Journal of ASTM International October 2009. Vol. XX No. XX

Paper ID

Available online at www.astm.org

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Electrical Arc Ignition Testing for Constellation Program

Introduction

NASA Johnson Space Center (JSC) Materials and Processes Branch requested that NASA JSC White Sands Test Facility (WSTF) perform testing for the Constellation Program to evaluate the hazard of electrical arc ignition of materials that could be in close proximity to batteries. Specifically, WSTF was requested to perform wire-break electrical arc tests to determine the current threshold for ignition of generic cotton woven fabric samples with a fixed voltage of 3.7 V, a common voltage for handheld electrical devices. The wire-break test was developed during a previous test program to evaluate the hazard of electrical arc ignition inside the Extravehicular Mobility Unit [1].

Test System

All tests were performed in a test chamber in Cell 131 of the High Pressure Test Area at WSTF. The humidity was kept to a minimum by the introduction of dry gases into the test chamber. The test chamber was a 4-inch stainless steel cross with clamp-type ports. The chamber ports accommodated a gas inlet and outlet, a view window for normal and high-speed video recording, a test sample mounting block,

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a thermocouple for temperature measurement, and power for the electrical arcing. The test system is shown in Figure 1.

The arcing and electrical test system included a power supply capable of providing a maximum of 10 amps at 28 Vdc. The power supply was designed to emulate batteries while allowing flexibility for different voltages and currents during testing. Two identical TENMA®[4] Model# TSX3510 power supplies were used along with a transistorized current limiter. This power supply scheme was very quick to respond to the rapid load changes produced by arcing events.

Test Environment

Tests were originally requested to be performed in 34 % oxygen at 8.0 psia. However, the test system was not designed to allow testing at sub-atmospheric pressures. Therefore, the request was changed to perform tests at 14.7 psia (+0.5, - 0.0) using a mixed gas supply containing 34 % oxygen, with the balance being nitrogen.

Wire-break Test Method

The wire-break test method was performed by clamping the ends of a single strand of fine wire, and shaping the wire into a “U” so that the bottom of the “U” was in contact with the test material (Figure 2). Applying current and voltage to the wire caused the wire to heat up and eventually break. As the wire heated up, the test material was preheated; and when the wire broke, an arc occurred.

The batch of wires used in this test series were composed of silver-coated copper, supplied by Phelps Dodge High Performance Conductors.[5] All tests were performed with 34 AWG (American Wire Gauge) wire.

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[4] TENMA® is a registered trademark of Premier Farnell Corporation, Independence, Ohio.

[5] Phelps Dodge High Performance Conductors is now IWG High Performance Conductors, a subsidiary of International Wire Group, Inman, South Carolina.

Each test consisted of one wire-break event, which was observed for visual evidence of test material ignition. A material failed at the test current if it ignited once in a maximum of 60 tests. A material passed at the test current if there was no ignition in 60 tests. For each test, current and voltage measurements were taken at a rate of 10 kHz. In addition, the ambient temperature in the test chamber and the test pressure were recorded at a rate of 1 Hz. High-speed video and normal speed video were recorded for each ignition.

Test Materials and Sample Preparation

Previous electrical arc ignition testing [1] included testing of generic cotton woven fabric test samples, which were cut from new unwashed white t-shirts. Test data indicate that materials such as moleskin are easier to ignite by electrical arc than generic cotton; however, generic cotton was selected as a material that represented the worst-case of materials that could be in close proximity to batteries in the Constellation Program. The generic cotton woven fabric samples used for this testing were from the same package of white t-shirts used in the previous testing.

The size of the test samples was not standardized; however, it was ensured that the wires were not placed in close proximity to the edge of the samples. The test material was frayed using a wire brush, resulting in surfaces that were fuzzier and easier to ignite. The test samples could be used for multiple tests as long as the wire did not contact the same area from test to test.

All of the samples were tested in the horizontal configuration, and each test sample was mounted to the sample mounting plate using adhesive tape. It was ensured that the tape was not in close proximity to the wire and arcing event. In addition, when taping the materials to the mounting plate, the materials were not stretched in such a way that they would shrink away from the wire once it began to heat up.

It was possible for the wire to melt through the test material, creating a short between the wire and the sample mounting plate. Therefore, a slide cover glass was placed underneath the test sample when it was mounted to the sample mounting plate, as shown in Figure 2.

During checkout tests, it was observed that the preheating of the wire prior to the wire-break event was creating a hole in the test material, leaving no material in close proximity to the arcing event. Previous testing indicated that test materials must be in close proximity to the arcing event in order for ignition to occur [1]. Therefore, the cotton was configured in three layers to ensure the test material was in close proximity to the arcing event.

Procedures and Observations

Before testing commenced, the test voltage was set to 3.7 V and the current was set to slightly lower than the desired test conditions. The test sample was mounted to the sample mounting plate using tape, and the wire was clamped into place.

Next, the test chamber was sealed, purged, and pressurized. Power was then applied to the wire, and the test conductor manually increased the current until the wire broke, creating an arcing event. If an ignition occurred, testing was continued at a lower current level. If no ignition occurred, high-speed video and visual inspection were used to verify that the wire broke in the desired location (i.e., in a location touching the test sample). The test sample could then be retested on another, untested, location.

The current required to break each specific wire depended on several variables. The more heat that went into the sample, the more current was required to break the wire. Therefore, the thermal properties of the material and the quality of the contact between the wire and test sample affected the current required to break the wire. Imperfections on the wire could cause the wire to break at a lower current. Further, the longer the wire “U,” the less current was required to break the wire.

Test Results and Discussion

Testing was performed with the largest wire size (34 AWG) and the highest current possible. There was no ignition of the test material in these conditions, as summarized in Table 1. In order to determine the conditions that would lead to ignition, some tests were performed with increased gas pressure inside the test chamber. Tests that resulted in ignition at increased pressures are summarized in Table 2.

The test results indicate that the hazard of electrical arc ignition is greatly reduced as oxygen concentration and pressure are decreased. This trend is consistent with data from other tests performed in oxygen-enriched environments. It would be expected that the generic cotton woven fabric material is flammable in 34 % oxygen at 14.7 psia; however, the test results show that with a voltage of 3.7 V and the maximum current possible in the test system, the amount of energy in a wire-break arc test is not sufficient to produce ignition. Increasing the pressure to 32.9 psia did result in ignition of the material.

References

[1] Smith, S., T. Gallus, S. Harper, and H. Beeson, "Electrical Arc Ignition Testing of Spacesuit Materials", Proceedings at the *Eleventh International Symposium on Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres*, STP 1479, Eds. D.B. Hirsch, R. Zawierucha, T. A. Steinberg, H. M. Barthelemy, ASTM International, West Conshohocken Pennsylvania, October 18-20, 2006.

TABLE 1—*Results of Testing in 34 (+0.5, -0.0) Percent Oxygen at 14.7 psia (+0.5, -0.0).*

Test Material	Test Results	Current Tested (A)			Voltage Tested (V)		
		Average	Maximum	Minimum	Average	Maximum	Minimum
Generic cotton	No ignition in 60 tests	6.83	9.06	5.68	3.77	3.87	3.57

TABLE 2—*Tests Resulting in Ignition in 34 (+0.5, -0.0) Percent Oxygen at Increased Test Pressures.*

Test ID	Test Pressure (psia)	Available Current at Ignition (A)	Available Voltage at Ignition (V)
cev gc22	42.5	9.48	3.73
cev gc23	42.4	7.36	3.85
cev gc35	32.9	8.64	3.67

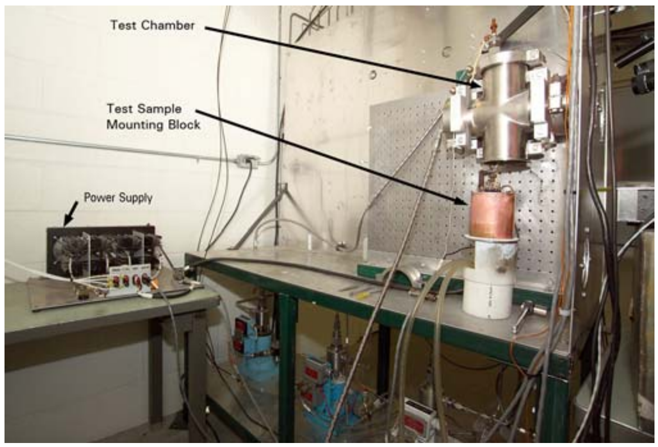

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FIG. 1—*Test system.*

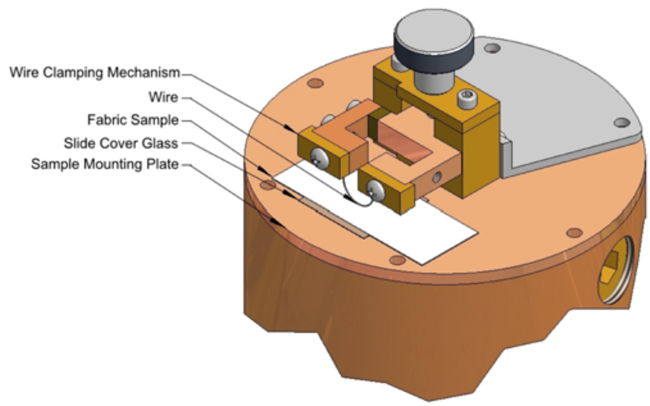

FIG. 2—*Wire-break test setup.*