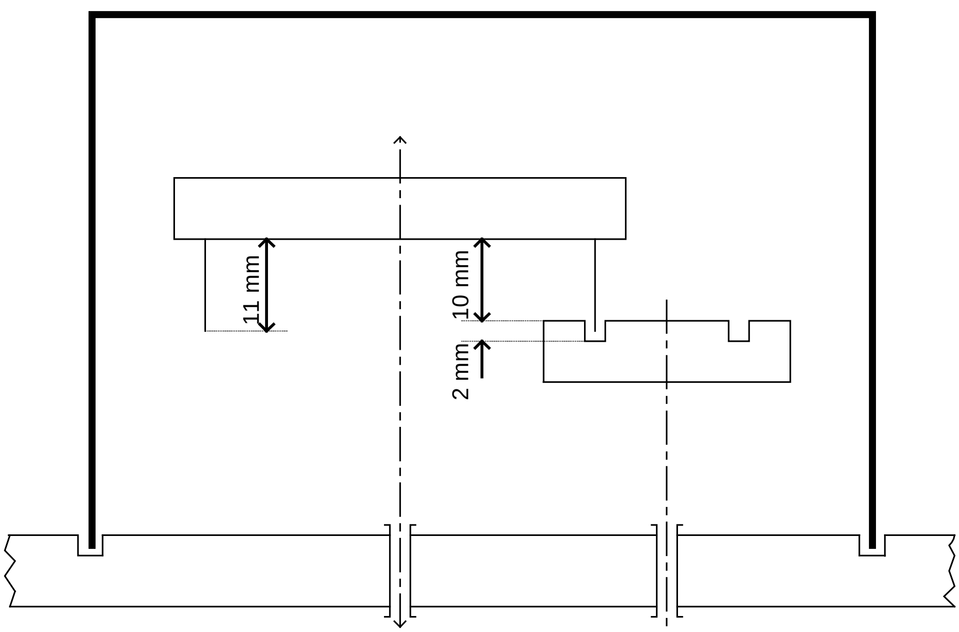
For accident investigations, only 8 mil tungsten (currents up to 5 amperes) or copper (currents over 5 amperes) are to be used for the electrodes (ref. ASOP2026).

7.2.2.2. Select the number of wire electrodes to be used in the spark test apparatus. Generally, four wire electrodes will be used. However, one or two electrodes may be used in order to allow for adequate charging time of capacitive circuits, or to allow more time for batteries to recover. Record the number of wires used throughout testing.

7.2.2.3. Verify none of the wire electrodes are damaged (e.g. bent or split) or worn. Replace wire electrodes as necessary. See Section 7.5 for the proper procedure for preparing tungsten electrodes. The No. 24 AWG copper electrodes need no special preparation since they do not split or fray, and only need to be cut to desired length.

7.2.2.4. Secure each wire electrode to its holder so that each electrode overlaps the disc 1 (± 0.5) millimeters as shown below.

Note: It may be necessary to have an increased overlap when copper wires are used in the wire electrode holder so that make and break contact between the electrodes is maintained throughout the spark ignition test.



7.2.2.5. After installing new electrodes, run the spark test apparatus for approximately 40 cycles to verify the electrodes have no brittle ends. If necessary, repeat sections 7.2.2.3 and 7.2.2.4.

7.2.3. Spark Test Apparatus Inspection. Verify the spark test apparatus is clean; all gas mixture ports and lines are properly connected and are not obstructed; the mechanical drive mechanism operates smoothly; brushes are clean and are firmly connected to the electrode/disc shafts; all seals and gaskets are properly seated and are in good condition; and, the speed of the wire electrode is set to 80 (± 2) revolutions per minute. Clean, repair, adjust, or replace as necessary.

7.2.4. Test Gas. The standard test gas is 8.3 (± 0.2) % methane-in-air by volume. Record the test gas used throughout testing.

7.2.5. Test Gas Setting

7.2.5.1. Set the gas mixing equipment to provide a carrier (air) flow rate of 2.0 (± 0.5) liters/minute.

7.2.5.2. Adjust the gas mixing equipment to provide a component (methane) flow rate to achieve the proper test gas concentration. This will be approximately 0.18 liters/minute for methane. The gas analyzer may be used to verify the proper test gas concentration.

Note: Allow the test gas mixture to flow through the spark test apparatus ignition chamber for at least one minute before starting each spark ignition test or calibration test.

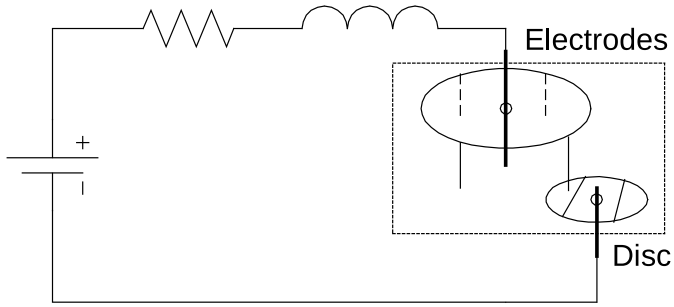
7.3. Calibration Test Procedure. The calibration of the spark test apparatus must be verified by the following procedure before, and immediately following, each spark ignition test for a circuit to pass testing. Neither a pre-test nor post-test calibration is required for a circuit to fail testing.

Note: Be sure to connect the wire electrode holder at positive polarity as shown for the entire calibration.

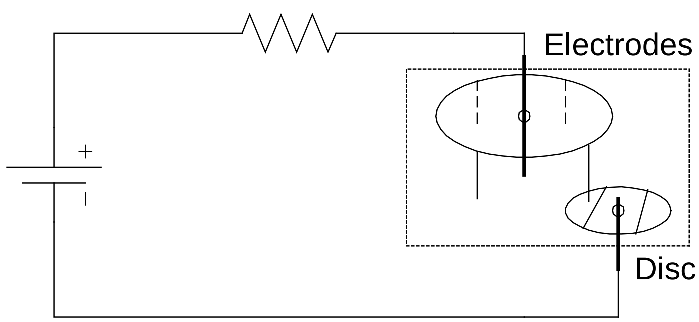
Note: A pre-test calibration is only valid for 1.5 hours of spark ignition testing (e.g. all testing must be completed within 1.5 hours from the time the pre-test ignition was obtained), and the post-test calibration procedure must be initiated within 15 minutes of test completion.

7.3.1. If the circuit to be tested contains an inductive component that is greater than 5 μH, the calibration test circuit shall be set up according to 7.3.1.1. If the circuit to be tested contains 5 μH of inductance or less, the calibration test circuit shall be set up according to 7.3.1.2. Record the method used to calibrate the spark test apparatus (i.e. resistive or inductive). Also record the voltage and current measured at the point of test.

7.3.1.1. Inductive Calibration. Connect the spark test apparatus in series with a 100 mH (± 10) air core inductor, and a 24 (± 0.1) volt DC power source (either a battery or DC power supply) that is current limited by non-inductive resistors to 106 (± 1) mA for a methane-air test gas as follows:



7.3.1.2. Resistive Calibration. Connect the spark test apparatus in series with a 24 (± 0.1) volts DC power source (either a battery or DC power supply) that is current limited by non-inductive resistors to 1.45 (± 0.05) amperes for a methane-air test gas as follows:



7.3.1.3. The following table summarizes the above parameters to be used for methane-air mixtures and also provides the parameters to be used for the calibration involving the use of a copper disc when testing high frequency/high voltage circuits (see Appendix):

Test Gas	Disc Material	Resistive Calibration	Inductive Calibration
8.3 % methane-air	Cadmium	1.45 (± 0.05) amperes	106 (± 1) milliamperes
8.3 % methane-air	Copper	3.6 (± 0.1) amperes	160 (± 1) milliamperes

For accident investigations, the calibration currents when utilizing a brass disc and either 8 mil tungsten or 24 AWG electrodes are 3.6 (± 0.1) amperes and 160 (± 1) milliamperes for resistive and inductive calibrations, respectively.

7.3.2. Start the spark test apparatus and verify the wire electrode holder speed is still set to 80 (± 2) revolutions per minute. Note: No Programmable Logic Controller (PLC) on or off dwell times of the spark test apparatus are to be used for pre- or post-test calibrations.

7.3.3. Continue running the spark test apparatus until either an ignition of the test gas occurs or after 400 cycles (assuming 4 electrodes are used) of the wire electrode holder have been completed (5 minutes if using a stopwatch), whichever occurs first. If fewer than 4 electrodes are used, then the number of revolutions shall be increased. Three electrodes will require 534 revolutions (6 minutes and 41 seconds), 2 electrodes will require 800 revolutions (10 minutes), and one electrode will require 1600 revolutions (20 minutes). Stop the spark test apparatus, and record the number of cycles of the wire electrode holder (1.333 times the elapsed time in seconds if using a stopwatch).

Number of wire electrodes	Number of calibration cycles
4	400
3	534
2	800
1	1600

Note: Three electrodes are generally not used. However, three may need to be assumed if one of four breaks at an unknown time.

7.3.4. Disconnect the calibration circuit from the spark test apparatus.

7.3.5. If ignition of the test gas did not occur within 400 cycles, corrective actions must be taken until a calibration is achieved. The following should be checked:

- Proper test gas mixture
- Accurate voltage or current readings

- Condition and position of the wire electrodes (replace as necessary)
- Condition of the disc
- Electrical connections within the calibration test circuit
- DC resistance less than 50 milliohms through the spark test apparatus as measured with a wire electrode contacting the disc
- Leakage currents (as detected by a 500 volt dielectric withstand test applied between the wire electrodes and the disc under open-circuit conditions
- Leakage of the test gas including the gasket around the ignition chamber
- Correct disc and electrode materials

Note: The following may also have an influence on the ability to calibrate the spark test apparatus: oxygen content of the carrier gas (air), and environmental conditions such as temperature, pressure, and humidity

7.3.6. Replace and adjust as necessary, and repeat the calibration test procedure.

7.4. <u>Spark Test Procedure</u>

7.4.1. Connect the test circuit to the spark test apparatus. The test circuit shall be constructed of suitable components and representative samples to simulate the worst-case normal or fault condition of the circuit being evaluated for intrinsic safety as determined by circuit analysis.

7.4.1.1. Measure and record the electrical parameters of each representative sample of the critical components submitted by the applicant for test. Compare these measured values with the applicant's specifications for these components. If one or more samples are not within their relevant specifications; or, if all of the samples have an inductance value significantly lower than its specified nominal value or a resistance value significantly higher than its specified nominal value, suspend testing.

7.4.1.2. Select for test a sample(s) of the component having the highest inductance, the lowest resistance or that would store the most energy as determined by calculation or test.

7.4.2. Measure and record the value of each critical and suitable component.

7.4.3. Describe the normal or fault condition(s) simulated by the test circuit. Include a schematic diagram of the test circuit on the test sheet. Identify each critical component in the test circuit. Photographs may also be taken to aid in describing the test circuit.

7.4.4. Apply the appropriate safety factor to the test circuit if less than 2 faults have been applied. Record the method used to attain the safety factor. Note: The safety factor must be observed at the point of test (e.g. at the spark test apparatus terminals) (ref. Appendix point 4).

Note: A safety factor is not applied for accident investigations (ref. ASOP2026).

7.4.5. Measure and record the input voltage and current.

7.4.6. Measure and record the voltage and current at the point of test. For circuits with currents in excess of 10 amperes, the current at the point of test shall be measured through the complete circuit, including electrode to disc contact resistance. An acceptable method of measuring current in excess of 10 amperes is to measure the voltage drop across a known, suitable resistor that is included in the test circuit while an electrode is on the disc.

Note: A representative waveform may be necessary to describe a transient voltage or current.

7.4.7. Reset and start the spark test apparatus counter or stopwatch. Make appropriate periodic measurements of the electrical parameters in the test circuit (at least every 500 cycles) to assure that the electrical energy at the point of test is maintained throughout the spark ignition test. If the electrical energy at the point of test is not being maintained (e.g. the current at the point of test falls below 90 % of the starting value), the following controls must be employed:

- Interrupt the test, as necessary to prevent components from overheating,
- Replace or recharge batteries, or

- Cool overheated components with a fan, by submersing the component in oil, by heatsinking, or by placing in an environmental chamber for cooling

Note: The spark test apparatus is not to be cooled. It must remain at ambient temperature.

7.4.8. The following table indicates at what cycle of the test to reverse polarity at the point of test, and when the test is complete depending on the number of electrodes used.

Number of wire electrodes	Number of cycles to reverse polarity	Number of total test cycles
4	500	1000
3	667	1334
2	1000	2000
1	2000	4000

Note: Three electrodes are generally not used. However, three may need to be assumed if one of four breaks at an unknown time.

7.4.9. Reverse the polarity of the spark test apparatus at the midpoint of the test. Measure and record the input voltage and input current to the test circuit and the voltage and current at the point of test.

7.4.10. Stop the spark test apparatus immediately after ignition of the test gas or at the completion of the test. Record the number of completed cycles of the wire electrode holder. Measure and record the input voltage and input current to the test circuit and the voltage and current at the point of test.

7.4.11. Post-test calibration test. If the test circuit did not cause the test gas to ignite, conduct a calibration of the spark test apparatus per Section 7.3. If a post-test calibration is not obtained, the spark test shall be considered invalid.

Note: If the test circuit fails by igniting the test gas, a post-test calibration is not required.

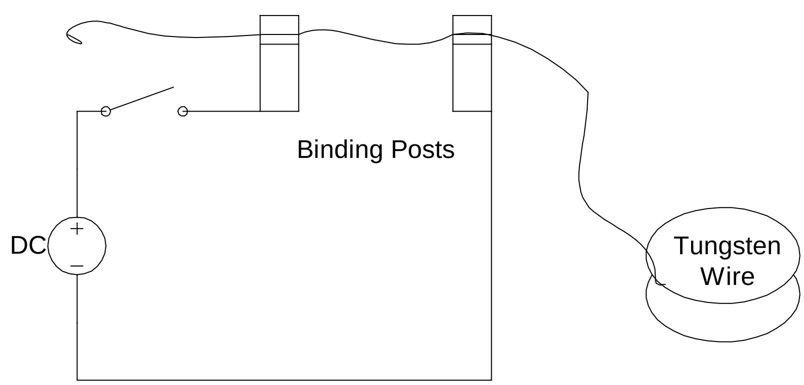
7.5. <u>Tungsten Electrode Preparation (if necessary)</u>

Note: The following is the procedure used by MSHA. Alternative forms of electrode preparation may be used provided they result in equivalent electrodes from both an electrical and mechanical standpoint.

WARNING: BURN HAZARD. **You must exercise caution when inserting and removing the wire from the binding posts. Be certain that the switch is open prior to handling. Also, shield the wire so that the hot, flying debris does not cause personal and/or property damage.**
WARNING: BRIGHT LIGHT. **You must not look at the wire while fusing which may cause permanent damage to your eyes.**
WARNING: TOXIC FUMES. **You must vent the smoke/fumes created from burning the tungsten wire to prevent inhalation.**

7.5.1. Set a power supply voltage to 30 (± 5) volts, and the short-circuit/overcurrent setting of the power supply to 10 (± 2) amperes.

7.5.2. Connect the circuit shown below:



7.5.3. With the switch open and without cutting the tungsten wire, place the free end of the wire from the roll into two binding posts separated by 1.5 (± 0.25) inches.

7.5.4. Close the switch until the high current fuses (burns open) the tungsten wire.

7.5.5. Open the switch and remove the tungsten wire from the binding posts.

Note: The "beads" or brittle portion of the electrode formed from the melting of the tungsten wire may be removed at this time.

7.5.6. Repeat the above procedure until the necessary number of electrodes is formed. The desired length of the electrode after fusing both ends and removing the brittle portion is approximately 2 inches.

8.0 TEST DATA

8.1. Ambient temperature.

8.2. Description of the circuit under test. This narrative description is to identify the applicant/company of the circuit or component tested, the model or part number of the circuit or component tested, the type of equipment, and identify each faulted component and its failure mode in the test circuit (when testing under fault conditions). State if the circuit was tested in normal operation, one fault, two faults, or more than a two fault condition.

8.3. Method of applying the safety factor to the point of test in the circuit (if less than two faults are applied). The safety factor at the point of test in the circuit is to be verified by in-circuit electrical measurements.

8.4. Electrical parameters of each critical component in the test circuit (e.g. current/power ratings, measured resistance, measured inductance, measured capacitance, measured Equivalent Series Resistance (ESR) of capacitors, etc.).

8.5. Electrical schematic diagram of the test circuit including the point of test in the circuit. Each critical component shall be identified and referenced to a component or components on a drawing or parts list.

8.6. Optional photograph(s) showing the test circuit.

8.7. Measurements of the input voltage and current to the test circuit.

8.8. Voltage and current measurements at the point of test for each time the test is interrupted (e.g. start of test, midpoint of test, and end of test, at a minimum), and the number of completed cycles of the wire electrode holder for each portion of test (including cycles until an ignition, if applicable). A representative waveform may be necessary to describe a transient voltage or current.

8.9. List of all test instruments used, their serial numbers, and calibration due dates (if applicable).

8.10. Wire electrode material (8-mil tungsten, 10-mil tungsten, or No. 24 AWG copper), quantity of electrodes, disc material (cadmium or copper), and test gas mixture (8.3 % methane-air).

8.11. Method used to calibrate the spark test apparatus (resistive or inductive), parameters of the calibration circuit (e.g. voltage, current, and inductance if applicable), and the number of completed cycles of the wire electrode holder for each calibration.

8.12. Speed of the spark test apparatus for the testing, and whether PLC dwell-on or dwell-off features were used as well as these times.

8.13. Laboratory name and location if done at a location different from the laboratory preparing the test sheet.

9.0 PASS/FAIL CRITERIA

9.1. A test circuit passes if it does not ignite the test gas during the spark ignition test. The spark ignition test is valid only if there was a successful calibration test immediately before and after the spark ignition test.

9.2. An ignition during spark ignition testing is a failure regardless of whether a pre-test or post-test calibration is obtained.

Appendix

General

1. Components that may overheat may be cooled by a fan, attached to a heatsink, submerged in an ice or oil bath, cooled through the use of an environmental chamber, or the spark ignition test be can be periodically interrupted to allow the components to cool.

2. The electrical ratings of critical components should not be exceeded during the spark ignition tests. Suitably-rated components used in place of actual circuit components must have similar electrical characteristics to those components specified in the approval documentation such that the energy waveform at the point of test has similar characteristics (i.e. the voltage and current waveforms will vary only in magnitude, not waveshape, after the voltage or current is increased to establish a safety factor for testing).

3. The safety factor of 1.5 on energy at the point of test is to be achieved by one of the following methods:

   Resistive circuits. For spark ignition testing of resistive circuits having an inductance value less than or equal to 5 μH, the energy at the point of test shall be increased by a factor of 1.5 in order of preference as follows:

   - Increase the test voltage by the square root of 1.5,
   - Decrease the value of limiting resistance to obtain 1.5 times the test current at the point of test,
   - Increase both the voltage and current (by decreasing the limiting resistance) to obtain the 1.5 safety factor on energy at the point of test.

   Inductive circuits. For spark ignition testing of inductive circuits, the energy at the point of test shall be increased by a factor of 1.5 in order of preference as follows:

   - Increase the supply voltage by the square root of 1.5 to attain the test current at the point of test,
   - Decrease the value of limiting resistance by the square root of 1.5 to attain the test current at the point of test.

Capacitive circuits. For spark ignition testing of capacitive circuits, the energy at the point of test shall be increased by a factor of 1.5 by increasing the voltage by the square root of 1.5.

4. For obtaining an adequate safety factor at the point of test, it is not acceptable for the input voltage and current to be raised if this effect is not observed at the spark test apparatus terminals. For example, a solenoid that requires testing of the coil contains triplicated 13-volt zener diodes across it would need to have the reverse voltage rating of the zener diodes increased appropriately to allow (for example) the safety-factored 16-volt power supply voltage to be applied to the coil. An acceptable way of accomplishing this is replacing the nominal 13-volt zener diodes with 16-volt zener diodes from the same diode series/family. Without making this substitution of zener diodes, the current through the solenoid coil would not be safety-factored. The safety-factored input voltage would be clamped by the 13-volt zener diodes which would not be acceptable for this test. One 13-volt zener diode for the situation described above may be left in the circuit for a ‘two-fault’ test that does not require the application of a safety factor. Both situations (2 faults without safety factor and 1 fault with safety factor) must be considered in the evaluation of the circuit.

5. A safety factor may be applied to a test circuit simulating a two fault or worst-case fault condition if it simplifies or reduces the number of spark ignition tests. However, if the test circuit ignites the test gas with 2 or more faults applied and with a safety factor applied, it does not mean the circuit should be considered a potential spark ignition hazard. Additional spark ignition tests may be required to determine the intrinsic safety of the circuit under normal, one fault and two fault conditions.

6. Special consideration must be given to non-linear power source outputs where a graph of the output voltage versus current is not linear (ref. ACRI2011). These special cases include power sources that employ active current-limiting or that have trapezoidal shaped output graphs.

High frequency/high voltage circuits

7. When testing AC electrical circuits with the voltage level or frequency exceeding 24 volts peak or 60 Hz, respectively, the test conditions at the point of test shall be modified only by electrical means to achieve the required safety factor. Only 8.3 % methane-air mixtures shall be used as the test gas. The use of a more easily ignitable test gas shall not be used to attain the safety factor. The test procedure shall be conducted twice as follows:

- Conduct the calibrations and spark test procedure with appropriately sized tungsten electrodes and a cadmium disc.

- Conduct the calibrations and spark test procedure with 24 AWG copper electrodes and a copper disc.

Battery powered circuits

8. When conducting tests that require applying a safety factor of 1.5, one of the following methods, or their equivalents, shall be used:

   a. Additional individual cells identical to the cells used in a multi-cell battery pack may be added in series and/or parallel, as appropriate, to yield a simulated battery with at least 1.5 times the capacity of the battery used in the apparatus; or

   b. The battery voltage or current values, as appropriate, may be simulated with a suitable power supply or high capacity battery and the values increased so that the energy level is increased by a factor equal to 1.5; or

   c. The intended batteries may be used either two in series for double voltage or two in parallel, as appropriate, yielding a safety factor greater than 1.5.

   Note: Method "c" may be a more stringent test than methods "a" and "b" but may be used if it simplifies testing. Failure to pass this test does not imply the circuit is unsafe. Intrinsic safety may be determined by use of method "a" or "b".

9. When batteries are used for spark ignition test, at least four tests with fresh or fully-charged batteries, two for each polarity, shall be conducted.

10. For the purpose of evaluation and test, the battery voltage shall be considered to be the maximum open circuit voltage of a fresh, fully-charged battery based on measurement, the manufacturer's specifications, or voltages listed in ACRI2001, whichever is greater.

11. The battery short circuit current shall be the maximum current under short circuit conditions as determined by the Battery Flash Current Test of ASTP2202.

12. A suitable DC power supply or high-capacity battery may be used to simulate a battery supply in the test circuit.

13. If the intrinsically safe circuit is powered by non-rechargeable (primary) batteries, the test circuit may be powered by a modified battery assembly

containing batteries identical to the batteries specified in the approval documentation. This modified battery assembly shall be constructed of an appropriate number of battery cells connected in parallel and/or series to sustain the minimum required electrical energy at the point of test throughout each spark ignition test. Each test shall be conducted with fresh, fully-charged batteries in the modified battery assembly.

Note: If the minimum number of batteries connected in series causes the battery voltage to be increased significantly higher than the required test circuit voltage and the test circuit ignites the test gas, this does not imply that the circuit should be considered a potential spark ignition hazard without conducting further tests using a power supply or high-capacity battery. For example, an intrinsically safe circuit powered by a nominal 12-volt lantern battery (open-circuit voltage 14-volts) is to be used to supply 17.1 volts (14 V x √1.5) to the test circuit. The modified battery assembly would likely be greater than 24 volts (12 V * 2 batteries) because the minimum number of batteries required to supply the required test voltage would be two. In this case, the circuit would have been tested with a safety factor more than two times the required 1.5 safety factor.

Capacitive Circuits

14. The test shall be set up such that all significant energy storing capacitors in the test circuit have sufficient time to assure the capacitors are completely charged prior to a wire in the spark test apparatus contacting the disc. The number of wires in the wire electrode holder may be reduced to two wires (located on opposite sides of the holder) or to one wire to allow sufficient time for the capacitors to recharge. If either of these methods does not provide the required charging time for the capacitors, one wire can be used in the spark test apparatus or the spark test apparatus stopped for an appropriate delay period each cycle while the wire is not contacting the disc. If this method is used, the speed of the make-break between the wire electrode and disc shall be the same as in normal testing without stopping the spark test apparatus. The number of revolutions of the wire electrode holder in the spark test apparatus shall be increased four times (4000 cycles) if one wire is used and two times (2000 cycles) if two wires are used in the spark ignition test. The voltage across the capacitors should be monitored during the spark ignition test set-up.

Note: A Programmable Logic Controlled (PLC) spark test apparatus that includes the ability to stop the spark test apparatus electrodes off the disc may be used as an alternative to removing electrodes to allow adequate capacitor charging time. If this PLC method is used, the fact this was used as well as the dwell-off time setting should be documented on the test sheet.

15. The Equivalent Series Resistance (ESR) of any capacitors used in testing should be measured and documented on the test sheet. The ESR is critical in knowing since the resistance in the discharge path of capacitors (both internal and external resistance) can have an effect on the spark test results (ref. circuit shown with Figure 11.4 of ACRI2001).

Inductive Circuits

16. The current at the point of test shall be adjusted to draw maximum documented current considering worst case tolerance. For example, a spark ignition test of four parallel connected 80 ohm (± 5 %) solenoids at 16 volts shall be adjusted to draw 0.842 amperes [16 volts/(80 ohms * 0.95 tolerance/4)] at the point of test. One acceptable way to achieve the increased current is to raise the input voltage. Another acceptable way to achieve increased current is to cool the coils (e.g. environmental chamber) to a point that the desired current is reached. If one or more samples are not within their relevant specifications for inductance; or, if all of the samples have an inductance value significantly lower than its specified nominal value, request clarification from the applicant. The discrepancies can be resolved by revising the specifications or documenting how the measurements are to be determined to verify that the samples of the components tested by MSHA represent the components used in the final assembly of the product.

Note: The spark test apparatus is not to be cooled. It must remain at ambient temperature.

17. Electric motors shall be tested in a locked rotor condition if this represents the worst-case test condition. The worst-case test condition may be determined by measuring the input current to the motor under normal load, no load and stalled conditions. The condition that draws the highest current is likely to be the worst-case condition for spark ignition testing. If the worst-case condition cannot be ascertained, conduct several spark ignition tests of the motor under various load conditions.

18. When testing inductive components with a high inductance, it may be necessary to also test by stopping the wire electrode on the disc to allow the test current to reach steady-state value prior to leaving the disc. If this method is used, the speed of the break between the wire electrode and disc shall be the same as in normal testing (e.g. 80 RPM) without stopping the spark test apparatus. If

manual starting and stopping of the apparatus is used, this should be documented on the test sheet.

Note: A Programmable Logic Controlled (PLC) spark test apparatus that includes the ability to stop the spark test apparatus electrodes on the disc may be used as an alternative to manually starting and stopping the spark test apparatus. If this PLC method is used, the fact this was used as well as the dwell-on time setting should be documented on the test sheet.

19. When testing inductive components with a high inductance (e.g. relays or solenoids), the current waveform shall be viewed with an oscilloscope to determine the worst case test scenario. For example, a solenoid's inductance may be higher with the actuator blocked either in or out.

Other component considerations

20. Current interrupting devices such as fuses, circuit breakers, PTCs, etc., are considered not effective to prevent a spark ignition hazard. They shall be removed or bypassed during spark ignition testing.

21. Oscillators, particularly those used in DC-to-DC converters, shall be tested considering the worst-case tolerance values and faults of associated components used to set the voltage output of the circuit. Some DC-to-DC converters are known to generate very high voltages when not properly biased. NOTE: The requirements for high frequency / high voltage circuits may be applicable.

The spark ignition testing of circuits powered by constant voltage transformers shall be conducted using the maximum voltage and current from the transformer considering the tolerance value and faults of capacitors across the transformer windings. Some constant voltage transformers are known to have secondary voltages much greater than its specified voltages when certain capacitors connected to the transformer windings are open-circuited.

United States Department of Labor
MSHA
Mine Safety and Health Administration

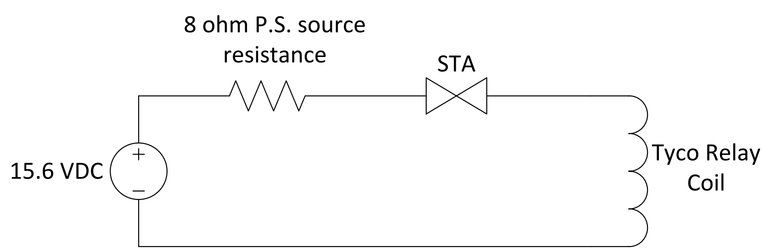
DATA SHEET NO.	2
INVESTIGATION	IA-XXXXX
TEST SHEET NO.	1
PAR NO.	99999
COMPANY	John Doe Inc.
TESTER	ABC
ASTP NO.	2232
RESULTS	PASS
DATE	5/2/2014

SPARK IGNITION TEST

Subject:

Spark test conducted with simulated safety factored power supply output powering the Tyco P/N V23076-A1001-C133 relay and one fault applied by opening the freewheeling diode connected in parallel to the relay coil.

TEST CIRCUIT



CIRCUIT PARAMETERS:

Measured relay resistance = 94.3 ohms

Measured relay inductance = 125.7 mH
R = eight 1 ohm, 1%, 250 W bench resistors

Maximum P.S. output = 12.72 volts
S.F. obtained by increasing P.S. output Voltage by SQRT (1.5)

P.S. source resistance consists of the Minimum resistance including tolerance of R1 and R2 on drawing A123

REFERENCE: DRAWING NO. REV.

TEST PARAMETERS:
8.3 % METHANE-AIR TEST GAS
FOUR 8-MIL WIRE ELECTRODES
CADMIUM DISC
INDUCTIVE CALIBRATION

TEST EQUIPMENT:
Fluke 27 Multimeter S/N 12 (cal.due 10/31/14)
Matheson Model 8284 Dynablender S/N 23
Gilibrator 2 S/N 25 (cal. Due 10/31/14)
Sencore LC103 S/N 76 (cal.due 10/31/14)

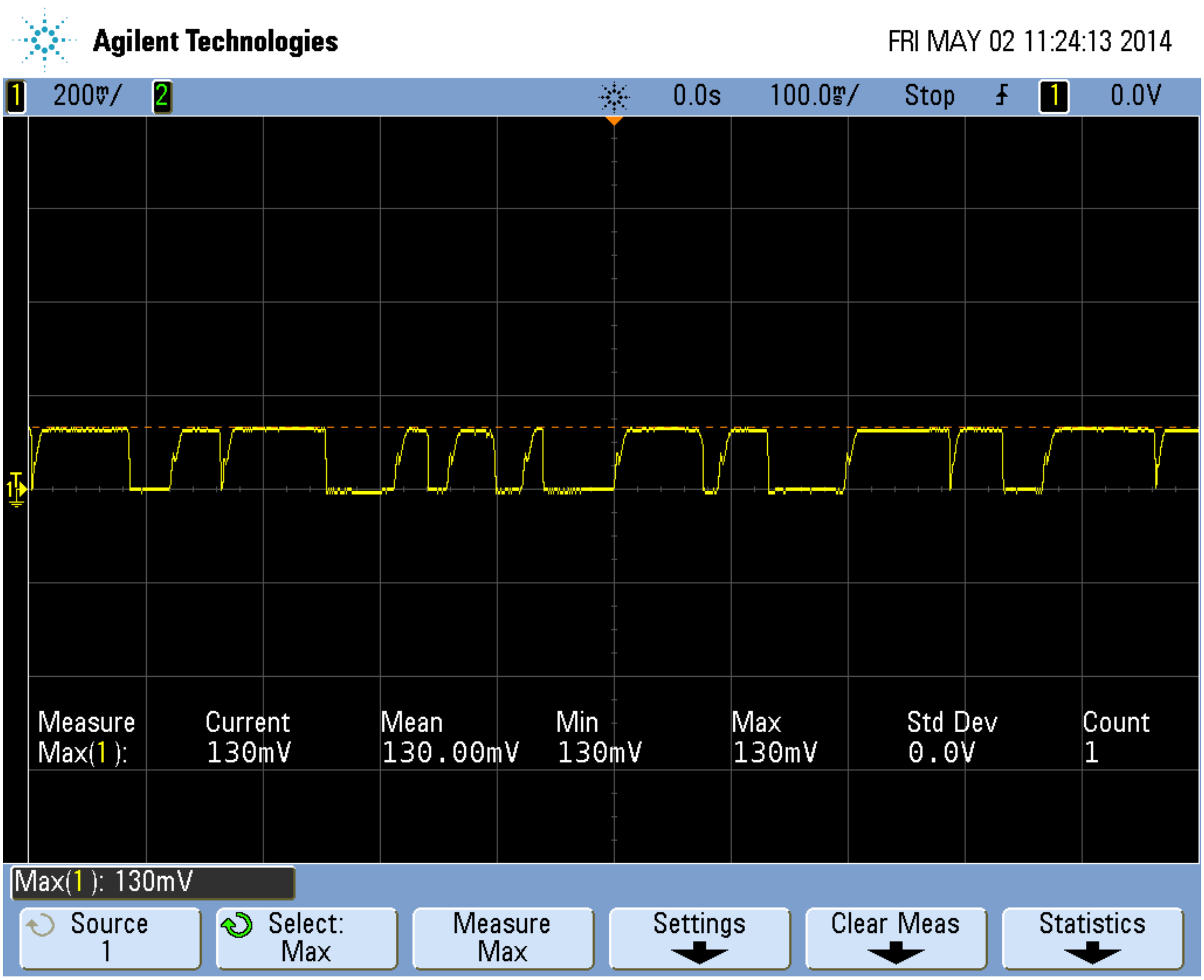
	V_{IN}	I_{IN}			V_{POT}	I_{POT} (A)	IGN ?	CYCLE	COMMENTS
Pre Cal	24.09	106.5mA					Yes	2	80RPMs (no dwell)
Start					15.60V	151.4mA			80RPMs (no dwell)
500							NO		
Middle					15.60V	150.6mA			80RPMs (no dwell)
Start							NO		
501-1000					15.60V	150.3mA			80RPMs (no dwell)
Post Cal	24.09	106.4mA					Yes	7	80RPMs (no dwell)

Ambient = 22 ˚C (Omega Model 650, S/N 59, cal. due 10/31/14)

Comments: Agilent 6038A DC power supply (S/N 55) was used for testing and for calibration. The current at the POT was observed to be dropping slightly during the test due to heating of the relay coil. The test was therefore paused for 15 minutes after 500 cycles to allow for cooling. The current through the relay was measured with an Agilent DS06052A (S/N 11) scope and Agilent N2781A (S/N 44) current probe (both cal. due 10/31/14) at the completion of the test and confirmed to be reaching steady state current at 80 RPMs with no dwell time settings (see the attached waveform on the following page). Coil inductance reconfirmed at completion of test. Test conducted at ABC Labs in Pittsburgh, PA.

DATA SHEET NO.	2
INVESTIGATION	IA-XXXXX
TEST SHEET NO.	1b
PAR NO.	99999
COMPANY	John Doe Inc.
TESTER	ABC
ASTP NO.	2232
RESULTS	PASS
DATE	5/2/2014

SPARK IGNITION TEST (cont'd)



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.
RESULTS
DATE

SPARK IGNITION TEST

Subject:

TEST CIRCUIT

CIRCUIT PARAMETERS:

REFERENCE: DRAWING NO. REV.

TEST PARAMETERS:

TEST GAS: 8.3 % METHANE: - AIR
4 / 2 / 1 WIRE ELECTRODES : 8-MIL / 10 MIL TUNGSTEN / 24-AWG COPPER
DISC : CADMIUM / BRASS / COPPER
CALIBRATION : RESISTIVE / INDUCTIVE

TEST EQUIPMENT:

	V_{IN}	I_{IN}			V_{POT}	I_{POT} (A)	IGN ?	CYCLE	COMMENTS
Pre Cal									
Start									
500									
Middle									
Start									
501-1000									
Post Cal									

Ambient =

Comments:

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.	
RESULTS	
DATE	

SPARK IGNITION TEST (cont'd)