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EXPLOSIVE ATMOSPHERE TESTING AND INTRINSIC SAFETY ANALYSIS OF E/T LIGHT® EMERGENCY TRIAGE LIGHTS

Model Nos.: v6.8 A and v6.8 IR with Mechanical Battery Reversal Protection

FINAL REPORT
Consisting of 18 Pages

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Report Date: July 16, 2018

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EXECUTIVE SUMMARY

Southwest Research Institute's (SwRI) Fire Technology Department, located in San Antonio, Texas, performed explosive atmosphere testing and intrinsic safety analysis of Southwest Synergistic Solutions *E/T Light®* Emergency Triage Lights Model Nos. v6.8 A and v6.8 IR with mechanical battery reversal protection. Testing and engineering evaluations were performed for Texas A&M Engineering Extension Service (TEEX) on behalf of Southwest Synergistic Solutions:

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Explosive atmosphere testing was performed on June 4 and 5, 2018, in accordance with the MIL-STD-810G Method 511.5 Procedure I, *Explosive Atmosphere,* dated October 31, 2008. Testing was performed in a sealed chamber with an explosive atmosphere (3.8 vol. % n-Hexane in air). The simulated test altitude was 40,000 ft with a slow simulated descent rate (≤ 328 ft/min). The simulated altitude was achieved by decreasing the chamber pressure with a vacuum pump, sealing the chamber, and then slowly allowing ambient air to flow back into the chamber. The test chamber temperature was controlled to the maximum operating temperature of the test samples, approximately 130 °F (54.4 °C). *E/T Light®* Model Nos. v6.8 A and v6.8 IR were evaluated individually. Each sample was secured in the test chamber containing the explosive atmosphere. The samples were power cycled and operated throughout the test.

Both *E/T Light®* Model Nos. v6.8 A and v6.8 IR did not cause ignition of the explosive atmosphere within the test chamber; and, therefore, met the requirements of MIL-STD-810G Method 511.5 Procedure I.

E/T Light® Model Nos. v6.8 A and v6.8 IR circuitry were also analyzed for conformance to IEC 60079-11 for determination of intrinsic safety. Based upon SwRI's evaluation of E/T Light® Model Nos. v6.8 A and v6.8 IR with mechanical battery reversal protection, the circuits can meet the requirements for an intrinsically safe device. The assessment was based upon IEC 60079-11 Annex A. Section A.3 provided reference curves and tables to evaluate the simple schematic provided by Southwest Synergistic Solutions. Based upon Figures A.1, A.2, and A.3, the low voltage of the battery allow the device to be well below the minimum igniting voltage curves. The power dissipation in the device cannot be estimated due to the lack of information on the diodes and no in-line resistors, however during operation no hot spots or elevated temperatures were observed on the operating unit. Finally, the silicone isolation of the device provides adequate separation from other circuitry. The mechanical battery reversal protection prevents the battery from making contact with the circuit if it is inserted backwards; which has been selected by the manufacturer instead of reverse voltage protection. The mechanical battery reversal protection may qualify as adequate reverse voltage protection.

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1.0 INTRODUCTION

The objective of this program was to analyze Southwest Synergistic Solutions' products, identified as *E/T Light* ® Model Nos. v6.8 A and v6.8 IR with mechanical battery reversal protection, for intrinsic safety. An engineering evaluation was performed in accordance with IEC 60079-0, *Explosive Atmospheres – Park 0: Equipment – General Requirements,* and IEC 60079-11, *Explosive Atmospheres – Part 11: Equipment Protection by Intrinsic Safety "i",* to analyze the components for intrinsic safety. Performance testing was conducted in accordance with MIL-STD-810G, *Method 511.5, Explosive Atmosphere – Procedure I.* While MIL-STD-810G is not intended for intrinsic safety determination, it provides a performance evaluation of the device to not ignite an explosive atmosphere of n-hexane. This fuel is used since its ignition properties are at least as severe as the properties of high-octane aviation gasoline, JP-4, and JP-8 jet engine fuel.

The results presented in this report apply only to the materials tested, in the manner tested, and not to any similar materials or material combinations.

2.0 TEST SPECIMENS

Southwest Synergistic Solutions, provided the specimens for testing. Two models, identified as *E/T Light*® Model Nos. v6.8 A and v6.8 IR, were received on May 14, 2018. Two of each model were provided (one of each model for explosive atmosphere testing, and one of each model for intrinsic safety evaluation). Both models are approximately 1 in. diameter and 3 in. long when encased in the silicone cover. The internal circuitry and battery case are approximately ¾ in. diameter by 1 3/8 in. long. Model No. v6.8 A contains four colored LEDs (Red, Yellow, Green, and Blue), and Model No. v6.8 IR contains three colored LEDs (Red, Green, and Blue) and an IR LED. The Model No. v6.8 A microcontroller is labeled V6.9_AMB, and the Model No. v6.8 IR microcontroller is labeled V7.2_IR. Note, the testing and evaluation results contained in this report apply specifically to the model/version number evaluated. Figure 1 and Figure 2 show Model No. v6.8 A, and Figure 3 and Figure 5 show Model No. v6.8 IR.

A plastic washer (approx. 0.6 in. OD × 0.26 ID and 0.0275 in. thick) with tabs that attach to the base of the battery clips, between the circuit board and battery, was subsequently provided by Southwest Synergistic Solutions in order to protect the circuit from reverse battery insertion. The washer prevents the battery from coming in contact with the LED leads or battery contact pad, as well as elevating the battery within the sleeve so that the battery cap cannot be installed in the proper orientation; thus, preventing reverse voltage to the circuit from an incorrectly installed battery. The mechanical battery reversal protection was received for review on June 29, 2018. Figure 5 shows the mechanical battery reversal protection, as installed in Model No. v6.8 A. The intrinsic safety analysis applies to Model No. v6.8 A and v6.8 IR with the mechanical battery reversal protection installed.

Figure 1. ***E/T Light*® Model No. v6.8 A (With and Without Silicone Case).**

Figure 2. ***E/T Light*® Model No. v6.8 A (Disassembled).**

Figure 3. ***E/T Light*® Model No. v6.8 IR.**

Figure 4. ***E/T Light*® Model No. v6.8 IR (Disassembled).**

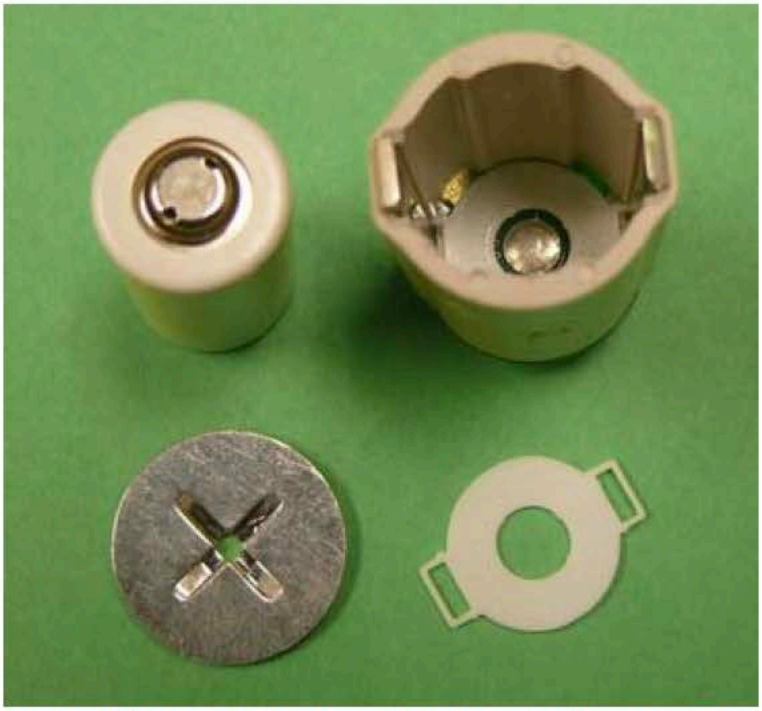

Figure 5. ***E/T Light®*** **Model No. v6.8A with Mechanical Battery Reversal Protection (Clockwise from Top Right – Washer Installed, Spare Washer, Battery Cover, and Battery).**

3.0 EXPLOSIVE ATMOSPHERE TESTING

Explosive Atmosphere testing was performed at SwRI's Fire Technology Department, located in San Antonio, Texas. *E/T Light®* Model Nos. v6.8 A and v6.8IR were tested on June 4 and 5, 2018, respectively. The following subsections outline the test setup, procedure, and results. Testing was not performed with the mechanical battery reversal protection washer, but it is not expected to alter the results of the testing.

3.1 Test Setup

The test chamber was air tight and had an internal volume of 72.5 L without the test specimen present. A thick polycarbonate plate was bolted to the front flange of the chamber to view the test specimen while protecting the test operator. A manipulator arm, sealed through the polycarbonate plate, was used to operate the test specimen. The test chamber was wrapped with resistance heaters and insulation, and a temperature controller was utilized to set and maintain the test temperature to the test specimens' maximum allowable temperature. Thermocouples were placed on the test chamber's inner surface, at the center of the chamber atmosphere, and on the test specimen's surface to monitor temperatures throughout the test.

An explosion verification vessel with a spark ignition system was used to prove that the fuel-air mixture inside the test chamber was explosive. An additional thermocouple was placed inside the explosion verification vessel.

A vacuum pump was used to exhaust the contents of the test chamber and explosion verification vessel, and to simulate altitude within the test chamber. Ambient air was allowed to enter the chamber at a controlled rate to simulate a slow descent. A hypodermic syringe was used to introduce the n-Hexane into the chamber through a septum. Test chamber pressure was monitored by an absolute pressure transducer.

3.2 Test Procedure

The test specimens were tested at SwRI for compliance to MIL-STD-810G, *Method 511.5, Explosive Atmosphere – Procedure I,* dated October 31, 2008. *E/T Light* ® Model Nos. v6.8 A and v6.8 IR were tested individually. Prior to each test, the test specimen was secured in a sample holder within the test chamber so that the push-button could be activated via the manipulator arm. The test specimens were battery-powered and operated via a single push-button; no power/signal wires were required. Both Model Nos. v6.8 A and v6.8 IR were evaluated in Mode 7 (considered most severe).

Testing was performed between 40,000 ft and ambient pressure. A homogeneous fuel-air mixture of approximately 3.8% n-Hexane by volume (1.8 stoichiometric equivalents of n-Hexane in air) was used to minimize the energy required for ignition. The pressure was used, along with the chamber volume, chamber temperature, and specific gravity of n-Hexane, to calculate the volume of 95% n-Hexane to achieve 3.8% by volume n-Hexane, according the equation provided in the test standard:

$$Volume\ n - Hexane(mL) = 4.27 \times 10^{-4} \left[\frac{(net\ chamber\ vol\ (L)) \times (chamber\ pressure\ (pascals))}{\left(chamber\ temp\ (K)\right) \times (specific\ gravity\ of\ n - hexane)} \right]$$

The chamber volume was determined as 67.7 L by subtracting the volume of the test specimen and sample holder from the empty chamber volume. The n-Hexane was held at laboratory temperature (70°F) to maintain a constant specific gravity for measurement before each test. The specific gravity at this temperature is 0.658 as determined by the table found in the standard. The temperature of the test chamber was maintained at approximately 130 °F (327.4 K). At the start of each test, n-Hexane was injected to the test vessel at 46,600 ft and the test vessel allowed to slowly reach the starting test conditions at 40,000 ft. Additional n-Hexane was added at approximately 30k, 20k, 10k, and 1k ft simulated altitude. Chamber pressure was calculated based on the target simulated test altitudes.

After the *E/T Light* ® was secured in the chamber and the chamber was sealed, the general procedure performed was as follows:

1. Performed Pre-Test Operational Test and Powered Off test specimen.
2. Test Chamber was heated to approximately 130 °F.
3. Adjusted the chamber air pressure to simulate the test altitude (40,000 ft) plus at least 2,000 m.

4. The proper volume of n-Hexane for the given test pressure was measured into a syringe at laboratory temperature and injected into the test chamber through the septum.
5. The pressure was increased to the test altitude plus 1,000 m, and the test chamber atmosphere was allowed to circulate for at least 10 min and slowly descend to the test altitude.
6. Powered-on the test specimen and began operational tests and power cycling through Step 8.
7. Decreased the simulated altitude to 1,000 m above test facility altitude (ambient pressure) at a rate of 100 m/min.
8. Powered-off test specimen
9. Checked the potential explosiveness of the fuel-air mixture by attempting to ignite a sample of the explosive atmosphere mixture in the explosion verification vessel, which is isolated from the test chamber. The spark igniter in the explosion verification vessel was activated and the temperature and pressure gauge on the vessel was monitored for a sudden spike, which confirmed ignition of the internal gases.
10. Test completed. Repeat for next test specimen.

3.3 Results

Ignition of the explosive atmosphere did not occur during the test of the *E/T Light* ® Model Nos. v6.8 A and v6.8 IR. The atmosphere was successfully ignited in the explosion verification vessel after the simulated descent for each test; this verified that the test specimens were tested in an explosive mixture. Graphical test data can be found in Appendix A, and photographs depicting the test setup and assembly are included in Appendix B.

E/T Light ® Model Nos. v6.8 A and v6.8 IR met the requirements of MIL-STD-810G, *Method 511.5, Explosive Atmosphere – Procedure I.*

4.0 INTRINSIC SAFETY ANALYSIS

SwRI's Electrical Systems Department in the Applied Power Division performed an evaluation of the *E/T Light* ® Model Nos. v6.8 A and v6.8 IR with mechanical battery reversal protection for intrinsic safety according to IEC 60079-0, *Explosive Atmospheres – Park 0: Equipment – General Requirements,* and IEC 60079-11, *Explosive Atmospheres – Part 11: Equipment Protection by Intrinsic Safety "i,"* specifically IEC 60079-11 Annex A.1 and A.2. The following subsections discuss the electrical circuit, intrinsic safety evaluation, and results.

4.1 Electrical Circuit

Southwest Synergistic Solutions, provided a circuit diagram of *E/T Light* ® Model Nos. v6.8 A and v6.8 IR which is presented in Appendix C. It is apparent the circuits contain no inductive and minimal capacitive components. Both circuit boards contain a microcontroller (U1, a PIC16), an internal battery, some discrete components, and 4 indicator LEDs controlled by a user interface switch. In the client-provided circuit diagram, C1 was only labeled with "0.1" which SwRI assumed this meant 0.1 µF, a common debounce and bypass capacitor value. The diodes were lacking part numbers, making SwRI unable to evaluate their power dissipation capabilities or additional features like internal resistors.

4.2 Intrinsic Safety Evaluation

IEC 60079-0, Section 23.3 specifies allowable primary cell types. The selected Lithium Manganese Dioxide cell in the *E/T Light* ® Model Nos. v6.8 A and v6.8 IR is present on Table 13, making it an acceptable choice for an intrinsically safe device. It also instructs the use of 3.7V for all spark hazard assessments and 3.0V for temperature rise evaluations. SwRI made the assumption that the primary cells are not expected or anticipated to be changed while the light is in a hazardous environment.

IEC 60079-11, Annex A.1 presents the three basic criteria for an intrinsically safe circuit:

a) No spark ignition danger
b) No surface temperature ignition danger
c) Circuit is adequately separated from other circuits

Annex A.2 presents the curves and tables used to evaluate the spark ignition danger without experimentation. The light can be roughly approximated by simple resistive and capacitive circuits, assuming the microcontroller is acting as a switch, the microcontroller is terminating the circuit through an internal resistance, and the diode is a simple two-port device. Based upon Figures A.1, A.2, and A.3, there is no spark danger due to the low voltage of the battery. Using the maximum open circuit voltage instructed for this battery chemistry (3.7V), the voltage is low enough that it does not present a spark hazard. Further considering Table A.2, the voltage and capacitance are low enough to not be a concern either. The 3.7V and 0.1 µF are below the limits that are listed in the tables in Annex A.2.

IEC 60079-11, Section 5.6 references the thermal considerations within IEC 60079-0, Sections 5.2-5.4 and Section 26.5.1 which specify the maximum allowable surface temperatures across the electrical components. Based upon the estimations from the schematics and empirical observations on the operating circuit, the dissipated powers and component temperatures are well within all of the IEC 60079 restrictions. From empirical observations, no individual components reach any elevated temperatures, well below those listed in IEC 60079-0, Section 5.3.2.2, Table 2, *Classification of maximum surface temperature for Group II electrical equipment.* Group II is for electrical equipment intended for use in areas with explosive gas atmosphere other than mines. IEC 60079-0, Section 5.3.2.2, Table 2 specifies the most stringent maximum surface temperature as ≤ 85 °C. When operated and observed, the surface temperature of the individual components were well below this requirement for "Temperature class T6."

Referencing, IEC 60079-11, Table 3, all traces observed on the circuit board are more than adequately sized for the expected currents that will be observed.

The silicone enclosure separates the circuit from other circuits and undesirable electrical contact when it is closed.

IEC 60079-11, Section 6.4 requires the intrinsically safe apparatus have protection against reverse polarity of the voltage source. The circuitry does not contain any electrical reverse voltage protection, like a diode or MOSFET. The mechanical battery reversal protection (plastic washer) prevents the battery from making contact with the circuit if it is inserted backwards; which has been selected by the manufacturer instead of reverse voltage protection. The mechanical battery reversal protection may qualify as adequate reverse voltage protection.

4.3 Results

Based upon SwRI's evaluation of the *E/T Light* ® Model Nos. v6.8 A and v6.8 IR with mechanical battery reversal protection, the circuit can meet the requirements for an intrinsically safe device. The assessment was based upon IEC 60079-11 Annex A.1 and A.2. Due to the low voltage of the power source, low power dissipation within the device, silicone enclosure, and mechanical battery reversal protection the device can operate as an intrinsically safe circuit.

APPENDIX A
EXPLOSIVE ATMOSPHERE TEST
GRAPHICAL DATA
(CONSISTING OF 1 PAGE)

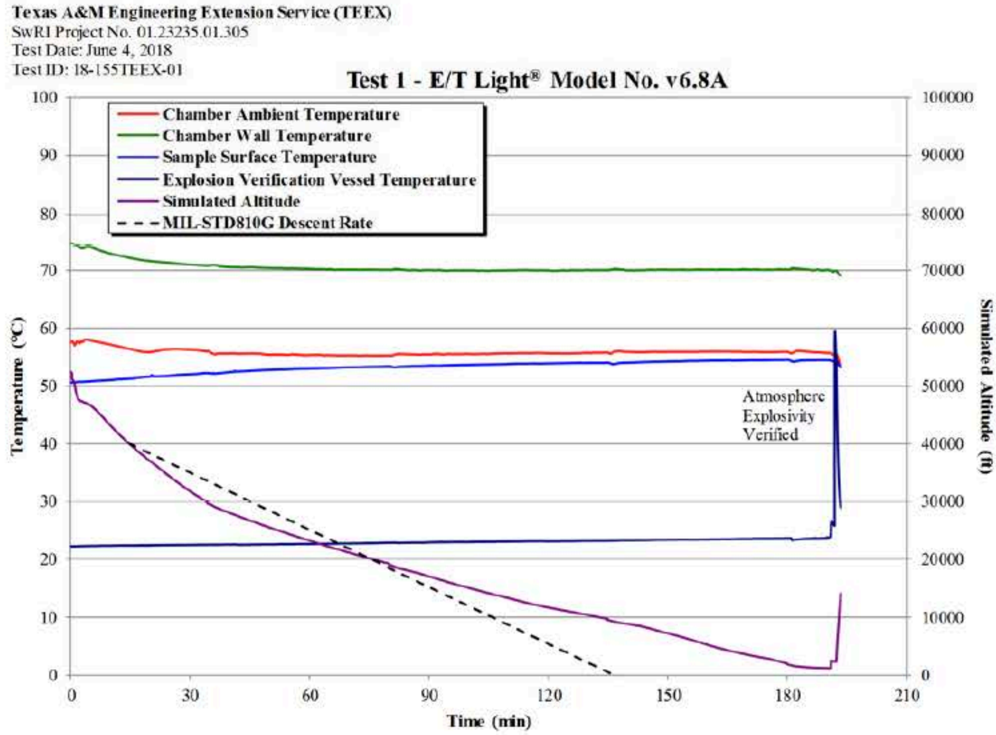

Figure A-1. Explosive Atmosphere Test No. 1, *E/T Light®* Model No. v6.8A .

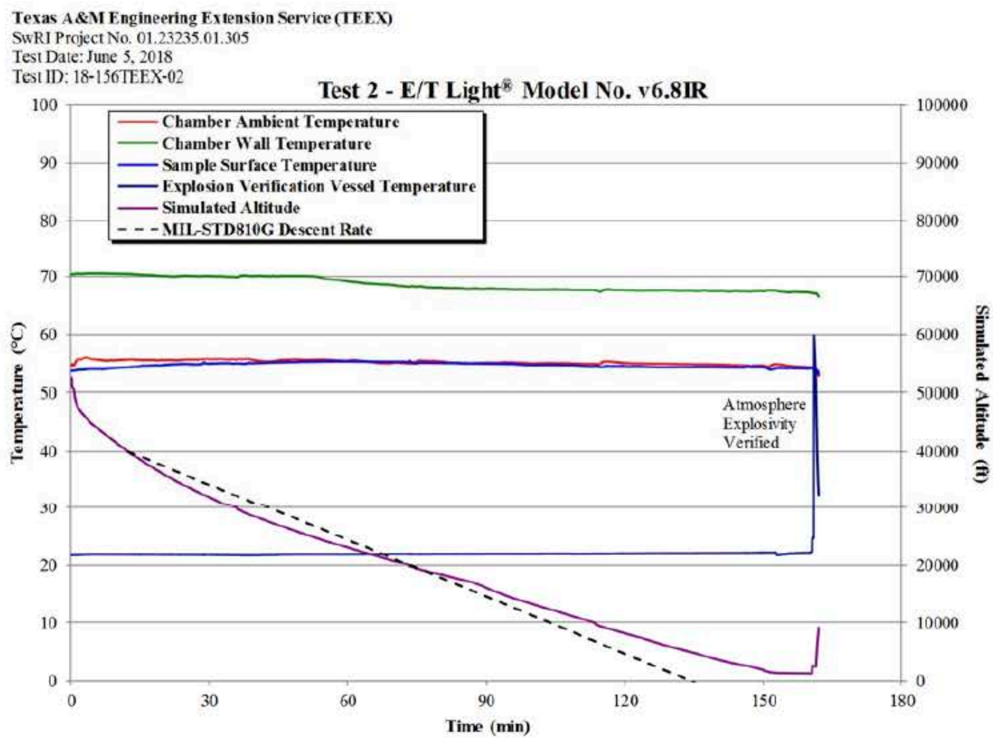

Figure A-2. Explosive Atmosphere Test No. 2, *E/T Light®* Model No. v6.8IR.

APPENDIX B
EXPLOSIVE ATMOSPHERE TEST
PHOTOGRAPHS
(CONSISTING OF 2 PAGES)

Figure B-1. Overall Test Setup.

Figure B-2. *E/T Light* ® Model No. v6.8 A, Installed in Test Chamber, Prior to Test.

Figure B-3. *E/T Light* ® Model No. v6.8 IR, Installed in Test Chamber, Prior to Test.