

Shipping Container R&D Test Plan

R&D Test Plan – Proposed Pyrophobic Shipping Container

MAC-061880-001 Rev C

July 9, 2013

Prepared By: Galen McDermed

REVISION HISTORY

REV	PREPARED BY	DATE	APPROVED	DESCRIPTION OF CHANGES
A	G. McDermed	07/01/2013	GM, CM	Initial Release.
B	G. McDermed	07/03/2013	GM, CM	Added cell table, amended internal test procedure.
C	G. McDermed	07/09/2013	GM, CM	Amended 2.6 and 3.2 for external test.

Table of Contents

REVISION HISTORY	2
1. Introduction	4
1.1 Reference Documents.....	4
1.2 Special Requirements.....	4
2. R&D TEST PLAN	4
2.1 Test Facility.....	4
2.2 Test Samples	4
2.2.1 Flame Penetration Test.....	4
2.2.2 Material External Exposure Test	5
2.2.3 Internal Thermal Runaway Containment Test	5
2.2.4 Conductivity Test.....	5
2.2.5 Toxicity Test	5
2.2.6 Cell Sample Specifications.....	5
2.3 Test Sample Pre-Conditioning.....	5
2.3.1 Flame Penetration Test Samples.....	5
2.4 Test Sample & Equipment Conformity.....	5
2.5 Flame Penetration Test Procedures.....	6
2.6 Material External Exposure Test Procedures.....	6
2.7 Internal Thermal Runaway Containment Test	7
2.8 Conductivity Test.....	7
2.9 Toxicity Test.....	7
2.10 Test Data	7
3. RESULTS.....	8
3.1 PASS/FAILURE Criteria for the Flame Penetration Test	8
3.2 PASS/FAILURE Criteria for the Material External Exposure Test	8
3.3 PASS/FAILURE Criteria for the Internal Thermal Runaway Containment Test	8
4. REPORT.....	8
APPENDIX A – Drawing and Picture of Sample Shipping Container	9
APPENDIX B – Equipment List and Calibration Information	10

1. Introduction

The purpose of this test plan is to demonstrate the ability of the Pyrophobic Intumescent Material to serve as a shipping container for the storage and shipping of Lithium and Lithium Ion cells and batteries. The container is required to meet certain derived testing guidelines for its intended use aboard cargo and passenger aircraft.

1.1 Reference Documents

- Federal Aviation Regulation 14 CFR Part 25.853 Amdt 23-116
- Federal Aviation Regulation 14 CFR Part 25, Appendix F Part 3
- Federal Test Method Standard 191 (FED-STD-191)
- “Fire Protection for the Shipment of Lithium Batteries in Aircraft Cargo Compartments” by Harry Webster November 2010
- 49 CFR Parts 173, 175, and 178

1.2 Special Requirements

Testing will be witnessed by McDermed Aviation Consultants.

2. R&D TEST PLAN

This test plan specifies the testing of sample shipping containers. The testing will be performed according to the procedures set forth in this plan.

2.1 Test Facility

Testing will be performed at Mobile Power Solutions, 1815 NW 169th Place Suite 5050 Beaverton, OR 97006-7485.

2.2 Test Samples

2.2.1 Flame Penetration Test

The test samples for the Flame Penetration Test will be made out of the same material and thickness of the proposed shipping container. The test samples be 6”x6” x (the container thickness at its thinnest spot). A minimum of three samples are required and the results averaged.

2.2.2 Material External Exposure Test

The test samples for the Material External Exposure Test will be manufactured samples of the proposed Pyrophobic shipping container, representative of the configuration to be used in the shipping of Lithium and Lithium Ion cells and batteries aboard cargo and passenger aircraft. A minimum of three test samples are required and the results averaged.

2.2.3 Internal Thermal Runaway Containment Test

The test samples for the Material External Exposure Test will be manufactured samples of the proposed Pyrophobic shipping container, representative of the configuration to be used in the shipping of Lithium and Lithium Ion cells and batteries aboard cargo and passenger aircraft. A minimum of three test samples are required and the results averaged.

2.2.4 Conductivity Test

No Samples are required unless it is determined by analysis that the proposed sample may have conductive properties. In the event of a potentially conductive material one sample will be required in the configuration to be used in the shipping of Lithium and Lithium Ion cells and batteries aboard cargo and passenger aircraft.

2.2.5 Toxicity Test

No Samples are required.

2.2.6 Cell Sample Specifications

Size	18650
State of Charge	Approx. 50%
Cathode	Lithium Cobalt Oxide
Anode	Graphite

2.3 Test Sample Pre-Conditioning

2.3.1 Flame Penetration Test Samples

All of the samples must be conditioned to $70^{\circ} \pm 5^{\circ}\text{F}$ and 50 percent \pm 5 percent relative humidity for 24 hours. This data is recorded on a temperature and humidity chart recorder. Values are to be verified by McDermed Aviation Consultants. A copy of the chart will be provided with the final report. The date and time the samples have been stored in a conditioning chamber shall be recorded on the R&D Test Report.

2.4 Test Sample & Equipment Conformity

McDermed Aviation Consultants will verify conformity and inspection of the test samples and the test equipment. An equipment list will be obtained which will include the make, model, serial number, and if applicable calibration date of all equipment used. The equipment list will be included in the final report.

2.5 Flame Penetration Test Procedures

A minimum of three samples of the same material must be tested and the results averaged. Each sample must be mounted horizontally. The sample must be exposed to a Bunsen or Tirrill burner with a nominal 3/8 inch I.D. tube adjusted to give a flame of 1 ½ inches in height. The minimum flame temperature measured by a calibrated thermocouple pyrometer in the center of the flame must be 1700° F (927°C). The flame must be applied to the center of the sample. Expose the test sample to the flame for a period of 5 minutes and then turn off the burner. The test may be terminated earlier if flame penetration is observed. A thermocouple measurement will be taken at a height of 4 inches above the test sample for the duration of the test. The data collection rate must be at a minimum of 1Hz for the duration of the test. Observations of the behavior of test specimens during flame exposure including time of occurrence will be recorded along with the time at which flame penetration occurs, if applicable, for each of three samples tested. All three tests will be video recorded.

2.6 Material External Exposure Test Procedures

A minimum of three samples of the same material must be tested and the results averaged. Each sample will be filled with 18650 Lithium Ion Cobalt Oxide Cells. The sample must have a minimum of 7 thermocouples one placed on each installed cell. The external temperature of the chamber will be monitored by at least 1 thermocouple placed 1 inch above the sample's center. The exterior of the sample will be monitored by at least 7 thermocouples attached to the faces of the sample's exterior walls and lid. The data collection rate must be at a minimum of 1Hz for the duration of the test. Each sample will be exposed to an external temperature of 400° F (205°C) for 3 hours in an environmental chamber. The ramp time to achieve 400° F should be as quick as practical not to exceed 1 hour. The test will be terminated after 3 hours. Observations of the behavior of test samples during temperature exposure including time of occurrence will be recorded along with the time at which thermal runaway in any cell occurs, if applicable, for each of three samples tested. All three tests will be video recorded.

2.7 Internal Thermal Runaway Containment Test

A minimum of three samples of the same material must be tested and the results averaged. Sample 1 will have six 18650 Lithium Ion Cobalt Oxide Cells inserted into it. The center chamber in the sample will have a cartridge heater capable of reaching 1100° F (594° C) placed inside along with a calibration thermocouple if necessary. Sample 2 will have six 18650 Lithium Ion Cobalt Oxide Cells inserted into it. One of the outer chambers in the sample will have a cartridge heater capable of reaching 1100° F (594° C) placed inside along with a calibration thermocouple if necessary. Sample 3 will be configured in the way that produced the highest external temperature unless a thermal runaway propagation was observed then it should be configured in the way thermal runaway propagation occurred. Thermocouples will be attached to each installed cell so as to best monitor cell temperature. Thermocouples will also be placed on the exterior of the sample so as to monitor sample wall and cover temperature. The number of thermocouples used must sufficiently map the exterior of each sample. Energize the heater cartridge for 30 minutes. If a cell enters thermal runaway the heating cartridge will be turned off. After 30 minutes the test will be terminated. The data collection rate must be at a minimum of 1Hz for the duration of the test. Observations of the behavior of test specimens during temperature exposure including time of occurrence will be recorded along with the time at which thermal runaway in any cell occurs, if applicable, for each of three samples tested. All three tests will be video recorded.

2.8 Conductivity Test

No test will be performed at this time unless deemed necessary by McDermed Aviation Consultants. An agreed upon procedure will be established if necessary.

2.9 Toxicity Test

No test will be performed at this time unless deemed necessary by McDermed Aviation Consultants. An agreed upon procedure will be established if necessary.

2.10 Test Data

The resulting test data for each test will be recorded along with any observations and failures. A final test report will be compiled detailing all tests and outcomes.

3. RESULTS

3.1 PASS/FAILURE Criteria for the Flame Penetration Test

The sample must prevent penetration by a flame of at least 1700° F (927° C) for a period of 5 minutes. The peak temperature measured at 4 inches above the sample must not exceed 400° F (205° C). Flame penetration is determined by a visible flame on the non-exposed side of the sample. Smoke is allowed. Distortion is allowed on either side of the sample as long as no penetration occurs. Ash and debris are allowed on the exposed side of the sample.

3.2 PASS/FAILURE Criteria for the Material External Exposure Test

The external temperature of the sample on any of its surfaces must not exceed 450°F (232°C) for an elapsed time of greater than or equal to 1 minute. Smoke is allowed. Ash and debris and distortion are allowed on the exterior or interior of the sample if they do not endanger the cells inside. Thermal runaway in any cell is allowed.

3.3 PASS/FAILURE Criteria for the Internal Thermal Runaway Containment Test

Smoke leaking through seals is acceptable. Ash and debris and distortion are allowed on the exterior or interior of the sample if they do not endanger the cells inside. Fire and flames escaping through seals or sidewalls or top and bottom is not acceptable. The container must maintain its integrity until the internal temperature returns to ambient.

4. REPORT

After successful completion of the testing, the results will be provided to McDermed Aviation. A final report will then be generated by McDermed Aviation to support Pyrophobic's project development efforts.

APPENDIX A – Drawing and Picture of Sample Shipping Container

APPENDIX B – Equipment List and Calibration Information